ORISON

innOvative Research Infrastructure based on Stratospheric balloONs

USES AND NEEDS REPORT

Version 1.0

31.08.2016

Deliverable

H2020 INFRASUPP-02-2015 project "Innovative Research Infrastructure based on stratospheric balloons"

Topic: INFRASUPP-02-2015 Innovative procurement pilot action in the field of scientific instrumentation

Project Title: Innovative research infrastructure based on stratospheric balloons — ORISON

Proposal No: 690013 - ORISON

Duration: Feb 1, 2016 - Jul 31, 2017

WP	WP 2
Del. No	D2.1
Title	Uses and Needs Report
Lead Beneficiary	“CSIC”
Nature	“Report”
Dissemination Level	“Public”
Est. Del. Date	01/09/2016
Version	1.0
Date	31.08.2016
Status	Released
Lead Author	P. Maier, pmaier@mpe.mpg.de, MPE
Approved by	J.L. Ortiz, ortiz@iaa.es, CSIC-IAA

TABLE OF CONTENTS

LIST OF ABBREVIATIONS AND DEFINITIONS

Abbreviation	Definition
ALAN	Artificial Light at Night
AO	Adaptive optics
BLAST	Balloon-borne Large Aperture Submillimeter Telescope
DLR	German Aerospace Center
ESA	European Space Agency
FIR	Far-Infrared
FWHM	Full Width Half Maximum
IDP	Interplanetary Dust Particles
IR	Infrared
JAXA	Japan Aerospace Exploration Agency
KBO	Kuiper Belt Object
LEO	Low Earth Orbit
LOS	Line Of Sight
MBA	Main Belt Asteroid
MIR	Mid-Infrared
n.a.	Not available / not applicable
NASA	National Aeronautics and Space Administration
NIR	Near-Infrared
PSF	Point Spread Function
SOFIA	Stratospheric Observatory for Infrared Astronomy
STO	Stratospheric Terahertz Observatory
TBD	To be determined
TEP	Transient Electrical Phenomena
TNO	Trans-Neptunian Object
UV	Ultraviolet

REFERENCE DOCUMENTS

[RD1]	Grechko, G. M., Gurvich, A. S., Kan, V., Pakhomov, A. I., Podvyazny, Y. P., and Savchenko, S. A., Observation of Atmospheric Turbulence at Altitudes of 20-70 km, Doclady of Russian Academy of Science, Geophysics, 357, 683-686, 1997 (in Russian).
[RD2]	H.C. Ford, L.D. Petro, C. Burrows, C. Ftaclas, M.C. Roggemann, and J.T. Trauger, Artemis: A Stratospheric Planet Finder, NASA Technical Report, 2003.
[RD3]	Benn, C. R., Ellison, S. L., La Palma Night-Sky Brightness, Technical Report, 2007.
[RD4]	Lemke, D., Frey, A., Haussecker, K., Hofmann, W., Salm, N., Schütz, H., Ballonteleskop THISBE 1 – Technik, Ergebnisse, Erfahrungen, Research Report, 1976 (in German).
[RD5]	Hurford, T. A., Mandell, A., Reddy, V., Young, E., Observatory for Planetary Investigations from the Stratosphere, 46th Lunar and Planetary Science Conference, 2015.
[RD6]	Young, E., Hibbitts, C., Emery, J., Hendrix, A., Merline, W., Grundy, W., Retherford, K., Balloon-Borne Telescopes for Planetary Science: Imaging and Photometry, White Paper.
[RD7]	Hibbits, C., Bauer, J., Bernasconi, P., Clarke, J., Domingue, D., Emery, J., Gladstone, R., Greathouse, T., Hansen, G., Harris, W., Hendrix, A., Izenberg, N., Lisse, C., Paxton, L., Percival, J., Retherford, K., Rivkin, A., Swain, M., Young, E., Stratospheric Balloon Missions for Planetary Science: A Petition for the Formation of a Working Group to Study the Feasibility of a Facility Platform to Support Planetary Science Missions.
[RD8]	Stiller, G. P., Clarmann, von, T., Funke, B., Glatthor, N., Hase, F., Höpfner, M. and Linden, A., Sensitivity of trace gas abundances retrievals from infrared limb emission spectra to simplifying approximations in radiative transfer modelling, J. Quant. Spectros. Radiat. Transfer, 72(3), 249–280, 2002.
[RD9]	Rothman, L. S., Gordon, I. E., Babikov, Y., Barbe, A., Chris Benner, D., Bernath, P. F., Birk, M., Bizzocchi, L., Boudon, V., Brown, L. R., Campargue, A., Chance, K., Cohen, E. A., Coudert, L. H., Devi, V. M., Drouin, B. J., Fayt, A., Flaud, J. M., Gamache, R. R., Harrison, J. J., Hartmann, J. M., Hill, C., Hodges, J. T., Jacquemart, D., Jolly, A., Lamouroux, J., Le Roy, R. J., Li, G., Long, D. A., Lyulin, O. M., Mackie, C. J., Massie, S. T., Mikhailenko, S., Müller, H. S. P., Naumenko, O. V., Nikitin, A. V., Orphal, J., Perevalov, V., Perrin, A., Polovtseva, E. R., Richard, C., Smith, M. A. H., Starikova, E., Sung, K., Tashkun, S., Tennyson, J., Toon, G. C., Tyuterev, V. G. and Wagner, G., The HITRAN2012 molecular spectroscopic database, J. Quant. Spectros. Radiat. Transfer, 130(0), 4–50, 2013.
[RD10]	Funke, B., López-Puertas, M., Garcia-Comas, M., Kaufmann, M., Höpfner, M. and Stiller, G. P.: GRANADA: A Generic RAdiative traNsfer AnD non-

	LTE population algorithm, J. Quant. Spectros. Radiat. Transfer, 113(14), 1771–1817, 2012.
[RD11]	López-González, M. J., Rodríguez, E., Shepherd, G. G., Sargoytchev, S., Shepher, M. G., Aushev, V. M., Brown, S., García-Comas, M., Wiens, R. H., Tidal Variations of O_2 Atmospheric and OH(6-2) airglow and Temperature at Mid-Latitudes from SATI Observations, Annales Geophysicae, 2005.
[RD12]	Garrido, D., Gaug, M., Doro, M., Font, Ll., López-Oramas, A., Moralejo, A., Influence of Atmospheric Aerosols on the Performance of the MAGIC Telescopes, 33rd International Cosmic Ray Conference, Rio de Janeiro, 2013.
[RD13]	Lord, S., Atmospheric Considerations and Advantages, Presentation at KISS Airship Workshop, Pasadena, 2013.
[RD14]	Thomason, L., Peter, Th. (editors), Assessment of Stratospheric Aerosol Properties, Report, 2006.
[RD15]	Thomason, L., Burton, S., Luo, B., Peter, T., SAGE II Measurements of Stratospheric Aerosol Properties at non-Volcanic Levels, Atmospheric Chemistry and Physics, 8, 983-995, 2008.
[RD16]	Hanafy, M., Roggemann, M., Guney, D., Detailed Effects of Scattering and Absorption by Haze and Aerosols in the Atmosphere on the Average Point Spread Function of an Imaging System, Journal of the Optical Society of America, 31, 1312-1319, 2014.
[RD17]	Kopeika, N., Dror, I., Sadot, D., Causes of Atmospheric Blur: Comment on Atmospheric Scattering Effect on Spatial Resolution of Imaging Systems, Journal of the Optical Society of America, 15, 3097-3106, 1998.
[RD18]	Dror, I., Kopeika, N., Experimental Comparison of Turbulence Modulation Transfer Function and Aerosol Modulation Transfer Function through the Open Atmosphere, Journal of the Optical Society of America, 12, 970-980, 1995.
[RD19]	Osborn, J., Föhring, D., Dhillon, V.S., Wilson, R.W., Atmospheric Scintillation in Astronomical Photometry, accepted for publication in Monthly Notices of the Royal Astronomical Society, arXiv:1506.06921, 2015.
[RD20]	Kerber, F., Querel, R.R., Hanuschik, R., Quantifying photometric observing conditions on Paranal using an IR camera, Proceedings of SPIE 9149, Observatory Operations: Strategies, Processes, and Systems, 2014.
[RD21]	Leone, D., NASA Does About-Face on SOFIA, Requests Full Funding, Article on Spacenews.com (http://spacenews.com/nasa-does-about-face-on-sofia-requests-full-funding/), 02.02.2015.
[RD22]	Witze, A., White House budget to ground SOFIA, Nature News (http://www.nature.com/news/white-house-budget-to-ground-sofia-1.14821), 04.03.2014.
[RD23]	Gehrz, R. D., Becklin, E. E., de Buizer, J., Herter, T., Keller, L. D., Krabbe, A., Marcum, P. M., Roellig, T. L., Sandell, G. H. L., Temi, P., Vacca, W. D., Young, E. T., Zinnecker, H., Status of the Stratospheric Observatory for Infrared Astronomy (SOFIA), Advances in Space Research, 48 (6), 1004-1016, 2011.

[RD24]	Dankanich, J., Kremic, T., Hibbitts, K., Young, E., Landis, R., Planetary Balloon-Based Science Platform Evaluation and Program Implementation, Final Report, 2016.
[RD25]	Mommert, M., Hora, J. L., Harris, A. W., Reach, W. T., Emery, J. P., Thomas, C. A., ... & Smith, H. A., The discovery of cometary activity in Near-Earth asteroid (3552) Don Quixote, The Astrophysical Journal, 781(1), 25, 2014
[RD26]	Madiedo, J. M., Ortiz, J. L., Morales, N., & Cabrera-Caño, J., Analysis of Lunar Impact Flashes Recorded During the Activity Period of the Lyrid Meteor Shower in 2013, In Lunar and Planetary Science Conference (Vol. 47, p. 1124), 2016.
[RD27]	Milillo, A., Fujimoto, M., Kallio, E., Kameda, S., Leblanc, F., Narita, Y., Cremonese, G., Laakso, H., Laurenza, M., Massetti, S., McKenna-Lawlor, S., Mura, A., Nakamura, R., Omura, Y., Rothery, D.A., Seki, K., Storini, M., Wurz, P., Baumjohann, W., Bunce, E.J., Kasaba, Y., Helbert, J., Sprague, A., the other Hermean Environment WG members, The BepiColombo mission: An outstanding tool for investigating the Hermean environment, Planetary and Space Science 58, 40–60, 2010.
[RD28]	Benkhoff, J., van Casteren, J., Hayakawa, H., Fujimoto, M., Laakso, H., Novara, M., Ferri, P., Middleton, H.R., Ziethe, R., BepiColombo - Comprehensive exploration of Mercury: Mission overview and science goals, Planetary and Space Science 58, 2–20, 2010.
[RD29]	Mouawad, N., Burger, M., Killen, R., Potter, A.E., McClintock, W.E., Vervack Jr., R.J., Bradley, E.T., Benna, M., Naidu, S., Constraints on Mercury's Na exosphere: Combined MESSENGER and ground-based data, Icarus 211, 21-36, 2011.
[RD30]	Vervack Jr., R.J., McClintock, W.E., Killen, R.M., Sprague, A.L., Anderson, B.J., Burger, M.H., Bradley, E.T., Mouawad, N., Solomon, S.C., Izenberg, N.R., Mercury's Complex Exosphere: Resolts from MESSENGER's Third Flyby, Science, 329, 672-675, 2010.
[RD31]	Broadfoot, A.L., Kumar, S., Belton, M.J.S., McElroy, M.B., Mercurys's Atmosphere from Mariner 10: Preliminary Results, Science, 185, 166-169, 1974
[RD32]	Broadfoot, A.L, Shemansky, D.E., Kumar, S., Mariner 10: Mercury Atmosphere, Geophysical Research Letters, 3, 577-580, 1976.
[RD33]	Potter, A.E., Morgan, T.H., Potassium in the Atmosphere of Mercury, Icarus, 67, 336-340, 1986.
[RD34]	Gomes, R., Levison, H.F., Tsiganis, K., Morbidelli, A., Origin of the cataclysmic Late Heavy Bombardment period of the terrestrial planets, Nature, 435, 466-469, 2005.
[RD35]	Morbidelli, A., Levison, H.F., Gomes, R., The dynamical structure of the Kuiper Belt and its primordial origin, In: Barucci, M.A., Boehnhardt, H., Cruikshank, D.P., Morbidelli, A., The Solar System Beyond Neptune, pp. 275-292, 2008.

[RD36]	NASA, DLR, The Science Vision for the Stratospheric Observatory for Infrared Astronomy, 2009.
[RD37]	Gibb, E.L., Mumma, M.J., Dello Russo, N., DiSanti, M.A., Magee-Sauer, K., Methane in Oort cloud comets, Icarus, 165, 391-406, 2003.
[RD38]	Crovisier, J., Leech, K., Bockelée-Morvan, D., Brooke, T.Y., Hanner, M.S., Altieri, B., Keller, H.U., Lellouch, E., The Spectrum of Comet Hale-Bopp (C/1995 O1) Observed with the Infrared Space Observatory at 2.9 Astonomical Units from the Sun, Science, 275, 1904-1907, 1997.
[RD39]	Lippi, M., The composition of cometary ices as inferred from measured production rates of volatiles, PhD Thesis, 2010.
[RD40]	Villanueva, G.L., Mumma, M.J., Bonev, B.P., DiSanti, M.A., Gibb, E.L., Böhnhardt, H., Lippi, M., A Sensitive Search for Deuterated Water in Comet 8P/Tuttle, The Astrophysical Journal, 650, L5-L9, 2009.
[RD41]	Bus, S., Vilas, F., Barucci, M.A., Visible-Wavelength Spectroscopy of Asteroids, In: Bottke, W.F., Cellino, A., Paolicchi, P., Binzel, R.P., Asteroids III, 2002.
[RD42]	De Sanctis, M.C., Combe, J.-Ph., Ammannito, E., Palomba, E., Longobardo, A., McCord, T.B., Marchi, S., Capaccioni, F., Capria, M.T., Mittlefehldt, D.W., Pieters, C.M., Sunshine, J., Tosi, F., Zambon, F., Carraro, F., Fonte, S., Frigeri, A., Magni, G., Raymond, C.A., Russell, C.T., Turrini, D., Detection of Widespread Hydrated Materials on Vesta by the VIR Imaging Spectrometer on Board the Dawn Mission, The Astrophysical Journal Letters, 758, L36, 2012.
[RD43]	Campins, H., Hargrove, K., Pinilla-Alonso, N., Howell, E.S., Kelley, M.S., Licandro, J., Mothé-Diniz, T., Fernández, Y., Ziffer, J., Water ice and organics on the surface of the asteroid 24 Themis, Nature, 464, 1320-1321, 2010.
[RD44]	Cloutis, E.A., McCormack, K.A., Bell III, J.F., Hendrix, A.R., Bailey, D.T., Craig, M.A., Mertzman, S.A., Robinson, M.S., Riner, M.A., Ultraviolet spectral reflectance properties of common planetary minerals, Icarus, 197, 321-347, 2008.
[RD45]	Busarev, V.V., New Reflectrance Spectra of 40 Asteroids: A Comparison with the Previous Results and an Interpretation, Solar System Research, 50, 13-23, 2016.
[RD46]	Tedesco, E.F., Gradie, J., Discovery of M Class Objects among the Near-Earth Asteroid Population, The Astronomical Journal, 93, 738-746, 1987.
[RD47]	Vilas, F., Hatch, E.C., Larson, S.M., Sawyer, S.R., Gaffey, M.J., Ferric Iron in Primitive Asteroids: A 0.43-µm Absorption Feature, Icarus, 102, 225-231, 1993.
[RD48]	Li, Jian-Yang, Bodewits, D., Feaga, L.M., Landsman, W., A'Hearn, M.F., Mutchler, M.J., Russel, C.T., McFadden, L.A., Raymond, C.A., Ultraviolet spectroscopy of Asteroid (4) Vesta, Icarus, 216, 640-649, 2011.
[RD49]	Butterworth, P.S., Meadows, A.J., Ultraviolet Reflectance Properties of Asteroids, Icarus, 62, 305-318, 1985.

[RD50]	Madiedo, J. M., Trigo-Rodríguez, J. M., Ortiz, J. L., Castro-Tirado, A. J., & Cabrera-Caño, J., Bright fireballs associated with the potentially hazardous asteroid 2007LQ19, Monthly Notices of the Royal Astronomical Society, 443(2), 1643-1650, 2014.
[RD51]	Moser, D. E., & Cooke, W. J., The 2016 Perseids, Stanford Meteor Environments and Effects Workshop, 2015.
[RD52]	Caswell, R. D., McBride, N., & Taylor, A., Olympus end of life anomaly—a Perseid meteoroid impact event?, International Journal of Impact Engineering, 17(1), 139-150, 1995.
[RD53]	Sánchez de Miguel, A., Gomez, M.A., Byn, M., Mayo, D., Perseids 2016 from the stratosphere: Daedalus 20/Orison Pathfinder 2, Video data, doi:10.5281/zenodo.60546.
[RD54]	Vaubaillon, J., Colas, F., & Jorda, L., A new method to predict meteor showers-II. Application to the Leonids, Astronomy & Astrophysics, 439(2), 761-770, 2005.
[RD55]	Sánchez de Miguel, A., Ortiz, J.L., López-Moreno, J.J., Duffard, R., Maier, P., Müller, T., Wolf, J., Graf, F., Schindler, K., ORISON, stratospheric instrumentation project with potential applications in meteoroid science, Meteoroids 2016 conference contribution, 2016.
[RD56]	Rambaux, N., Galayko, D., Mariscal, J. F., Breton, M. A., Vaubaillon, J., Birlan, M., ... & Fouchet, T., Detection of spectral UV from meteors by a nanosatellite. In Proceedings of the International Meteor Conference, pp. 182-184, 2014.
[RD57]	Jenniskens, P., Tedesco, E., Murthy, J., Laux, C. O., & Price, S., Spaceborne ultraviolet 251–384 nm spectroscopy of a meteor during the 1997 Leonid shower, Meteoritics & Planetary Science, 37(8), 1071-1078, 2002.
[RD58]	Brown, P., Spalding, R. E., ReVelle, D. O., Tagliaferri, E., & Worden, S. P., The flux of small near-Earth objects colliding with the Earth, Nature, 420(6913), 294-296, 2002.
[RD59]	Appleton, E., & Naismith, R., The radio detection of meteor trails and allied phenomena, Proceedings of the Physical Society, 59(3), 461, 1947.
[RD60]	Gill, J. C., & Davies, J. G., A radio echo method of meteor orbit determination, Monthly Notices of the Royal Astronomical Society, 116(1), 105-113, 1956.
[RD61]	Messenger, S., Opportunities for the stratospheric collection of dust from short-period comets, Meteoritics & Planetary Science, 37(11), 1491-1505, 2002.
[RD62]	Braga-Ribas, F., Sicardy, B., Ortiz, J.L., Snodgrass, C., Roques, F., Vieira-Martins, R., Camargo, J.I.B., Assafin, M., Duffard, R., Jehin, E., Pollock, J., Leiva, R., Emilio, M., Machado, D.I., Colaza, C., Lellouch, E., Skottfelt, J., Gillon, M., Ligier, N., Maquet, L., Benedetti-Rossi, G., Ramos Gomes Jr, A., Kervella, P., Monteiro, H., Sfair, R., El Moutamid, M., Tancredi, G., Spagnotto, J., Maury, A., Morales, N., Gil-Hutton, R., Roland, S., Ceretta, A., Gu, S.-h., Wand, X.-b., Harpsøe, K., Rabus, M., Manfroid, J., Opitom, C., Vanzi, L., Mehret, L., Lorenzini, L., Schneiter, E.M., Melia, R., Lecacheux,

	J., Colas, F., Vachier, F., Widemann, T., Almenares, L., Sandness, R.G., Char, F., Perez, V., Lemos, P., Martinez, N., Jøregensen, U.G., Dominik, M., Roig, F., Reichart, D.E., LaCluyze, A.P., Haislip, J.B., Ivarsen, K.M., Moore, J.P., Frank, N.R., Lambas, D.G., A ring system detected around the Centaur (10199) Chariklo, Nature, 508, 72-75, 2014.
[RD63]	Ortiz, J.L., Sicardy, B., Braga-Ribas, F., Morales, N., Duffard, R., Santos-Sanz, P., Vieira-Martins, R., Camargo, J.I.B., Assafin, M., Roques, F., Widemann, T., Lecacheux, J., Colas, F., Lessons learned from stellar occultations by Trans-Neptunian Objects and prospects for the future, European Planetary Science Congress 2014.
[RD64]	Philipona, R., Kräuchi, A., Brocard, E., Solar and thermal radiation profiles and radiative forcing measured through the atmosphere, Geophysical Research Letters, 39, L13806, 2012.
[RD65]	Della Corte, V., Palumbo, P., De Angelis, S., Ciucci, A., Brunetto, R., Rotundi, A., DUSTER (Dust in the Upper Stratosphere Tracking Experiment and Return): a balloon-borne dust particle collector, Memorie della Societa Astronomica Italiana, Supplement, 16, 14-21, 2011.
[RD66]	Fornasier, S., Lantz, C., Barucci, M.A., Lazzarin, M., Aqueous alteration on main belt primitive asteroids: Results from visible spectroscopy, Icarus, 233, 163-178, 2014.
[RD67]	Heller, R., Marleau, G.-D., Pudritz, R. E., The formation of the Galilean moons and Titan in the Grand Tack scenario, Astronomy and Astrophysics, 579, L4, 2015.
[RD68]	Mousis, O., Hautier, D., Constraints on the presence of volatiles in Ganymede and Callisto from an evolutionary turbulent model of the Jovian subnebula, Planetary and Space Science, 52, 361-370, 2004.
[RD69]	Committee on the Planetary Science Decadal Survey, National Research Council, Vision and Voyages for Planetary Science in the Decade 2013-2022, 2011.
[RD70]	Grasset, O., Prieto-Ballesteros, O., Dougherty, M.K., Titov, D., Erd, Ch., Bunce, E., Coustenis, A., Blanc, M., Coates, A., Drossart, P., Fletcher, L., van Hoolst, T., Hussmann, H., Jaumann, R., Krupp, N., Tortora, P., Tosi, F., Wielders, A., Habitability of the giant icy moons: current knowledge and future insights from the JUICE mission, European Planetary Science Congress 2012.
[RD71]	Lane, A., Domingue, D., IUE's view of Callisto: Detection of an SO_2 absorption correlated to possible torus neutral wind alterations, Geophysical Research Letters, 24, 1143-1146, 1997.
[RD72]	McChord, T.B., Coradini, A., Hibbits, C.A., Capaccioni, F., Hansen, G.B., Filacchione, G., Clark, R.N., Cerroni, P., Brown, R.H., Baines, K.H., Bellucci, G., Bibring, J.-P., Buratti, B.J., Bussoletti, E., Combes, M., Cruikshank, D.P., Drossart, P., Formisano, V., Jaumann, R., Langevin, Y., Matson, D.L., Nelson, R.M., Nicholson, P.D., Sicardy, B., Sotin, C., Cassini VIMS observations of the Galilean satellites including the VIMS calibration procedure, Icarus, 172, 104-126, 2004.

[RD73]	Jessup, K.L., Spencer, J.R., Ballester, G.E., Howell, R.R:, Roesler, F., Vigel, M., Yelle, R., The atmospheric signature of Io's Prometheus plume and anti-jovian hemisphere: evidence for a sublimation atmosphere, Icarus, 169, 197-215, 2004.
[RD74]	Walker, C., Kulesa, C., Bernasconi, P., Eaton, H., Rolander, N., Groppi, C., Kloosterman, J., Cottam, T., Lesser, D., Martin, C., Stark, A., Neufeld, D., LIsse, C., Hollenbach, D., Kawamura, J., Goldsmith, P., Langer, W., Yorke, H., Sterne, J., Skalare, A., Mehdi, I., Weinreb, S., Kooi, J., Stutzki, J., Graf, U., Brasse, M., Honingh, C., Simon, R., Akyilmaz, M., Puetz, P., Wolfire, M., The Stratospheric THz Observatory (STO), Proceedings of SPIE, 773, 77330N, 2010.
[RD75]	Pascale, E., Ade, P.A.R., Bock, J.J., Chapin, E.L., Chung, J., Devlin, M.J., Dicker, S., Griffin, M., Gundersen, J.O., Halpern, M., Hargrave, P.C., Hughes, D.H., Klein, J., MacTavish, C.J., Marsden, G., Martin, P.G., Martin, T.G., Mauskopf, P., Netterfield, C.B., Olmi, L., Patanchon, G., Rex, M., Scott, D., Semisch, C., Thomas, N., Truch, M.D.P., Tucker, C., Tucker, G.S., Viero, M.P, Wiebe, D.V., The Balloon-borne Large Aperture Submillimeter Telescope: BLAST, The Astrophysical Journal, 681 (1), 400-414, 2008.
[RD76]	Devlin, M.J., Ade, P.A.R., Aretxaga, I., Bock, J.J., Chapin, E.L., Griffin, M., Gundersen, J.O., Halpern, M., Hargrave, P.C., Hughes, D.H., Klein, J., Marsden, G., Martin, P.G., Mauskopf, P., Moncelsi, L., Netterfield, C.B., Ngo, H., Olmi, L., Pascale, E., Patanchon, G., Rex, M., Scott, D., Semisch, C., Thomas, N., Truch, M.D.P., Tucker, C., Tucker, G.S., Viero, M.P., Wiebe, D.V., Over half of the far-infrared background light comes from galaxies at $z \geq 1.2$, Nature, 458, 737-739, 2009.
[RD77]	Küppers, M., O'Rourke, L., Bockelée-Morvan, D., Zakharov, V., Lee, S., von Allmen, P., Carry, B., Teyssier, D., Marston, A., Müller, T., Crovisier, J., Barucci, M.A., Moreno, R., Localized sources of water vapour on the dwarf planet (1) Ceres, Nature, 505, 525-527, 2014.
[RD78]	Hartogh, P., Lis, D. C., Bockelée-Morvan, D., de Val-Borro, M., Biver, N., Küppers, M., et al., Ocean-like water in the Jupiter-family comet 103P/Hartley 2. Nature, 478, 218-220, 2011.
[RD79]	Hartogh, P., Lellouch, E., Moreno, R., Bockelée-Morvan, D., Biver, N., Cassidy, T., et al., Direct detection of the Enceladus water torus with Herschel. Astronomy and Astrophysics, 532: L2, 2011.
[RD80]	Anglada-Escudé, G., et al., A terrestrial planet candidate in a temperate orbit around Proxima Centauri, Nature 536, 437-440, 2016.
[RD81]	Pascale, E., et al., The balloon-borne exoplanet spectroscopy experiment (BETSE), European Planetary Science Congress 2015, 861, 2015.
[RD82]	Pascale, E., et al., Detecting Exoplanet Atmospheres Using High Altitude Balloon Telescopes, European Planetary Science Congress 2014, 780, 2014.
[RD83]	Pascale, E., et al., The Balloon-Borne Exoplanet Experiment (EchoBeach), European Planetary Science Congress, 1036, 2013.
[RD84]	Tinetti, G., Encrenaz, T., Coustenis, A., Spectroscopy of planetary atmospheres in our Galaxy, Astron Astrophys Rev, 21:63, 2013.

[RD85]	N. Narita et al. (2015), "MuSCAT: a multicolor simultaneous camera for studying atmospheres of transiting exoplanets", JAI 1:4, 045001
[RD86]	Colón, D., Ford, E.B., Morehead, R.C., Constraining the false positive rate for Kepler planet candidates with multicolour photometry from the GTC, MNRAS 426, 342-353, 2012.
[RD87]	Marois, C., Doyon, R., Racine, R., Nadeau, D., Lafreniere, D., Vallee, P., ... & Macintosh, B., Direct Exoplanet Imaging around Sun-like Stars: Beating the Speckle Noise with Innovative Imaging Techniques, Journal of the Royal Astronomical Society of Canada, 99, 130, 2005.
[RD88]	Amado, P. J., Quirrenbach, A., Ribas, I., Caballero, J. A., Sánchez-Carrasco, M. A., Reiners, A., ... & Mandel, H., CARMENES. I. A radial-velocity survey for terrestrial planets in the habitable zones of M dwarfs, A historical overview, arXiv preprint arXiv:1210.5465, 2012
[RD89]	Barban, C., Matthews, J. M., De Ridder, J., Baudin, F., Kuschnig, R., Mazumdar, A., ... & Sasselov, D., Detection of solar-like oscillations in the red giant star ε Ophiuchi by MOST spacebased photometry, Astronomy & Astrophysics, 468(3), 1033-1038, 2007.
[RD90]	Rucinski, S., Carroll, K., Kuschnig, R., Matthews, J., & Stibrany, P., Most (microvariability & oscillations of stars) Canadian astronomical micro-satellite, Advances in Space Research, 31(2), 371-373, 2003.
[RD91]	Barstow, M. A., Binette, L., Brosch, N., Cheng, F. Z., Dennefeld, M., De Castro, A. G., ... & Moisheev, A., The WSO: a world-class observatory for the ultraviolet, In Astronomical Telescopes and Instrumentation (pp. 364-374), International Society for Optics and Photonics, 2013.
[RD92]	De Bruijne, J. H. J., Science performance of Gaia, ESA's space-astrometry mission, Astrophysics and Space Science, 341(1), 31-41, 2012.
[RD93]	Lawrence, A., Warren, S. J., Almaini, O., Edge, A. C., Hambly, N. C., Jameson, R. F., ... & Emerson, J. P., The UKIRT infrared deep sky survey (UKIDSS), Monthly Notices of the Royal Astronomical Society, 379(4), 1599-1617, 2007.
[RD94]	Laureijs, R., Euclid assessment study report for the ESA Cosmic Visions, arXiv preprint arXiv:0912.0914, 2009. https://arxiv.org/ftp/arxiv/papers/0912/0912.0914.pdf
[RD95]	Bond, H. E., Henden, A., Levay, Z. G., Panagia, N., Sparks, W. B., Starrfield, S., ... & Munari, U., An energetic stellar outburst accompanied by circumstellar light echoes, Nature, 422 (6930), 405-408, 2003.
[RD96]	Pérez-González, P. G., Rieke, G. H., Egami, E., Alonso-Herrero, A., Dole, H., Papovich, C., ... & Barmby, P., Spitzer View on the Evolution of Star-forming Galaxies from z= 0 to z~ 3, The Astrophysical Journal, 630(1), 82, 2005.
[RD97]	Thilker, D. A., Bianchi, L., Meurer, G., De Paz, A. G., Boissier, S., Madore, B. F., ... & Hameed, S., A search for extended ultraviolet disk (XUV-Disk) galaxies in the local universe, The Astrophysical Journal Supplement Series, 173(2), 538-571, 2007.

[RD98]	Klypin, A., Kravtsov, A. V., Valenzuela, O., & Prada, F., Where are the missing galactic satellites?, The Astrophysical Journal, 522(1), 82.universe. The Astrophysical Journal Supplement Series,173(2), 538, 1999.
[RD99]	Rodríguez-Muñoz, L., Gallego, J., Pacifici, C., Tresse, L., Charlot, S., de Paz, A. G., ... & Villar, V., Recent stellar mass assembly of low-mass star-forming galaxies at redshifts 0.3< z< 0.9 based on observations carried out with the European Southern Observatory (ESO) Very Large Telescope (VLT) at the La Silla Paranal Observatory under programs 088. A-0321 and 090. A-0858, The Astrophysical Journal, 799(1), 36, 2015.
[RD100]	Espinosa, J. R., González-Martín, O., Rodríguez, N. C., Pérez-González, P. G., Mas-Hesse, J. M., Muñoz-Tuñón, C., ... & Caballero, A. H., Episodic star formation in a group of LAEs at z= 5.07, Monthly Notices of the Royal Astronomical Society: Letters, 444(1), L68-L72, 2014
[RD101]	Riess, A. G., Filippenko, A. V., Challis, P., Clocchiatti, A., Diercks, A., Garnavich, P. M., ... & Leibundgut, B. R. U. N. O., Observational evidence from supernovae for an accelerating universe and a cosmological constant, The Astronomical Journal, 116(3), 1009, 1998.
[RD102]	Christian, H. J., Frost, R. L., Gillaspy, P. H., Goodman, S. J., Vaughan Jr, O. H., Brook, M., ... & Orville, R. E., Observations of Optical Lighting Emissions from above Thunderstorms Using U-2 Aircraft. Bulletin of the American Meteorological Society, 64(2), 120-123.
[RD103]	Jehl, A., Farges, T., & Blanc, E. (2013). Color pictures of sprites from non-dedicated observation on board the International Space Station. Journal of Geophysical Research: Space Physics, 118(1), 454-461, 1983.
[RD104]	Farges, T., & Blanc, E., Characteristics of lightning, sprites, and human-induced emissions observed by nadir-viewing cameras on board the International Space Station, Journal of Geophysical Research: Atmospheres,121(7), 3405-3420, 2016.
[RD105]	Franz, R. C., Nemzek R.J., Winckler, J.R., Television Image of a Large Upward Electrical Discharge Above a Thunderstorm System, Science, 249, 48-51, 1990.
[RD106]	Heavner, M. J., J. S. Morrill, C. Siefring, D. D. Sentman, D. R. Moudry, E. M. Wescott, and E. J. Bucsela, Near-ultraviolet and blue spectral observations of sprites in the 320–460 nm region: N2 (2PG) emissions, J. Geophys. Res., 115, A00E44, 2010.
[RD107]	Kanmae, T., H. C. Stenbaek-Nielsen, M. G. McHarg, and R. K. Haaland, Observation of blue sprite spectra at 10,000 fps, Geophys. Res. Lett., 37, L13808, 2010.
[RD108]	Siefring, C. L., J. S. Morrill, D. D. Sentman, and M. J. Heavner, Simultaneous near-infrared and visible observations of sprites and acoustic-gravity waves during the EXL98 campaign, J. Geophys. Res., 115, A00E57, 2010.
[RD109]	Altermatt, F., & Ebert, D., Reduced flight-to-light behaviour of moth populations exposed to long-term urban light pollution, Biology letters, 12(4), 20160111, 2016.

[RD110]	Gaston, K. J., & Bennie, J., Demographic effects of artificial nighttime lighting on animal populations, Environmental Reviews, 22(4), 323-330, 2014.
[RD111]	Longcore, T., & Rich, C., Ecological light pollution, Frontiers in Ecology and the Environment, 2(4), 191-198, 2004.
[RD112]	Snow, W. F., The spectral sensitivity of Aedes aegypti (L.) at oviposition, Bulletin of entomological research, 60(04), 683-696, 1971.
[RD113]	Pacheco-Tucuch, F. S., Ramirez-Sierra, M. J., Gourbière, S., & Dumonteil, E., Public street lights increase house infestation by the Chagas disease vector Triatoma dimidiate, PLoS One, 7(4), e36207, 2012.
[RD114]	Burkett, D. A., Butler, J. F., & Kline, D. L., Field evaluation of colored light-emitting diodes as attractants for woodland mosquitoes and other Diptera in north central Florida, Journal of the American Mosquito Control Association-Mosquito News, 14(2), 186-195, 1998.
[RD115]	Papagiannakopoulos, T., Bauer, M. R., Davidson, S. M., Heimann, M., Subbaraj, L., Bhutkar, A., ... & Jacks, T., Circadian Rhythm Disruption Promotes Lung Tumorigenesis, Cell Metabolism, 2016.
[RD116]	Chepesiuk, R., Missing the dark: health effects of light pollution, Environmental Health Perspectives, 117(1), A20, 2009.
[RD117]	Kloog, I., Stevens, R. G., Haim, A., & Portnov, B. A., Nighttime light level co-distributes with breast cancer incidence worldwide, Cancer Causes & Control, 21(12), 2059-2068, 2010.
[RD118]	Cajochen, C., Altanay-Ekici, S., Münch, M., Frey, S., Knoblauch, V., & Wirz-Justice, A., Evidence that the lunar cycle influences human sleep, Current Biology, 23(15), 1485-1488, 2013.
[RD119]	Miller, S. D., Haddock, S. H., Elvidge, C. D., & Lee, T. F., Detection of a bioluminescent milky sea from space, Proceedings of the National Academy of Sciences of the United States of America, 102(40), 14181-14184, 2005.
[RD120]	Kyba, C., Garz, S., Kuechly, H., de Miguel, A. S., Zamorano, J., Fischer, J., & Hölker, F., High-resolution imagery of Earth at night: new sources, opportunities and challenges, Remote sensing, 7(1), 1-23, 2014.
[RD121]	Sánchez de Miguel, A., Variación espacial, temporal y espectral de la contaminación lumínica y sus fuentes: Metodologia y resultados [Ph. D. thesis], Universidad Complutense de Madrid, 2015.
[RD122]	Liu, Y., Prabhu, D., Trumble, K. A., Saunders, D., & Jenniskens, P., Radiation modeling for the reentry of the Stardust sample return capsule, Journal of Spacecraft and Rockets, 47(5), 741-752, 2010.

1 INTRODUCTION

The Uses and Needs Report serves to investigate and present the uses for which a stratospheric observation platform would be beneficial and to identify the scientific needs associated with each use. Based on the findings presented in this report, the technical requirements for an observation platform will be derived in the further course of the project. This will make it possible to determine the configuration that best meets the demands and interests of the scientific community.

The Uses and Needs Report is structured in two main parts: the description of the unique conditions in the stratosphere, including a comparison to existing capabilities in chapter 3, and the description of potential science cases and their scientific needs in chapter 4.

2 SCOPE

The purpose of the Uses and Needs Report is to include

"… the definition of expected uses of the platform and needs of the potential stakeholders."

To reach this goal, a public survey using a questionnaire distributed at scientific conferences, via mailing lists, on the ORISON website, and other channels, internal surveys among researchers, a workshop at the SEA assembly, and literature research were carried out. It should be noted that both the extent of detail of the individual needs as well as the number of use cases presented in the report represent the state of knowledge at the time of writing. It is expected that through the ongoing dissemination activities, e.g. presentations at conferences and communication with colleagues, further potential uses will be revealed throughout the project. Those will be taken into account for the infrastructure development wherever possible and represented in future reports if appropriate.

It should furthermore be noted that the uses identified are affected by a natural bias of the small project group mainly representing the planetary science community. Efforts were undertaken to counteract the bias by systematically surveying other communities, but a certain effect prevails.

Some of the colleagues who contributed potential science cases asked for them to be handled confidentially. In these cases, efforts were undertaken to include the needs of these science cases in the description of general needs for the respective scientific area. The specified needs for confidential cases were furthermore included in the summary statistics.

Given the widely different uses of nomenclature for infrared spectral ranges in different communities, it should be noted at this point that throughout this report, the following nomenclature is used: near-infrared (NIR): 0.7 µm to 5 µm; mid-infrared (MIR): 5 µm – 50 µm; far-infrared (FIR): > 50 µm.

3 STRATOSPHERIC CONDITIONS AND EXISTING CAPABILITIES

3.1 CURRENT OBSERVATIONAL CAPABILITIES

Besides mid- and high-stratospheric platforms, three basic types of capabilities for astronomical observations currently exist, based on the location of the instrument platform: ground-based facilities, airborne facilities, and space-based facilities. Airborne facilities in this context are

Table 1: List of exemplary space-based observatories

Observatory	Spectral range	Aperture diameter	Status
XMM-Newton	X-rays, UV, visible	0.7 m	Operational
Hisaki	EUV	0.2 m	Operational
International UV Explorer	UV	0.45 m	Decommissioned in 1996
Galaxy Evolution Explorer	UV	0.5 m	Decommissioned in 2013
Astrosat	UV, visible	0.4 m	Operational
Hubble Space Telescope	UV to NIR	2.4 m	Operational
World Space Observatory	UV	1.7 m	Planned for 2021
MOST	Visible	0.15 m	Operational
BRITE	Visible	0.03 m	Operational
NEOSsat	Visible	0.15 m	Operation with restricted fine pointing capability
Kepler	Visible	0.95 m	Operational with restricted pointing capability
Euclid	Visible to NIR	1.2 m	Scheduled for launch in 2020
Spitzer Space Telescope	(N-)IR	0.85 m	Operational (without cryogen)
WISE/NEOWISE	(N-)IR	0.4 m	Operational (without cryogen)
Herschel Space Telescope	IR	3.5 m	Deactivated in 2013
James Webb Space Telescope	IR	6.5 m	Scheduled for launch in 2018

understood to be airplane-based and limited to regular observations up to about 15 km altitude, even though this qualifies as the low stratosphere. *For the sake of readability, when using the term "stratospheric infrastructure" in this report, we will refer to altitudes above 20 km, whereas observatories at lower altitudes will be referred to as "airborne".* Space-based facilities in this context mostly mean space telescopes, as opposed to in-situ missions for solar system research. A description in this document cannot do justice to all the long and highly developed observing techniques and intelligent compensations of instrument- or environment-induced limitations for all these facilities. Instead of an exhaustive description of all existing capabilities, only a short overview shall be provided at this point. The precise current capabilities concerning individual science cases will be covered in more detail for each case in this report and in the following technical and functional assessment.

Table 2: Exemplary current and past balloon-borne observatories

Observatory	Primary Target	Spectral Range	Aperture diameter	Status
Golden Dragon	Galaxies, dust	FIR, > 40 µm	1 m	Inactive, several flights in 1980s
Balloon-borne Large Aperture Telescope (BLAST)	Galaxies, star formation	250 µm, 350 µm, 500 µm	2 m	Several flights from 2003 to 2010
Stratospheric Terahertz Observatory (STO)	Interstellar medium	158 µm, 205 µm	0,8 m	Active, several flights from 2009 to 2016
SUNRISE	Sun	UV, visible	1 m	Several flights from 2009 to 2013
Balloon Observation Platform for Planetary Science (BOPPS)	Comets and planetary targets	NUV, visible, NIR	0.8 m	Last flight in 2014
SuperBIT	Dark matter, dark energy	Visible, 300-900 nm	0.5 m	First test flight in 2016

Ground-based capabilities are very well developed and large observatories cover all ranges of the electromagnetic spectrum reachable through the atmosphere. Locating the large facilities, such as the European Very Large Telescope, or the Atacama Large Millimeter/submillimeter Array at highly elevated and dry sites, in combination with sophisticated observing and calibration techniques, allows them to overcome some of the limitations posed by Earth's atmosphere. Particular techniques that greatly improve ground-based capabilities are e.g. interferometry / very-long-baseline interferometry in radio astronomy and means to correct wavefront distortions such as adaptive optics (partly with further tricks such as using laser guide stars).

In terms of airborne infrastructure, two general implementations shall be mentioned: large observatories, to which we currently only count the Stratospheric Observatory for Infrared Astronomy (SOFIA) operated by NASA and DLR, carrying a 2.7 m telescope for visible, infrared, and submillimetre observations; and smaller, often temporary observatories, based on smaller aircraft, e.g. business jets, and readily used to observe meteors, eclipses, other re-entry events, but also other astronomical targets.

Large space-based observatories are very limited in number due to their very high cost. While the decline in launch costs due to new launch providers and the advent of micro- and nano-spacecraft may be reducing the cost of access to space missions in general, physical size requirements (in combination with remaining technological immaturity of e.g. optical interferometry via formation flying) make it unlikely that state-of-the-art astronomical observatories will be affected in a disruptive manner in the short term. An exemplary list of space-based observatories considered most relevant in relation to stratospheric infrastructures is provided in table 1. Note that missions covering wavelength ranges not accessible in the stratosphere were generally left out. Equally X- and γ-ray observatories are not reflected in grater detail since primary payloads in this spectral range are expected to be too heavy at the moment to fit the goal of ORISON.

Finally, a short overview over exiting balloon-borne capabilities for the mid- and high-stratosphere shall be provided in table 2. It should be noted that besides tests of ultra-long duration balloons for flights of 100 days and more launching from New Zealand, longer flights are currently launched exclusively from remote locations, such as Antarctica or Kiruna.

3.2 STRATOSPHERIC CONDITIONS AND RELATED ADVANTAGES

Each of the abovementioned observation sites has its advantages and disadvantages. Ground based observatories are severely limited by atmospheric effects, whereas spaceborne observatories are strictly limited by operational constraints, accessibility, and have comparatively high deployment and operational costs.

Operating an observatory in the mid- or high-stratosphere can considerably reduce the disadvantages posed by the atmosphere and promises at the same time operations at lower costs and without some of the constraints imposed by space missions. The following sections lay out the most important conditions in the stratosphere relevant to science and operations. They include the investigation of the difference in conditions at different altitudes within the stratosphere in order to allow the informed choice of a necessary operating altitude as a trade-off between required conditions and effort to reach the altitude.

Table 3: Temperature and pressure at different relevant altitudes

Altitude [km]	Temperature [K]	Pressure [mbar]
15	217	120
20	217	55
30	227	12
35	237	6
40	251	3

Temperature & Pressure

As figure 1 and table 3 show, pressure conditions above ca. 10 km start to get very close to low vacuum conditions (particularly what design of technical equipment is concerned).

Temperatures, depending on the altitude, can be as low as -70 °C. It should be noted in this context that the standard atmosphere provides an orientation but instrument qualification requirements will be more severe due to strong variations in the atmospheric conditions. While effects of these conditions need to be taken into consideration for instrument design, they also offer certain advantages:

- In combination with the radiation environment close-to-space conditions usable for instrument tests or biological/material exposure to close-to-space stress conditions are present;
- The lower temperature conditions as compared to most ground-based observatories can make active instrument cooling unnecessary for some science cases;
- The lower temperature of the remaining gas environment induces lower background emissions in the thermal IR.

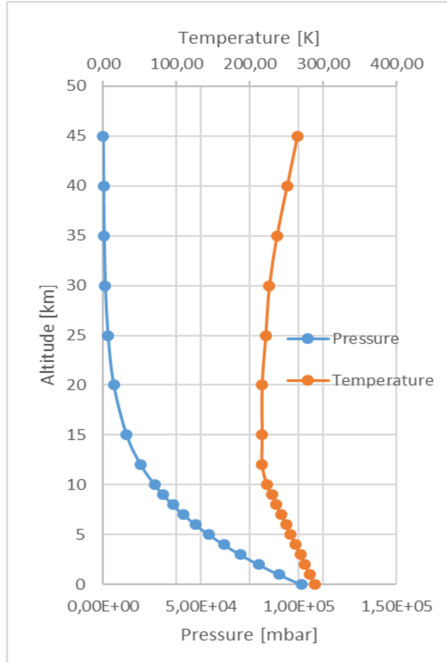

Figure 1: Atmospheric temperature and pressure profiles (U.S. Standard Atmosphere)

Turbulence and Seeing

Atmospheric turbulence severely degrades the quality of optical observations by broadening the image of point sources (the point spread function, PSF). This leads to a limitation in the achievable spatial resolution, independent of the telescope's size, and also to a severe degradation of the telescope's sensitivity due to the image's spread over a larger detector area. Most atmospheric turbulence occurs in the lower regions of the troposphere, particularly within the surface and the planetary boundary layers and, due to wind shear, around the tropopause at ca. 10 km altitude. Contributions to optical turbulence in the stratosphere above 20 km are about two orders of magnitude smaller than in the troposphere, as figure 2 shows.

Turbulence still exists on scales that can have a noticeable effect, however, particularly if the line of sight is not along or very close to the zenith.

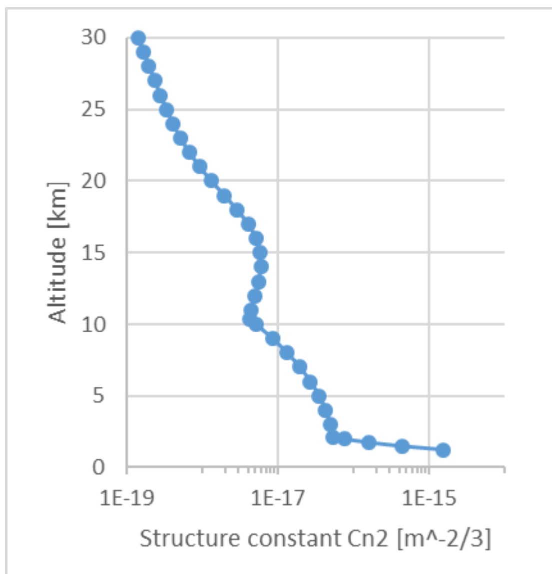

Figure 2: Altitude profile of the index of refraction structure constant according to the CLEAR I model as a measure of optical turbulence

Figures 3 to 7 thus show the derived Fried parameter r_0 for different altitudes, wavelengths, and zenith angles. r_0 thereby can be regarded as the maximum telescope aperture diameter for which observations close to the diffraction limit can be practically achieved (not accounting for lucky imaging).

A close look at these data shows that for observations at wavelengths above 300 nm, the resolution of long-exposure images taken with a 1 m aperture telescope is primarily diffraction limited above 20 km already, if the zenith angle is close to 0 deg.

On the other hand, this means that for observations in the far and mid UV it can be worthwhile to observe from altitudes higher than 20 km in order to avoid negative effects on the imaging resolution and signal spread even for telescopes of 0.5 or 1 m aperture. At longer wavelengths, this advantage is lost since the diffraction limit of small telescopes becomes as large as or larger than the seeing for ground-based telescopes. The same advantage still can apply for observations at longer wavelengths, however, if they require observations at large zenith angles. Examples can be observations with very long exposure times or observations for which the same target at low declinations has to be observed continuously for several hours (such as certain exoplanet transits).

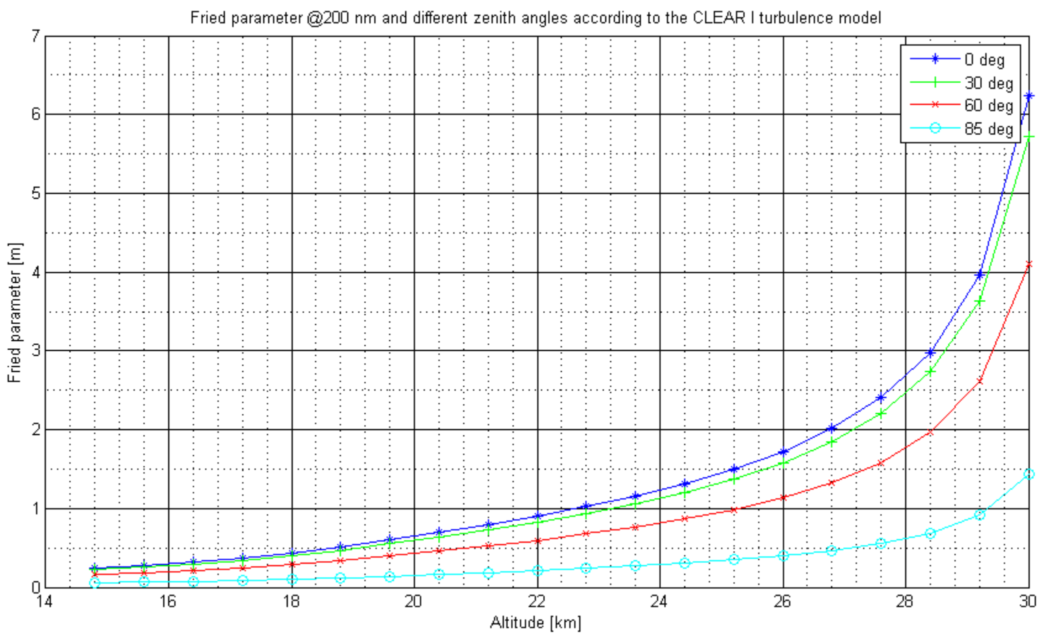

Figure 3: Fried parameter following the CLEAR I turbulence model for observations at 200 nm

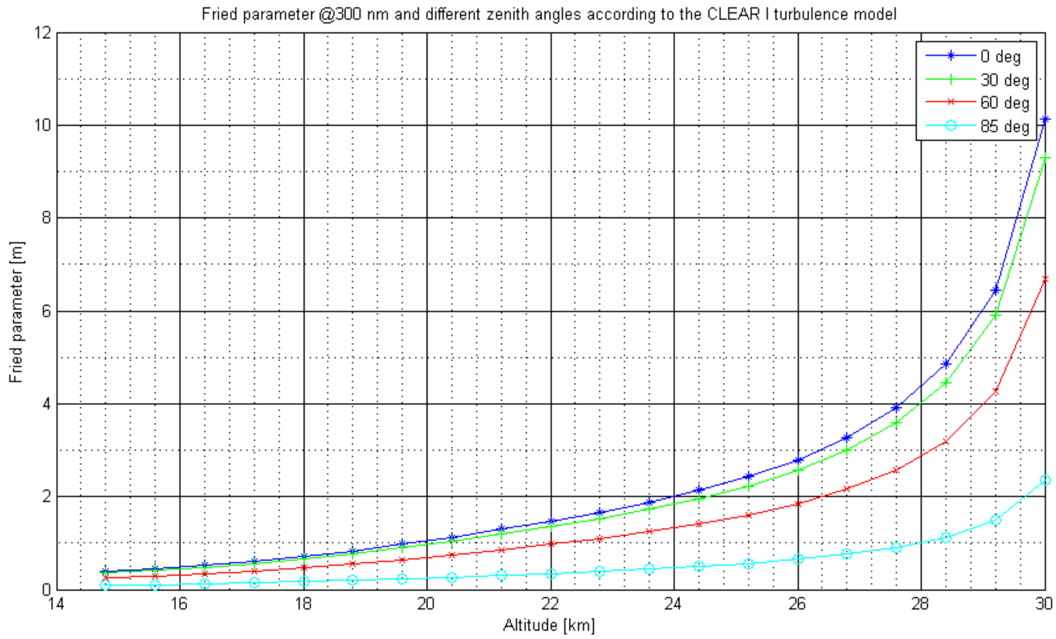

Figure 4: Fried parameter following the CLEAR I turbulence model for observations at 300 nm

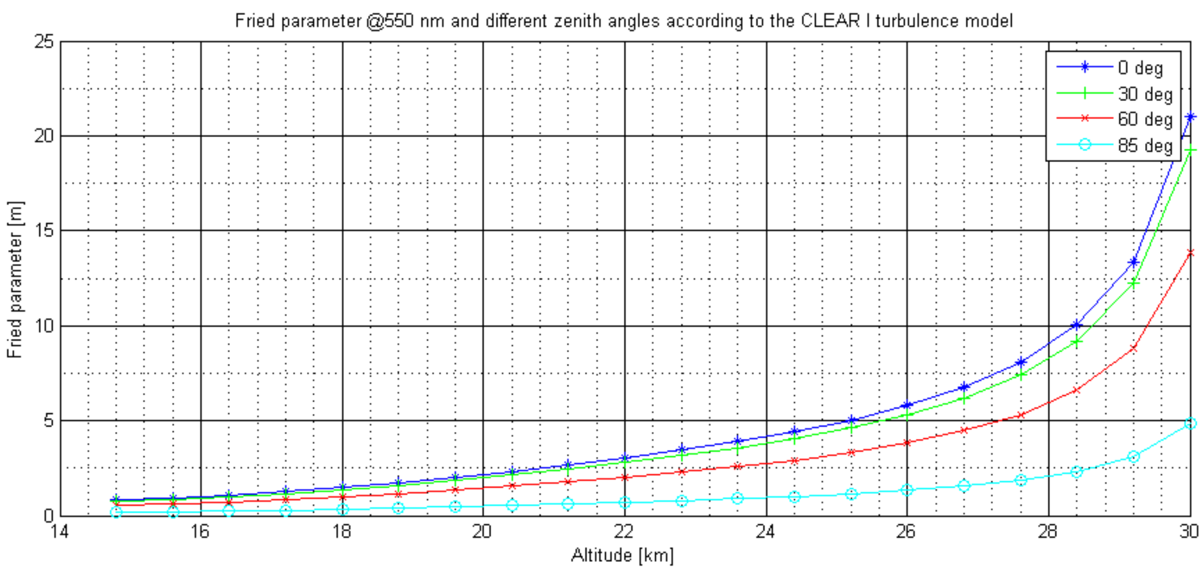

Figure 5: Fried parameter following the CLEAR I turbulence model for observations at 550 nm

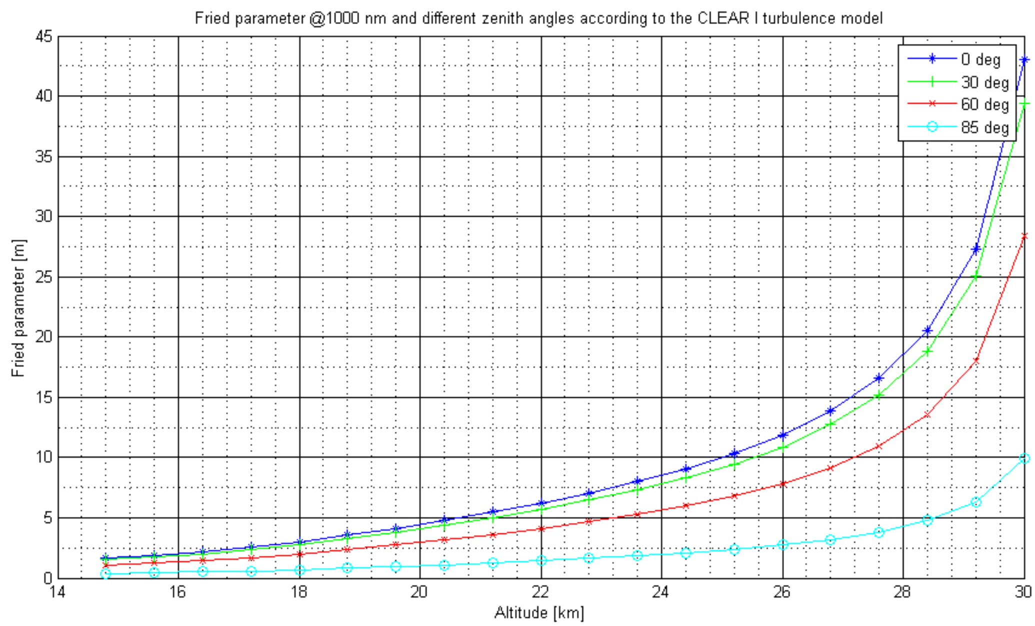

Figure 6: Fried parameter following the CLEAR I turbulence model for observations at 1000 nm

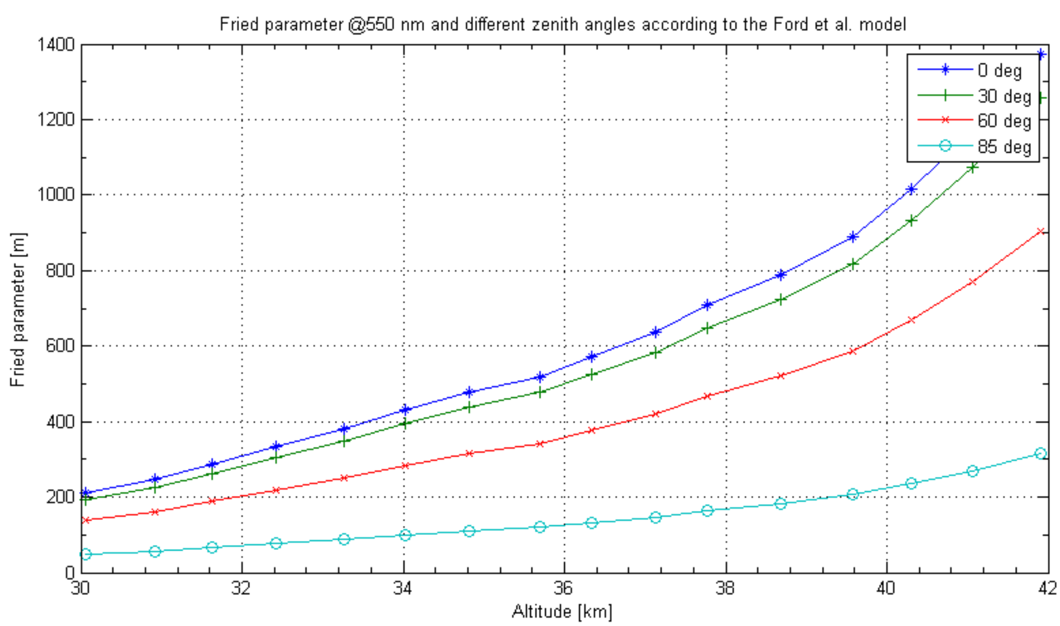

Figure 7: Fried parameter derived from turbulence data from stellar scintillation measurements from the MIR space station for observations at 550 nm[1]

[1] Based on original observation data from [RD1], taken in processed form from [RD2]. Discontinuity with regard to earlier plots is due to a difference between the CLEAR I and MIR-based data sets at 30 km.

Sky Brightness and its Variation

Sky brightness is one of the main sources of background noise for terrestrial observations. It is caused by several sources. For regions without background stars these are particularly airglow, zodiacal light, reflected ground-based light pollution, Rayleigh scattering of sun- and moonlight, and aurora at high latitudes. During daytime, the sky is far too bright in the visible and near IR for astronomical observations due to Rayleigh scattering of sunlight (except for a few rare applications).

At a good ground-based observation site, the sky brightness during a moonless night is dominated by airglow and zodiacal light [RD3] (and the atmospheric scattering thereof). The sources of both are located either at the very edge of the atmosphere or beyond. Airglow is caused by the emission of atoms and molecules (particularly OH) which are excited by UV solar radiation during the day. The primary emission regions are above 80 km altitude. Zodiacal light is sunlight scattered by interplanetary dust.

Both sources thus still contribute to night-time sky brightness at balloon altitudes. Due to the location above most of the atmospheric gas mass, however, it can be expected that the contributions due to atmospheric scattering of airglow and zodiacal light are minimised. A comparison of ground-based measurements and measurements from previous balloon missions as depicted in figures 8 and 9 seem to confirm this.

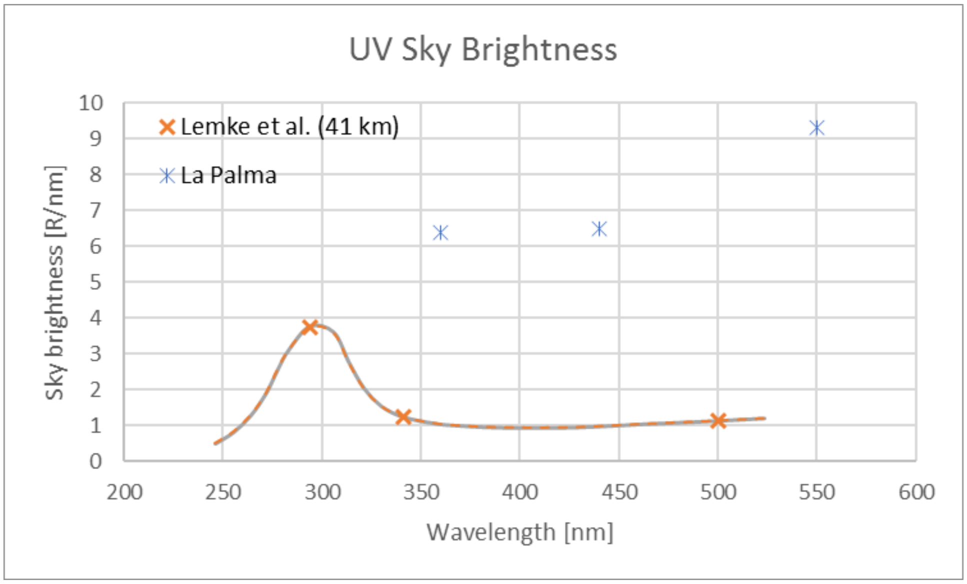

Figure 8: Night-time continuum sky brightness at UV wavelengths from long-term measurements at La Palma (2300 m) [RD3] and the THISBE balloon flight (41 km) [RD4][2]

[2] Sky brightness expressed in spectral apparent emission rate, unit Rayleigh/nm. Thereby: 1 R = apparent emission of $1*10^6$ photons/cm^2/column/s(/4πsr)

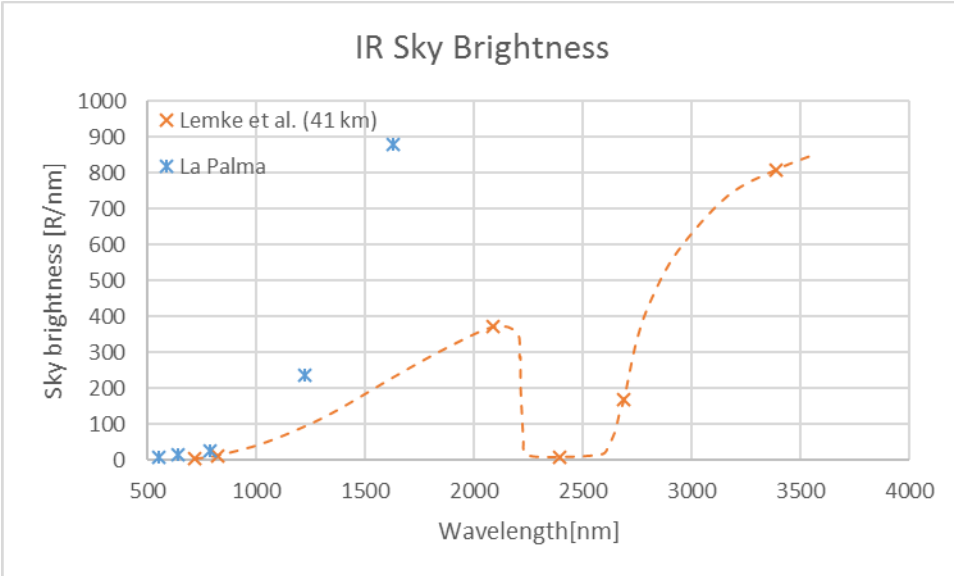

Figure 9: Night-time continuum sky brightness at IR wavelengths from long-term measurements at La Palma (2300 m) [RD3] and the THISBE balloon flight (41 km) [RD4]

While the present data unfortunately does not allow for a comparison of sky brightness at different stratospheric altitudes, it shows that the sky is considerably darker at stratospheric altitudes than at ground-based observation sites even during moonless nights.

The difference during daytime is much stronger when most of the sky brightness is caused by Rayleigh scattering of sunlight. As figures 10 and 11 show, a difference of around two orders of magnitude between sky brightness on the ground and at 40 km altitude is expected. Figure 10 also shows that the sky brightness hardly increases from the opposite-to-sun direction to a separation angle of about 60 deg between the sun and the line of sight (LOS).

At most wavelengths, however, the daytime sky even at 40 km altitude is still expected to be 1000 to 100,000 times brighter than at night, which will likely forbid many kinds of astronomical observations (note that the dip between 230 and 300 nm is due to remaining atmospheric absorption in the O_3 Hartley bands where atmospheric transmission is significantly hindered). Notable exceptions are high resolution observations of solar system planets and relatively bright stars which are bright enough to still provide feasible targets. Experience from past missions to 32 km altitude seems to confirm this assessment [RD5].

Only for wavelengths above 3000 nm the model suggests that night- and daytime brightness should be similar, i.e. that in the regard of atmospheric background noise observations can as well be conducted during the day.

It should be noted, however, that to confirm the daytime sky brightness, particularly the variation over altitude, it would be beneficial to conduct simple assessment flights with sky quality meters or similar equipment to gather experimental data.

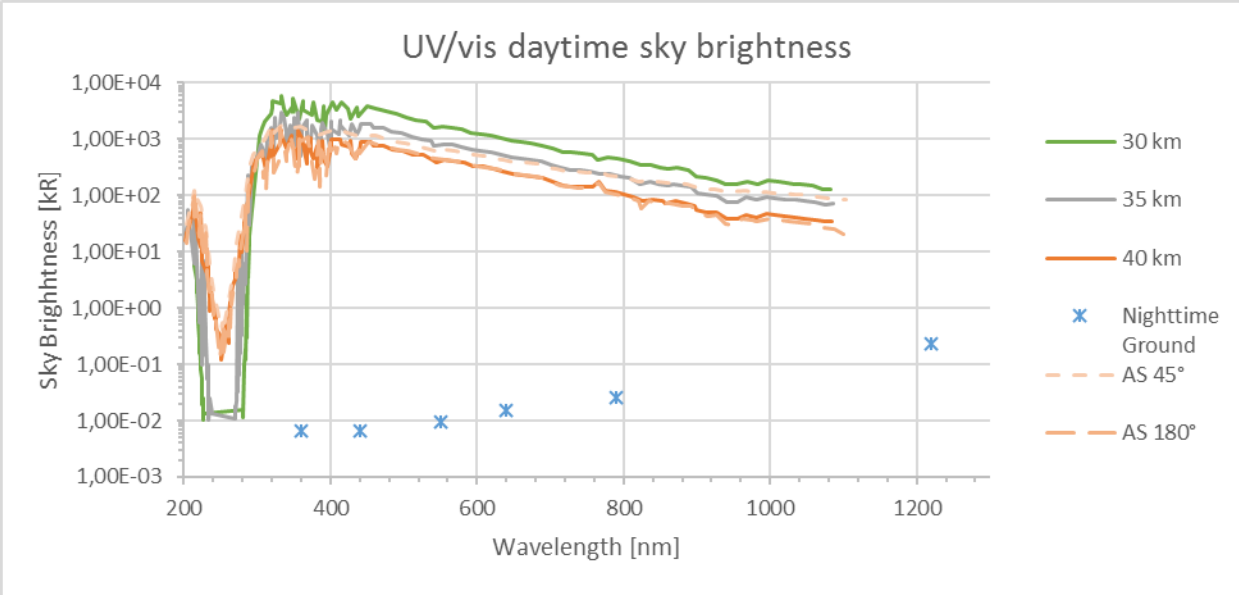

Figure 10: Daytime sky brightness at UV, visible, and NIR wavelengths as results of MODTRAN simulations. All stratospheric data is extracted from [RD6]. All stratospheric data assumes a sun zenith angle of 55 deg and a look zenith angle of 60 deg. Values at 30, 35, and 40 km are at a separation angle between sun and line of sight (LOS) of 60 deg. AS 45 and AS 180 are values for separation angles of 45 deg and 180 deg respectively, at an altitude of 40 km. Ground based data from [RD3].

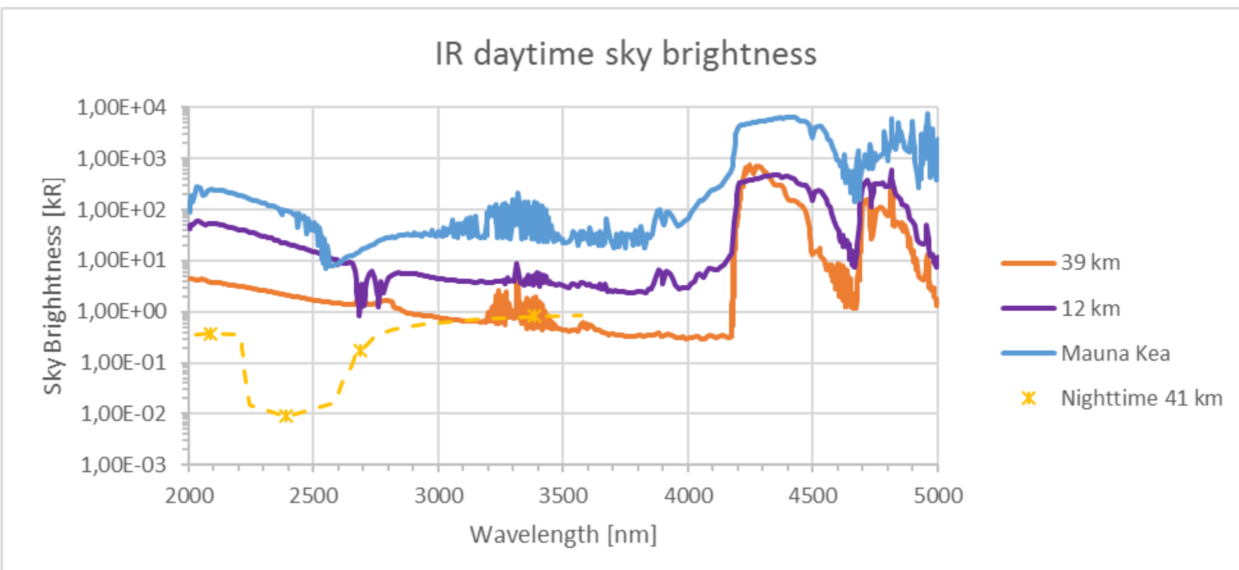

Figure 11: Daytime sky brightness in the near infrared. Data from [RD7]. Nighttime data from [RD4].

For spectroscopic and photometric observations, not only the absolute sky brightness as a contribution to noise but also the variation of sky brightness as a systematic error in the photometric data is of relevance. The most interesting variations in this regard are short term variations on timescales similar to or smaller than an observation sequence which can hardly be corrected for by observations of standard stars and telluric subtraction. Benn and Ellison [RD3] describe variations of less than 0.1 mag (or up to about 10 %) over the course of a night in airglow continuum brightness. López-González et al. [RD11] furthermore describe variations of up to 300 R over 6 h in the O_2 band (at 867 nm) and up to around 500 R over 6 h in the OH Meinel band (at 836 nm).

Atmospheric Transmission

For ground-based observations, unfortunately Earth's atmosphere blocks large parts of the electromagnetic spectrum through absorption and scattering. Observations are only possible through spectral windows with good transmission that are rather small compared to the full electromagnetic spectrum. Stratospheric platforms can mostly overcome these limitations by enabling observations from above 99% of the absorbing and scattering atmosphere. In the following, the different spectral regions and the benefits of observing them from the stratosphere are discussed shortly.

As figure 12 shows, the atmospheric ozone (O_3) and molecular oxygen (O_2) completely block the ultraviolet radiation below around 320 nm wavelength. At 39 km altitude, additional spectral regions down to ca 280 nm, and, more notably, between 190 and 220 nm become available. These additional bands enable observations particularly of some molecular emission bands: OH, atomic oxygen, CO_2 UV doublet and FDB bands, CO Cameron bands, NO and N, SO and SO_2, and H_2. [RD7] Wavelengths below ca. 190 nm still get absorbed in the Shumann-Runge bands of thermospheric/mesospheric oxygen, wavelengths between 220 nm and 280 nm get absorbed by remaining stratospheric ozone in the Hartley bands.

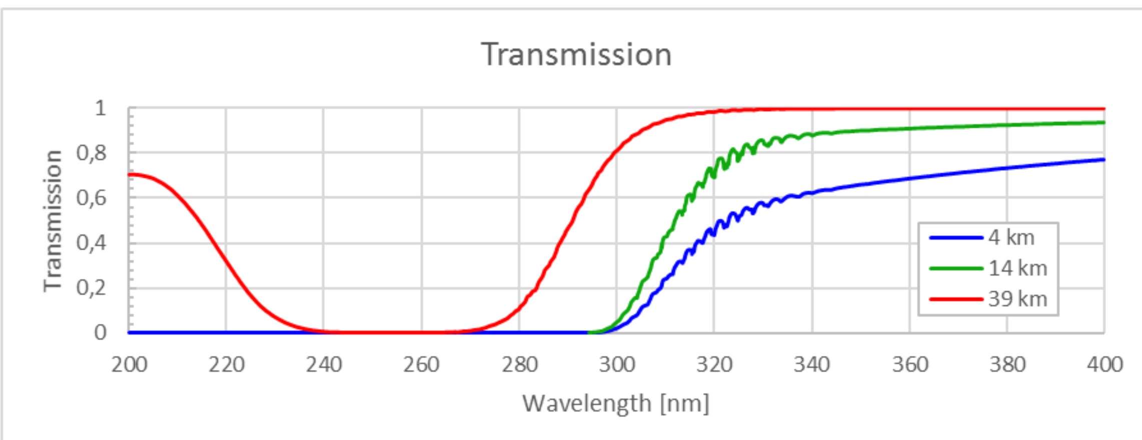

Figure 12: Atmospheric transmission in the UV at different altitudes (data from [RD7])

Similarly, X-Ray and Gamma-Ray radiation that is blocked for ground-based observations becomes available at stratospheric altitudes.

At infrared wavelengths, most atmospheric absorption is caused by water vapour, CO_2, or methane. Particularly water vapour and CO_2 absorption still cause considerable limitations also at altitudes reachable by aircraft, as figure 13 shows. At stratospheric altitudes, however, the full near-infrared spectrum and the mid-infrared spectrum up to 20 nm become available (see also figure 13). Figure 15 furthermore indicates that many more regions in the rest of the mid-infrared and the far-infrared become accessible as well.

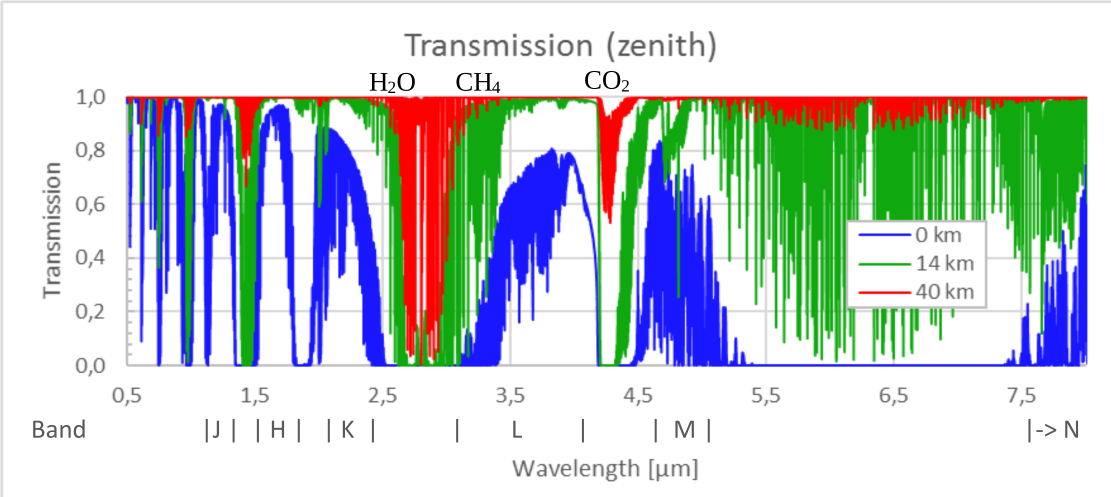

Figure 13: Atmospheric transmission in the near- and mid-infrared at different altitudes[3]

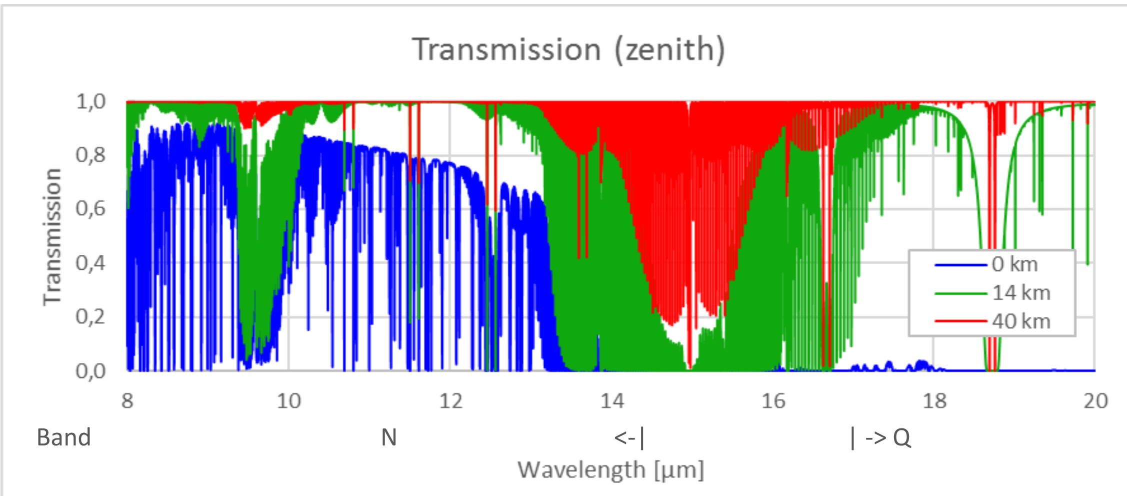

Figure 14: Atmospheric transmission in the mid-infrared at different altitudes[3]

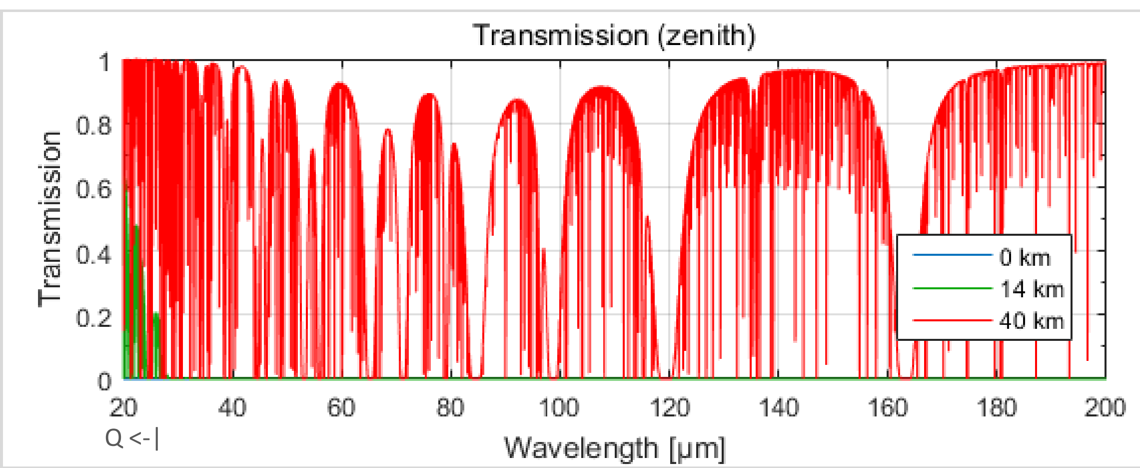

Figure 15: Atmospheric transmission in the mid- and far-infrared at different altitudes[3]

Figures 16 to 18 furthermore compare the transmission at different altitudes within the stratosphere in order to allow the determination of required flight altitudes.

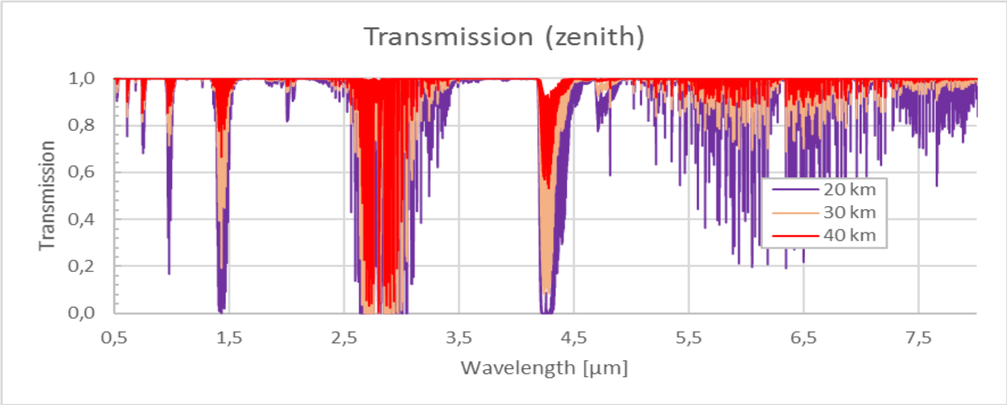

Figure 16: Atmospheric transmission from the visible to the MIR for different stratospheric altitudes[3]

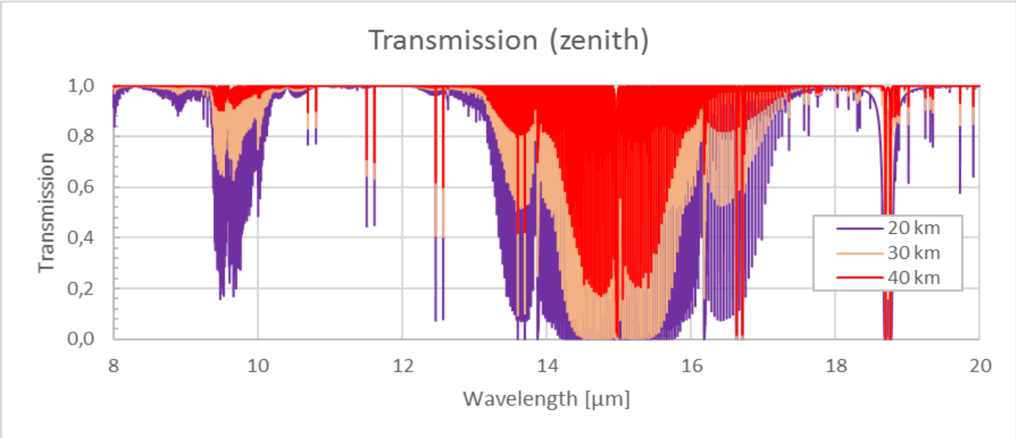

Figure 17: Atmospheric transmission in MIR for different stratospheric altitudes[3]

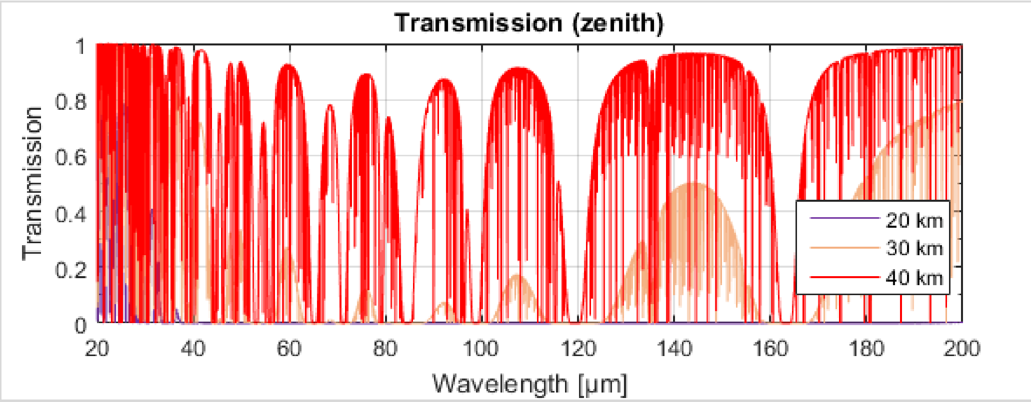

Figure 18: Atmospheric transmission in the far-infrared for different stratospheric altitudes. Note that at wavelengths longer than ca. 40 µm, there is no transmission down to 20 km.[3]

[3] Calculations were carried out using the Karlsruhe Optimized and Precise Radiative Transfer Algorithm (KOPRA) [RD8], using spectroscopic data from the HITRAN 2012 database [RD9] and atmospheric composition from [RD10] for the nighttime April 45 deg N case.

Atmospheric Scattering Effects on Contrast and Spatial Resolution

Atmospheric scattering of sunlight is the main cause of daytime sky brightness, and atmospheric scattering of radiation from an astronomical target plays a significant role in the aforementioned reduction of atmospheric transmission. However, atmospheric scattering of light coming from an astronomical target also affects observations by a) reducing the contrast of the observation around the target object and b) broadening the target's point spread function. Both of these degradations are mainly the effect of small angle forward scattering by particles of comparable or larger size than the wavelength of the incoming light (Mie scattering). In the atmosphere, these particles are primarily aerosols. The most significant density of aerosols is located in the troposphere below 10 km altitude and thus mostly affects ground-based observations. However, a layer of increased density of primarily sulfuric acid and water solution droplets (the Junge layer) is located in between 15 and 25 km altitude and thus relevant at least for low-flying stratospheric missions.

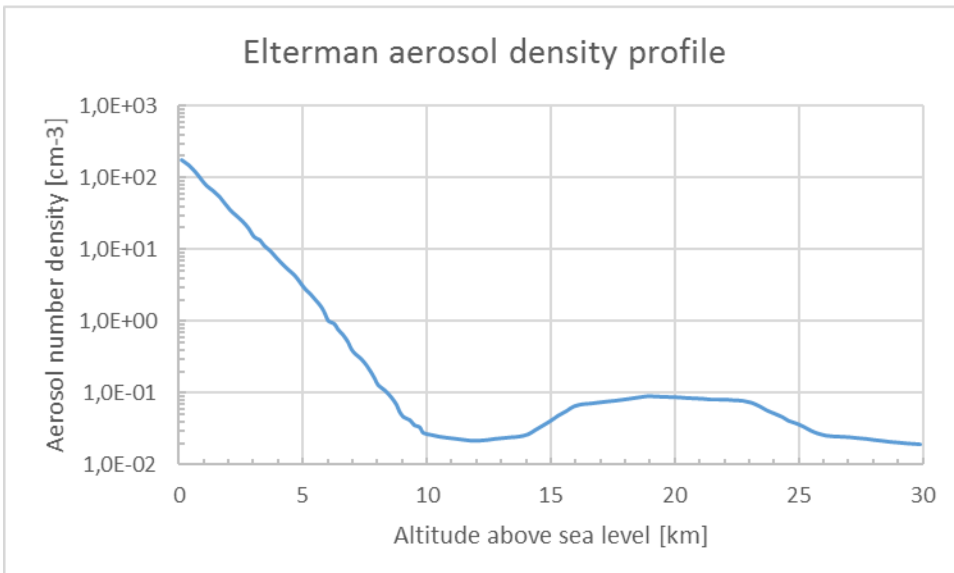

Figure 19: Aerosol density profile according to the Elterman model. Data from [RD12].

Figure 19 shows the Junge layer in the Elterman atmospheric density model, which in form and quantity correlates well with measurements [RD14],[RD15].

To properly assess the two aforementioned effects of Mie scattering on PSF degradation, a Monte Carlo simulation on the radiation transfer from a particular target, potentially including effects of adjacent bright areas in case of an extended target, through the relevant atmospheric volume would need to be carried out. An analysis of this detail may turn out to be beneficial or necessary for particular science cases.

To avoid simulations, simple approximations can be made as a first step, however. The scattering coefficient, and thereby at least the PSF broadening, are linearly proportional to the number of aerosol particles in the light path and the length of the light path. [RD16] This allows us to estimate the scattering effect by aerosols at higher altitudes by scaling results of ground based measurements [RD17],[RD18] with the changed aerosol density and the light path length through a particular aerosol layer.

These estimates suggest that the PSF width (FWHM) of the scattered light can be estimated to be roughly at the order of: 0.01 arcsec at 20 km altitude and 30 deg zenith angle, 0.4 arcsec at 20 km altitude and 90 deg zenith angle; 10E-4 arcsec at 25 km altitude and 30 deg zenith angle, 0.01 arcsec at 25 km altitude and 90 deg zenith angle.

For small pixels and observation lines of sight rather close to the horizontal direction, Mie scattering thus can be expected to have some influence on PSF broadening and contrast reduction at 20 km altitude. For larger pixels and lines of sight well above the horizontal direction, the influence on contrast and sharpness degradation is expected to be of minor importance even at altitudes as low as 20 km.

To properly judge the influence of Mie scattering on image quality degradation particularly in lower parts of the stratosphere, however, systematic measurements at different altitudes would be necessary.

Effect of Scintillation Noise on Photometric Accuracy

In addition to PSF broadening, atmospheric turbulence has a second effect on image quality. Local focusing and defocusing of the wavefront passing through regions of different refraction indices leads to spatial intensity fluctuations in a telescope's pupil plane. While these intensity fluctuations are not very important for conventional imaging applications, they can severely degrade the results of observations requiring high photometric accuracy, such as exoplanet transit observations. We estimate the scintillation noise at stratospheric altitudes based on the comparatively conservative approach proposed by Osborn et al. [RD19] for a 0.5 m telescope flying at mid-latitudes.

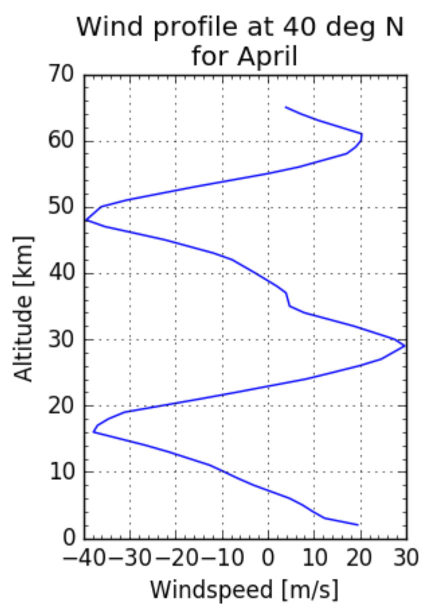

Figure 20: Average wind profile at 40 deg N latitude for the month of April. Data from SPARC.

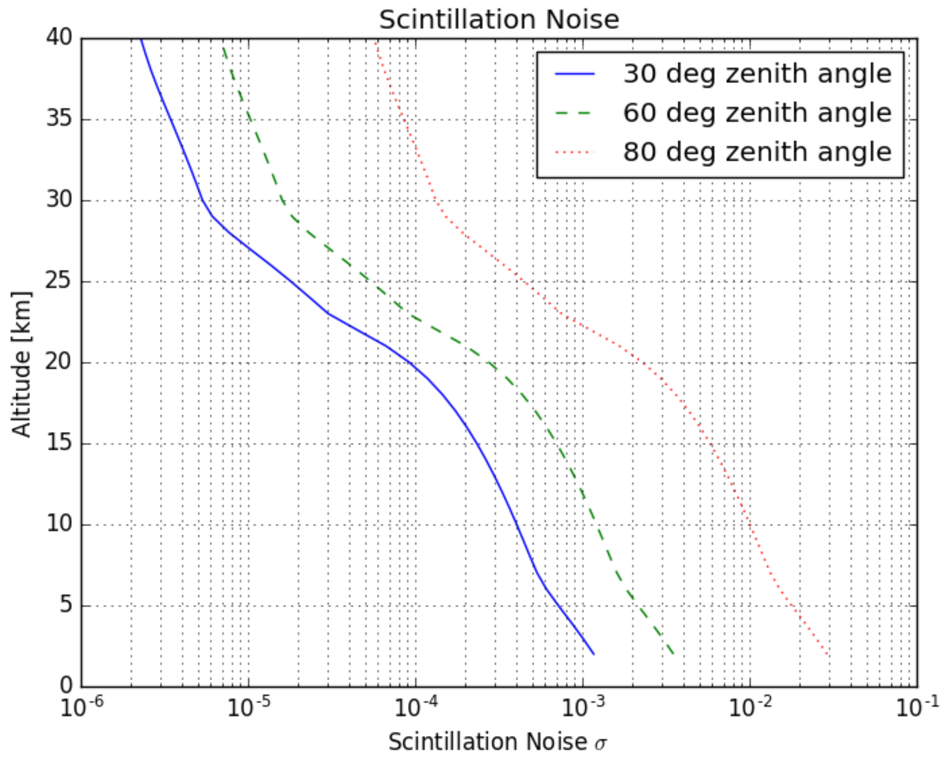

Figure 21: Expected scintillation noise for a 0.5 m telescope and 60 s exposure time. Wind data used is taken from SPARC data (average values for 1992 to 1997) for 40 N latitude and average values for April (April provides the highest scintillation noise values at high altitudes). Wind profile see figure 20.

Figure 21 shows the expected scintillation noise for a 0.5 m aperture and an assumed shortest exposure time of 60 s. The scintillation noise decreases with longer exposure times due to temporal averaging effects, so that the data shown provides a conservative indication for longer exposure times. The data shows clearly that the expected scintillation noise above 30 km can be expected to be about two orders of magnitude lower than on the ground or even at airplane altitudes. These altitudes thus provide a significantly improved environment concerning photometric accuracy.

The wind profile underlying the calculation is shown in figure 20.

Differential refraction

Differential refraction by the atmosphere has the effect of spatially spreading the light of a point sources and producing a spectrum of any sky source along the parallactic angle. Due to the variation in air density over height, the atmosphere acts as a sort of a prism or disperser which produces a spectrum of up to a few arcseconds long, depending on the airmass. This has an impact for ground based spectroscopy because spectrograph slits have to be aligned at the parallactic angle for each observation. Alternatively, the telescopes have to use Atmospheric Dispersion Correctors. Without this correction, light is lost outside the spectrograph slit.

The lack of this phenomenon in the stratosphere is advantageous for spectroscopic observations since these corrections are not needed and furthermore significantly smaller slit widths can be used, leading to much higher potential throughput compared to ground-based observations.

The lack of differential refraction moreover benefits applications requiring high-precision astrometry by reducing the spread of light in the image plane.

3.3 UNIQUE FEATURES IN RELATION TO CURRENT CAPABILITIES

The previous section treated the conditions in the stratosphere in technical detail. At this point, the unique features a stratospheric platform offers in comparison to other science platforms shall be shortly summarised. For this purpose, the unique features are first listed and explained in some detail. Table 4 then provides a concise comparison between stratospheric platforms and other current capabilities.

Scientific/observational aspects

- Stratospheric platforms provide **access to almost the entire electromagnetic spectrum**; only space-based platforms can improve this aspect.
- The **spatial resolution** of stratospheric platforms is not limited by atmospheric turbulence. Ground based optical observatories hardly reach spatial resolutions smaller than 1 arcsecond due to atmospheric turbulence, current airborne observatories are similarly limited due to flight-induced turbulences. A 0.5 m aperture telescope at 20 km or above, in contrast, could reach diffraction limited spatial resolutions between 0.1 and 0.4 arcseconds in the UV and visible spectral bands. (With the use of adaptive optics, diffraction limited performance can be achieved from the ground as well, mostly in the near infrared. The corrections are valid for tiny fields of view, however, and the technical requirements are important.)
- Spectroscopic and astrometric measurements are not limited by **differential refraction**.
- Stratospheric platforms allow **daytime observations** of certain targets (e.g. solar system planets and relatively bright stars) which are not possible from the ground. This also allows us to observe these targets throughout much more extended portions of the year as compared to ground based observations which are limited to observations around opposition to the sun due to the night constraint. In addition, it also eliminates the interruptions in observability of these objects along the 24h-cycle, which otherwise hinder the identification of cyclic phenomena around this frequency. In case of ground based observations, this would need to be solved by using multiple telescopes at different longitudes.
- Locations above most of the atmospheric wide-angle (Rayleigh) scattering and with low background brightness allow **high contrast** observations of faint sources close to bright sources. With the use of adaptive optics, high contrast observations can also be obtained on the ground, but require a considerable technical effort and the final PSFs have long wings which still affect the achievable contrast.
- Atmospheric absorption and emissions and the variations thereof severely limit the **photometric accuracy** of ground-based observations to about a millimagnitude. While

interfering brightness variations of the high-altitude airglow can only be omitted by space-based observations, stratospheric platforms suffer significantly less from variations in atmospheric transmission and atmospheric thermal emissions in the infrared.

Operational aspects

- Stratospheric platforms lack some of the **observation time constraints** that particularly ground-based observatories face. This particularly concerns the independence of cloudy skies or high atmospheric water vapour content. At the best ground-based observation sites, like Cerro Paranal, for example, the number of cloud-free nights is only around 60% [RD20]. Missing light pollution from man-made sources as well as less scattering of light from bright celestial sources, e.g. the moon, also improve the sensitivity and the observational flexibility of stratospheric platforms. On the other hand, the deployment of stratospheric platforms is limited by wind and other weather conditions (visibility for save launch and landing, lightning,…) and manoeuvrability above 25 or 30 km still has to be demonstrated.
- Balloon missions allow **access to experiments** for inspection, repair, improvement, refill of operating fluids, or replacement in between flights, which is a considerable advantage over space missions. While they do not allow real-time access during observations such as for ground-based or airborne platforms, similar operating concepts with several replaceable instruments on a single platform are possible.
- Balloon missions offer observations at **considerably lower costs** than space missions.
- Based on the easy access to experiments, potentially short turnaround times of a few weeks or even days, and comparably very low costs, stratospheric platforms offer **high flexibility to use or test latest technology**.

Table 4: Comparison of stratospheric platforms with other science platforms

Aspect	Observation Platform				
	Ground-based	**Airborne (ca. 12 km[4])**	**Mid stratosphere (20 km)**	**High stratosphere (40 km)**	**Space-based**
Scientific/observational aspects					
Accessible spectral bands	Visible, very limited near- to very short MIR, few bands in submillimetre	Better transmission in UV down to ca. 310 nm, visible, most of IR (notable exceptions in the H_2O, CO_2 absorption bands), limitation of absorption lines in far IR and submillimetre	Visible, most of IR with remaining limitations at H_2O and CO_2 lines. Weakening of transmission at far-IR and submillimetre absorption lines.	UV from 190 to 220 nm, additional UV down to 280 nm, visible, all IR and submillimetre with only few attenuations at strong absorption lines.	No limitations
Achievable spatial resolution	Without adaptive optics or lucky imaging seeing-limited to about 1 arcsec in good observatories.	UV, visible, NIR and shorter part of MIR: turbulence-limited to about 1.5 arcsec or worse, depending on induced turbulence by the aircraft parts. Above that: diffraction limited.	Theoretically diffraction limited for 0.5 m telescopes in NIR and above. Close to diffraction limited for 0.5 m telescopes down to NUV.[5]	Theoretically diffraction limited for telescopes with more than 10 metres aperture size. Potentially down to about 0.1 arcsec in the UV with 0.5 m aperture.	Theoretically diffraction limited.

[4] Service ceiling of SOFIA is 14 km

[5] Numbers are based on turbulence-model-based calculations of the Fried parameter and are pending experimental verification particularly at visible and shorter wavelengths. The diffraction limit of a 0.5 m aperture telescope in the near infrared (NIR, at 1 µm) is about 0.5 arcseconds. The diffraction limit of a 0.5 m aperture telescope in the near UV (NUV, at 300 nm) is about 0.15 arcseconds.

Achievable spectral information	Airglow emission lines and thermal sky background in the IR interfere with science observations.	Airglow emission lines (OH, sodium, oxygen) interfere with science observations.	Airglow emission lines (OH, sodium, oxygen) interfere with science observations.	Airglow emission lines (OH, sodium, oxygen) interfere with science observations.	No atmospheric limitations.
Achievable photometric accuracy	Limited by atmospheric absorption and emission variations and background brightness to the millimagnitude level.	No interference by tropospheric absorption and emission variations.	Interference by absorption and emission variations in lower stratosphere and airglow.	Dominating limitation is airglow variation.[6]	No atmospheric limitations.
Achievable contrast	Severely limited by atmospheric scattering.	Improving contrast →			No atmospheric limitations.
Operational aspects					
Cost (total lifetime cost)[7]	Several billion EUR[8]	About 1 billion EUR[9]	Few 10s MEUR	Few 10s MEUR	Several billion EUR[10]
Observation time constraints	Severely limited by weather and moon (ca. 60% of cloud-free nights at e.g. Cerro Paranal)	Limitations due to flight layouts, e.g. ca. 4 h time on one target.[11]	Launch limitations due to wind/weather conditions, no zenith viewing	Launch limitations due to wind/weather conditions, no zenith viewing	In low Earth orbit: ca. 45 min max. continuous observations

[6] Hardly any measurements on sky brightness, its variations, and atmosphere-induced astronomical object brightness scintillations in the higher stratosphere exist. Experimental assessment of these parameters would be technically and scientifically interesting.

[7] See [RD24], besides information on airborne infrastructure.

[8] For Keck

[9] For SOFIA, ca. USD 1 billion to build the infrastructure [RD21], ca. USD 80 million annual operating costs [RD22] (or ca. USD 1 million per flight [RD23])

[10] For Hubble Space Telescope

[11] For regular operations. Can differ for targets of different elevations. Longer observations possible if required.

Access to instruments for control, repair, or improvement	Very good real-time access	Very good real-time access	No access during single flights of several days	No access during single flights of several days	No access after launch
Chance to flexibly use latest technology	Very good, hardly any size restrictions, few safety restrictions	Very good, few size restrictions, some flight safety restrictions	Very good, however severely size limited	Very good, however severely size limited	Very restricted
Possible structure size	Very large structures (e.g. Arecibo: 340 m)	Limited, mostly in size (SOFIA: 2.7 m)	Limited in size and mass (several tons)	Limited in size and mass (few tons)	Limited in size and mass (few tons, JWST: 6.5 m mirror)

4 POTENTIAL SCIENCE CASES

Having examined the relevant stratospheric conditions, and having pointed out the benefits of high stratospheric platforms, this chapter presents science cases for which a stratospheric observation infrastructure can be of great benefit. Firstly, a general introduction is given to the kinds of science cases stratospheric observations are suitable for and to the ones which will be further presented in detail in this document. This is followed by the description of a rough categorization of potential/required instruments and observation types that will help to sort the science cases and ease the later concept selection and design. Finally, an overview of pre-filtered science cases is presented and selected areas are discussed in more detail.

4.1 TYPES OF SCIENCE CASES SUITABLE FOR STRATOSPHERIC OBSERVATIONS

As chapter 3 indicates, a stratospheric platform opens up a very large range of potential science cases that either become possible or feasible with a smaller infrastructure compared to ground-based observations. In summary, these are science cases that

- Require observations in spectral ranges for which the atmosphere is not transparent (X-rays, Gamma-rays, UV, large parts of infrared, large parts of millimetre and submillimetre);
- Require detection of spectral features that interfere with telluric bands and thus need to be meticulously correct to the best extend possible for ground-based observations if possible at all (UV, visible, infrared, millimetre, and submillimetre);
- Require high photometric stability;
- Require spatial resolution which can only be reached by a few complex systems (adaptive optics) from the ground or from airplanes (mainly infrared);
- Require scheduled observations independent of cloud cover, precipitated water vapour, or moon phase constraints;
- Require high-contrast observations that are impossible from the ground due to atmospheric scattering;
- Require observations that would be impossible from the Earth due to operational constraints, such as most daytime observations;
- Require time-critical measurements, particularly follow-ups on space-based measurements;
- Could be investigated from highly booked high-class ground-based, airborne or space-based facilities but can be investigated at potentially lower cost or with better accessibility of observation time from a stratospheric platform.

An attempt to list all potential science cases would be beyond the scope of this report. Instead, based on the aims of the ORISON project, a sensible pre-selection of promising science cases has been carried out. As a basis for this, potential science cases were collected from literature, via a survey of scientists, and the project team itself. Out of the cases reviewed, the ones that are estimated to be feasible for a mid-sized infrastructure (e.g. approx. 0.5 m aperture of an optical instrument) are listed. Furthermore, an emphasis is put on optical observations since the state of instrument development and diversity in this domain well suits the ORISON goal of an affordable, flexible, and versatile infrastructure (thus, e.g. FIR/submm observations were investigated with less priority due to the complexity induced by the instruments and cooling requirements).

Based on this pre-filtering, we find the most promising uses of the infrastructure to be mostly in the areas of planetary science, stellar astrophysics, galactic and interstellar astronomy, atmospheric science, and Earth observation.

4.2 CATEGORIZATION OF INSTRUMENTS

In order to better judge the foreseeable requirements concerning instrumentation and to be able to better analyse the needs, a rough categorization of the required instruments, their expected sizes, and some basic parameters is already undertaken at this point. The categories used are shortly explained in the following.

For types of instruments, the following categories are used:

- *Telescope* – each instrument requiring an aperture of more than a commercial DSLR (digital single-lens reflex) lens;
- *Imager* – monochrome imager. Not necessarily with changeable filters;
- *Spectrograph;*
- *Objective-prism camera* – a commercially available camera with a prism filter to provide spectra of point sources;
- *Filter Imager* - monochrome imager with changeable filters;
- *RGB camera* – calibratable commercial imaging camera able to image in three bands which can be converted to standard astronomical photometric systems.

For rough instrument sizes, the following distinction is used:

- *Small* – instruments of a total mass of not more than several kg, of which several can be flown as secondary payloads, or several can be flown to make one primary payload;
- *Medium* – instruments of a total mass up to ca. 30 kg, of which at most one can be flown as a secondary payload. A dedicated mission might be necessary;
- *Large* – instruments that must be flown as primary payload. Most instruments requiring a telescope qualify as such. It may, however, be possible to combine several large instruments to use the same telescope.

4.3 CONSIDERED SCIENCE CASES AND THEIR NEEDS

Table 5 shows an overview of pre-filtered science cases (see section 4.1) with the most important common needs and the assignment of required instruments and instrument sizes as described in section 4.2. An effort was made to already quantify technical needs where possible (such as required spectral resolution, sensitivity, or spatial resolution) to facilitate the following technical and functional requirements analysis. These values are to be regarded as indicative data that mostly require further refinement for the favoured use cases, also taking into account details of the later potential operational concepts.

A more detailed description of the most interesting science cases follows in the next sections, where each science case can be traced to the ones presented in table 5 back by its identifier ("SC-TOPIC-##", where TOPIC is one of the following abbreviations: PS – planetary science; SR – stellar astrophysics; G – galaxies and interstellar medium; AS – atmospheric science; EO – Earth observation; O - others).

Table 5: Overview of potential science cases

ID	Primary target	Name	Spectr. Region	Spectr. res.	Required sensitivity	Spatial res.	FoV	Instr. type	Instr. size	Stratospheric advantage
Planetary Science (PS)										
SC-PS-1	Mercury	Volatile variability and budget	NUV-IR (0.2 - 1 µm)	> 1 nm	< 10 R	> 1”	Narrow	Telescope, spectrograph	Large	Daytime observations close to the sun (> 21 deg) possible
SC-PS-2	Comets	Volatile abundances in different regions of the solar system	IR (2.7 - 5.6 µm)	0.1 nm	1E-18 W/m^2	> 3”	Narrow	Telescope, spectrograph	Large	Atmospheric transmission at emission line wavelengths.
SC-PS-3	Comets	Different volatile abundances on Oort cloud objects & KBOs[12,13]	IR (2.7 - 5.6 µm)	0.1 nm	1E-18 W/m^2	> 3”	Narrow	Telescope, spectrograph	Large	Atmospheric transmission at emission line wavelengths.
SC-PS-4	Comets	Measure organic precursor molecules[13]	IR (2.7- 5.6 µm)	0.1 nm	6 mJy at 3.6 µm, 65 mJy at 4.5 µm [RD25]	> 3“	Narrow	Telescope, spectrograph	Large	Atmospheric transmission at emission line wavelengths.
SC-PS-5	Comets	Determine isotopic composition of water	IR (2.7 - 5.6 µm)	0.05 nm	6 mJy at 3.6 µm, 65 mJy at 4.5 µm [RD25]	> 3”	Narrow	Telescope, spectrograph	Large	Atmospheric transmission at emission line wavelengths.

[12] Kuiper Belt objects

[13] Compare also [RD24]

ID	Primary target	Name	Spectr. Region	Spectr. res.	Required sensitivity	Spatial res.	FoV	Instr. type	Instr. size	Stratospheric advantage
SC-PS-6	Asteroids	Constrain space-weathering effect on small bodies	NUV-visible (0.2 - 0.4 µm)	> 1nm	TBD[14]	> 1"	Narrow	Telescope, spectrograph	Large	Atmospheric transmission at larger parts of the UV-vis reflectance slope
SC-PS-7	Asteroids	Constrain OH abundance on different asteroids to study volatile depletion[13]	NIR (2.8 µm)	10 nm	< 1%	> 1"	Narrow	Telescope, spectrograph	Large	Atmospheric transmission at the absorption band wavelengths.
SC-PS-8	Asteroids, comets	Study surface composition	NUV to IR (0.2 - 3.1 µm)	2 nm[15]	< 1%	> 1"	Narrow	Telescope, spectrograph	Large	Atmospheric transmission at the absorption band wavelengths, no interference of atmospheric lines.
SC-PS-9	Asteroids, comets, KBOs	Abundance and distribution of different (taxonometric) object classes	Visible-NIR (0.4 - 1 µm)	100 nm	V < 22, J< 18	> 1"	Wide	Survey telescope	Large	Good seeing, stable photometry
SC-PS-10	Centaurs, TNOs[16]	Sizes and nature of Centaurs and TNOs via occultations	Visible	n.a.	V<20	> 1"	Narrow	Telescope, imager	Large	No cloud-cover restrictions for time-critical observations

[14] Depends on highly variable distance and phase angle of targeted asteroids to Earth. Requires further performance study.

[15] If metallic species, e.g. iron ions are to be measured as well.

[16] Trans-Neptunian Objects

ID	Primary target	Name	Spectr. Region	Spectr. res.	Required sensitivity	Spatial res.	FoV	Instr. type	Instr. size	Stratospheric advantage
SC-PS-11	MBAs[17]	Detect exospheres on asteroids via occultations	Visible	n.a.	V<20	> 1”	Narrow	Telescope, imager	Large	No cloud-cover restrictions for time-critical observations
SC-PS-12	Cosmic dust	Collect cosmic dust	n.a.	n.a.	n.a.	n.a.	n.a.	Dust collector	Small	Least possible mixture with terrestrial dust
SC-PS-13	Meteoroids	Meteoroid environment measurement via lunar impact flashes	Visible	n.a.	V > 9 [RD26]	0.5”	Wide	Telescope, imager	Large	Increased sensitivity due to missing atmospheric background & atmospheric scattered light from illuminated side
SC-PS-14	Meteoroids	Measurement of meteors & their spectra	NUV, Visible, NIR	5 nm	Not critical	Not critical	Wide	Objective-prism camera	Small	Increased sensitivity, reduced atmospheric absorption, no cloud cover restrictions
SC-PS-15	Meteoroids	Sporadic meteor flux via infrasound measurements	infrasound	n.a.	n.a.	n.a.	n.a.	Infrasound sensor	small	Proximity to source

[17] Main belt asteroids

ID	Primary target	Name	Spectr. Region	Spectr. res.	Required sensitivity	Spatial res.	FoV	Instr. type	Instr. size	Stratospheric advantage
SC-PS-16	Moon	Distribution and transportation of volatiles, particularly H_2O and OH	NIR (2.5 - 5 µm)	2 nm	TBD	TBD	Wide	Telescope, spectrograph	Large	Accessibility of spectral range
SC-PS-17	Callisto & Ganymede	Determine volatile constituents	UV, visible, NIR (0.19 - 5 µm)	0.8 - 16 nm[18]	< 2%	> 1"	Narrow	Telescope, spectrograph	Large	Atmospheric transmission at emission line wavelengths.
SC-PS-18	Io	Loss and production of atmospheric constituents	UV (0.2 - 0.41 µm)	< 1nm	ca. 2% or 2 kR/nm[19]	> 1"	Narrow	Telescope, spectrograph	Large	Atmospheric transmission at absorption and emission feature wavelengths
SC-PS-19	Europa	Search for organics on Europa	IR (3.0 – 5.6 µm)	TBD[20]	TBD[20]	> 1"	Narrow	Telescope, spectrograph	Large	Atmospheric transmission at absorption feature wavelengths
SC-PS-20	Solar System Planets	Measure vertical aerosol structure and the cloud morphology and motions for dynamical purposes	UV, vis, NIR, MIR	TBD[20]	TBD[20]	0.1"	Narrow	Telescope, filter imager	Large	Atmospheric transmission, hardly any interference with telluric lines

[18] Depending on spectral range. See section 4.3.1.4 for details.

[19] See section 4.3.1.4 for details.

[20] Precise need requires further assessment including consideration of favourable observation geometry. Current capabilities in the NIR are very limited, however.

ID	Primary target	Name	Spectr. Region	Spectr. res.	Required sensitivity	Spatial res.	FoV	Instr. type	Instr. size	Stratospheric advantage
SC-PS-21	Jupiter	Observe impact flashes on Jupiter	Visible	n.a.	V > 7	0.5”	n.a.	Telescope, imager	Large	All-day observations possible
SC-PS-22	Solar System bodies	Observe gaseous volatiles (H_2O, O_2,…) on solar system objects	FIR (750, 1100, 1250, 1650 GHz)	n.a.	1 Jy	1’	Narrow	Telescope, spectrograph	Large	Atmospheric transmission at absorption feature wavelengths, highly reduced pressure broadening of telluric lines
SC-PS-23	Exoplanets	Exoplanet candidate follow up and study of exoplanet exosphere characteristics	Visible, NIR	Sloan g,r,z, or also JHK	0.1 %	TBD	Narrow	Telescope, filter imager	Large	Atmospheric transmission in NIR, photometric accuracy
SC-PS-24	Exoplanets	Study composition of exoplanet atmospheres	NIR (1-5 µm)	R~200	TBD	TBD	Narrow	Telescope, spectrograph	Large	Atmospheric transmission in NIR, photometric accuracy
SC-PS-25	Exoplanets	Study free floating exoplanets/brown dwarfs	MIR to FIR	Wide filters	TBD	TBD	Narrow	Telescope, filter imager	Large	Atmospheric transmission in MIR and FIR
Stellar Astrophysics (SR)										
SC-SR-0	General	Sensitive photometry in several bands	NUV, vis, NIR (0.3 - 2.4 µm)	UBV bands	J,H,K: > 18.2 mag V: > 22 mag	n.a.	n.a.	Telescope, filter imager	Large	Atmospheric transmission, precise photometric measurements

ID	Primary target	Name	Spectr. Region	Spectr. res.	Required sensitivity	Spatial res.	FoV	Instr. type	Instr. size	Stratospheric advantage
SC-SR-1	Nebulae	Image faint nebulae around bright stars	n.a.	n.a.	n.a.	n.a.	Narrow	Telescope, imager	Large	Lack of atmosphere allows high-contrast imaging
SC-SR-2	Stars	Image light echoes around bright stars	n.a.	n.a.	n.a.	n.a.	Narrow	Telescope, imager	Large	Lack of atmosphere allows high-contrast imaging
SC-SR-3	Stellar disks	Understand the role of disks in astronomical engines (star formation)	n.a.	n.a.	n.a.	n.a.	Narrow	Telescope, imager	Large	Lack of atmosphere allows imaging of spatially close high-contrast objects
SC-SR-4	Stars	Long duration deep surveys of nearby stellar populations	n.a.	n.a.	n.a.	n.a.	Wide	Telescope, filter imager	Large	High spatial contrast due to diffraction-limited imaging
Galaxies and Interstellar Medium (G)										
SC-G-0	General		K-band (2.0 – 2.4 µm)	K-band	>= 25 mag	n.a.	n.a.	Telescope, imager	Large	Accessibility of spectral band
SC-G-1	Ultra fine structures	n.a.	NUV, vis, NIR	n.a.	n.a.	ca 2”	n.a.	Telescope, imager	Large	All spectral regions accessible
SC-G-3	n.a.	n.a.	J-band	Wide and narrow filters	n.a.	ca 2”	n.a.	Telescope, filter imager	Large	Spectral region accessible

ID	Primary target	Name	Spectr. Region	Spectr. res.	Required sensitivity	Spatial res.	FoV	Instr. type	Instr. size	Stratospheric advantage
Atmospheric Science (AS)										
SC-AS-1	Upper atmos-pheric lightning	Investigate physical processes behind upper atmospheric lightning	UV, vis, NIR	n.a.	n.a.	n.a.	Wide	High-speed camera, objective-prism camera	Small	Large observational volume, safe observations, long observational times
SC-AS-2	Stratos-pheric Winds	Determine local atmospheric motion vectors	n.a.	n.a.	n.a.	n.a.	n.a.	GNSS module, wind sensor	Small	Local conditions precisely measureable
SC-AS-3	Radiation	Determine high altitude radiation levels to support atmospheric and climate models	n.a.	n.a.	n.a.	n.a.	n.a.	Pyranometer, pyrgeometer	Small	Only measurable locally
SC-AS-4	Stratos-pheric particles	Determine high-altitude particles to understand particle transport through the atmosphere, determine high-altitude effects of air pollution	n.a.	n.a.	n.a.	n.a.	n.a.	Passive sampler	Small	Only measurable locally
SC-AS-5	Stratos-pheric clouds	Classify cloud types in multiple wavelengths via infrared limb spectra	MIR	n.a.	n.a.	n.a.	n.a.	Simple spectrograph	Small	No obstruction by lower atmosphere and weather

ID	Primary target	Name	Spectr. Region	Spectr. res.	Required sensitivity	Spatial res.	FoV	Instr. type	Instr. size	Stratospheric advantage
Earth Observation (EO)										
SC-EO-1	Light pollution	Detect light pollution	NUV, vis, NIR (0.3 - 1 µm)	n.a.	> 21.5 mag/sr	10 m/px[21]	Wide	RGB camera	Small	Top-down view, large coverage area
SC-EO-2	Bio-luminescence	Detect bioluminescence	Visible (0.4 – 0.6 µm)	n.a.	> 1.8E-4 $W/m^2/sr$	n.a.	Wide	RGB camera	Small	Top-down view, large coverage area
Others (O)										
SC-O-1	Space debris	Verify/improve atmospheric re-entry and breakup models	Visible	n.a.	n.a.	n.a.	Wide	RGB camera	Small	High resolution and high contrast imaging possible, no limitation by cloud cover.
SC-O-2	Biological	Study stress resistance and molecular stress response in lifeforms due to space conditions	n.a.	n.a.	n.a.	n.a.	n.a.	Biological containers	Small	Environment of combined stresses close to space conditions (temperature, pressure, radiation)
SC-0-3	Biological	Study stratospheric bacteria (bacillus aerius, bacillus aerophilus, bacillus stratosphericus, bacillus altitudinis)	n.a.	n.a.	n.a.	n.a.	n.a.	Biological collector	Medium	Only in situ measurable

[21] Ground sampling distance in metres/pixel

4.3.1 Planetary Science

4.3.1.1 Mercury

Science Description:

Mercury's exosphere is highly dynamic and driven by a complex interplay of processes. With Mercury only possessing a weak magnetic field and a weak gravitational force, the exospheric gases are highly exposed to and influenced by dynamics of the nearby star. While the solar wind depletes the exosphere to some extent, the current models suggest that – through various effects – solar activity also plays a major role in repopulating the exosphere with material from the Hermean surface while charged solar particles populate the Hermean magnetosphere directly [RD27]. Among those processes thought to dominate the exospheric composition are thermal desorption, photon stimulated desorption, solar wind and charged particle sputtering, meteoroid impact vaporisation, and chemical sputtering [RD27]. All of which are temporarily and spatially variable to different degrees and in different forms. Closely monitoring the spatial and temporal variation of the Hermean exosphere over day-night cycles [RD27], the solar cycle [RD28], Mercury's orbit cycle, but also for sporadic events (e.g. increased meteor fluxes) thus would help to understand the role of the different components in the formation and dynamics of it.

Currently confirmed exosphere constituents are O, H, He, Na, K, Ca, Ca+, and Mg, with Na, K, and Ca detected by ground-based observations and the rest by Mariner 10 or MESSENGER spectroscopic measurements [RD29]. Characteristic emission lines of these particles are therefore important measurands for exospheric dynamics. In situ space missions, like ESA's upcoming BepiColombo mission, will provide highly sensitive and spatially resolved measurements of these species [RD28]. Orbiting missions can, however, only provide snapshot measurements in time and space. To further investigate the dynamical processes, it would be beneficial to obtain information on exospheric constituents on a global scale. While balloon missions will likely not be able to provide high-spatial resolution observations, they potentially can provide measurements of the global volatile budget at coarse spatial resolution. Such measurements would be highly valuable to detect sporadic events on a global scale, to connect local measurements to simultaneous global measurements and to determine timescales of global dynamics. In order to properly cover the timeframes of interest, observations should cover several days to preferably several weeks at least.

Table 6: Emission wavelengths of confirmed species

Species	Wavelength [nm]	Line strength [R]
Ca+	393.5 [RD30]	< 10 [RD30]
H	121.6 [RD32]	70 [RD32]
He	58.4 [RD31]	45 [RD31]
O	130.4 [RD32]	63 [RD32]
Na (D1) (D2)	589.6 [RD29] 589.0 [RD29]	<470k [RD29]
K	769.9 [RD33]	
Ca	422.8 [RD30]	<1k [RD30]

As the ground-based discovery of Na, K, and Ca show, some of the volatiles can also be observed from the ground. Besides the interference with telluric emissions for the other constituents, ground based observations are also severely affected by the orbital geometry. Mercury observations can almost exclusively be carried out during (Earth) daytime when scattered sunlight provides a major obstacle, at best during short times and at low elevations during dawn/dusk. The effect is worsened by the angular proximity of Mercury to the sun, with a maximum separation of about 21 deg from the sun as seen from Earth. This small separation from the sun has also prevented more observations with space telescopes in Earth orbit. SOFIA currently does not allow daytime observations, either. A balloon mission with less pointing restrictions than a space telescope might be able to fill this gap in observations.

Science objective:

SC-PS-01: Determine the volatile variability and volatile budget of Mercury to understand its formation and evolution.

Science needs:

SC-PS-01: Measure atomic emission lines of volatiles (O, H, He, Na, K, Ca, Ca+, see table 6) and their temporal and spatial variations with a sensitivity of at least 10 R over several days, preferably weeks. Spectral region: NUV-NIR (0.2-1 µm). Type of observation: spectroscopy. Required spectral resolution: > 1 nm. Required angular resolution: > 1 arcsecond.

4.3.1.2 Small Bodies

Science Description:

Small solar system bodies are remnants and direct witnesses of our solar system's formation process, whose material is thought to have only been slightly altered since the formation of the planets. Their study thus can reveal a wealth of information about many aspects of the solar system formation process, among others about the distribution mechanisms of water, the local distribution of processes during the formation, their timescales, and even about the formation routes to complex organic molecules. Small bodies have received considerable attention over the last years, particularly through in-situ missions to comets and asteroids, such as NASA's Deep Impact mission, JAXA's Hayabusa mission, or most recently ESA's Rosetta mission, but also through highly-sensitive space-based observations and high-dispersion ground based observations. However, many important questions remain to be answered.

Comet volatiles. The abundance and precise composition of volatiles on comets provides a good record of their past and their potential origin. A good understanding of the current account of volatiles in different groups of comets, particularly in Oort cloud comets and Kuiper Belt objects

Table 7: Emission wavelengths and measured emission line strengths of confirmed gaseous species in comet comas. Some line strengths were calculated from flux densities, some converted to an assumed 5 mag comet.

Species	Wavelength [µm]	Line strength [W/m^2]
H_2O	2.7 [RD38]	1.6E-16 [RD38]
CO_2	4.25 [RD38]	1.3E-16 [RD38]
CO	4.65 [RD38]	7.6E-17 [RD38]
CH_4	3.3 [RD37]	1E-17 [RD37]
OH	3.28 [RD37]	3E-18 [RD37]
HCN	3.02 [RD39]	1.5E-19 [RD39]
C_2H_6	3.35 [RD39]	1.5E-18 [RD39]
CH_3OH	5.52 [RD39]	1E-18 [RD39]
HDO	3.7 [RD40]	< 1.5E-19 [RD40]

would provide an important test of current models of solar system formation [RD36], in particular the "Nice Model" which predicts a considerable mixing between the abovementioned dynamic populations [RD34][RD35]. Particular volatiles whose abundances and mixing ratios are of interest (and which have already been detected through gas state emissions on comets) are CO_2 [RD38], CO [RD38], OH [RD37], HCN [RD39], H_2O [RD38], and organics such as CH_4 [RD37], C_2H_6 [RD39], and CH_3OH [RD39]. Among these, the organics are additionally interesting in respect to the question where and how complex organic molecules first started to form. Another measurand of particular interest is the abundance of deuterated water (HDO) on comets, since it allows (in combination with the easier measurable abundance of H_2O) the comparison of D/H ratios in cometary and terrestrial water and thus might provide a clue towards the origin of Earth's water [RD40]. The difficulty to measure these species during the perihelion passage of a comet differs considerably. All of them show emission lines in the NIR and very short MIR between 2.7 µm and 5.6 µm, however at considerably different line widths and line strengths. Many of them are very present in the Earth's atmosphere and thus can only be measured if either the telluric contribution is precisely known and subtracted or if telluric and cometary lines are separated due to Doppler shift (and can be discriminated by very high spectral resolution measurements) [RD39]. These telluric lines are weaker, but still present at altitudes reachable by airplane. Balloon-borne observations at altitudes around 40 km would allow the measurement of some of these volatile species and other undetected ones around cometary perihelion passage without the restrictions and the considerable effort (e.g. use of adaptive optics (AO) systems) applicable to ground-based or airborne observations and cheaper than with space-based instruments.

Small bodies compositions. Another diagnostic tool to probe the formation of the solar system and the applicability of the current formation models is the mineral/solid state composition of asteroids. Findings about their composition help to trace their origin, their thermal origins, but can also provide views into the interior of once-larger parent bodies [RD41]. In a first step, asteroids are routinely grouped into spectral classes. Closer investigation of smaller and weaker features in the spectrum of reflected sunlight however also allow the detection of certain species or classes thereof. Such detectable species are water ice [RD43], frozen methanol or photolytic products of methanol [RD44], hydrated minerals through the detection of OH [RD42], but also mineral classes through e.g. the detection of different iron ions (Fe^{2+}, Fe^{3+}) [RD45],[RD47]. Traces of water and iron-rich minerals (which can also be used as a potential indicator of dissolved platinum group metals [RD46]) in main belt or near-Earth asteroids are additionally interesting to pre-filter potential targets for asteroid

Table 8: Measured absorption features of selected species on asteroids.

Species	Wavelength [µm]	Band depth [%]
OH	2.8 [RD42]	< 4 [RD42]
H_2O	3.1[22] [RD43] 2.04 [RD44]	10 [RD43] 12 [RD44]
CH_4	2.27 [RD44]	9 [RD44]
Fe ions	0.2 [RD45] ~1 [RD45] ~0.5 [RD45] 0.43 [RD47]	n.a. n.a. n.a. 3-4 [RD47]

[22] Most prominent and unambiguous indicator [RD66]

mining. Observations of these absorption features from the ground are partly possible, but severely complicated by strong telluric absorption bands and night-sky emission lines. UV features (details of the absorption edge below 400 nm [RD48], absorption features around 300 nm [RD49] and 200 nm [RD44]) are not accessible from the ground at all.

Characterisation of distant small bodies. The vast majority of small bodies in the asteroid belt and beyond are too distant and small to obtain resolved images from. This particularly applies to the Centaurs (orbiting between Jupiter and Neptune) and Trans-Neptunian Objects. Due to an unknown albedo, their sizes usually cannot be determined precisely without additional measurements of thermal emissions, and little can be said about their nature. Some of them are very interesting objects, however, which have been shown to have exospheres (such as Pluto), occur in binary systems, or have rings [RD62]. A way to detect these features from Earth are observations of stellar occultations by these objects, which are time- and location-critical, however [RD63]. A balloon-based platform would remove the severe limitations of cloud-cover for these observations. It would, however, also require excellent orbit/position knowledge of both the target and a sufficiently large number of stars. Access to the GAIA star catalogue might be a requirement for a meaningful implementation of this science case.

Meteoroid and dust environment. The meteor environment in the inner solar system does not only have practical implications for the operation of spacecraft, but also yields a lot of scientifically interesting information concerning transport of material to the planets and on their parent bodies. Further determining the flux of meteoroids of different sizes will help to answer a number of related questions. Another very interesting group of small particles to study are cosmic dust particles, which include pre-solar matter and provide unparalleled insight into planetary and stellar formation material. Particles that are particularly expected to be collectable in the stratosphere at 30 to 40 km altitude are Interplanetary Dust Particles (IDP) [RD65] and interstellar dust particles.

Science objectives:

SC-PS-2: Study the potential local distribution of evaporation and condensation of solids from hot gas by determining volatile abundances on different small solar system bodies.

SC-PS-3: Test the solar system formation models by determining potential differences in volatile abundances of Oort cloud and Kuiper Belt comets.

SC-PS-4: Determine the chemical paths to complex organic molecules by studying the distribution of precursor molecules in Kuiper belt objects, Oort cloud objects, and asteroids.

SC-PS-5: Determine the source of terrestrial water and other volatiles.

SC-PS-6: Constrain the effect of space weathering on small body surfaces by studying the reflectance slope at the boundary between NUV and visible.

SC-PS-8: Study the surface composition of asteroids (particularly near-Earth asteroids) and comets.

SC-PS-10: Determine sizes, size distribution, and nature (binaries, rings) of Centaurs and Trans-Neptunian Objects.

SC-PS-11: Detect potential exospheres around main belt asteroids

SC-PS-12: Determine the composition of presolar material by studying cosmic dust particles.

SC-PS-13: Further determine the density and composition of the interplanetary meteoroid environment.

Science needs:

SC-PS-2: Measure molecular emission lines of volatiles (H2O, CO_2, CO, CH_4, OH, HCN, C_2H_6, CH_3OH, see table 7) in cometary comas around perihelion passage with a sensitivity of at least 1E-18 W/m^2. Spectral region: 2.7-5.6 µm. Type of observation: spectroscopy. Required spectral resolution: R~20,000. Required angular resolution: > 3 arcseconds.

SC-PS-3: Measure molecular emission lines of volatiles (H2O, CO_2, CO, CH_4, OH, HCN, C_2H_6, CH_3OH, see table 7) in cometary comas around perihelion passage with a sensitivity of at least 1E-18 W/m^2. Spectral region: 2.7-5.6 µm. Type of observation: spectroscopy. Required spectral resolution: R~20,000. Required angular resolution: > 3 arcseconds.

SC-PS-4: Measure molecular emission lines of volatiles (H2O, CO_2, CO, CH_4, OH, HCN, C_2H_6, CH_3OH, see table 7) in cometary comas around perihelion passage with a sensitivity of at least 1E-18 W/m^2. Spectral region: 2.7-5.6 µm. Type of observation: spectroscopy. Required spectral resolution: R~20,000. Required angular resolution: > 3 arcseconds.

SC-PS-5: Measure molecular emission lines of volatiles, including HDO (H2O, CO_2, CO, CH_4, OH, HCN, C_2H_6, CH_3OH, see table 7) in cometary comas around perihelion passage with a sensitivity of at least 1E-19 W/m^2. Spectral region: 2.7-5.6 µm. Type of observation: spectroscopy. Required spectral resolution: R~40,000. Required angular resolution: > 3 arcseconds.

SC-PS-6: Measure the UV-vis reflectance slope of asteroids in different parts of the solar system. Spectral region: 0.2-0.4 µm. Type of observation: medium-resolution spectroscopy. Required spectral resolution: > 1 nm. Required angular resolution: > 1 arcsecond.

SC-PS-8: Measurand: absorption features in the reflectance spectrum. Spectral region: NUV to IR (0.2 - 3.1 µm). Type of observation: spectroscopy. Required spectral resolution: down to 2 nm preferable to detect features of metallic species as well. Required sensitivity: < 1%.

SC-PS-10: Observe several occultation events of stars by Centaurs and Trans-Neptunian Objects from a point within the occultation shadow path over their entire duration. Spectral region: visible. Type of observation: imaging with sufficient time resolution to detect beginning, end, and changes in the shadow.

SC-PS-11: Observe several occultation events of stars by main belt asteroids from a point within the occultation shadow path over the entire duration. Requires observatory to be placed inside the shadow path, which corresponds to the size of the target. Spectral region: visible. Type of observation: imaging with sufficient time resolution to detect beginning, end, and changes in the shadow. Sensitivity depends on the brightness of stars observed.

SC-PS-12: Sample at least 20 m^3 of air at an altitude between 30 and 40 km to collect cosmic dust particles.

SC-PS-13: Observe impact flashes of meteoroids on the lunar night side.

4.3.1.3 Meteors

Science Description:

The study of meteors and meteorites is key for the understanding of the formation of our solar system, but also very important for the safety of artificial satellites and our planet. Meteors usually originate from comets or asteroids that are located on orbits with close encounters with Earth's orbit, and eventually can produce large fireballs [RD50]. Indeed, the largest annual meteor showers, the Perseids and the Geminids, originate from two potentially hazardous objects, the comet 109/P Swift-Tuttle and the asteroid (3200) Phaethon. Additionally, meteors themselves can be potentially harmful to satellites, mainly during outbursts [RD51],[RD52]. Observations from the stratosphere, like the last ORISON test mission [RD53], can produce data that can help to track the predictions of meteor shower models [RD54].

Observing meteors from the stratosphere has multiple benefits [RD55], like access to larger atmospheric volumes and UV transparency [RD56] of the upper atmospheric layers. UV observations of meteors are of particular interest since prebiotic features have been observed in this spectral range [RD57]. Additional observations of interest include infrasound measurements of meteors [RD58] and optical observations in support of radio meteor shower observations during daytime [RD59], both to improve knowledge of the size-frequency distribution. While the radio measurements have provided a possibility to carry out daytime observations at all, they do not reach the orbit determination accuracy of optical observations [RD60]. These observations could go hand-in-hand with the lunar impact flash observations to monitor sporadic meteoroids as described in SC-PS-12 (see section 4.3.1.2). The last use that shall be mentioned is dust collection during meteor showers that can be used to collect cometary material [RD61] (for needs of this case, see also science case SC-PS-06 in section 4.3.1.2).

Science Objectives:

SC-PS-14: Determine meteor size-frequency distributions & their spectra during meteor showers.

SC-PS-15: Measure the size-frequency distributions of sporadic meteors (and during showers) via infrasound measurements

Science Needs:

SC-PS-14: Measurable: Light intensity in several bands. Spectral region: NUV-V-NIR (300-1000 nm). Spectroscopy UV-V-NIR. Minimum duration: < 1 day. Tolerable slew rate: < 6 deg/s

SC-PS-15: Measurable: Infrasound signature of meteors, fireballs, and atmospheric explosions. Minimum duration: 1 week.

4.3.1.4 Satellites of the Giant Planets

Science Description:

The satellites of our solar system's giant planets provide a number of highly diverse worlds with many details of them still unexplored. In their diversity, they provide, important information about the formation processes of planetary bodies in the solar system, an important check for solar system formation models [RD67], and insight into the interconnected mechanisms involving the planets itself and their moons that form their planetary environments. A number of the moons has been studied in detail,

particularly selected moons of Saturn by the Cassini mission and selected moons of Jupiter by the Galileo mission. Many details, however, are still unknown. These include details on the volatile composition (including noble gases) of the Galilean moons which provide important constraints on their formation conditions in the solar nebula or in the Jovian subnebula [RD68],[RD69]. Particularly, the differences in volatile composition of Ganymede and Callisto are still to be explored in more detail [RD69]. In addition to the current composition, temporal processes need to be observed in order to understand source and loss processes of species that can help understand the evolution of the bodies and to infer to their state during their early life [RD69]. Of further interest is the aspect of habitability and the connected potential presence of organic material. Especially Europa is an interesting target to search for organics, since the potential between ocean and rock layer on Europa may enhance habitability conditions [RD70].

Table 9: Past Observations of Ganymede and Callisto

Spectral range	Spectral Sampling [nm]	Sensitivity [%]
185 nm-330 nm	0.8 [RD71]	< 2 [RD71]
350 nm - 1050 nm	7.3 [RD72]	ca. 3 [RD72]
800 nm - 5100 nm	16.6 [RD72]	ca. 5 [RD72]

Many of the strong absorption and emission bands of the interesting volatiles are at wavelengths not observable from the ground and thus require observations from either space or the stratosphere. Stratospheric balloon observations can contribute important information on composition on a global level and on global atmospheric budgets via their temporal variability. Furthermore, they can complement in-situ space missions with observations at different phase angles and times.

Table 10: Spectral features of SO_2 in Io's atmosphere

Wavelength (range)	Band width	Band strength
205 nm - 230 nm[23]	1 nm [RD73]	ca. 7% [RD73]
290 nm - 310 nm[23]	1 nm [RD73]	ca. 7% [RD73]
280 nm[24]	n.a.	13 kR/nm [RD73]
404 nm[24]	n.a.	9.5 kR/nm [RD73]

Science Objectives:

SC-PS-17: Determine the difference in volatile constituents between Callisto and Ganymede and monitor their variation.

SC-PS-18: Quantify loss and production of constituents of Io's atmosphere, and monitor their variation.

SC-PS-19. Search for organics on the surface of Europa.

Science Needs:

SC-PS-17: Measure volatile abundances in ices, particularly carbon, hydrogen, oxygen, nitrogen, noble gases and their isotopes on Ganymede and Callisto. Spectral region: ultraviolet, visible,

[23] Several narrow absorption features within the range

[24] Emission line

infrared. Type of observation: spectroscopy. Required spectral resolution: preferably better than past observations (see table 9). Required spatial resolution: resolved preferable, but disk integrated spectra sufficient. Particularly for Ganymede: observations should cover low phase angles since space-based observations so far have only covered high phase angles.

SC-PS-18: Measure the temporal variability of density and composition of Io's atmosphere, by using at least SO_2 as a marker (spectral features see table 10). Spectral region: 200 nm – 410 nm. Type of observation: spectroscopy. Required spectral resolution: < 1 nm. Required spatial resolution: disk integrated spectra sufficient. For a more detailed version of the science case, spatial resolution of 200 km or better would allow conclusions on the source of the atmosphere's high density component (volcanism or sublimation).

SC-PS-19: Identify organics on the surface of Europa. Observation type: spectroscopy.

4.3.1.5 Solar System at submillimetre wavelengths

Science Description:

Observations in the submillimetre domain provide a unique window for the study of atomic and molecular gas. The very high achievable spectral resolution allows not only to study molecular abundances, but also to determine the shapes of absorption lines. In a solar system context, this allows e.g. conclusions about vertical distributions of molecules in atmospheres of planets and satellites or in comae.

Submillimetre observations are severely limited from the ground. Particularly in between 30 µm and 300 µm, atmospheric absorption makes observations from the ground practically impossible. Conditions at SOFIA altitudes are better, but telluric absorption lines are still considerably pressure broadened in the remaining atmosphere. At 30 to 40 km altitude, the line width of telluric absorption lines is narrow enough to allow discrimination between the telluric lines and Doppler shifted absorption features on solar system objects.

Recent flights of the Stratospheric Terahertz Observatory (STO) [RD74] and the Balloon-borne Large Aperture Submillimetre Telescope (BLAST) [RD75],[RD76] have strikingly demonstrated the feasibility of carrying out submillimetre observations on interstellar and galactic targets from balloons. In the solar system, space based observations have been carried out with e.g. Herschel, which, among others, lead to the detection of water vapour around the dwarf planet (1) Ceres [RD77], the first detection of the D/H ratio in a Jupiter family comet [RD78], and the first detection of the Enceladus water torus [RD79]. With the required cryogen supplies on Herschel, Spitzer, and Akari having depleted, however, no space-based capabilities in this region are currently available, while many questions regarding gas atmospheres on the planets, their moons, and small bodies remain to be answered.

Science Objectives:

SC-PS-22: Measure the abundance and vertical distribution of gases (O2, H2O, HCl,…) and their isotopologues in the atmospheres of solar system comets, planets, and their moons. Measure the abundance, local distribution, and temporal variation (rotational, seasonal, orbital) of gases around small bodies.

Science Needs:

SC-PS-22: Measurable: absorption bands at high spectral resolution with a sensitivity of at least 1 Jy. Spectral region: submillimetre. Type of observation: spectroscopy. Observation of small bodies and planetary moons at different points on their orbit and the orbit of their host planet.

4.3.1.6 Exoplanets

Science Description:

Little more than 20 years after the first exoplanet has been discovered, more than 3500 planets in more than 2600 planetary systems are known today. The study of exoplanets has become the most rapidly growing field in modern astronomy; holding the promise of finding an Earth-like planet in a potentially habitable zone, and potentially, signatures of life. Strong indicators of a terrestrial planet at our closest star, Proxima Centauri, have just been revealed [RD80], catching attention by the mass media world-wide. A particular priority in exoplanet science will be spectroscopy to study their atmospheres.

A variety of questions exist that are potentially of interest for a balloon borne mission:

- Follow-up observations are required for transit surveys to validate candidates as true planets by eliminating false positives. With high-precision multicolor transit photometry, it is possible to distinguish an eclipsing binary (causing significant differences in transit depth at different wavelength) from a transiting planet (where transit depth is only weakly dependent on wavelength; see Narita et al., [RD85]; Colón, Ford & Morehead, [RD86]). In addition, multicolor transit depth observations act as low resolution transmission spectroscopy of exoplanet atmospheres (see references in Narita et al., [RD85]); providing e.g. clues on presence of haze or clouds. At least seven exoplanets have been characterized in this way so far. High-precision photometry in visible bands (i.e. Sloan g, r, z) can be used to meet both goals, which would allow for a cost-effective instrument design; photometry in near-infrared bands (JHK) is of interest as well. It should be noted that simultaneous multiband photometry of a transit avoids systematic effects, as stellar activity (e.g. flares, sun spots) can affect luminosity and hence transit depth.

  With the anticipated launch of the Transiting Exoplanet Survey Satellite (TESS) in December 2017 that will target the closest and brightest main sequence stars, it is expected to discover a number of small planets around very bright stars which could be ideal targets for a small to medium sized balloon telescope. Compared to ground-based observatories, a stratospheric platform could provide highest-precision photometry (absence of scintillation noise) and access to wavelengths otherwise obscured by telluric bands.

- Spectroscopy of exoplanets is of strong interest to study chemical composition of exoplanet atmospheres. Again, the near infrared wavelength range of 1-5 µm is of particular interest. Tinetti, Encrenaz and Coustenis [RD84] provide an in-depth analysis of exoplanet spectroscopy and conclude:
  - Above 2 µm, spectral signatures are stronger as all molecules have their fundamental vibration-rotation bands in this range.
  - The flux ratio between planet and star increases at longer wavelengths. Peak emission is at shorter wavelengths for hotter exoplanets.

- At wavelengths of 1-2 µm, reflected and scattered starlight is measured. For transit spectra below 2 µm, molecular signatures are complex and not fully understood, especially at high temperatures, making it harder to identify molecules.

  Spectroscopy at even longer wavelengths (up to ~16 µm) would be desirable due to the reasons above, but presents major challenges (availability of detectors, characteristics of detectors, warm telescope) and has been discarded for the envelope of a balloon mission, given that the wavelength range of 1-5 µm already contains all key molecular signatures of interest.

  A balloon borne mission for low resolution exoplanet spectroscopy in the 1-5 µm band based on a ~0.5 m telescope has been discussed by Pascale et al. [RD81],[RD82]. Being limited to relatively small telescope diameters, such a mission would focus on characterizing hot Jupiters and warm Neptunes, but would potentially allow to study a significant sample of this population. Again, this science case is unique to a balloon-borne platform as it provides unobscured access to wavelengths that are affected by telluric bands for groundbased observations. Observations would potentially be even possible during daytime [RD81].

  An even more ambitious balloon borne mission to study exoplanet atmospheres is the EchoBeach proposal [RD83], which utilizes a 1.6 m telescope in the 4-14 µm band. However, such a complex mission appears to be beyond the goals of ORISON.

- Another target of interest could be free floating exoplanets, or brown dwarfs. A good example is Wise 0855, the 4th closest exoplanet to the Sun and one of the coldest exoplanets known, having an estimated temperature of 250 K. Given its low temperature, mid- to far-IR observations would be required; given its luminosity, only multi band photometry appears to be possible. This could complement e.g. WISE observations.

Science Objectives:

SC-PS-23: Exclude false positives among exoplanet candidates through follow-up observations. Study characteristics of exoplanet atmospheres.

SC-PS-24: Study the chemical composition of exoplanet atmospheres.

SC-PS-25: Study free floating exoplanets.

Science Needs:

SC-PS-23: Measurable: high precision multi-color relative transit photometry lightcurves. Spectral region: visible, NIR. Spectral resolution: standard filters, e.g. Sloan g,r,z, or JHK. Type of observation: relative photometry. Required sensitivity: for atmospheric characteristics: 0.1%.

SC-PS-24*:* Measurable: spectroscopic signatures of atmospheric molecules. Spectral region: NIR (1-5 µm). Spectral resolution: ca. 200. Type of observation: transit spectroscopy.

SC-PS-25: Measurable: spectral luminosity characteristics of free floating exoplanets/brown dwarfs. Spectral region: MIR to FIR. Type of observation: multi band photometry.

4.3.2 Stellar Astrophysics

Science Description:

The study of the stars is fundamental in the development of astrophysics. From brown dwarfs to blue supergiants, the study of all stages of stellar evolution is key to understanding the cosmological evolution and to finding live on other planets. In order to understand this process, it is necessary to not only be able to have the best spectral and spatial coverage, but as well to have high temporal coverage to detect transient events or transits. For this reason, it is important to have continuous observations of stars [RD87] with planets. This is a potential need of projects like Carmenes [RD88], as follow up of HST or WSO [RD91] observations in the UV (with WSO still not certain to be launched). One example of this permanent observation is the microvariability, proven by MOST [RD89],[RD90]. There is also a need of continuous surveys of the entire sky in all wavelengths in order to have better proper motions and trace the stars' variabilities. Several surveys are currently ongoing, like Gaia [RD92], which will make photometry of the entire sky brighter than V = 20.7. To be more competitive than Gaia, one will need to go deeper than V = 22; deeper than J = 18.3 to be more competitive than UKIDDS [RD93]; and deeper than J and H = 24 to compete with the future mission EUCLID [RD94]. EUCLID will not have a K band, which could be a very interesting case. A very interesting window for atmosphere observations is located at 2.4 µm, where the K band has part of its transmission.

The possibility of stratospheric observatories to carry out high contrast observations furthermore enables a number of science cases to be followed, e.g. high contrast observations for the detection of nebulae or light echoes accompanying astrophysical events [RD95].

Science Objectives:

SC-SR-0: General

Science Needs:

SC-SR-0: Measureable: Light intensity in several bands (J,H,K,V,B,U). Spectral region: NUV-V-NIR (200-2400 nm). Sensitivity: J,H,K: >18.2, V: >22, UB: TBD. Type of observation: photometry. Minimum duration: < 1 day.

4.3.3 Galaxies and Interstellar Medium

Science Description:

Galaxy evolution is one of the key topics to investigate when trying to understand how the universe is built [RD96]. During the last 20 years, many discoveries have been made in this field, each posing new questions. Notable examples include the extended star formation disks detected in the UV [RD97] or the problem of the lack of satellite galaxies predicted by the cosmological models [RD98]. Also, the decrease of star formation is a topic of current investigation, for which the formation of new satellite galaxies is one of the key parameters [RD99]. In order to answer these questions and to understand the evolution of galaxies, all stages of galaxy evolution need to be investigated, which requires access to the deepest possible images in several observation windows [RD100]. Additional topics of potential include the detection and observation of supernovae [RD101] to track the speed of the expansion of the universe.

Access to the near UV and K band will be crucial to accomplish these scientific cases.

Science Needs:

SC-G-0: Measureable: K band >= 25 mag

SC-G-1: Measureable: Ultra faint structures in all wavelengths NUV, vis, NIR.

SC-G-3: Measureable: Wide and narrow filters in the J band.

4.3.4 Atmospheric Science

Science Description:

Since the mid-1980s, there have been several airplane missions to study photometric lightning optical emissions from stratospheric planes [RD102] and transient electrical phenomena (TEP) imaging missions from low Earth orbit (LEO), such as the sporadic and non-dedicated imaging campaigns from the International Space Station and the Space Shuttle [RD103],[RD104]. Nevertheless, these missions were carried out from expensive platforms and no spectroscopic studies were undertaken.

The use of stratospheric platforms such as the one envisioned within ORISON will provide a timely, cost-effective, and unique opportunity to investigate lightning triggered TEP taking place all the way from the cloud tops (15 km) to the lower ionosphere (90 km) of the Earth [RD105].

In particular, the availability of stratospheric platforms will open the door to carry out frequent UV (200 - 400 nm) and NIR (800 - 1100 nm) imaging and spectroscopy campaigns of TEP emissions. Due to atmospheric absorption, this type of campaign is not possible from ground-based platforms and until now the detection and analysis of UV [RD106],[RD107] and NIR [RD108] emissions from TEP have been hardly investigated due to the considerable cost of high-altitude airplane flights and satellite missions, which so far have been the only possibility.

Among other interesting scientific results, UV imaging and spectroscopy from stratospheric balloons will allow us to quantify the electric field within such enormous electrical discharges. This will be a key step to understand the dynamics, electric and chemical influence (O_3, NO_x production and/or loss) of different types of TEP such as Blue Starters, Blue Jets, Sprites, Halos, Beads, and Giant Blue Jets in the Earth's upper atmosphere.

Finally, the launch of instrumented balloons in the context of the ORISON project to study upper atmospheric electrical activity is very timely and complementary with other European missions such as ASIM of ESA, TARANIS of CNES, and MST of EUMETSAT that will be operative starting 2018 and will focus on recording and analysing transient atmospheric electricity phenomena from low Earth orbits (ASIM and TARANIS) and geostationary orbits (MST).

Of additional interest are measurements of general atmospheric conditions for which in-situ measurements can provide more precise data than remote observations. This includes particularly wind measurements as inputs to atmosphere models and predictions, measurement of radiation in order to support the understanding of atmospheric radiation transport and climate science [RD64], and measurements of differently sized particles with passive or active samplers in order to support the understanding of atmospheric particle transport, stratospheric aerosol effects on climate [RD65], and the high-altitude effects of air pollution and volcanic activity.

Science Objective:

SC-AS-01: Detection, Imaging, and Spectroscopy of Upper Atmospheric Electrical Activity from Stratospheric Balloons.

SC-AS-02: Measure the momentary local atmospheric motion vectors at the balloon's position.

Science Needs:

SC-AS-01: Measureable: UV (200 - 400 nm), visible (400 - 800 nm) and NIR (800 - 1100 nm) imaging and spectroscopy.

SC-AS-02: Measurable: balloon position and relative wind. Data must be available in near real time, i.e. within three hours after measurement.

4.3.5 Earth Observation

Science Description:

The nocturnal ecosystems are defined by the darkness. When Artificial Light At Night (ALAN) disturbs the natural status, the ecosystems suffer modifications that usually produce loss of biodiversity [RD109]-[RD111]. To be able to trace the environmental impact of ALAN it is necessary to detect the sources of light pollution, the sky brightness produced by ALAN, and to develop models that can complement these measurements. As in other fields of research, these sources need to be studied in several spectral bands due to the differential spectral response of the affected species to light [RD112]-[RD114]. However, not only nocturnal species are badly affected by light pollution, also diurnal species like humans are affected. Prove of this can be found in the Cancer studies [RD115]-[RD117], sleep quality studies [RD118], and Vector-borne diseases studies [RD113].

Additionally, some forms of bioluminescence can be detected from space [RD119]. The number of nocturnal remote sensing platforms that can detect light pollution sources, its effect, and bioluminescent species is very limited, however [RD120],[RD121]. A balloon-borne platform could fill this gap and provide information on the environmental and health impact of light pollution (SC-E-1) and track the presence of bioluminescence through remote sensing technics (SC-E-2). For SC-EO-01, the highest spatial resolution possible (at least 10 m/px ground sampling distance) is required, measured in at least three bands in the visible, with a sensitivity of 0.5 lx. For SC-EO-02, it is necessary to obtain the most sensitive measurements possible.

Science Objectives:

SC-EO-01: Light pollution

SC-EO-02: Bioluminescence

Science Needs:

SC-EO-01-N1: Measureable: Light intensity in several bands. Spectral region: NUV-V-NIR (300-1000 nm). Sky brightness: 21.5 mag/sr Type of observation: photometry. Minimum duration: < 1 day.

SC-EO-02-N1: Measureable: Light intensity in several bands. Spectral region: V (0.4-0.6 µm). Type of observation: imaging. Sensitivity: 1.8E-4 $Wm^{-2}sr^{-1}$ (DMSP-Band). Minimum duration: < 1 days.

4.3.6 Others

Stratospheric platforms can furthermore be useful for numerous other applications. Two particular interesting ones should be mentioned here.

Firstly, the location in the stratosphere provides a prime vantage point to observe re-entry of man-made objects without obstruction by clouds and spectral limitations by absorption. Burn-up or breakup of space debris objects mostly takes place at around 70 km altitude, and also the most interesting part of aerothermodynamic processes of re-entry capsules takes place in between 80 and 40 km altitude. Stratospheric platforms located between 30 and 40 km thus additionally offer very large observational volumes compared to lower observation points. Observations of space-debris re-entry and particularly of space-debris breakup allow to test and improve re-entry models and predictions, which effect the calculation of re-entry risk magnitude and risk corridor location. Observations of capsule re-entry and the involved aerothermodynamic processes would furthermore provide an opportunity to test and improve the accuracy of theoretical models used for the design process [RD122].

Secondly, the mid stratosphere provides a cheaply reachable analogue for certain conditions also encountered in space. To some extent, it can thus well be used to test instruments or conduct experiments that require near-space conditions. For tests of spacecraft instruments, the optical conditions in the stratosphere can be of interest. Furthermore, the stratosphere provides a low-temperature, low-pressure, and high-radiation environment that can be interesting for electronics tests and is of high interest for biological combined-stress tests. A stratospheric infrastructure in this case provides a cheaper option compared to simulating the combined pressure, temperature, and radiation conditions in a laboratory environment.

4.4 SUMMARY OF SCIENCE CASES

Our analysis of science cases that could be investigated from a stratospheric platform showed a good potential for such a platform. The number of proposed investigations from high stratospheric platforms, even published, is rather high. Equally, the reception of a potential stratospheric infrastructure in different scientific communities was very good. As described above, we found most feedback and the most promising cases in the areas of planetary science, stellar astrophysics, galactic and interstellar astronomy, atmospheric science, and Earth observation. Particularly the first three coincide with large astronomical science communities[25]. In the following we shortly summarize the needs of the considered science cases to provide guidance for the choice of technical infrastructure options to be studied further.

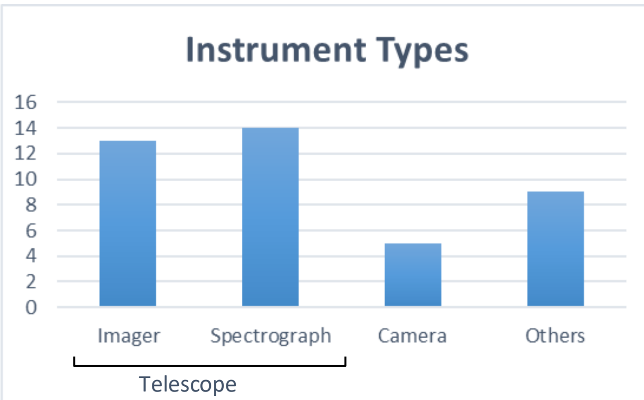

Figure 22: Required instrument type

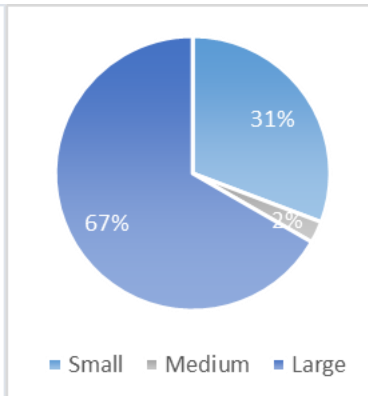

Figure 24: Required instruments by size class

As figure 22 shows, the majority of considered science cases require either an imager or a spectrograph. Even though it is not a scientific need per se, it is worth noting that for five of the considered science cases an instrument of the size of a commercial DSLR camera or similar is sufficient. 23 cases would require a telescope with a larger aperture, with either an imager or a spectrograph thereafter. This tendency is also reflected in the distribution of estimated instrument sizes shown in figure 24. Almost 2/3 of the cases, including all but one of those requiring a telescope, likely require a large instrument. For about a third of the cases, a small instrument that potentially could be carried as a secondary payload, would likely be sufficient.

The next defining need for the choice and design of the infrastructure is the spectral region in which observations are required.

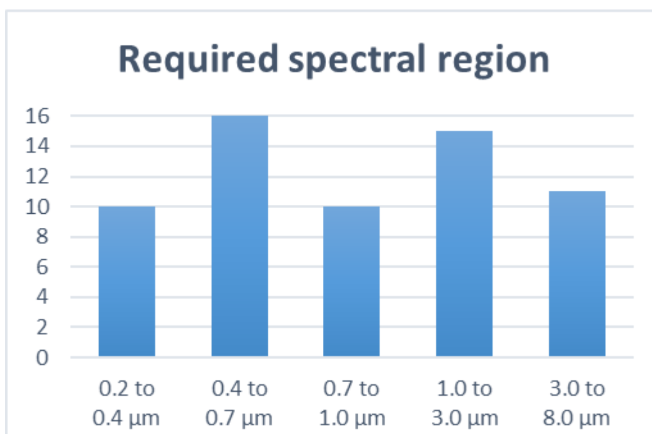

Figure 23: Spectral regions required for imaging/spectroscopic/photometric science cases. Cases that require observations over more than one of the listed regions are counted for several regions.

[25] The three communities account for ca. 75% of IAU (International Astronomical Union) division members

The division of spectral regions used for the purpose of this analysis is practically oriented along the spectral ranges that different instruments cover:

- 0.2 to 0.4 µm are covered by UV (e.g. CCD) detectors;
- The visible range from 0.4 to 0.7 µm can be covered by standard silicon-based visible-optimized CCD or CMOS detectors;
- The NIR range from 0.7 to 1.0 µm can be covered by IR-enabled silicon detectors;
- 1.0 to 3.0 µm can be partially covered by InGaAs (Indium-Gallium-Arsenide) based detectors, partially by HgCdTe[26];
- Wavelengths beyond 3.0 µm can be covered by HgCdTe (Mercury Cadmium Telluride) based detectors (at comparably high cost of detectors).

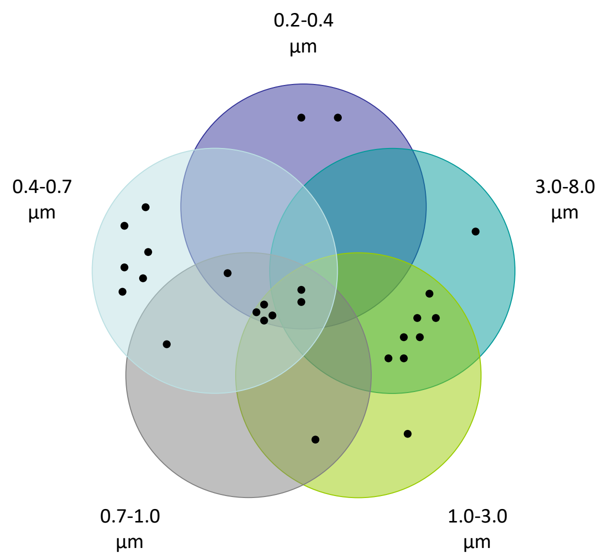

Figure 25: Science cases per spectral region and overlaps thereof

As figure 23 indicates, a large fraction of cases require at least partly observations in the visible range between 0.4 and 0.7 µm, but no clear preferred spectral regions is obvious. For most science cases, however, observations are required that cover more than one of the abovementioned regions (see figure 25). Further investigations of the corresponding cases need to clarify whether observations over the entire range need to be carried out simultaneously from the same platform (potentially requiring beam-splitting), whether they can be carried out by supporting ground-based observations, or whether they can also be carried out time-separated.

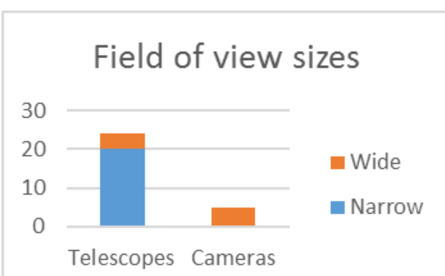

Figure 26: Required simultaneous sky coverage

Looking at further details of the needs, it shows that most telescope cases only require the simultaneous coverage of a rather small area of the sky (expressed as a narrow field of view, see figure 26). The cases requiring a large sampling area/volume coincide with those requiring a smaller instrument.

A closer look at the spectroscopy cases shows a significant difference in required spectral resolution at the different wavelength ranges (see figure 27). While the requirements tend to be moderate in the UV, a large portion of the IR cases require very high spectral resolution.

[26] Currently sensitive InGaAs sensors are available up to ca. 1.65 µm, but current development might hold promising results for longer wavelengths as well.

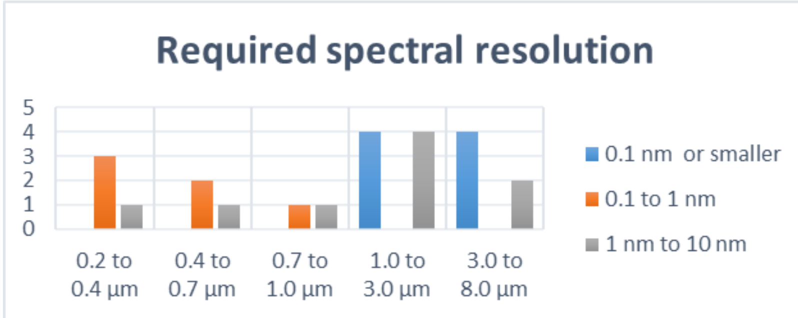

Figure 27: Required spectral resolution for spectroscopy at the different considered wavelength ranges

4.5 SUMMARY OF FURTHER SURVEY FINDINGS

Finally, we present a summary of additional information on scientific needs and preferences concerning a stratospheric infrastructure as collected via a survey we conducted among representatives of different scientific communities. The survey was conducted using the questionnaire in Annex I, which was also made available on the orison.eu project webpage, and distributed at scientific conferences, workshops, via mailing lists, and personal networks. Information from the first part of the survey is included in the summary presented in section 4.4. Information provided in this section is not necessarily connected to individual science cases, but rather represents general needs of the surveyed scientists.

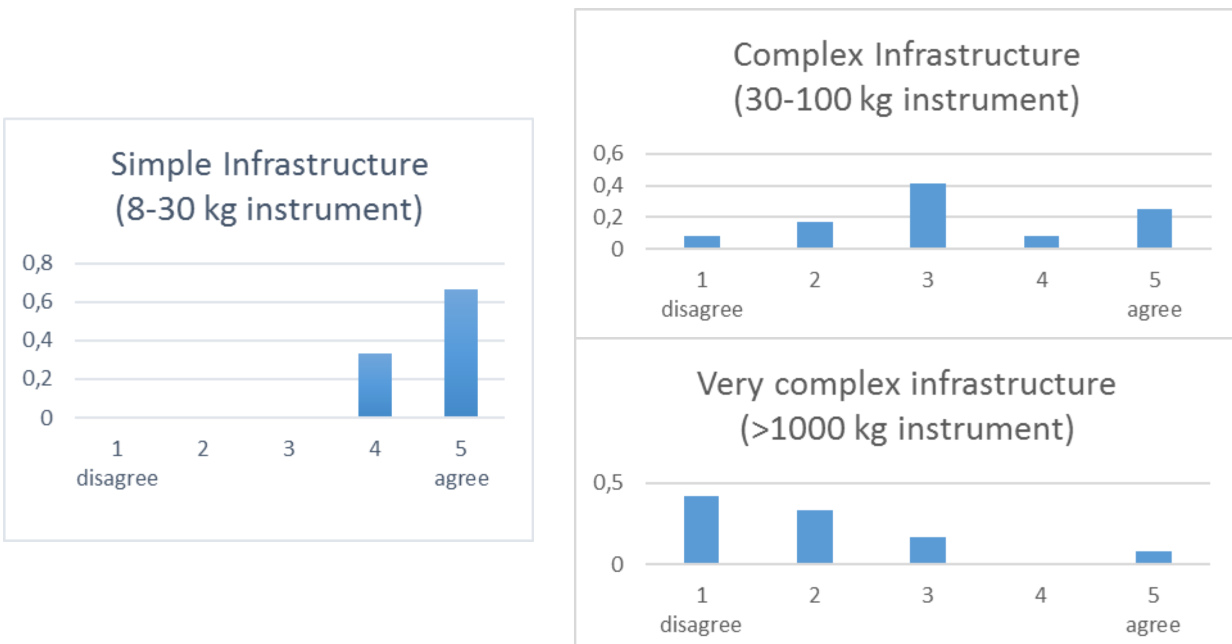

Figure 28: Preferred infrastructure sizes. Bars indicate which fraction of surveyed scientists agree to a certain degree that an infrastructure of the particular size would be of interest to them. Masses refer to instrument masses (excluding telescope) that can be carried. A simple infrastructure was furthermore estimated to have a development time of ca. one to two years, a complex infrastructure one of three to four years, and a very complex one a development time of more than five years.

Firstly, a clear preference for light, simple infrastructures with short development times of one to two years is notable (compare figure 28). It must be stressed, however, that the masses indicated refer to instrument masses (camera/spectrograph/…) only and do not include a telescope, which will likely constitute a significant portion of infrastructure mass.

Interestingly, though, the preference towards simpler infrastructures does not imply a clear preference for flexibility in terms of launch sites and flight trajectories. Only ca. 45% of participants indicated that they would prefer mobility of the launch site. The rest was equally split in ca. 27% preferring a permanent launch site, and ca. 27% with no preference.

What minimum altitude is concerned a clear preference for altitudes higher than 30 km is obvious, as figure 29 shows. Many participants did not provide an answer concerning their preferred altitude, though, so that this conclusion should not be used as an ultimate decision driver. The question on preferred mission duration also only provides a slight indication of a preference towards moderate mission durations of several hours to several days (compare figure 30).

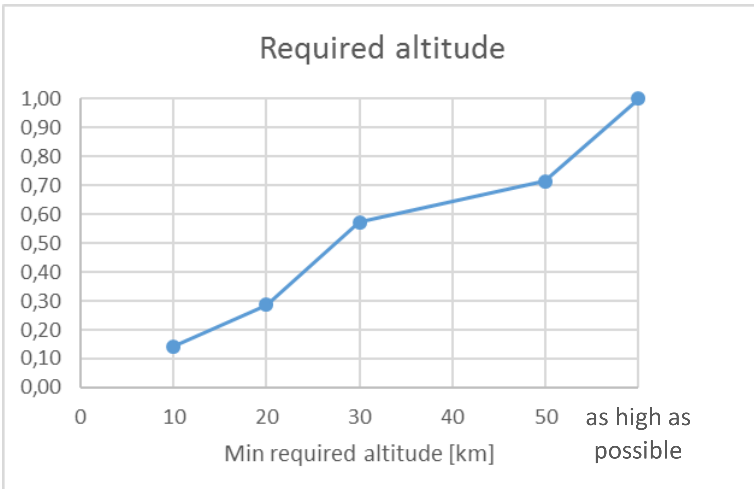

Figure 29: Cumulative fraction of surveyed scientists satisfied by a certain flight altitude

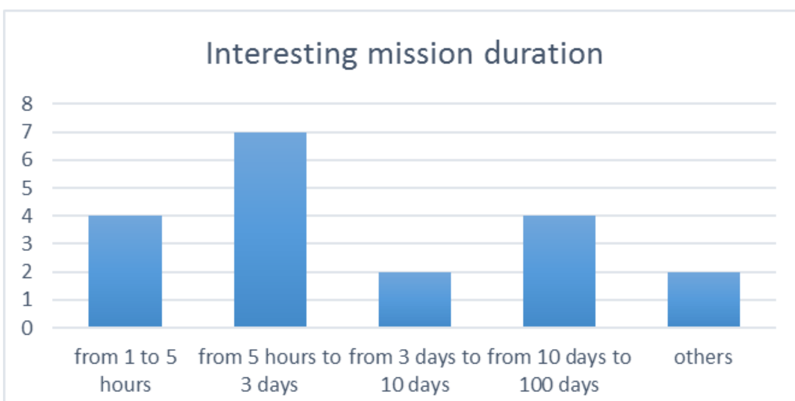

Figure 30: Duration of stratospheric missions of interest to surveyed scientists. Multiple answers were possible.

ANNEX I

Printout version of the ORISON scientific uses questionnaire which was made available as a digital questionnaire on the project website (orison.eu). The questionnaire will remain available throughout the project duration.

Would you like to observe from the high Stratosphere?

Form for researchers that would like to participate in the ORISON project

* Required

This feedback form is to be filled out by members of the research community and is meant to help us design a mid-size infrastructure for stratospheric observations.

(More info on the potential infrastructure and its advantages at the end of this form)

1. **What is your main research topic?** *

   Mark only one oval.

   - ( ) Astronomical observation
   - ( ) Earth observation
   - ( ) Atmospheric observation
   - ( ) Other: ____________________

2. **Please provide a short description of your research field** *

   ____

3. **Name of your scientific case** *

   ____

4. **Description of your scientific case** *

   ____
   ____
   ____
   ____
   ____

5. **What is your window of observation?** *

Check all that apply.

- [ ] Gamma rays
- [ ] X-rays
- [ ] UV
- [ ] Visible
- [ ] Near infrared
- [ ] Mid infrared
- [ ] Far infrared
- [ ] Microwaves
- [ ] Radio
- [ ] Particles
- [ ] Cherenkov
- [ ] Other: ____________________

6. **Spectral range (nm)/Spectral resolution (nm) [Photometry and spectroscopy]**

(Typical Bandwidth of your filters or spectroscopy resolution) Example: 450-700nm/100nm or 450-700/~1nm (preferred format) but others are also accepted like: Visible RGB, JHK Infrared ... but please add additional information on the description about your typical observing bands. Add as much spectral ranges that you need.

____

____

____

____

____

7. **Field of view(º)/Angular resolution(º/px)**

____

8. **Length of observation(s)/temporal resolution(s)**

____

9. **Duration of the missions that you are interested in**

Check all that apply.

- [ ] from 1 to 5 hours
- [ ] from 5 hours to 3 days
- [ ] from 3 days to 10 days
- [ ] from 10 days to 100 days
- [ ] Other: ____________________

10. **Observing modes**

Check all that apply.

- [ ] Imaging
- [ ] Photometry
- [ ] Spectroscopy
- [ ] Polarimetry
- [ ] Other: ____________________

11. **Tracking stability better than**

Mark only one oval.

- ( ) 0.1 arcsec
- ( ) 1 arcsec
- ( ) 10 arcsec
- ( ) 1 degree
- ( ) 10 degree
- ( ) Other

12. **Special needs and additional information**

E.g. special instruments you require (IFU,...)

____

____

____

____

____

13. **Points that you consider critical for your application or for your scientific case**

____

____

____

____

____

14. **Contact person** *

____

15. **Contact e-mail** *

____

16. **Institution**

____

17. **Your position**

Mark only one oval.

- ⬭ PhD student
- ⬭ Post-doc
- ⬭ Junior researcher
- ⬭ Senior researcher
- ⬭ Group leader / manager
- ⬭ Other: ____________________

18. **Comments and feedback about this form**

____
____
____
____
____

19. **Do you want that your scientific case be treated in a confidential way?** *

We will need to use some information for the description of the infrastructure but your science case will be dealt with in a confidential way so that the information provided will not be public

Mark only one oval.

- ⬭ Yes
- ⬭ No

20. **Add Links to files additional information (links to Dropbox or articles)**

Example: https://www.dropbox.com/sh/%%%%%%%%/%%%%%

____
____
____
____
____

Aspects of funding / shareholding

21. **Would your team or your institution be able to provide funds to at least cofund a small part of the infrastructure?**

In case that the final infrastructure design suits your needs and keeping in mind a possible future public procurement to build the infrastructure (within the context of the European H2020 funding scheme in its public procurement calls)

Mark only one oval.

- ⬭ Yes
- ⬭ No
- ⬭ No idea
- ⬭ Other: ____________________

22. **Would your team or your institution prefer to procure observation time/data relevant to your science case rather than cofunding the infrastructure?**

Mark only one oval.

- Yes
- No
- No idea
- Would not prefer it, but it would also be an option
- Other: ____________________

23. **Are you interested in a relatively simple infrastructure that can deploy instruments of around 8-30 kg? (Short development) (1-2 years)** *

(Excluding the telescope)

Mark only one oval.

	1	2	3	4	5	
Disagree	◯	◯	◯	◯	◯	Agree

24. **Are you interested in a more complex infrastructure that can deploy instruments of 30-100 kg? (Long development) (3-4 years)** *

(Excluding the telescope)

Mark only one oval.

	1	2	3	4	5	
Disagree	◯	◯	◯	◯	◯	Agree

25. **Are you interested in a really complex infrastructure that can deploy payloads of the order of 1000 kg or more? (Very long development) (>5 years). This is actually beyond the scope of ORISON but your feedback on this is also important** *

Mark only one oval.

	1	2	3	4	5	
Disagree	◯	◯	◯	◯	◯	Agree

Other operational aspects

26. **What is the weight that you estimate for an instrument that would suit your needs?**

____

27. **Would you prefer a permanent launching site or would you prefere mobility?**

____

28. **If you prefer or require a certain flight altitude, what would it be?**

____

This feedback form is to be filled out by members of the research community and is meant to help us design a mid-size infrastructure for stratospheric observations.

Your feedback will help us to design and advocate a low-cost, balloon-based research platform within the Innovative Research Infrastructure based on Stratospheric Balloons (ORISON) project. The project is currently undertaken under European Comission funding by the Instituto de Astrofísica de Andalucía (IAA-CSIC), the University of Stuttgart, Ernst & Young, and the Max Planck Institute for Extraterrestrial Physics with the goal to assess the feasibility and identify a potential funding scheme to create the infrastructure.
The envisioned balloon-based platform would offer observation conditions similar to that of a space mission, such as demonstrated by highly successful missions in the past (SUNRISE solar science missions, BOPPS planetary science mission,...) but at considerably lower costs, e.g.:

- Close to diffraction limited resolving power (1 arcsec or less in the UV and VIS spectra)
- Close to 100% atmospheric transmission in the NUV (http://bit.ly/uv-trans) , VIS, and NIR (http://bit.ly/ir-trans)
- Limited atmospheric background that ease spectroscopy and allow daytime observations for certain applications
- Observations independent of weather conditions
- Flight altitude ca. 35 km
- Duration between several hours and up to 100 days possible

For more information on the project, please consult:

http://asteroidstnos.iaa.es/content/project-orison or at http://www.orison.eu

To design the payload and final infrastructure we are seeking input from different teams that can have different science cases and can be interested in the final infrastructure. So please fill out the following questionaire.

If you are interested in several different configurations, please fill this form several times. Keep in mind that the infrastructure could be modular, so some modules can be permanent and other modules can be temporal.