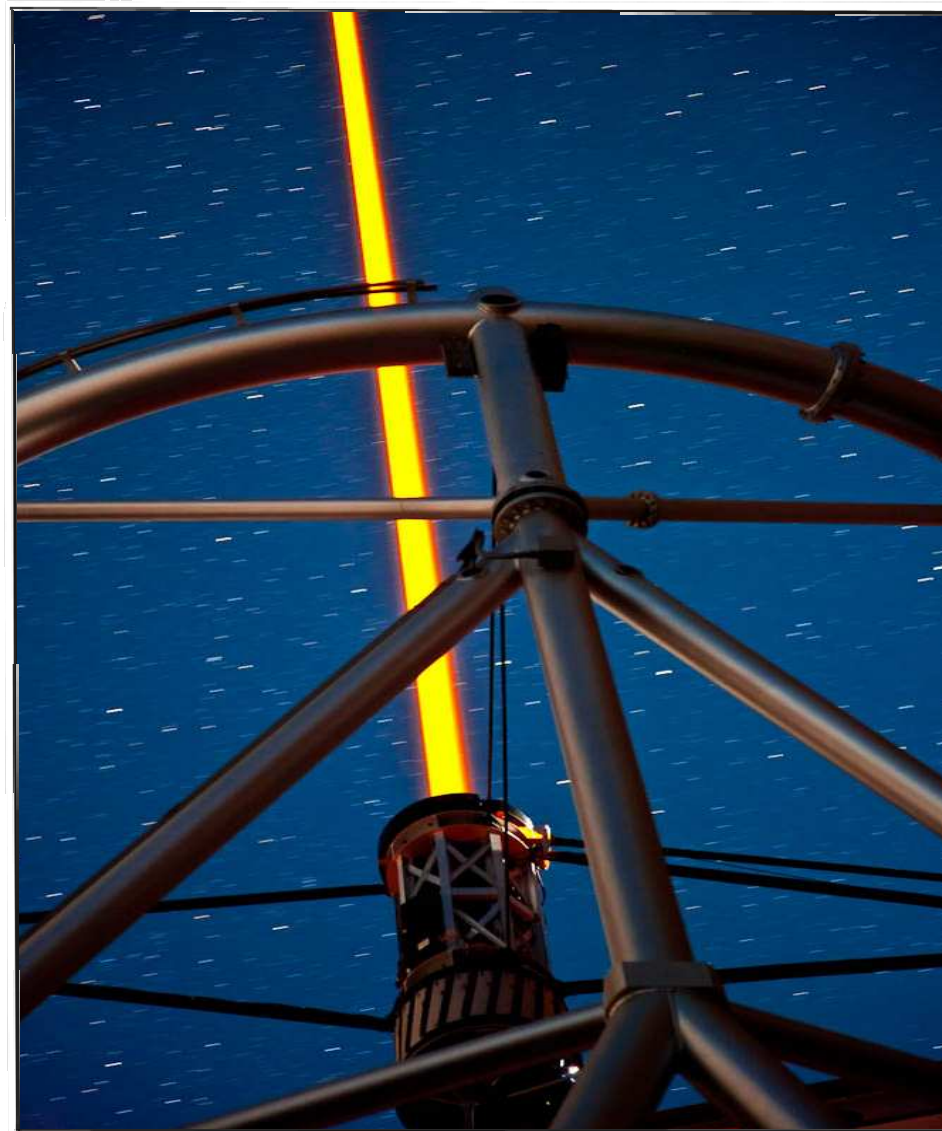


Gemini Multi-Conjugate Adaptive Optics System (GeMS)

Gemini South Adaptive Optics Imager (GSAOI)

Rodrigo Carrasco
Gemini Observatory
(on behalf of GeMS and GSAOI teams)

- * Introduction (brief)
- * GeMS overview
- * GSAOI overview
- * From commissioning/SV to Operations
- * GeMS/GSAOI on-sky performance
- * Science with GeMS/GSAOI
- * Observing with GeMS/GSAOI
- * **GSAOI Data and data processing**



Introduction

AO/MCAO/GeMS documentation and links

AO Tutorial (Andrei Tokovinin): <http://www.ctio.noao.edu/~atokovin/tutorial/index.html>

Introduction to MCAO: <http://www.gemini.edu/sciops/instruments/gems/mcao-nutshell>

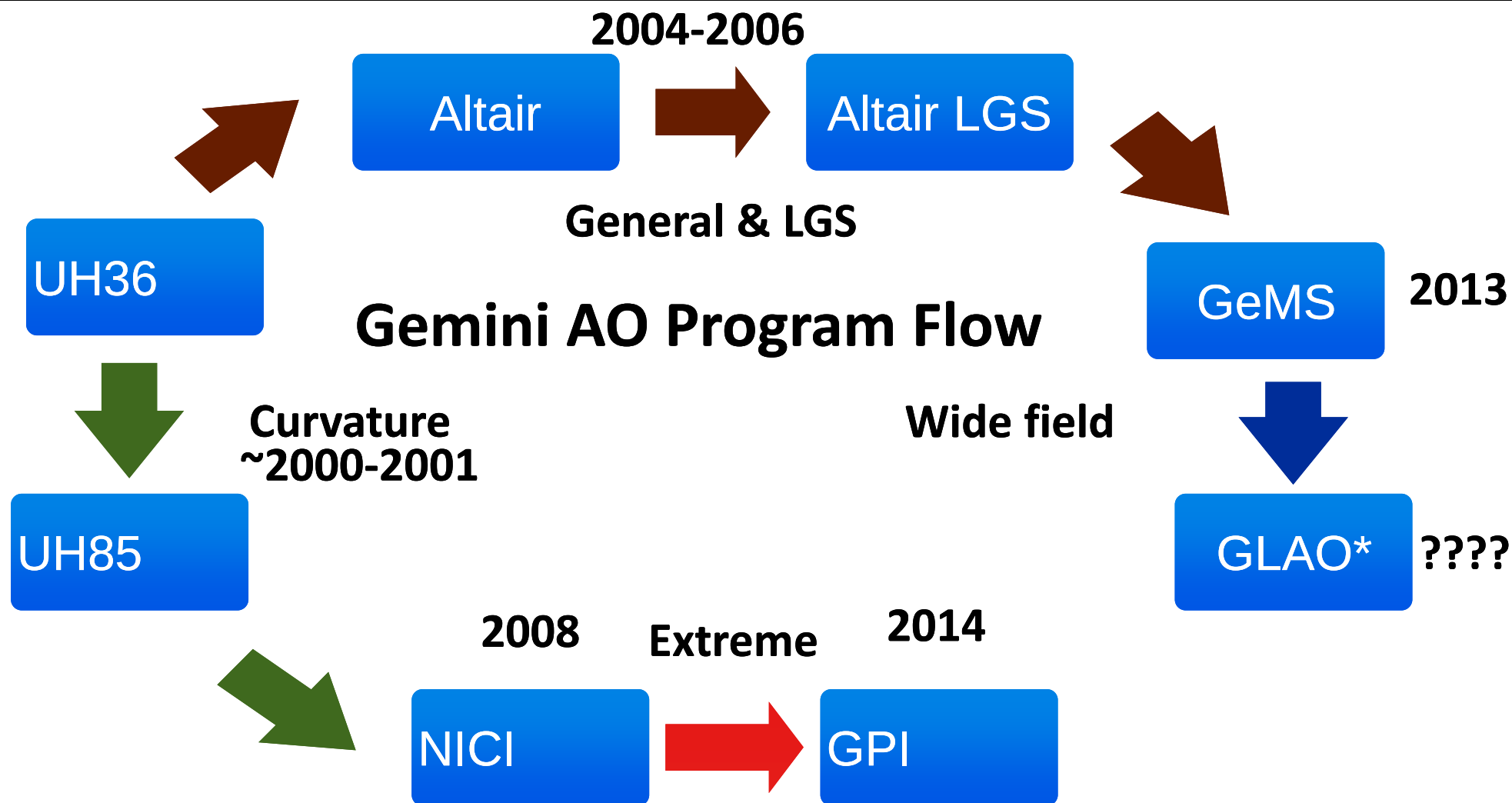
Introduction to GeMS: <http://www.gemini.edu/sciops/instruments/gems/introduction-gems>

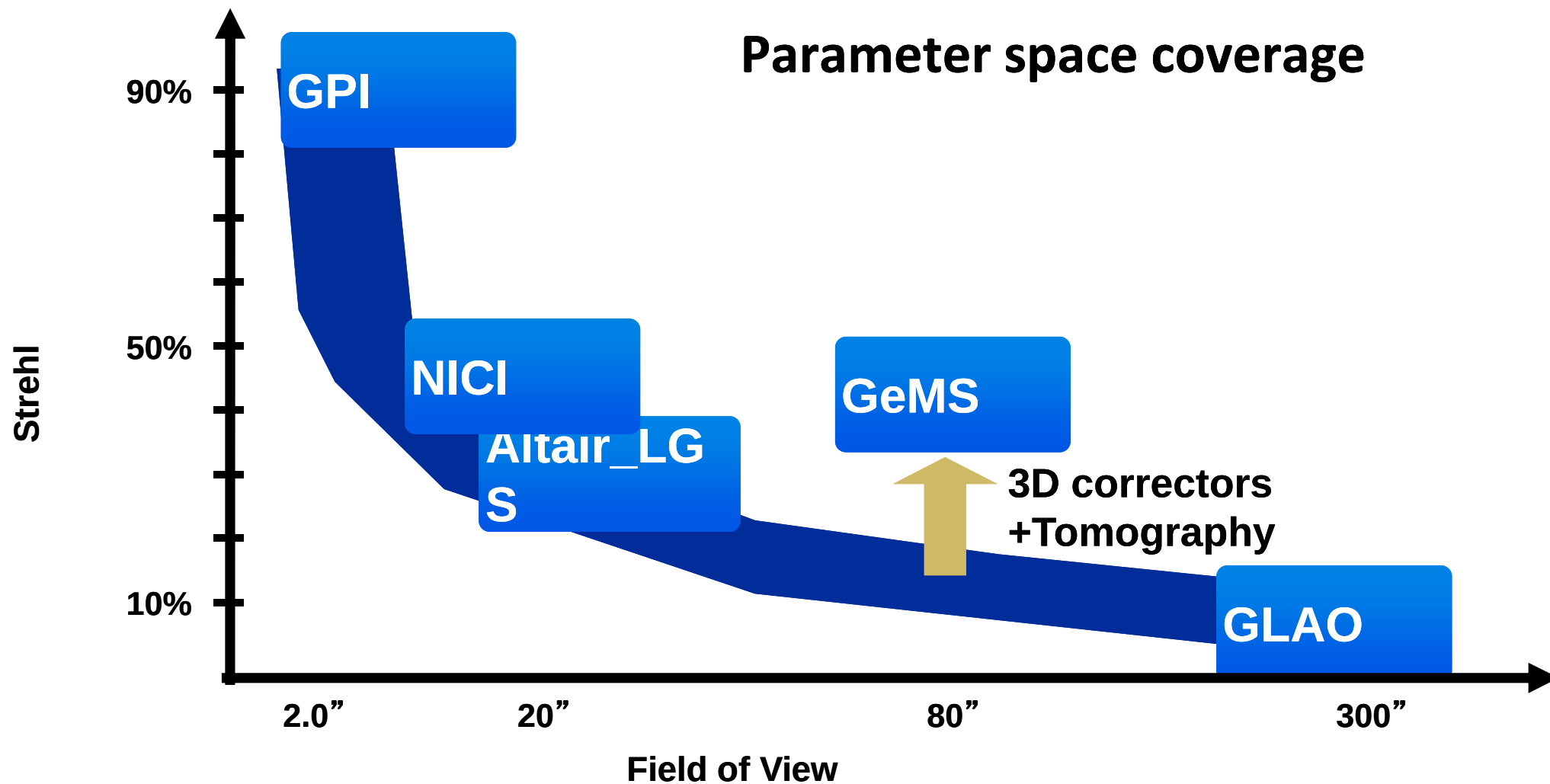
Refereed articles

- Rigaut et al., 2014, MNRAS, [437, 2361](#) “[Gemini multi-conjugate adaptive optics system review](#) - I. Design, trade-offs and integration”
- Neichel et al. 2014, MNRAS, 440, 1002 “Gemini multi-conjugate adaptive optics system review - II. Commissioning, operation and overall performance”

Conference proceedings:

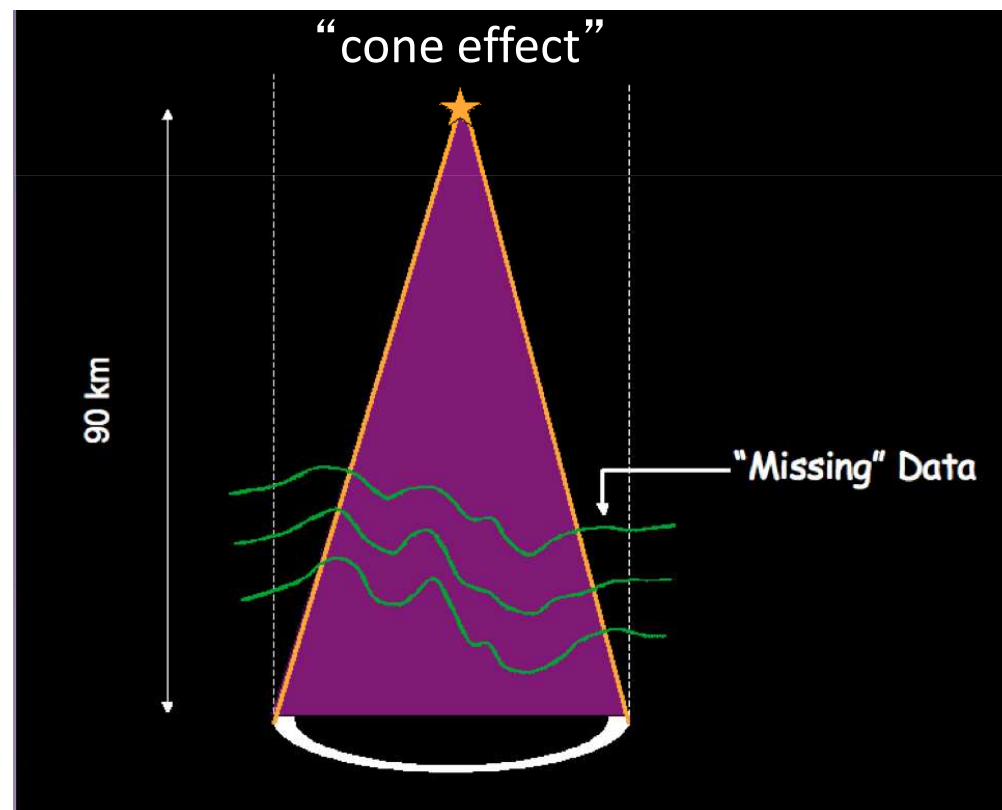
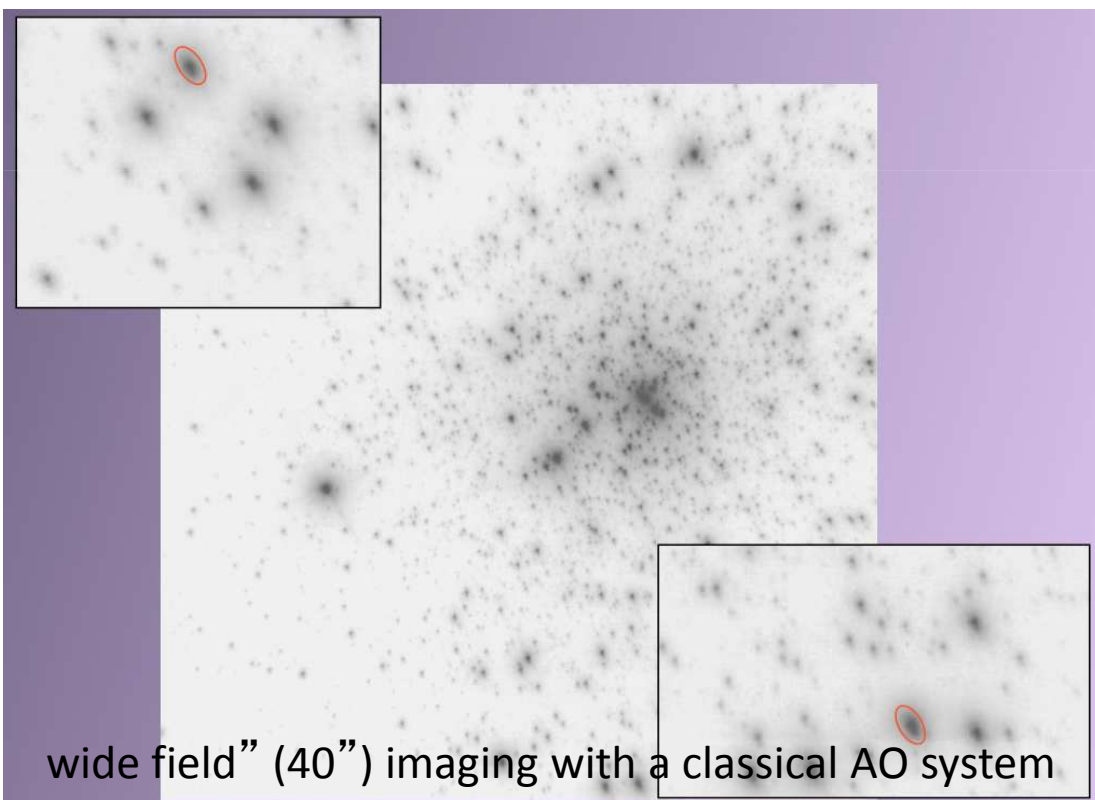
- Vidal et al. 2013, AO4ELT3 proceeding “GeMS telemetry”
- Hibon et al. 2013, AO4ELT3 proceeding “GeMS/GMOS-S”
- Lu et al. 2013, AO4ELT3 proceeding “GeMS astrometric performance”
- Rigaut et al., 2012, SPIE, 8447 “GeMS performance”
- More documents at <http://www.gemini.edu/sciops/instruments/gems/documents>





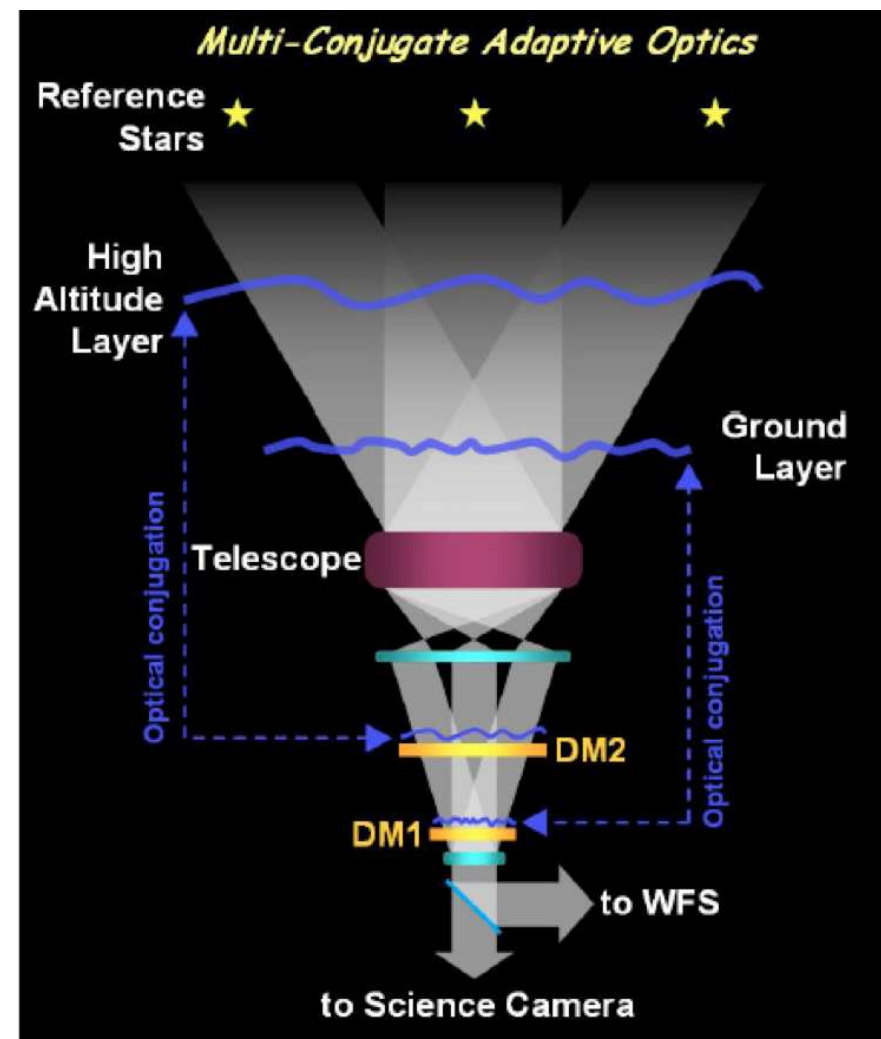
SCAO - Single-Conjugate Adaptive Optics (classical AO)

- Limited isoplanatic angle (20" in J band, 30" in H band, and 40" in K band)
- cone effect
- limited sky coverage



* MCAO - Multi-Conjugate Adaptive Optics

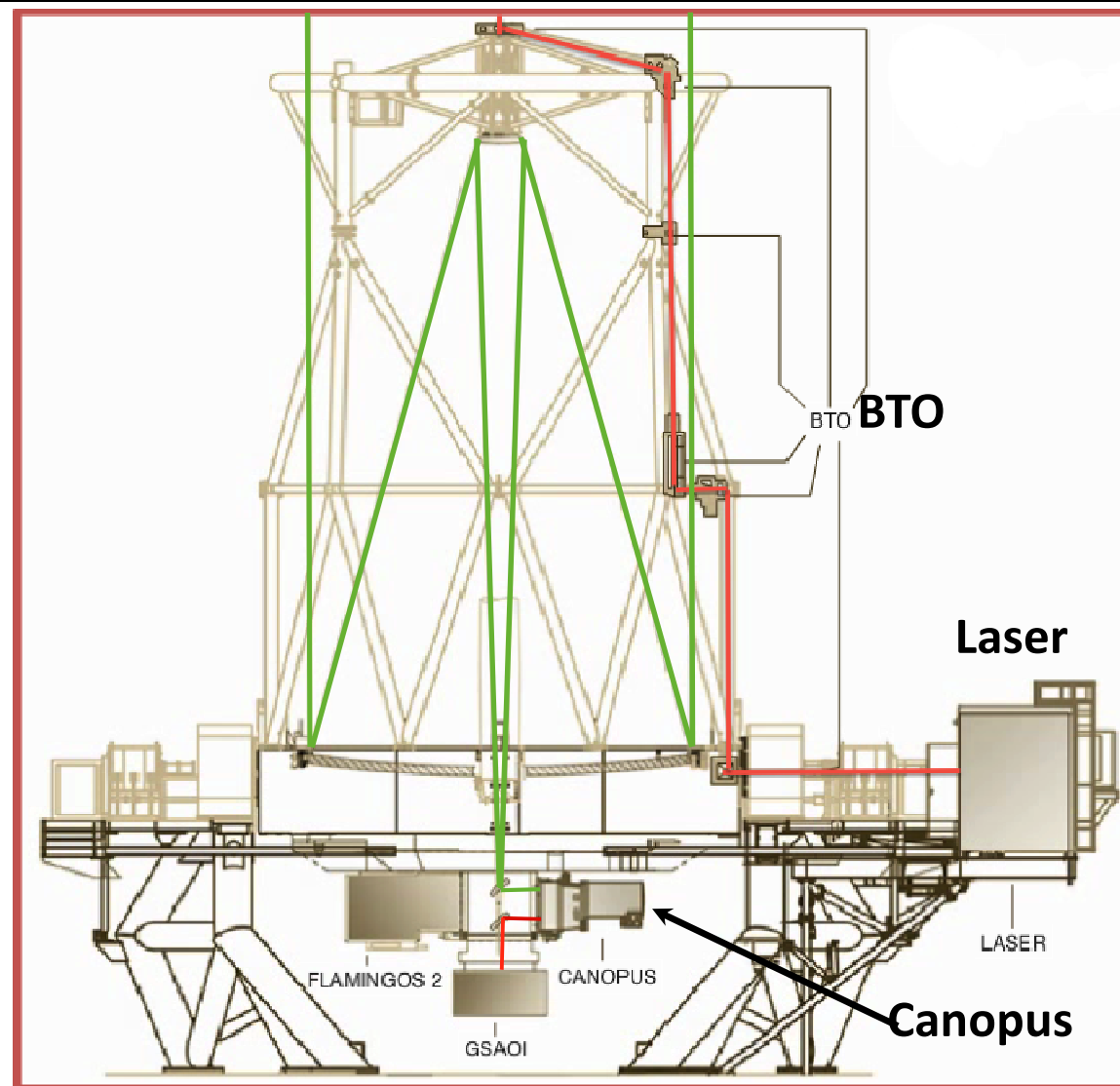
- * provides uniform image quality (diffraction-limited in the near-IR) over a much wider field than regular AO (up to two arcmin in diameter depending on the IQ criterion)
- * removes the "cone effect" associated with the use of laser guide stars.
- * larger sky coverage (wide field)



GeMS overview

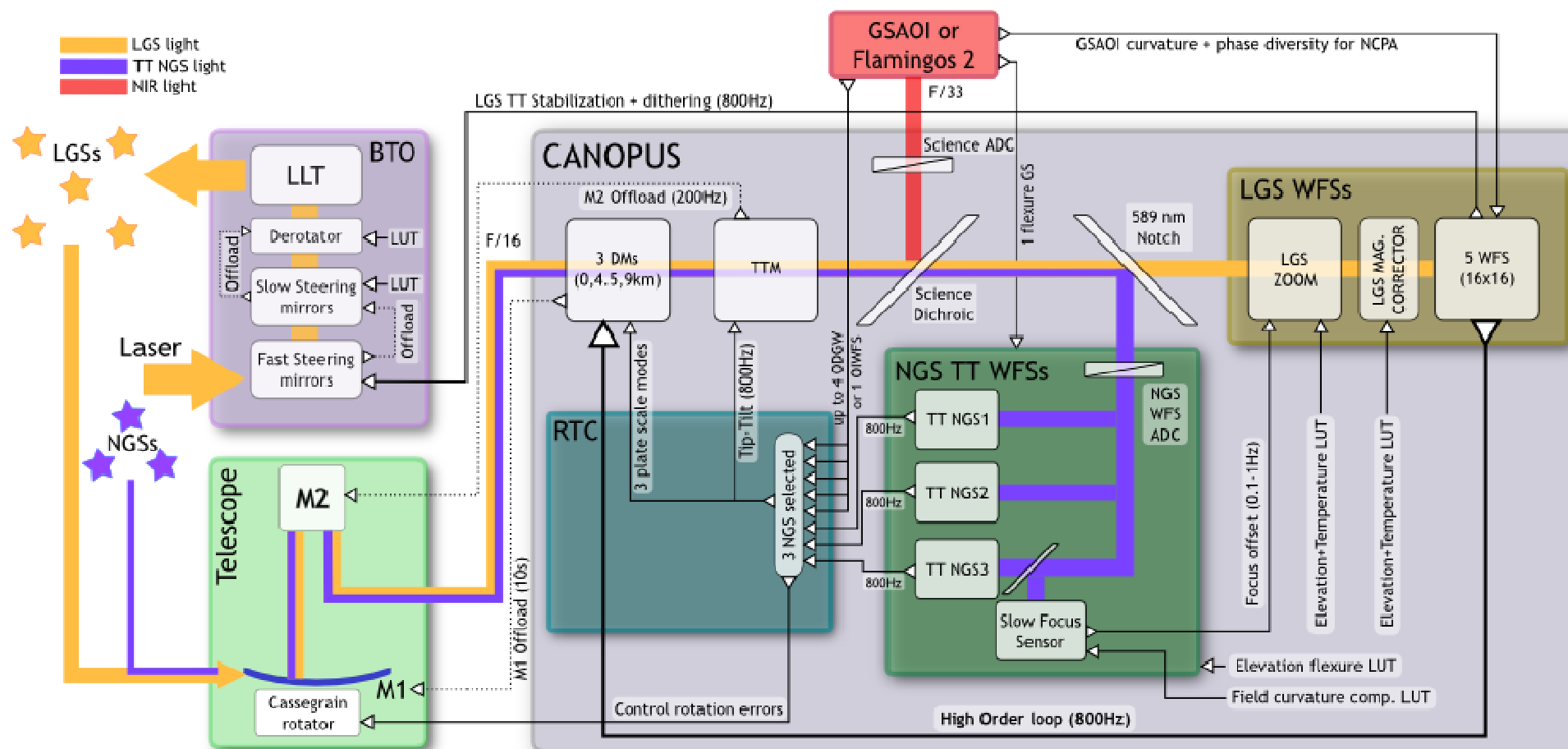
GeMS Overview

- * Three main subsystems
 - * Laser
 - * Beam Transfer Optics (BTO)
 - * AO bench (Canopus)
- * All three system are linked together loops and offloads.
- * Instrument feed by GeMS
 - * GSAOI (near-infrared imager)
 - * Flamingos-2 (NIR MOS & Imager - see Percy's talk)
 - * GMOS-S (Optical MOS & Imager)



- * **50W laser** split in 5x10W (in practice 4W on sky/LGS) - Laser, BTO
 - * **5 sodium Laser Guide Stars** on X shape, 60 arcsec on a side, with 5 **16x16 Shack Hartmann WFS**
- * Tip-Tilt, plate scale and rotation correction done from either:
 - * (up to) **3 visible NGS** (Canopus) + one flexure GS using On-Detector Guide Window (ODGW, GSAOI)
 - * (up to) **3 NIR ODGW** (GSAOI) + one visible GS for slow focus (Canopus)
- * **3 Def. Mirrors** conjugated at 0, 4.5 and 9 km (currently 0 and 9 only) (Canopus)
- * **Many other subsystems:** Laser Launch Telescopes, Laser Traffic Control, Plane traffic control, Telescope laser extension, Safety systems, etc, etc
- * Commissioning started - 01/2011

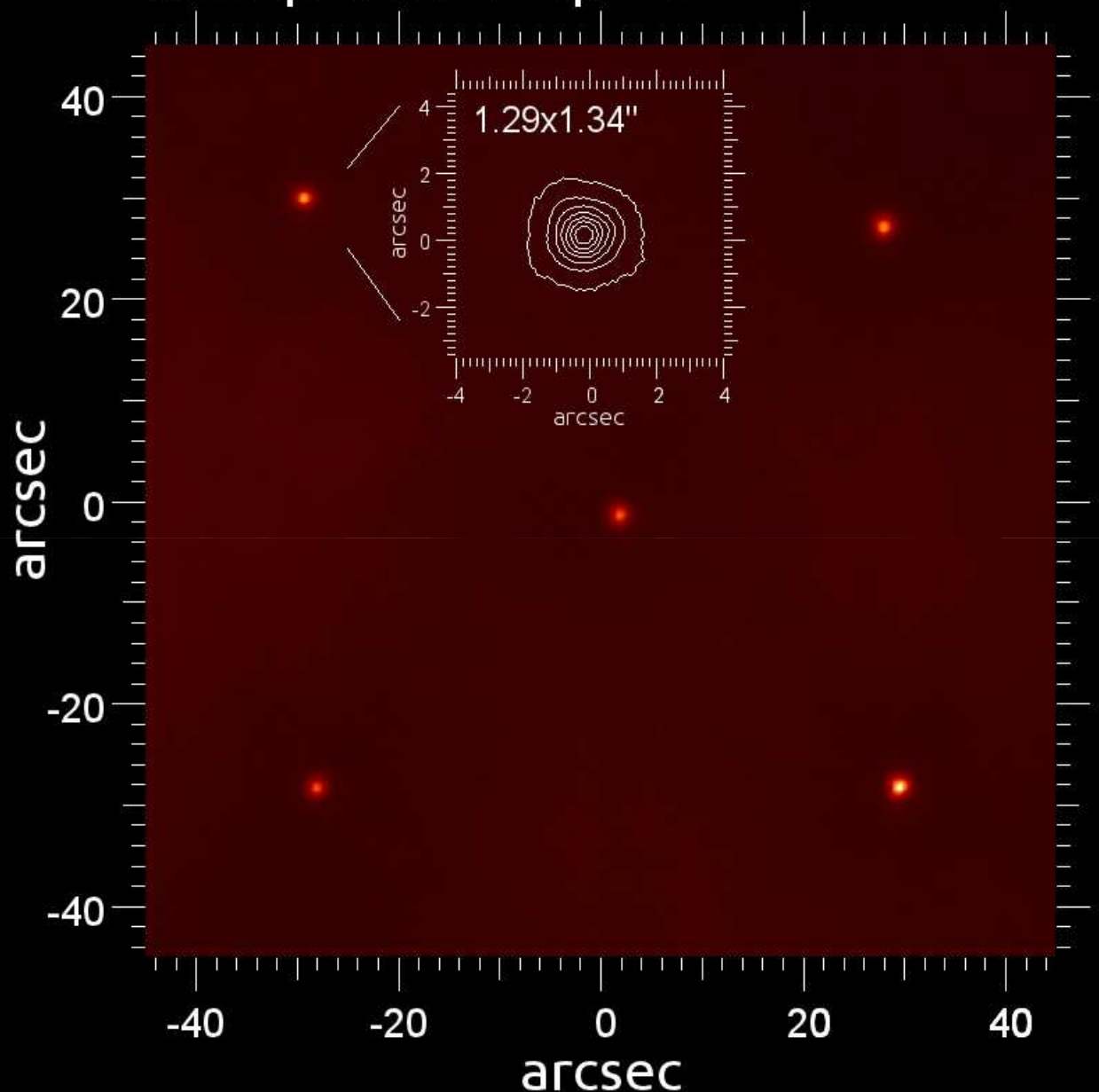
GeMS Overview



~ 20 loops and offloads

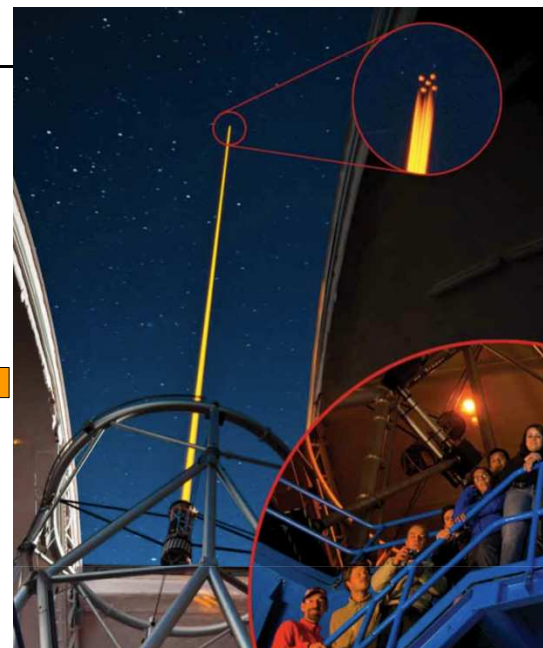


LGS spots 2011apr18

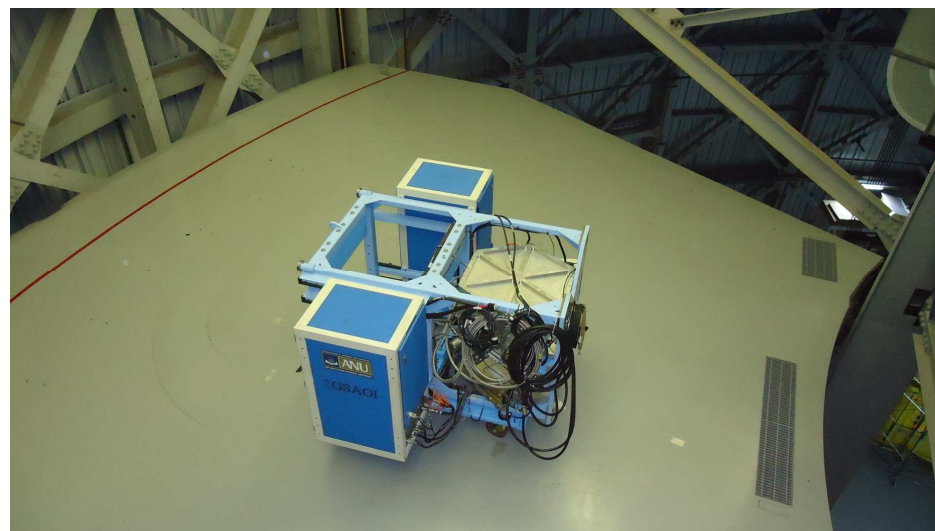


LGS constellation

GeMS Overview



To science instruments



GSAOI overview

GSAOI documentation and links

GSAOI Web pages: <http://www.gemini.edu/sciops/instruments/gsaoi/?q=sciops/instruments/gsaoi>

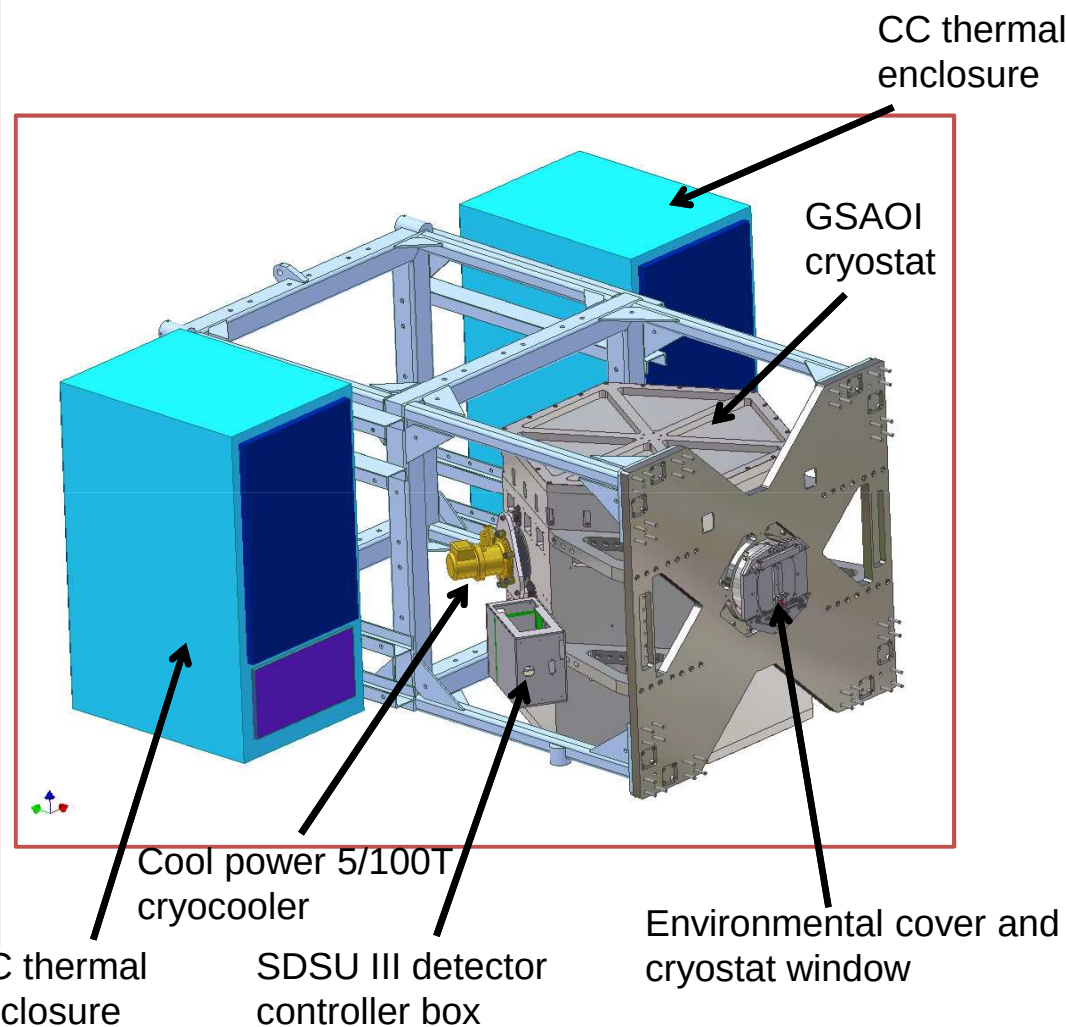
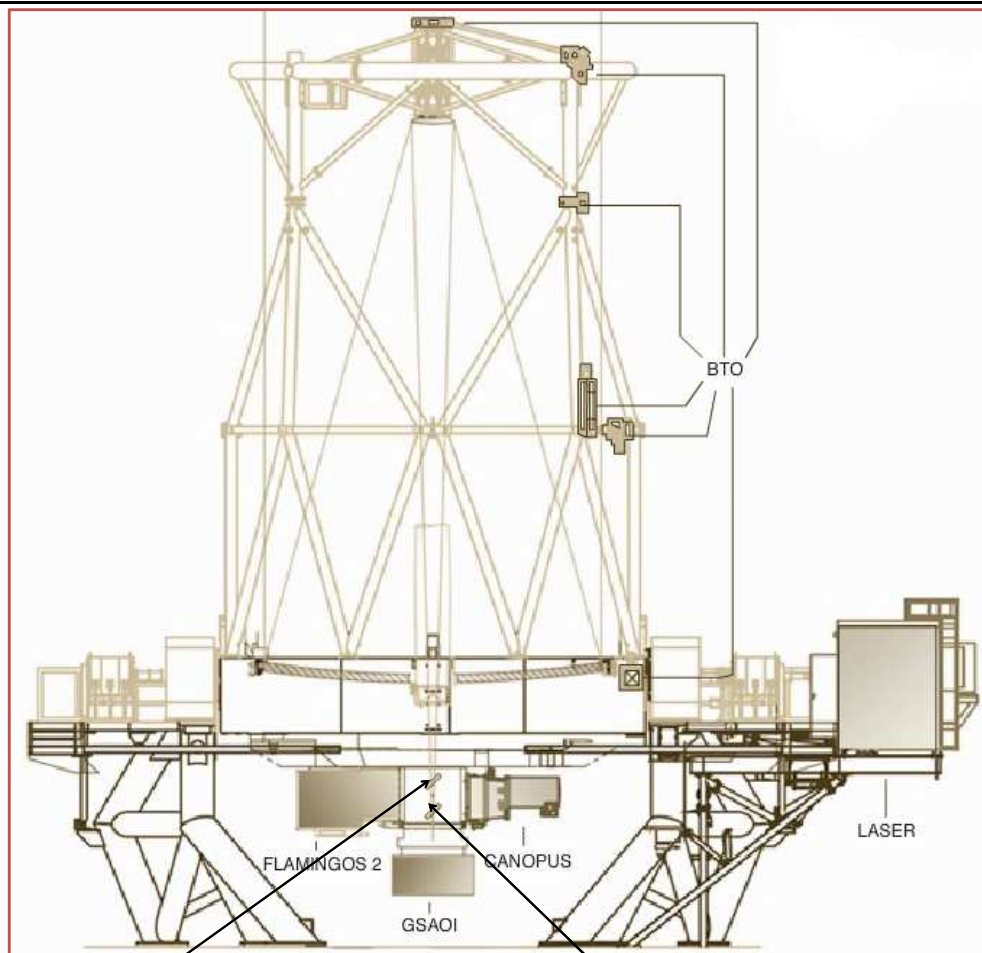
Conference proceedings:

- McGregor et al. 2004, SPIE, 5492, 1033 “Gemini South Adaptive Optics Imager (GSAOI)”
- Carrasco et al. 2012, SPIE, 8447, 84470N “Results from commissioning of the Gemini South Adaptive Optics imager (GSAOI) at Gemini South”

- More documents at

<http://www.gemini.edu/sciops/instruments/gsaoi/documents/?q=sciops/instruments/gsaoi/documents>

GSAOI Overview



AO Fold mirror

Science Fold mirror

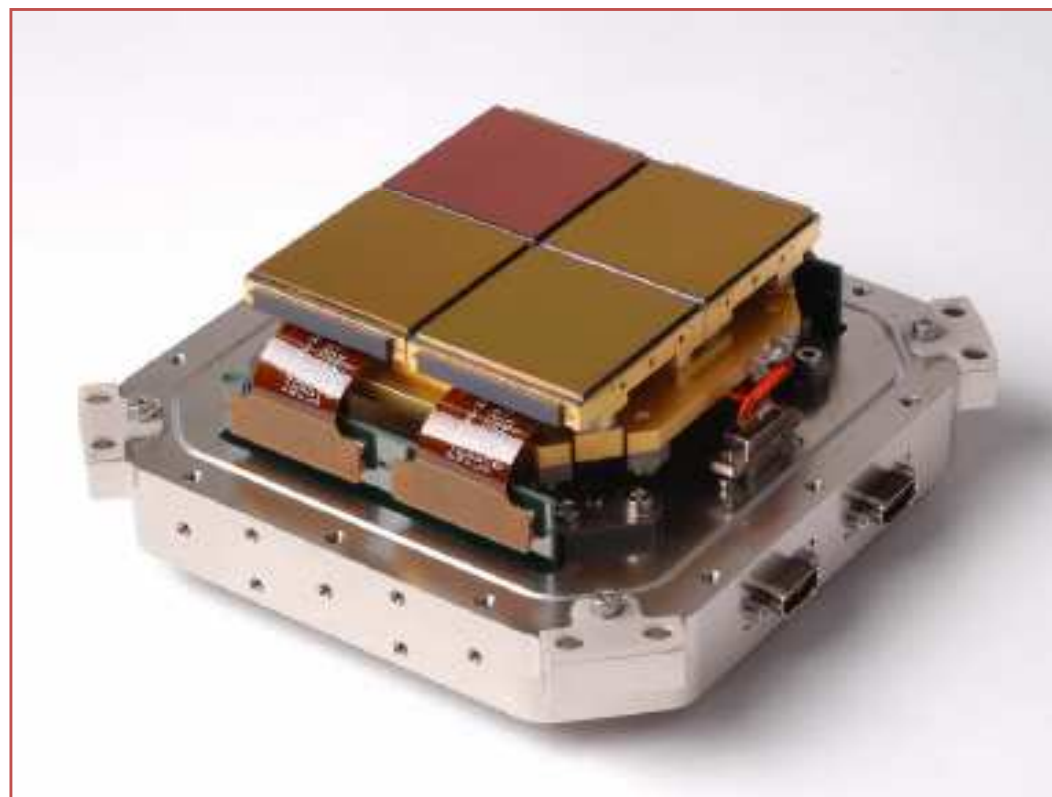
DC thermal enclosure

Cool power 5/100T cryocooler

SDSU III detector controller box

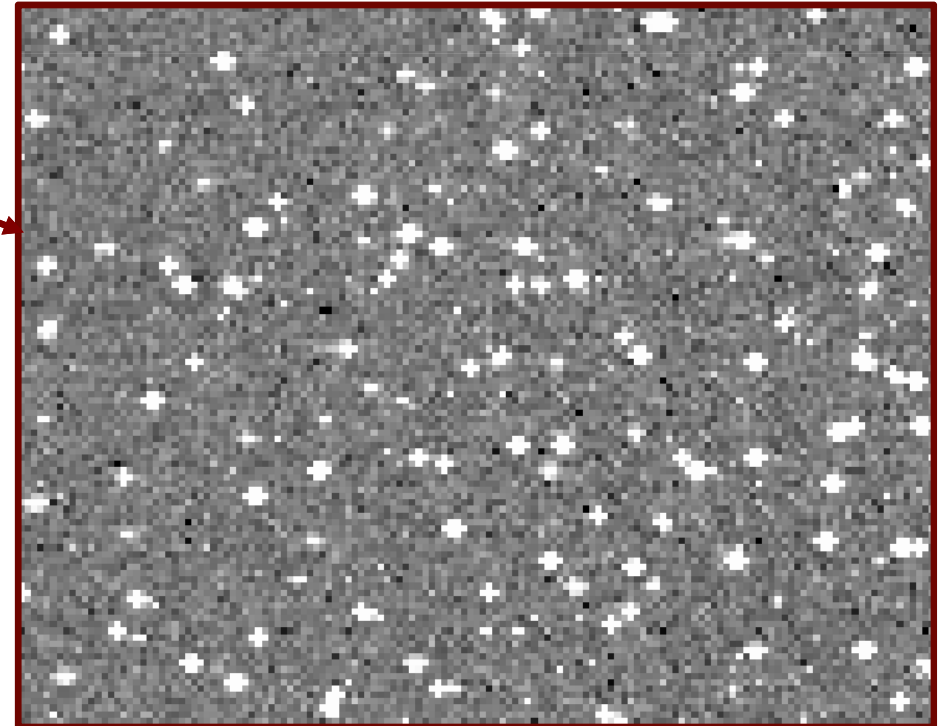
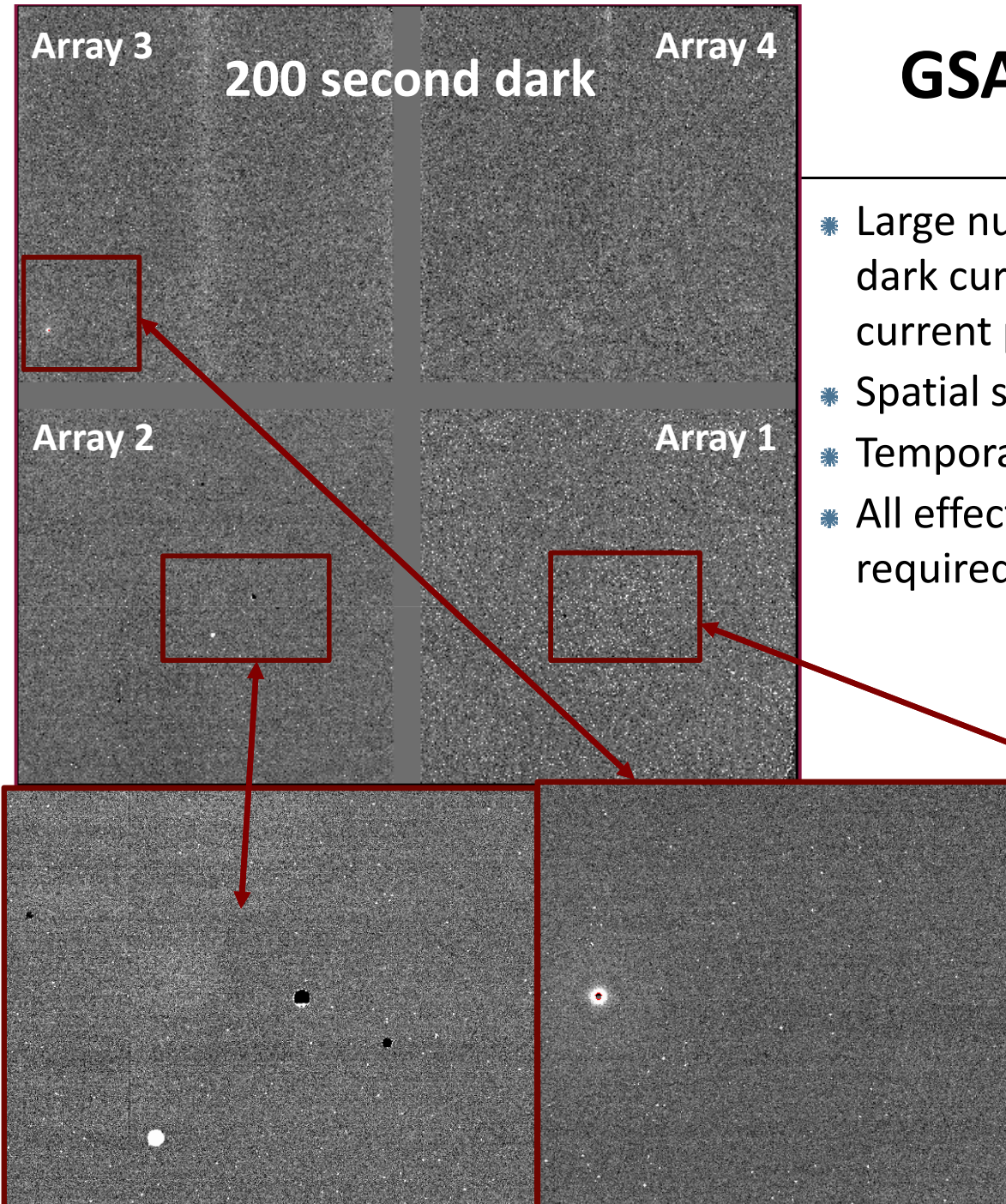
Environmental cover and cryostat window

- * 4 Rockwell 2048x2048 HAWAII-2RG HgCdTe arrays
 - * 0.9 – 2.6 μ
 - 2040 x 2040 active pixels (18 μ m) -- 2 x 2 mosaic of 4080 x 4080 pixels (85" x 85" on-sky)
 - Pixel scale: 0.02", Gaps between array: ~3" (2.5mm)
- 4 amplifiers per array (512 x 2048)
 - Simultaneously read out
 - minimum read out time and exp. : 5.3sec
- Low dark current: ~0.01 e-/s/pix
 - Large number of "hot" pixels
 - Spatial structure (up to 10 ADU)
- Imperfect cosmetic
 - Dead pixels
 - Light emitting-diode pixels
 - Linearity correction is required

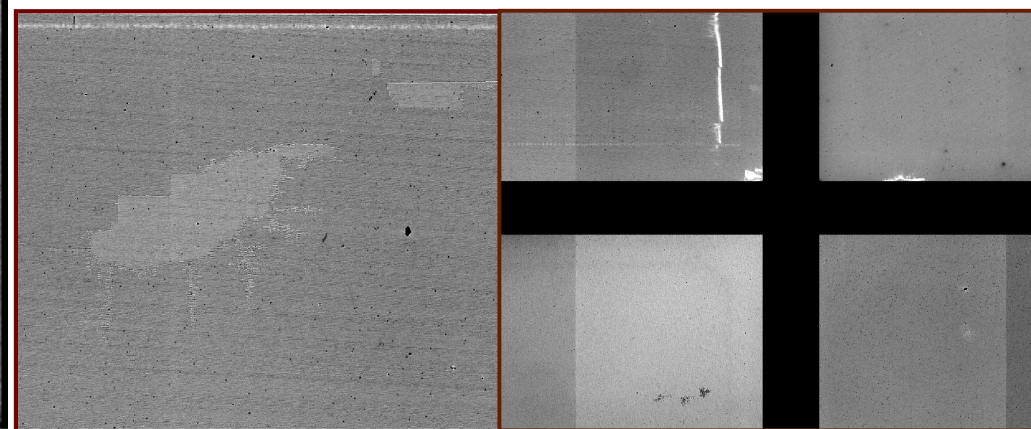
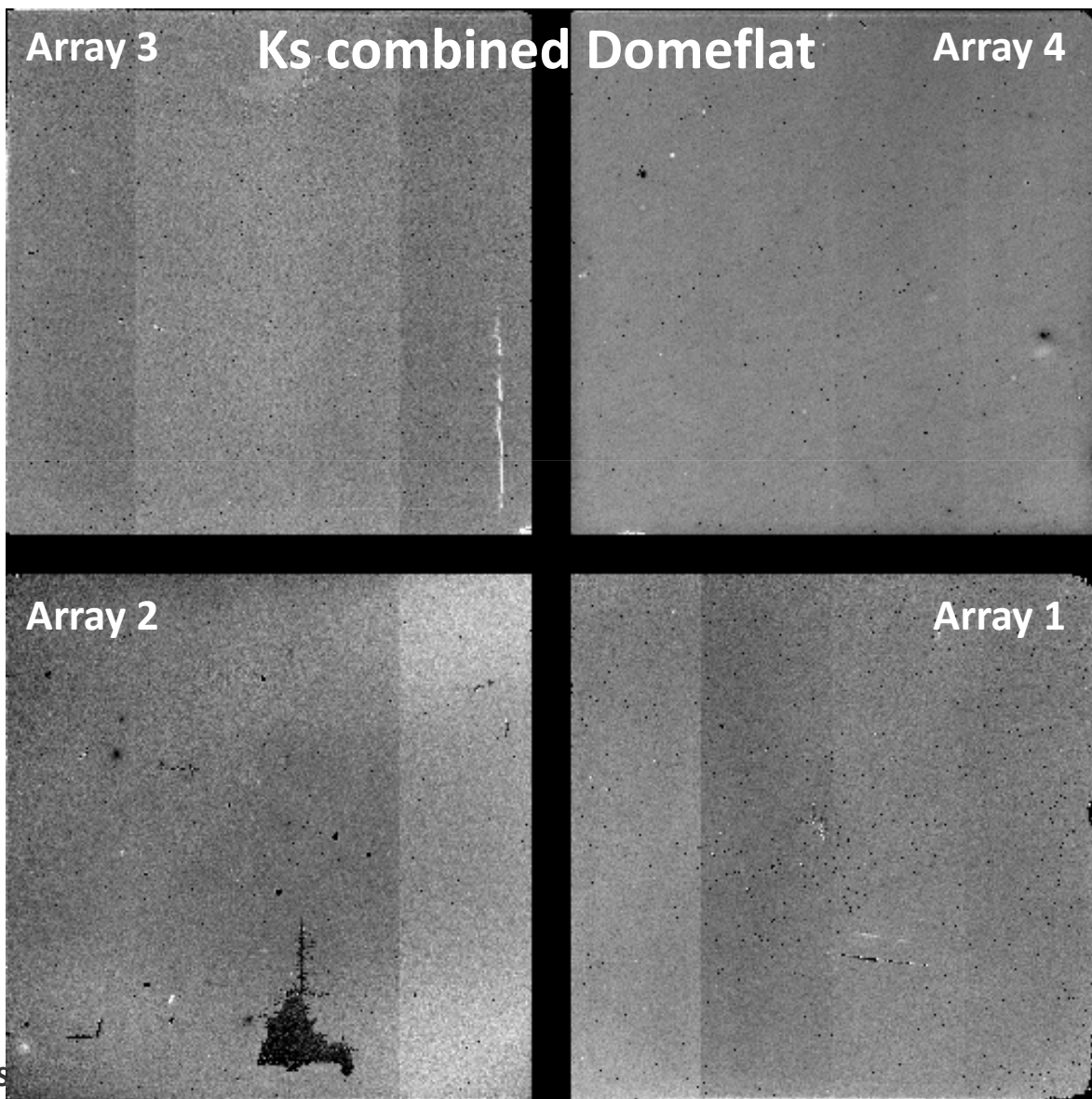


GSAOI overview: darks

- Large number of hot pixels. Appear as a single high dark current pixels with adjacent moderately high dark current pixels (cross shape form)
- Spatial structure within each array (up to 10 ADU).
- Temporal variation in amplitude within each array.
- All effects are small --> dark subtraction is not required.

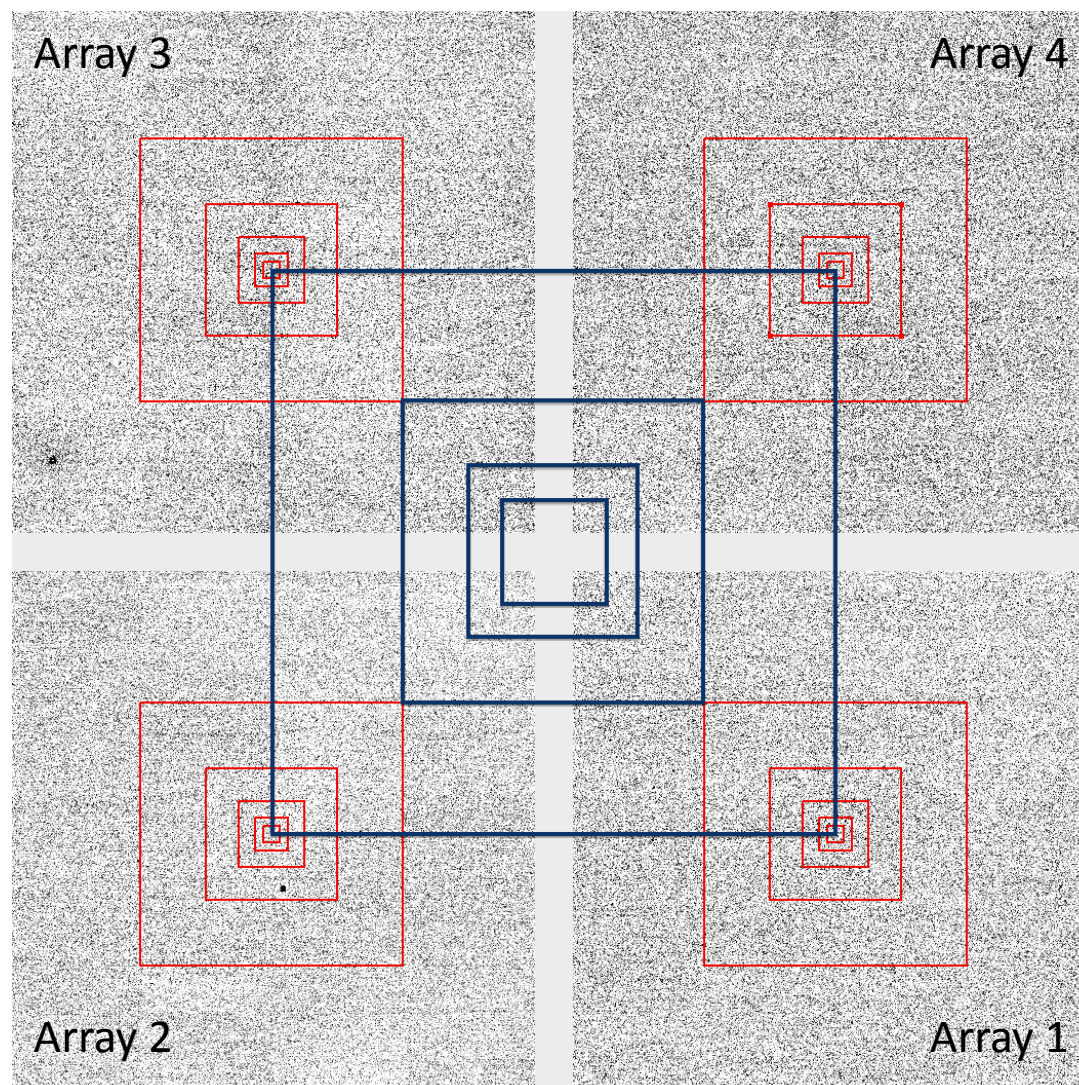


GSAOI overview: flats

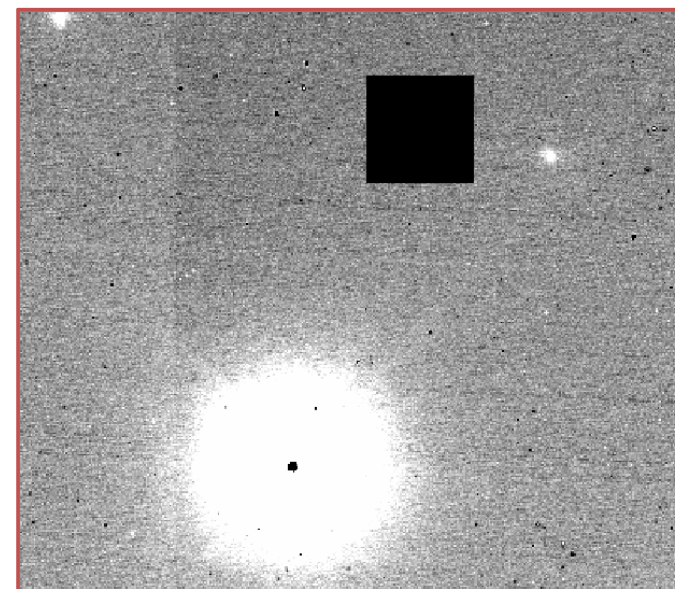


GSAOI overview: ROIs

- * Full frame readout
 - * 4096 x 4096 pixels
- Center of each detector
 - 32x32, 64x64, 128x128, 512x512 and 1024x1024
- Center of the mosaic
 - 64x64, 128x128, 512x512 and 1024x1024
- Shorter read out speed
 - Photometric Standards
 - Instrument testing
 - Detector characterization
- Not offered for science yet

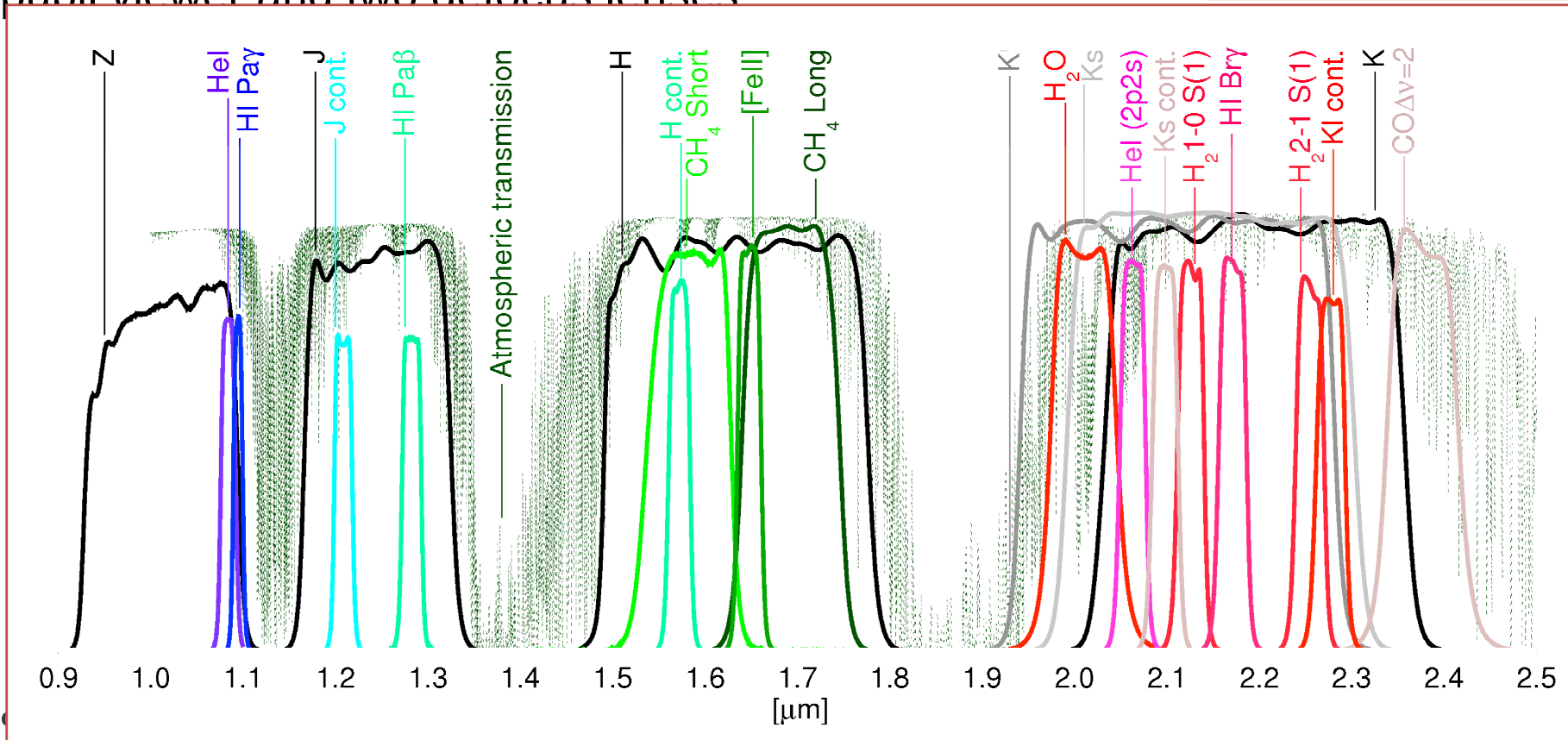
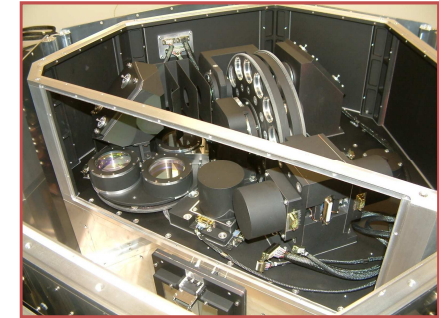


- * One programable ODGW per detector
 - * Correction for differential flexure between Canopus and GSAOI
 - * can be used for fast tip-tilt correction (mode 3 ODGW + 1 CWFS for SFS)
- Sizes between 2x2 - 128x128 pixels
 - Science: 4x4 or 8x8 pixels
- Read out sub-arrays while remaining pixels are integrating.
- ODGW for fast tip-tilt correction not implemented yet.
- ODGW for flexure correction → works, but there are some issues.



GSAOI overview: Filters

- * 2 filter wheels
- * Broad- (Z, J, H, K', Ks and K) and narrow-band (16) filters
- * 1 utility wheel
- * pupil viewer and two defocus lenses

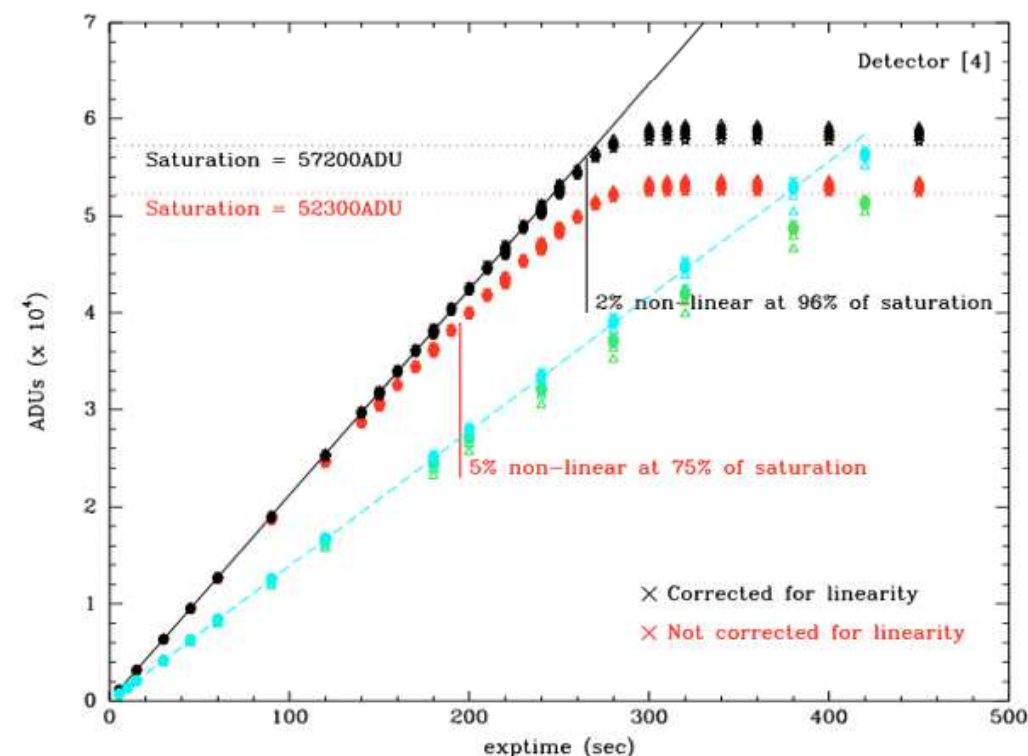


- Implemented using a polynomial fit to raw data counts using H- and Z-band flats

$$L.C.F = a + b * ADU + c * ADU^2$$

- L.C for count levels > 3000 ADU

Detector	a	σ_a	b	σ_b [$\times 10^{-7}$]	c	σ_c [$\times 10^{-11}$]	Correlation	σ_{res}
1	0.9947	0.0007	7.4	0.7	2.5	0.1	0.993	0.003
2	0.9940	0.0010	6.0	1.0	3.7	0.3	0.989	0.005
3	0.9947	0.0006	7.1	0.6	2.2	0.1	0.991	0.003
4	0.9959	0.0006	5.7	0.6	2.7	0.1	0.991	0.003



- Count levels < 3000 ADU
 - Presence of non-linear behavior of increasing response to lower levels.
 - Effect is as large as the scatter in the data points
- Linearity correction is implemented in the GSAOI IRAF package.

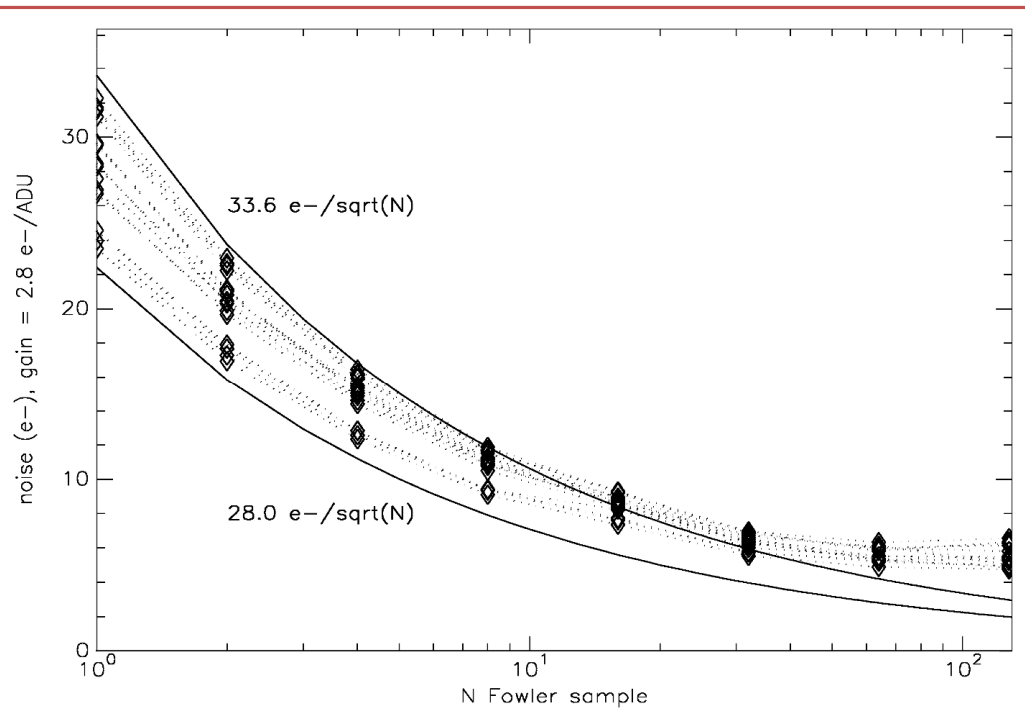
GSAOI overview: read out noise and gain

- * Readout noise --> determined using darks exposures for different Fowler Sampling NDRs 2, 8, 16 and 32
- * Gain --> determined using the same dataset used for linearity correction

Fowler-Mortara Variance Analysis Method

$$V_{\text{ADU}} = (\text{RN}_{\text{ADU}})^2 + S_{\text{ADU}}/g$$

Readout noise vs. FS (2008, Lab. measurements)



Readout noise and Gain (03/2011)

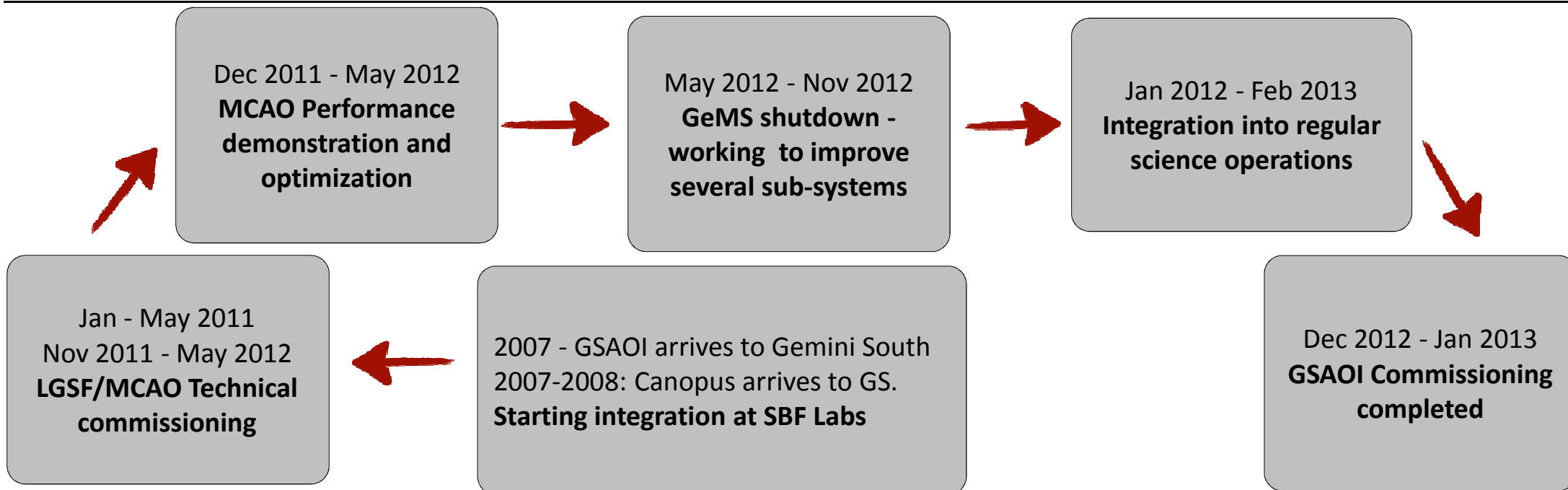
Detector	Read noise [ADU]				Gain [e-/ADU]
	FS1 – 1	FS 4-4	FS 8-8	FS16 – 16	
1	11.6	5.6	4.2	3.2	2.434
2	9.5	4.9	3.7	2.9	2.010
3	11.2	5.9	4.4	3.3	2.411
4	12.4	6.3	4.8	3.7	2.664

Readout modes implemented in GSAOI

Mode	Fowler Sampling	NDRs	Read Noise	Readout time	Min. Exp. Time
Bright Object	1	2	28 e-	10.0 sec	5.3 sec
Faint Object	4	8	13 e-	26.2 sec	21.1 sec
Very Faint Object	8	16	10 e-	47.7 sec	42.2 sec

From Commissioning/SV to Operations

10 years of development ~100 night of commissioning



- | Aug 2012 - Call for System Verification process:
 - 28 proposals requesting 138 hours (offered ~60 hours) --> oversubscription factor of 2.3!!!
 - 13 programs observed between Dec 2012 - March 2013 --> 89% completion
- | September 2012 - regular call for proposal for 2013B
 - 16 programs accepted (184 hours) --> oversubscription factor of 2

2014 - GeMS moved to regular science operations



François Rigaut, Benoit Neichel, Rodrigo Carrasco, Fabrice Vidal, Marcos A. van Dam, Vincent Garrel, Maxime Boccas, Céline d'Orgeville, Gustavo Arriagada, Vincent Fesquet, Ramon L. Galvez, Gaston Gausachs, Chad Cavedoni, Angelic W. Ebberts, Stan Karewicz, Eric James, Javier Lührs, Vanessa Montes, Gabriel Perez, William, N. Rambold, Roberto Rojas, Shane Walker, Matthieu Bec, Gelys Trancho, Michael Sheehan, Benjamin Irarrazaval, Corinne Boyer, Brent L. Ellerbroek, Ralf Flicker, Damien Gratadour, Aurea Garcia-Rissmann, Felipe Daruich, Constanza, Araujo, Alvaro Arias, Andrew Cardwell,, Emanuel Costa, Sarah Diggs, Camila Duran, Ariel Lopez, Claudio Marchant, Eduardo Marin, Cristian Moreno, Peter Pessev, Rolando Rogers, Carlos Segura, Andrew Serio, Chad Trujillo, Cristian Urrutia, Patricio Veliz, Tomislav Vucina, Claudia Winge, Michelle Edwards, Etienne Artigau, and many others

- * A long path since January 2011 → 1.8 years of commissioning
- * GeMS/GSAOI Commissioning completed at the end of January 2013 → some pending tasks: e.g. ODGW fast tip-tilt mode
- * Lesson learned
 - * Operate GeMS is not straightforward
 - * Key resources are required to support GeMS/GSAOI for every night
 - * System efficiency could be significantly improved (current SE ~ 50%)
 - * AO performance is average (**from an AO Scientist Point of View** 😊!!!)

From Comm./SV to Operations

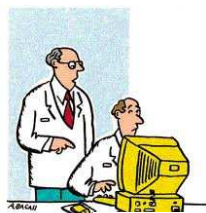
Current support



→ 3 Spotters



→ 1 laser technician



→ AO Scientists



→ Instrument operator



→ Telescope operator

7 people + Eng. Support

Requires a good coordination



GOAL

1 Laser Tech + 1 tel. operator
+ 1 Instrument Operator

GeMS/GSAOI on-sky performance

Gemini Observatory, GeMS-GSAOI first light

NGC288, H band
13mn exposure

Field of View 87"x87"
FWHM = 0.080"
FWHM rms = 0.002"

NIRI/Altair FoV
(22" x 22")

Gemini Observatory, GeMS/GSAOI
NGC2362, H band, 195s exposure
Single field, 85"x85"

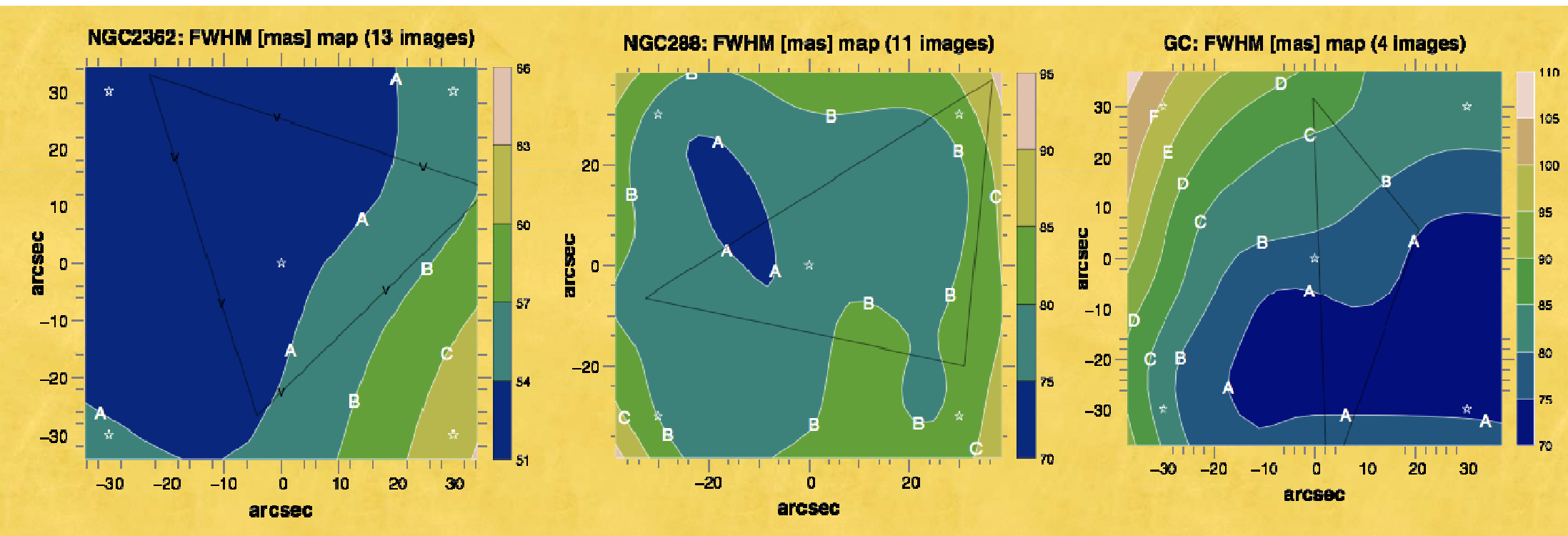
Q3: FWHM = 52.5 $\pm$ 2.5 mas Ellipticity = 9 $\pm$ 2% Strehl = 35.1 $\pm$ 1.3%

Q2: FWHM = 53.3 $\pm$ 3.7 mas Ellipticity = 7 $\pm$ 4% Strehl = 32.9 $\pm$ 2.6%

Q4: FWHM = 56.2 $\pm$ 4.1 mas Ellipticity = 10 $\pm$ 4% Strehl = 24.2 $\pm$ 6.3%

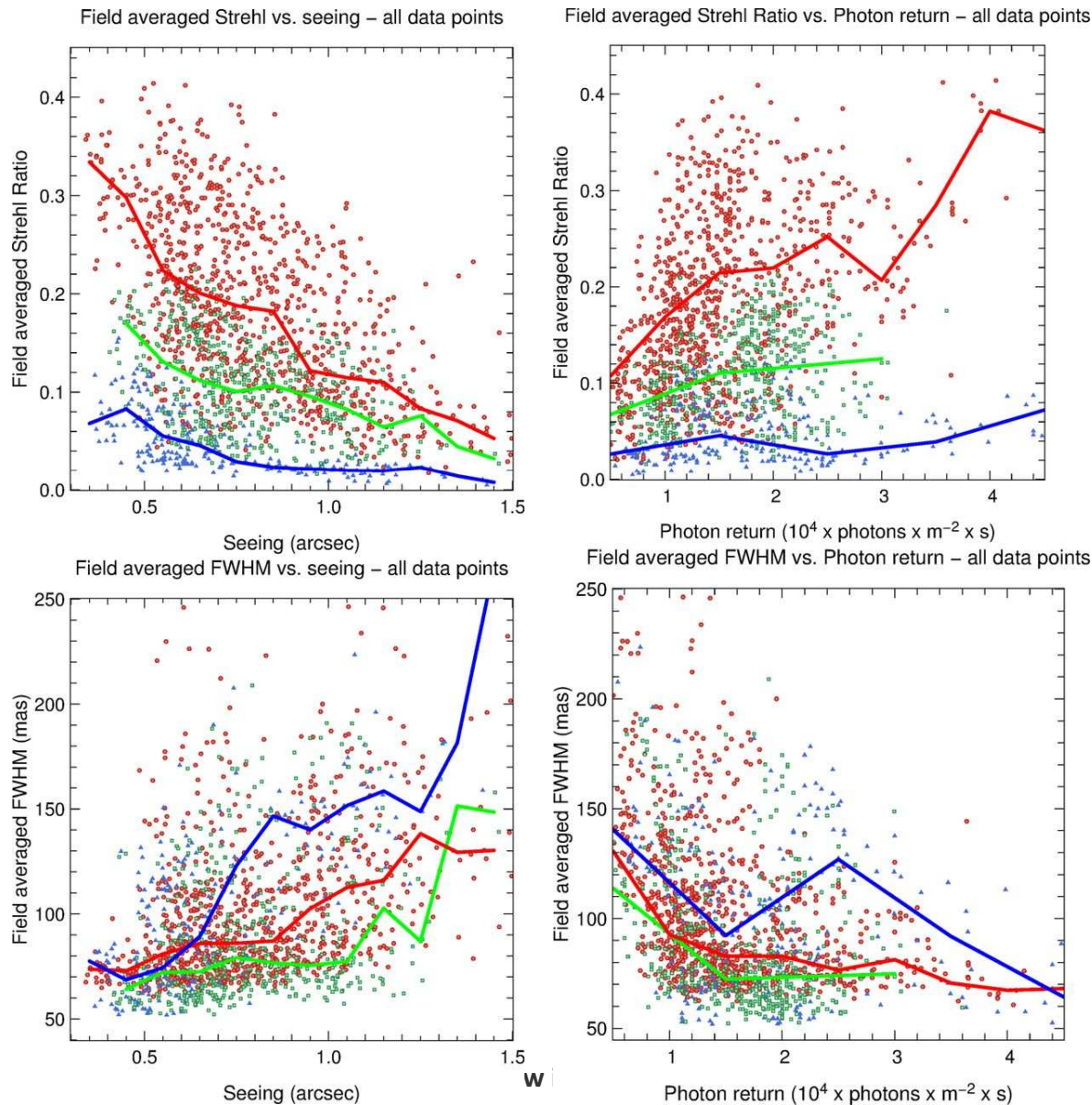
Q1: FWHM = 58.4 $\pm$ 4.3 mas Ellipticity = 12 $\pm$ 7% Strehl = 27.3 $\pm$ 3.0%

Data set	#images	total exptime	lambda [mic]	Seeing ["]	Loop freq. [Hz]	FWHM avg [mas]	FWHM rms [mas]	Strehl (avg) [%]
NGC2362	13	195s	1,65	0,3	250	53	2,0	30
NGC288	11	780s	1,65	0,65	200	80	2,5	18
GC	4	60s	2,10	0,6	300	84	3,5	19



PSF is uniform, with 3-4% FWHM relative variations over GSAOI field of view

Average Strehl and FWHM delivered by GeMS (Neichel et al. 2014, MNRAS, 440, 1002)



- Based on observations performed between December 2012 and May 2013 (33 nights)
- Using 3 NGS, images with $t_{\text{exp}} > 10$ sec and 950, 454 and 243 GSAOI scientific images in K, H and J bands. Median seeing 0.73" (at 550nm).

Table 1. Delivered average Strehl ratios for different seeing conditions (seeing @ 550nm)

Natural Seeing @550nm	Strehl ratio (J)	Strehl ratio (H)	Strehl ratio (K)	Gemini IQ constrain (zenith)
<0.45"	10%	15%	30%	20%-ile
0.45" - 0.80"	5%	10%	15%	70%-ile
0.80" - 1.00"	2%	5%	10%	85%-ile

Table 2. Delivered FWHM for different seeing conditions (seeing @ 550nm)

Natural Seeing @550nm	FWHM (J)	FWHM (H)	FWHM (K)	Gemini IQ constrain (zenith)
<0.45"	0.08"	0.07"	0.06"	20%-ile
0.45" - 0.80"	0.13"	0.10"	0.09"	70%-ile
0.80" - 1.00"	0.15"	0.13"	0.12"	85%-ile

Original requirements for IQ=20%-ile

Filter	J	H	K
Strehl	16%	35%	55%

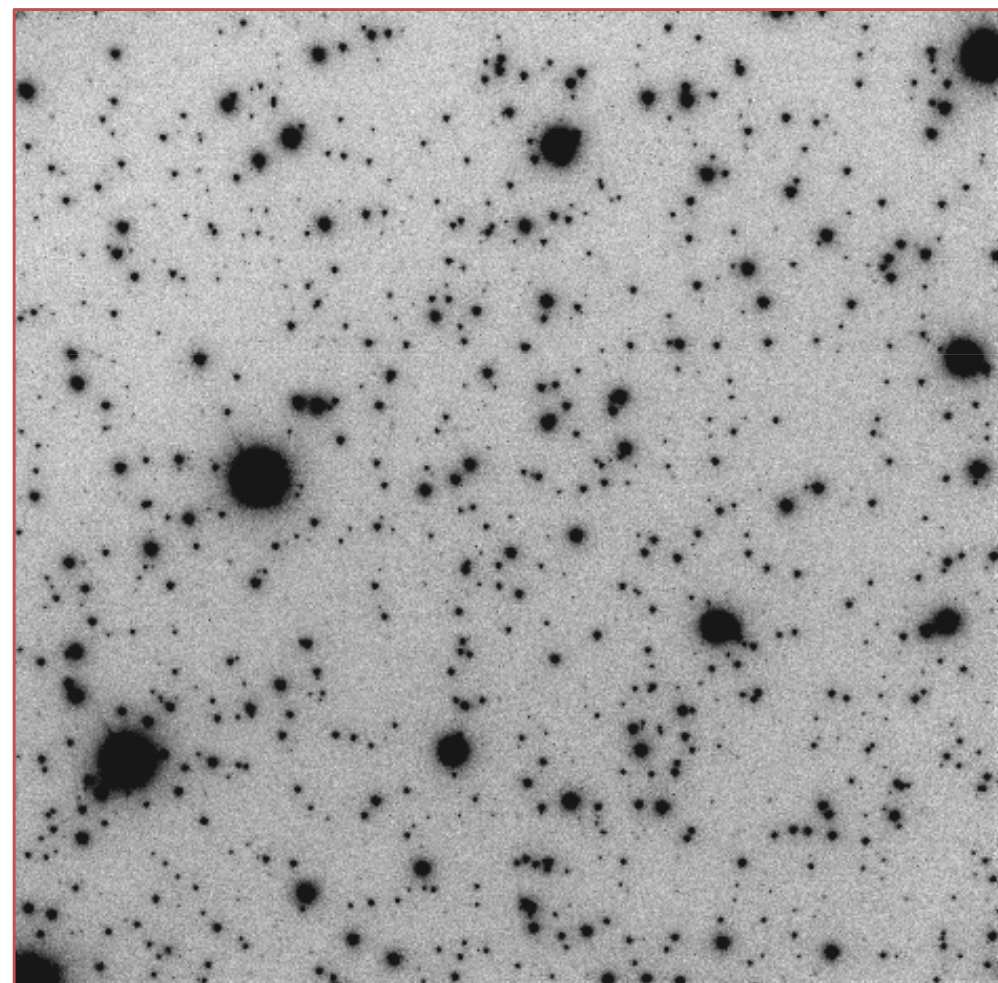
GeMS/GSAOI System throughput

- ✱ End-to-end system throughput calculated from the measured zero points (Dec. 2011 - April 2012).
- For H and K the throughput obtained are better than the throughput assumed for the instrument initially (0.23). For J band is similar.

Carrasco et al. 2012, SPIE, vol. 8447

Run	Filters		
	T _J	T _H	T _K
May 2011	0.24	0.35	0.24
Dec 2011		0.39	
Jan 2012	0.19	0.32	0.28
April 2012	0.21	0.38	0.28

NGC 288, 13 minutes (13 x 60sec)
H-band, FWHM=<0.08">



Photometric Zero Points and Background Surface Brightness

- * Photometric ZP. Measured using aperture photometry with DAOPHOT
 - * Aperture size: 1.4 FWHM
 - * Instrumental magnitudes ($m_\lambda = -2.5 * \log (F_\lambda)$) compared with the 2MASS magnitudes (or with other catalogs when available).

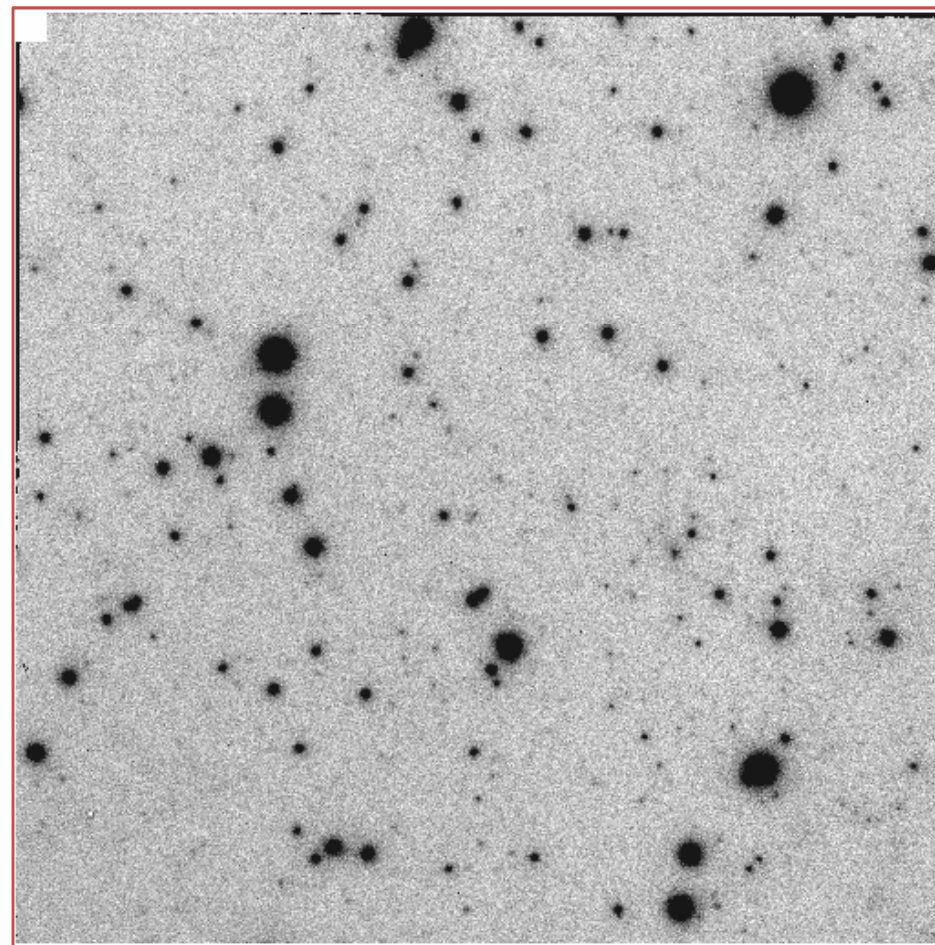
	Filters						
	J		H		K _s		
Date (UT)	ZP	S.B.	ZP	S.B.	ZP	S.B.	Comments
20110518	-26.59	14.94	-26.63	13.19	-26.17	12.10	Dust in the cryostat window
20111216			-26.75	13.29			Cryostat window cleaned
20120112	-26.30	15.65	-26.51	13.68	-25.95	12.18	
20120215	-26.09	15.09	-26.01	13.18	-25.08	11.09	cryostat window coating damage
20120415	-26.43	15.31	-26.72	13.80	-26.12	12.38	New Cryostat window installed
20120430			-26.65	13.93			

- * Sky brightness at Cerro Pachón:
 - * $\mu_J = 16.2 \text{ mag/["]}$,
 $\mu_H = 13.8 \text{ mag/["]}$,
 $\mu_K = 14.6 \text{ mag/["]}$
 - * Differences in J-band and K_s

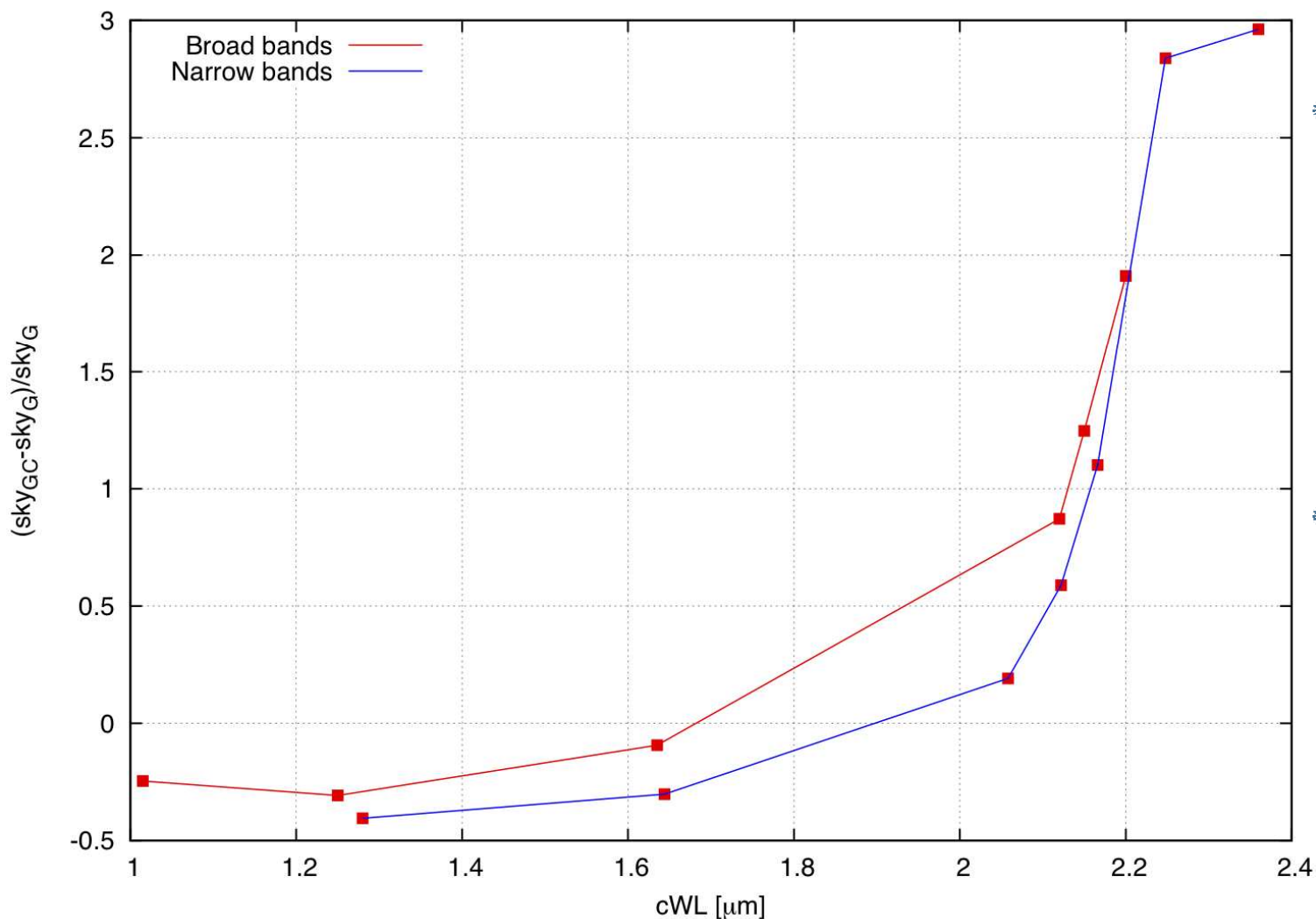
Stability of the photometry

- ✱ LMC observations (2012 Feb):
 - ✱ Large offsets ($\sim 10''$)
 - ✱ Comparing the magnitudes of the same stars observed in different arrays.
- ✱ Main differences between arrays
 - $\Delta m_{1,2} = -0.015$
 - $\Delta m_{1,3} = -0.032$
 - $\Delta m_{1,4} = -0.030$
- Photometric accuracy: ~ 0.05 mag
- Difference due to:
 - Flat fielding
 - Accuracy in the Gain determination

LMC Astrometric field (Array. 3)

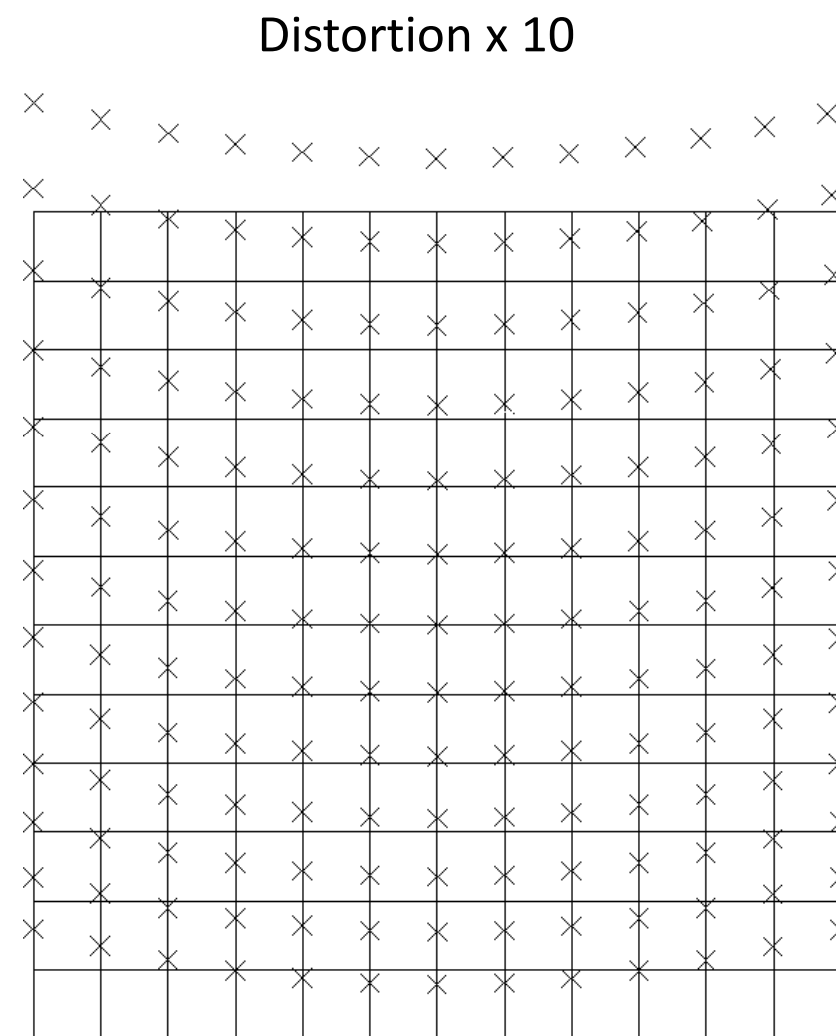


Background brightness



- * Determination of background contribution from CANOPUS using observations of sky blank fields with GSAOI+CANOPUS and with GSAOI by-passing CANOPUS.
- * Large contribution in the thermal background (>1.8 microns) from CANOPUS

- ✱ The GSAOI field is distorted by the off-axis parabola system used in GeMS.
- ✱ The good news -- most of the distortion can be calibrated out.
- ✱ The bad news -- residual “dynamic” distortion --> depends on NGS asterism --> difficult to remove
- ✱ Affects data reduction --> mosaic and combine images



GeMS performance is limited by:

- * Laser
 - * Stability
 - * BTO transmission and polarization improvement --> on-going
 - * Laser beam quality
 - * Low photon return during the summer (December - March)
 - * More laser power --> feasibility to acquire a new laser for 2015+
- * Canopus
 - * Limiting magnitude for NGS WFS is not what was expected: problems in the design flow and alignment issues
 - * current limiting magnitude $R=15.5$ ($R=17.5$ original --> limited sky coverage)
 - * New NGS are expected to be installed in 2015 (ANU/Gemini effort) --> $R=17.5 - 18.0$

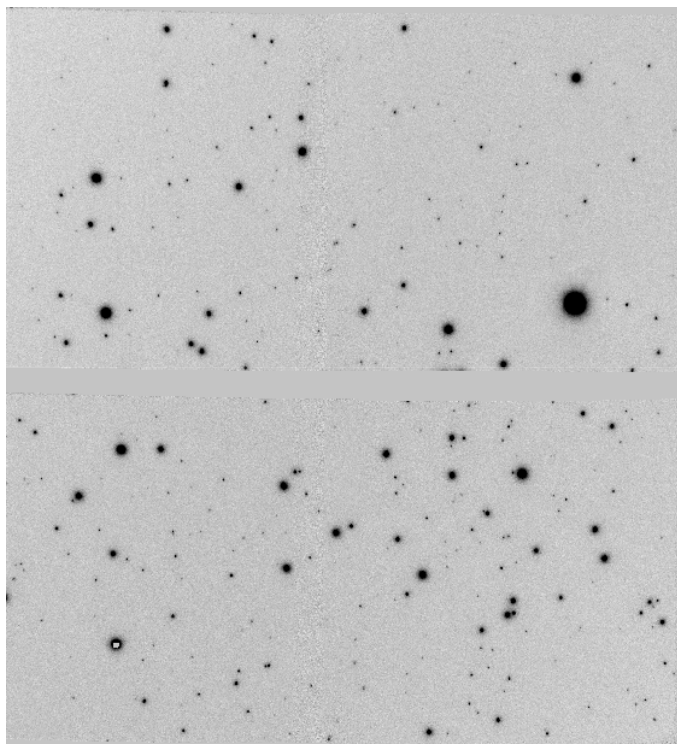
Science with GeMS/GSAOI

Key Science drivers for GeMS identified by Gemini Community, SC, CA, October 2000

- * Low mass stellar and sub-stellar mass functions in young star-forming regions.
- * Stellar population variations in star-forming regions (e.g. Ophiuchus).
- * Open cluster mass functions to the bottom of the H-burning sequence and the end of the white dwarf cooling sequence to provide independent age determinations.
- * Mass functions in nearby globular clusters over a range of metallicities.
- * Stellar populations of super-star cluster analogs in the Galaxy and Magellanic Clouds such as NGC 3603 and 30 Doradus.
- * SN1a zero point calibration via red giant branch tip star distances to E/S0 galaxies.
- * Stellar populations in starburst regions of nearby galaxies.
- * Evolution of dIrr versus dE galaxies in different environments.
- * Early chemical histories of nearby galaxy spheroids.
- * Intergalactic stars in nearby galaxy clusters.
- * Color distributions among extragalactic globular clusters.
- * Spatially resolved spectral energy distributions of high redshift field galaxies.
- * Evolution of galaxies in high redshift clusters.

Haffner 16: A Young Moving Group in the Making

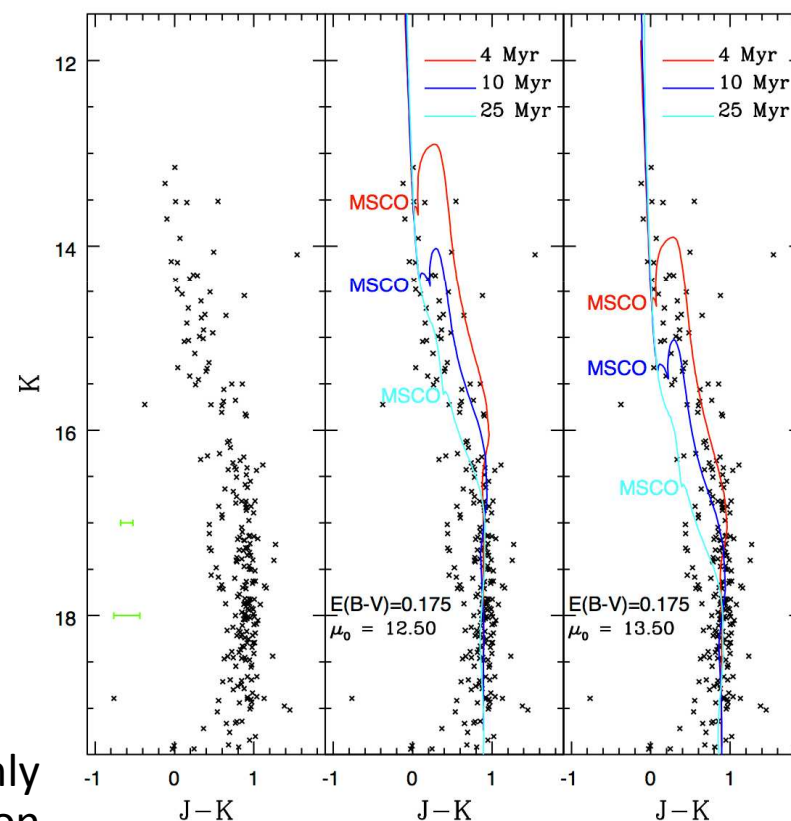
[T. J. Davidge](#), E. R. Carrasco, [C. Winge](#), [P. Pessev](#), B. Neichel, [F. Vidal](#), [F. Rigaut](#), 2013, PASP, [125](#), 1181



FWHM in J: 0.24"
FWHM in K: 0.15"

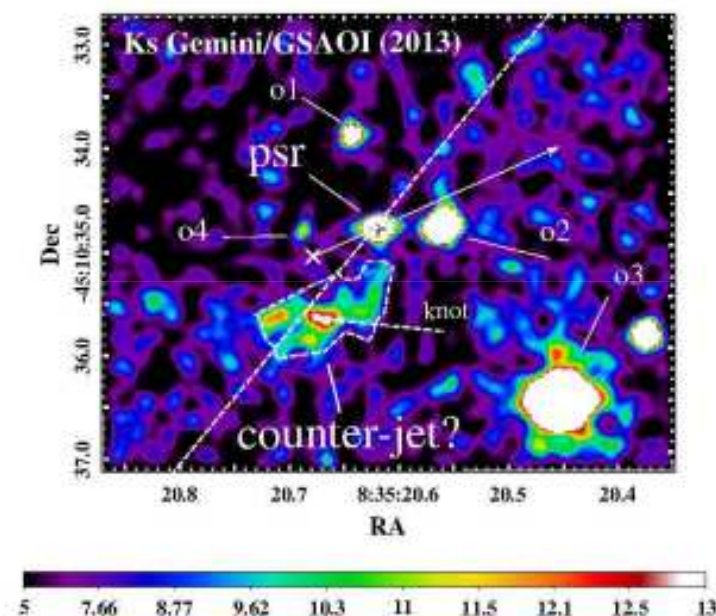
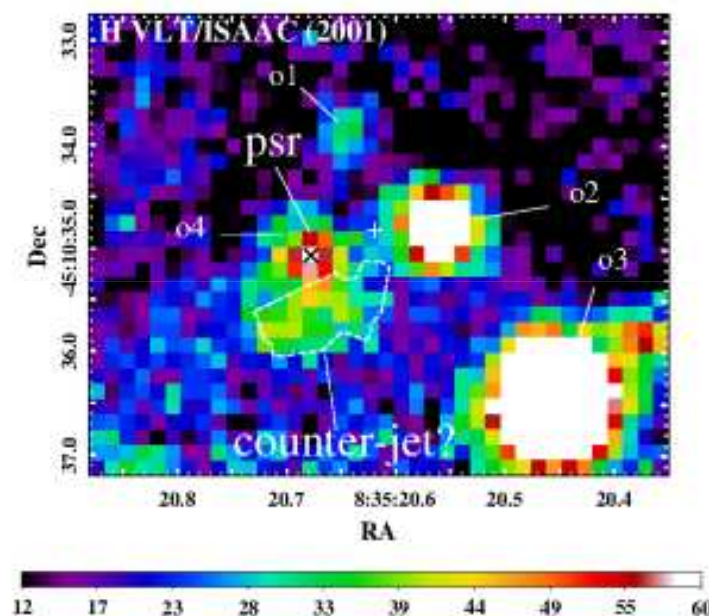
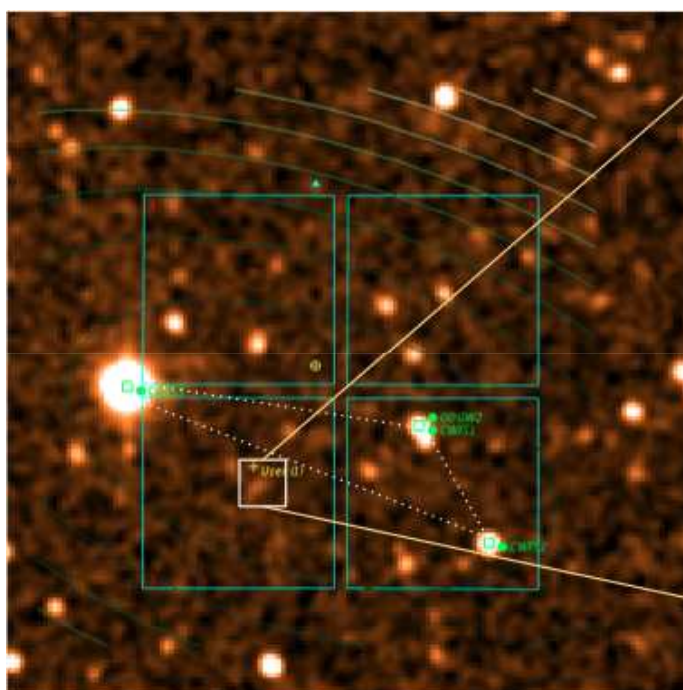
Gemini IQ=85%-ile

- A rich population of PMS stars is identified with an age < 10 Myr
- When compared with the solar neighborhood, Haffner 16 is roughly a factor of two deficient in objects with sub-solar masses.
- PMS objects in the cluster are also more uniformly distributed on the sky than bright MS stars.



The Vela pulsar and its likely counter-jet in K_s band

D. Zyuzin, Yu. Shibano, A. Danilenko, R. E. Mennickent, and S. Zharikov, 2013, ApJ, 775, 101

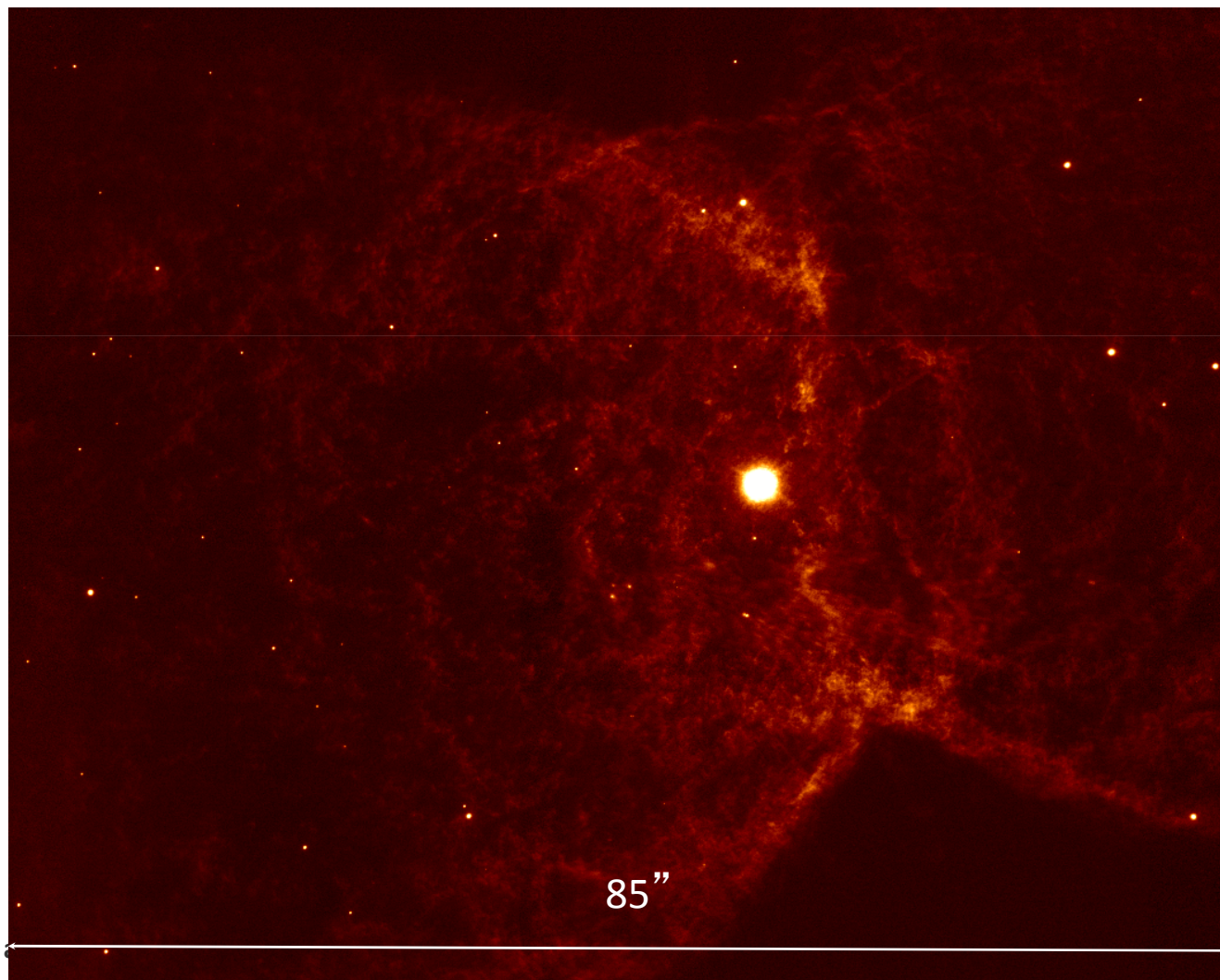


For the first time, we have firmly detected the pulsar in K_s band with K_s~21.8 mag, and have resolved in detail an extended feature barely detected previously in the immediate vicinity of the pulsar in the J_sH bands. The pulsar K_s flux is fully consistent with the extension of the flat optical spectrum of the pulsar toward the IR and does not confirm the strong IR flux excess in the pulsar emission suggested earlier by the low spatial resolution data. The extended feature is about two times brighter than the pulsar and is likely associated with its X-ray counter-jet. It extends ~2" southward of the pulsar along the X-ray counter-jet and shows knot-like structures and a red spectrum.

Galactic planetary nebula NGC 2346 with GeMS/GSAOI (L Stanghellini, A. Manchado, R. Shaw, A. Garcia-Hernandez, E. Villaver, P. Garcia-Lario)

Observations: narrow-band H2 1-0 S(1) 2.122, Br γ 2.166, and H2 2-1 S(1) 2.248 nm filters; observing time 3h including overhead for all filters, bright H2 image only needed 1/3h. Final combined, distortion corrected, dithered images FWHM $\sim$ 0.08'' for the H2 1-0 image

“The images shows unprecedented detail (FWHM 0.08'' across field) which is ideal to study in details the knots and filaments expected in such a PN. The pixel size is 7 AU at the distance of NGC 2346, by comparison, the Helix program on HST was based on resolving knots of 28 AU”



Low mass

g regions

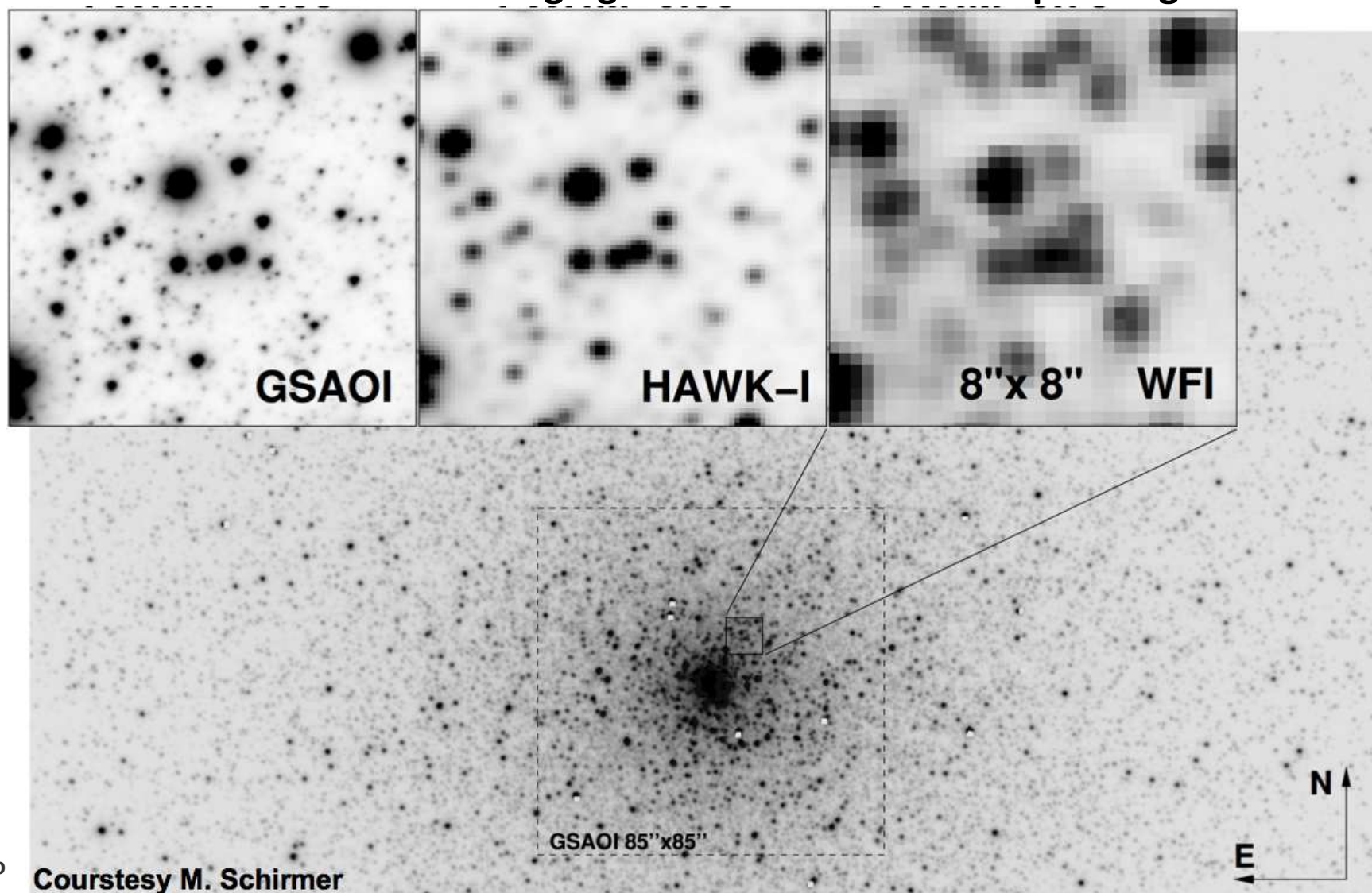
and A. Damineli

s have been suggested
nd of the IMF in R136
t about 2 Msun

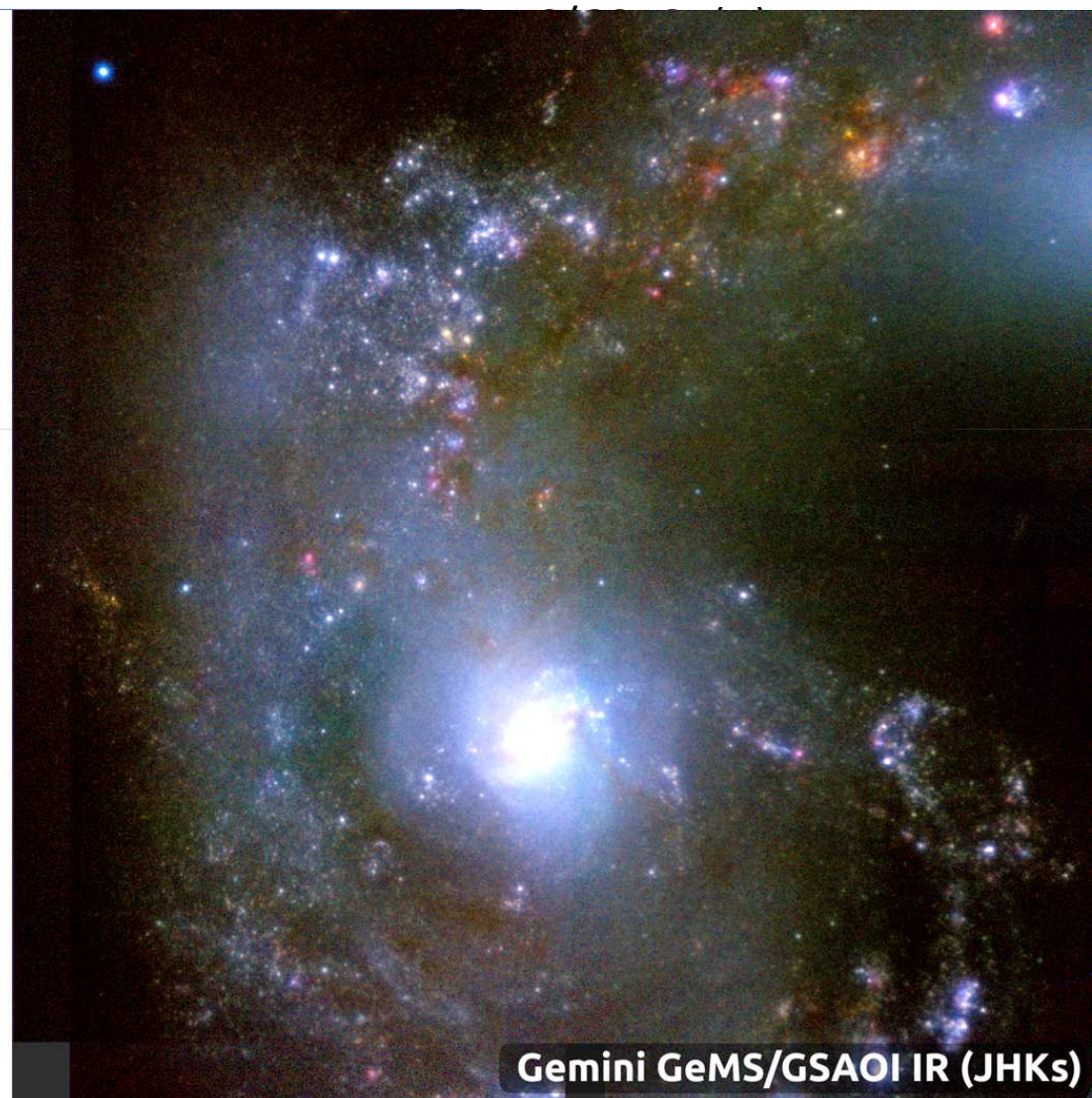
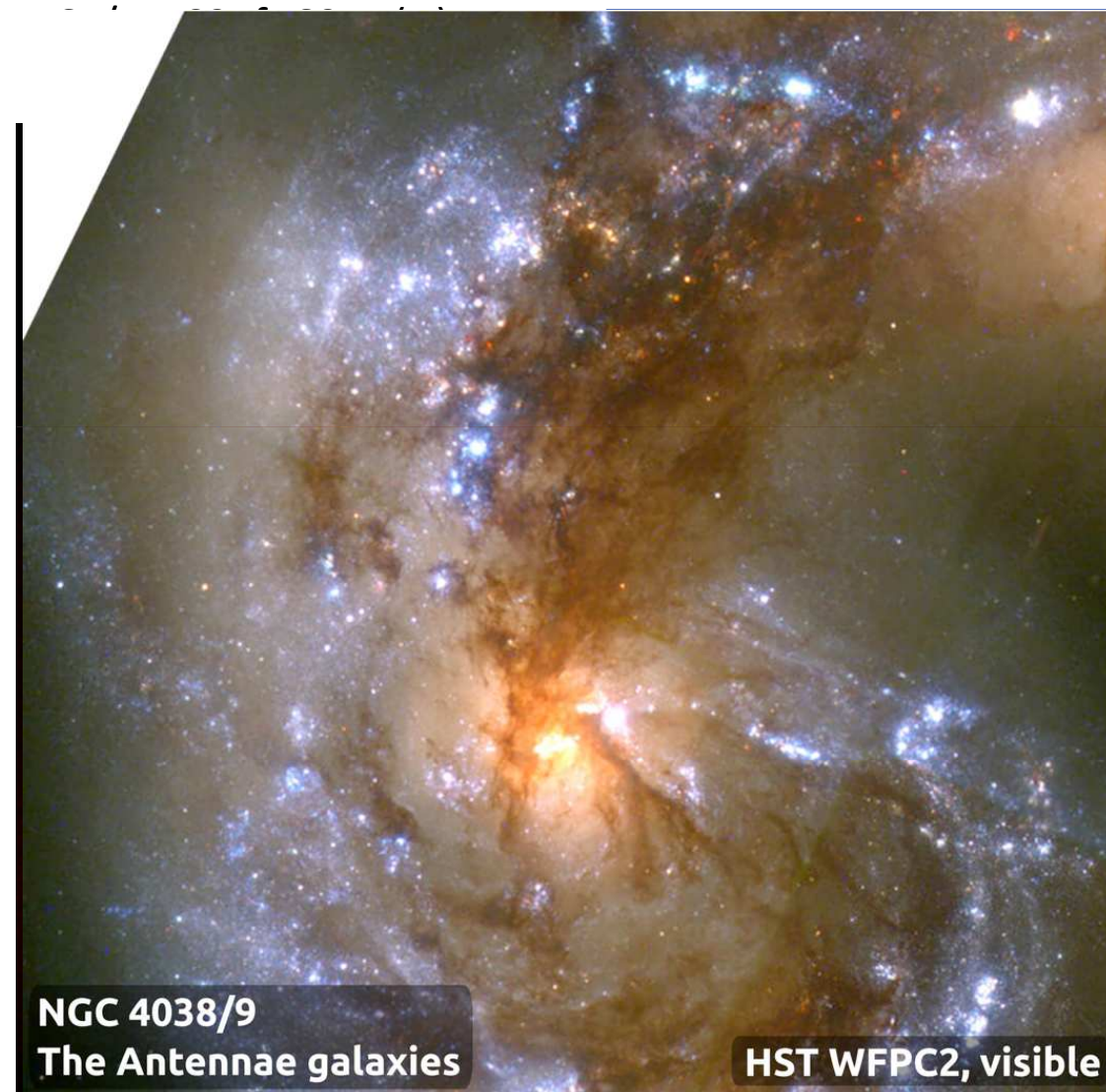
deep images in JHKs
ole cluster R136/R141-
the pre main sequence
($M \sim 1$ Msun)

minutes per filter)
 $\sim 0.12'' - 0.18''$

Wide field imaging of NGC 1851: different pointings

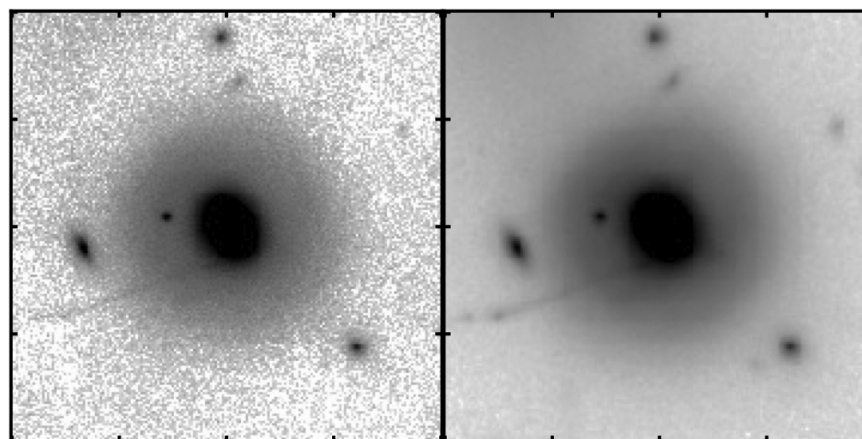
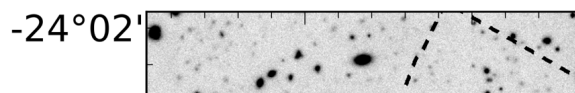


Young Star clusters in merging/interacting systems



* 5.3 hours of on-source

HST/WFC3 F160W



p Ks-images
IS/GSAOI

122", only one NGS used

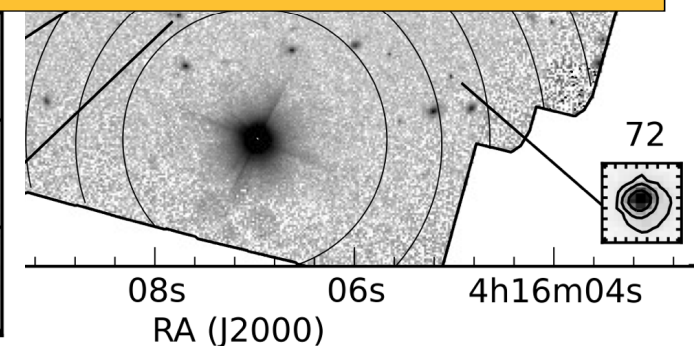
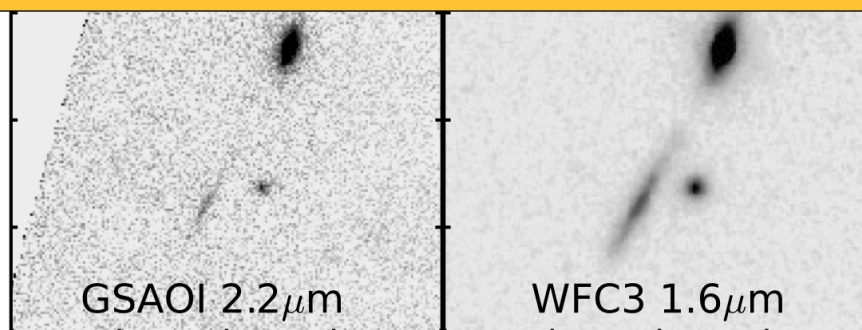
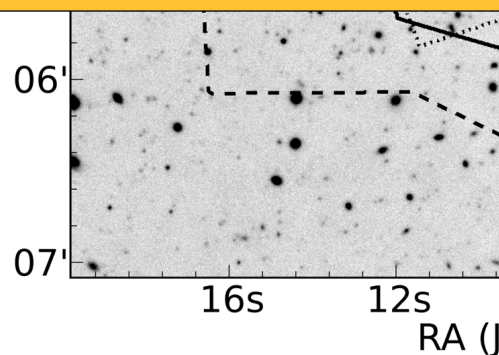
GeMS/GSAOI Ks-band



* GS-2013B-DD-1 -> Raw data is public and available from Gemini Science Archive

* Combined images with 0.02", 0.03" and 0.06" resolution (the last 2 match the HST/ACS and WFC3 data) will be available at end of August from Gemini/GeMS/GSAOI web pages.

* 2014B -> Deep Ks-band images of Abell 2744



Precise Astrometry with GeMS

GeMS/GSAOI can be used for precise astrometry due to the powerful combination of high spatial resolution and a large field of view. Potential astrometric science cases: exo-planets, star formation, stellar evolution, star clusters, nearby galaxies, black holes and neutron stars, and the Galactic center.

- * analysis of deep, mono-epoch images, multi-epoch images and distortion calibrated data (2011-2012)
- * an astrometric error below **0.2 mas** can be achieved for single epoch, not dithered data with exposure times > 60s, if enough stars are available in the field to remove high-order distortions
- this performance is not reproducible for **multi-epoch observations and dithered** data --> and an additional systematic error of **0.4 mas is evidence**

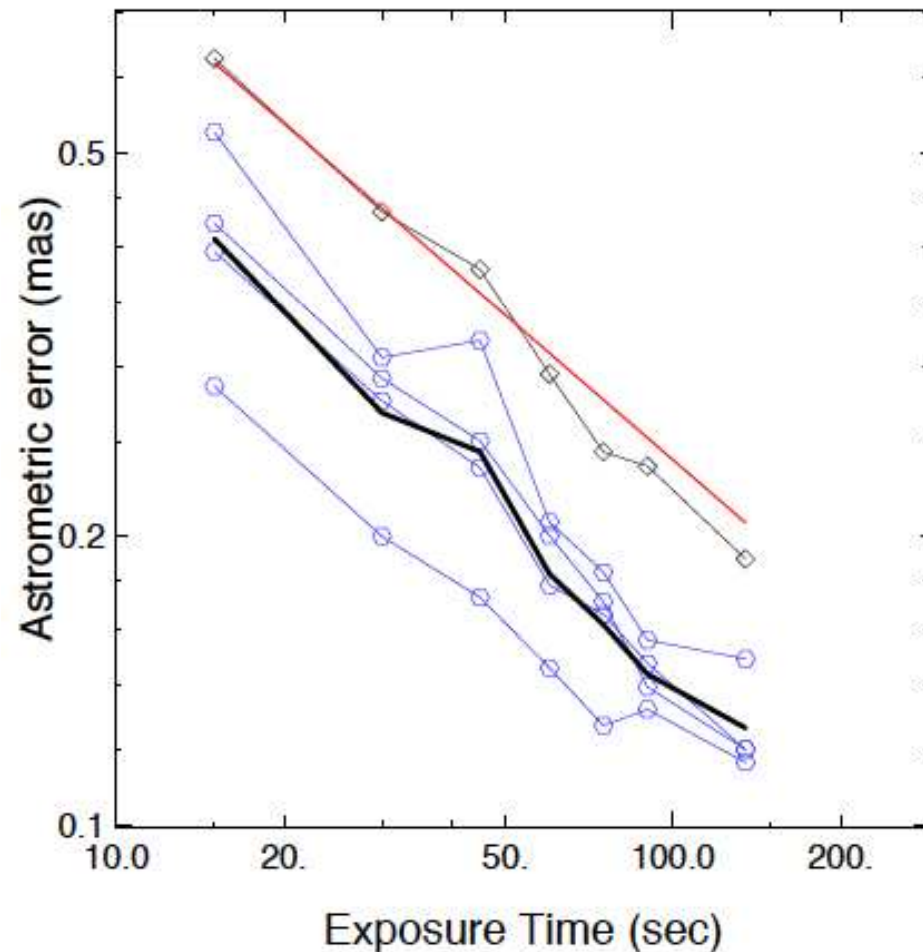
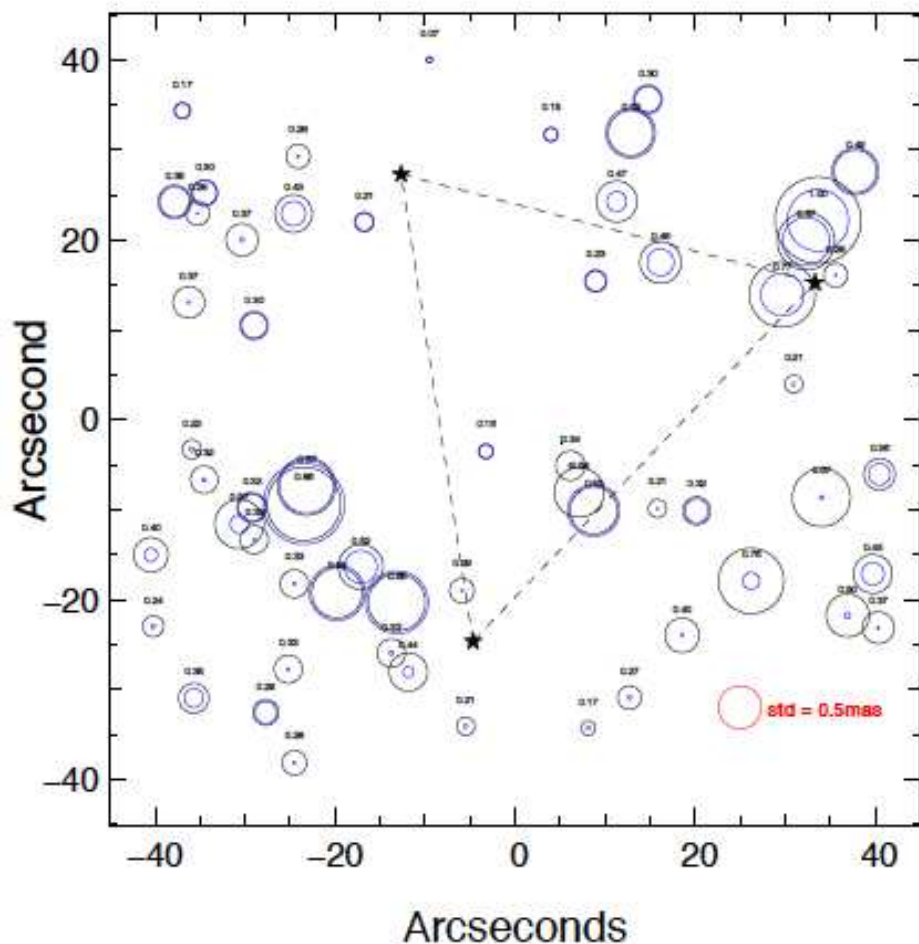
Neichel, Lu, Rigaut, Ammons, Carrasco & Lassalle (2014, MNRAS, submitted)

Astrometric error - single epoch, no dithering

NGC2362 – 19Dec – 15s.

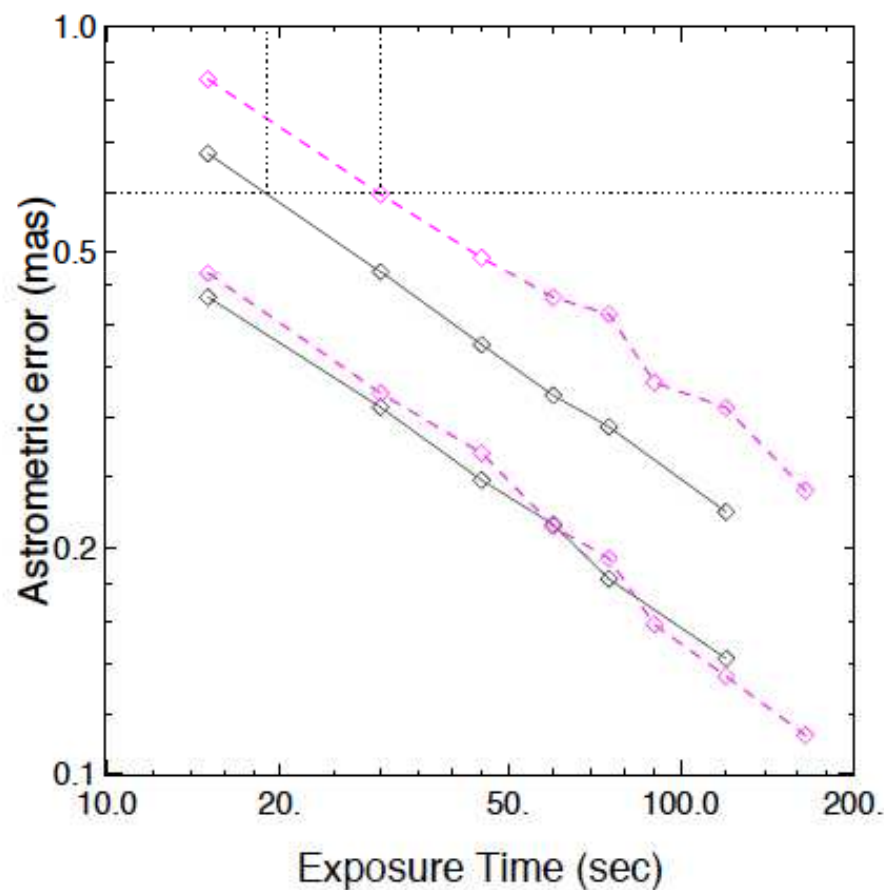
27 images

Quadrant vs. full-frame



Astrometric error - single epoch, dithering and no dithering data

35 images observed with a 4-point square
dithering of 3" x 3"



Observing with GeMS/GSAOI

Great IDEA



submit your proposal with Phase I Tool

<http://www.gemini.edu/node/12176#PIT>

Untitled - Gemini PIT 2014B 2014.2.2

File Edit View Catalog Help

Overview

Title:

Abstract:

TAC Category: Select

Keywords: 0 Selected

Attachment: PDF attachment goes here.

Name	Institution	Phone	Email
Principal Investigator			

Overview Time Requests Scheduling Submit TAC

Observations

Group by: Conditions Resources Targets

Item	Time	Guiding	Vis	GSA
------	------	---------	-----	-----

Sum observation times: 0.00 hr

| Lookup

Observations Band 3 Targets

Problems

Description	Section
☐ Please create observations with conditions, targets, and resources.	Observations
☐ Please provide a PDF attachment.	Overview
☐ Please provide a title.	Overview
☐ Please provide an abstract.	Overview
☐ Please provide full contact information for Principal Investigator.	Overview

Ready

When the proposal is accepted  **Phase II using the Observing Tool**

Gemini Observing Tool (OT)

“Software used for detailed definition and pre-planning of observations from approved proposals during the Phase II process. The OT is also the high-level interface for on-site (classical and staff) observers. It supports observations with all facility instruments.”

Other Tools used by the observers (Gemini staff and classical observers) with GeMS/GSAOI

- *GSAOI Instrument Status Display
- *MCAO Yorick Smart tool (MYST) to monitor the GeMS loops, LCH shutter windows, etc.
- *On-site IRAF/PyRAF installation and the GSAOI package
- *ODWG Quick Look Tool monitor
- *Telemetry tools for on-site real time quality assessment (Strehl and AO corrected FWHM values)

Target component

GSAOI component

GeMS component

GSAOI sequence component

Offset iterators

Science Program Editor - Example program

File Edit View Go Help

Open Back Forward Cut Copy Paste Plot Image Libraries Apply Reapply Edit

Observation

Group

Note

Component

Iterator

Observe

Example program

- [1] NGC 2362 (07h18m, -24)
- Observing Conditions
- Targets (NGC 2362)
- GSAOI
- GeMS Adaptive Optics
- Sequence
- GSAOI Sequence
 - Offsets: on-source
 - Observe (1X)
 - Offsets: sky
 - Observe (1X)

Target Environment

Use this component to enter the base position and wave front sensor targets for this observation.

Type Tag	Name	RA	Dec	Dist	B	V	R	J	H	K
Base	NGC 2362	07:18:35.939	-24:58:33.66	0						
CWFS1 (1)	0650-0125281	07:18:34.083	-24:58:01.05	0.69		11.47	12.06	11.479	11.259	11.177
CWFS2 (1)	0650-0125290	07:18:34.486	-24:59:17.13	0.8	10.984	11.145	11.25	11.394	11.344	11.318
CWFS3 (1)	0650-0125360	07:18:38.413	-24:58:20.04	0.6	9.432	9.641	9.76	9.831	9.911	9.891
ODGW2 (1)	0650-0125290	07:18:34.486	-24:59:17.13	0.8	10.984	11.145	11.25	11.394	11.344	11.318

Base Name NGC 2362

J2000 RA 07:18:35.939 Dec -24:58:33.66

Brightness Select →

Proper Motion RA 0.0 mas/year Dec 0.0 mas/year

Tracking Details

Image... Set Base From Image Manual GS... Auto GS Canopus

Auto GS will select: CWFS1

Show

Save Close

GSAOI observing sequence

See details at:

<http://www.gemini.edu/sciops/instruments/gsaoi/observation-preparation?q=node/11864>

Target Component

Target Environment

Use this component to enter the base position and wave front sensor targets for this observation.

Type Tag	Name	RA	Dec	Dist	V	R	J	H	K
● Base	OmegaCen	13:27:04.557	-47:26:01.17	0					
● CWFS1 (1)	0425-0432714	13:27:06.474	-47:25:23.44	0.71		10.94	8.955	8.199	8.065
● CWFS2 (1)	0425-0432435	13:27:00.552	-47:26:41.56	0.95		11.3	9.496	8.817	8.66
● CWFS3 (1)	0425-0432880	13:27:09.312	-47:26:04.48	0.81	11.6	11.48	9.655	8.978	8.802
● ODGW3 (1)	0425-0432485	13:27:01.681	-47:25:42.91	0.57			11.279	10.743	10.589








ODGW3 Name 0425-0432485 

J2000 RA 13:27:01.681 Dec -47:25:42.91

Brightness

✖ 11.279 J Vega
 ✖ 10.743 H Vega
 ✖ 10.589 K Vega


Proper Motion

RA 0.0 mas/year
 Dec 0.0 mas/year

Tracking Details

Image... Set Base From Image Manual GS... Auto GS Canopus

GSAOI Instrument Component

GSAOI

The GSAOI instrument is configured with this component.

Filter: Pos Angle: deg E of N

Exp Time: sec Coadds: exp/obs

Below recommendation (43.2 sec).

Read Mode \ ISS Port \

☒ Bright Objects
☐ Faint Objects / Broad-band Imaging
☐ Very Faint Objects / Narrow-band Imaging

Low Noise Reads: 2
 Read Noise: 28e-
 Exposure Time: >43.2 sec (recommended) 5.3 sec (min)

Filters

H2O ice (2.000 um)
 HeI (2p2s) (2.058 um)
 Ks-continuum (2.093 um)
 Br(gamma) (2.166 um)
 KI-continuum (2.270 um)
 K(prime) (2.120 um)
 H2 1-0 S(1) (2.122 um)
 K(short) (2.150 um)

GeMS component

GeMS Adaptive Optics

The GeMS Adaptive Optics system is configured with this component.

Atmospheric Dispersion Corrector ☐ On

Dichroic Beamsplitter ☒ 0.85 um
☐ 1 um

Astrometric Mode ☒ Off
☐ Regular
☐ Good
☐ Best

GSAOI Sequence Component

GSAOI Sequence Component
Iterate over GSAOI configurations with this component.

Title: GSAOI Sequence

Select Filter

- [Fe II] (1.644 um)
- CH4(long) (1.690 um)
- H2O ice (2.000 um)
- HeI (2p2s) (2.058 um)
- Ks-continuum (2.093 um)
- Br(gamma) (2.166 um)
- KI-continuum (2.270 um)
- K(prime) (2.120 um)
- H2 1-0 S(1) (2.122 um)
- K(short) (2.150 um)**
- K (2.200 um)
- H2 2-1 S(1) (2.248 um)

Available Items

- Coadds
- Exposure Time
- Filter**
- Read Mode
- ODGW Size
- Region of Interest
- Utility Wheel

Iteration Configuration (7 Items, 2 Steps)

Coadds	Exposure T...	Filter	ODGW Size	Read Mode	Region of In...	Utility Wheel
1	15.0	H (1.635 um)	64	Bright Obje...	Full Array	Clear
1	15.0	K(short) (2....	64	Bright Obje...	Full Array	Clear

Engineering component
(hidden in PI programs)

Utility wheel

Select Utility Wheel

- Extra-focal lens 1
- Extra-focal lens 2
- Pupil Imager
- Clear**

ODGW size

Select ODGW Size

- 4
- 6
- 8
- 16
- 32
- 64**

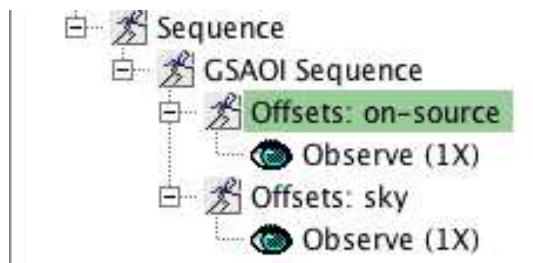
ROI setup (Phot. Std)

Select Region of Interest

- Full Array**
- Array 64
- Array 128
- Array 256
- Array 512
- Array 1K
- Central 64
- Central 128
- Central 256
- Central 512
- Central 1K
- Central 2K

Observing with GeMS/GSAOI

Offset iterator



Offset Sequence Component
Configure offset based patterns with this component.

Title: Offsets: on-source

Index	p	q	Guiding
0	0.0	0.0	on
1	4.0	4.0	on
2	-4.0	4.0	on
3	-4.0	-4.0	on
4	4.0	-4.0	on

Offset Sequence Component
Configure offset based patterns with this component.

Title: Offsets: sky

Index	p	q	Guiding
0	66.0	-150.0	off
1	70.0	-146.0	off
2	62.0	-146.0	off
3	62.0	-154.0	off
4	70.0	-154.0	off

Base Sequence Component

This component contains the sequence of operations that generates the observation science data.

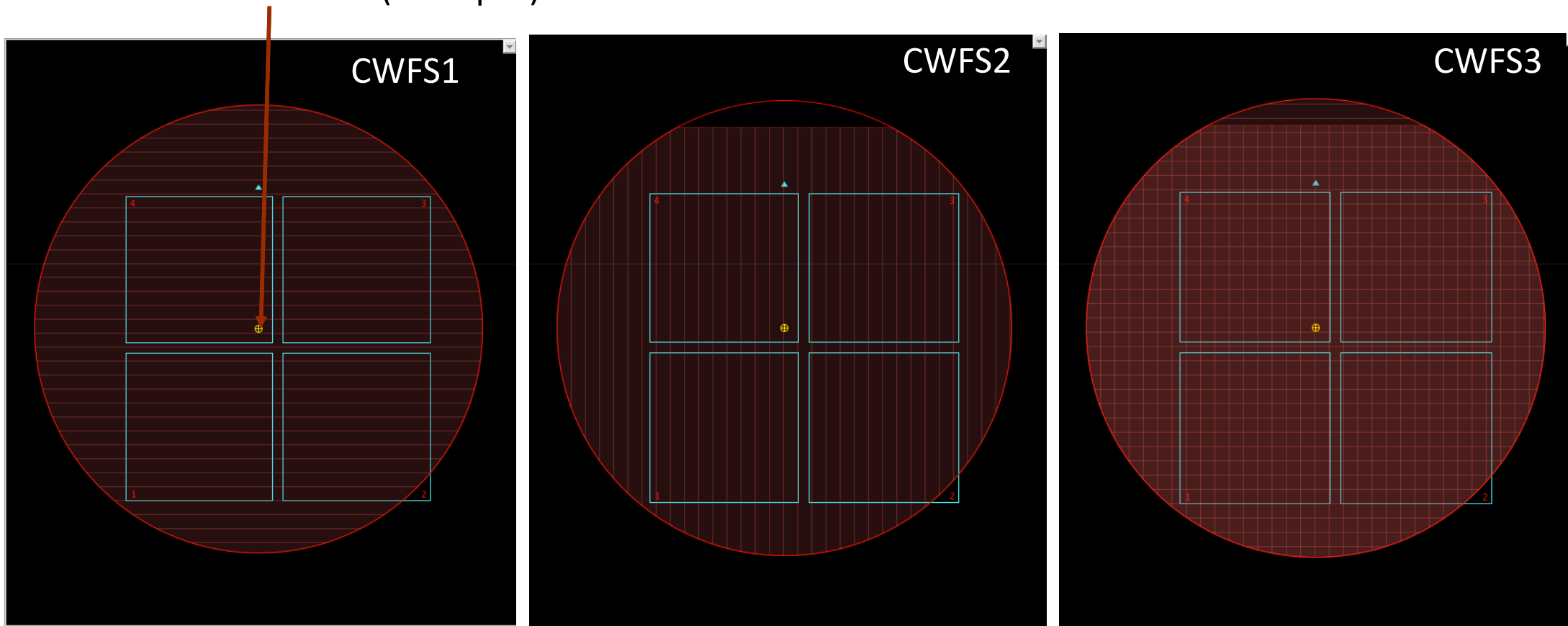
Title: Sequence

Sequence \ Timeline \

Data Label	Class	P	Q	Filter	Observing Wavelength	Guide With CWFS1	Guide With CWFS2	Guide With CWFS3	Guide With ODGW2
-001	Science	0.0	0.0	K(short) (2.150 um)	2.150	guide	guide	guide	guide
-002	Science	4.0	4.0	K(short) (2.150 um)	2.150	guide	guide	guide	guide
-003	Science	-4.0	4.0	K(short) (2.150 um)	2.150	guide	guide	guide	guide
-004	Science	-4.0	-4.0	K(short) (2.150 um)	2.150	guide	guide	guide	guide
-005	Science	4.0	-4.0	K(short) (2.150 um)	2.150	guide	guide	guide	guide
-006	Science	66.0	-150.0	K(short) (2.150 um)	2.150	freeze	freeze	freeze	freeze
-007	Science	70.0	-146.0	K(short) (2.150 um)	2.150	freeze	freeze	freeze	freeze
-008	Science	62.0	-146.0	K(short) (2.150 um)	2.150	freeze	freeze	freeze	freeze
-009	Science	62.0	-154.0	K(short) (2.150 um)	2.150	freeze	freeze	freeze	freeze
-010	Science	70.0	-154.0	K(short) (2.150 um)	2.150	freeze	freeze	freeze	freeze
-011	Science	0.0	0.0	CH4(short) (1.580 um)	1.580	guide	guide	guide	guide
-012	Science	4.0	4.0	CH4(short) (1.580 um)	1.580	guide	guide	guide	guide
-013	Science	-4.0	4.0	CH4(short) (1.580 um)	1.580	guide	guide	guide	guide
-014	Science	-4.0	-4.0	CH4(short) (1.580 um)	1.580	guide	guide	guide	guide
-015	Science	4.0	-4.0	CH4(short) (1.580 um)	1.580	guide	guide	guide	guide
-016	Science	66.0	-150.0	CH4(short) (1.580 um)	1.580	freeze	freeze	freeze	freeze
-017	Science	70.0	-146.0	CH4(short) (1.580 um)	1.580	freeze	freeze	freeze	freeze
-018	Science	62.0	-146.0	CH4(short) (1.580 um)	1.580	freeze	freeze	freeze	freeze
-019	Science	62.0	-154.0	CH4(short) (1.580 um)	1.580	freeze	freeze	freeze	freeze
-020	Science	70.0	-154.0	CH4(short) (1.580 um)	1.580	freeze	freeze	freeze	freeze

Position Editor: CWFSs patrol field area

GSAOI Base Position (Hot Spot)



Canopus field center at the GSAOI Base position Diameter: 2

Observing with GeMS/GSAOI

Position Editor - jsky9058302150519022303.fits

File View Go Graphics Catalog

Open Back Forward Cut Levels Catalogs Images Manual GS Auto GS

Browse
Drag
Erase

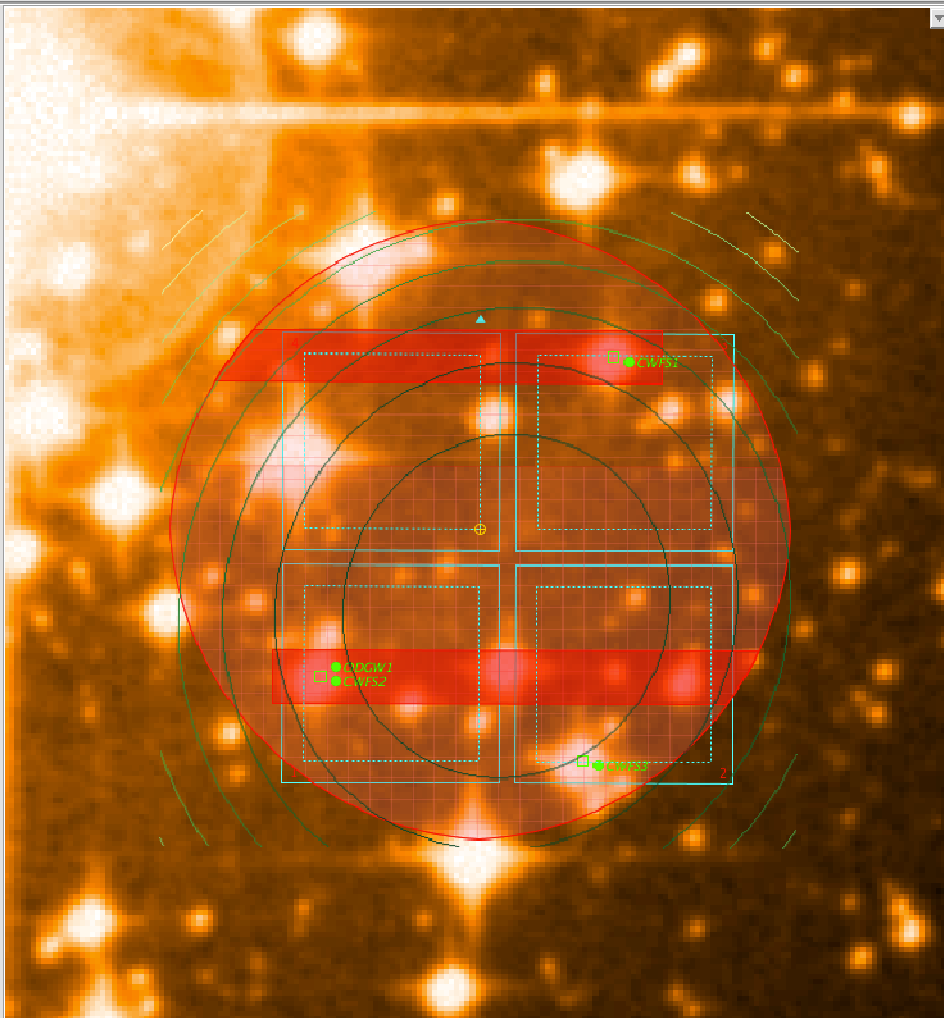
+ CWFS1
+ CWFS2
+ CWFS3
+ ODGW
+ PWFS1
+ Target
+ Offset

Target
☒ Base
☒ Guide
☐ Target
☒ Catalog
☐ Offset

Field Of View
☐ Acq Cam
☒ Canopus
☒ CWFS1
☒ CWFS2
☐ Both

☒ ODGW
☒ Strehl
☐ PWFS
☒ Science

Auto GS Options
☒ Canopus
☐ PWFS1



i Strehl: avg=31 ± 0.2, min=30.7, max=31.1, FWHM=0.06

4x 392.2, 351.5 13210.0 07:18:39.923, -25:00:09.75 J2000 CASB -- STScI Fpg

Position Editor - jsky8190757475285600840.fits.gz

File View Go Graphics Catalog

Open Back Forward Cut Levels Catalogs Images Manual GS Auto GS

Browse
Drag
Erase

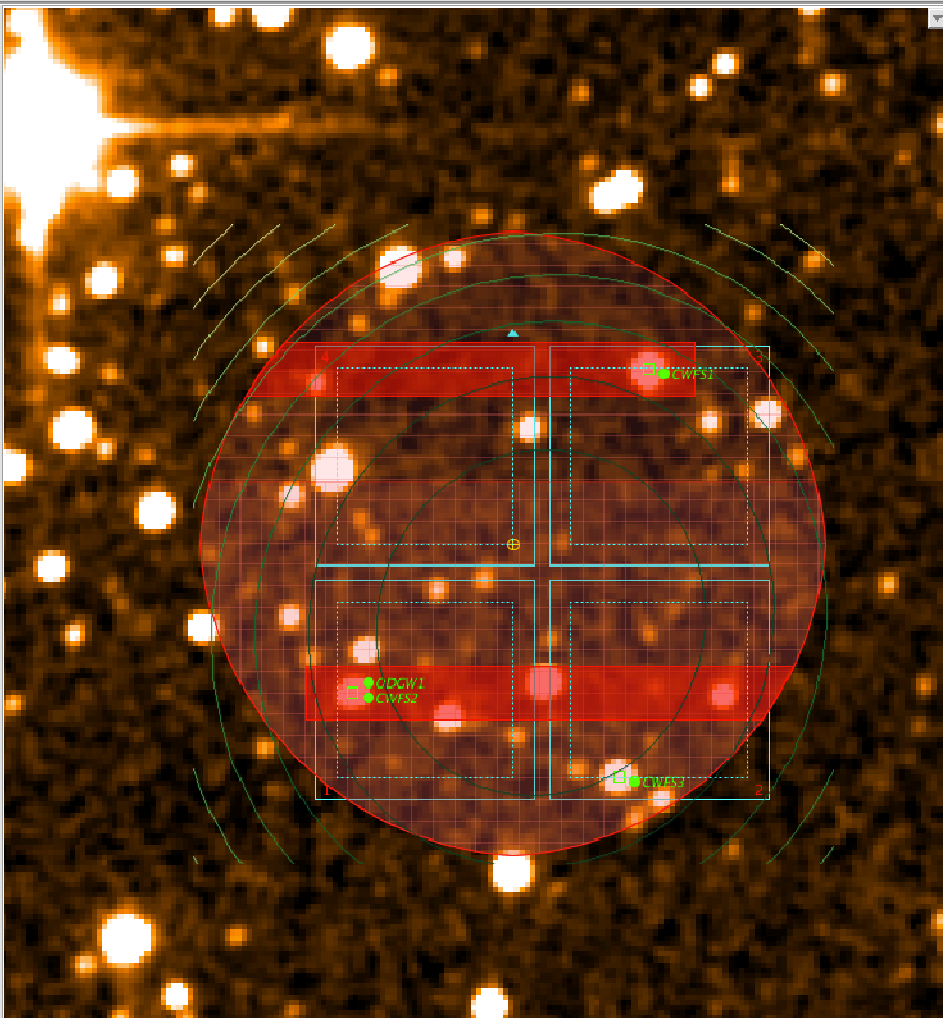
+ CWFS1
+ CWFS2
+ CWFS3
+ ODGW
+ PWFS1
+ Target
+ Offset

Target
☒ Base
☒ Guide
☐ Target
☒ Catalog
☐ Offset

Field Of View
☐ Acq Cam
☒ Canopus
☒ CWFS1
☒ CWFS2
☐ Both

☒ ODGW
☒ Strehl
☐ PWFS
☒ Science

Auto GS Options
☒ Canopus
☐ PWFS1

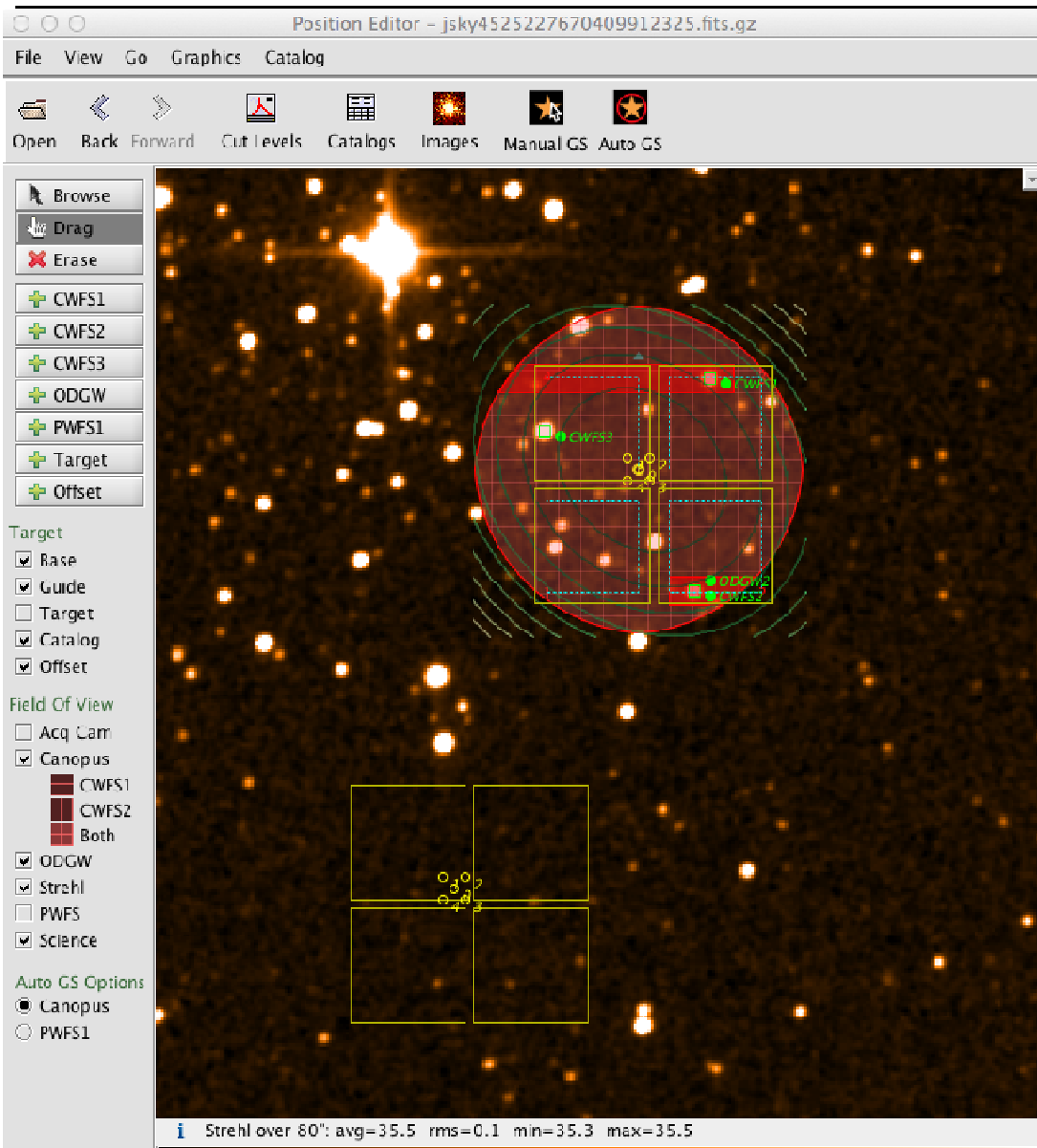


i Strehl: avg=31 ± 0.2, min=30.7, max=31.1, FWHM=0.06

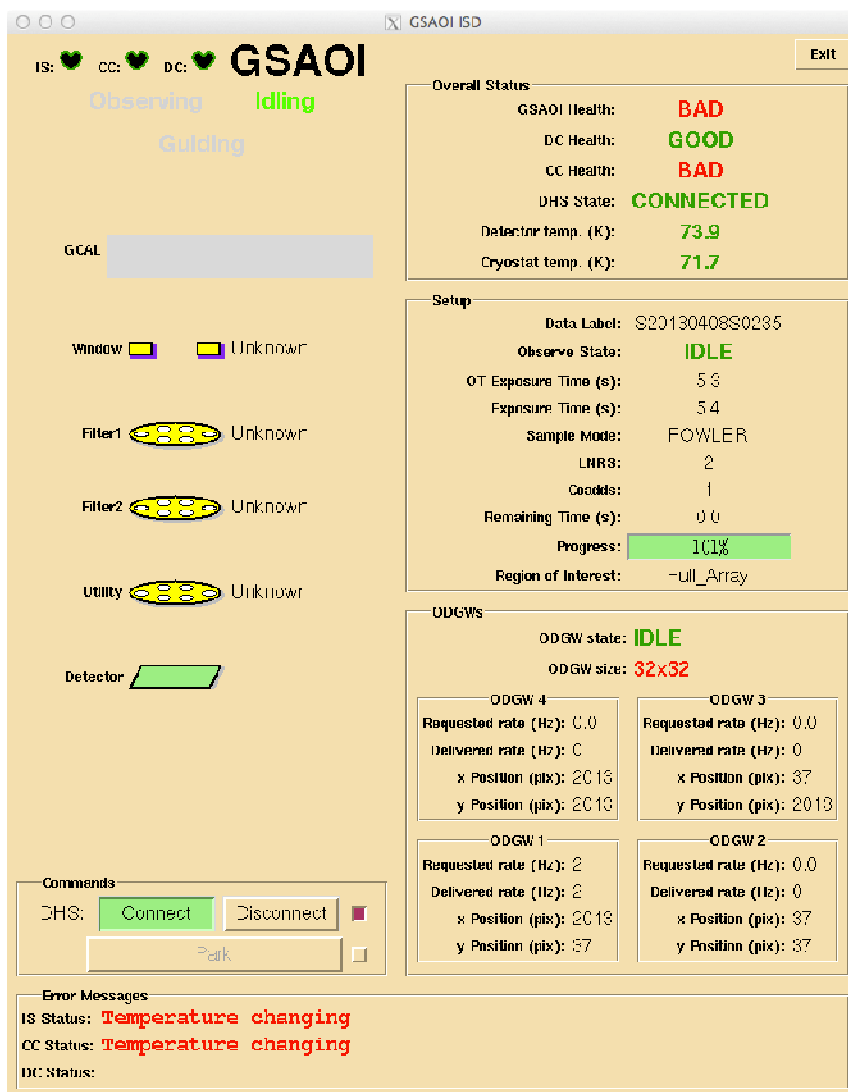
4x 163, 555.5 671.61536 07:18:37.138, -25:00:07.84 J2000 2MASS K

Phase II checks

- Canopus CWFS limiting magnitude $R=15.5$
- CWFS/ODGW are not outside the patrol field areas at different offsets (error message).
- Offset to the sky: laser must be shuttered when the offsets are larger than 5 arcmin from bse position → **this is not done automatically**
A separate sequence is required
- Phase II templates for
 - Sparse field
 - Crowded fields (sky $< 5'$)
 - Crowded fields (sky $> 5'$)



Observing with GeMS/GSAOI



GSAOI ISD and DMs → open from the Gemini pull down menus

Gemini → Instruments → GSAOI ISD/DM



End of the night – park the instrument

- Close the window cover
- Mover Filter 1 to blocked position
- Move Filter 2 to blocked position

Observing with GeMS/GSAOI

gsoaiDc.dll

GSAOI Detector Controller V1.9.0 **DC**

Observe Mode

Read method FOWLER

Nr resets 1

Nr Fowler samples 1

Nr coadds 1

Exposure (s) 5.4

Read Time (s) 5.4

Region of Interest Full Array

actual exposure time (s)

View Mode

Read method DCS

Exposure (s) 5.6

Disabled Enabled

ODGW Mode

Read method DCS

Exposure (s) 0.5000

Multiplier 3 4 0 0

2 1 1 1

Count 0 0 0

Rate(R/s) 0.00 0.00 0.00

Success(%) 0 0 0

ID

Data label

Observation Status SALSA Alert

Preparing ☐	observe counter 1	Observe	View
Acquiring ☐	Time last observe 15:02:30	Time elapsed (s) 5.5	0.0
Reading out ☐	View counters 0 0	Time left (s) 0.0	0.0
Saving ☐	Time last view	Coadd counter 1	0
Stopping ☐	Observing ☐ Guiding ☐	Read set counter 2	0
Aborting ☐	Viewing ☐ Idling ☒	Fowler counter 1	0
		Row counter 4096	0

System Status

Conting Name	GSAOI	State	RUNNING	Health	GOOD
Simulation Mode	NONE	Debug Mode	NIN	Last Result	SUCCESS
Health Msg					
Status Msg	Temperature interlock - waiting for CC link				
Temperature interlock					
Detector (K)			75.13		
Housing (K)			73.11		
			Detailed Health IDLE		

Observing with GeMS/GSAOI

gsoaiCc.dll

GSAOI

Components Controller V1.9.0

CC

System

Debug Mode: NONE State: RUNNING applyC: IDLE Health: BAD

Simulation Mode: NONE Health

Health Message: Temperature changing System Control

Mechanisms

Filter Selection
Menu1
Menu2
Blocked

Go
IDLE
Stop
Control
WARNING

Filter Wheel 1 Status Unknown

IDLE Control WARNING

Filter Wheel 2 Status Unknown

IDLE Control WARNING

Cover

Unknown Closed Select

CAR

Health

Go
IDLE
Stop
Control
WARNING

Utility Wheel

Unknown Clear Select

Go
IDLE
Stop
Control
WARNING

Interlocks

Temperature

IDLE
BAD
Control

Temperature

GSAOI Detector
75.1 K
Control

Health
GOOD

CLOSE

Observing with GeMS/GSAOI

Mca0 Yorick Smart Tool

File Load View Help

GeMS Status **NGS Controls** **GeMS Controls**

Loops and Offloads

Task	Status	Perf.	Message
LGS LOOP	■	DISABLED	
T.T. LOOP	■	DISABLED	
T.A. LOOP	■	DISABLED	
FLEX. LOOP	■	DISABLED	
CMAT OPTIM.	■	DISABLED	
NGS CENT. GAINS	■	DISABLED	
LGS CENT. GAINS	■	DISABLED	
DM0 > M1	■	DISABLED	
TT > M2	■	DISABLED	
LGSWFS > FSA	■	DISABLED	
SFS > LGSWFS	■	DISABLED	
NGS > CRCS	■	DISABLED	
FSA > KM	■	DISABLED	
LGS Steppers	■	DISABLED	

CANOPUS

Entrance Shutter	Closed
Exit Shutter	Closed
Science Beam Splitter	1
Science ADC	In
NGS Cal Source	Out
	0 Watts
LGS Cal Source	In
	50 %

LCH

Propagation Clearance 

TCS current UT: 16:35:26.2

Laser Status: NONE

Current Object: NONE

Time to Next Shutter: NOW

Miscellaneous

TCS current RA	01:04:17.287
TCS current dec	-30:27:59.68
TCS current AZ	+146.9999
TCS current EL	+90.0494
TCS current IT	13:35:26.2
Laser Power	UNKNOWN
TCS Object	Zenith

PAM files

 Add a UT PAM file

Preferences

Fetch today's PAMs

RTC Status **AOM Status** **SFS Status** **BTO Status** **MYST Status** **MYST Server**

Health	Hbeat	Health	Hbeat	Health	Hbeat	Health	Hbeat	Health	Hbeat	Health	Hbeat
GOOD	1448	WARNING	31	BAD	14	GOOD	41	GOOD	75214	GOOD	75214

Time to next shutter : NOW

lgswfsgains: Read lgswfsgains_init.mat -> internal (current_centgains)

Observing with GeMS/GSAOI

Mcaoyorick Smart Tool

File Load View Help

GeMS Status

Spiral

Controller: aom NGS-1

Center (x,y): 0.0 0.0

Step sz: 0.5

Grid els: 11

Hand Paddle

Display: ngs1

Progress

Position

68 scan points

Show spiral

NGS Controls

ngs1: -40.00 -50.00
ngs2: -55.00 +50.00
ngs3: -2.00 +20.00

GeMS Controls

Astrometric

Astrometric Acq: ngs:owp STARTACQ

AOM RTC Tracking
☒ reset on start

Probe Offsets

Probe Offsets Integ.

Reset 1 Reset 2 Reset 3

NGS

Fake tracking

ON OFF

APDs

apd1 apd2 apd3

APDs Off!

Gate control...

Servers

	BUSY	TGTX	TGTY	LMO	POSX	POSY
ngsPr1		-40.0000	-50.0000		-39.9995	-50.0002
ngsPr2		55.0000	50.0000		55.0003	50.0002
ngsPr3		-2.0000	20.0000		-2.0000	20.0000

RT Status

Health: GOOD

Hbeat: 1430

AOM Status

Health: WARNING

Hbeat: 73

SFS Status

Health: BAD

Hbeat: 56

BTO Status

Health: GOOD

Hbeat: 83

MYST Status

Health: GOOD

Hbeat: 75254

MYST Server

health: GOOD

heartbeat: 75254

CLEAR

ACCEPTED
IDLE

Time to next shutter: NOW

lgswfsgains: Read lgswfsgains_init.mat -> internal (current: centgains)

File Load View Help

McAo Yorick Smart Tool

GeMS Status **NGS Controls** **GeMS Controls**

Loops

LGS LOOP	START
T.T. LOOP	START
T.A. LOOP	START
FLEX. LOOP	START
CMAT OPTIM.	START
NGS CENT. GAINS	START
LGS CENT. GAINS	START

Offloads

DM0 > M1	START
TT > M2	START
LGSWFS > FSA	START
SFS > LGSWFS	START
NGS > CRCS	START
FSA > KM	START
LGS Steppers	START

CANOPUS

Entrance Shutter	CLOSE	OPEN
Exit Shutter	CLOSE	OPEN
Science Beam Splitter	1.1 um	0.7 um
Science ADC	IN	OUT
NGS Cal Source	IN	OUT
	ON	OFF
LGS Cal Source	IN	OUT
	ON	OFF
DM0 Mask	IN	OUT

RTC Status

Health	GOOD	✓
Hbeat	1547	⌂

AOM Status

Health	WARNING	✗
Hbeat	30	⌂

SFS Status

Health	BAD	✗
Hbeat	13	⌂

BTO Status

Health	GOOD	✓
Hbeat	40	⌂

MYST Status

Health	GOOD	✓
Hbeat	75308	⌂

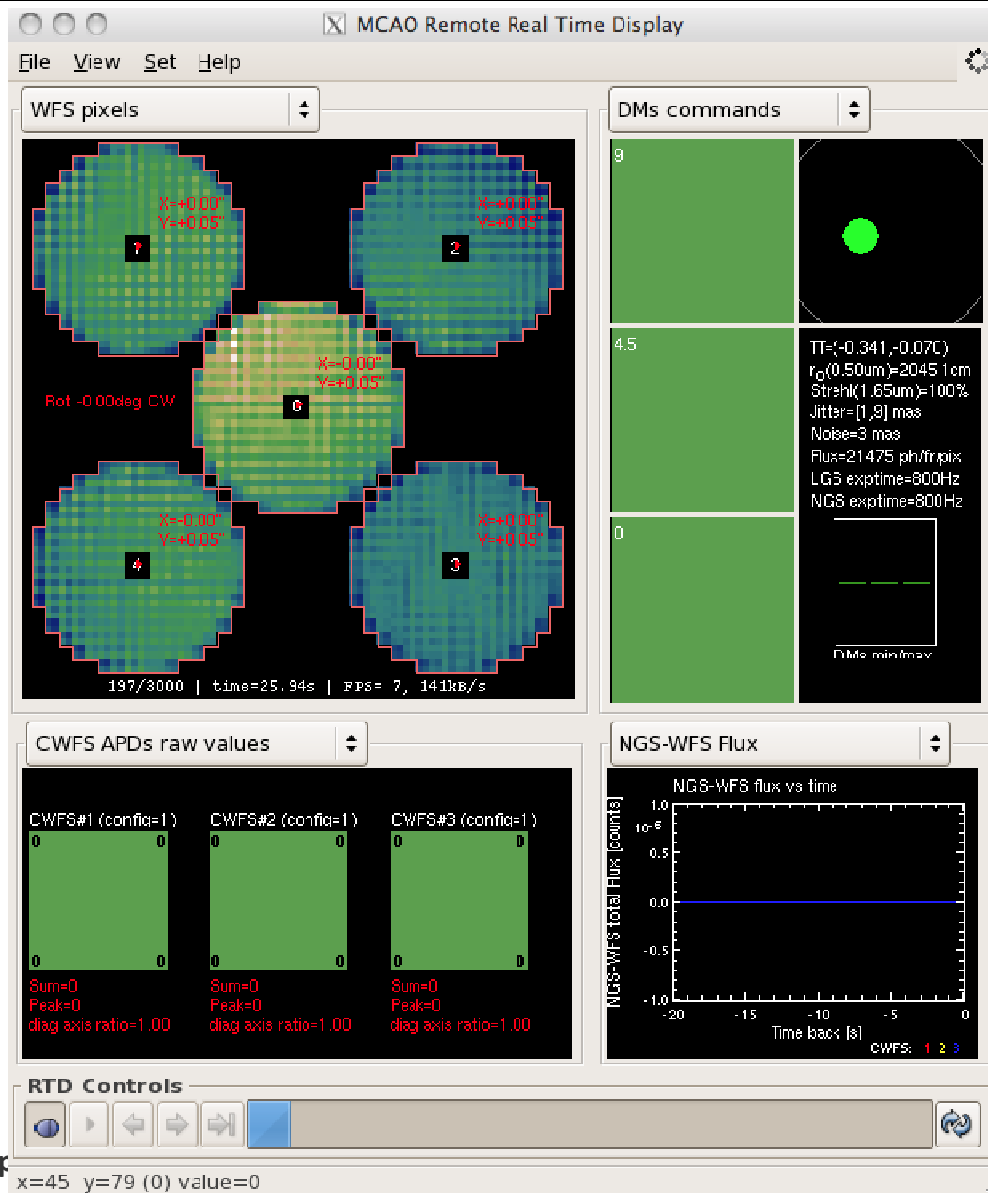
MYST Server

health	GOOD	✓
heartbeat	75308	⌂

CLEAR ACCEPTED IDLE

Time to next shutter : NOW

lgswwfs gains: Read lgsWfsGains_init.mat -> internal (current_centgains)



- Monitor all GeMS parameters:
 - LGS WFS, NGS WFS, r0, Strehl, flux, LGS and NGS guiding frequency.
- LGS WFS → very good clouds detector.
- Quick Look Tool → GSAOI images are displayed automatically for Quick image check.
- GSAOI IRAF/PyRAF package to evaluate the image quality

The On-site data quality assessment is done using a set of tools written by Fabrice Vidal to monitor and plot the delivered image quality (FWHM) and Strehl (web page interface)

GSAOIFile	FWHM	SR	seeing	seeing@LambdaObs	filter	object	ExpTime	LoopFreq
S20130321S0157	0.119	7.3	0.888	0.701	H CenA-arc	10.0	400.0	CLOSED Fast Fast Fast
S20130321S0158	0.103	8.1	0.905	0.714	H CenA-arc	10.0	400.0	CLOSED Fast Fast Fast
S20130321S0159	0.083	10.5	0.896	0.707	H CenA-arc	10.0	400.0	CLOSED Fast Fast Fast
S20130321S0160	0.085	9.1	0.688	0.543	H CenA-arc	10.0	400.0	CLOSED Fast Fast Fast
S20130321S0161	0.106	6.2	0.839	0.662	H CenA-arc	10.0	400.0	CLOSED Fast Fast Fast
S20130321S0162	0.104	7.9	0.608	0.479	H CenA-arc	10.0	400.0	CLOSED Fast Fast Fast
S20130321S0163	0.090	12.7	0.804	0.634	H CenA-arc	10.0	400.0	CLOSED Fast Fast Fast
S20130321S0164	0.090	11.7	0.842	0.665	H CenA-arc	10.0	400.0	CLOSED Fast Fast Fast
S20130321S0165	0.082	10.2	0.957	0.755	H CenA-arc	10.0	400.0	CLOSED Fast Fast Fast
S20130321S0166	0.096	8.2	0.995	0.785	H CenA-arc	10.1	400.0	CLOSED Fast Fast Fast
S20130321S0167	0.070	13.6	0.810	0.639	H CenA-arc	10.0	400.0	CLOSED Fast Fast Fast
S20130321S0168	0.078	9.2	1.017	0.802	H CenA-arc	10.0	400.0	CLOSED Fast Fast Fast
S20130321S0169	0.067	14.4	0.823	0.650	H CenA-arc	10.0	400.0	CLOSED Fast Fast Fast
S20130321S0170	0.075	11.8	0.913	0.720	H CenA-arc	10.0	400.0	CLOSED Fast Fast Fast
S20130321S0171	0.065	16.2	0.826	0.651	H CenA-arc	10.0	400.0	CLOSED Fast Fast Fast
S20130321S0173	0.062	16.4	0.622	0.491	H CenA-arc	10.0	400.0	CLOSED Fast Fast Fast
S20130321S0174	0.065	16.8	0.973	0.768	H CenA-arc	10.0	400.0	CLOSED Fast Fast Fast
S20130321S0175	0.081	10.4	0.981	0.774	H CenA-arc	10.0	400.0	CLOSED Fast Fast Fast

