GeMS/GSAOI

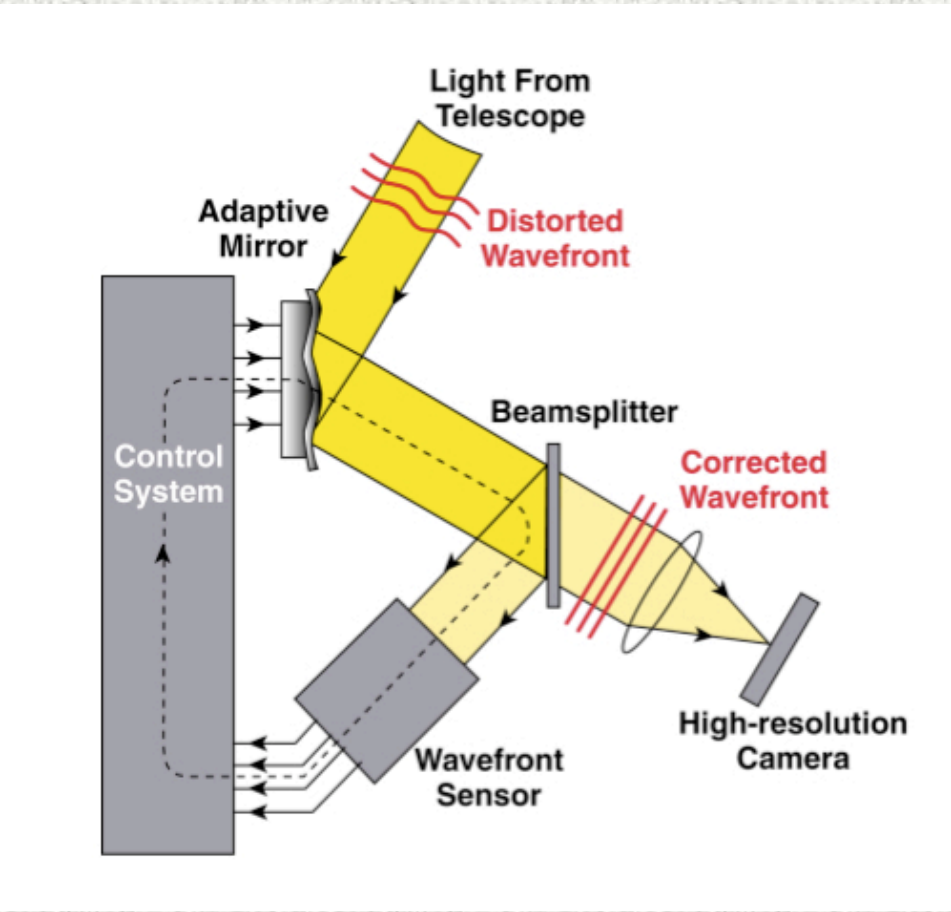
"A New Generation of Adaptive Optic"

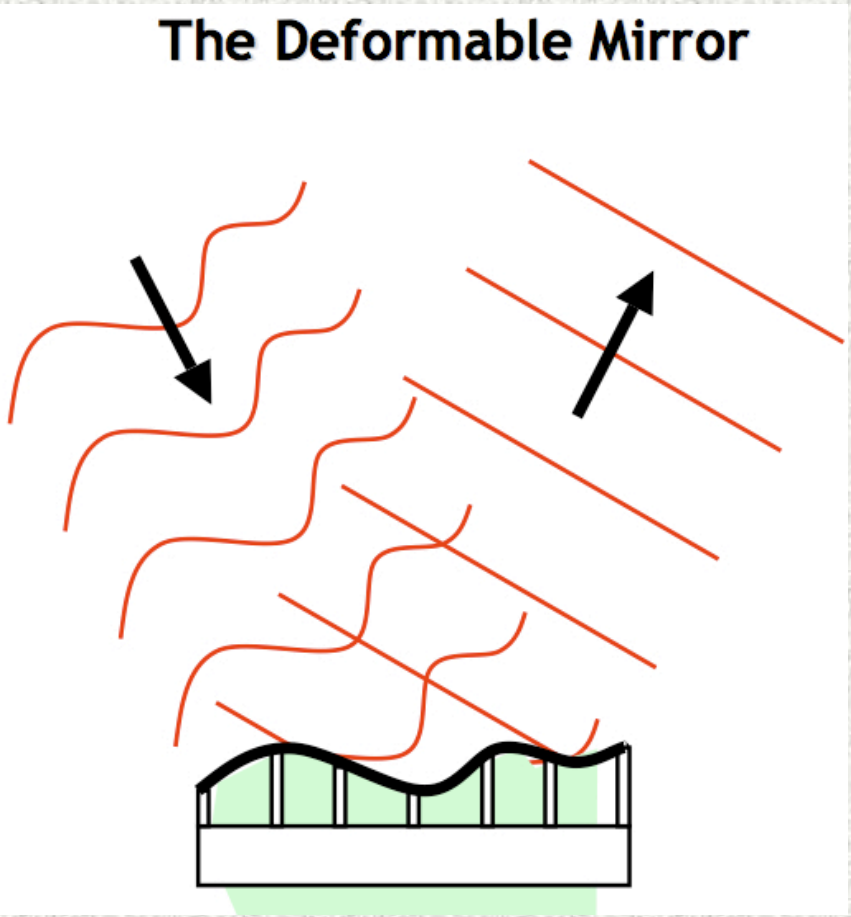
R. Carrasco, B. Neichel, F. Rigaut, M. Boccas, C. D'Orgeville, C. Trujillo, G. Trancho, V. Fesquet, M. Edwards + all GeMS/GSAOI teams

Gemini Observatory

Adaptive Optic

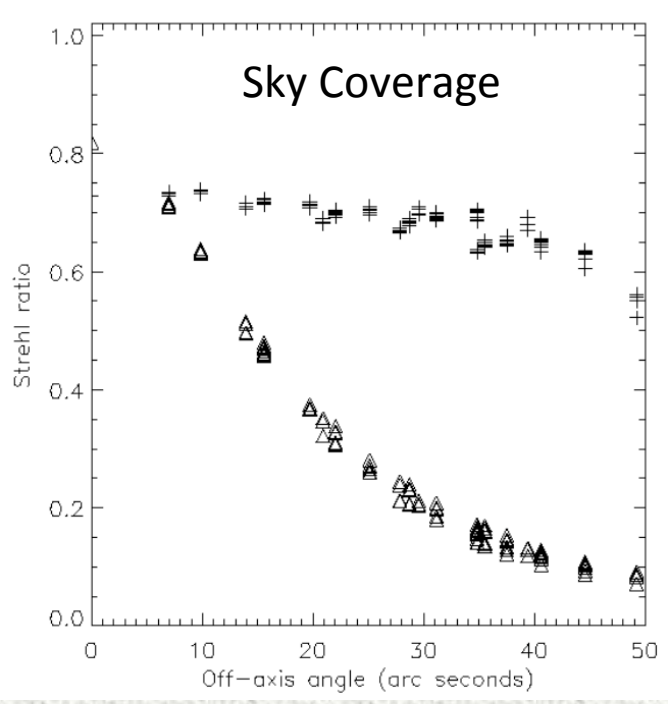
AO system: very basic scheme





GeMS: Gemini MCAO System

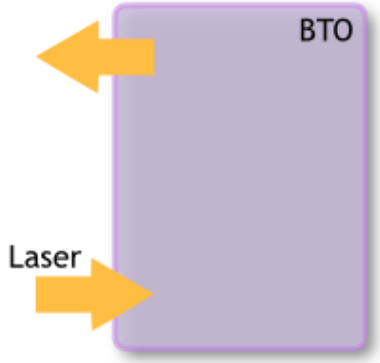
- Adaptive Optic facility for the Gemini South Telescope
- 3 main sub-systems:
  - Laser + Laser Launch Telescope (LTT)
  - Beam Transfer Optic (BTO)
  - Canopus (AO bench)
- Goal → deliver (diffraction limited + uniform) image quality (Near IR) in a FoV > 1 arcmin^2
- Two dedicated instruments:
  - GSAOI (NIR imager)
  - Flamingos-2 (NIR Imager and spectrograph).



- Strehl ratio under median seeing 0.7" (expected): ~15% (J), ~35% (H), ~55% (K)
- Strhel uniformity: 5% (J), 2% (K)
- Requires 3 TTP WFS (R<17.5mag)

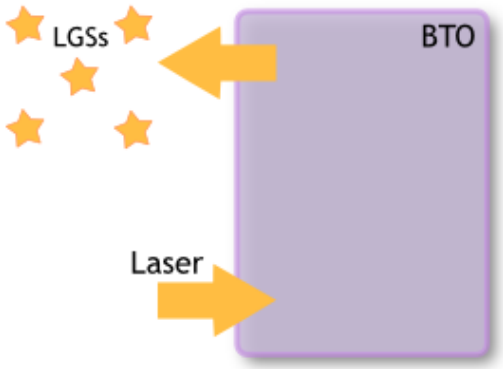
GeMS Introduction

Schematics of the three sub-systems



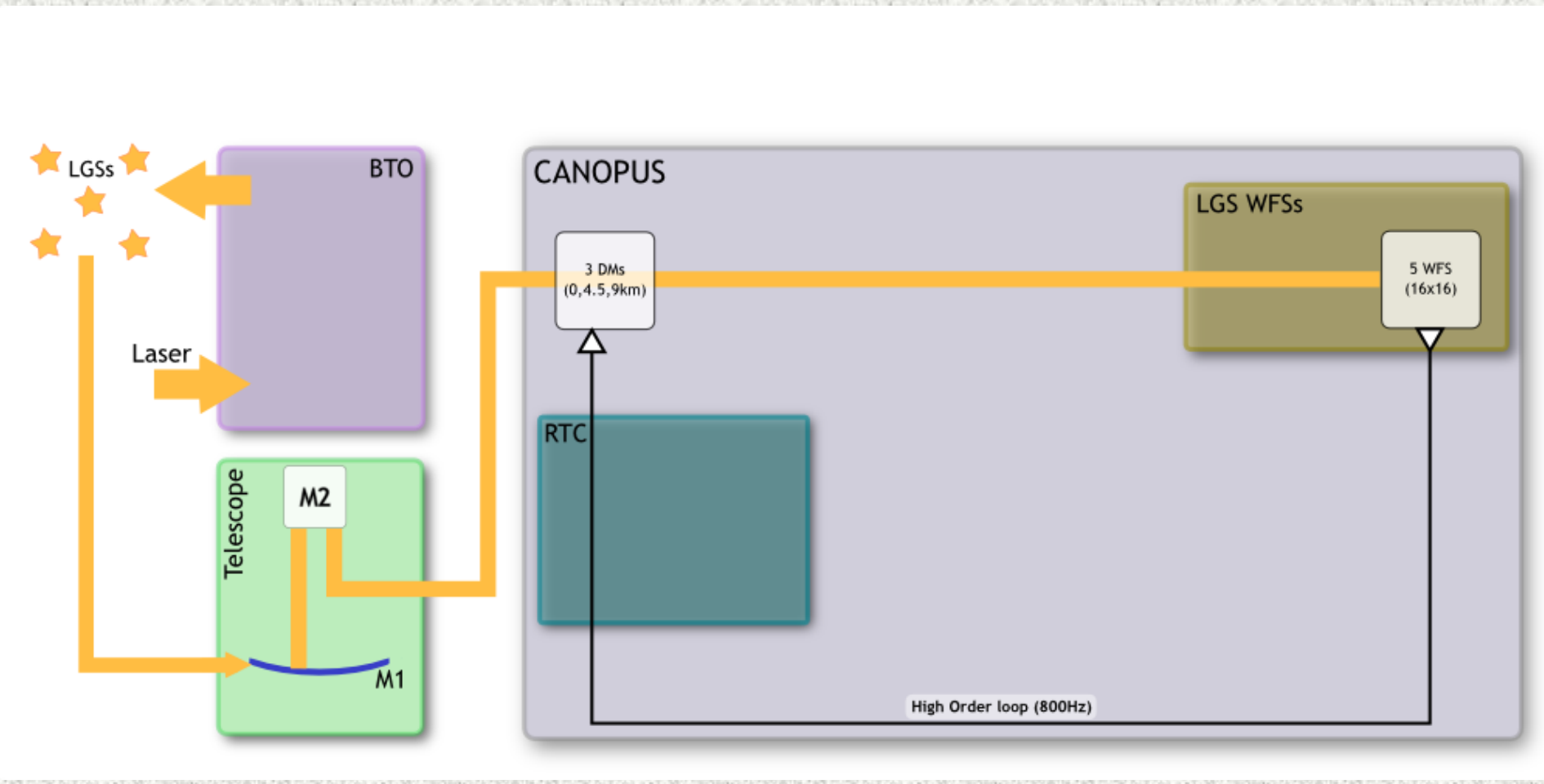
GeMS Introduction

- 1 x 50W laser is divided in 5x10W beams placed on the corner and center of a 1' FoV



GeMS Introduction

- 1 x 50W laser is divided in 5x10W beams placed on the corner and center of a 1' FoV
- 5 (16x16)SHWFS - 3DMs (totaling 917 actuators) - 800Hz conjugated at 0, 4.5, 9 km



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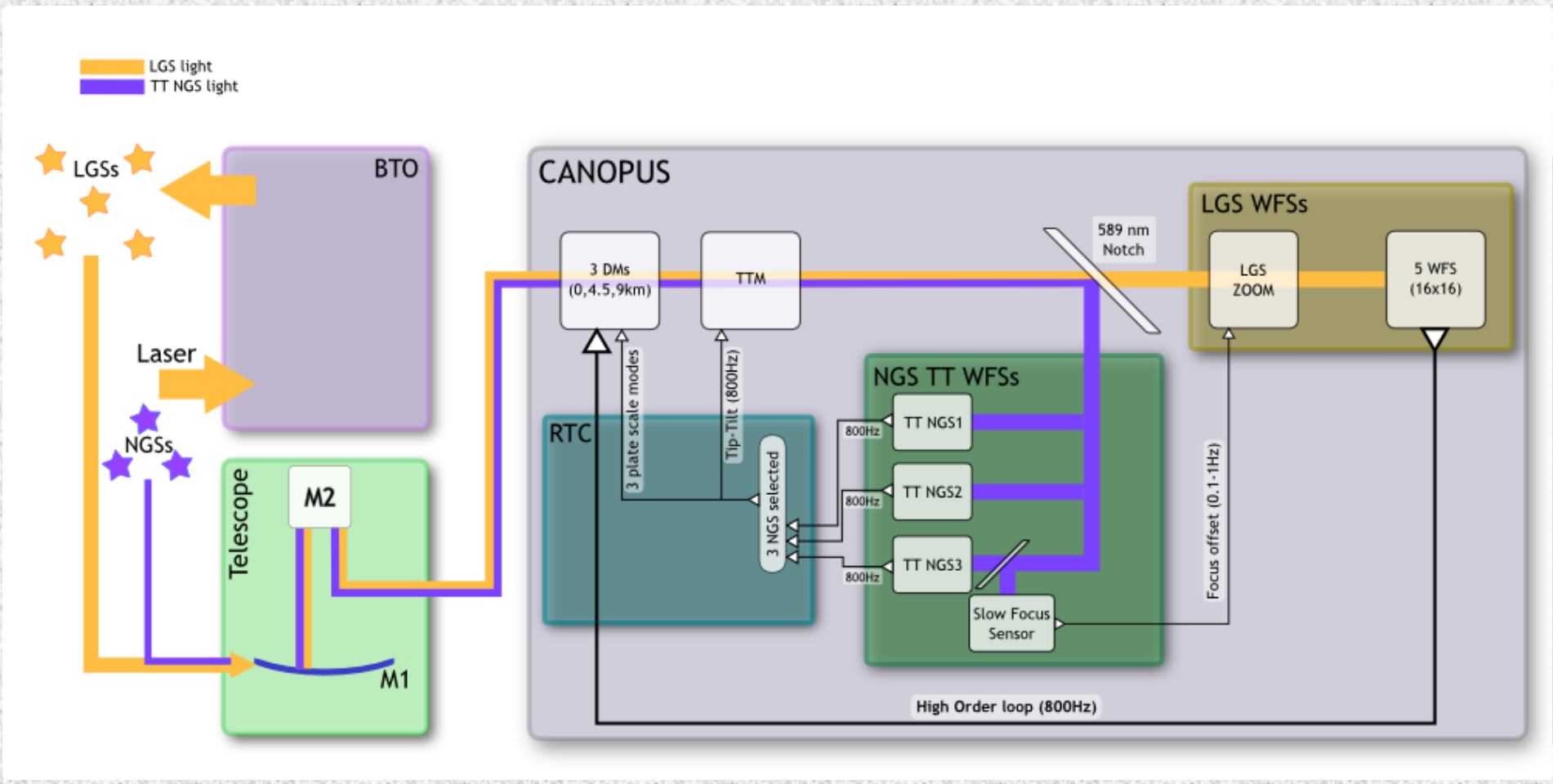
- 3 Avalanche Photo-Diodes based NGS TT WFSs - 800Hz - Plate scale modes - SFS



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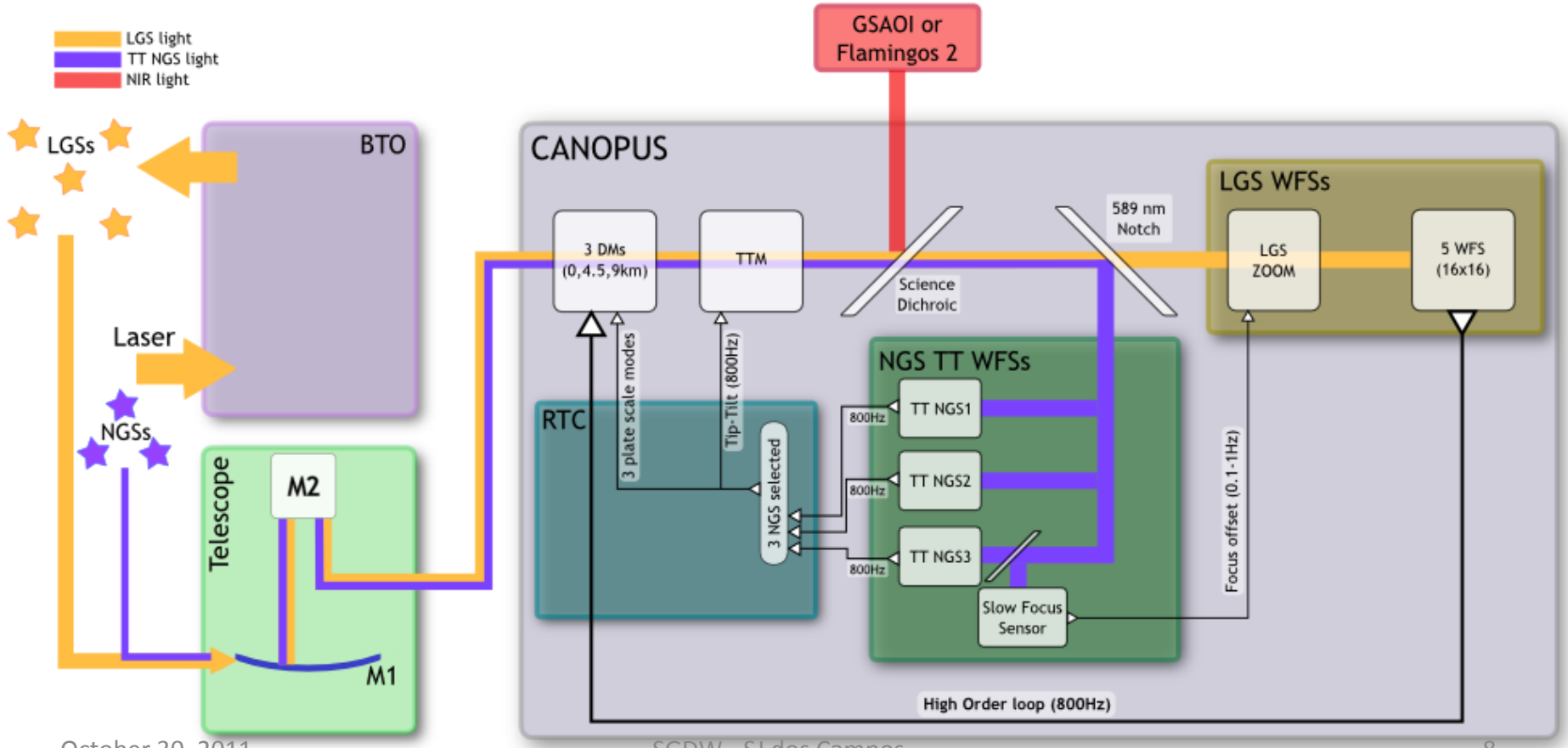

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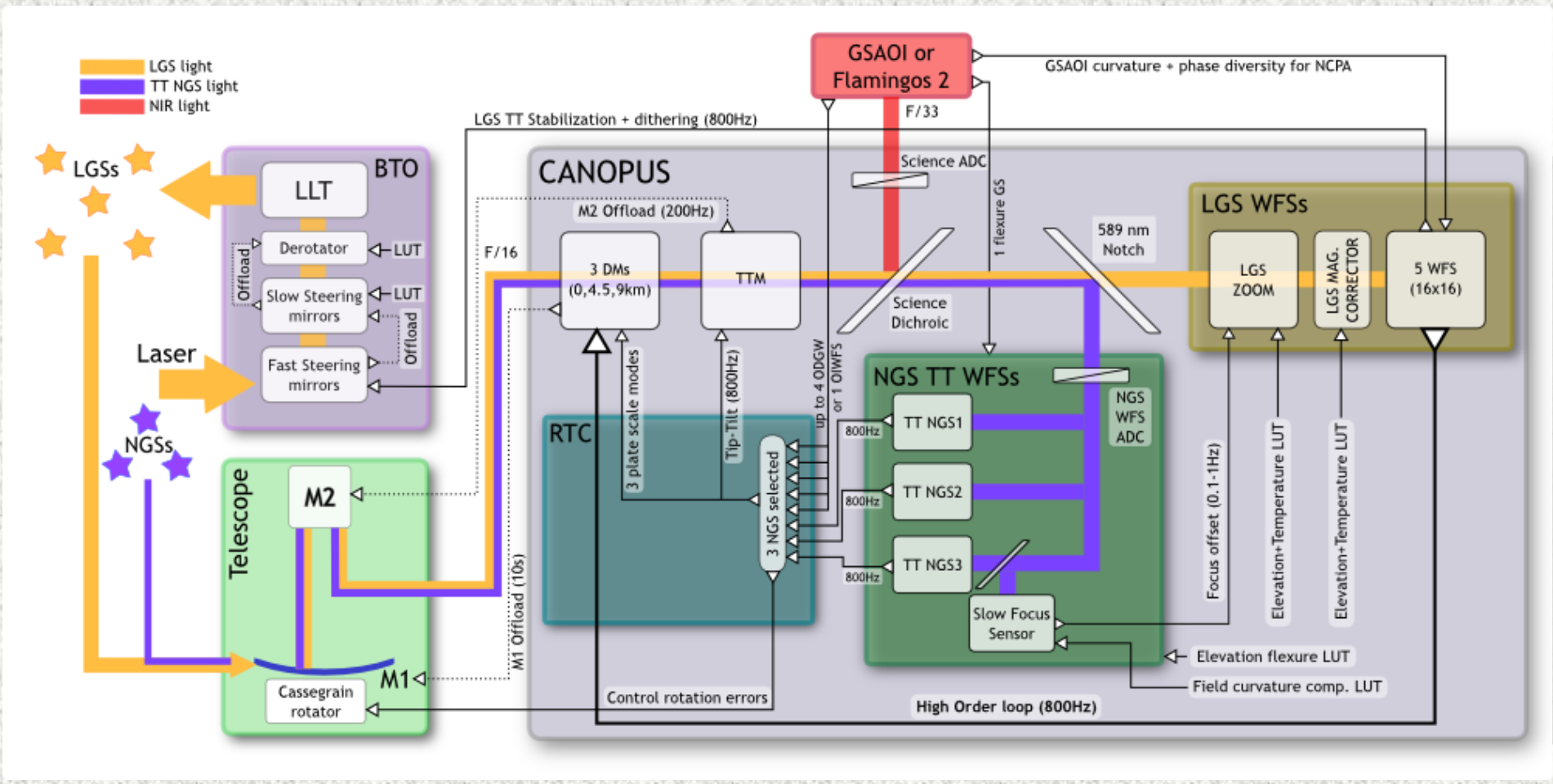
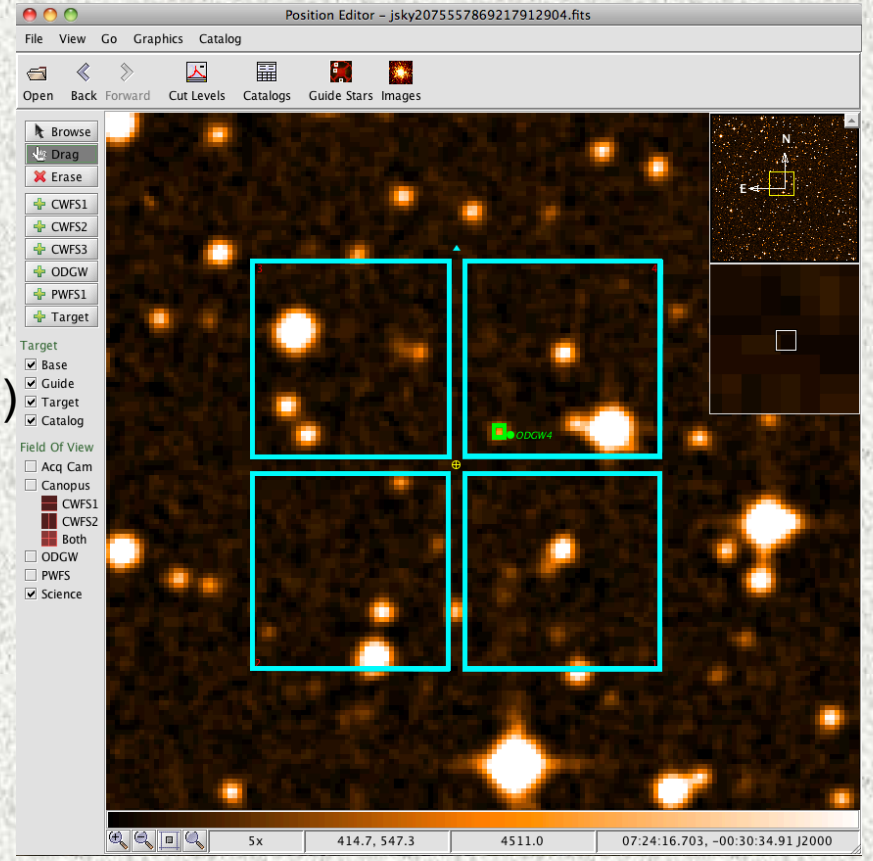
- Many other loops, LUT, offloads…



GSAOI introduction

- Gemini South Adaptive Optic Instrument (GSAOI) – near-infrared adaptive optic camera for use with GeMS
- Diffraction limited images at 0.9 – 2.5 μm
- 4080 x 4080 Rockwell HAWAII-2RG HgCdTe/CdZnTe illuminated array (Mosaic of 2 x 2 detectors). Gaps of 2.6”-2.8” (2mm)
- 0.02"/pixel plate scale; 85" x 85” FOV
- Broad-band filters: Z, J, H, Ks, K', K;
- 16 Narrow-band filters: zero-redshift emission lines
- On-Detector Guide Windows: User-selectable, one per detector mosaic quadrant
- Configurable ROIs



GSAOI introduction

Available GSAOI Filters

Filter Name	Central Wavelength (μm)	Coverage (μm)	50% cut-on Wavelength (μm)	50% cut-off Wavelength (μm)	Gemini Filter Number	Transmission Curves	Filter ID
Broad-band filters							
Z	1.015	0.170	0.930	1.100	G1102	plot / data	ED205-1
J	1.250	0.160	1.170	1.330	G1103	plot / data	ED191-1
H	1.635	0.290	1.490	1.780	G1104	plot / data	ED169-1
K(prime)	2.120	0.340	1.950	2.290	G1105	plot / data	ED278-2
K(short)	2.150	0.320	1.990	2.310	G1106	plot / data	ED196-1
K	2.200	0.340	2.030	2.370	G1107	plot / data	ED192-1
Narrow-band (zero redshifted) emission- and absorption-line filters							
J-continuum	1.207	0.018	1.198	1.216	G1108	plot / data	ED190
H-continuum	1.570	0.024	1.558	1.582	G1109	plot / data	ED141
CH_4(short)	1.580	0.100	1.530	1.630	G1110	plot / data	ED144
CH_4(long)	1.690	0.100	1.640	1.740	G1111	plot / data	ED151
K(short) continuum	2.093	0.031	2.078	2.108	G1112	plot / data	ED168
K(long) continuum	2.270	0.034	2.253	2.287	G1113	plot / data	ED163
He I 1.083 μm	1.083	0.016	1.075	1.091	G1117	plot / data	ED185
H I Pγ	1.094	0.011	1.089	1.100	G1118	plot / data	ED186
H I Pβ	1.282	0.019	1.272	1.292	G1119	plot / data	ED231
[Fe II] 1.644 μm	1.644	0.025	1.631	1.656	G1120	plot / data	ED150
H_2O	2.000	0.080	1.960	2.040	G1121	plot / data	ED188
He I (2p2s)	2.058	0.031	2.042	2.073	G1122	plot / data	ED165
H_2 1-0 S(1)	2.122	0.032	2.106	2.138	G1123	plot / data	ED162
H I Brγ	2.166	0.032	2.150	2.182	G1124	plot / data	ED166
H_2 2-1 S(1)	2.248	0.034	2.231	2.265	G1125	plot / data	ED164
CO Δv=2	2.360	0.080	2.320	2.400	G1126	plot / data	ED187

GSAOI introduction

Detector Characteristics

Type	Rockwell HAWAII-2RG HgCdTe
Array sizes	2048 x 2048 pixels each (2040 x 2040 active)
Detector area	4080 x 4080 pixels (~ 85" x 85")
Physical Pixel size	18 µm
Pixel scale	0.02" (TBC)
Spectral Response	0.9 µm to 2.6 µm (data / plot)
Gains	~ 2.8 e-/ADU (TBC)
Dark current	~ 0.01 e-/s/pix (~12 e- in the maximum integration time of 20 minutes)
Saturation	~ 48,000 ADU (TBC)
On-Detector Guide Windows (ODGW)	One programmable ODGW per detector

Mode	N° of Fowler Samples (LNRS)	NDR (non-destructive reads)	Read-Out Time (*)	Read Noise (ADU)	Read Noise (e-)
Bright Object	1	2	5.3 sec	~ 8.9 (TBC)	25 (TBC)
Faint Object	8	16	42.4 sec	~ 4.3 (TBC)	12 (TBC)
Very Faint Object	16	32	84.8 sec	~ 2.9 (TBC)	8 (TBC)

GSAOI introduction

Sensitivity Table

For additional information see the GSAOI public Web page

GSAOI Image Sensitivities: 1 hour on-source integration, 0.4" natural seeing through 0.08" x 0.08" square aperture and photometric conditions (50%-il Cloud Cover)				
Filter	Limiting Magnitude (mag)	Saturation Magnitude (mag)[1]	Assumed Strehl Ratio	Sky Brightness (mag/arcsec^2)
Z	25.6	14.8	0.2	17.1
J	24.1	13.9	0.2	14.9
H	24.1	14.0	0.4	14.0
K(prime)	23.9	13.3	0.6	13.5
K(short)	23.8	13.2	0.6	13.4
K	23.7	13.2	0.6	13.3
J-continuum	23.1	11.7	0.2	15.0
H-continuum	22.9	11.5	0.4	14.1
CH_4(short)	23.6	13.1	0.4	13.9
CH_4(long)	23.4	12.7	0.4	13.8
K(short) continuum	22.7	10.9	0.6	13.6
K(long) continuum	22.5	10.6	0.6	13.5
He I 1.083 µm	23.7	12.0	0.2	16.1
H I Pγ	23.5	11.5	0.2	16.2
H I Pβ	22.5	11.5	0.2	14.0
[Fe II] 1.644 µm	22.7	11.4	0.4	13.8
H_2O	23.3	11.8	0.6	13.9
He I (2p2s)	22.5	10.8	0.6	13.3
H_2 1-0 S(1)	22.6	10.8	0.6	13.4
H I Brγ	22.6	10.7	0.6	13.5
H_2 2-1 S(1)	22.5	10.6	0.6	13.5
CO Δv=2	22.4	11.2	0.6	12.6

GeMS/GSAOI Science

Key Science drivers for GSAOI identified by Gemini Community
Santa Cruz, CA, October 2000

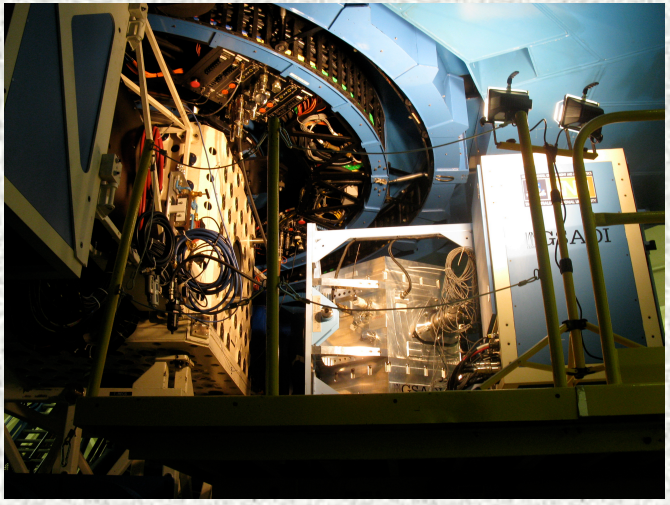
- Low mass stellar and sub-stellar mass functions in young star-forming regions
- Stellar population variations in star-forming regions (e.g. Ophiuchus).
- Open cluster mass functions to the bottom of the H-burning sequence and the end of the white dwarf cooling sequence to provide independent age determinations.
- Mass functions in nearby globular clusters over a range of metallicities.
- Ste
  Clo
- 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.

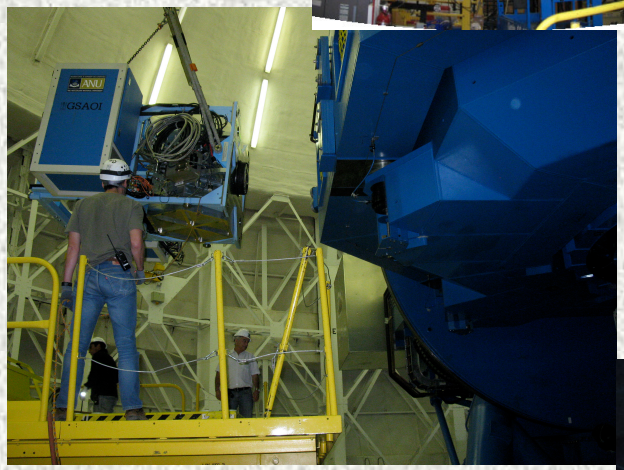
10 Years later still important science!

GeMS status: a Long Path

- 2007 – 2010 → Canopus characterization and integration of the opto-mechanical components
- March 2010 – July 2010 → Laser arrives and integration starts in the Lab
- July 2010 – Laser passed the AT and installed in the Laser enclosure (LSE)
- October 2010 – Laser high power spec achieved (57.6 Watts)
- January 2011(4 days) – First LGSF → the Laser is propagated
- February – May 2011 → Canopus Commissioning + GSAOI pre-commissioning blocks – May lost due to weather.
- April 2011 – fist light
- November 2011 – commissioning resumes
- 2012A – SV, 2012B → offer to community

GeMS status: a Long Path





GeMS

Commissioning team

Australia National Univerisity (ANU):

- Peter McGregor (PI)
- Peter Young (PM)
- Matt Doolan (SE)
- Jan van Harmelen

Gemini Science Team:

- Rodrigo Carrasco (IS, PM)
- Michelle Edwars
- Claudia Winge
- Peter Pessev
- Ariel Lopez
- Felipe Colazo *

Core Gemini Team:

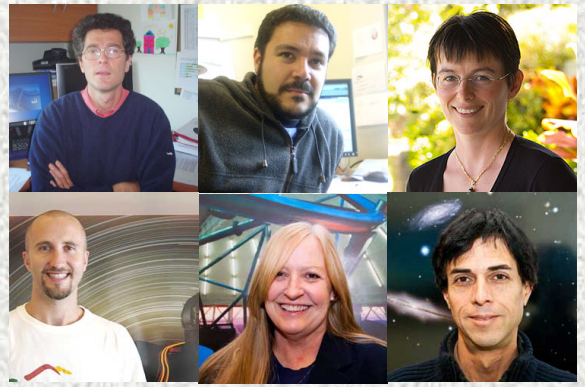
- Maxime Boccas (PM: GeMS)
- Francois Rigaut (PI: GeMS)
- Benoit Neichel (IS, GeMS)
- Chad Trujillo (GeMS)
- Mathieu Bec (PM: Canopus)*
- Celine D'Orgeville (PM: LGSF)
- Gelys Trancho (SE)*

Gemini Engineering Group

Gemini Software Group

At the summit → up to 22 people!!

Optic/Laser



SOS

Sys. Eng.

Spotter

Electronics

GSAOI

Mech. P.M.

Adaptive Optics

Software

Visitors

Commissioning preparation

Observing preparation → crucial step

- Includes: (Felipe Colazo)
  - Select the targets for a different commissioning runs
  - Prepare the list of target to submit to the Laser Clearinghouse (Space Command)
  - Observations
  - Results and Feedback
- Targets → different fields: standard stars, astrometric fields, open clusters, etc..
- Guiding capabilities define the type of targets for observation
  - 3 CWFS + 1 ODGW (flexure, 100Hz)
  - 1 CWFS (Slow focus) + 3 ODGW (flexure and Tip/Tilt at 800 Hz)
- Observing Tool, Mascot, and large catalogs.

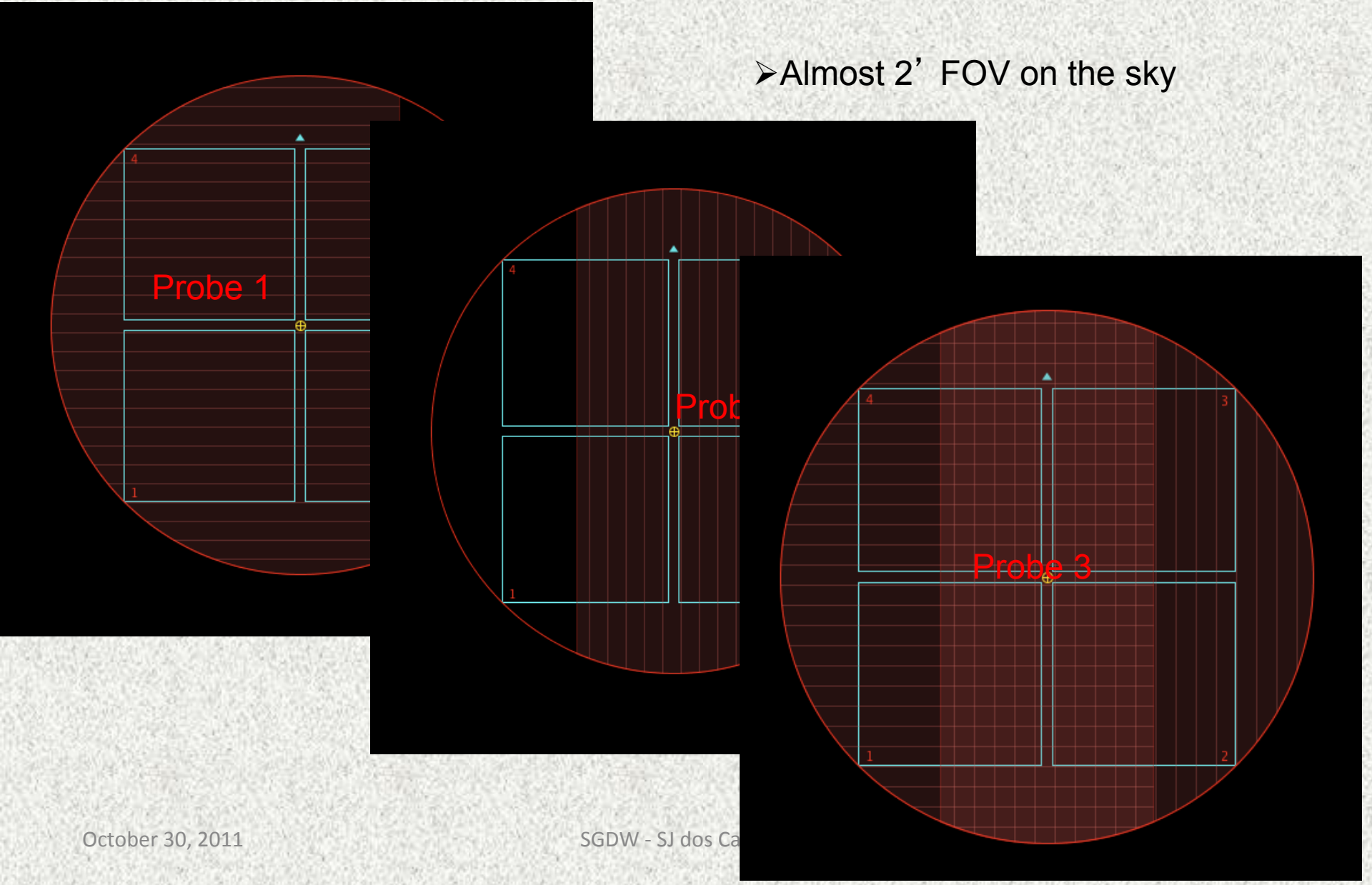
Commissioning preparation

Target Selection

- For each commissioning run
  - Targets with elevations higher than 45 degrees
  - Bright sources to test and characterize the Canopus WFS and define the GSAOI Hot Spot position
  - Astrometric fields to derive the GSAOI IAA, WCS, etc
- Tools used
  - Mascot
  - Observing Tool

Canopus Field of View

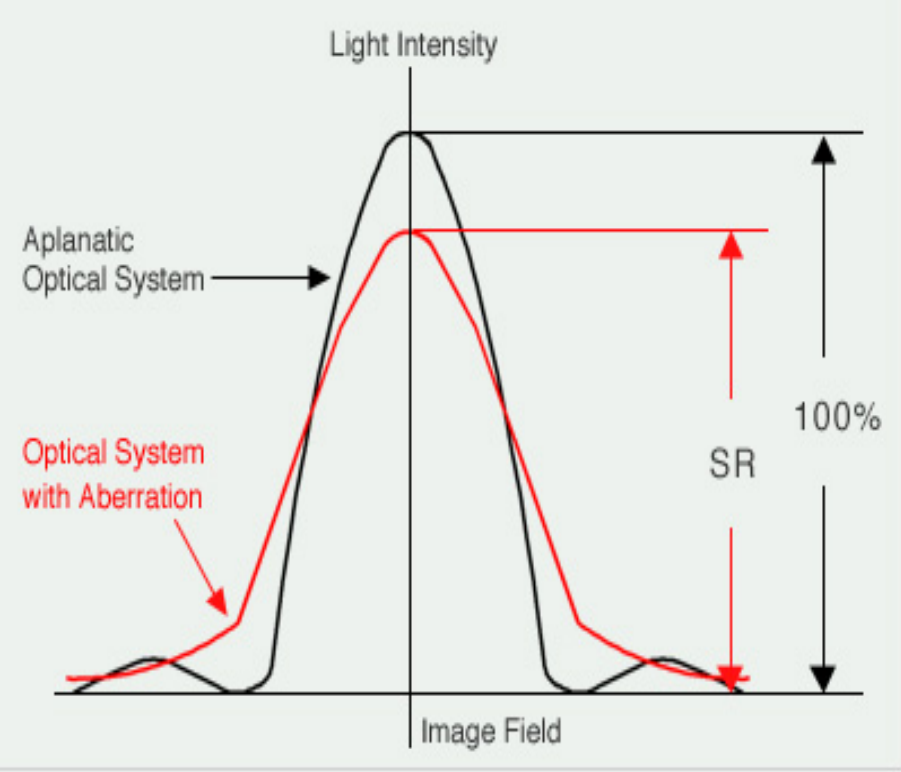
- Almost 2’ FOV on the sky



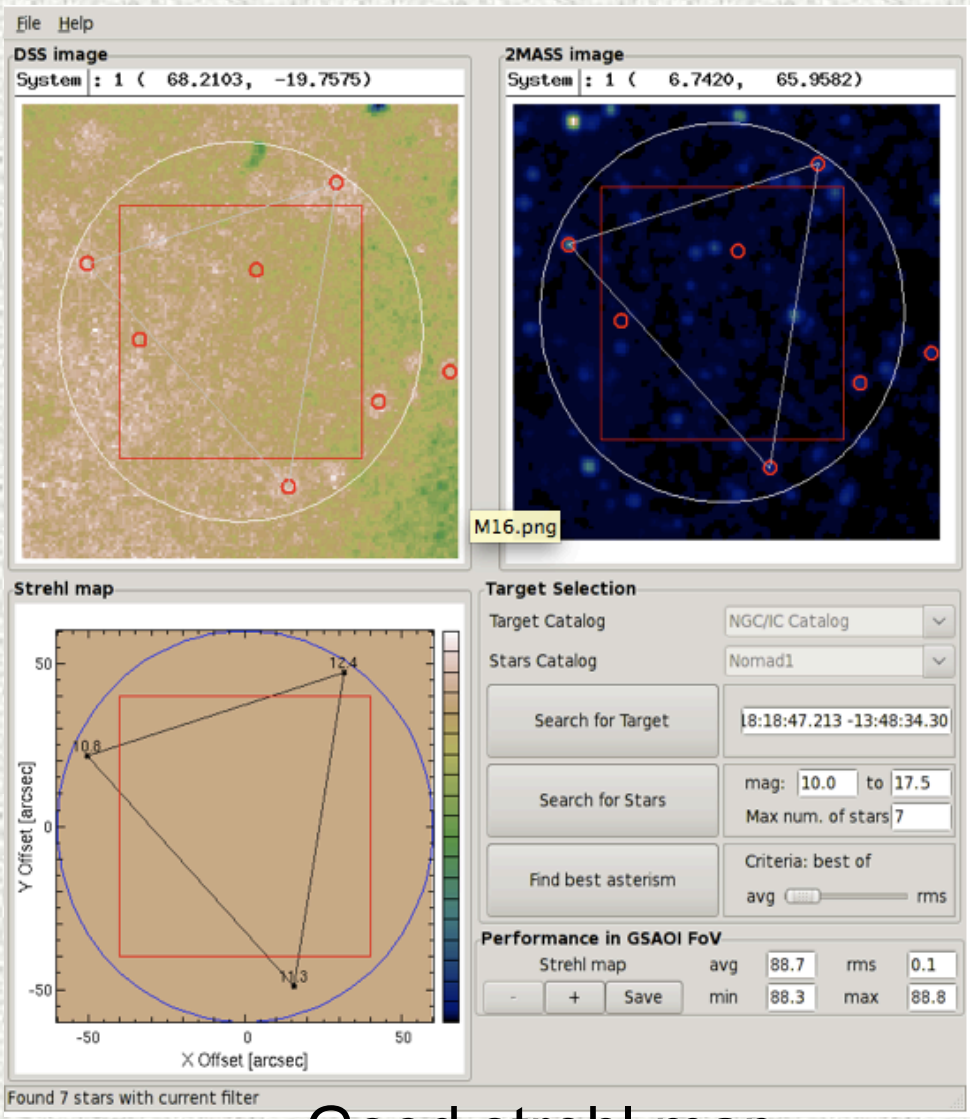
Commissioning preparation

Mascot

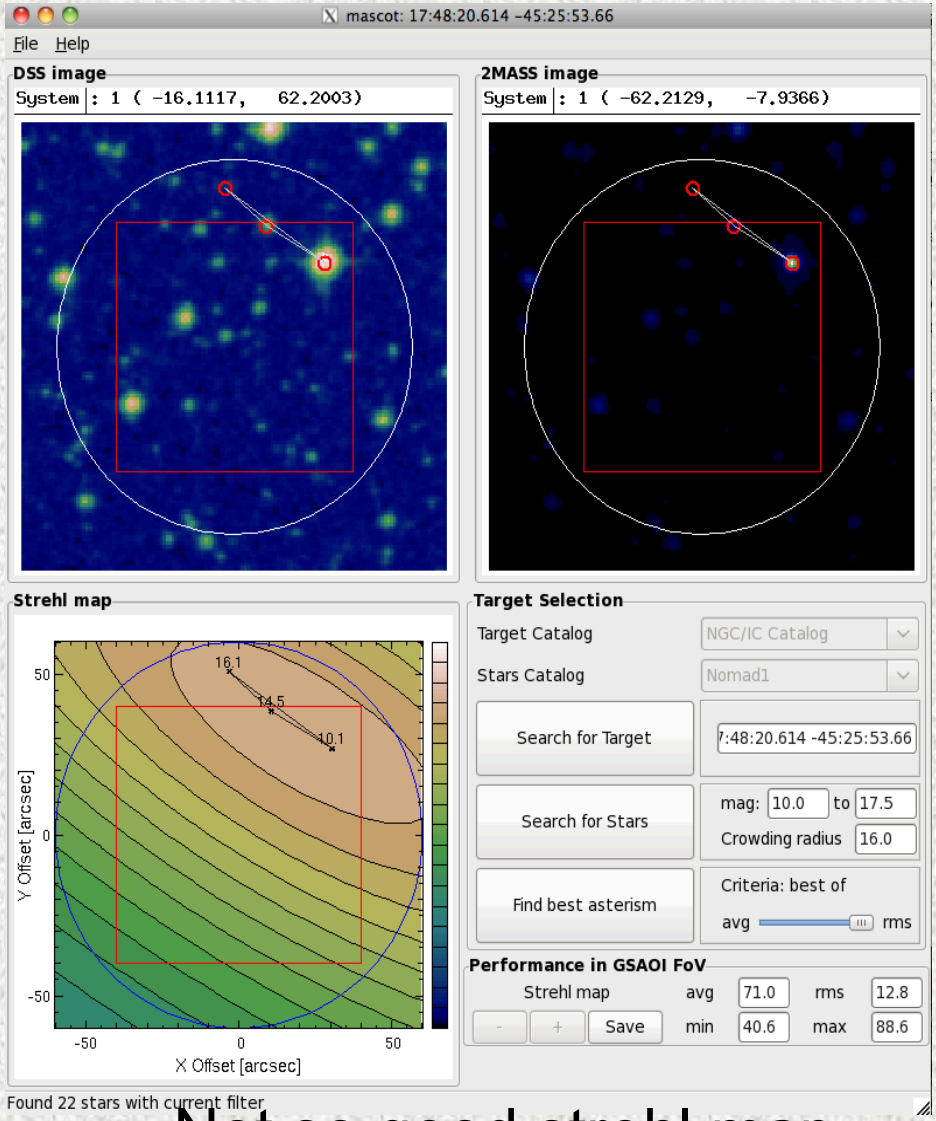
- Developed by F. Rigout
- Creates Strehl maps of a field with different triangular configuration of guide stars chose
- It delivers a very accurate model of what can be done by the AO
- Implemented in the Observing Tool (March 2012)
- Implementation in the PIT (2012B?)



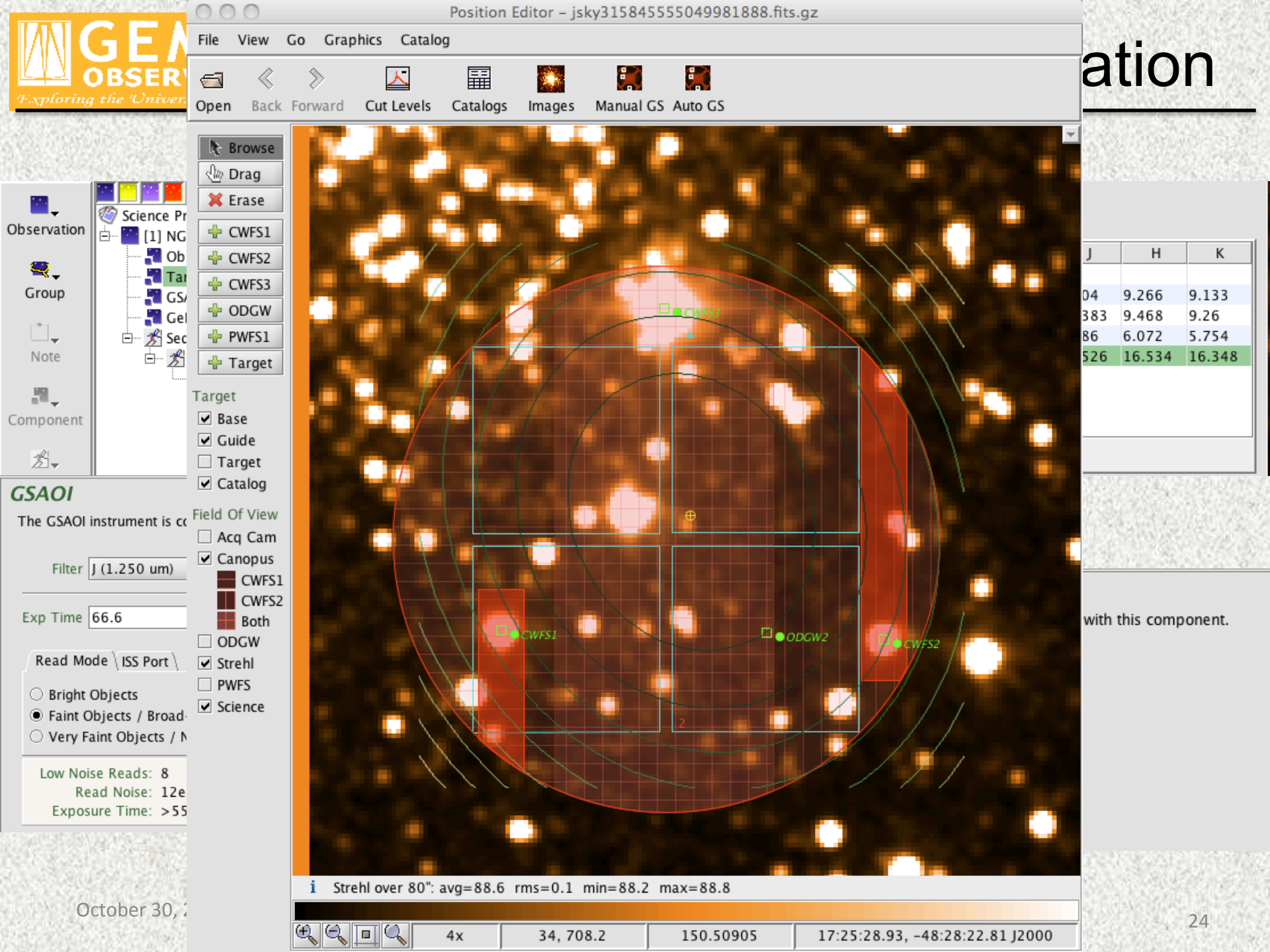
Commissioning preparation



Good strehl map



Not so good strehl map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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
Target
Base
Guide
Target
Catalog
Field Of View
Acq Cam
Canopus
CWFS1
CWFS2
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ODGW
Strehl
PWFS
Science
Observation
Group
Note
Component
GSAOI
Filter J (1.250 um)
Exp Time 66.6
Read Mode ISS Port
Bright Objects
Faint Objects / Broad
Very Faint Objects
Low Noise Reads: 8
Read Noise: 12e
Exposure Time: >55
J H K
04 9.266 9.133
383 9.468 9.26
86 6.072 5.754
526 16.534 16.348
with this component.
Strehl over 80": avg=88.6 rms=0.1 min=88.2 max=88.8
4x
34, 708.2
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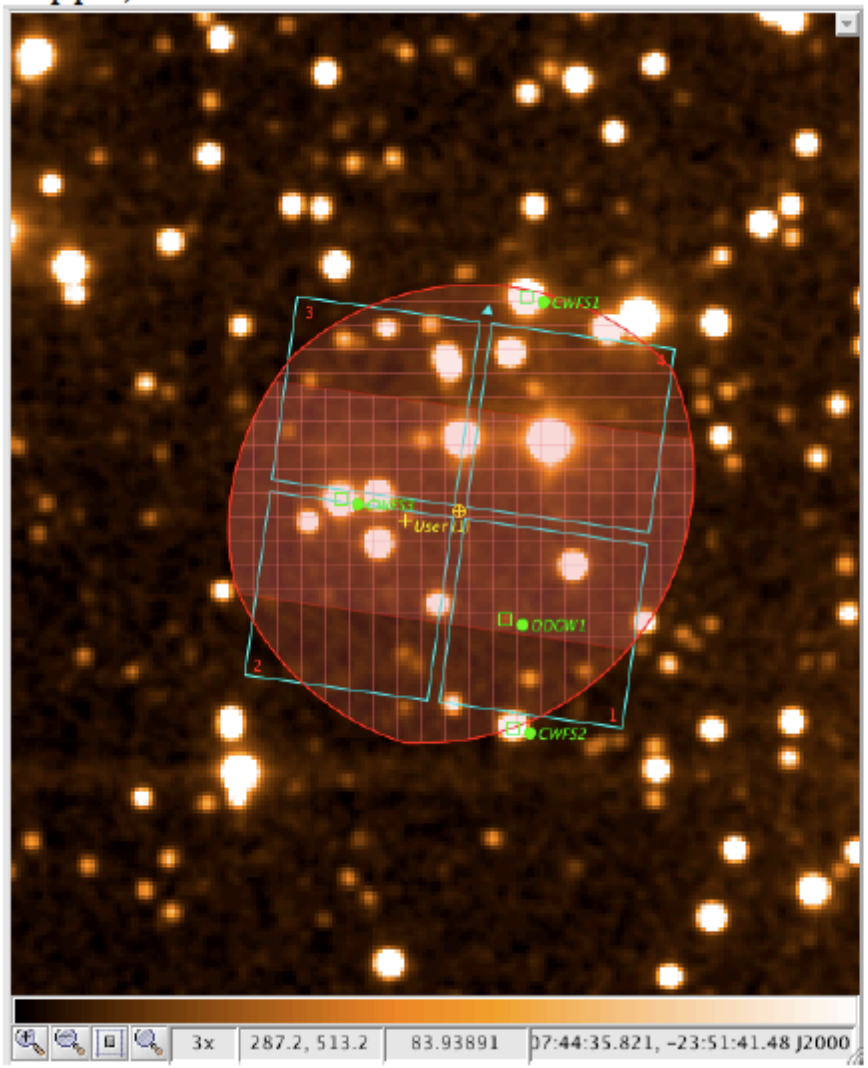
17:25:28.93, -48:28:22.81 J2000

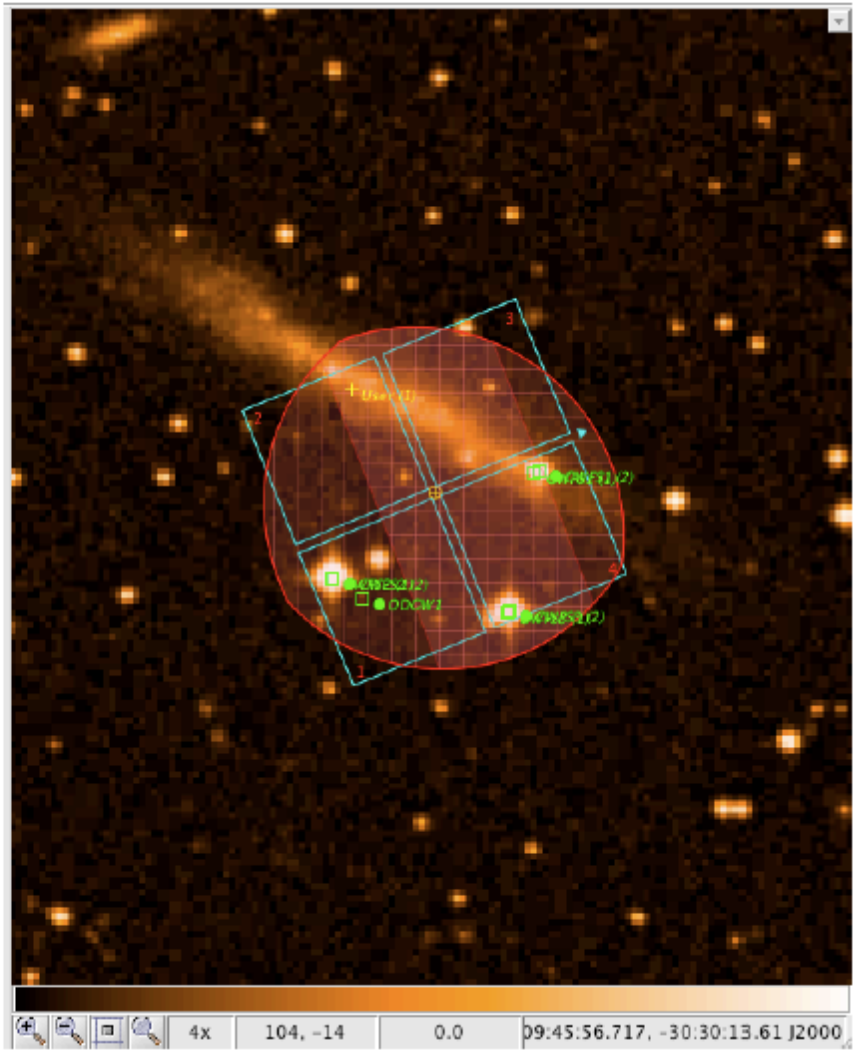
Commissioning preparation

Science Targets with good constellations

Puppis, Messier 93



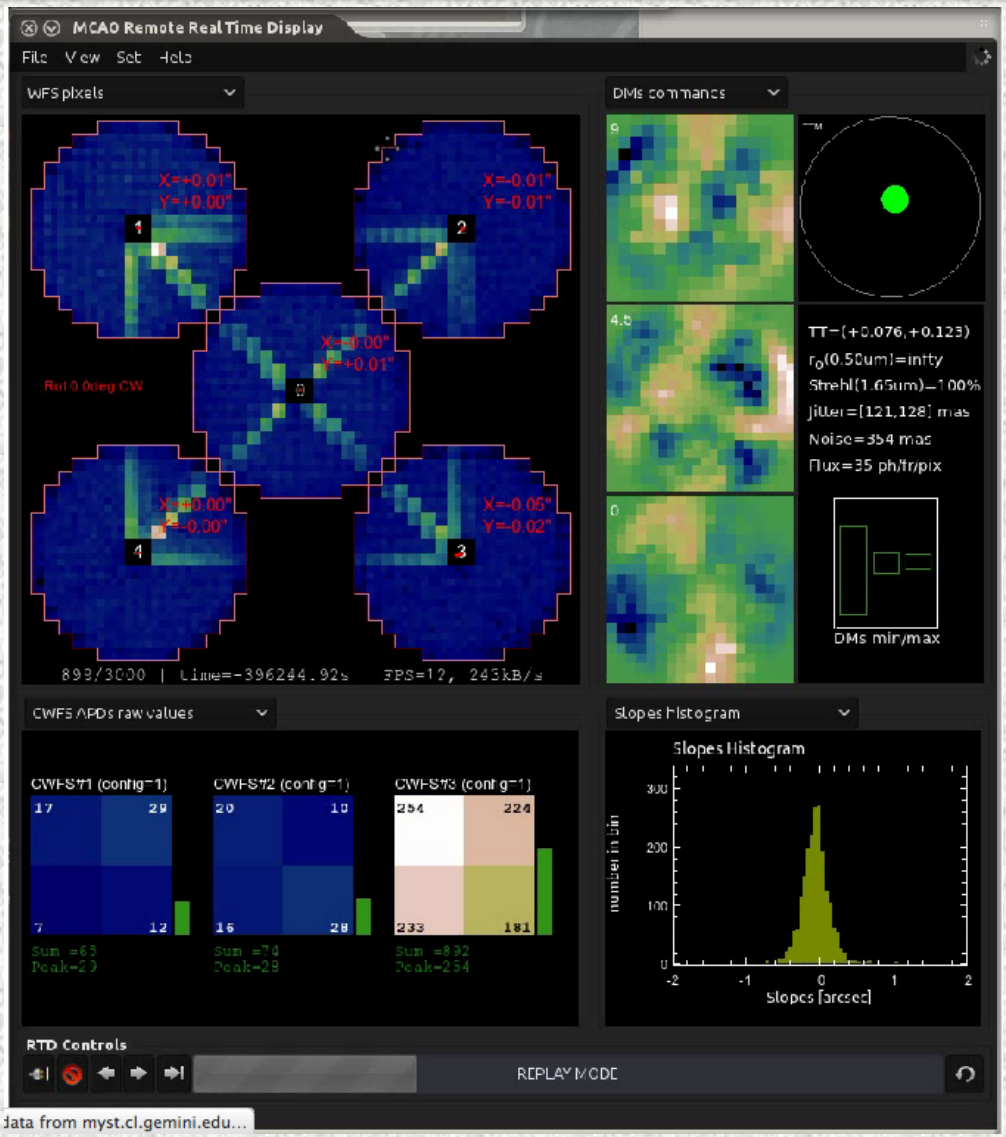
ESO 434-34



GeMS comm. results

GeMS Loops

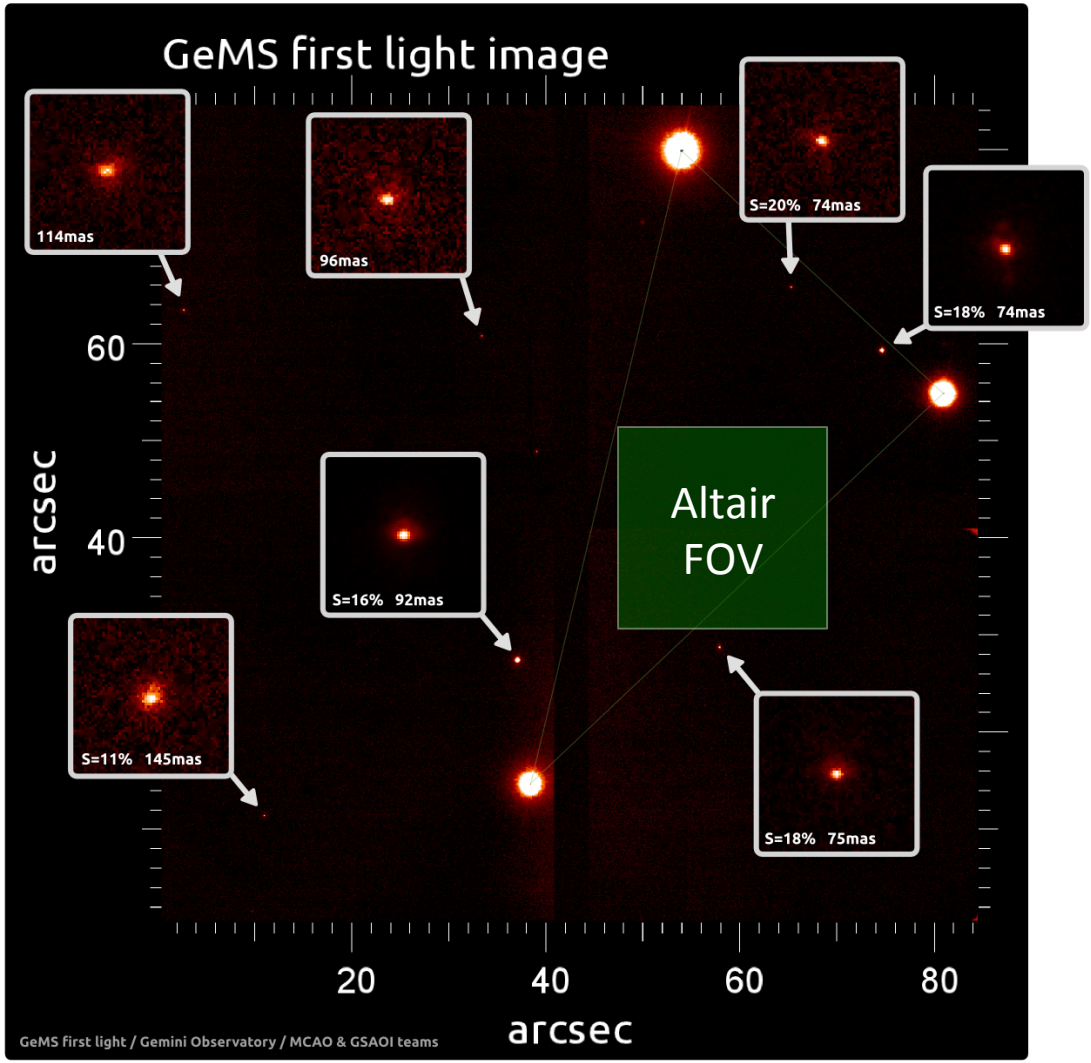
- Loop closed
  - FSA (Fast Steering Mirrors) offloads
  - LGS high order
  - M1 offloads
  - M2 offloads
  - Tip/Tilt from 3 NGS WFS
- Missing
  - Plate scale
  - Dithering
  - Slow focus WFS



GSAOI comm. results

- Day time
  - Pupil alignment
  - Detector characterization: read noise, dark, bad pixel mask
  - GCAL configuration and exp. times setup for all filters
  - Extensively software testing. A lot bug and problems fixed
  - Commissioning script in IRAF completed → base of the GSAOI reduction package.
  - Derived the linearity correction and gains for all detectors
- Night time
  - Initial Instrument Alignment Angle and WCS solution (AO loop open)
  - ODGW probe mapping → very good progress

GeMS/GSAOI comm. results



FIRST LIGHT IMAGE!!

April 2011

- Eng. First light (H2 filter)
- 6 loops/offloads closed
- No SFS
- No performance optimization
- No flexure compensation from ODGW
- Obtained after crude focus run
- Demonstrate basic features of MCAO

GeMS/GSAOI commissioning

Next few months

- November 2011/December 2011 – GeMS
  - Laser checks
  - Finish functionality and technical commissioning
  - Performance Optimization
  - Complete the integration into operation
  - Some GSAOI pending tasks (day time)
- January/February 2012 – GeMS/GSAOI
  - GSAOI commissioning: hotspot, IAA, WCS with loop closed
  - GSAOI detector performance: throughput, etc, on-sky
  - Science Commissioning

Stay tuned!!!


Thanks for your attention!!
Gracias por su atención!!
Obrigado pela sua atenção!!