



SPHERE

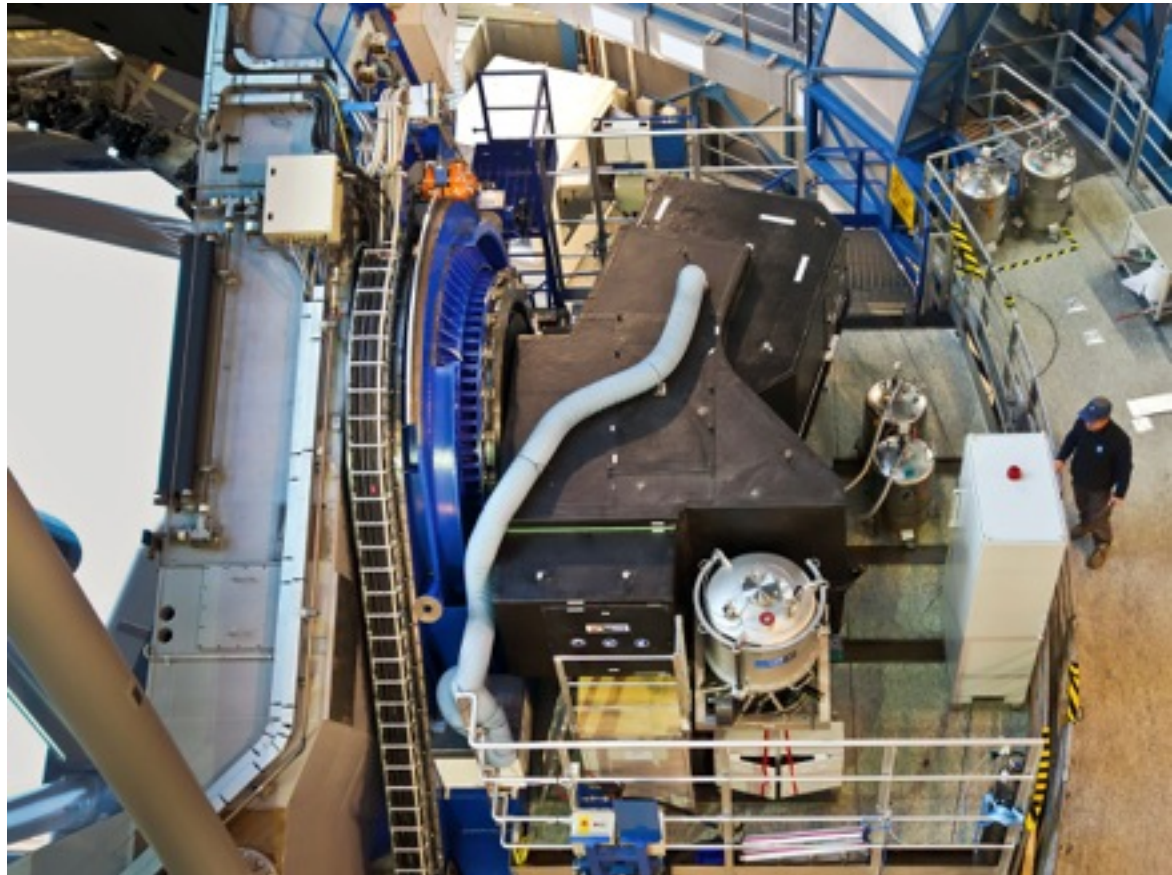
Spectro-Polarimetric High-contrast Exoplanet REsearch



ParanalScienceOperations

Julien H. Girard

SPHERE Instrument Scientist



Presentation of SPHERE

Its many modes, fantastic capabilities

Calibration Plan

Various types of calibrations, various goals => **choices**

Status & problems (often) encountered

Almost 2 years of regular operations, improved smoothness

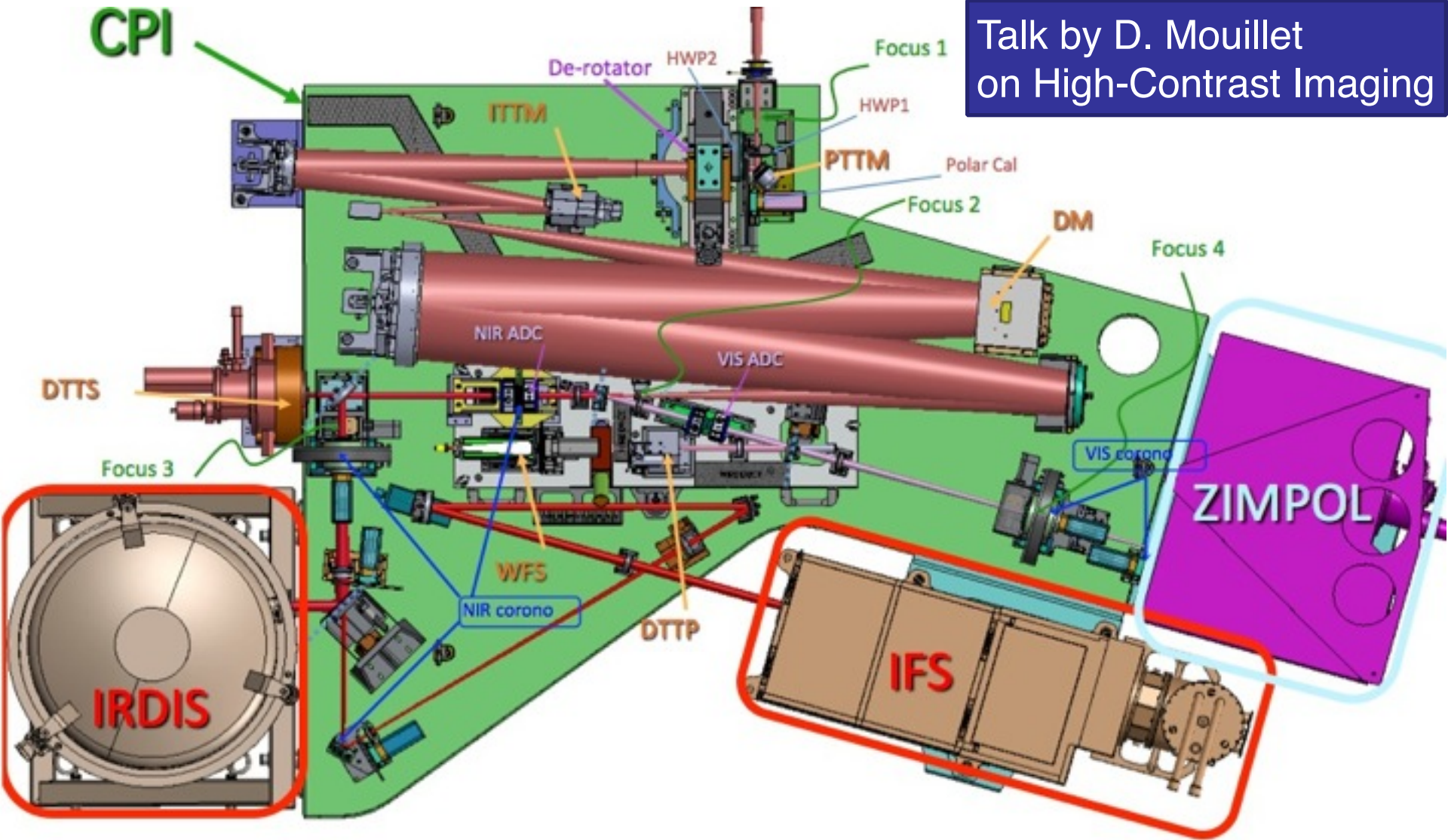
Focus on IRDIS DPI: push the limits

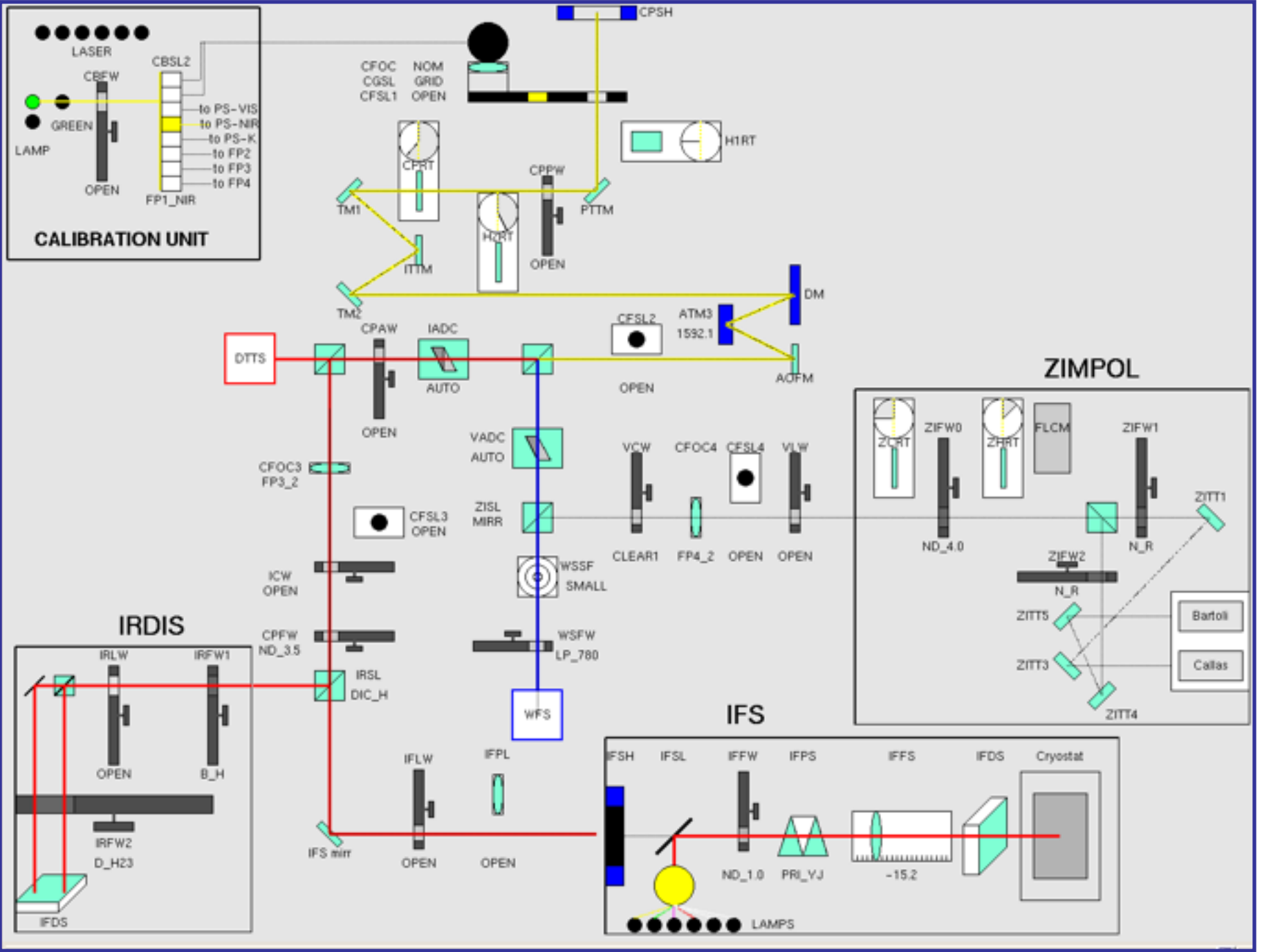
Accurate high-contrast imaging polarimetry

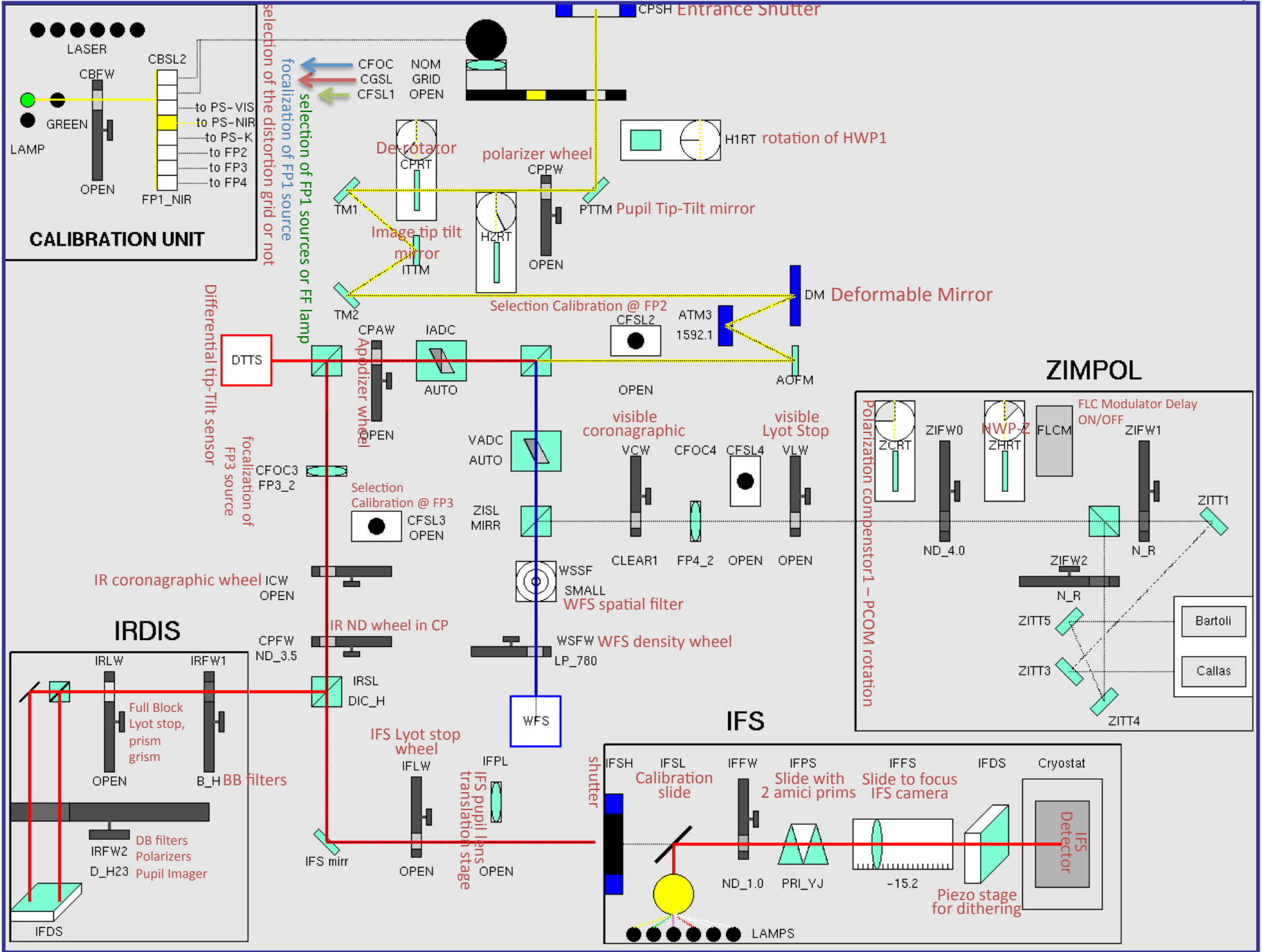
Towards characterising exo-planetary atmospheres through polarimetric direct imaging

PRESENTATION OF SPHERE

Talk by D. Mouillet
on High-Contrast Imaging





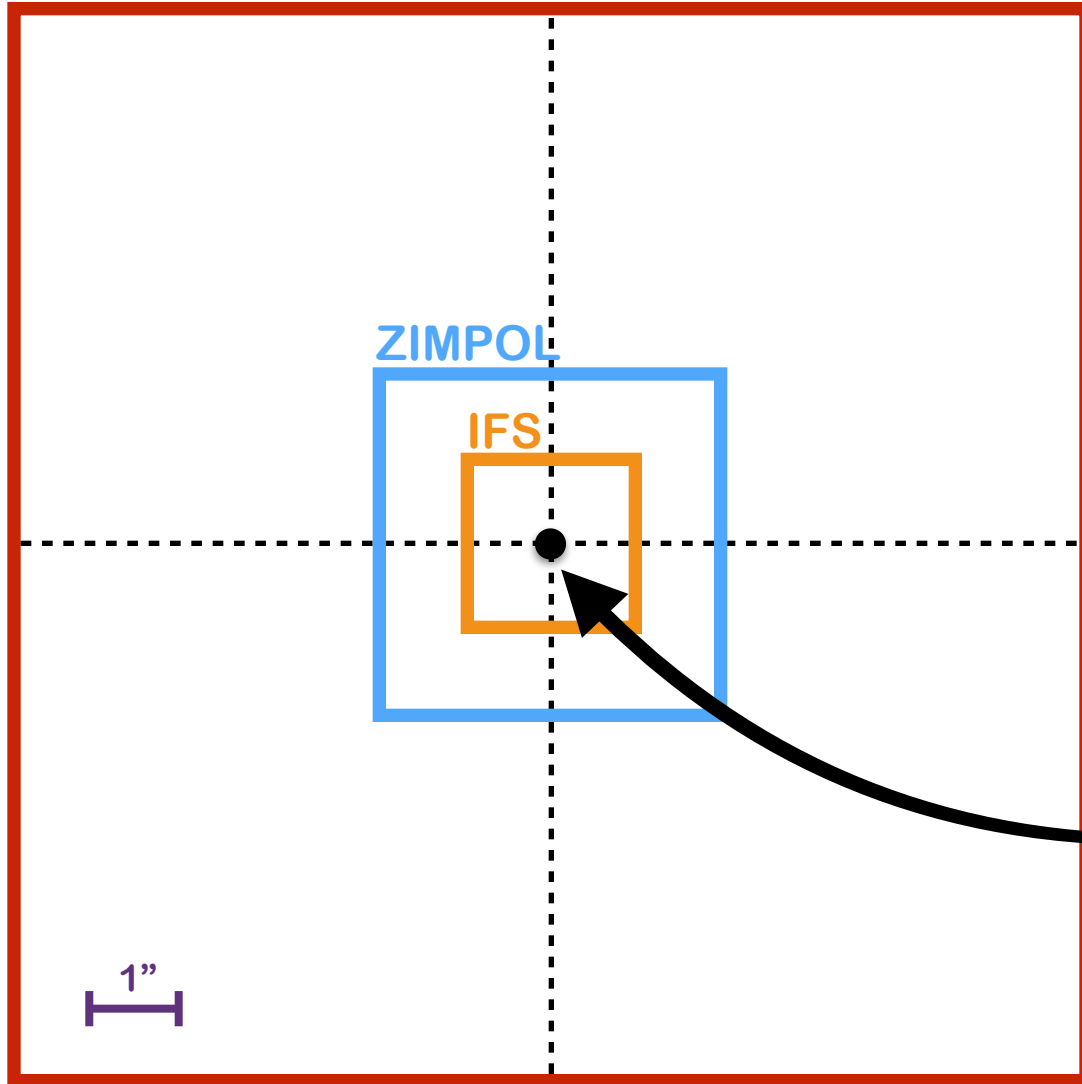


MODES OF SPHERE

	IRDIS	(IRD)IFS	ZIMPOL
Modes	(C) I DBI DPI LSS SAM (P100)	IFS (EXT) SAM (P100)	(C) I DPI SAM (P100)
Spectral range/ Resolution	0.95-2.32 μm	0.95-1.65 μm	500-900 nm
Field of View	11"x11"	1.7"x1.7"	3.5"x3.5" Mosaicing not yet offered
Rotator options	Pupil-stabilized (default) Field stabilized		Static (P1) Field-Stabilized (P2)

FIELD(S) OF VIEW OF SPHERE

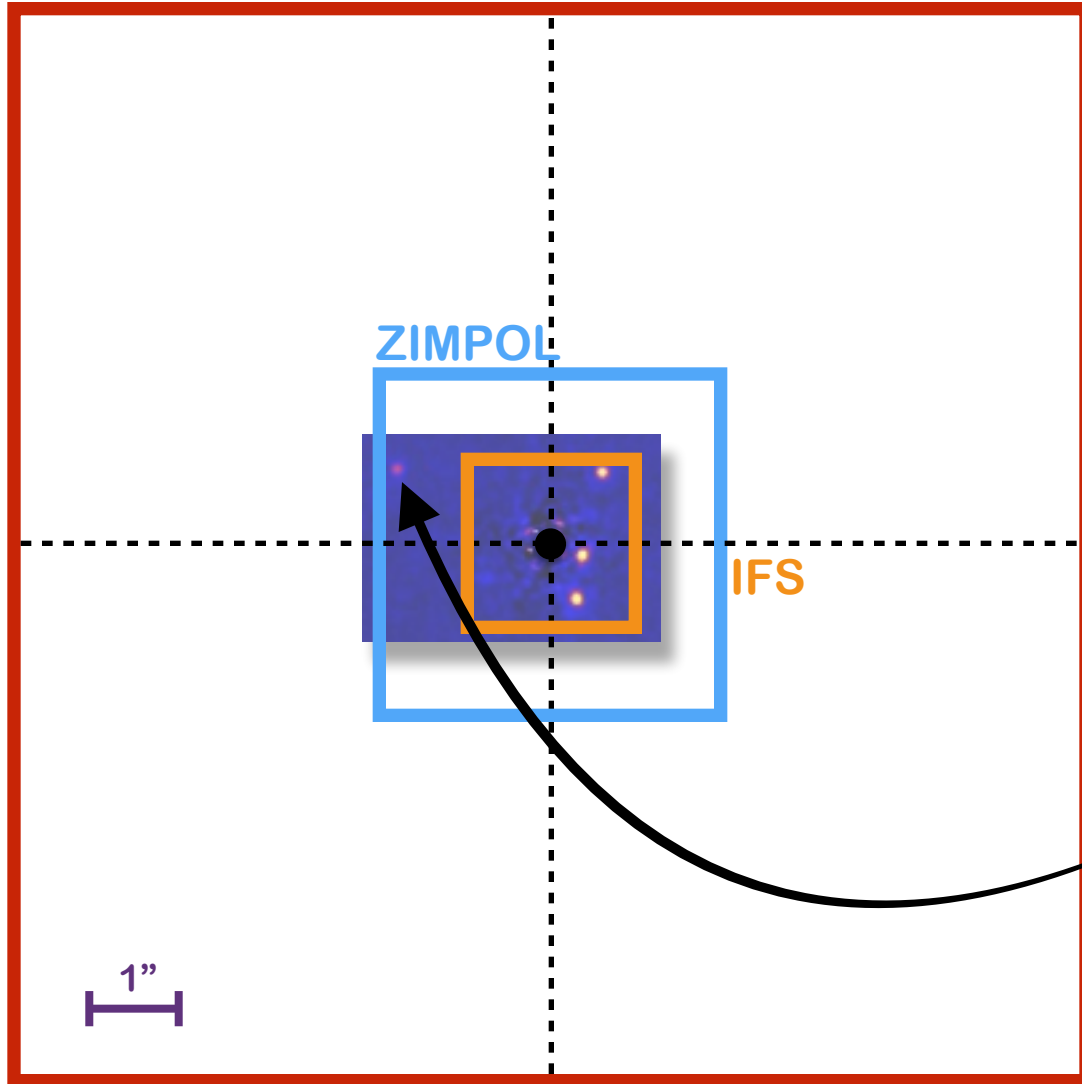
IRDIS



NGS
&
Coronagraph
always
on-axis

FIELD(S) OF VIEW OF SPHERE

IRDIS



HR8799 b
falls out
of IFS FoV

SPHERE'S CALIBRATION PLAN

Types of Calibrations

Static (long-term monitoring, maintenance / health check)

Dynamic (calibrate science data, QC0, Cal4Cal, can also feed HC)

Internal (usually daytime)

Flats, Darks, Backgrounds, etc.

On-sky (usually nighttime)

Examples: Photometric Standard Stars, Astrometric fields, etc.

AO / Common Path Calibrations (IQ, Coronagraph centering)

Special Calibrations (e.g. User Provided, specific to a project)

Various Goals

Provide calibrations to users, including archive users

Generate “Science Grade” Data Products

Maintain/improve immediate and long-term performances

Push specific performances, explore/characterise new mode/capability

Choices!

So many modes and combinations

A vibrant, competitive community

Discussions!!!

DATA CHAIN & QC0

Science Case/Idea **USER**

Simulate performances

Design OBServations

Set of constraints
versus knowledge/measurement
of the atmospheric conditions

QC grade can depends on
Instrument Health
behaviour versus (many parameters)

ETC/Manual

Choose appropriately

Perform / Classify (QC0)

Deliver Observations

ESO/SciOps

Analyse & Publish
or perish...

Archive

CALIBRATION PLAN: COMPLETENESS

CAL SPHERE calChecker: calibration completeness monitor

Last update: 2017-01-16T08:50:34 (UT) [?] [Old 00h:18m ago] [?] [?] Paranal date*: 2017-01-15 [?] server: www.eso.org HQ HELP ASSOC-RULES DETAILS

Last header: SPHER. 2017-01-14T08:45:23.413.hdr [transfer] [ngas] [?] *Date on this monitor changes at 21:00 UT. Refresh frequency: 102hr day and night

General news: Long-term calibrations and maintenance [complete overview](#) / [how to execute](#) [?]
 SPHERE news: all long-term calibrations within validity range

HC refresh analyze ISSUES mark BAD QUALITY HELP DATA ASSOC-RULES history... contact monitors: DataTransferMonitor | BandWidth

science calcal [?] Product availability depends on the data transfer to Garching and the archive access there (check the "transfer" and "ngas" flags above!)

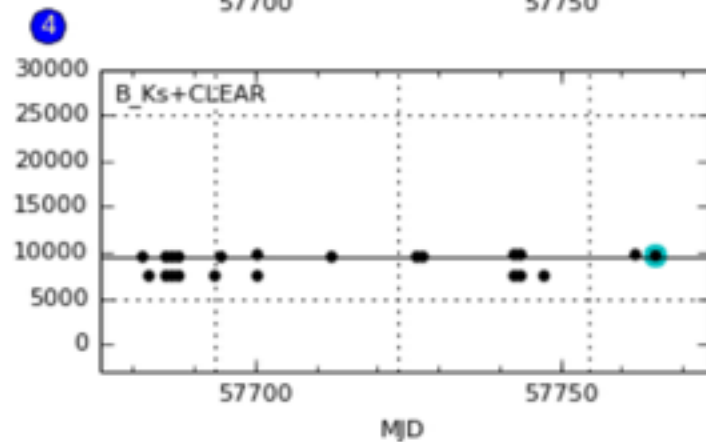
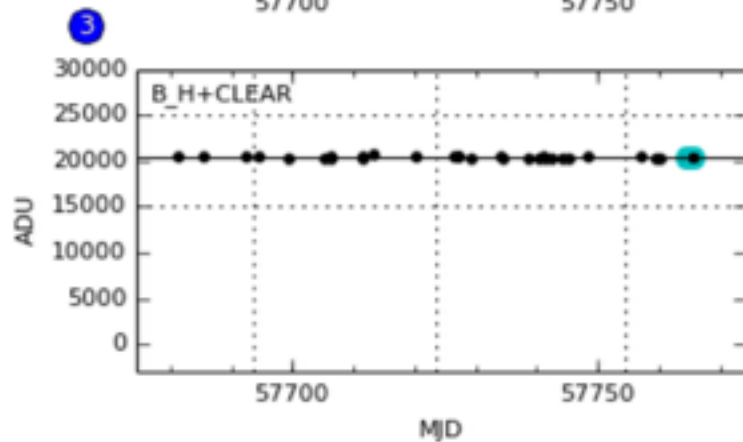
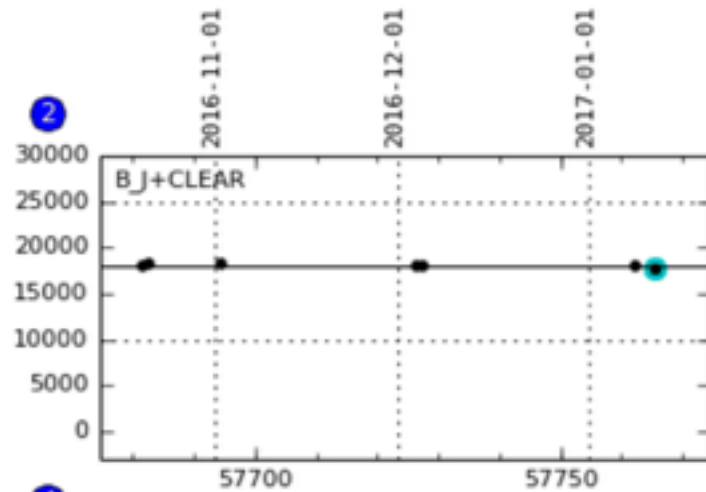
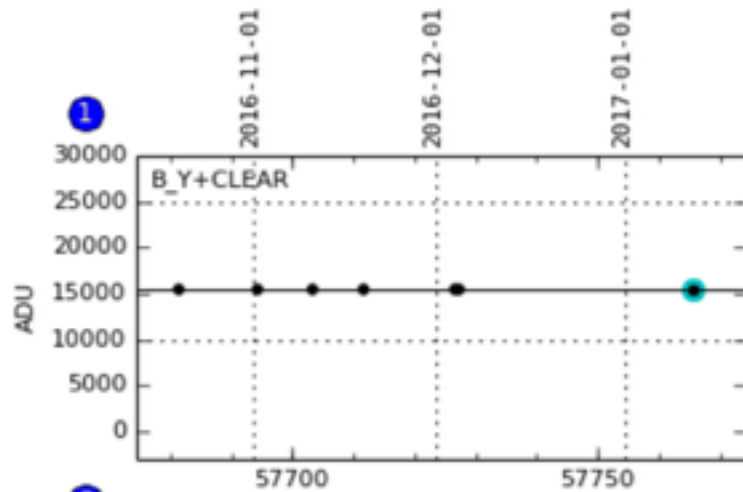
DATE*	2017-01-09	2017-01-10	2017-01-11	2017-01-12	2017-01-13	2017-01-14	2017-01-15	LOST?	Calibration action?	Setup:
<small>(color if science data acquired)</small>	<small>report NLT</small>	<small>report NLT</small>	<small>SM 231 report NLT</small>	<small>SM 80 report NLT</small>	<small>SM 144 report NLT</small>	<small>no data NLT</small>	<small>no data NLT</small>	<small>(may require OB [take these data types ... grade review])</small>	<small>...</small>	<small>... for these setups]</small>
Raw CAL displays: [?]	<small>CRW</small>	<small>CRW</small>	<small>CRW</small>	<small>CRW</small>	<small>CRW</small>	<small>no raw files</small>	<small>no raw files</small>			
Product quality: [?]	<small>✓ products</small>	<small>✓ products</small>	<small>✓ products</small>	<small>products</small>	<small>products</small>	<small>no products</small>	<small>no products</small>			
Data types: Setup:										
IRD_SCI_CL1 OPEN_B_Ks_ST_ALC2_CLEAR_12.0000000			<small>OK</small>				<small>no data (yet)</small>		<small>OK</small>	
IRD_SCI_DB1 ND_1.0_B_H_ST_ALC2_D_H23_4.0000000			<small>OK</small>						<small>OK</small>	
OPEN_B_H_ST_ALC2_D_H23_16.0000000				<small>OK</small>					<small>OK</small>	
OPEN_B_H_ST_ALC2_D_H23_32.0000000					<small>MISS (not yet analyzed)</small>			<small>RD_BACKLIRD_DARK</small>	<small>OPEN_B_H_ST_ALC2_D_H23_32.0000000</small>	
OPEN_B_H_ST_ALC2_D_H23_64.0000000				<small>OK</small>					<small>OK</small>	
IFS_SCI ND_1.0_YJ_16.0000000			<small>OK</small>						<small>OK</small>	
OPEN_YJ_16.0000000				<small>OK</small>					<small>OK</small>	
OPEN_YJ_32.0000000					<small>NOK (not yet analyzed)</small>			<small>ISLBACKLIES_DARK</small>	<small>OPEN_YJ_32.0000000</small>	
OPEN_YJ_64.0000000				<small>OK</small>					<small>OK</small>	
ZPL_SCI_IMG OPEN_CntHa_N_Ha_Standima			<small>OK</small>						<small>OK</small>	
OPEN_N_R_N_R_Standima				<small>OK</small>					<small>OK</small>	
ZPL_SCI_P2 ND_1.0_Cnt820_Cnt748_FastPol					<small>OK</small>				<small>OK</small>	
OPEN_B_Ha_CntHa_FastPol			<small>OK</small>						<small>OK</small>	
OPEN_Cnt820_Cnt748_FastPol					<small>OK</small>				<small>OK</small>	
OPEN_CntHa_B_Ha_FastPol					<small>OK</small>				<small>OK</small>	
OPEN_CntHa_CntHa_FastPol					<small>OK</small>				<small>OK</small>	
OPEN_V_N_R_FastPol		<small>OK</small>							<small>OK</small>	
OPEN_V_V_FastPol					<small>OK</small>				<small>OK</small>	

www.eso.org/observing/dfo/quality/SPHERE/reports/CAL/calChecker_SPHERE.html

MONITORING: HEALTH CHECK

SPHERE: IRDIS_CI counts in brightest flat (last 90 days)
QC data range: 2016-10-18 ... 2017-01-11*

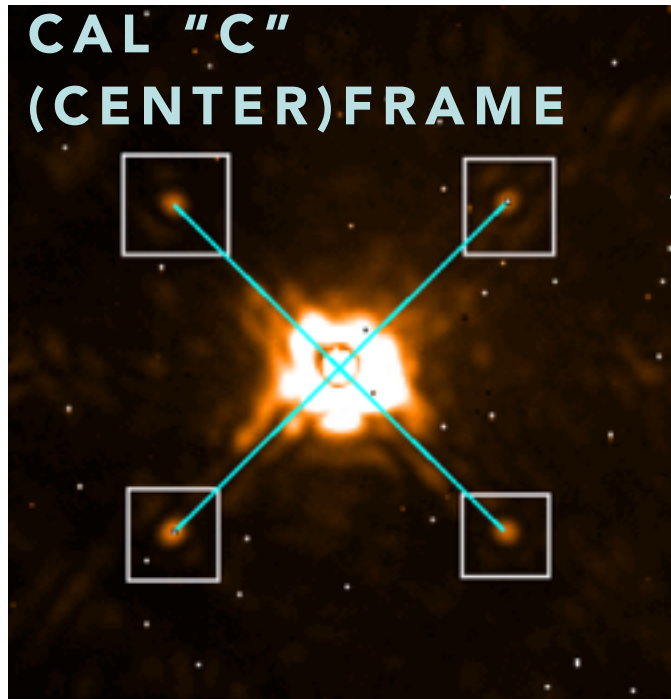
Talk by W. Hummel (Xshooter)



powered by QC: www.eso.org/HC

created by trendPlotter v3.6.2 on 2017-01-15T22:36:18

GENERATING SCIENCE DATA PRODUCTS (SDP)



+ **EVENTUAL
CAL
"S" (SKY)
FRAME**



**SPECIFIC TO SPHERE
(PIPELINE)**

www.eso.org/sci/software/pipelines/

SPHERE OPERATIONS STATUS

History

Commissioning June 2014 - December 2014 (4 runs)

Science Verification (calibrate science data, QC0, Cal4Cal, can also feed HC)

GTO (marginally started during commissioning, fully started in February 2015)

General Operations, including Service mode: P95 - April 2015 (nearly 2 years!)

Productivity

57 accepted/published Refereed Papers!

1 new planet detected (Wagner et. al 2016), many new disks in scattered lights, “other science”

Operations “smoothness”

SPHERE is mostly operated by 1 astronomer and/or one Telescope/Instrument Operator (TIO), “SciOps 2.0” is effective thanks to a simple QC0 scheme and

Still, many things remain to be improved

Better astrometric calibrations, information (WCS in headers)

QC0 based on contrast, aligned with Exposure Time Calculators (ETCs)

Performance analysis, correlations with atmospheric parameters, RTC data, predictions

Non-Common Path Aberrations NCPA mitigation: improve contrast

Low Wind Effect mitigation

Etc.

Discussions!!!

DAYTIME CALIBRATIONS EXAMPLES

Daytime calibrations for IRDIS

Calibration	Modes	Matching parameter(s)	Validity
Background	all	DIT	1 day
Lamp Flat	all	Filter	1 day
Distortion map	all except IRDIS_LSS	Filter, Coronagraph combination	1 week
Wavelength calibration	IRDIS_LSS	Slit/Grism combination	1 day

Daytime calibrations for IFS

Calibration	Modes	Matching parameter(s)	Validity
Dark	all	DIT	1 day
Lamp Flat	all	Prism	1 week
Wavelength calibration	all	Prism	1 week
Spectra registration	all	Prism	1 day
Distortion map	all	Filter (+dichroic), Coronagraph combination	1 week

DAYTIME CALIBRATIONS EXAMPLES

Daytime calibrations for ZIMPOL

Calibration	Modes	Matching parameter(s)	Validity
Bias	all	Readout mode	1 day
Dark	all	DIT, readout mode	on request
Imaging flat	all	Filter (+dichroic), readout mode, focal plane mask on substrate (if used)	1 day
Polarimetric flat	ZIMPOL_P1, ZIMPOL_P2	Filter (+dichroic), readout mode, focal plane mask on substrate (if used)	1 day
Modulation efficiency	ZIMPOL_P1, ZIMPOL_P2	Filter (+dichroic), readout mode	1 day

NOTE: ZIMPOL distortion maps are taken weekly in V, N_R, N_I for monitoring purposes.

COMPLEXITY, TRADE-OFFS, CHOICES

Observing mode	Comments	Service/Visitor mode
IRDIFS	- Pupil-stabilized (default) or Field stabilized - Coronagraph: ALC_YJH_S	S+V
	- 4QPM and other coronagraphs - NGS R > 11 mag	V
IRDIFS_EXT	- Pupil-stabilized (default) or Field stabilized - Coronagraph: ALC_YJH_S	S+V
	- 4QPM and other coronagraphs - NGS R > 11 mag	V
IRDIS_DBI	- Pupil-stabilized (default) or Field stabilized - Coronagraph: ALC_YJH_S, N_ALC_Ks with K-band filters	S+V
	- 4QPM and other coronagraphs - NGS R > 11 mag	V
IRDIS_CI	- Pupil-stabilized (default) or Field stabilized - Coronagraph: ALC_YJH_S, N_ALC_Ks with K-band filters	S+V
	- 4QPM and other coronagraphs - NGS R > 11 mag	V
IRDIS_LSS	Long Slit Spectroscopy in LRS and MRS	(S*)+V
IRDIS_DPI	Differential Polarimetric Imaging	S (BB_J only) + V
ZIMPOL_P1/P2	- Derotator: P1 (static) or P2 (Field-Stabilized) - Filters: combination of NB and BB filters not allowed - WFS/ZIMPOL splitter: GREY or DIC-HA - No coronagraph (allowing some saturation) or V_CLC_M_WF - Some saturation allowed - Detector/modulator: FastPol, SlowPol - Field-Position: on-axis	S+V
	- Other coronagraphs - NGS R > 11 mag - NB and BB filter combination	V
ZIMPOL_I	Same as P1/P2 but with readout mode StdImaging.	S+V
	- Other coronagraphs - NGS R > 11 mag - NB and BB filter combination	V

Many
modes
OK

Many
Combinations

Coronagraphs
Including Lyot stops
Filters

Difficult
Long Calibrations

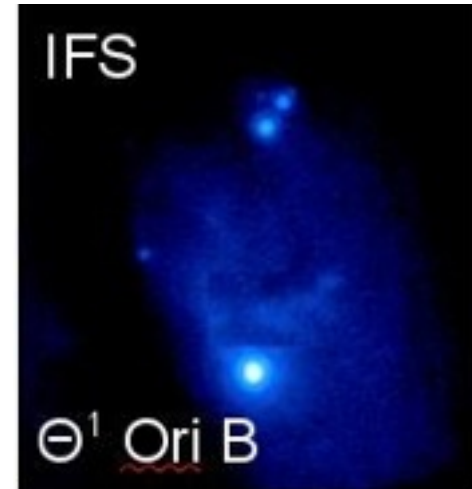
PROBLEMS ENCOUNTERED (EXAMPLES)

Astrometry: derotator positioning accuracy

True North calibration

Installation of a “TIM-board” for better time reference

Distortion grids not used (large separation candidates)



IRDIS Dual-band polarimetry

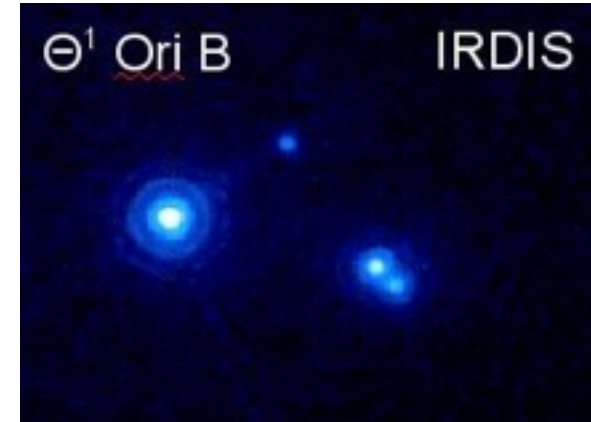
HWP control law

(cross-talks, bad polarisation efficiency)

QC0 with ZIMPOL

Short Wavelengths

Large Strehl (peak flux) variations



Low Wind Effect (LWE)

Affects Good seeing data

Is NOT seen by RTC (AO system)

FUTURE: COMBINATION OF TECHNIQUES/ MODES

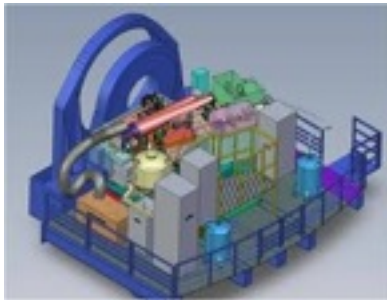
HDS+HC

Combining high-dispersion spectroscopy (HDS) with high contrast imaging (HCI)

RIAUD & SCHNEIDER+ 2007

SOON POSSIBLE @ VLT/UT3

SPHERE



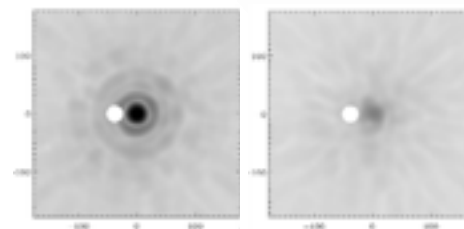
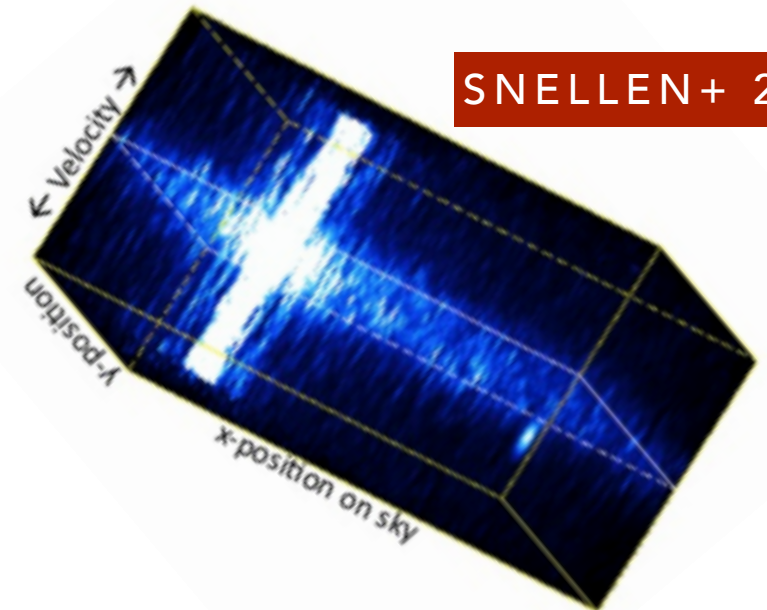
+

CRIRES+



+

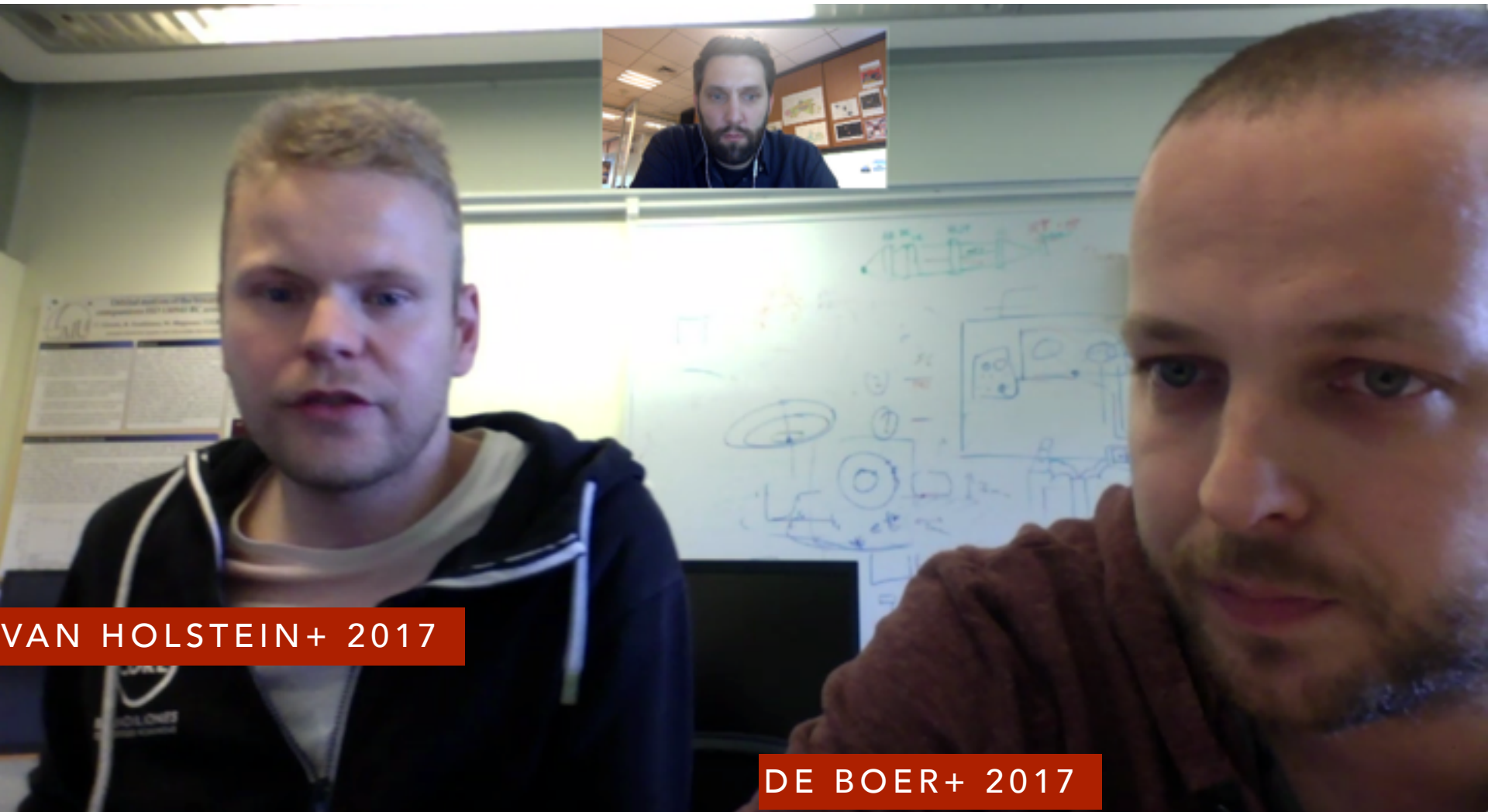
EXPRESSO



LOVIS+ 2016

FOCUS ON IRDIS/**DUAL** BEAM **POLARIMETRIC IMAGING (DPI)**

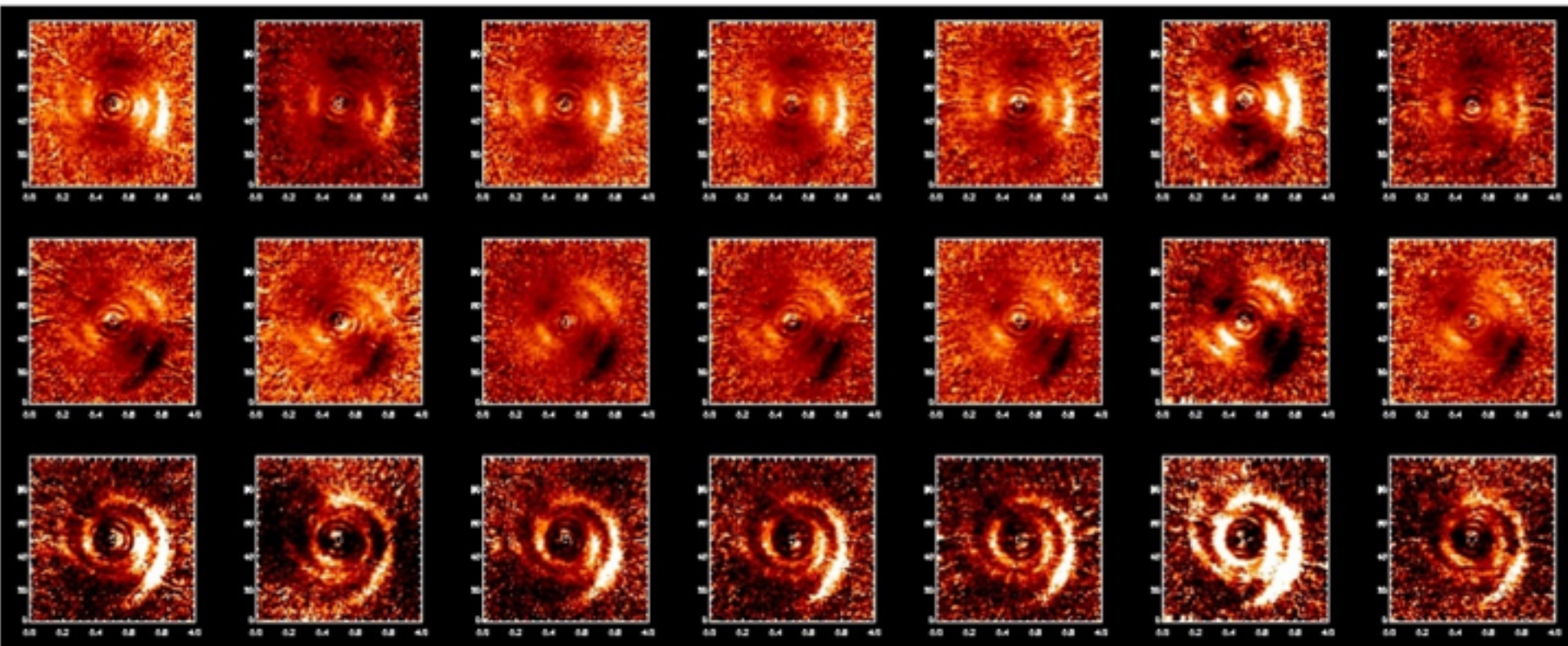
ROB **VAN HOLSTEIN** & JOS **DE BOER**



VAN HOLSTEIN+ 2017

DE BOER+ 2017

CHARACTERIZATION OF THE SPHERE/IRDIS/DPI MODE

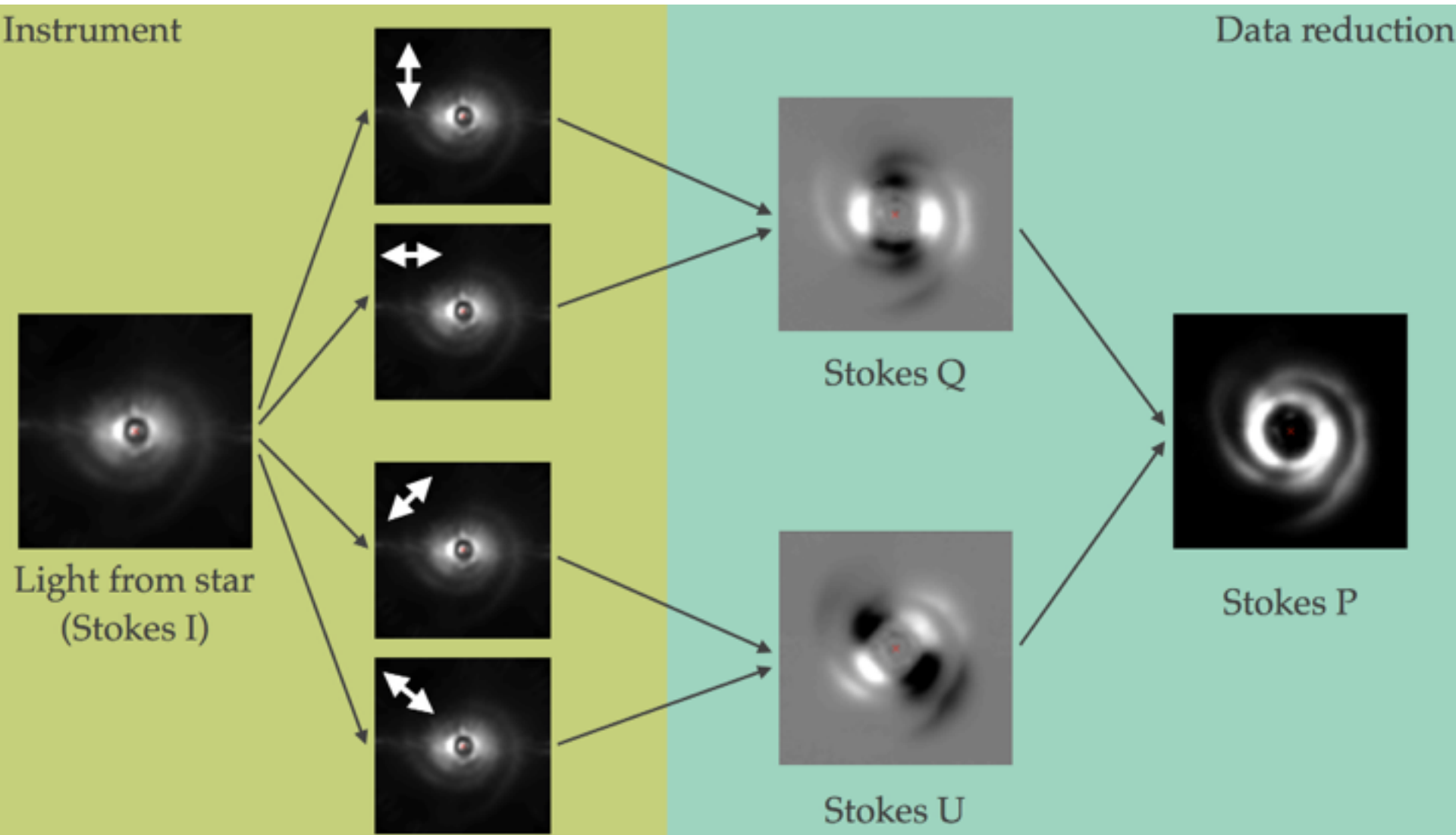


POLARIMETRIC EFFICIENCY / ACCURACY

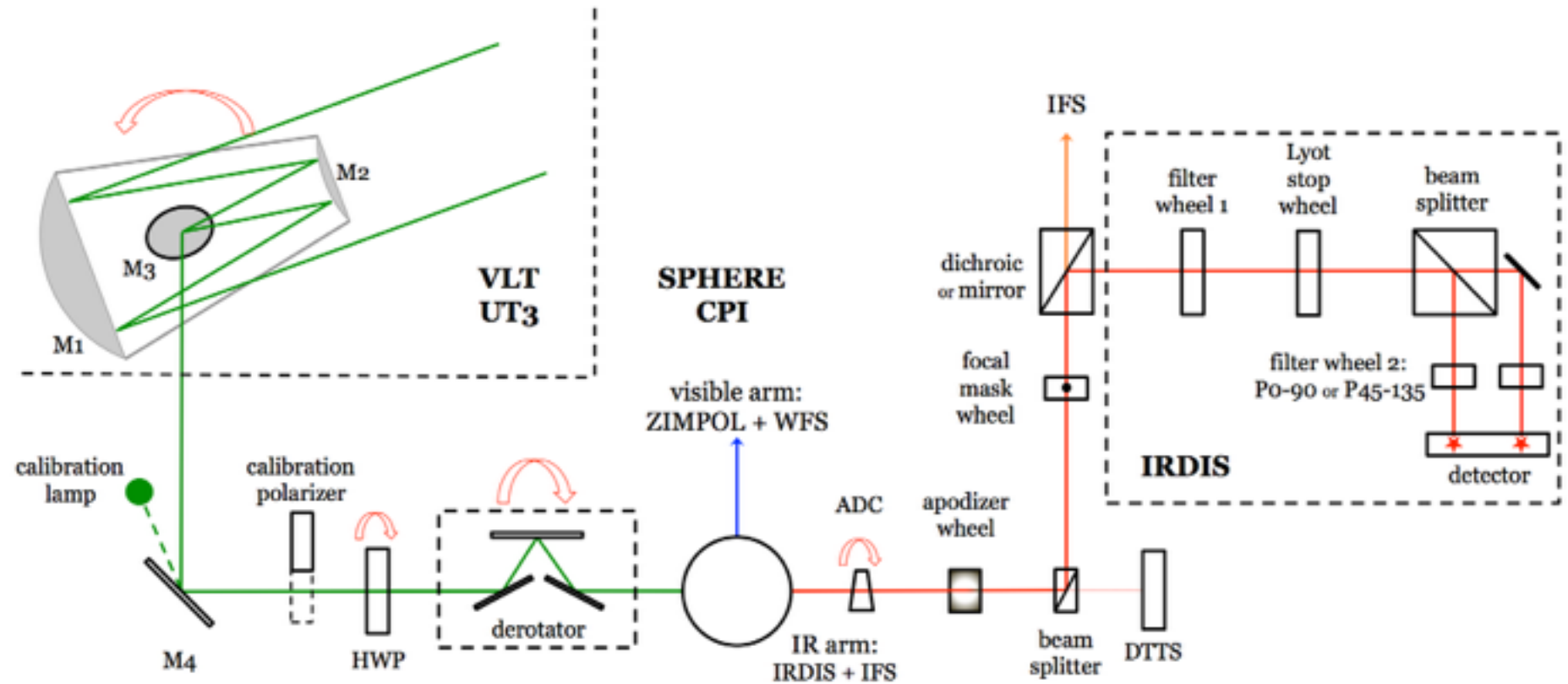
HWP CONTROL LAW

CROSS-TALKS & INSTRUMENTAL POLARIZATION

SPHERE/IRDIS/DPI MODE POLARIMETRIC DIFFERENTIAL IMAGING

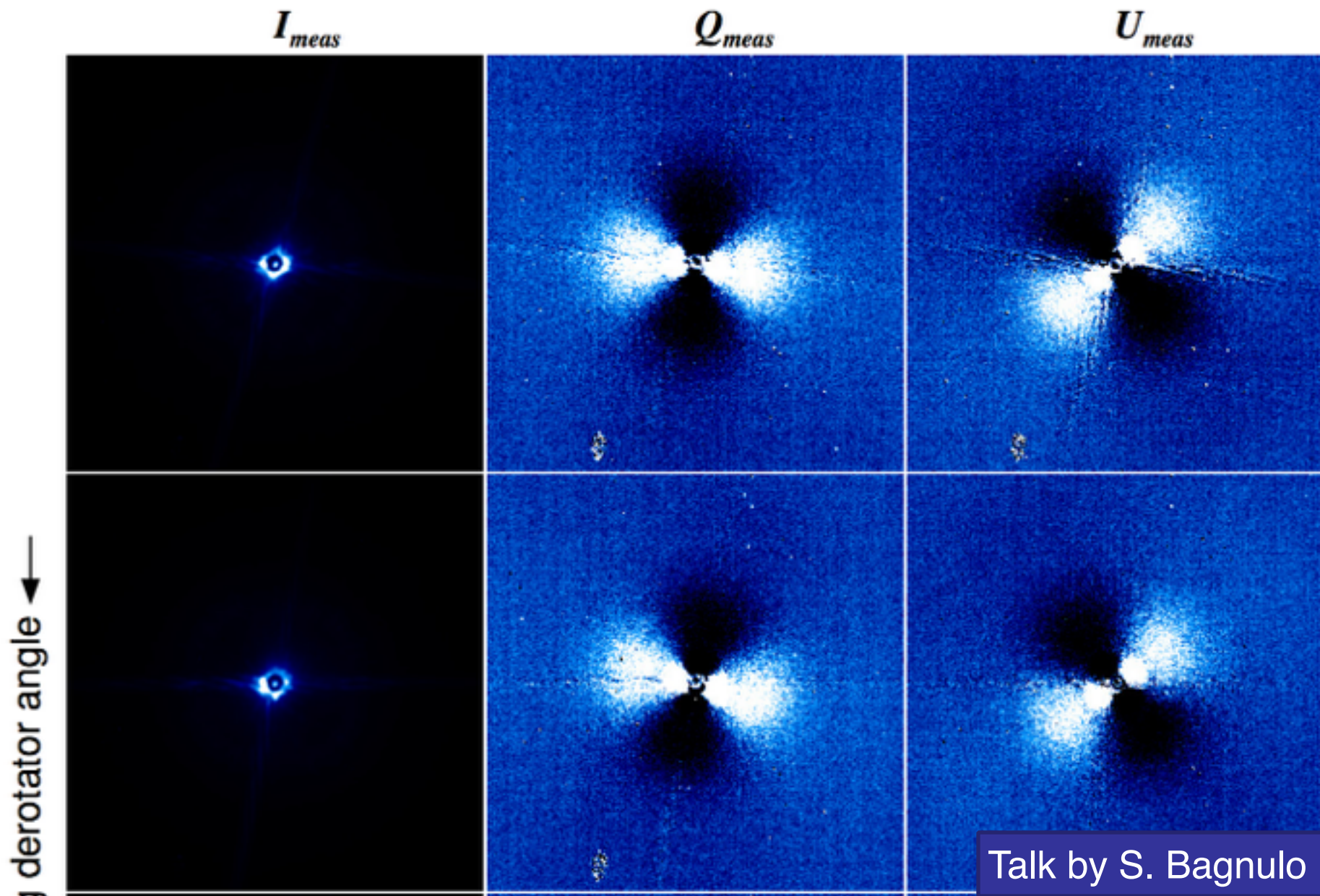


SPHERE/IRDIS DPI MODE

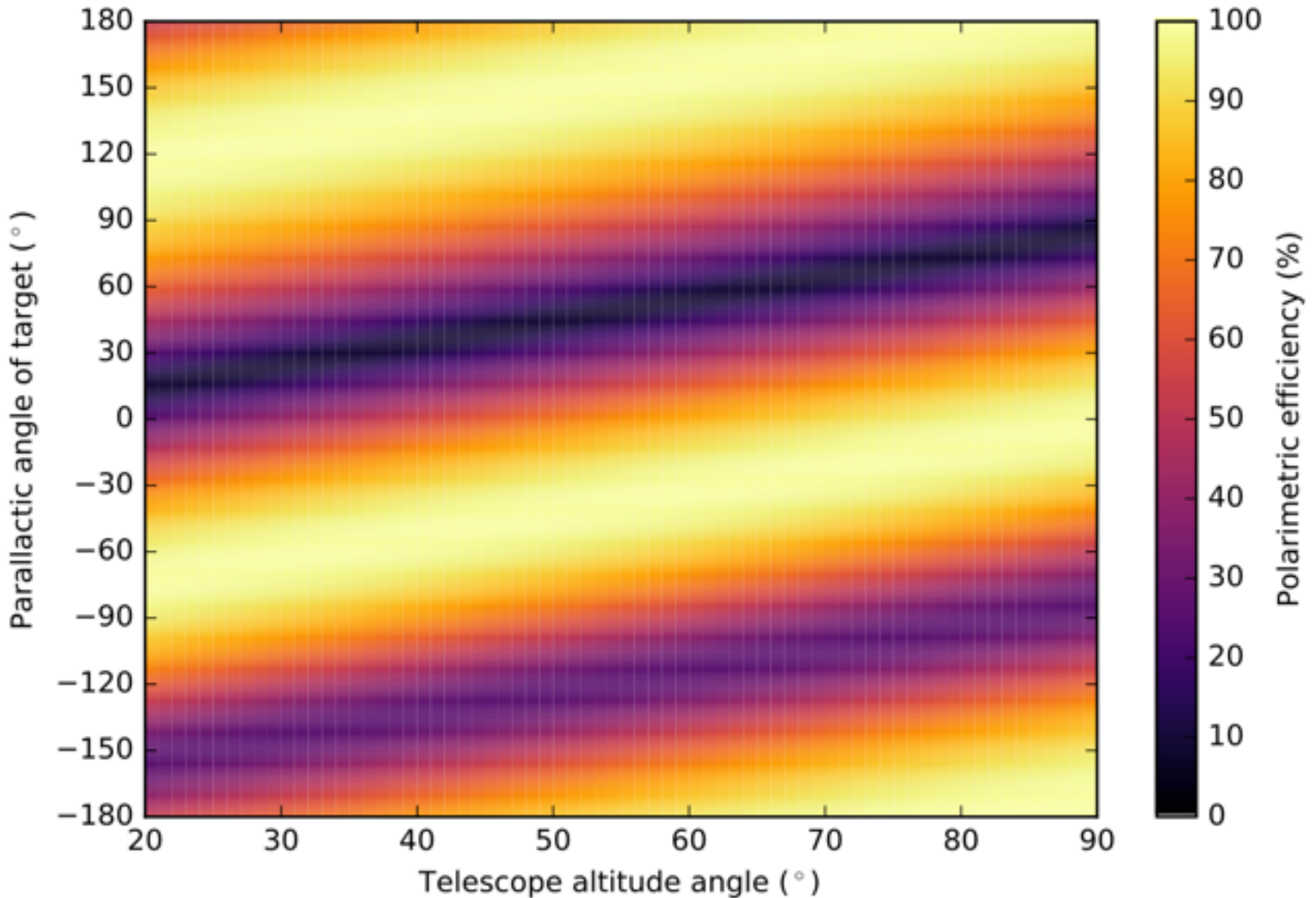


DE BOER+ 2017

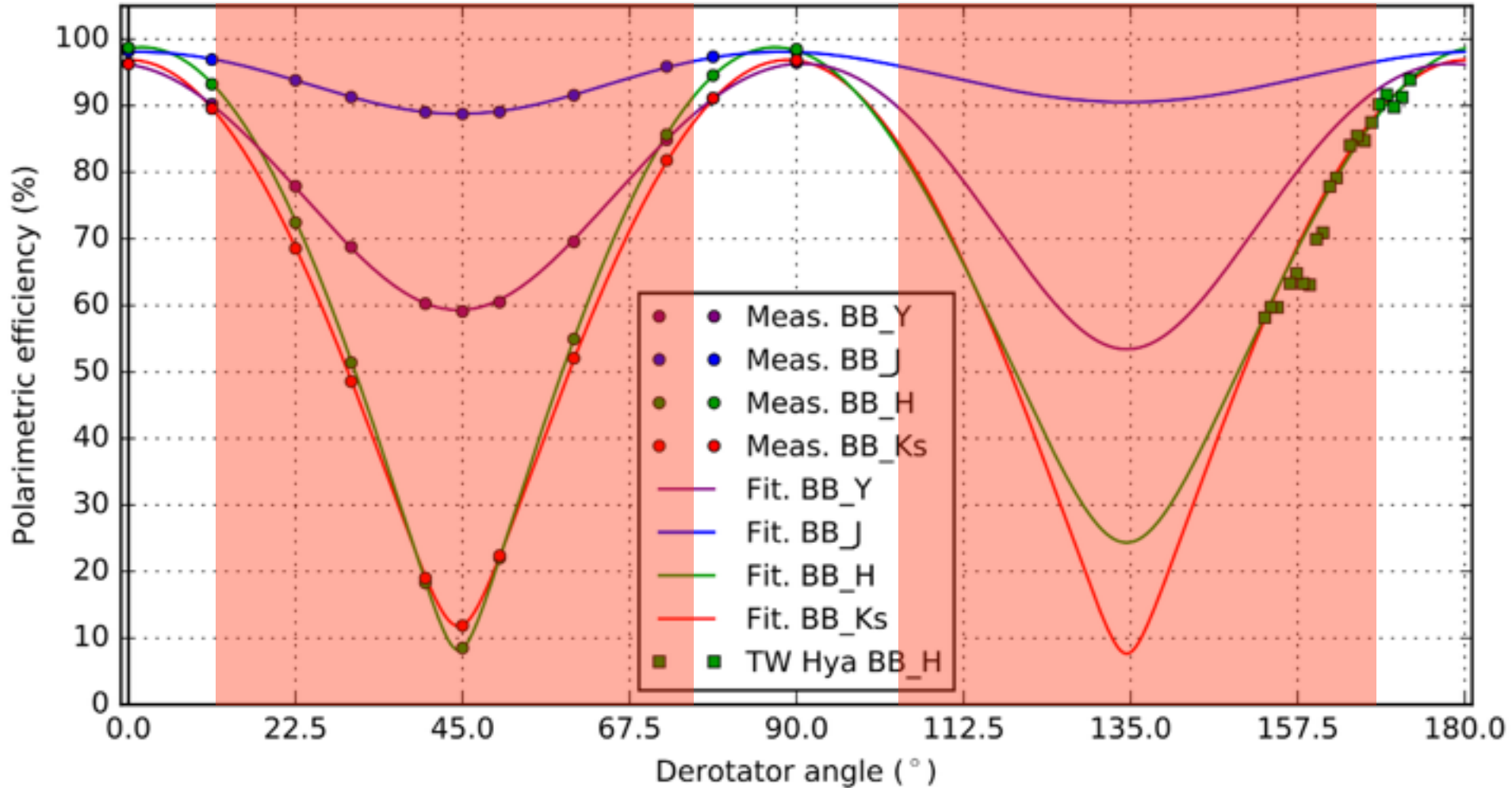
POLARIMETRIC EFFICIENCY (DATA)



POLARIMETRIC EFFICIENCY (2D)



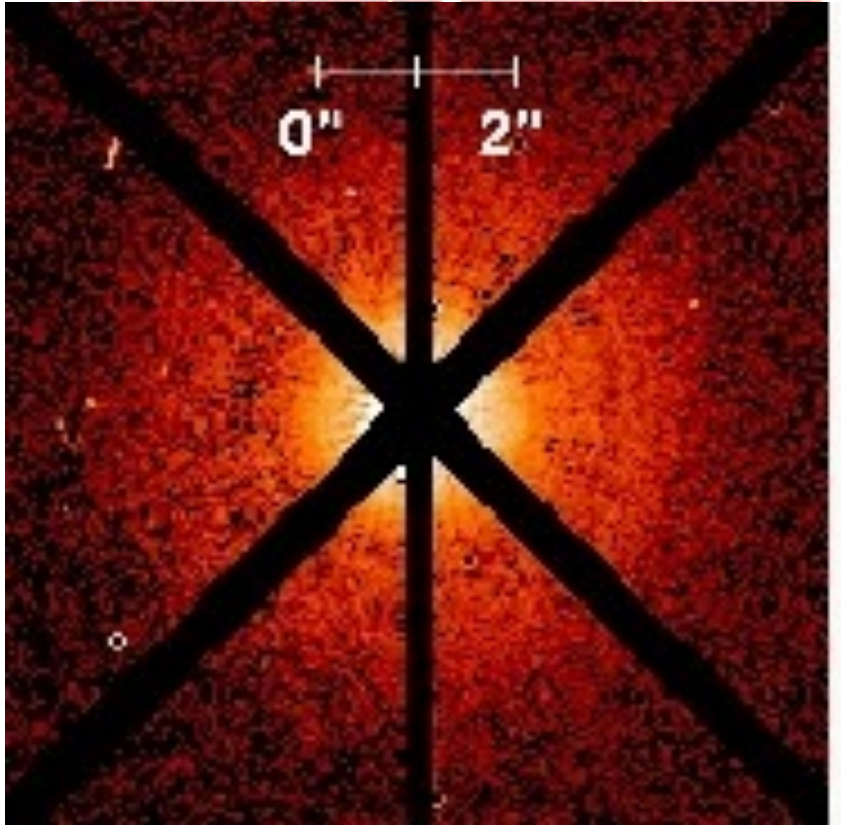
POLARIMETRIC EFFICIENCY (1D)



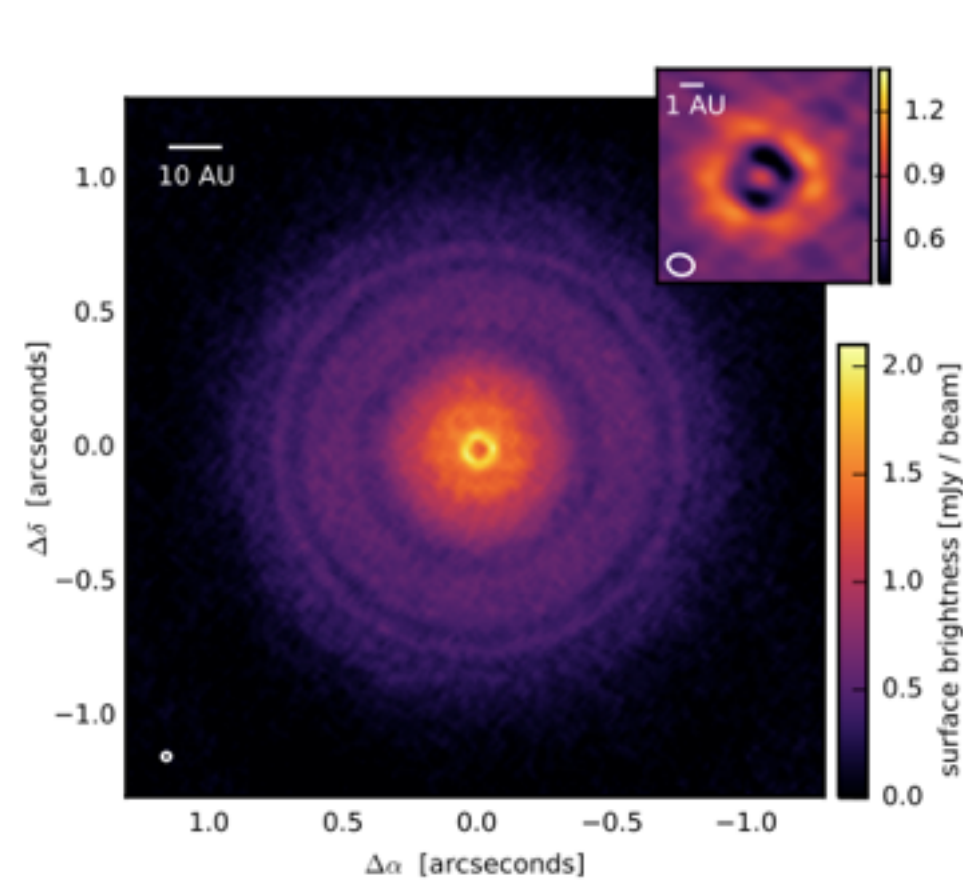
www.eso.org/sci/facilities/paranal/instruments/sphere/doc/IRDIS_DPI.html

TW HYDRA: SCATTERED LIGHT IMAGE & EARLY RESULTS

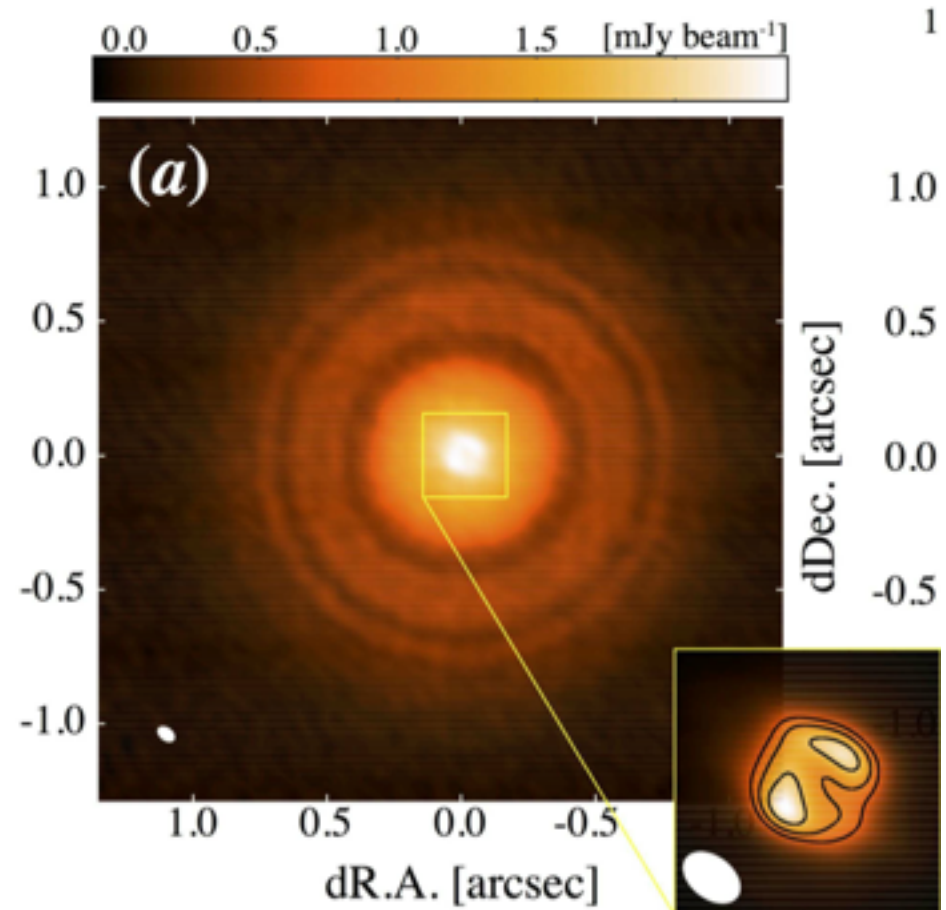
TW Hya in HST/WFPC2
Krist et al. 2000



TW HYDRA: ALMA



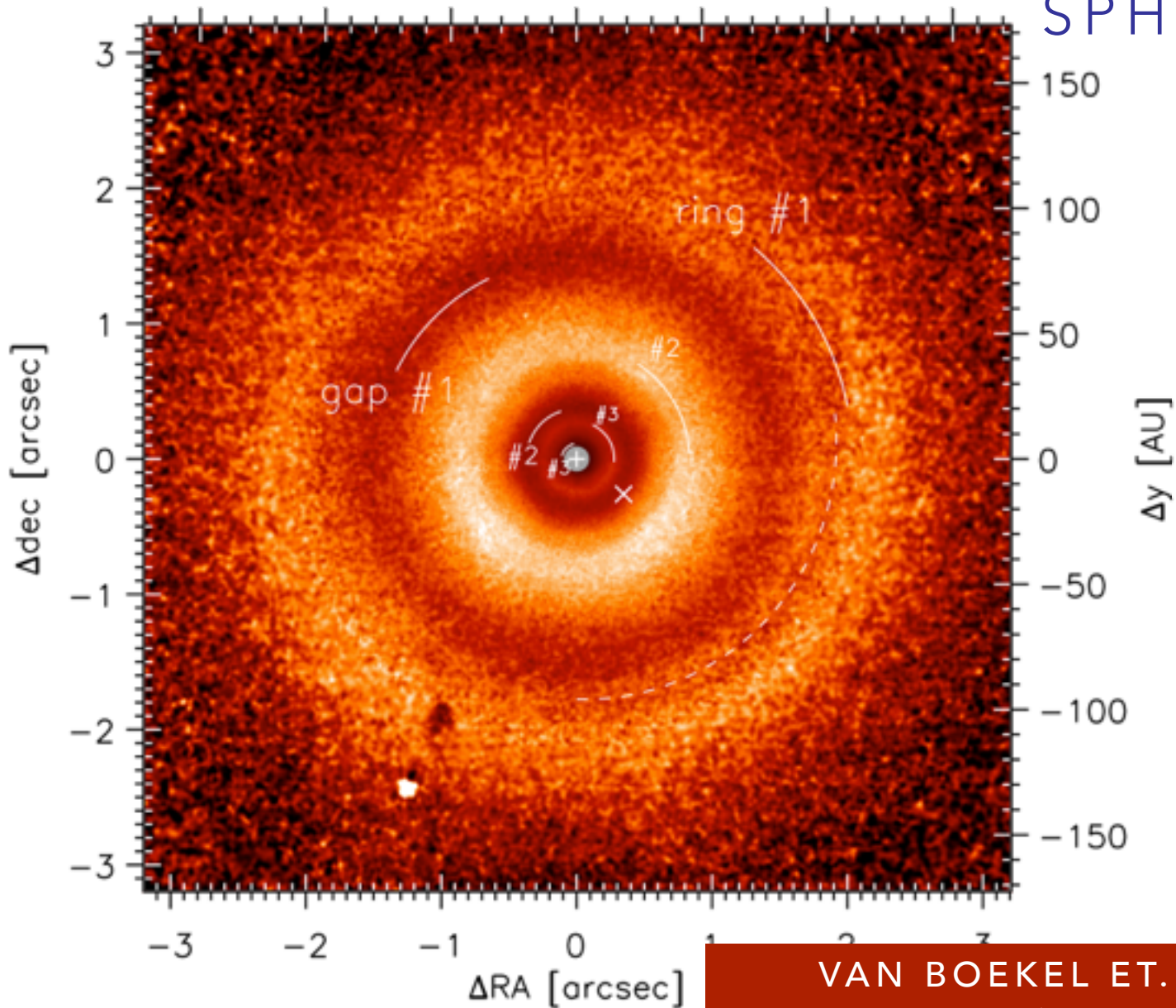
Andrews et al. 2016
Band 7 -- 870microns
beam 24 x 18 mas



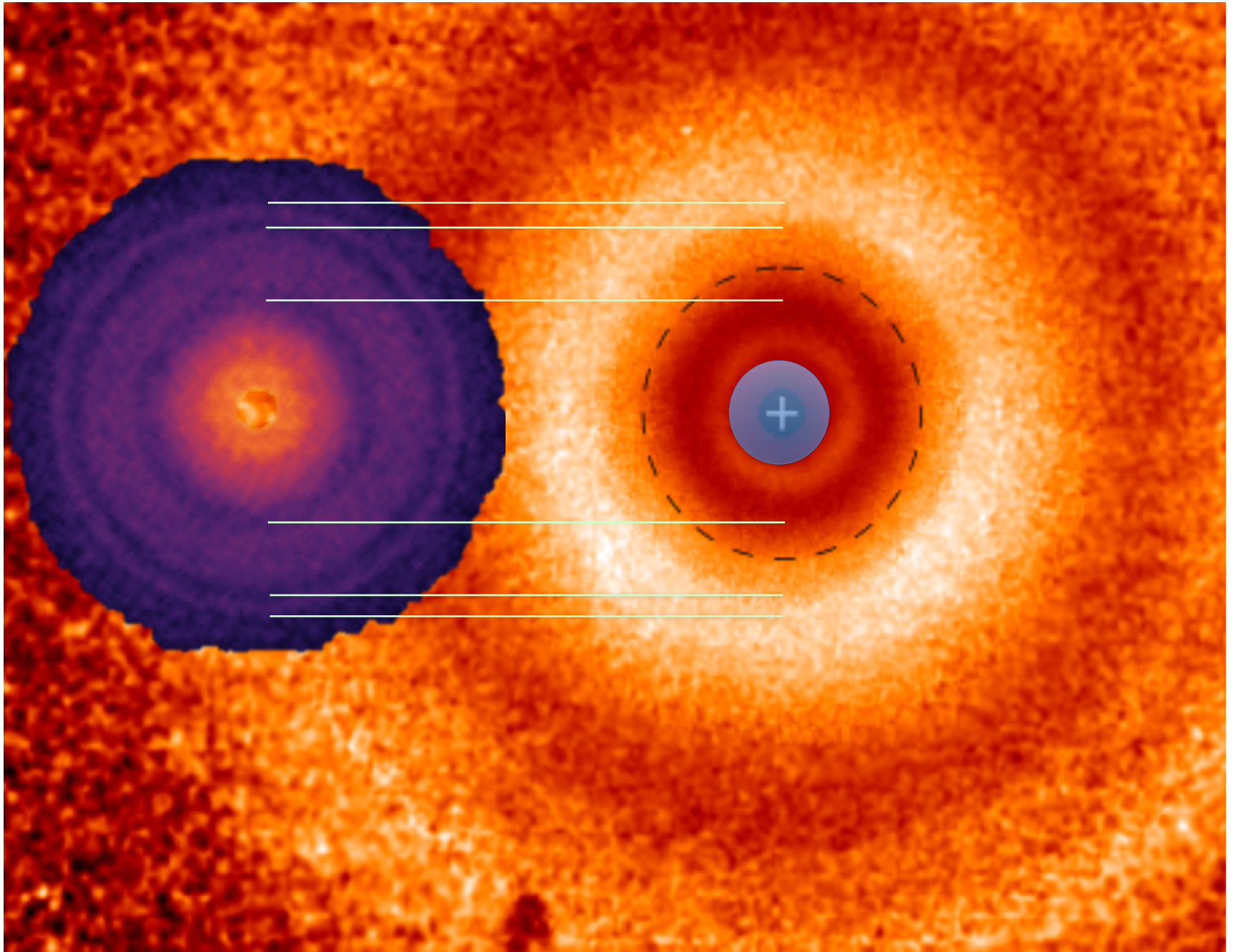
Tsukagoshi et al. 2016
Combined Band 4 + 6
Beam 72 x 47 mas

TW HYDRA: SCATTERED LIGHT WITH SPHERE

H-band, polarised intensity,
Image scaled by R^2 , FWHM 40mas

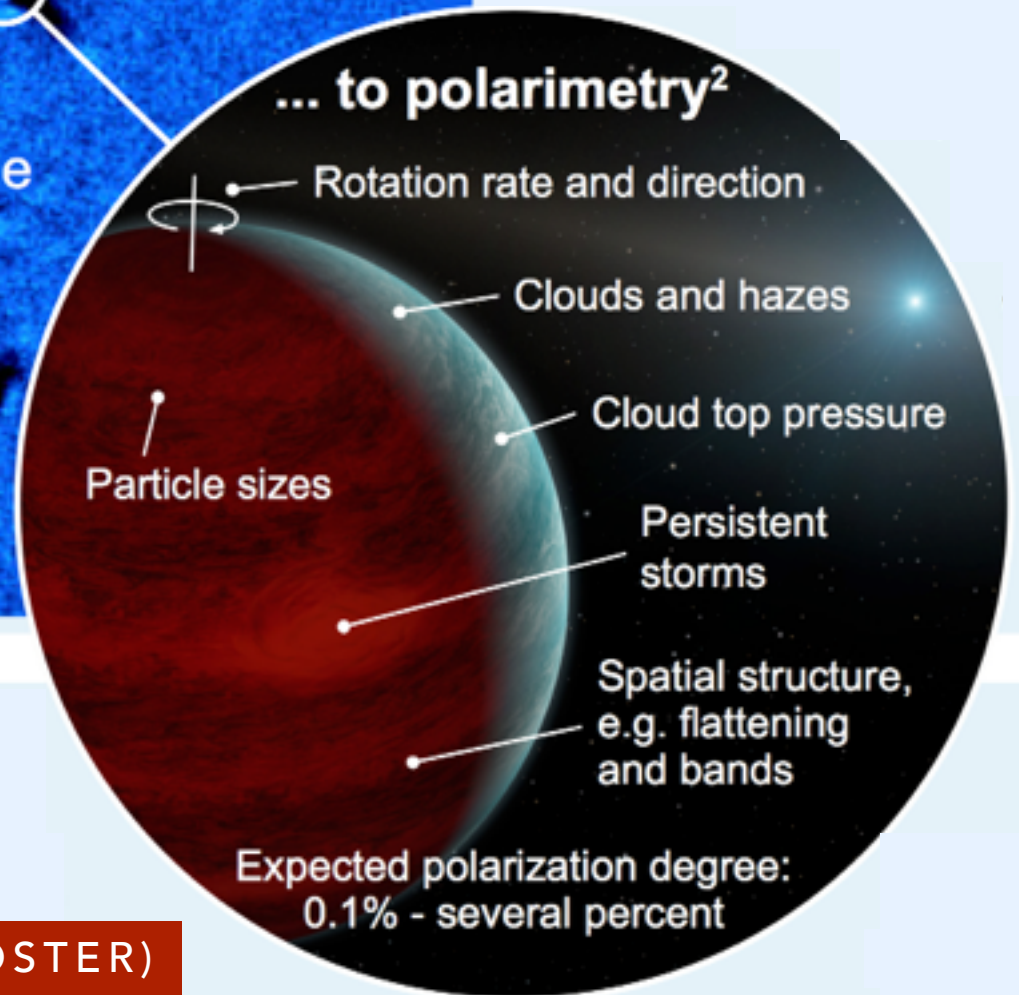
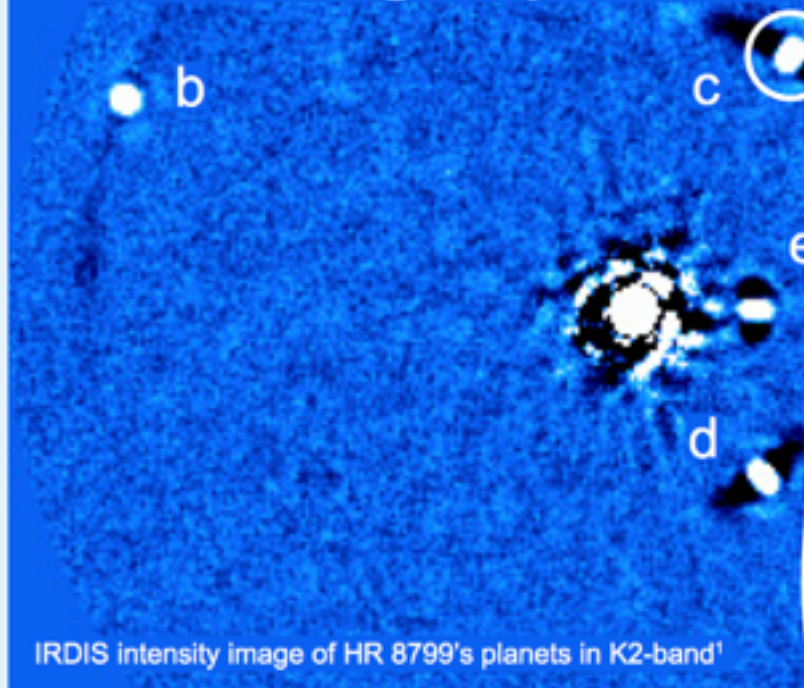


Data obtained as part of the SPHERE GTO programme

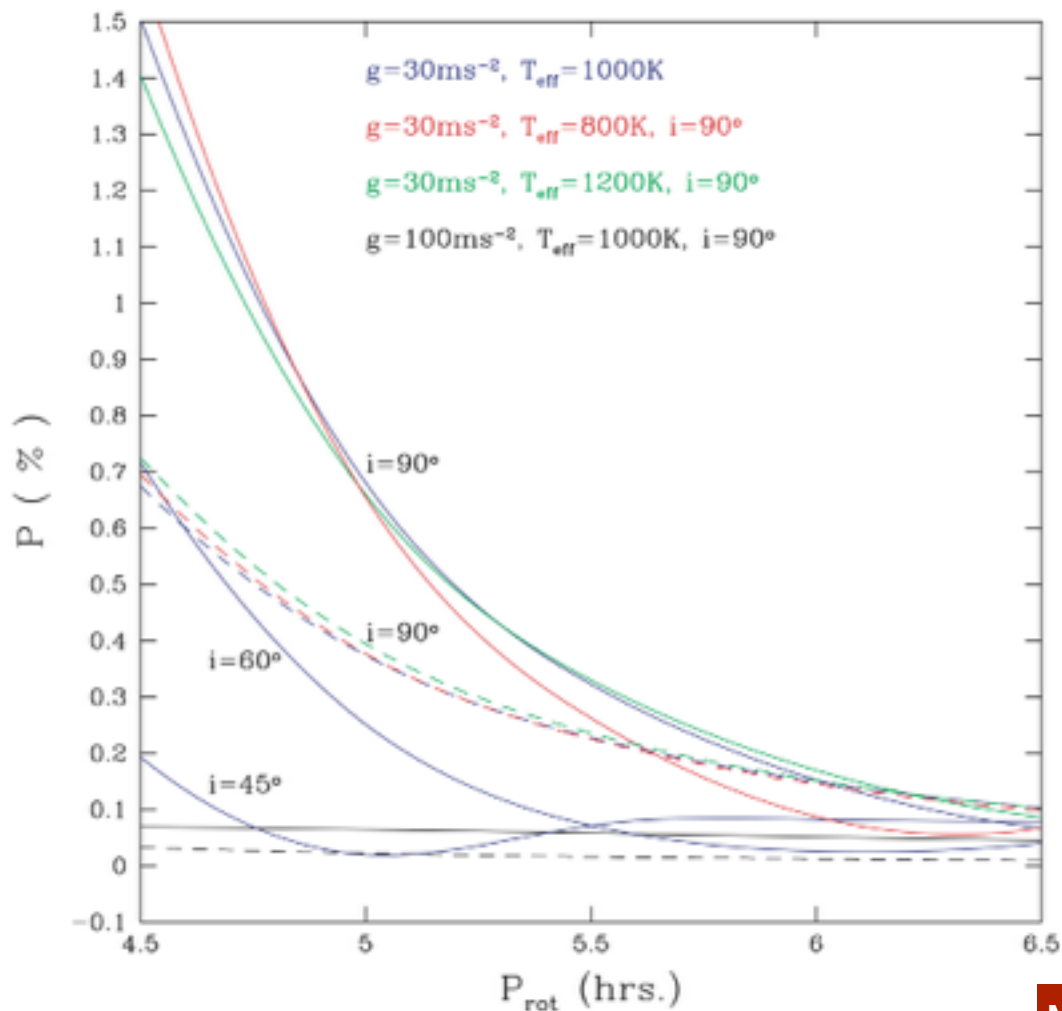


DETECTING POLARIZATION OF PLANETARY-MASS COMPANIONS?

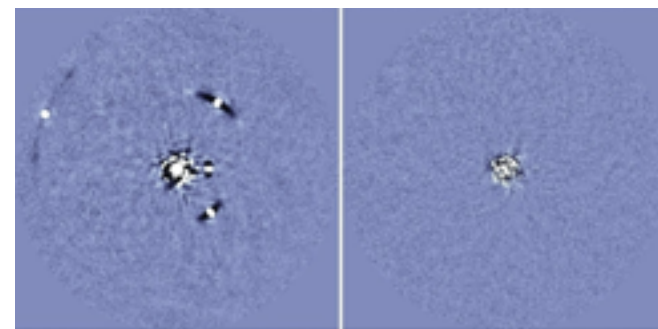
Characterizing exoplanets: from intensity...



DETECTING POLARIZATION OF PLANETARY-MASS COMPANIONS?

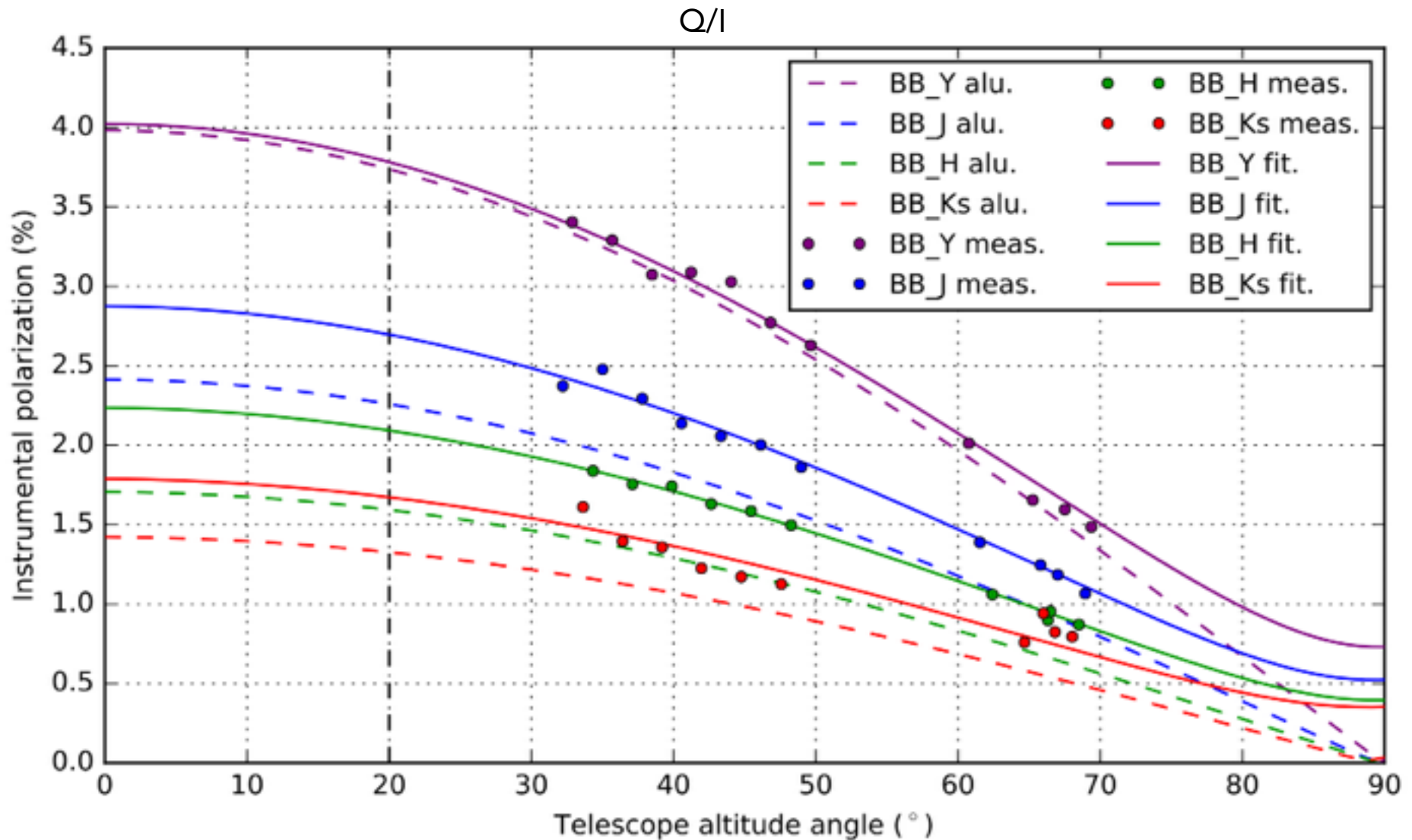


CURRIE+ 2013



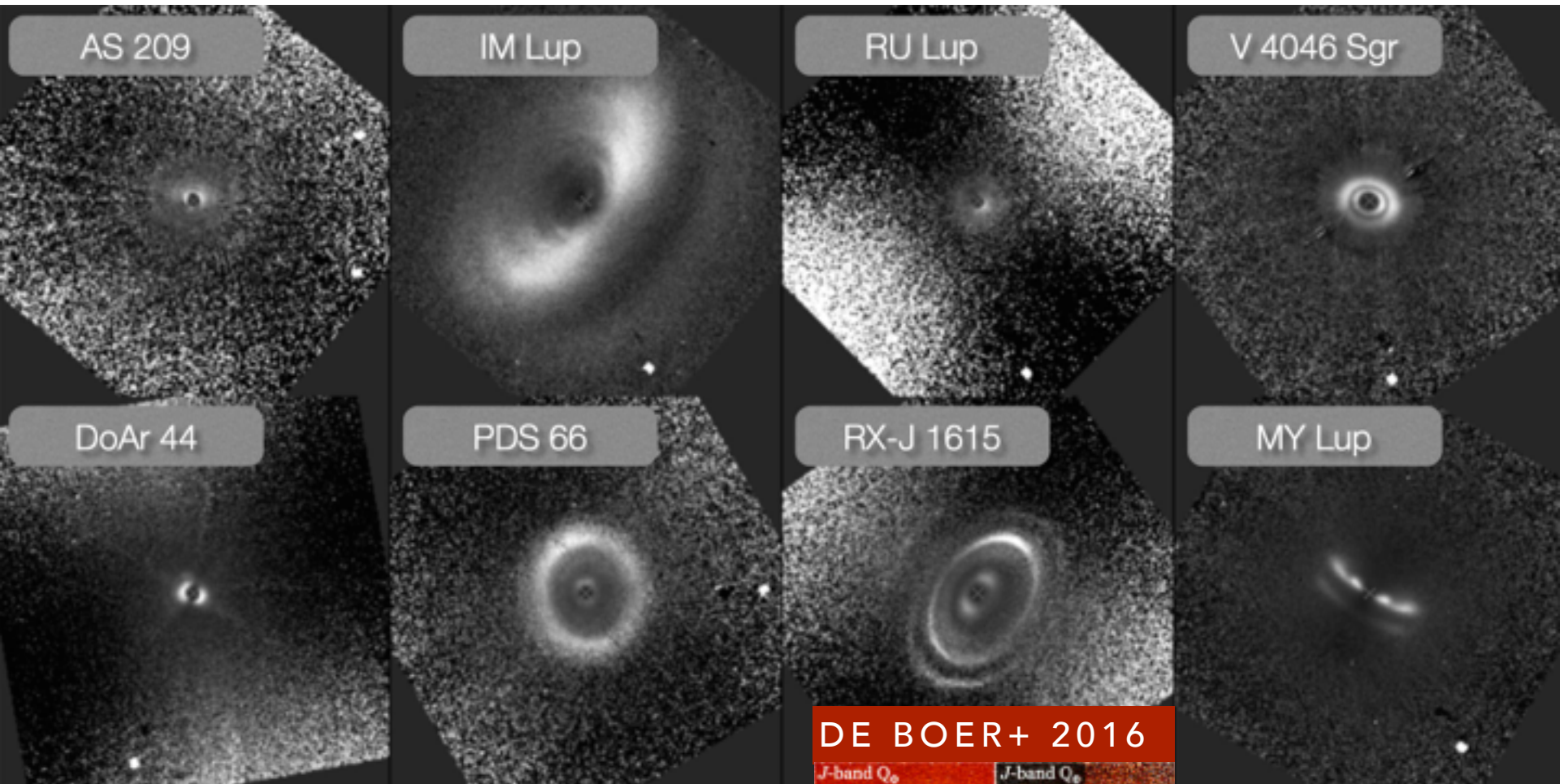
MAROIS+ 2008 ... ZURLO+ 2016

INSTRUMENTAL POLARIZATION

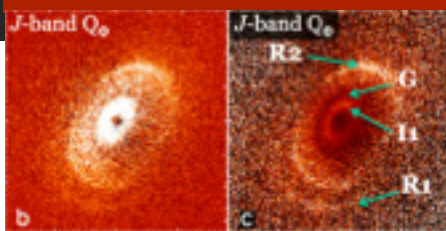


NEW DPI RESULTS FROM SPHERE

Gallery, courtesy of H. Avenhaus (2016 -)



DE BOER+ 2016

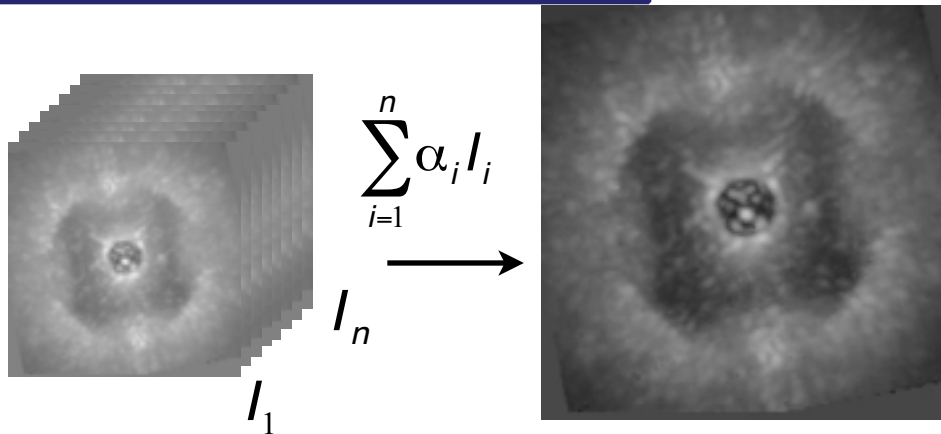


MORE TO COME!

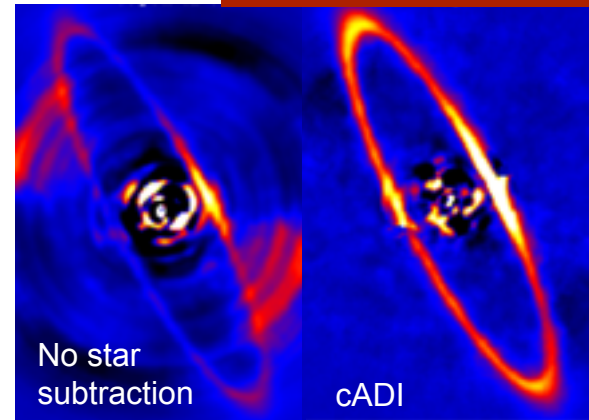
EXTRA SLIDES

POST-PROCESSING TECHNIQUES

Following Talk by D. Mouillet on High-Contrast Imaging



MILLI+ 2016
(INCL. GIRARD, ACCEPTED)



LOCI: linear combination of images to minimize the noise

LAFRENIÈRE+ 2007

PCA : orthogonalisation of library of images that is restrained to the first modes

SOUMMER+ 2012
AMARA+ 2012

Sparse Decomposition / **Low rank** approximation

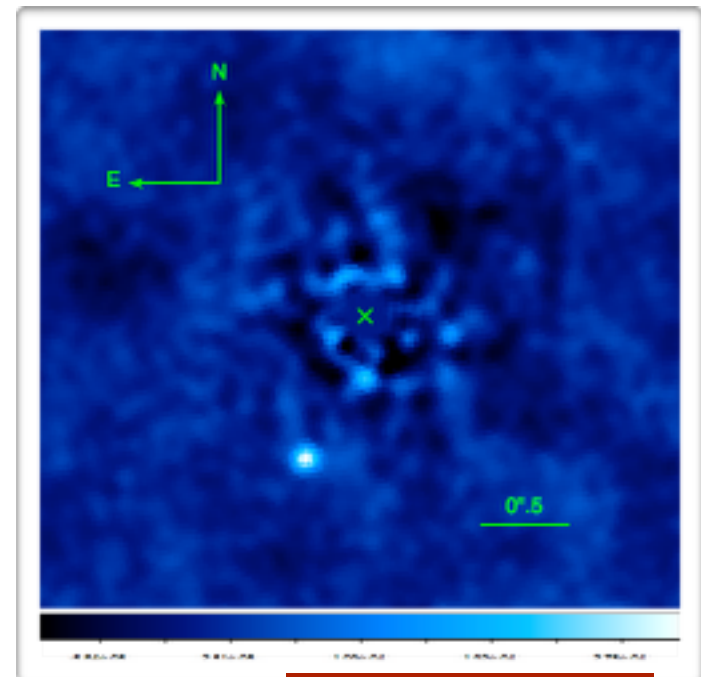
GOMEZ+2016 (PREP)

RDI WITH LARGE PSF LIBRARY

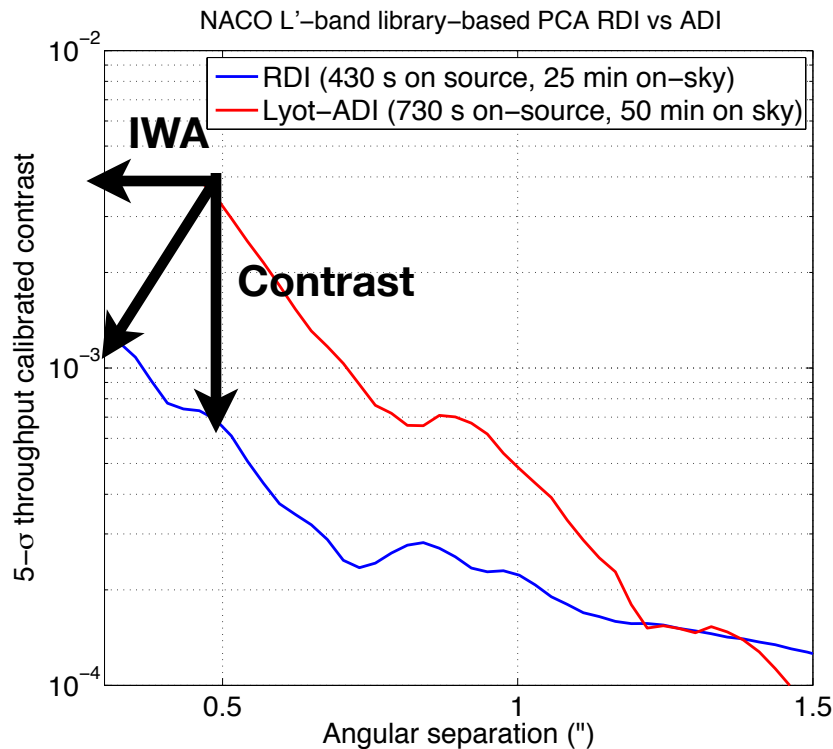
PCA: PRINCIPAL COMPONENT ANALYSIS

Large PSF DICTIONARY from survey

HIPXXX: NACO L-band



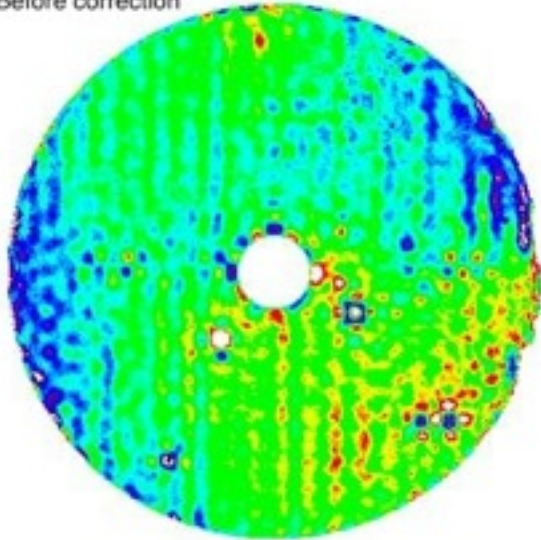
MAWET+2016



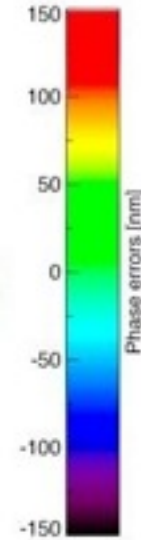
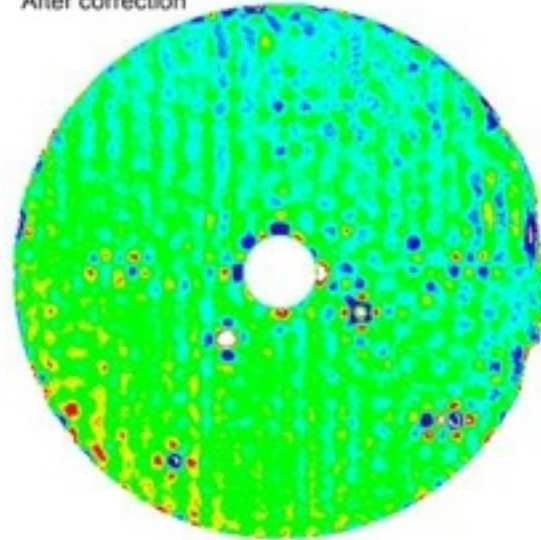
telescope efficiency x2 (SURVEYS!!) => **Strategy for Girard et al. L' filler survey**

BETTER "AO" CALIBRATION

Before correction



After correction

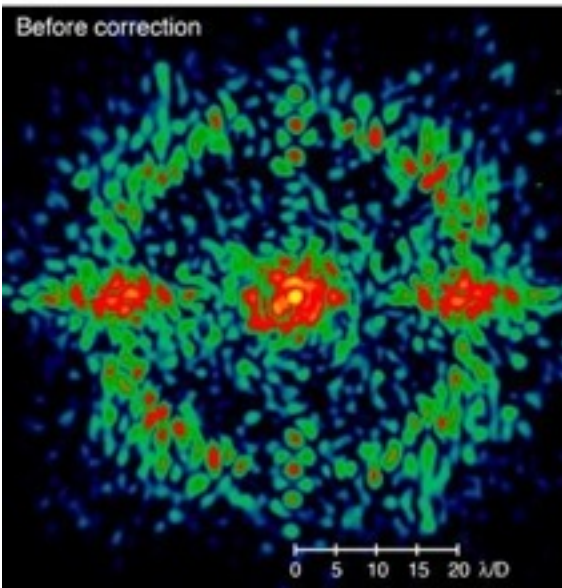


ZELDA

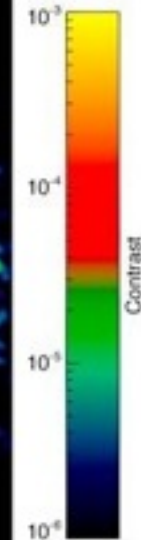
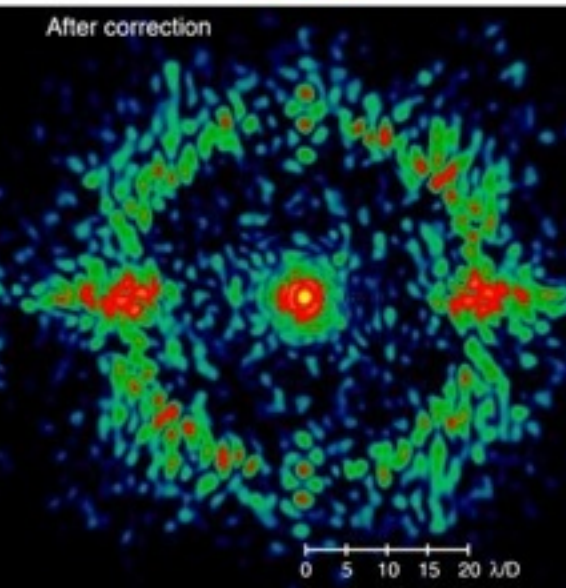
ZERNIKE WFS

INSIDE SPHERE/IRDIS

Before correction



After correction



N'DIAYE+2016

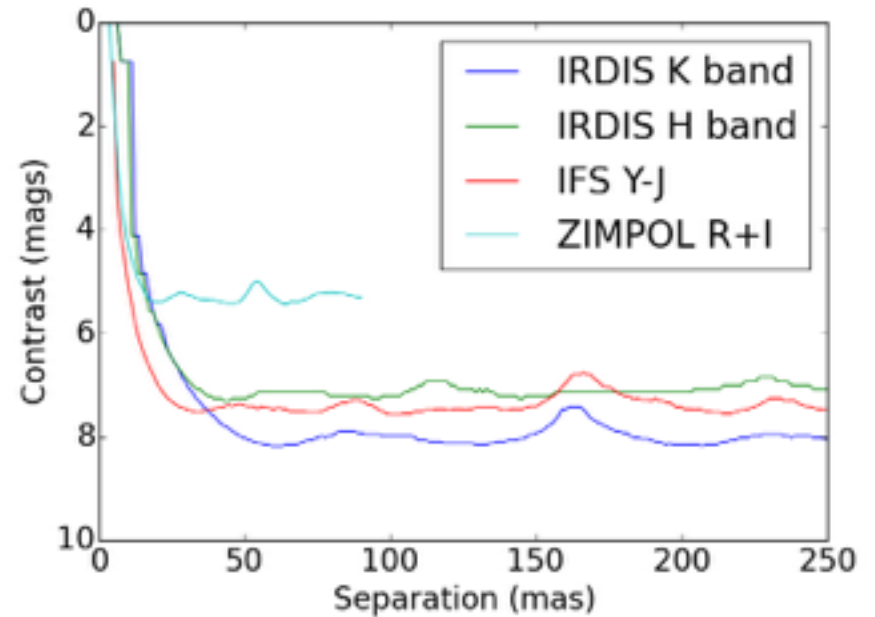
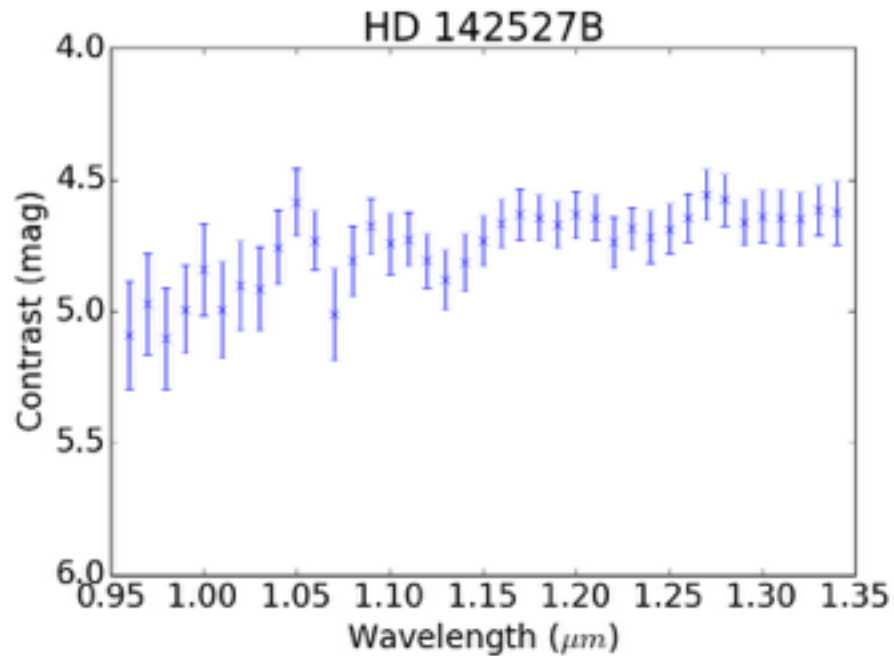
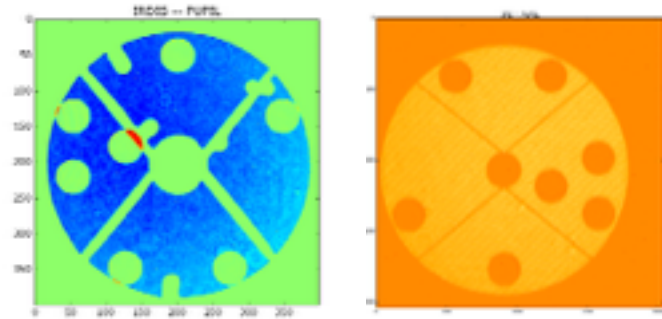
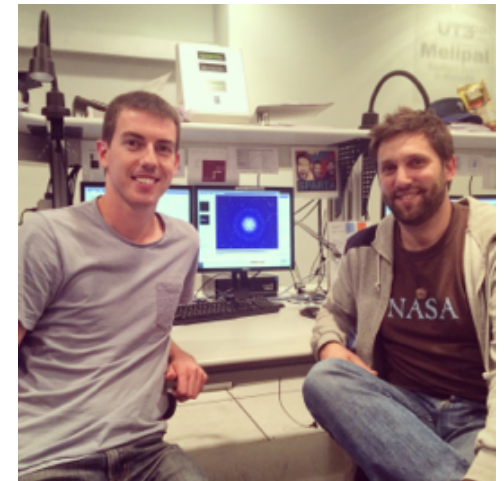
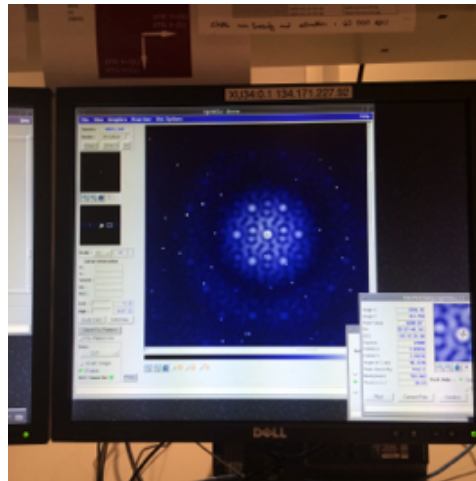
ACTION ITEM

FOR THE "PAC"

(MARCH 2017)

SPHERE SAM "PRE-COM"

CHEETHAM,
GIRARD+ 2016 (SPIE)



SPHERE SAM: ASTROMETRY!

