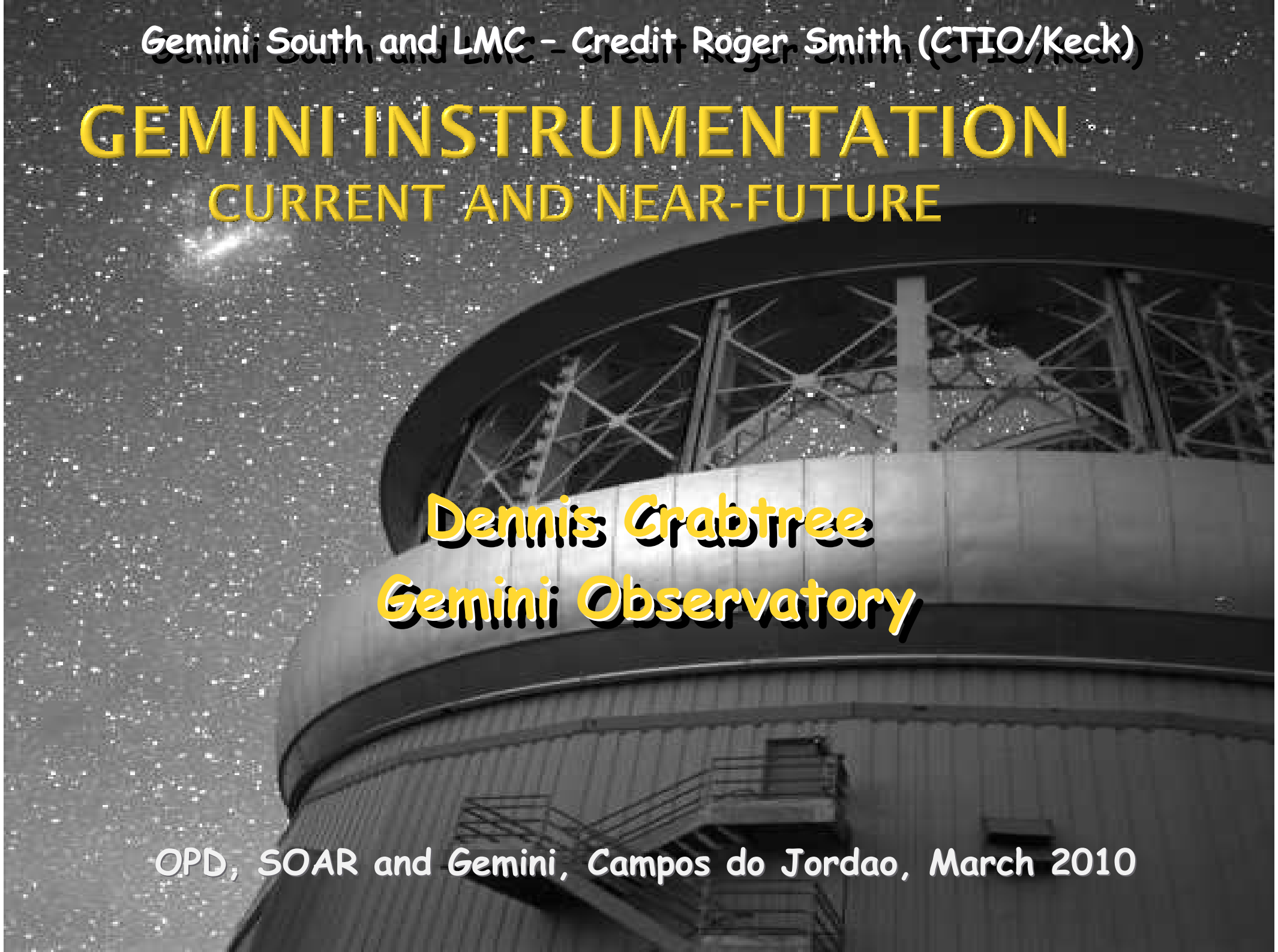
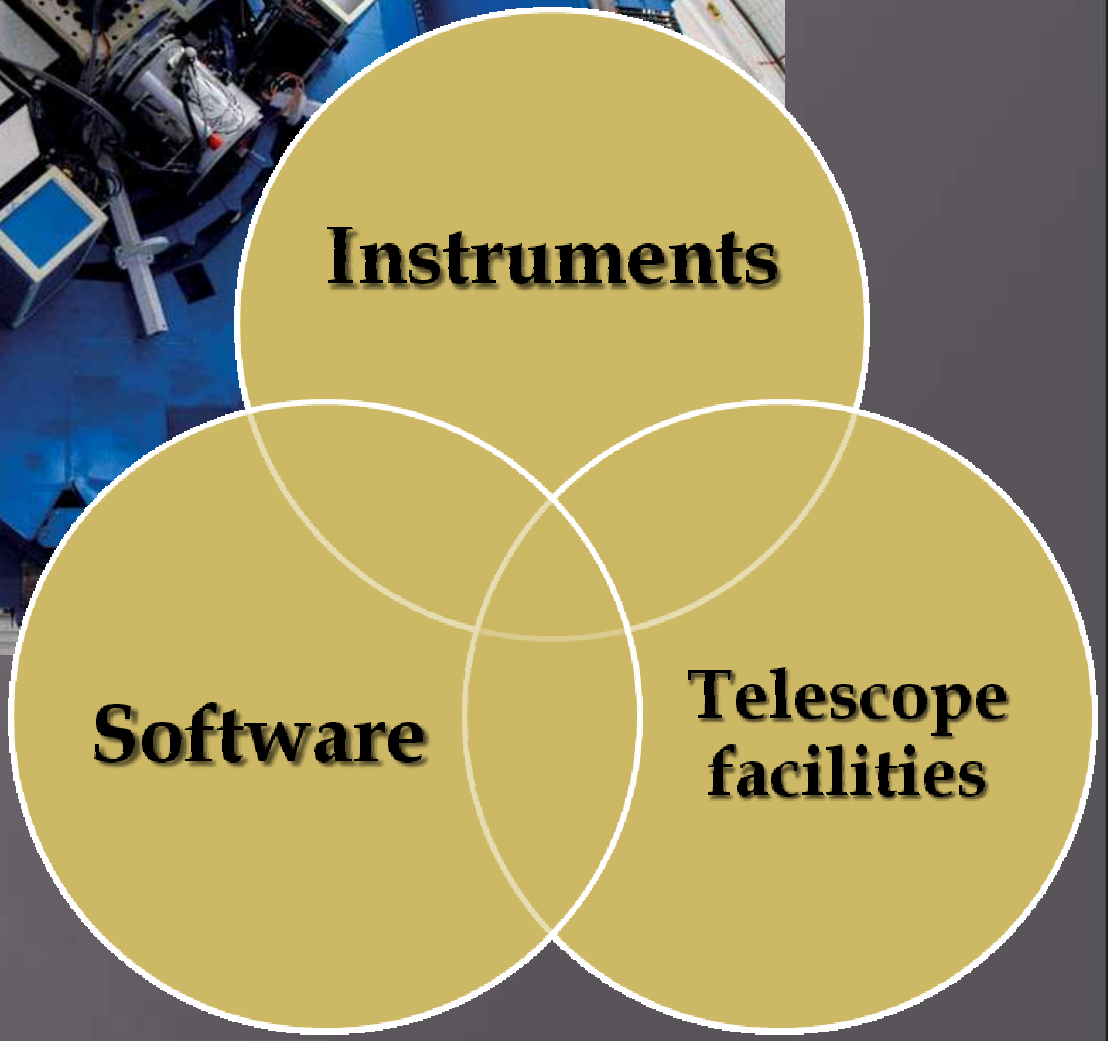



# GEMINI INSTRUMENTATION
## CURRENT AND NEAR-FUTURE

Dennis Crabtree
Gemini Observatory

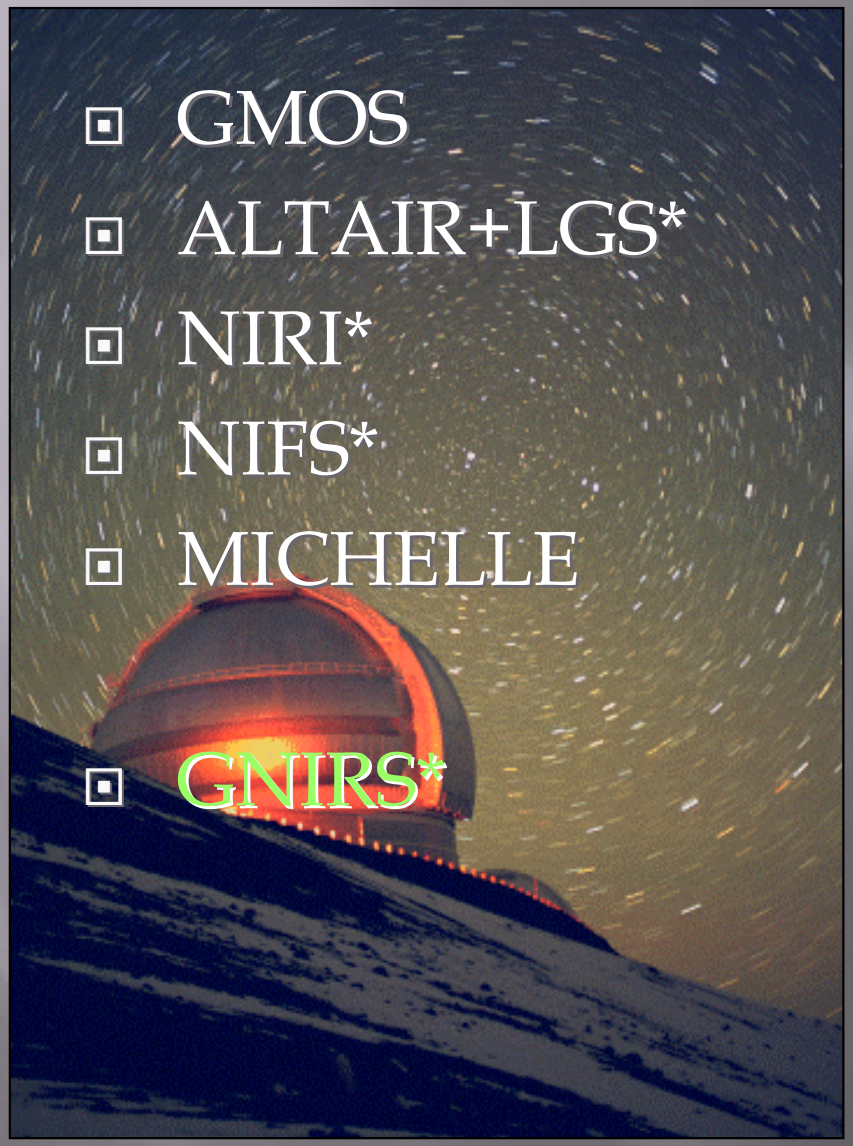
OPD, SOAR and Gemini, Campos do Jordao, March 2010




**Gemini's strengths:**

- **Observing flexibility**
- **IR sensitivity**
- **Image quality**

## Mauna Kea



- GMOS
- ALTAIR+LGS*
- NIRI*
- NIFS*
- MICHELLE
- GNIRS*

## Cerro Pachón

- GMOS
- T-ReCS
- NICI*
- Phoenix
- FLAMINGOS-2*
- GeMS* (MCAO/Canopus)
- GSAOI*
- GPI*

*AO instrumentation

# GMOS: Gemini Multi-Object Spectrograph (GN&GS)


**Optical Imaging**

- 5.5'x5.5' FOV; 0.073” pixels
- Broad (ugriz) and NB filters

**Spectroscopy**

- R ~ 600 – 4400
- Long-slit: 0.25 – 5.0” wide slits; 108” and 330” long.
- Multi-slit: ~60 0.5”+ slits are possible.
- IFU: 5”x7” 1000 element science + 500 elements for sky.

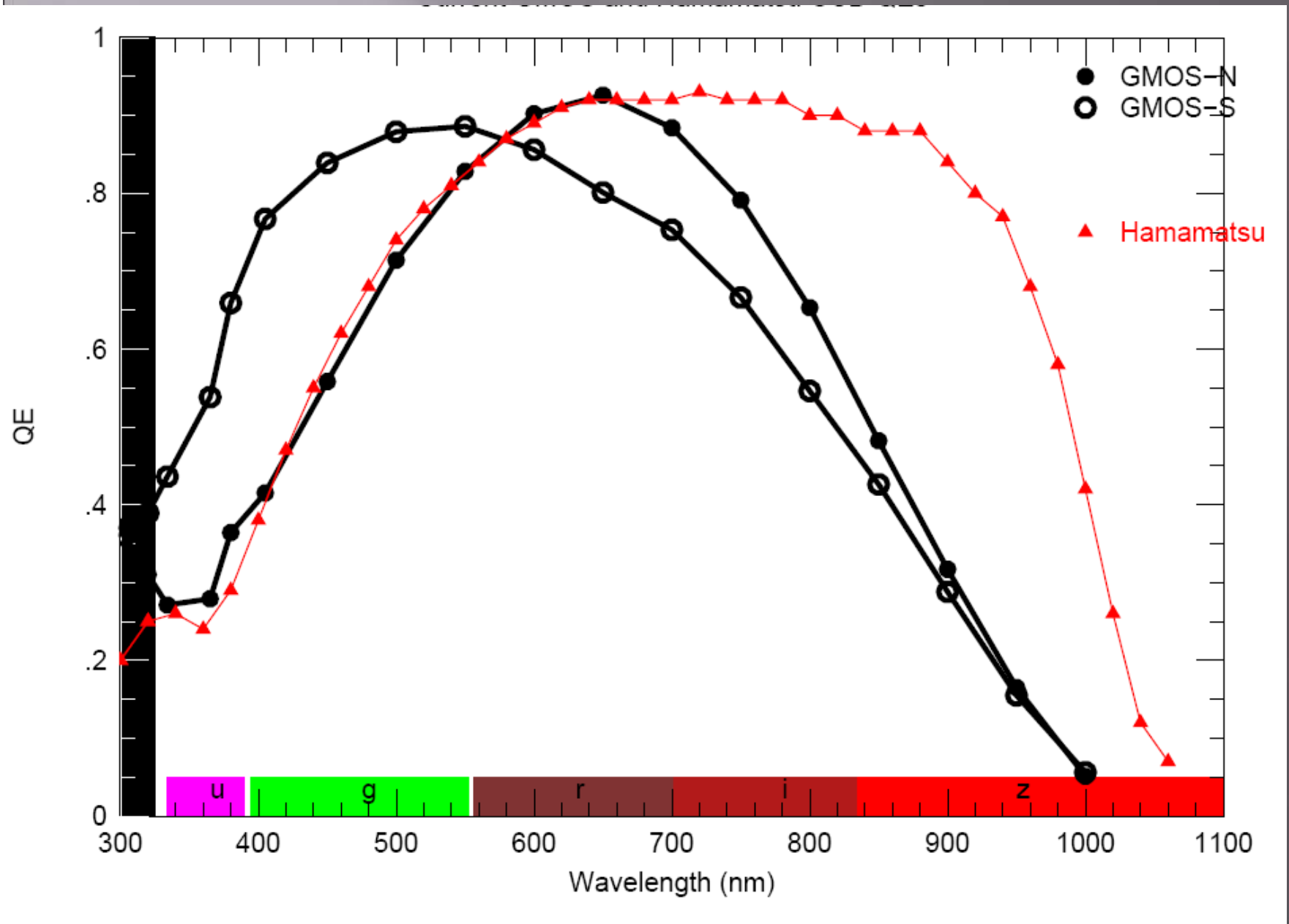
**Detectors**

- 3 E2V 2048x4608 pixels
- Planning now for GMOS-North upgrade to Hamamatsu CCDs in about 6 months.

**Nod and Shuffle**

- Improved sky subtraction
- Allows more (~200+) and shorter slits

# Hamamatsu CCDs for GMOS-N



# NIRI: Near-IR Imager (GN)

**Imaging**

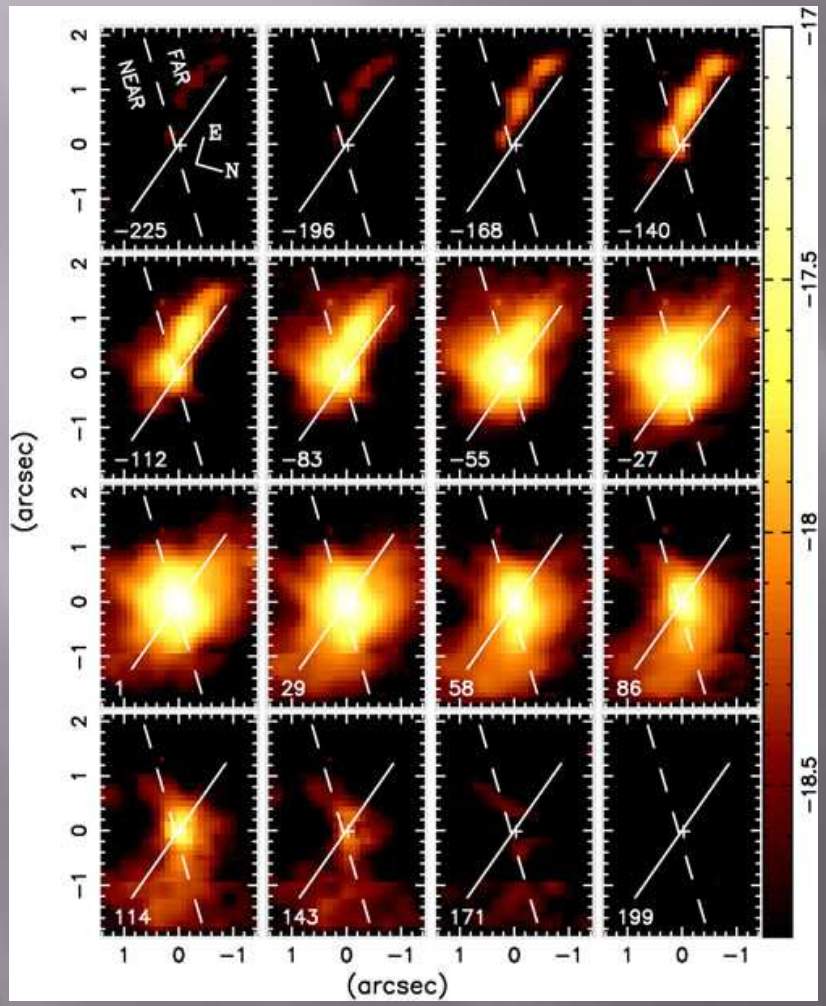
- f/6 0.12”/pix 120” FOV (natural seeing)
- f/14 0.05”/pix 51” FOV (L band, AO)
- f/32 0.02”/pix 22” FOV (M band, AO)
- 1 to 5 µm Y,J,H,K,L,M +NB filters
- Seeing-limited and Altair NGS/LGS AO

**Spectroscopy**

- R ~ 450-1650 single long slit
- f/6: 0.2-0.8” x 50-110” slits
- f/32: 0.1-0.2 x 22” slits
- ALADDIN-2 detector
- 1024x1024 pixels
- 0.9 to 5.5 µm

**Spectroscopy to be phased out when GNIRS is re-commissioned on Gemini-North**

# NIFS: Near-IR Integral Field Spectrometer (GN)




NIFS detection of gas inflow in NGC 4051 with 42km/s velocity slices along the $H_2$ profile.

**Integral Field Spectroscopy**

- Image slicer w/ 29 slices
- 3”x3” field
- ~70 detector pixels along each slice
- Spaxels ~0.1”x0.04”
- R ~ 5000
- z ,J ,H, K bands

**HAWAII-2RG detector**

- 2048x2048 pixels
- 0.9 – 2.5µm
- Coronagraphic mode also available

**Optimized for AO use with Altair**

# MICHELLE: Mid-IR Echelle Spectrometer (GN)

**Detector**

- 7 – 26 µm
- 320x240 Si:As IBC array
- Chopping and nodding (15” chop throw)

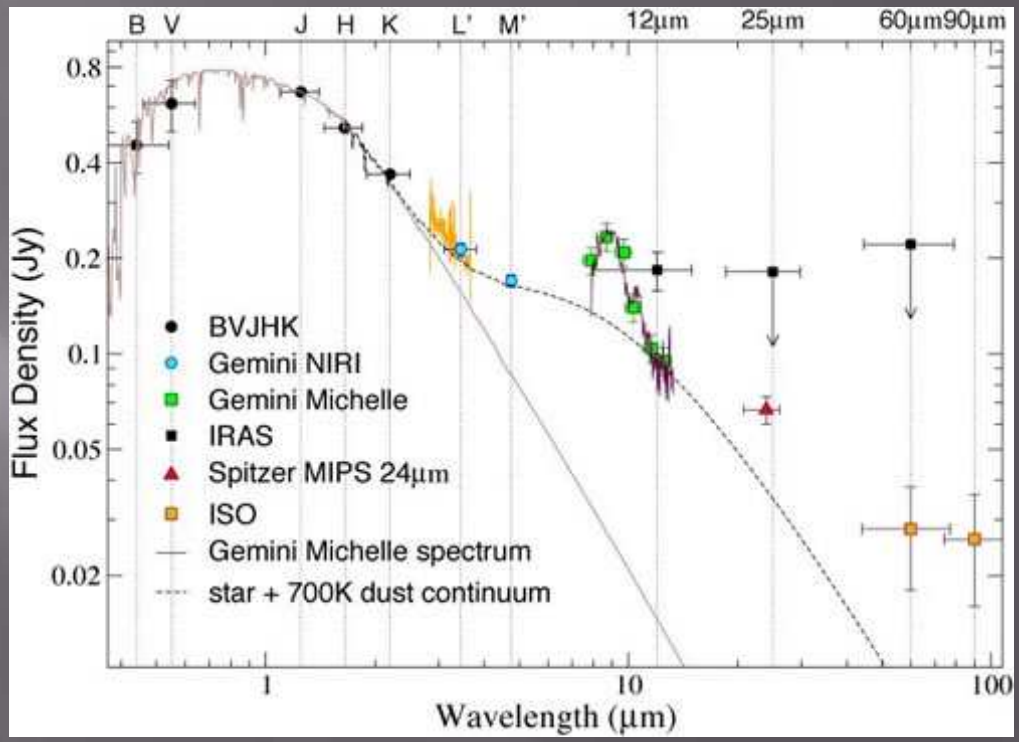
**Imaging**

- FOV 32”x24”; 0.1” pixels
- FWHM ~0.3” at 10 µm

**Spectroscopy**

- R ~100 – 3000 long slit
- R ~10,000 – 30,000 eschelle
- Slits 0.36”-1.3” wide x 43.2”

**Imaging polarimetry available**




**Michelle (plus other spectra) of HD 23514, in the Pleiades, providing evidence for colliding proto-planets.**

# GNIRS: Gemini Near-IR Spectrograph (coming to GN)

- 2 scales: 0.l5” and 0.05”/pixel
- Aladdin-3 detector
- 1024x1024 pixels
- 0.9-5.5 µm

Long Slit spectroscopy

- 0.9 – 2.5µm, R~5900, 18000
- 1.1 – 2.5µm, R~1700
- 2.9 – 5.5µm, R~1700, 5900, 18000
- $\Delta\lambda$: R1700: 0.3*$\lambda$; R5900: 0.09*$\lambda$; R18000: 0.03* $\lambda$

Cross-Dispersed spectroscopy

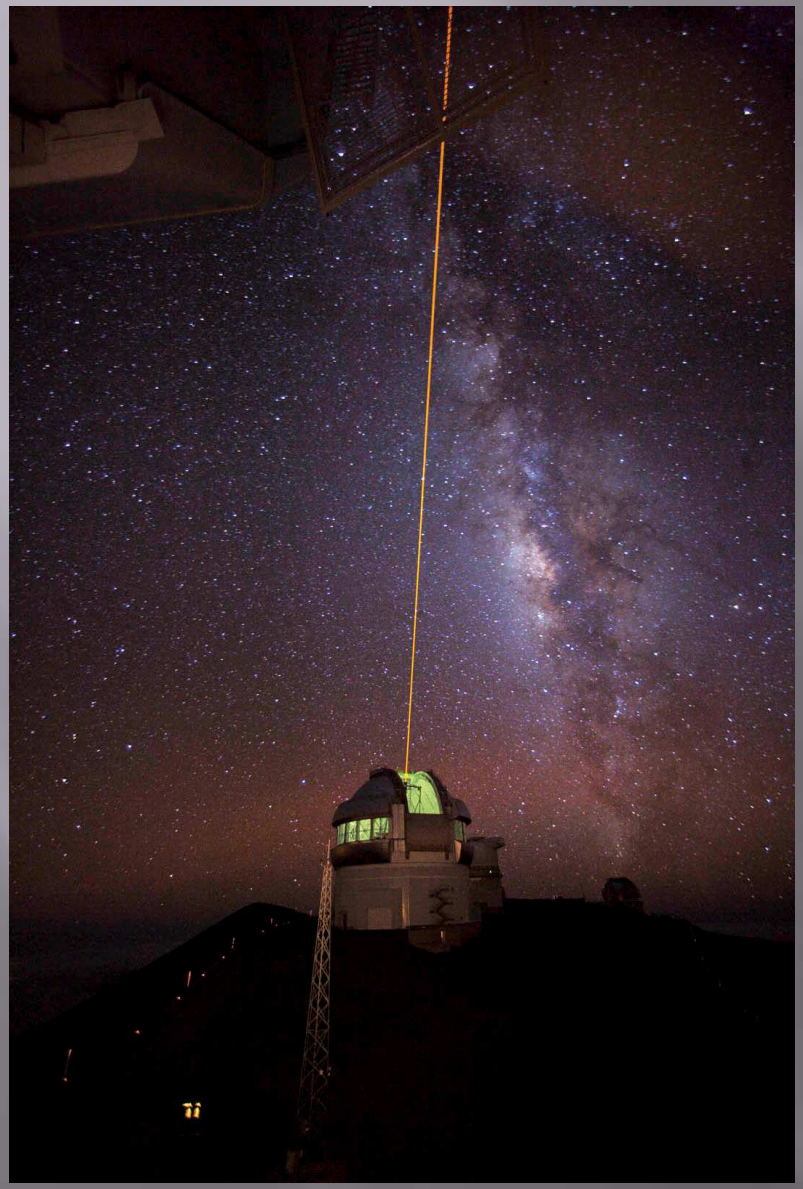
- 0.9 – 2.5µm, R=1700 full coverage
- R=5900, partial coverage

**GNIRS is being refurbished in Hilo after accidentally overheating ~3 years ago**

**GNIRS will be commissioned at GN in 2010A**

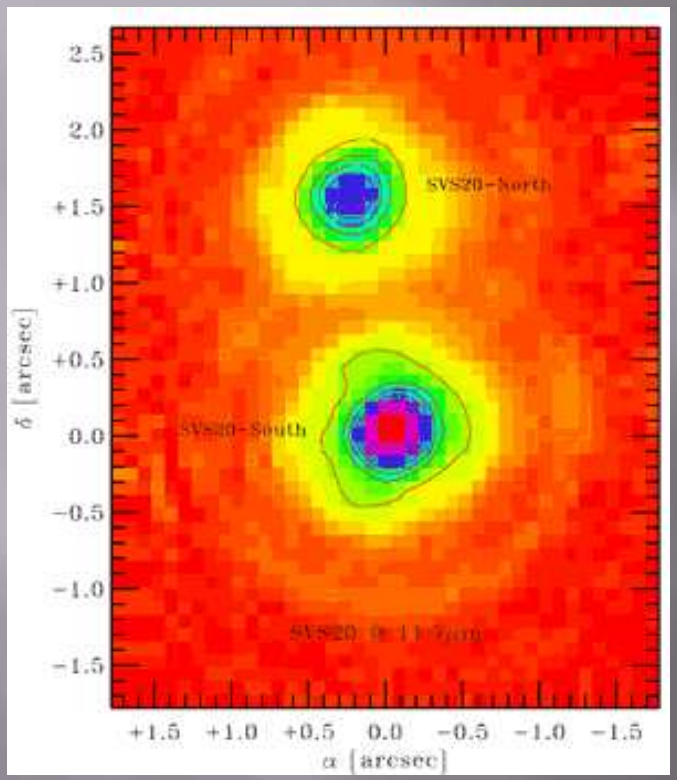
**Will use Altair NGS/LGS AO**

# Altair Adaptive Optics (GN)



- 177 element DM, 10 W sodium laser
- LGS science operations ~1 to 2 weeks/month (resource limited)
- NGS Strehl 0.2 to 0.4 (best at H, K)
- LGS Strehl ~0.3 at 2.2 μm (FWHM = 0.083”), PSF stable for a month at a time
- LGS sky coverage ~40% (4% for NGS)
- Working to increase sky coverage and reduce residual vibrations

# T-ReCS: Thermal Region Camera+Spectrograph (GS)




Thermal emission from dust around a protostellar binary system

**Detector**

- 320x240 Raytheon SBRC
- 5-28μm
- Chop and Nod (15" chop throw)

**Imaging**

- Filters: N, Q + NB
- FOV: 28.8"x21.6"
- 0.09"/pixel

**Long-slit Spectrograph**

- R~100, 1000 at 10μm
- Slits: 0.21"-1.32" x 21.6"

# NICI: Near IR Coronagraphic Imager (GS)


**Planet search campaign is well underway – many candidate planets**

**Open use in 2010B**

- **85 element curvature AO system**
  - **Strehl ratio: up to 40% at 1.6µm**
  - **Lyot coronagraph**
- **Dual channel imager**
  - **2 Aladdin-2 1024x1024 arrays**
  - **FOV: 18”x18”; 18mas/pixel**
  - **0.9 – 5.5µm**
  - **Filters: J-M, NB, and specialized 1.6µm methane filters**
  - **Spectral and angular differential imaging for planet searches**

**Contrast >$10^6$ inside 1-2”**

# Phoenix Near-IR Spectrograph(GS)

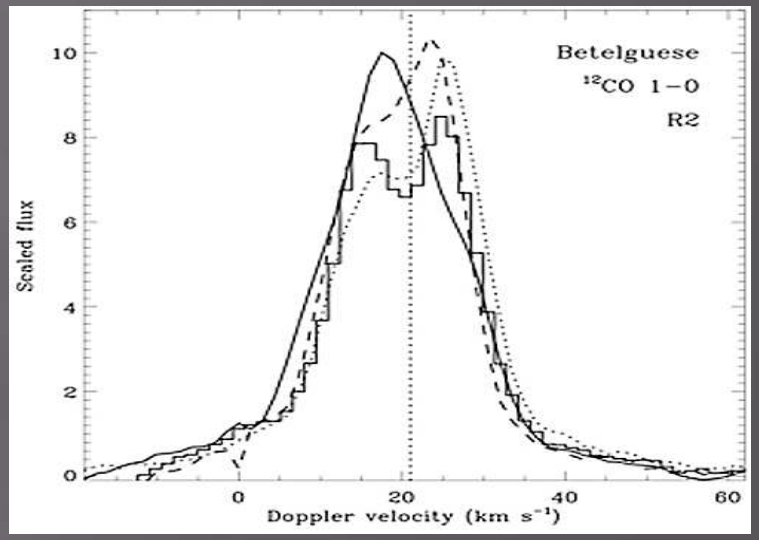
Long slit eschelle spectrograph

- 4 pix slit R~50,000
- 3 pix slit R~65,000
- 2 pix slit R~80,000
- Δλ: 0.005*λ, 1500 km/s (not cross-dispersed)
  - 21 order sorting filters

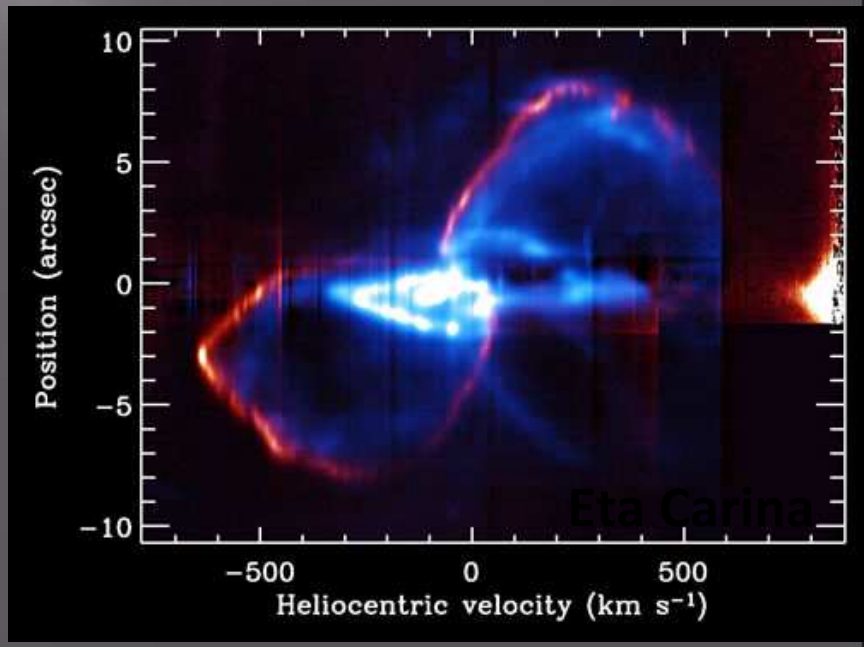
Aladdin-2 detector

- 1024x512 pixels
- 0.9-5.5 μm

Phoenix is on loan from NOAO




**Resolving velocity structure**



# FLAMINGOS-2: Near-IR Imager and MOS (GS)

**Imaging**

- 6.1’ FOV; 0.18”/pixel
- 2’ FOV; 0.09”/pixel (MCAO)
- Y, J, H, K filters
- ultra-narrow band, tunable filters for high-z searches

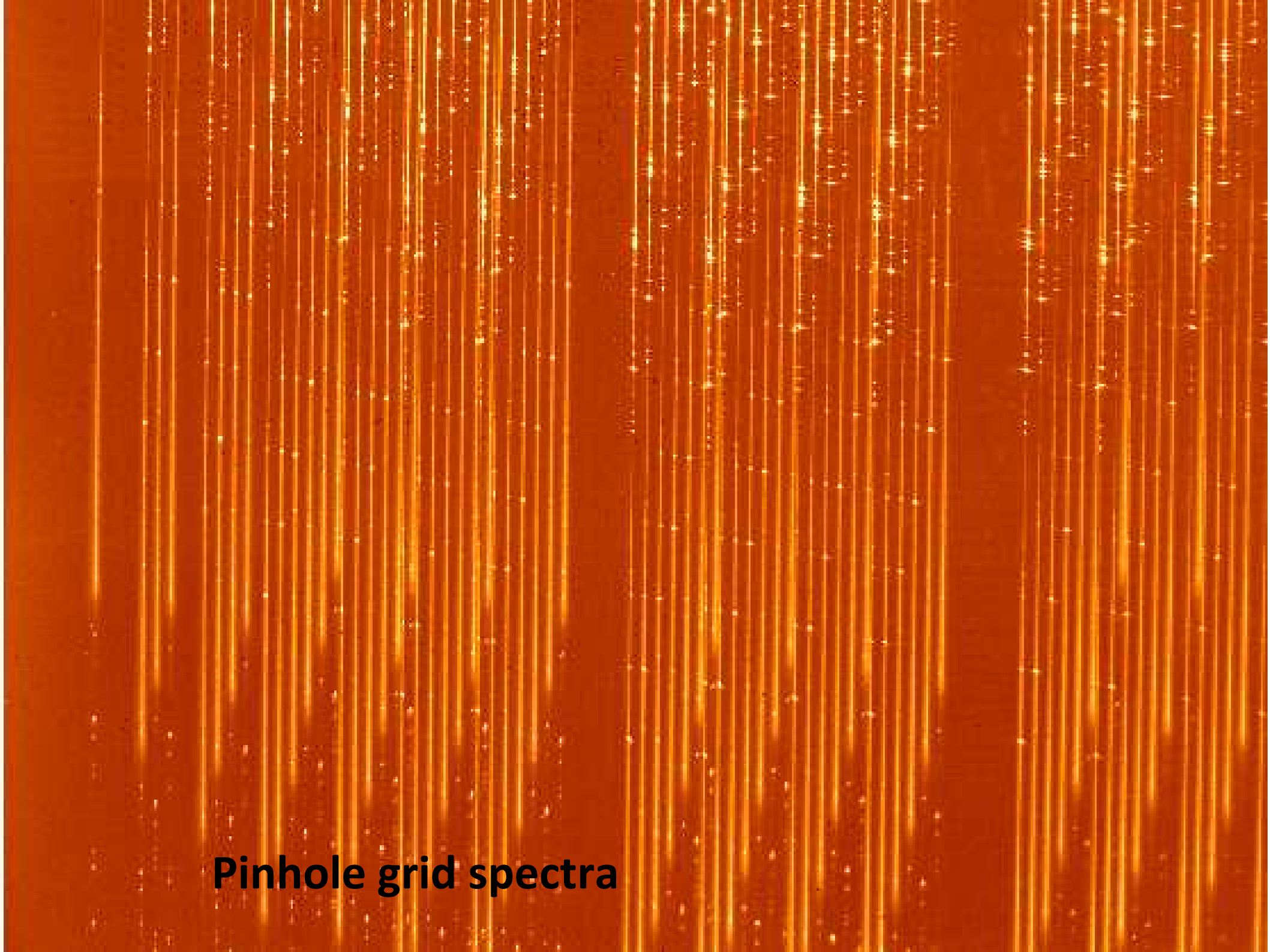
**Spectroscopy**

- R ~ 1200 – 3000
- FOV: 2'x6‘ (1’x2’ MCAO)
- Long-slit or custom multi-slit masks (9 cold at once, daytime swappable)
- HAWAII-2 Detector: 0.95 – 2.5µm

**FLAMINGOS-2 has finished acceptance testing – extensive work required before instrument is offered**

# Flamingos-2

- Additional work required for F-2 to be a facility-class instrument
- MOS wheel mechanism
- Gate valve light baffle
- MOS cooling time
- Cooling line and vacuum issues
- Replacement array expected in April


Pinhole grid spectra

# GeMS + GSAOI (GS)

Multi-conjugate AO known as GeMS (Gemini MCAO System)

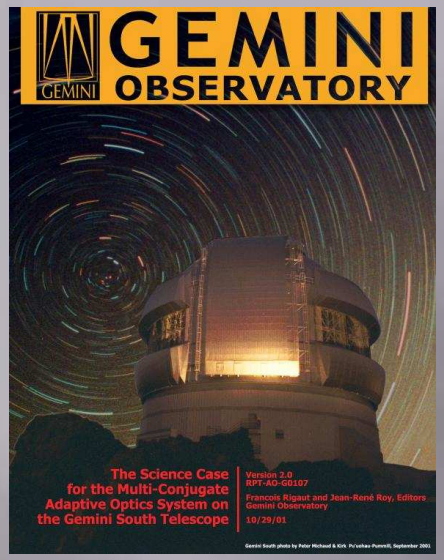
- AO bench = Canopus
- Laser enclosure and beam transfer optics installed
- Waiting on 50 W Na laser
- Uniform near diffraction limited PSF over 2’ FOV

GSAOI imager:

- 1.4’x1.4’ FOV; 0.02”/pixel
- 4 HAWAII-2RG detectors
- 0.9 – 2.5 µm JHK
- On-detector guide windows

# GeMS (MCAO)

Demonstrated Science



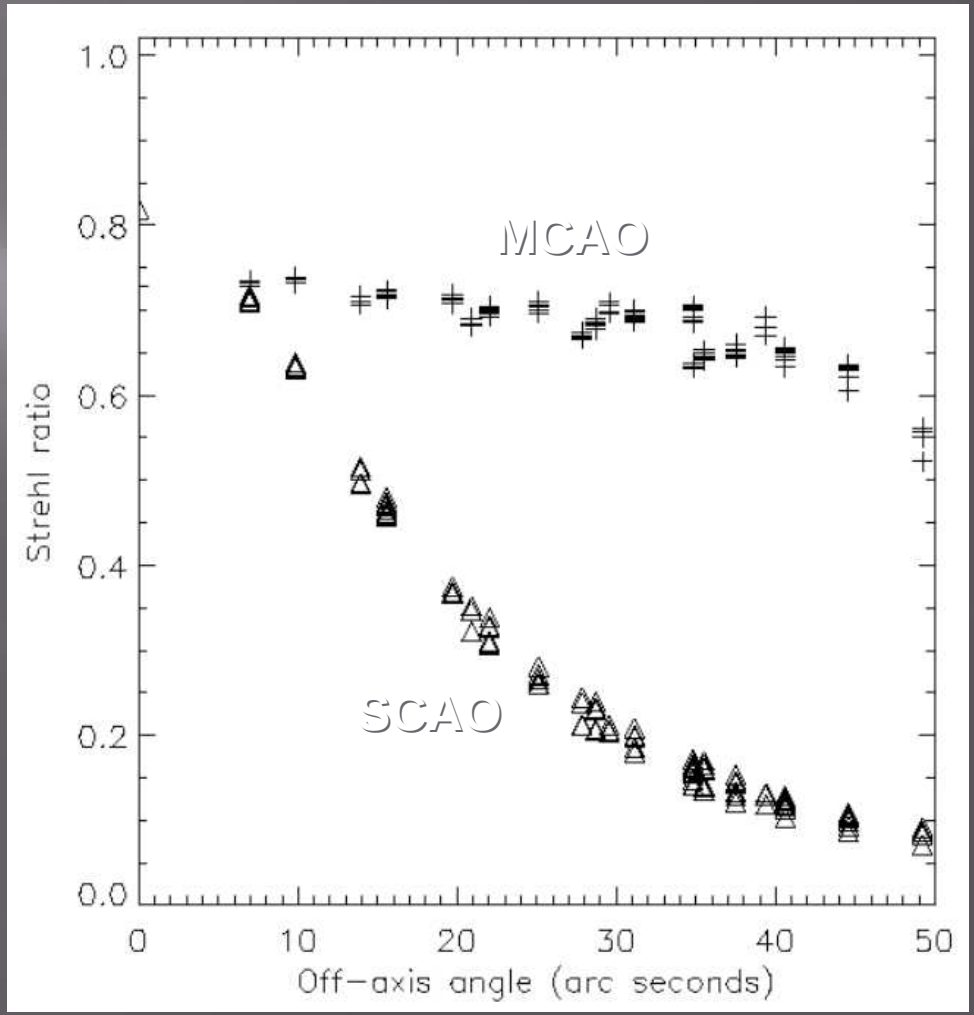

Demonstrated physics


- Major limitations of AO:
  - Sky coverage
  - Small field of view
- MCAO provide ~30% sky coverage (LGS) and ~80" FoV
- Photometric accuracy (8x gain w.r.t AO)

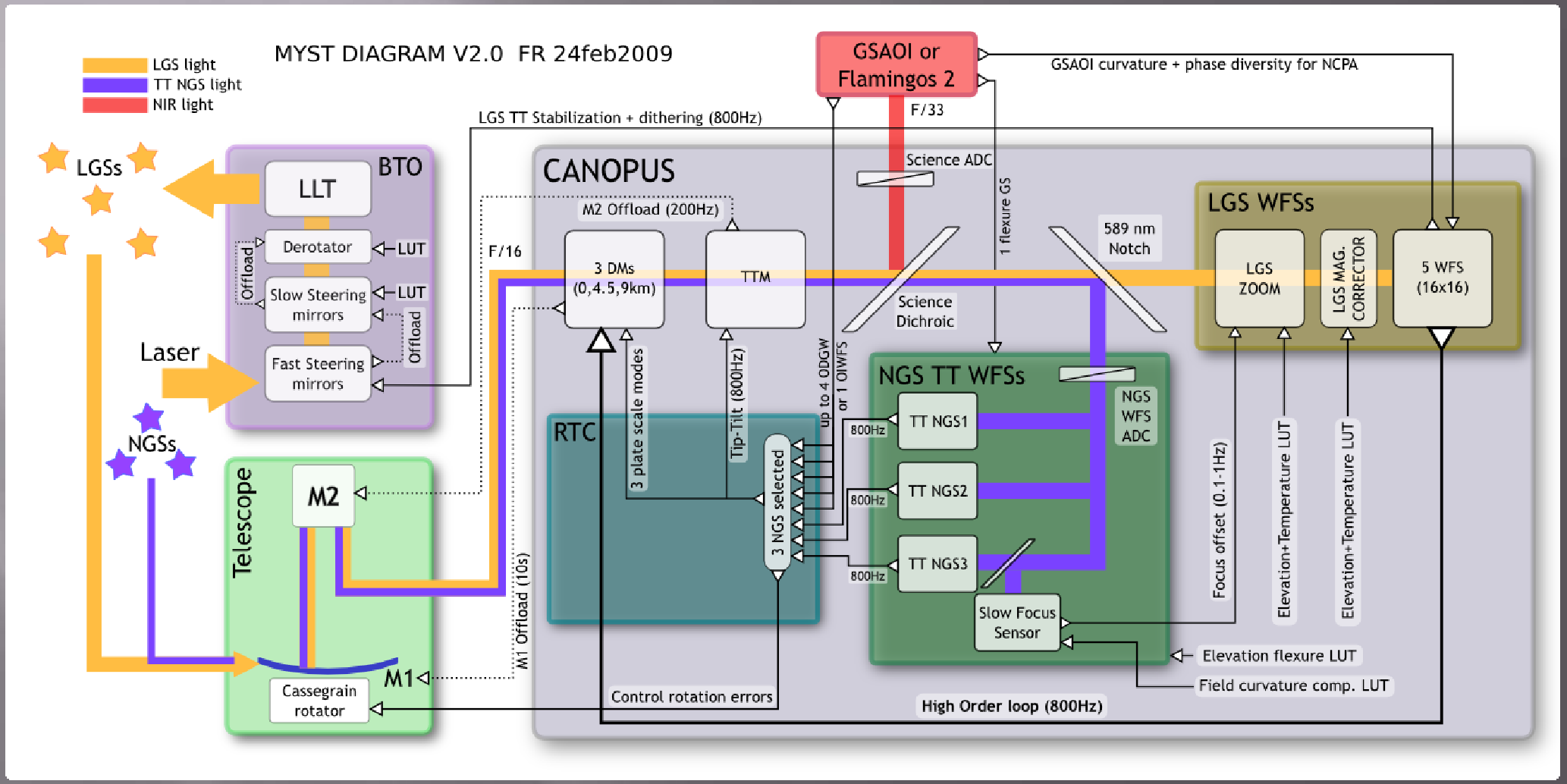
- Gemini MCAO:
- Work started mid 99
- Funding was secured 2001-2002
- Being integrated in La Serena
- First light in 2010

# GeMS performance

- Strehl under median seeing conditions (0.7")
  - J □ 20% ; H □ 40% ; K □ 60%
  - Strehl uniformity: J □ 5% ; K □ 2%
- Sky coverage:
  - Need 3 TT guide stars (Rlim = 18.5)
  - Galactic pole □ 10%
  - Average over whole sky □ 30%
  - Compatible with degraded modes of operation (1 or 2 TTGS)



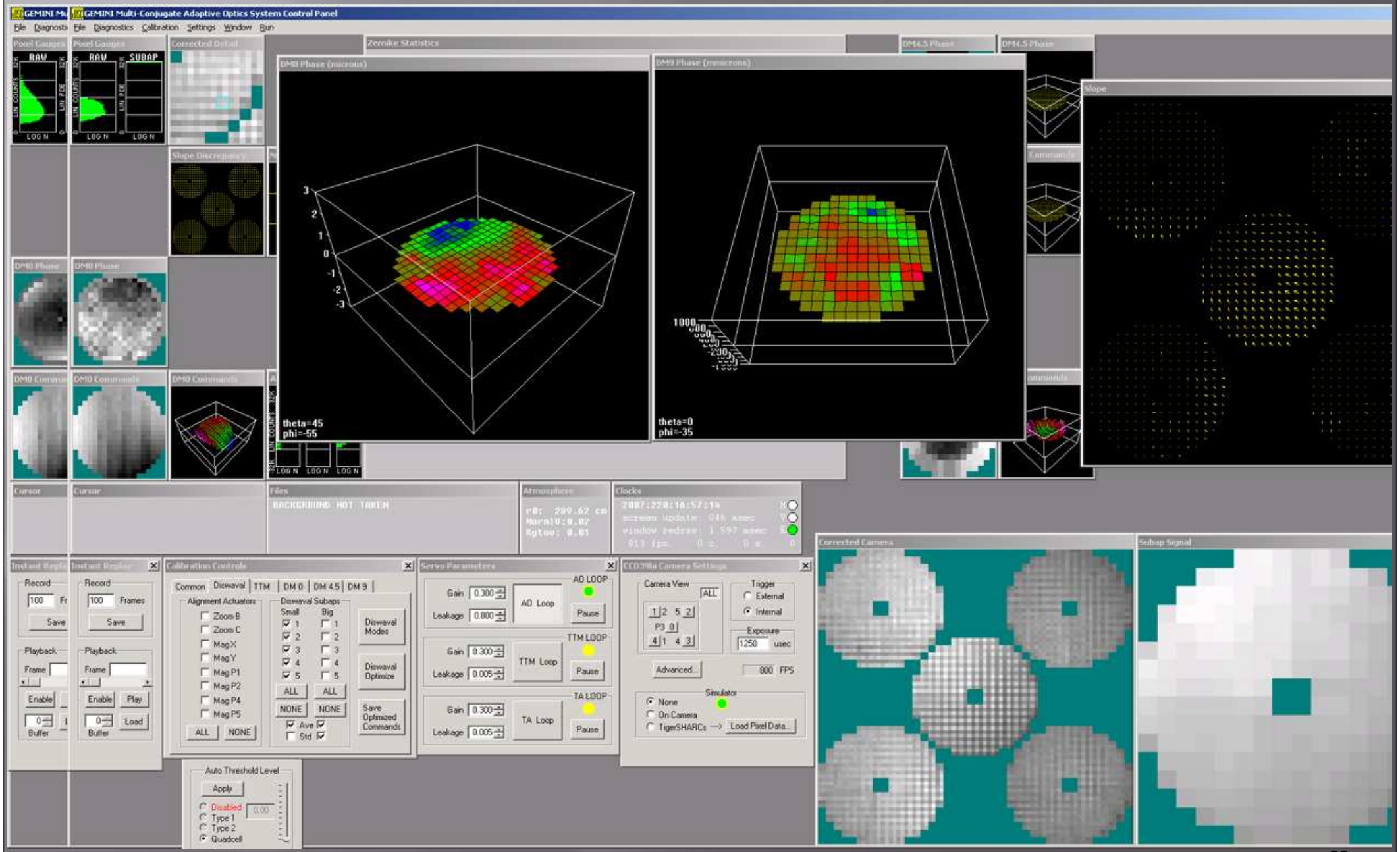
# GeMS block diagram



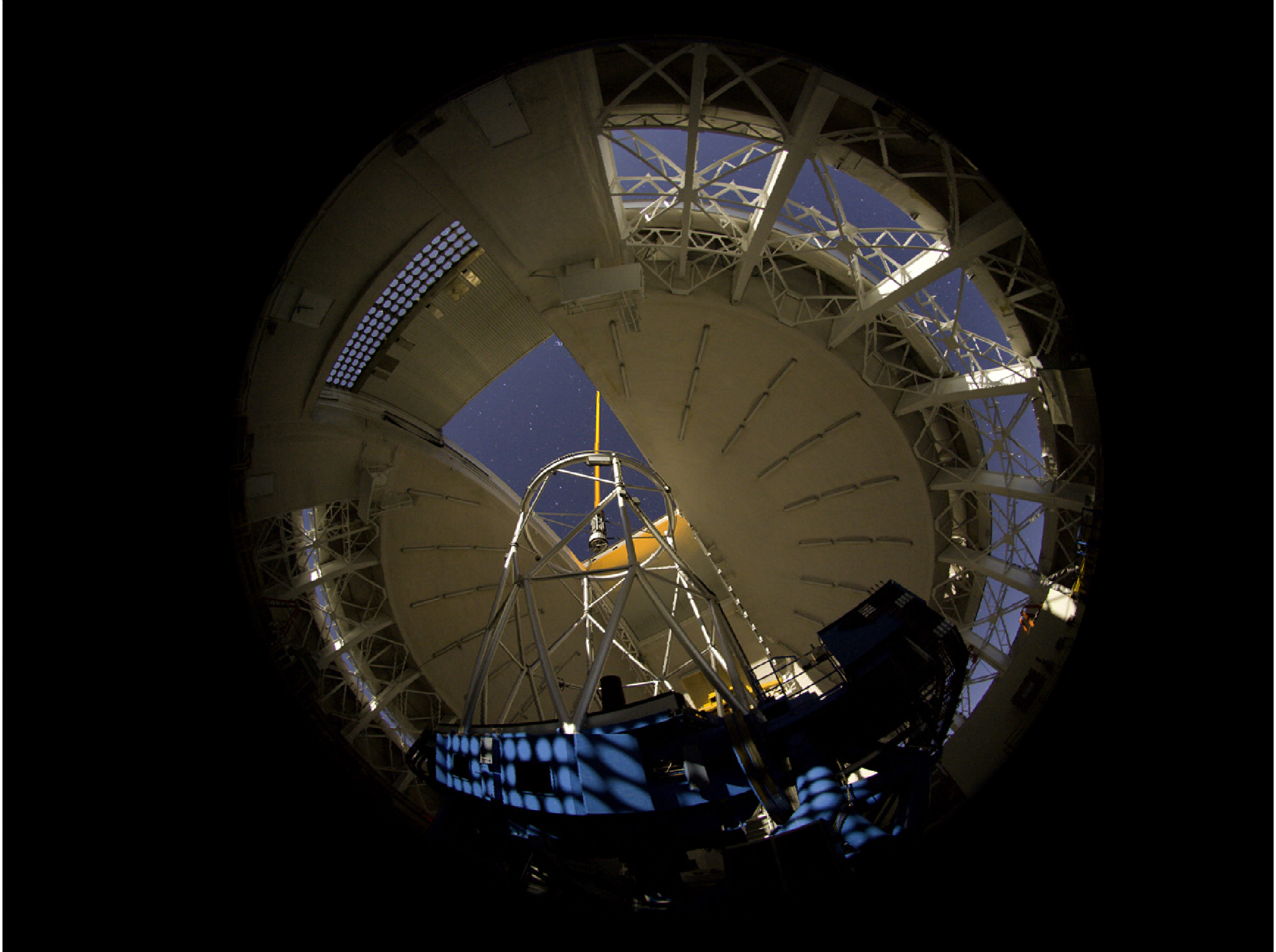
# "Side" subsystems (infrastructure)

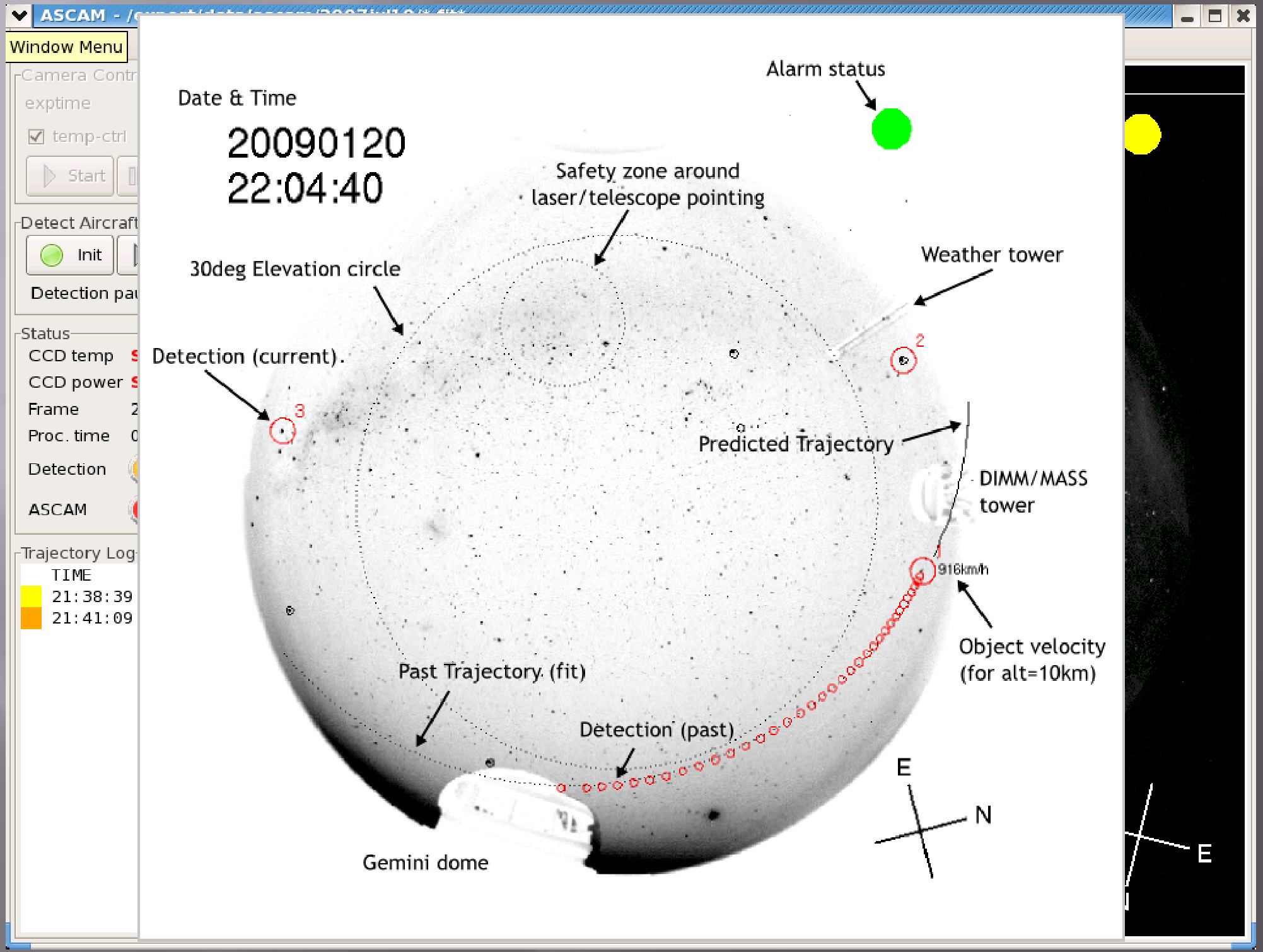
## Elevation platform extension

# All loops closed in the lab




GeMS
CANOPUS




ASCAM - /
Window Menu
Camera Contr
exptime
temp-ctrl
Start
Detect Aircraft
Init
Detection pau
Status
CCD temp
CCD power
Frame
Proc. time
Detection
ASCAM
Trajectory Log
TIME
21:38:39
21:41:09
Date & Time
20090120
22:04:40
Alarm status
Safety zone around
laser/telescope pointing
30deg Elevation circle
Weather tower
Detection (current).
2
3
Predicted Trajectory
DIMM/MASS
tower
916km/h
Object velocity
(for alt=10km)
Past Trajectory (fit)
Detection (past)
Gemini dome
E
N
E

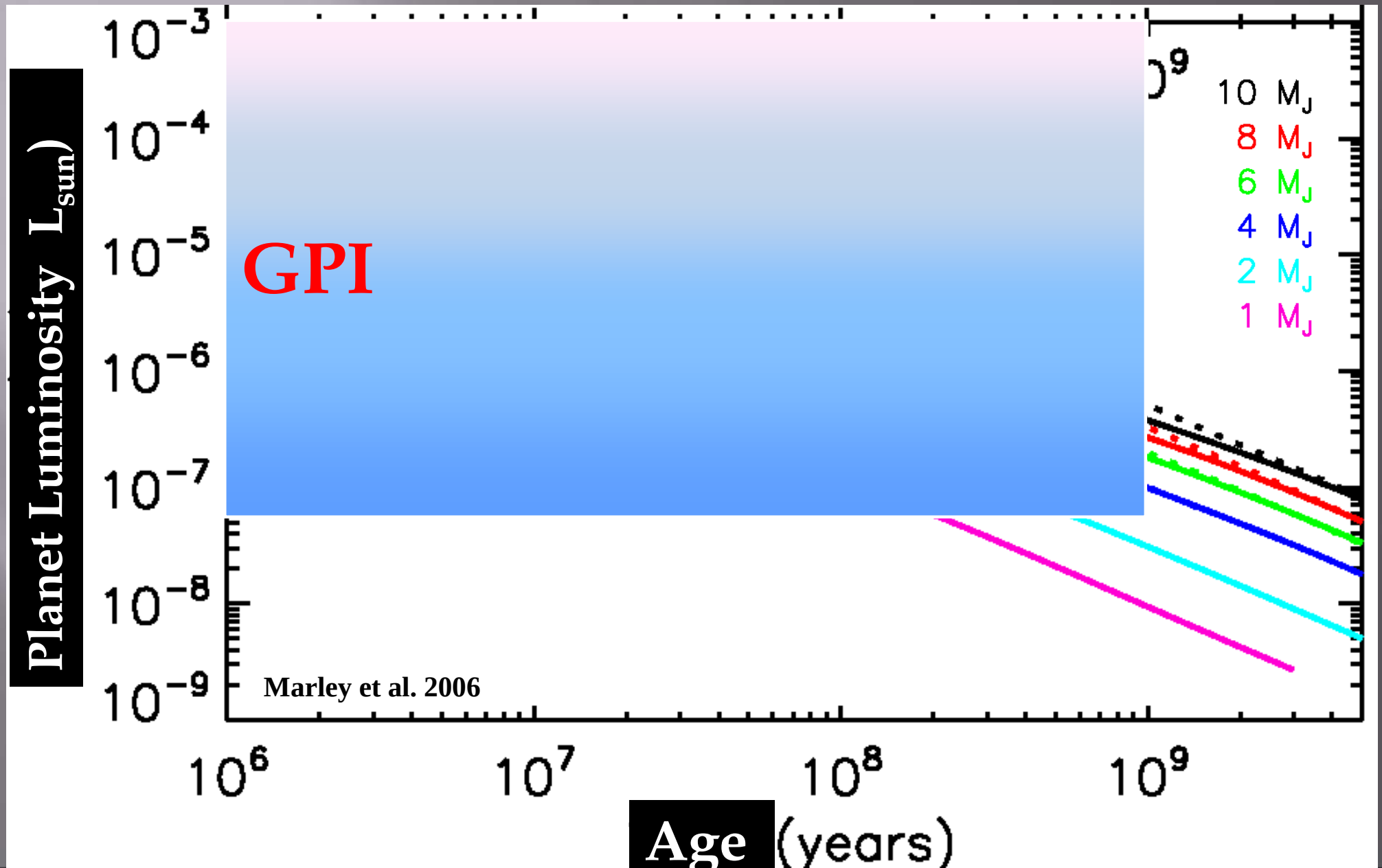
# GEMINI PLANET IMAGER

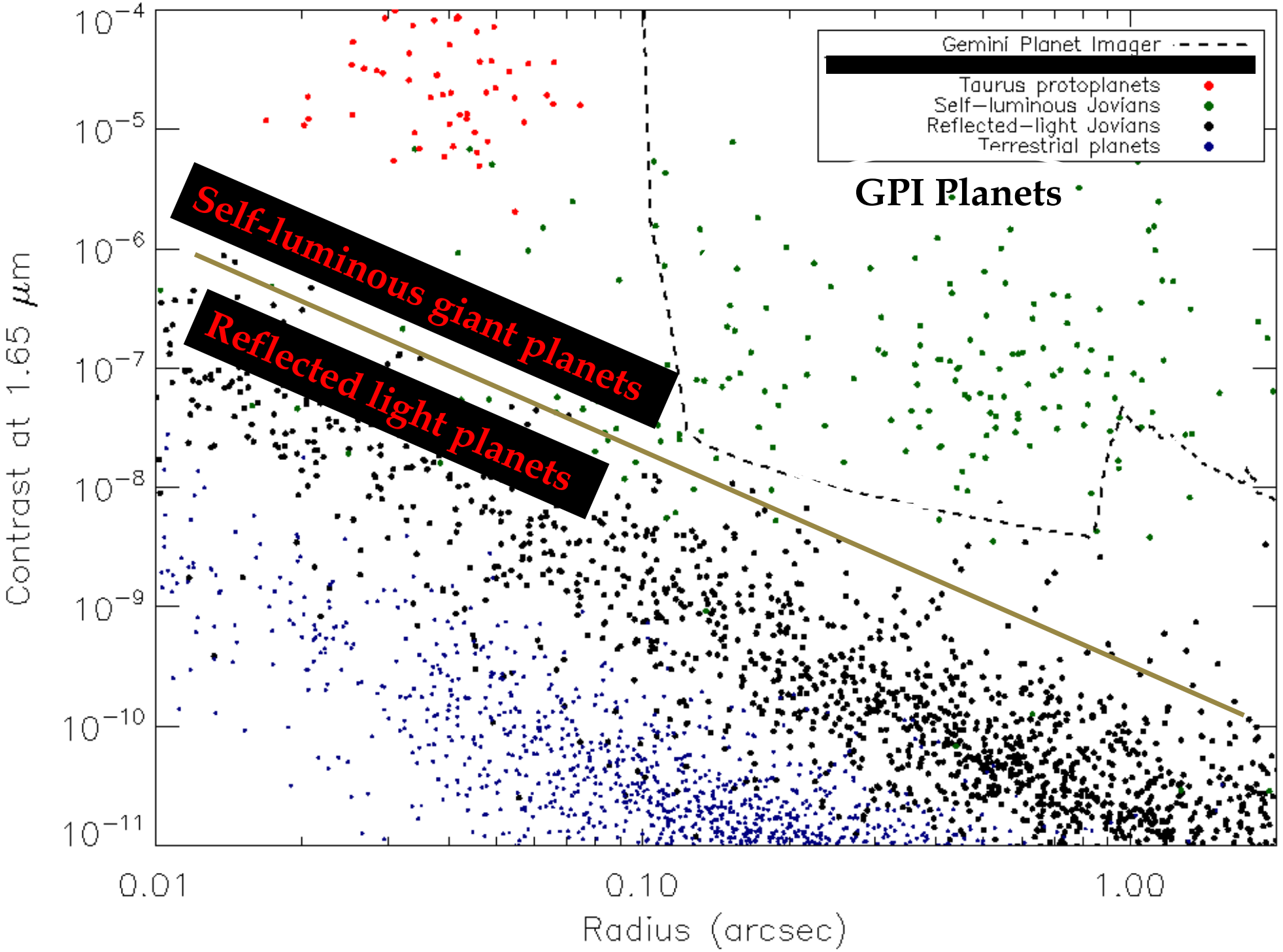

**PI: Bruce Macintosh**

**Project Scientist: James Graham**

**AMNH, HIA, JPL, LLNL, UCLA, UCSC, U. Montreal**

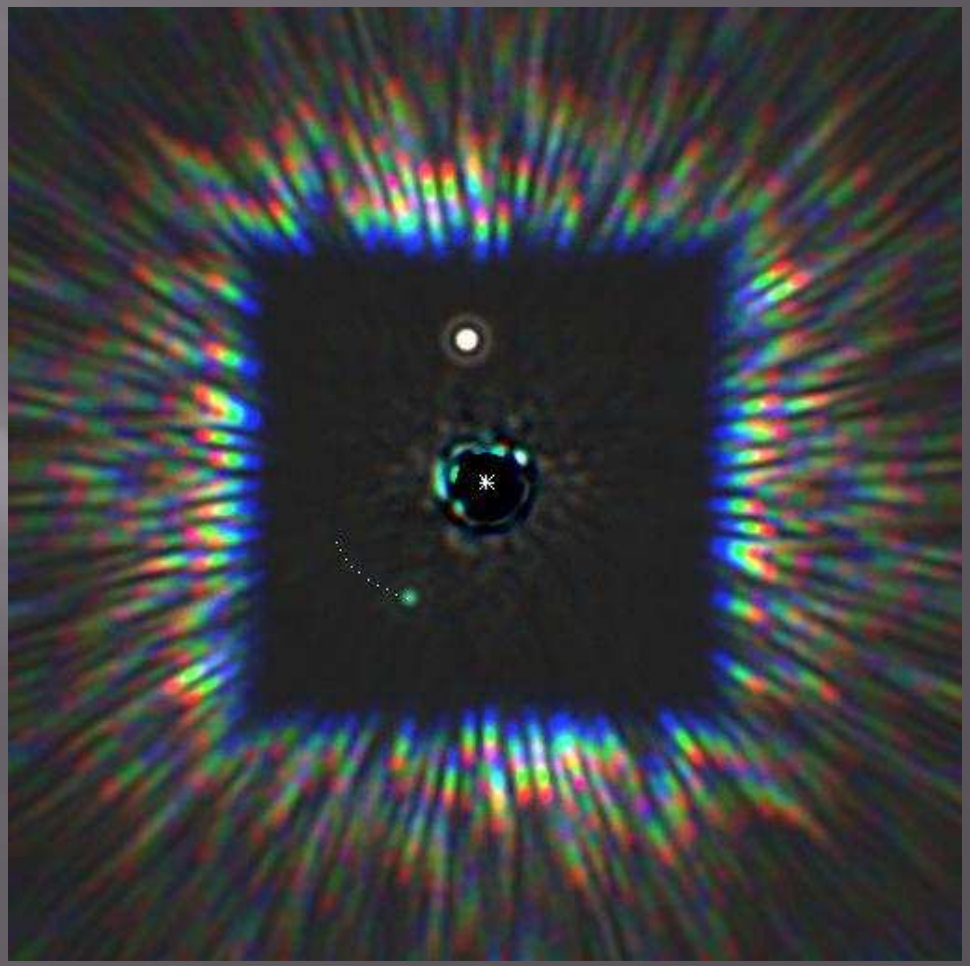
# Models of Young Planet Luminosity




Gemini Planet Imager
Taurus protoplanets
Self−luminous Jovians
Reflected−light Jovians
Terrestrial planets
GPI Planets
Self-luminous giant planets
Reflected light planets
Contrast at 1.65 μm
10^−4
10^−5
10^−6
10^−7
10^−8
10^−9
10^−10
10^−11
0.01
0.10
1.00
Radius (arcsec)

# Gemini Planet Imager (GS)

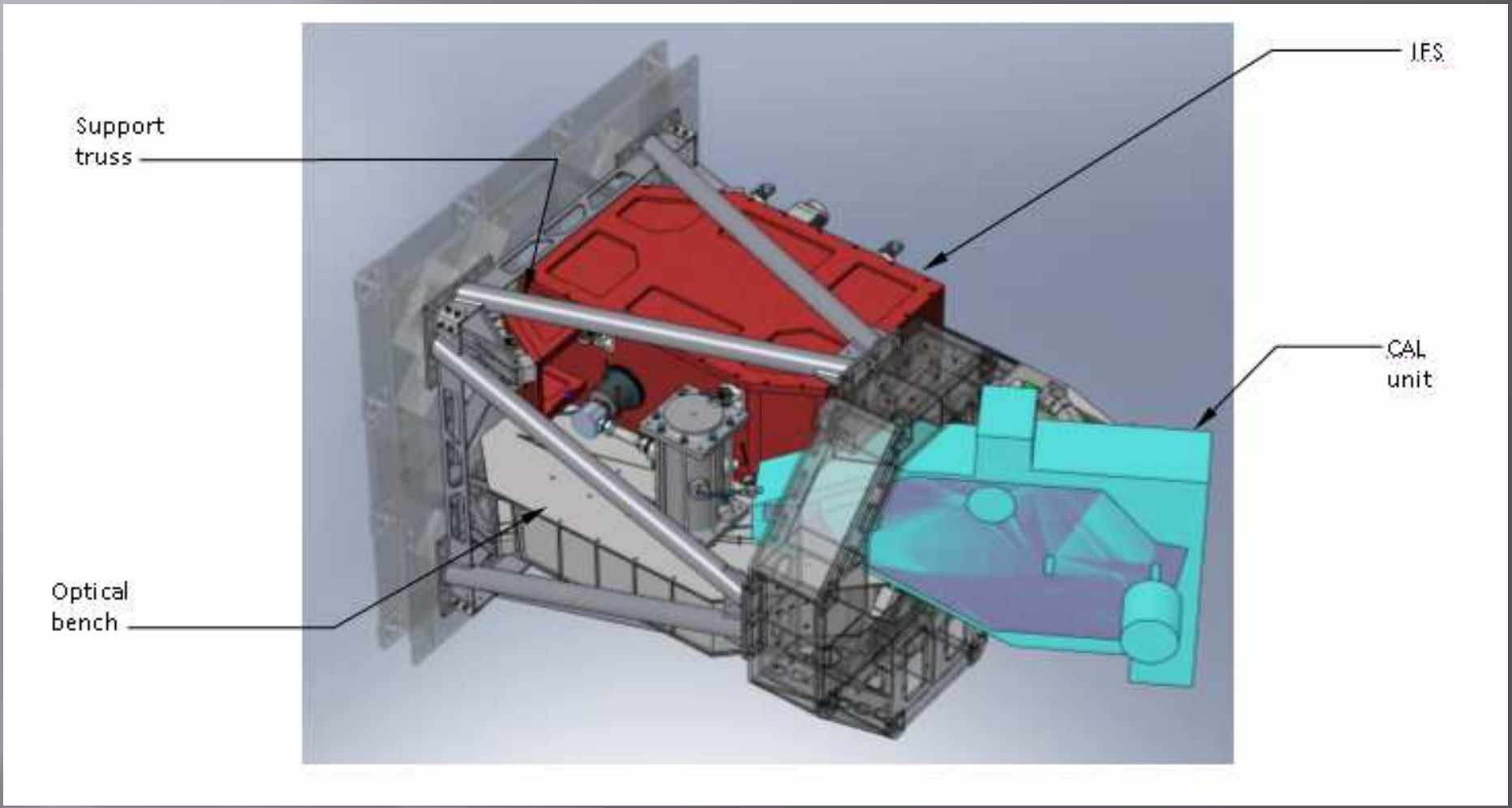
- "Extreme AO" Coronagraph designed for planet detection and characterization
- Specialized high-order AO system will produce Strehl ratios >80%
- High-order interferometric WFS to minimize NCP errors
- Sophisticated apodized Lyot coronagraph
- Low-resolution Integral field spectrograph



**GPI passed CDR and is under construction now**

**Delivery expected in mid-2011**

# GPI Design




**Final version of the GPI design, which is now more robust to vibrations.**

# Summary

- Gemini has a strong set of instrumentation covering optical – mid-IR
- Powerful new capabilities, although delayed, will be available in the next year
  - Flamingos-2, GNIRS
- GeMS will provide unique capability at Gemini South