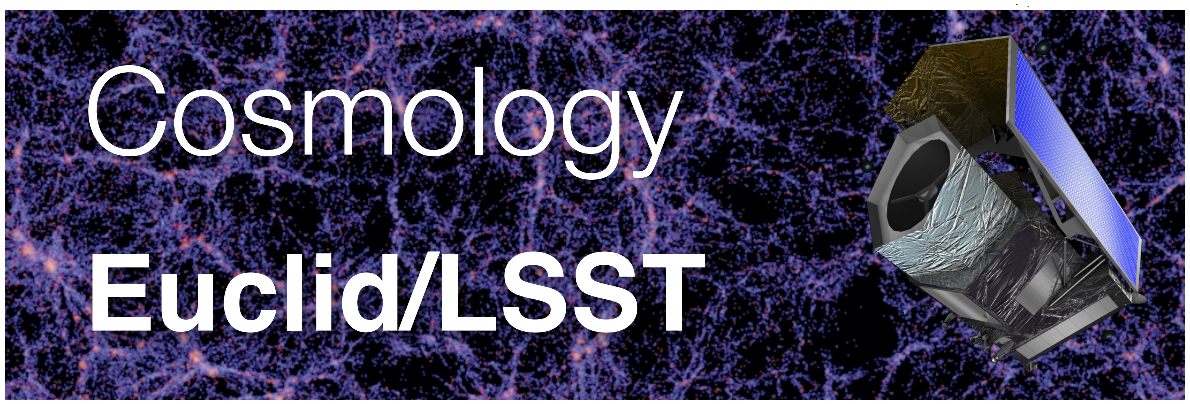
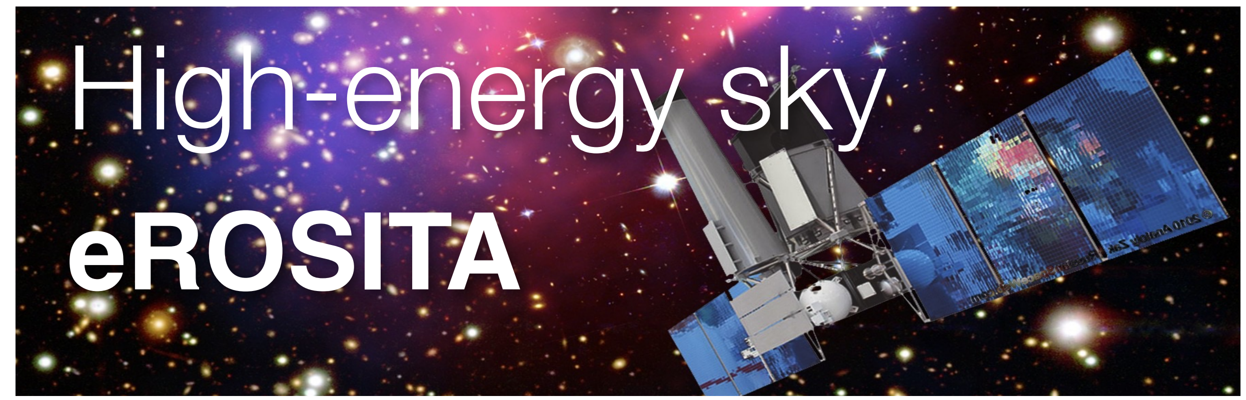
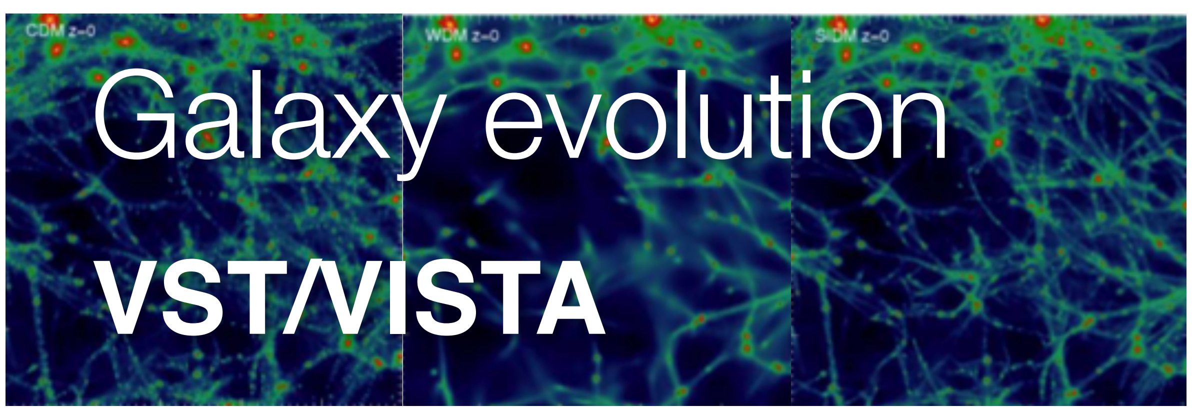
Science with 4MOST

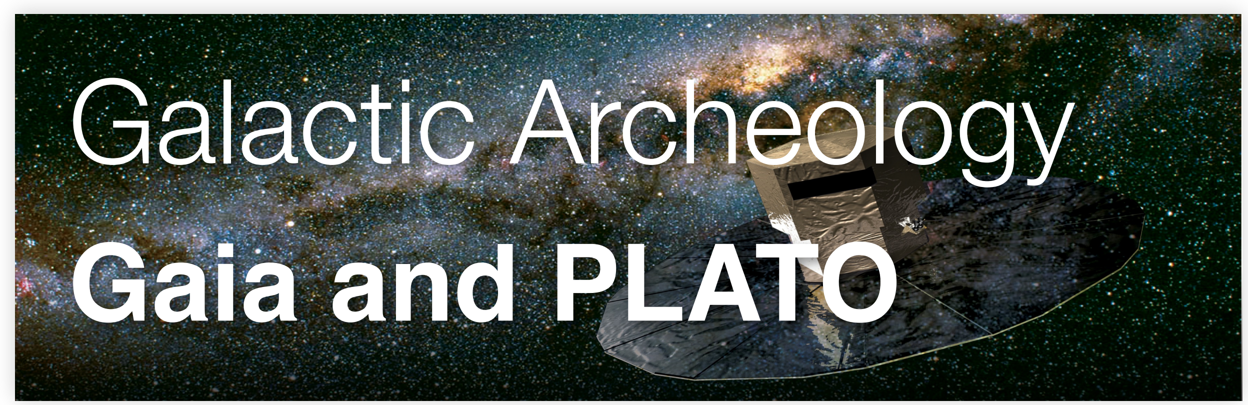
On behalf of the 4MOST science team
4MOST PI: Roelof de Jong

Science Themes









4MOST science is built around four major themes

Time-line

1

Date	Milestone Description
Summer 2019	Call for LoI
May 2019	Workshop for Community
November 2019	Call for Proposals
March 2021	ESO DG approval for 4MOST Survey Program

0

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Note - only one (1) call for the full 5 year survey

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D[illegible]	[illegible]
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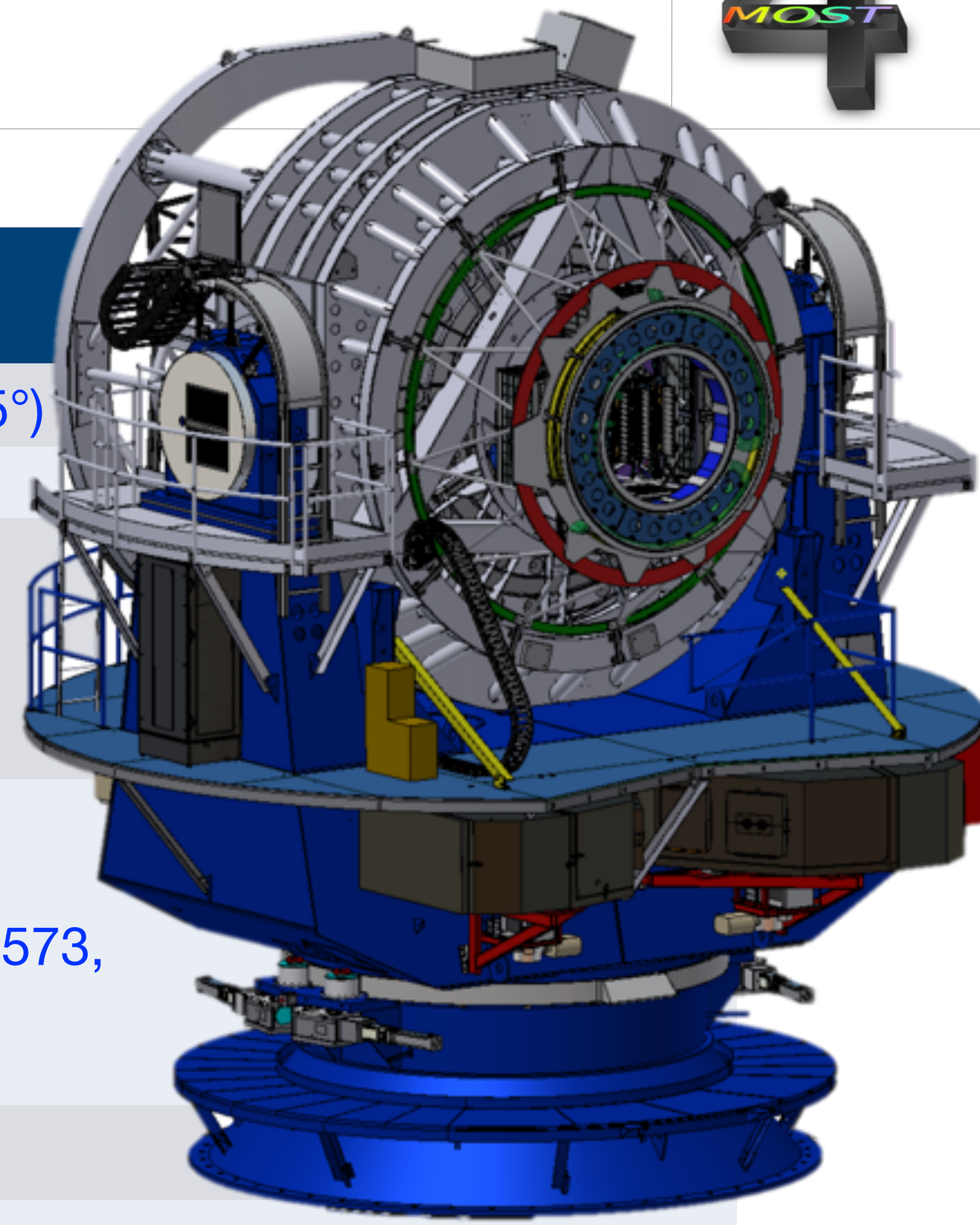
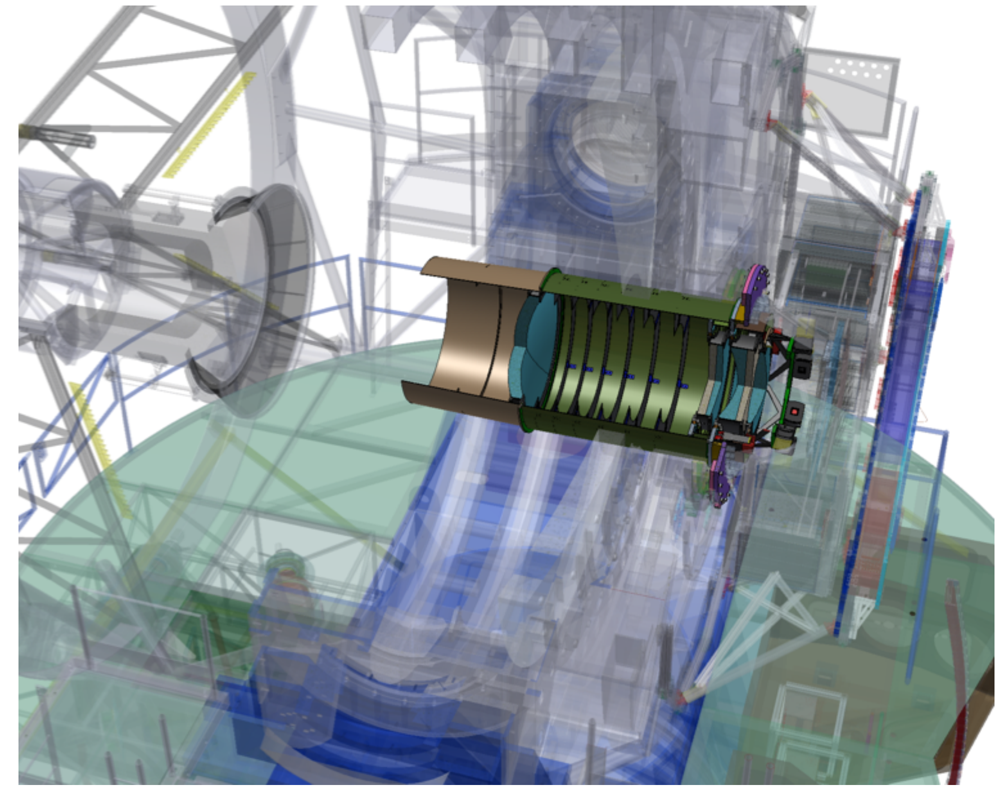
4MOST on VISTA



Specification	Design value
Field-of-View (hexagon)	~4.1 degree^2 (⌀>2.5°)
Multiplex fiber positioner	2436
Medium Resolution Spectrographs (2x) # Fibres Passband Velocity accuracy	R~4000–7500 812 fibres (2x) 370-950 nm < 1 km/s
High Resolution Spectrograph (1x) # Fibres Passband Velocity accuracy	R~20,000 812 fibres 392.6-435.5, 516-573, 610-679 nm < 1 km/s
# of fibers in ⌀=2' circle	>3
Fibre diameter	⌀=1.45 arcsec
Area (first 5 year survey)	>2h x 18,000 deg^2
Number of science spectra (5 year)	~75 million of 20 min

Wide Field Corrector and Atmospheric Dispersion Compensator (WFC/ADC)



4 Lenses Groups with 2 counter-rotating prisms

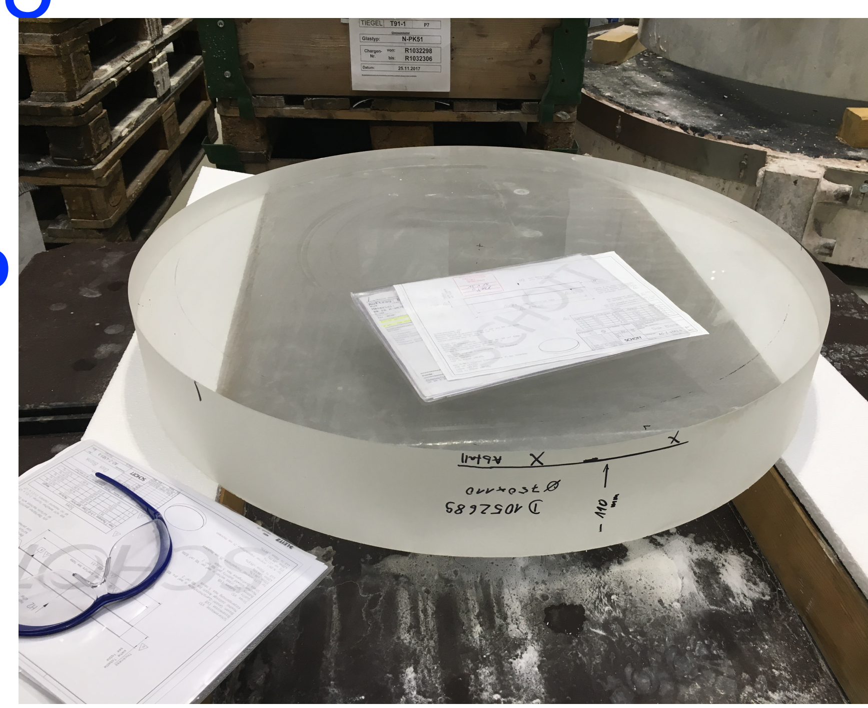
Field diam. = 2.5°

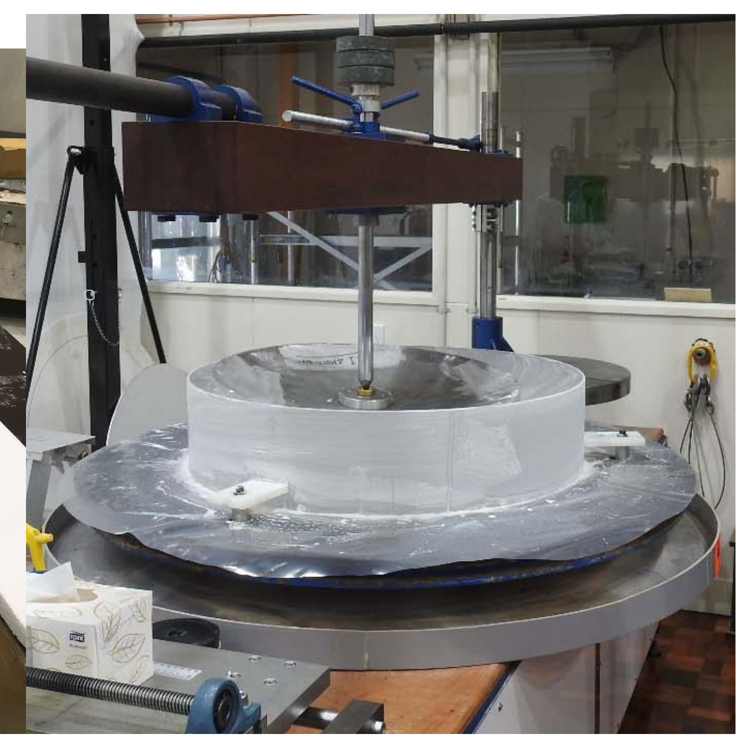
535 mm focal diameter

Largest lens ~930 nm

ADC functions to ZD=55°

Design and build at AIP





AESOP Fiber Positioner

Echidna style

2436 Fiber Probes

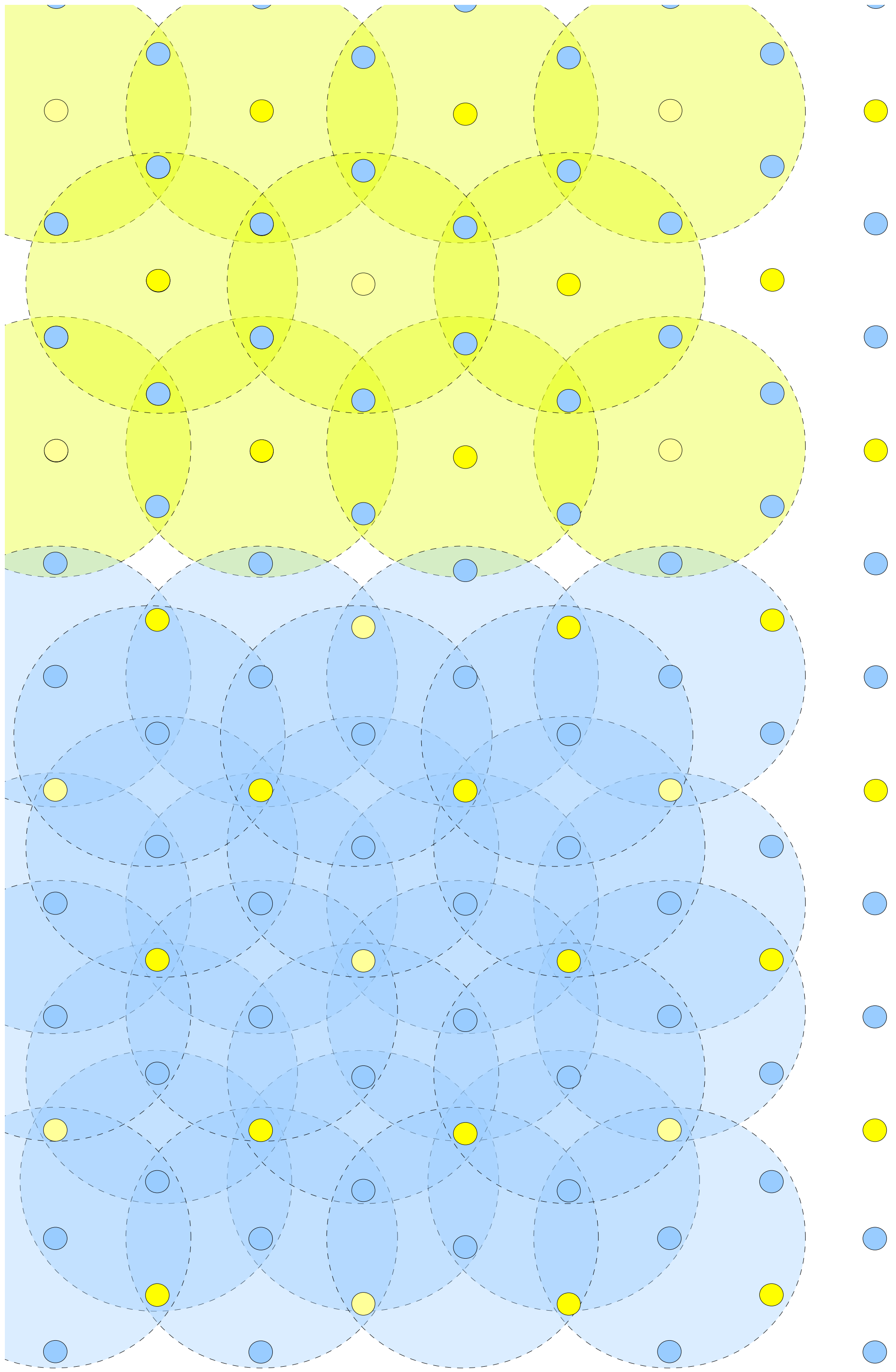
-patrol diameter 2.4x pitch

-minimum separation ~20”

-reconfiguration time <2 min during CCD readout

24 Fiducials

12 Guide Probes



AESOP Fiber Positioner

Echidna

2436 Fi

-patrol c

-minimu

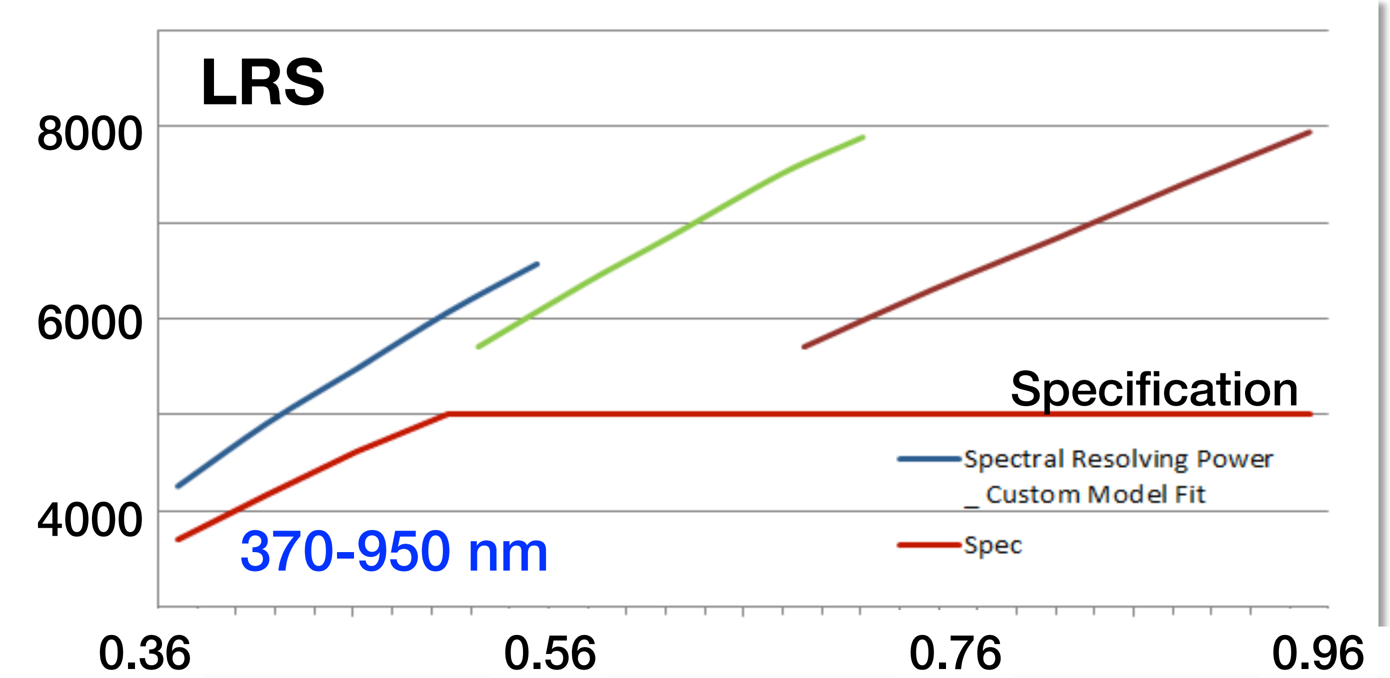
-reconfi
min dur

24 Fidu

12 Guid

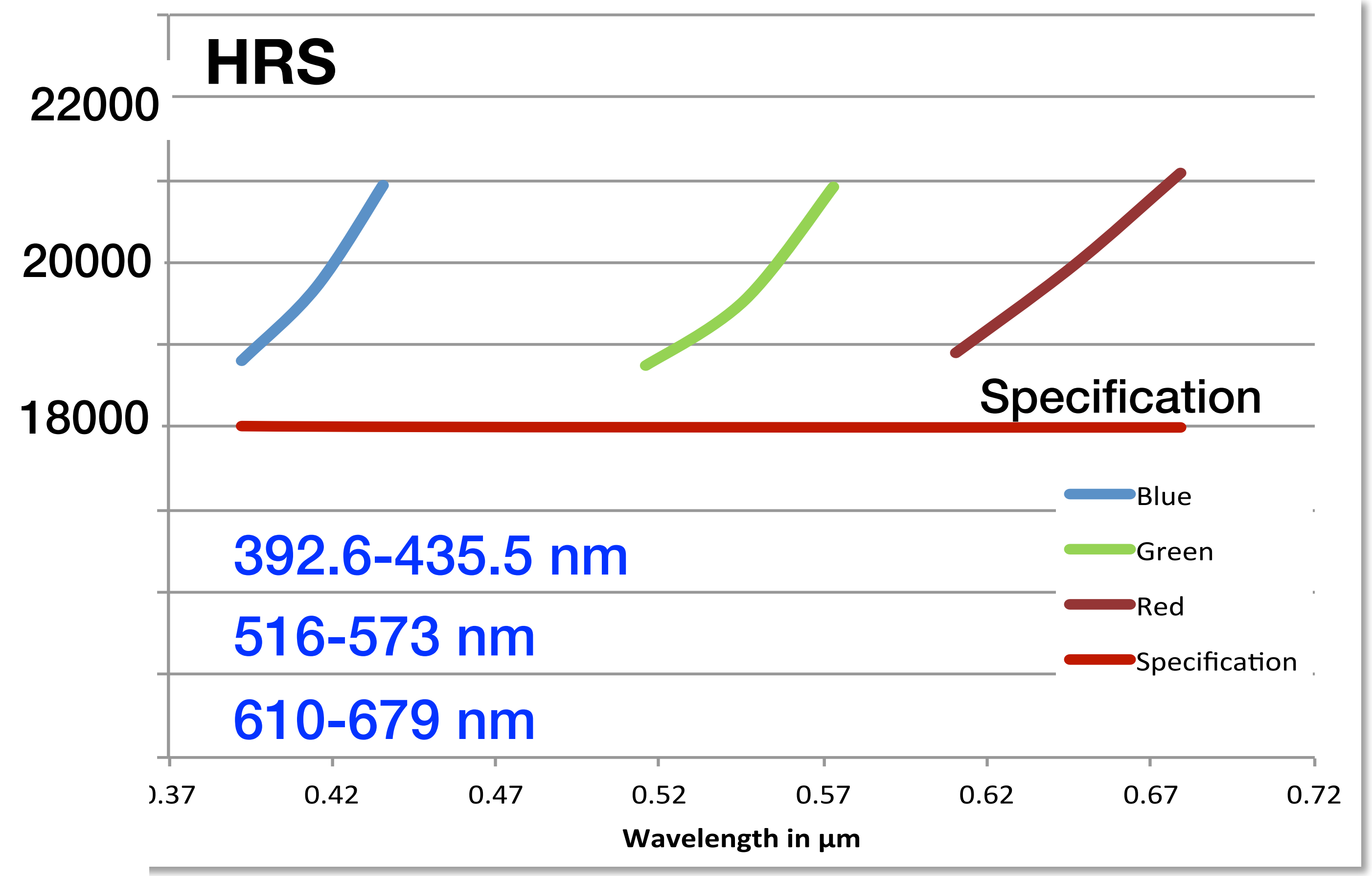
Low and high res. spectrographs

2 LRS & 1 HRS each have
3 arms
3 CCDs 6k x 6k
812 science fibers



LRS: Design and build at CRAL in Lyon.

HRS: Design and build at ZAH/LSW in Heidelberg.

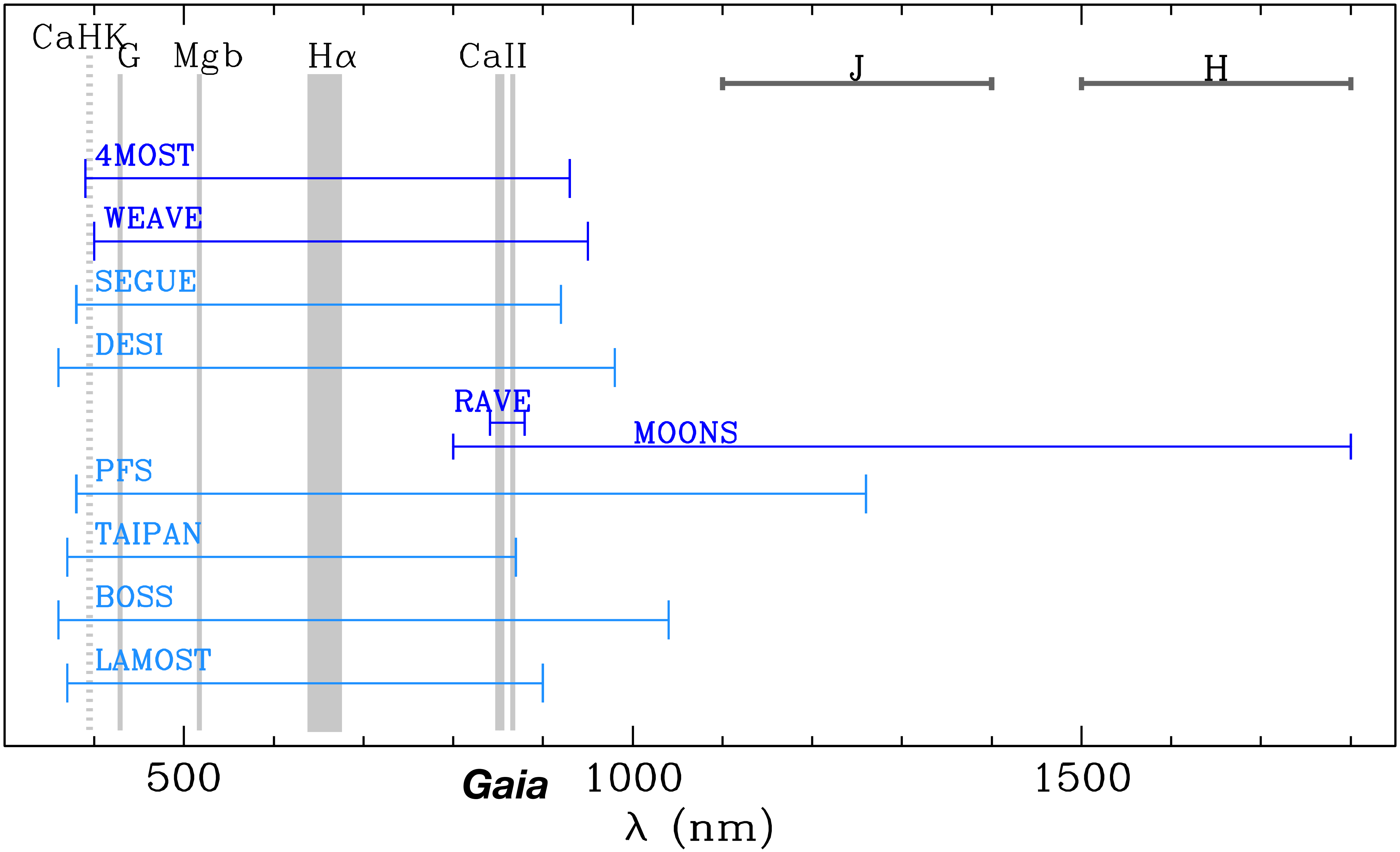


Comparing to other facilities

R ~ 2000 – 7500

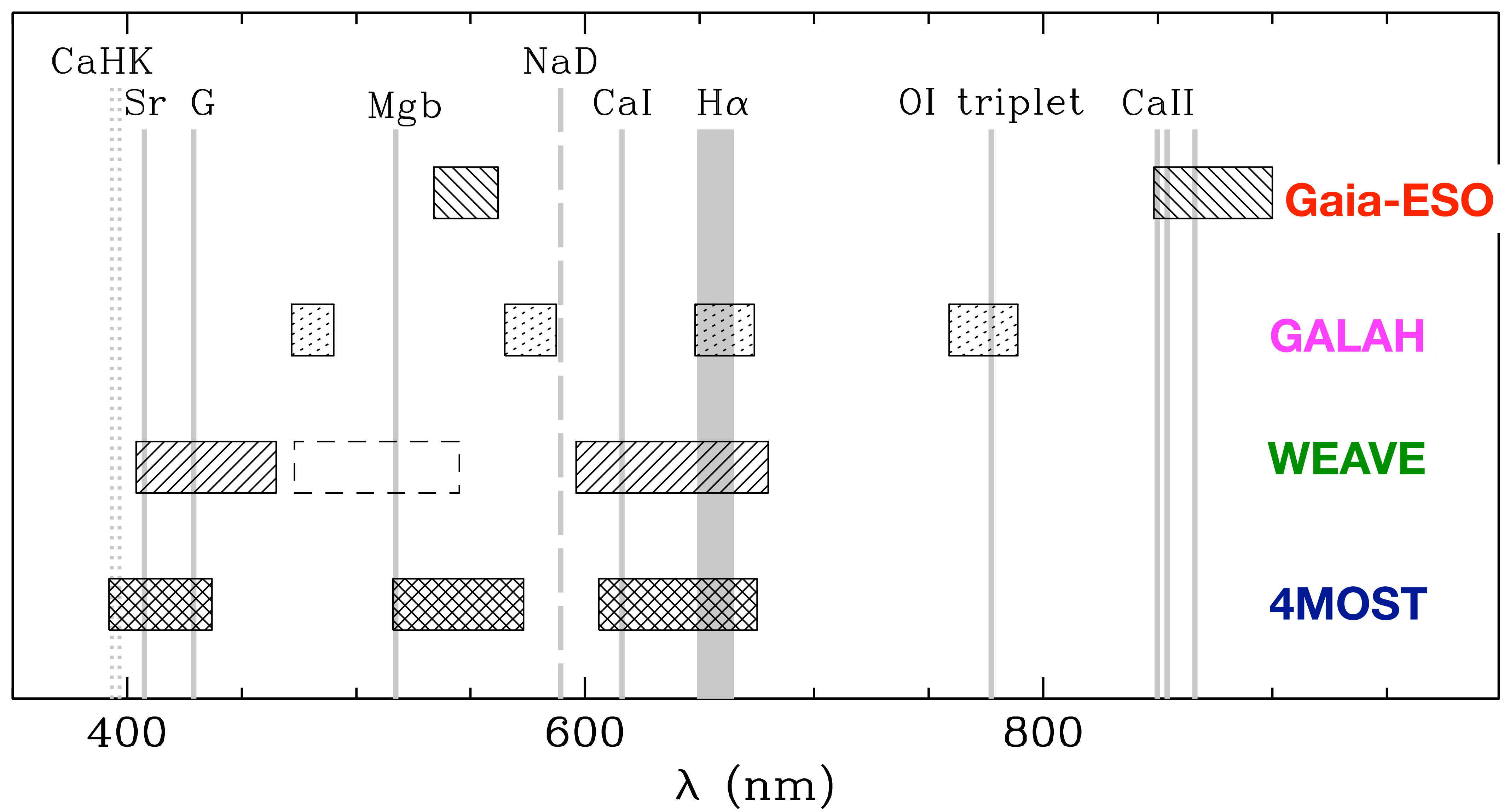
4MOST

WEAVE

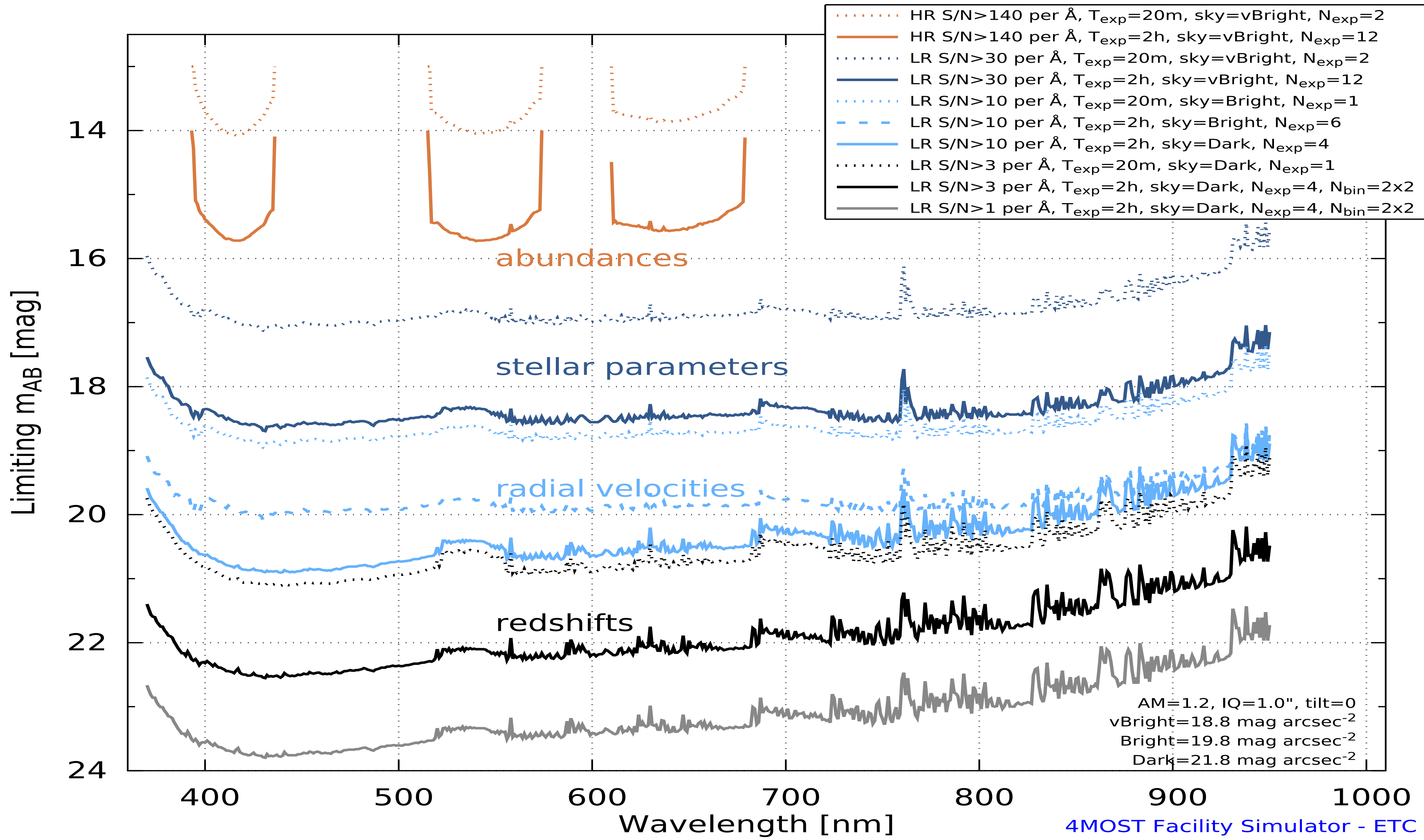


Comparing to other facilities

R ~ 20 000



Expected sensitivity



Gaia
G_limit=20

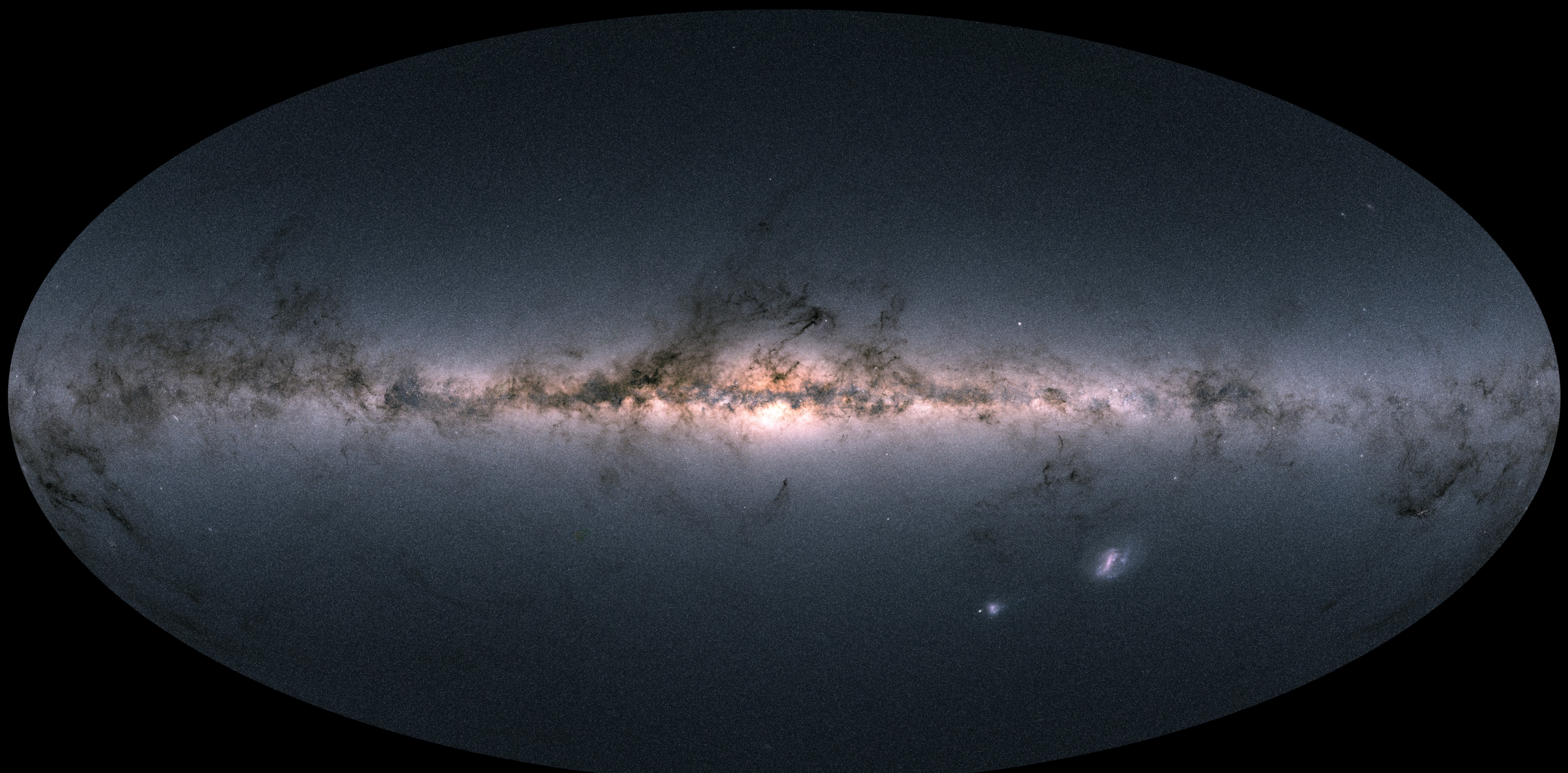
Ten consortium surveys

~70% of the fibre hours — the rest for community bids

No	Survey Name	Survey (Co-)PI
S1	Milky Way Halo LR Survey	Irwin (IoA) , Helmi (RuG)
S2	Milky Way Halo HR Survey	Christlieb (ZAH)
S3	Milky Way Disk and Bulge LR Survey	Chiappini, Minchev, Starkenburg (AIP)
S4	Milky Way Disk and Bulge HR Survey	Bensby (LU), Bergemann (MPIA)
S5	Galaxy Clusters Survey	Finoguenov (MPE)
S6	AGN Survey	Merloni (MPE)
S7	Galaxy Evolution Survey (WAVES)	Driver (USW), Liske (HHU)
S8	Cosmology Redshift Survey	Richard (CRAL), Kneib (EPFL)
S9	Magellanic Clouds Survey	Cioni (AIP)
S10	Time-Domain Extragalactic Survey (TiDES)	Nichol (Portsmouth)

Selected examples

Galactic Archaeology – *Gaia*



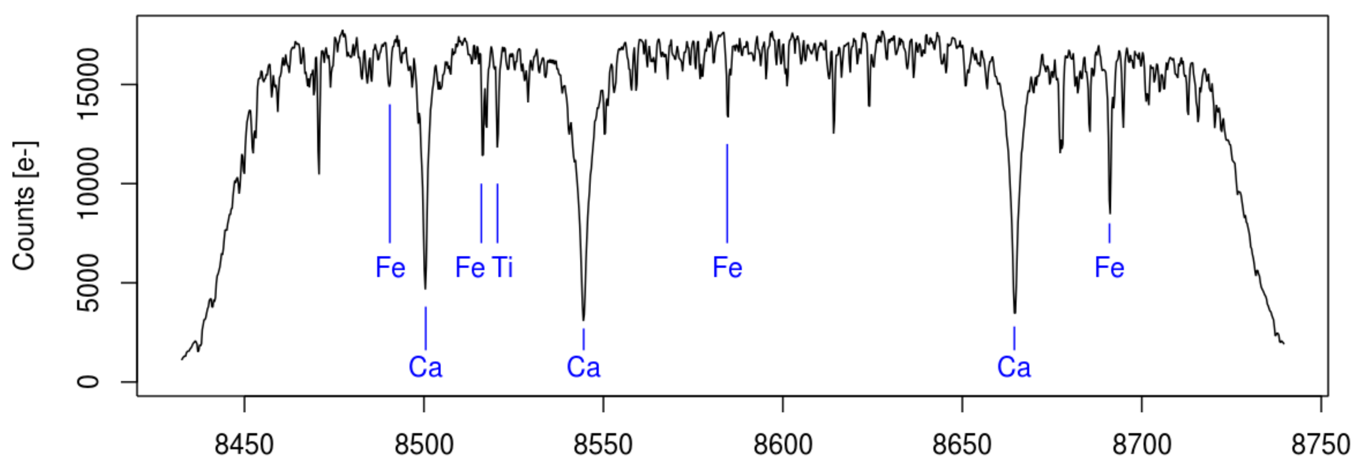
Requirement on RV accuracy to match *Gaia's* proper motion accuracy at the faintest magnitudes

Gaia's offerings

Spectral type	V [mag]	Vel. error [km s^{-1}]
B1V	7.5	1
	11.3	15
G2V	12.3	1
	15.2	15
K1III-MP (metal-poor)	12.8	1
	15.7	15

Need more (and longer) spectra at fainter magnitudes

- RVs to ~15.5 (tip RGB in the Bulge)
- Abundances to ~12.5 (a sun at 300 pc)



http://www.cosmos.esa.int/web/gaia/science-performance
Recio-Blanco et al. 2016 A&A 585 A93

Galactic Archaeology

Helmi
Irwin
Christlieb

Chiappini
Minchev
Starkenburg
Bergemann
Bensby

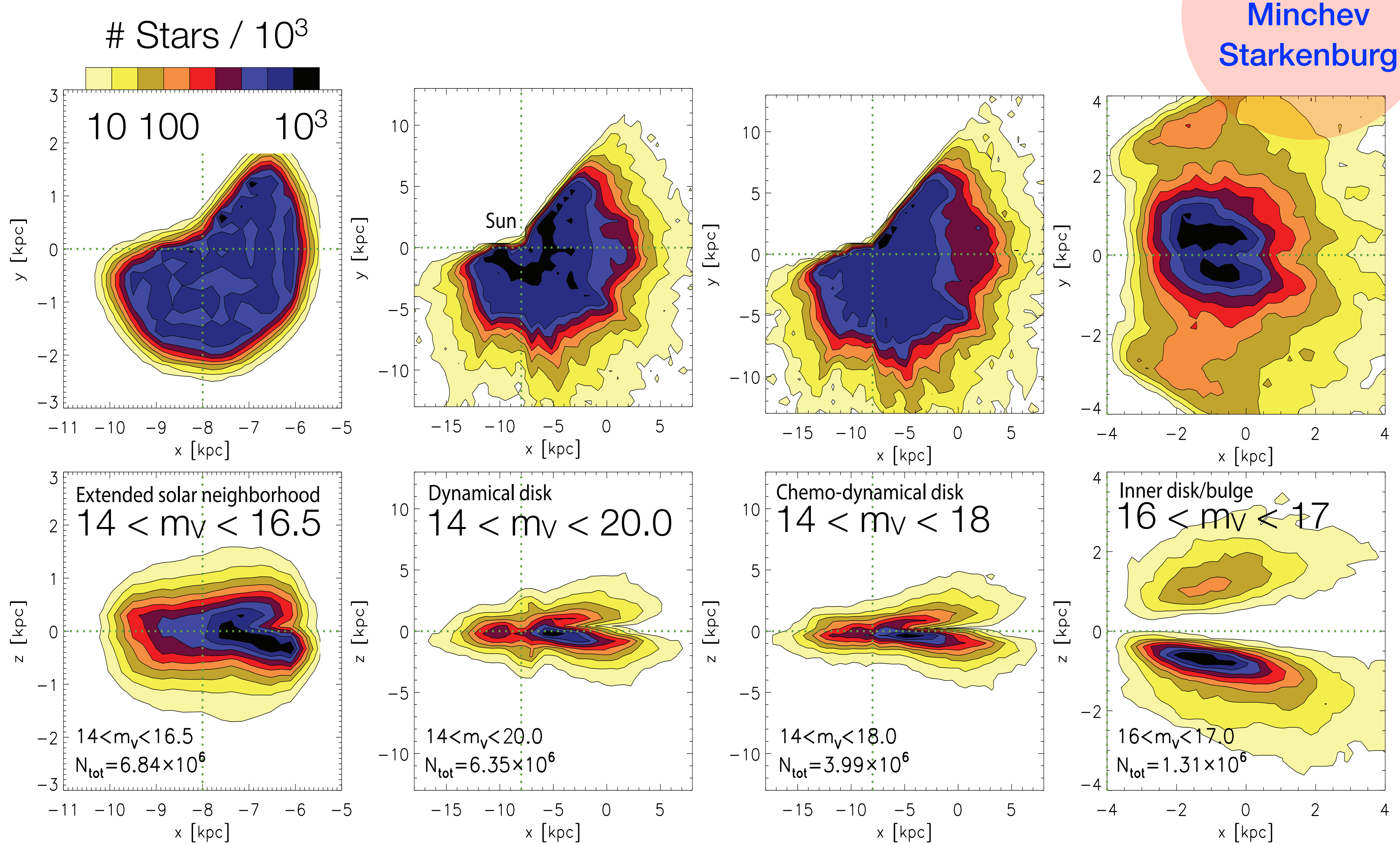
Cioni

- **Near-field cosmology tests**
  - overall mass, extent and structure of the MW dark matter halo
  - the nature of dark matter from tidal stream properties
- **Characterising the major Milky Way components**
  - the formation of the Bulge and the link to the high Z universe
  - the potential, substructure and influence of the central bar
  - chemodynamical analysis of the thick & thin disks formation history
- **The Galactic Halo and beyond**
  - full chemodynamical analysis of the Magellanic Clouds (sub-structure, ages, chromodynamics —> formation and evolution) 1000 deg2 – r<20 mag for 500,000 target
  - the properites of large scale streams (e.g. Sgr) in the Halo
  - probing the extent and properties of the stellar halo (e.g. RGBs, BHBs)
- **Extreme metal poor stars**
  - characterising early chemical evolution in the Halo and Bulge

Galactic Archaeology

Chiappini
Minchev
Starkenburg

Example



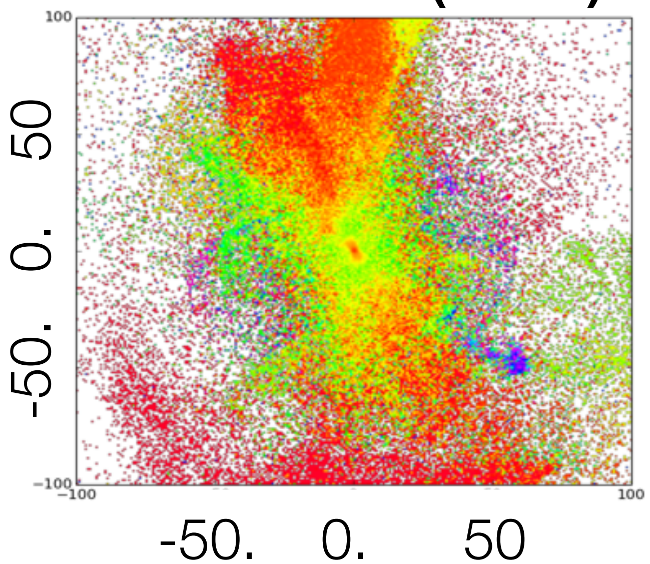
Low resolution disk & bulge

Largest planned survey to complement *Gaia*

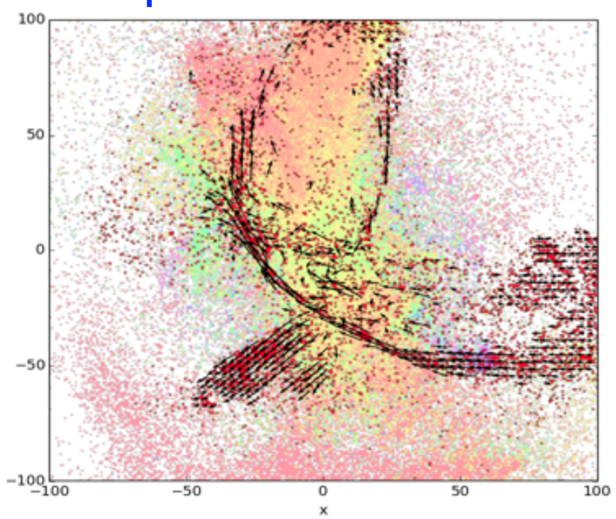
Figuring out the Milky Way halo and potential

Helmi
Irwin

Helmi et al. (2011)

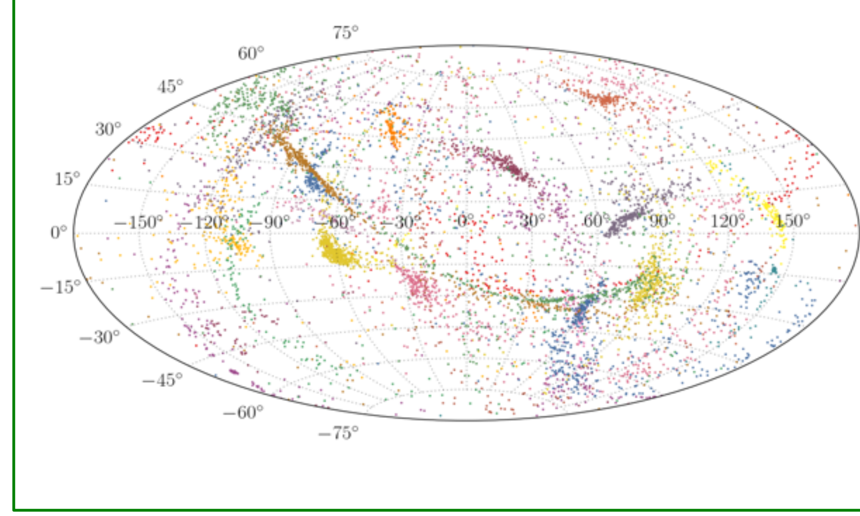


Aquarius simulation

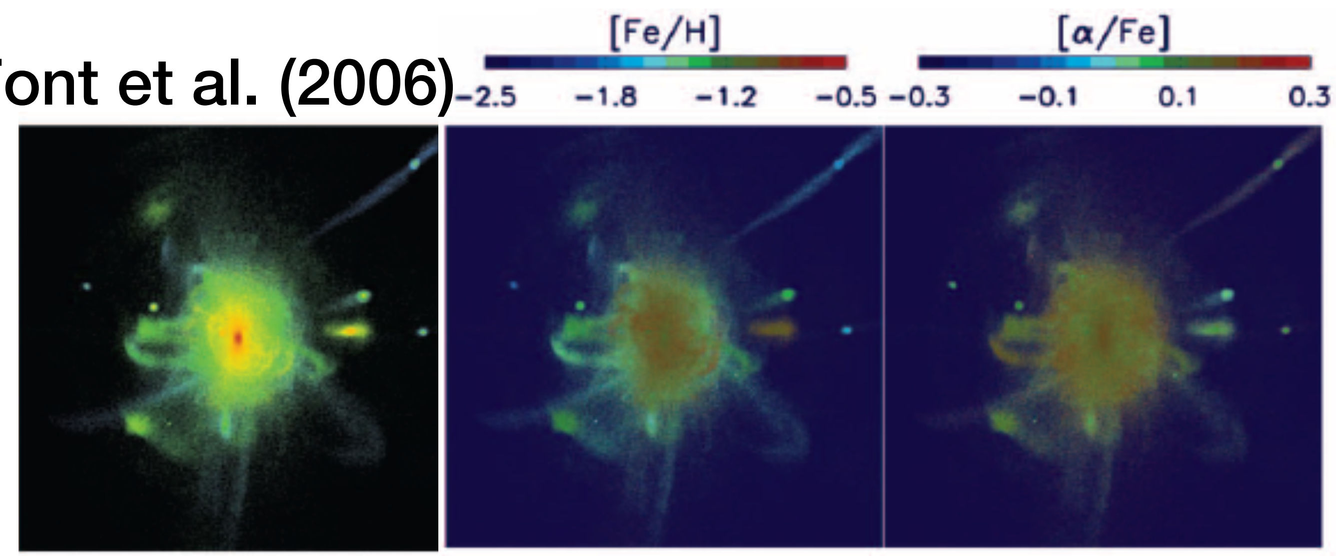


To disentangle the building blocks of the halo (i.e. different colours), **3D kinematics** are essential (because of strong spatial overlap and complexity of velocity field).

Aquarius simulation



Font et al. (2006)



Bullock & Johnston (2005) simulation

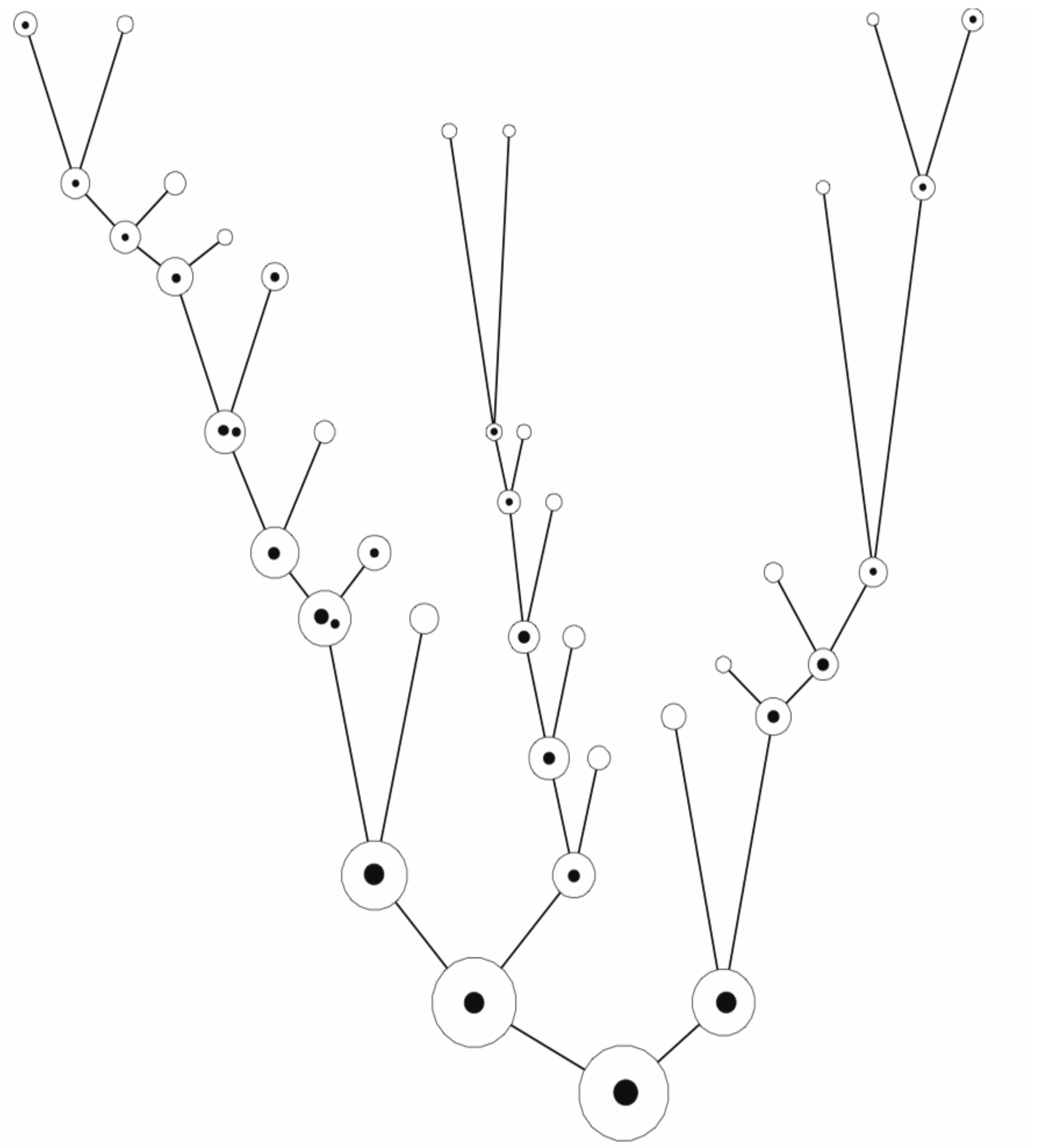
Elemental abundances can be used to characterize different (kinds of) building blocks

Thin streams are sensitive probes of the mass distribution. Also encounters with dark subhalos produce gaps whose properties depend on subhalo (and thus dark matter)

eROSITA - galaxy clusters and black-hole evolution

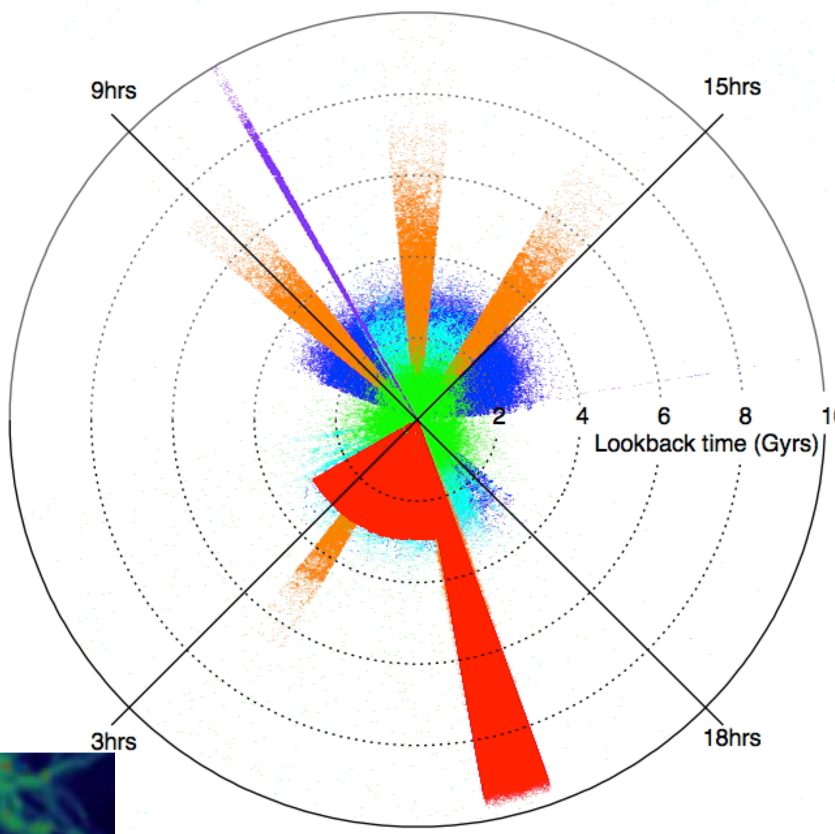
Merloni
Finoguenov

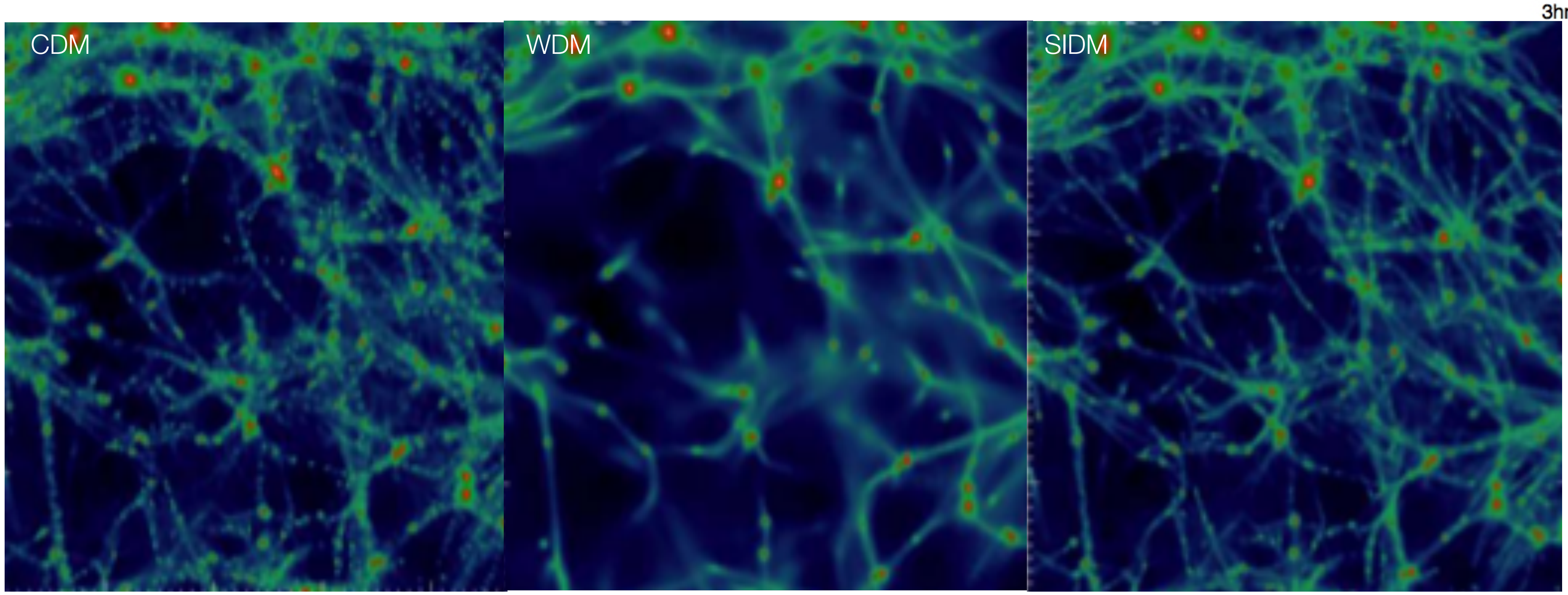
- The eROSITA instrument on board of the German – Russian Spectrum Röntgen Gamma satellite will locate ~2 million massive Black Holes in the centres of galaxies across the whole sky
- Strong cosmology constraints from Galaxy Cluster evolution
- AGN evolution and Galaxy-Black Hole co-evolution
- 4MOST is needed to determine accurate redshifts/distances to these objects to answer questions like:
  - What is the evolution of this massive Black Hole population?
  - What effects do the energy of these Black Holes have on the galaxies they live in?



WAVES – Galaxy evolution

- The distribution and properties of galaxies on small scales depend on Dark Matter flavour
- 4MOST will characterise millions of big and small galaxies in a few patches on the sky
- What are the Dark Matter characteristics on galaxy group scales?
- How do galaxies evolve to the smallest scales?



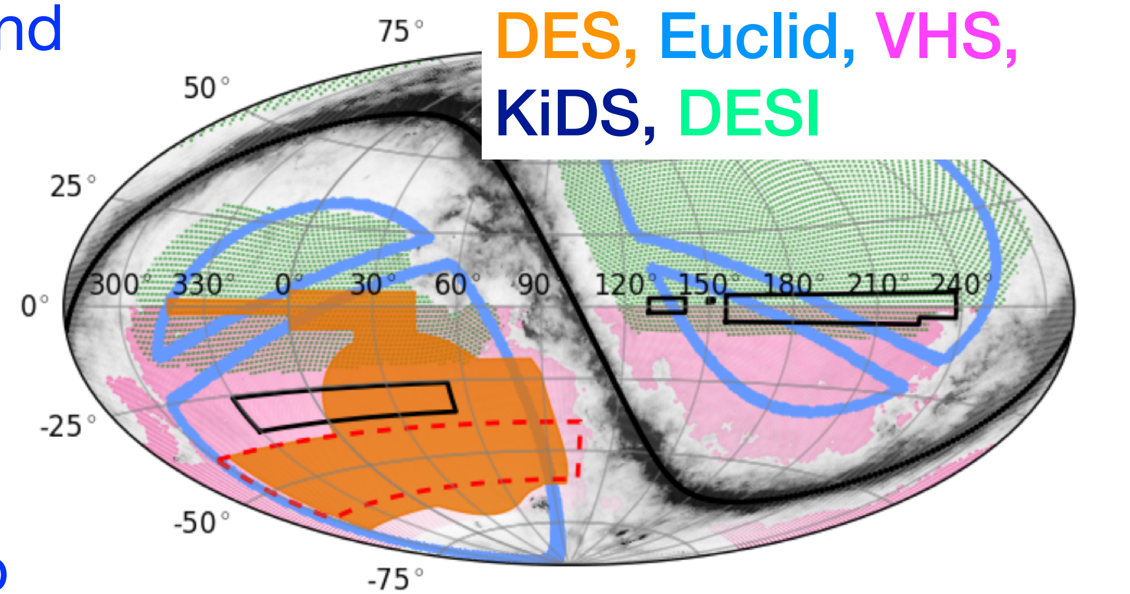


Driver
Liske

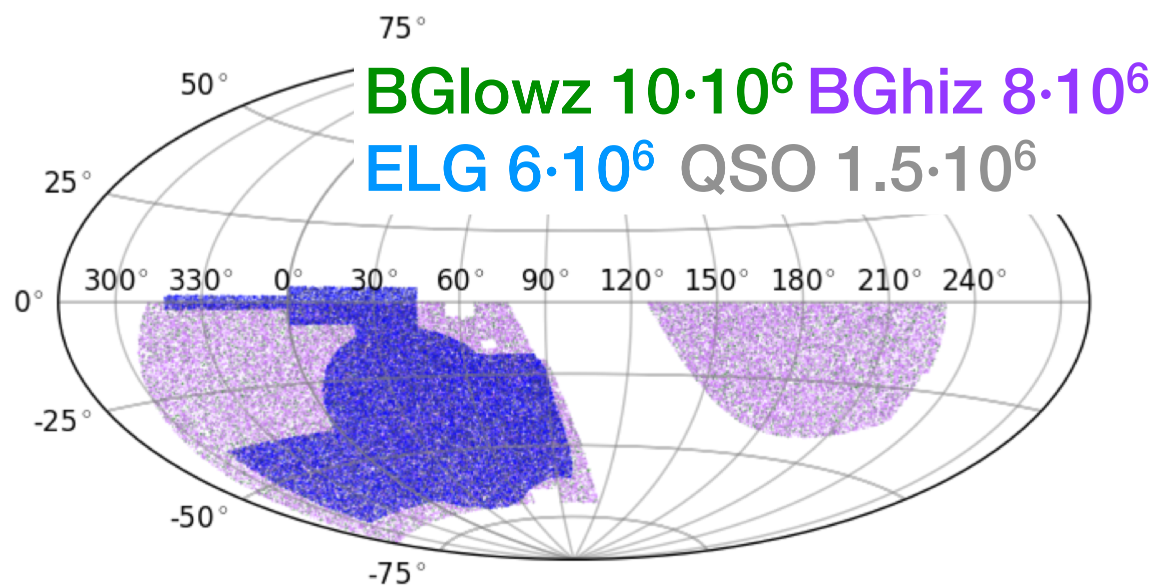
Cosmology surveys

Kneib
Richard

- Hard to be competitive with DESI for BAO measurements in terms of number of targets and timeline of the survey.
- Strengths: synergies with southern facilities:
  - cross-correlation with weak-lensing (DES)
  - synergies with radio surveys
  - synergies with CMB surveys
- DECAM provides the best quality of imaging to select targets, until we have LSST



Target	Imaging	Redshift	Density
BGlowz	VHS+WISE	0.05<z<0.4	250/deg2
BGhiz	VHS+WISE	0.4<z<0.8	700/deg2
ELG	DES	0.7<z1.1	1300/deg2
QSO	DES+WISE	0.9<z<3.5	290/deg2



4MOST Survey program

- Unique operations model for MOS instruments suitable for most science cases
- 4MOST program defined by Public Surveys of 5 years
- Surveys defined by Consortium and Community
- All Surveys will run in parallel
  - ➡ Surveys share fibres per exposure for increased efficiency

➡ This means that you need to simulate a survey plan in detail

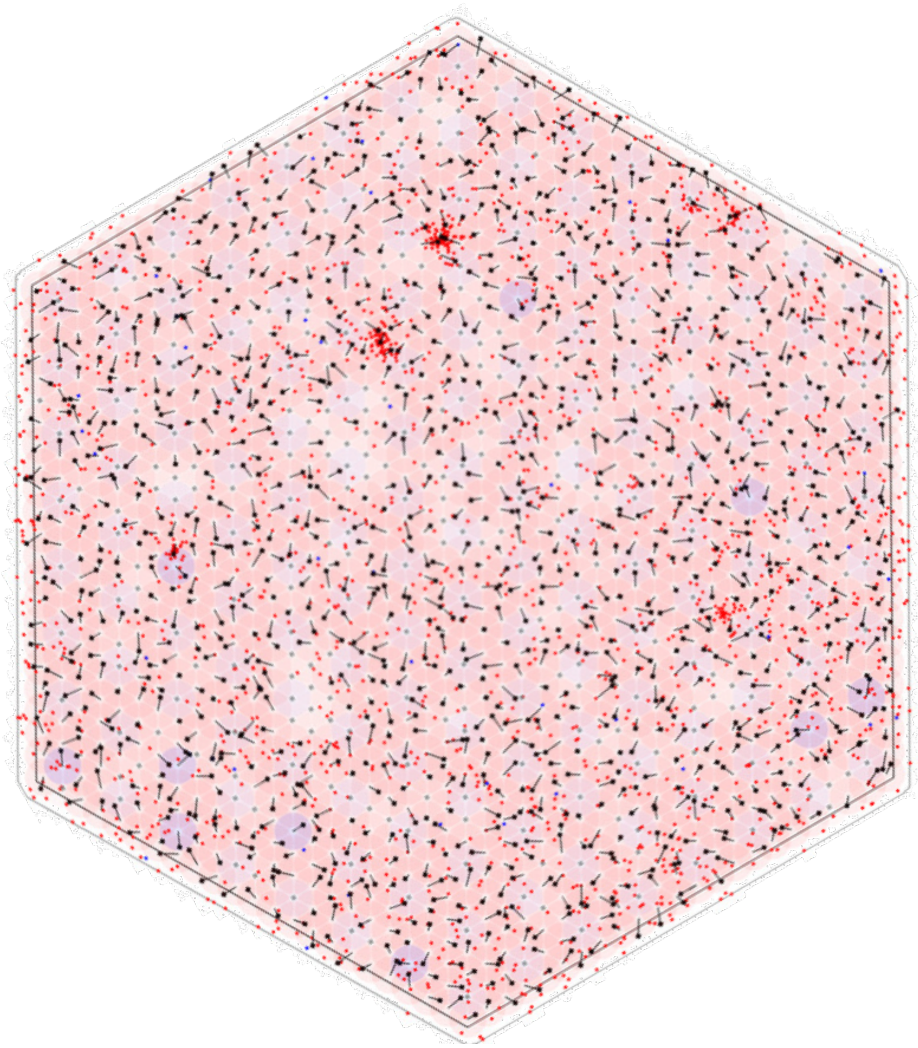
Simulation 1

```
#This is the night reports logfile for simulation: "round8/b/run04b"
#This log was first written at: Tue Nov 10 16:51:03 2015
#Original filename: night_reports.txt
#This logfile contains one entry per night of the survey giving breif info about night conditions
#Description of columns:
#Name       Description
#-----      ---------------------------------------------------------------------------
Night       Number of this night (1st night=1)
JD_midnight Julian date at local midnight (decimal days of Julian epoch)
JD_twi_eve  Julian date at the end of evening twilight (days)
JD_twi_morn Julian date at the beginning of morning twilight (days)
JD_start    Julian date at the beginning of survey (days)
-           Additional reports of adverse night conditions are appended to entry where applicable
#-----  ----------- ------  --------------------------------------------------------------
Night    1/1827 JD_midnight= 2458485.62500 JD_twi_eve= 2458485.54306 JD_twi_morn= 2458485.85278 JD_start= 2458485.00000 : The
cloud cover is too thick, closing dome all night, sorry!
Night    2/1827 JD_midnight= 2458486.62500 JD_twi_eve= 2458486.54375 JD_twi_morn= 2458486.85347 JD_start= 2458485.00000 :
Night    3/1827 JD_midnight= 2458487.62500 JD_twi_eve= 2458487.54375 JD_twi_morn= 2458487.85417 JD_start= 2458485.00000 :
Night    4/1827 JD_midnight= 2458488.62500 JD_twi_eve= 2458488.54375 JD_twi_morn= 2458488.85486 JD_start= 2458485.00000 : The
cloud cover is too thick, closing dome all night, sorry!
Night    5/1827 JD_midnight= 2458489.62500 JD_twi_eve= 2458489.54375 JD_twi_morn= 2458489.85556 JD_start= 2458485.00000 :
Night    6/1827 JD_midnight= 2458490.62500 JD_twi_eve= 2458490.54375 JD_twi_morn= 2458490.85556 JD_start= 2458485.00000 : The
cloud cover is too thick, closing dome all night, sorry!
Night    7/1827 JD_midnight= 2458491.62500 JD_twi_eve= 2458491.54375 JD_twi_morn= 2458491.85625 JD_start= 2458485.00000 : The
wind speed is too high, closing dome all night, sorry!


Night  181/1827 JD_midnight= 2458665.66700 JD_twi_eve= 2458665.47603 JD_twi_morn= 2458665.92047 JD_start= 2458485.00000 : We are
going to carry out planned maintenance all night, sorry!
Night  182/1827 JD_midnight= 2458666.66700 JD_twi_eve= 2458666.47672 JD_twi_morn= 2458666.92047 JD_start= 2458485.00000 : We are
going to carry out planned maintenance all night, sorry!
Night  183/1827 JD_midnight= 2458667.66700 JD_twi_eve= 2458667.47672 JD_twi_morn= 2458667.92047 JD_start= 2458485.00000 :
Night  184/1827 JD_midnight= 2458668.66700 JD_twi_eve= 2458668.47672 JD_twi_morn= 2458668.92117 JD_start= 2458485.00000 :
Night  185/1827 JD_midnight= 2458669.66700 JD_twi_eve= 2458669.47742 JD_twi_morn= 2458669.92117 JD_start= 2458485.00000 :
Night  186/1827 JD_midnight= 2458670.66700 JD_twi_eve= 2458670.47742 JD_twi_morn= 2458670.92117 JD_start= 2458485.00000 : The
wind speed is too high, closing dome all night, sorry!
Night  187/1827 JD_midnight= 2458671.66700 JD_twi_eve= 2458671.47742 JD_twi_morn= 2458671.92117 JD_start= 2458485.00000 :
```

Simulation 2

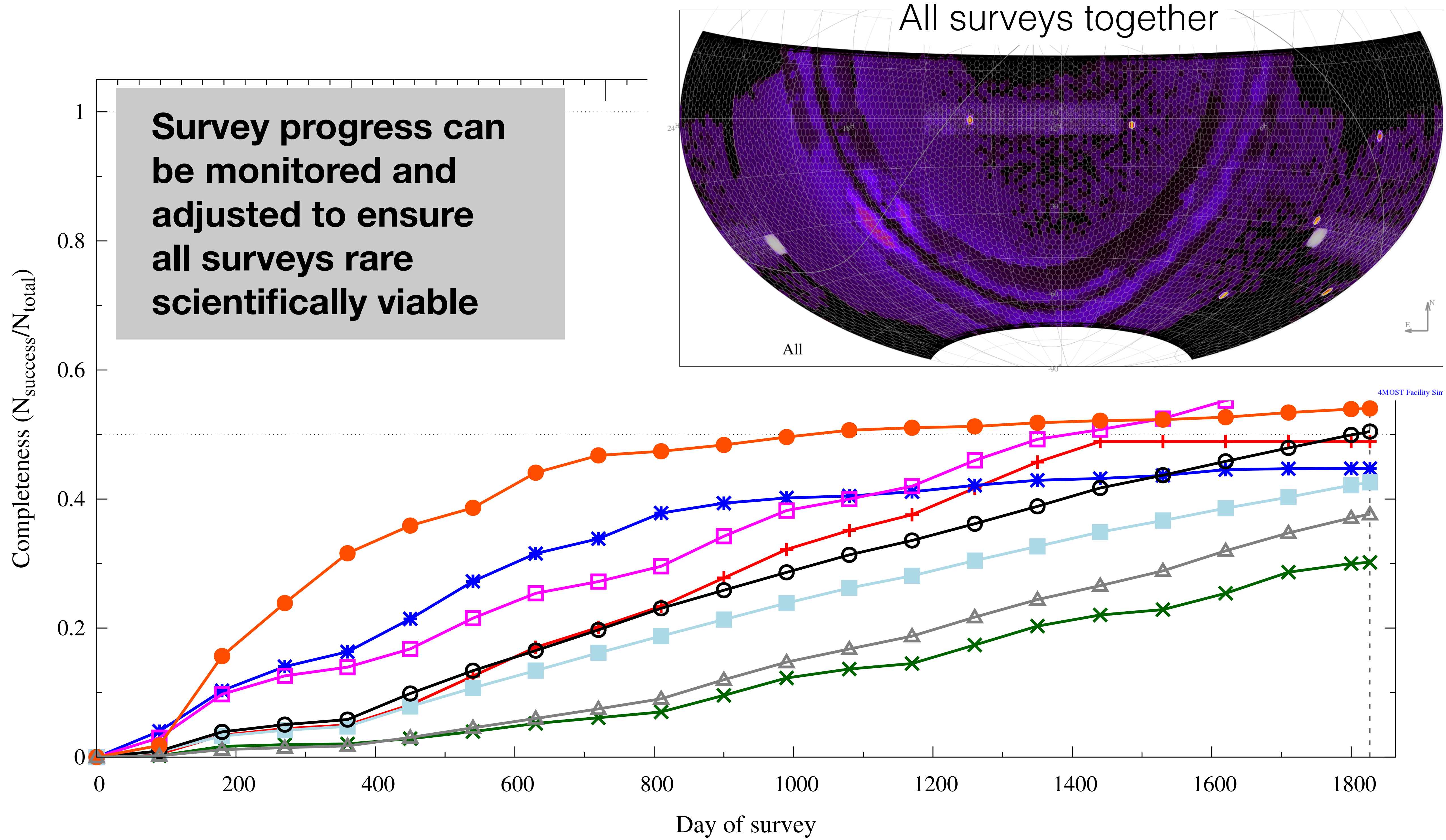
- Simulate throughput (from top of atmosphere to the detector), fibre assignment, survey strategy and verify total survey quality



Science case	S/N / Å	r_{AB}-mags	Targets (Millions)
S1 Milky Way Halo LR Survey	10	16–20.0	1.4
S2 Milky Way Halo HR Survey	140	12–15.5	0.6
S3 Milky Way Disk and Bulge LR	10–30	14–18.5	10.7
S4 Milky Way Disk and Bulge HR	140	14–15.5	2.0
S5 Galaxy Clusters Survey	4	18–22.0	0.8
S6 AGN Survey	4	18–22.0	0.5
S7 Galaxy Evolution Survey	4	18–22.5	1.4
S8 Cosmology Redshift Survey	4	20–22.5	10.4
S9 Magellanic Clouds	10–30	16-20.0	0.3
S10 Transients Survey (TiDES)	4	18–22.5	0.3
Total			**>27**

Simulations 3: Completion over five years

Survey progress can be monitored and adjusted to ensure all surveys rare scientifically viable



- If 0.5 means viable survey clearly some failed in this example

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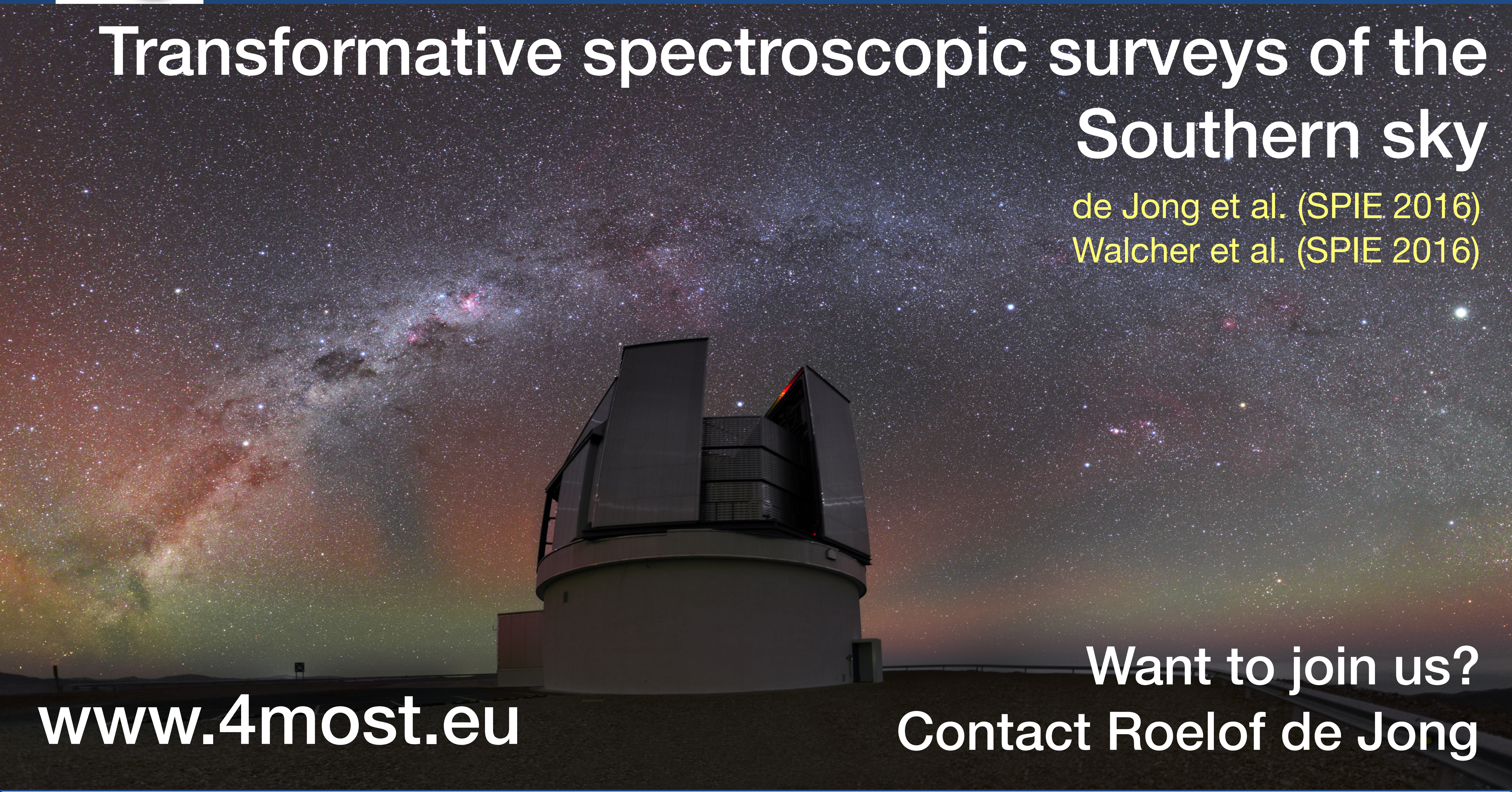
4MOST – 4m Multi-Object Spectroscopic Telescope



Transformative spectroscopic surveys of the Southern sky

de Jong et al. (SPIE 2016)
Walcher et al. (SPIE 2016)

Want to join us?
Contact Roelof de Jong

www.4most.eu

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