Current and Future Instrumentation at Gemini Observatory

Rubén Díaz

Gemini Observatory, NSF's NOIRLab

Gemini Instruments

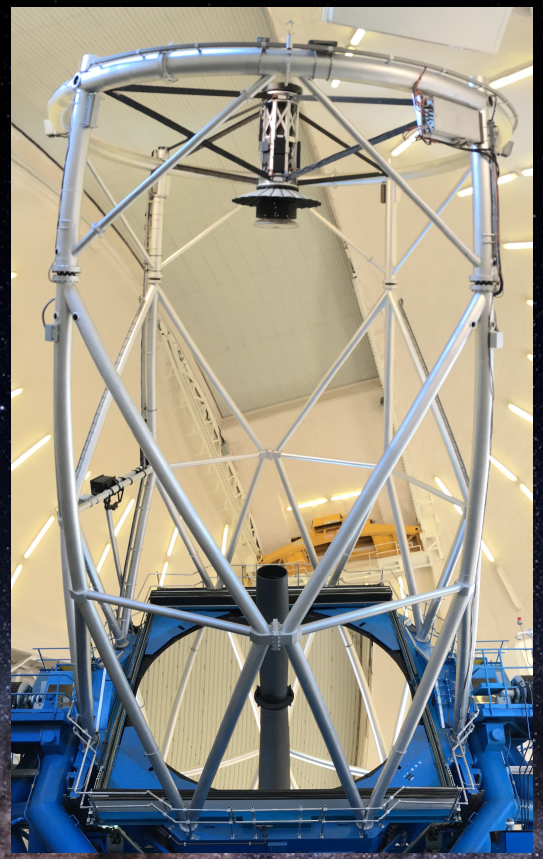
Both Gemini South (GS) and Gemini North (GN) 8.1m telescopes, are complemented by a suite of optical and IR instruments. Our operational mode offers to the user community 4 facility instruments plus a single adaptive optics (AO) system per telescope.

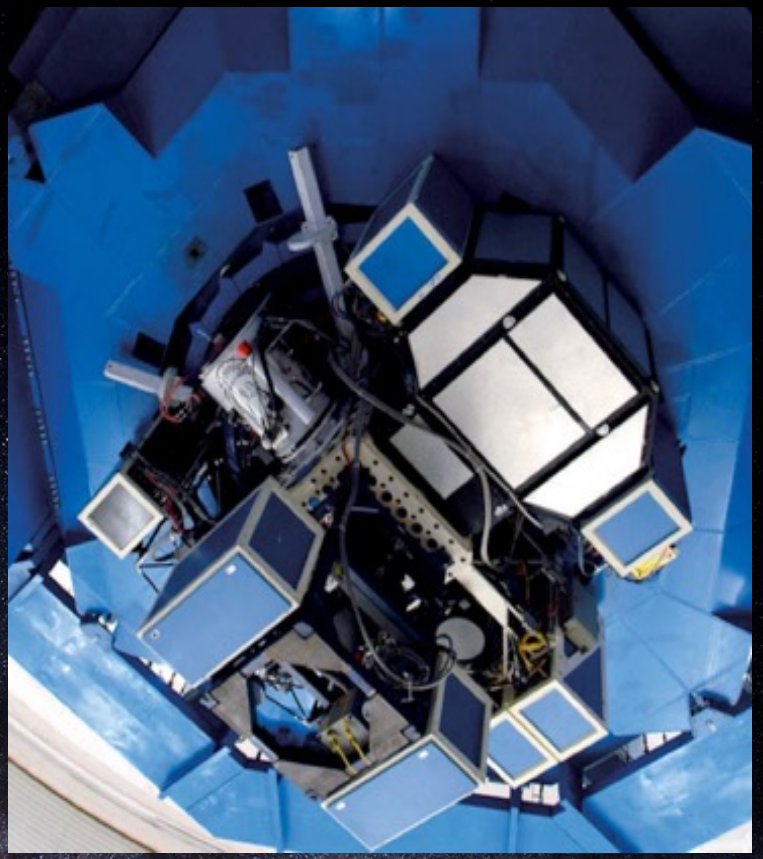
We keep our set of instrument capabilities competitive in 3 ways:

1) by replacing the least desirable instruments with new facility instrument,

2) by running an instrument upgrade program,

3) by supporting a visiting and community instrumentation program.





Left: Wide angle view of the Gemini South Telescope. The light truss structure and secondary mirror support are optimized for infrared observations. **Right:** The Instrument Support Structure (ISS) cube at the Cassegrain focus of Gemini North Telescope contains 5 ports, 1 for calibration sources, 1 for adaptive optics and 3 for instrumentation.

Facility Instrument Capabilities

The optical workhorse instruments are almost identical for both sites, with a typical science usage of ~900 h per year per instrument.

Each telescope also has a workhorse near-infrared spectrograph with a usage of ~500 h per year each.

Gemini provides spatial resolution of ~0.5" optical to ~0.35” NIR in all instruments under good natural seeing, 0.08” within a field of 10" by means of ALTAIR and 0.06” within a field of 85" by means of the GeMS MCAO.

The facility instrument suite **enables multi-instrument queue and switching instruments in about two minutes**, for efficiency and for strong Target of Opportunity service.

Gemini Facility Instrumentation, 2022B offered modes and 2018-2019 stats.

Instrument	Site	Visible	Infrared	Imager	Long Slit	IFU	MOS	AO Suptd.	Usage (hrs/yr)	FT Prop. % Demand [a]	Proposal % Demand [b]
GMOS-N	N	✓		✓	✓	✓	✓		850	56	48
GMOS-S	S	✓		✓	✓	✓	✓		1006	62	57
GNIRS	N		✓	~	✓	([c])		✓	516	14	16
F-2	S		✓	✓	✓		✓	([d])	476	34	15
GSAOI	S		✓	✓				✓	70	([e])	6
NIFS	N		✓			✓		✓	104	8	9
NIRI	N		✓	✓				✓	105	12	6
GHOST	S	✓				([f])			-	-	-

[a] The fraction of total hrs requested in all FT proposals received for the semester, per telescope. GN FT demand does not sum 100% because of the contributions from `Alopeke and GRACES. GPI FT demand was 4%.

[b] The fraction of total hrs requested in all proposals received for the semester, per telescope. It does not include LLP, DD, and FT programs. Neither site sums to 100% because of the contributions from non-facility instruments: `Alopeke, GRACES, POLISH2, Maroon-X at GN, and Zorro, IGRINS, Phoenix, and GASP at GS. GPI demand was 5%.

[c] GNIRS IFUs commissioning ongoing in 2022A.

[d] MOS commissioned completed, AO feasibility study planned for 2022A.

[e] GSAOI is not offered for FT proposals.

[f] High resolution fiber spectrograph, commissioning phase ongoing in 2022A.

Facility Instruments: **GMOS-S/N**

These are workhorse optical multifunction spectrographs and imagers.

Spectral range of 0.36–1.03 μm.

Core operating modes:

- 5.5′ square field of view, broad and narrow band imaging, IQ~0.5" under IQ 20%-ile.
- 5.5′ long slits, R ~630–4400 for 0.5" slit (depending on the grating). Max. R ~8800.
- 5.5′ x 5.5′ Multi-Object Spectroscopy.
- 7" x 5" or 3.5" x 5" IFU, fiber fed, 0.2" spaxels.

These are the most scientifically productive instruments at Gemini (>2000 refereed papers).

Detectors upgraded twice in the last decade, in 2017 by the current Hamamatsu detectors.

We are considering a replacement, or upgrading the detector focal planes into monolithic versions.

GMOS has 22 filter slots, and many times has welcomed user designed filters. We are considering a small upgrade of the broadband filter system to match those in the Rubin Observatory/LSST.

Another small upgrade is providing a new low-resolution grating to each GMOS with simultaneous coverage of range 0.4–0.8 μm with more uniform response in that range.

Facility Instruments: **GNIRS (GN)**

GNIRS is a workhorse NIR multifunctional spectrograph. Spectral range of 0.8–5.4 µm, variety of resolution modes sampled by four (short/long-blue/red) camera options. Core modes:

- Cross-dispersed spectroscopy, 0.8–2.5 µm, slit lengths 5 ”/7".
- R~1800–18,000 for 2-pixel slit.
- Long Slit spectroscopy in selected portions of the range, slit lengths 45”/99". R~1200–18000 for 2-pixel slit.
- Imaging in small FOV (~10") at 0.15"/pixel (SC) and 0.05"/pixel (LC).

Can be used with the ALTAIR AO system.

Instrument Upgrade Project: **GNIRS IFUs in build phase, commissioning started in July 2022.**

A repair of the short-red camera is considered for 2024.

Instrument/Mode	GMOS-N IFU-R	GMOS-N IFU	NIFS	GNIRS LR-IFU	GNIRS HR-IFU	GPI-2
Spatial sampling $(")^2$	0.2 × 0.2	0.2 × 0.2	0.103 × 0.043	**0.15 × 0.15**	**0.05 × 0.05**	0.014 × 0.014
Sampled field $(")^2$	3.5 × 5	5 × 7	3 × 3	**3.2 × 4.8**	**1.25 × 1.8**	2.4 × 2.4
Spaxels	500	1000	2000	**672**	**900**	~37,000
Max. spec. resolution	7100	7100	4500	**7200**	**18000**	80
Spectral range (μm)	0.36 – 1.03	0.36 – 1.03	0.94 – 2.4	**1.0 – 5.4**	**1.0 – 5.4**	0.9 – 2.4

Current and future IFU capabilities that will be available at Gemini North, which will allow to explore some synergies as the ones between the GMOS-N IFU-R and GNIRS LR-IFU modes.

Facility Instruments: **FLAMINGOS-2 (GS)**

F-2 provides workhorse imaging/spectroscopic capability. J, H, Kb, Ks, Kr imaging with a sampling of 0.18"/pixel and an image quality of 0.4" over a field of view of 6.1', for IQ 20%-ile conditions.

4.4′ long-slit mode with average spectral resolution R ~2800 over the single bands J, H and K-long (1.9-2.5 μm) and R ~1000 with simultaneous coverage on the wider spectral ranges YJH and HK.

The last upgrade performed in January 2022: **spectroscopic filters raising throughput in 8—12%, improved thermal insulation and upgraded utility wheel to add more filter slots.**

F2MOS capability now offered.

Mask Field of View	6′ x 2′	Targets from F2 pre-image or catalog.
Max. # of 4.5" length slits	72	Nodding along slits (100% on source).
Max. # of 1.8" length slits	153	Offsetting to sky (50% on source).
Spectral coverage	0.97—2.48 μm	YJH, HK, J, H, K-long band modes.
Spectral Resolution	700 / 2000	Single broad / extended band, 0.54" slits.
Spatial image quality	0.4"	H-band, IQ 20%-ile.
Max. # of masks/cycle	9	On-telescope mask exchage in dark time, with 2 nights out the queue.

We have started a **feasibility study on GeMS +F2 spectroscopy in order to offer AO supported MOS.**

Facility Instruments: **NIRI, NIFS & ALTAIR (GN)**

NIRI provides the primary NIR imaging capability at GN in the spectral range 0.9–5 µm, with a maximum field of 120" x 120" at 0.117"/pixel.

- Natural seeing imaging with three camera options: f/32, f/14, and f/6, with FOV of 22"x22", 51"x51", and 120"×120".
- The f/14 or f/32 camera can be fed by **ALTAIR for AO assisted imaging**.

Upgrade: a new ARC detector controller will be installed next year.

NIFS 3" x 3" integral field spectroscopy covers the range 0.95–2.4 µm with R ~ 5000.

- With **ALTAIR AO achieves spatial resolution of 0.15".**
- Coronographic mode using occulting disks of 0.2" and 0.5", suited to adaptive optics observations and best performing at H and K bands.

NIFS will be decommissioned in 2024.

ALTAIR is the facility natural/laser guide star AO system of GN, reproduces the telescope focal ratio (f/16), pupil size position. We have procured new dichroics to improve transmission under 1 µm and over 2.4 µm.

GN laser upgraded in late 2019.

Facility Instruments: **GSAOI & GeMS (GS)**

GSAOI is a NIR camera, covering the spectral range 0.9–2.4 μm, and samples a field of 85" x 85" at 0.02"/pixel. Only works as AO imager as it requires the f/33 beam from GeMS.

- 22 filters available, broad and narrow band.
- Hawaii-2RG detector mosaic, one of them has more artifacts than the others, but we have not yet considered a replacement.

We are considering to replace the optical window with a spare because the coating has developed small stains.

GeMS MCAO provides AO WF correction over 2'.

- Strehl ratio 15% to 30% (in the 1-2.5 μm range)
- Needs 3 natural guide stars with r < 18 mag.

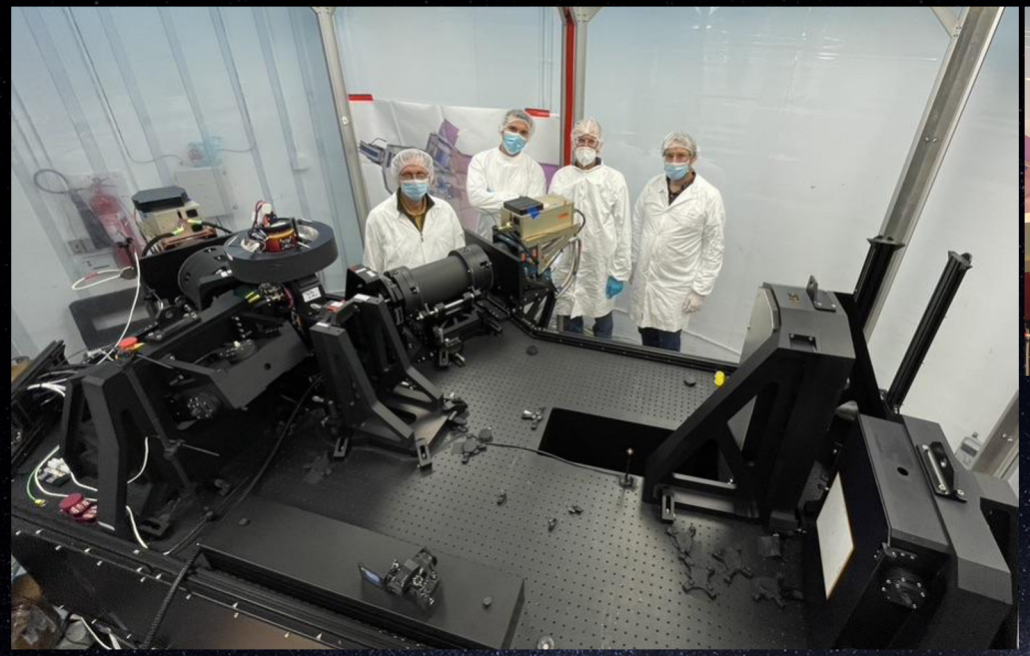
A new laser was commissioned in 2018, and the NGS-2 was commissioned in 2019.

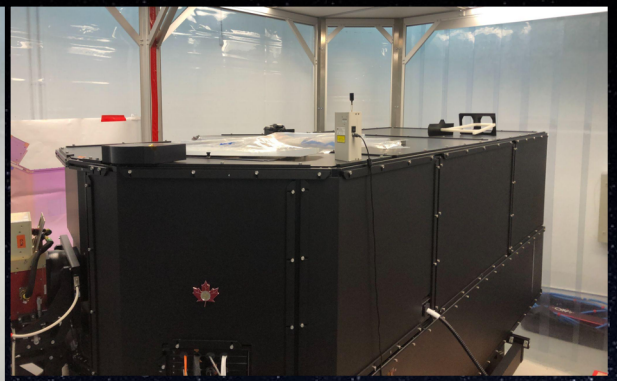
A third DM has been procured, now being delivered to GS.

We have started a project to **upgrade the Real Time Computer** in order to have a more stable system.

GeMS +F2 spectroscopy Feasibility Study has been started.

Future Facility Instrument GHOST (2022)



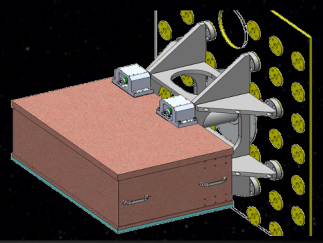


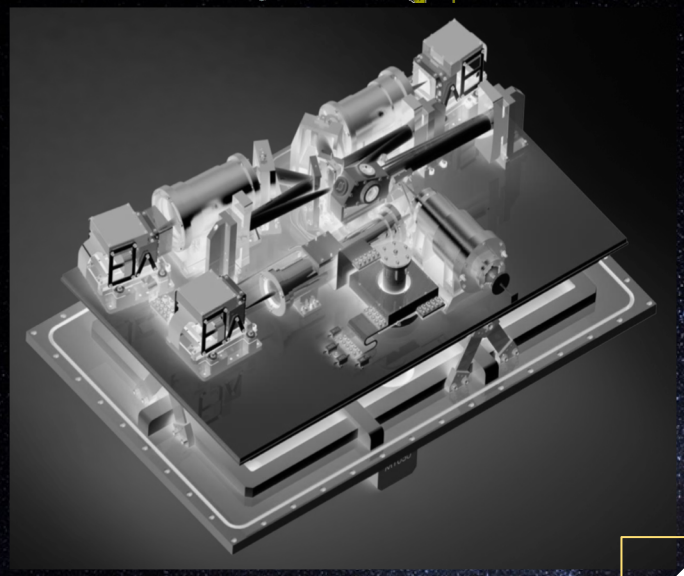
GHOST bench being integrated and inner enclosure assembled.

GHOST Cassegrain acquisition unit showing the mini-IFU arms.

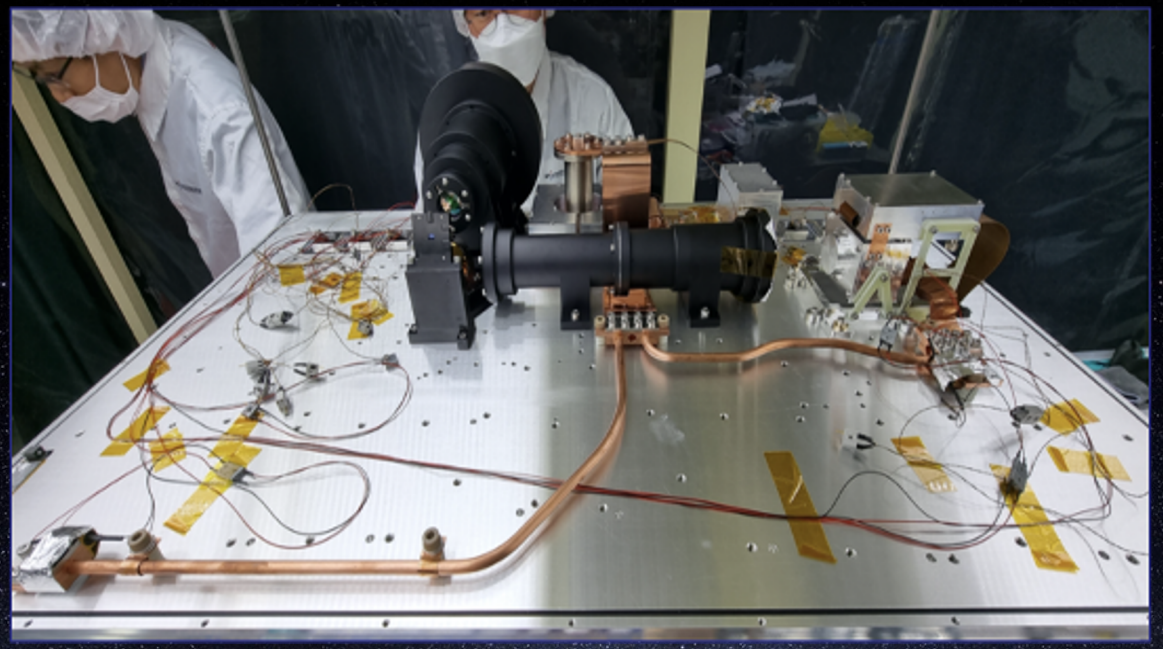
High throughput, simultaneous, continuous coverage ~360nm - 1µm.
R > 50k (55) 2 objects + sky on a 7.5' field.
R > 75k (85) 1 object + sky.
Built mainly by Hertzberg Astronomy and Astrophysics in Canada, and Anglo Australian Optics (ANU).

Future Facility Instrument IGRINS-2 (2023)

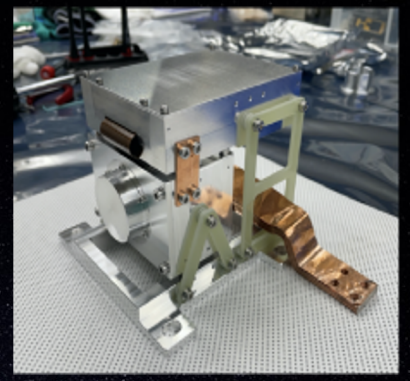


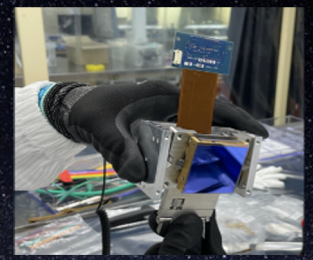


IGRINS-2 3D model. On the top the H & K arms, on the bottom the IO and SVC.



IGRINS-2 bench with fully assembled IO and the SVC, including the detector assembly and the cryogenic components.

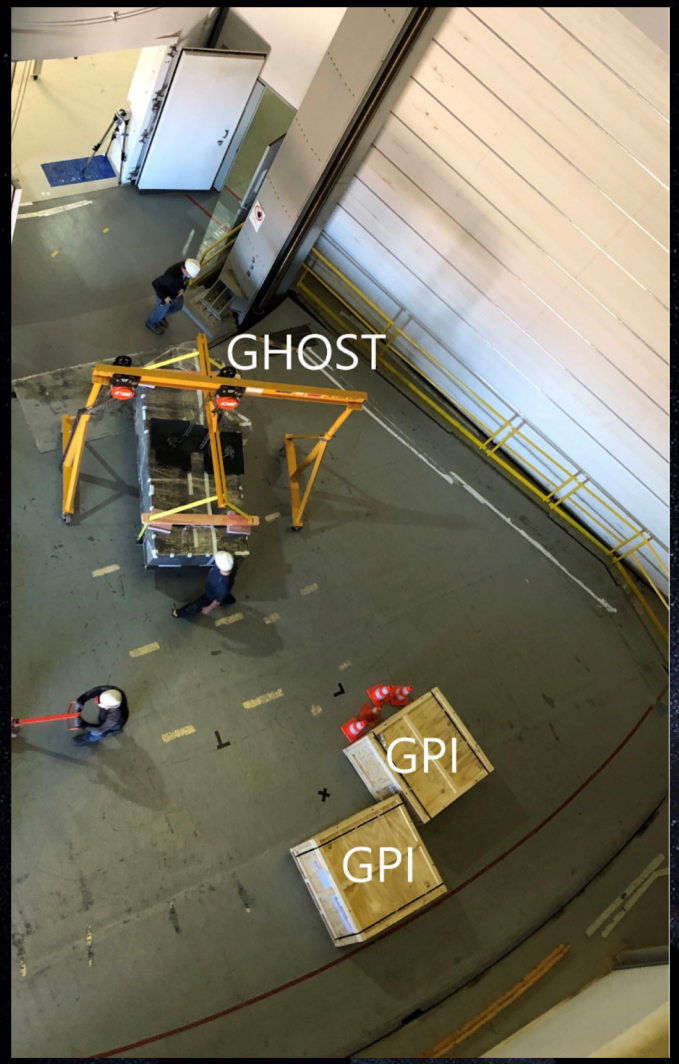


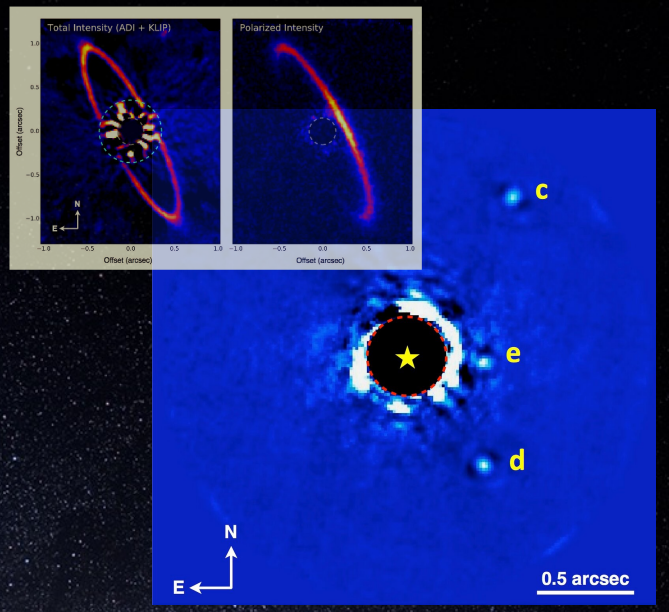


SVC detector assembly.

- **High-resolution near-infrared spectrograph** (R ~ 45,000; 1.45 - 2.45 μm), closely based on the original visiting instrument IGRINS. PI Chan Park, built by KASI.
- Progressing as planned into the assembly and integration phase.

GPI-2.0 upgrade (2024)





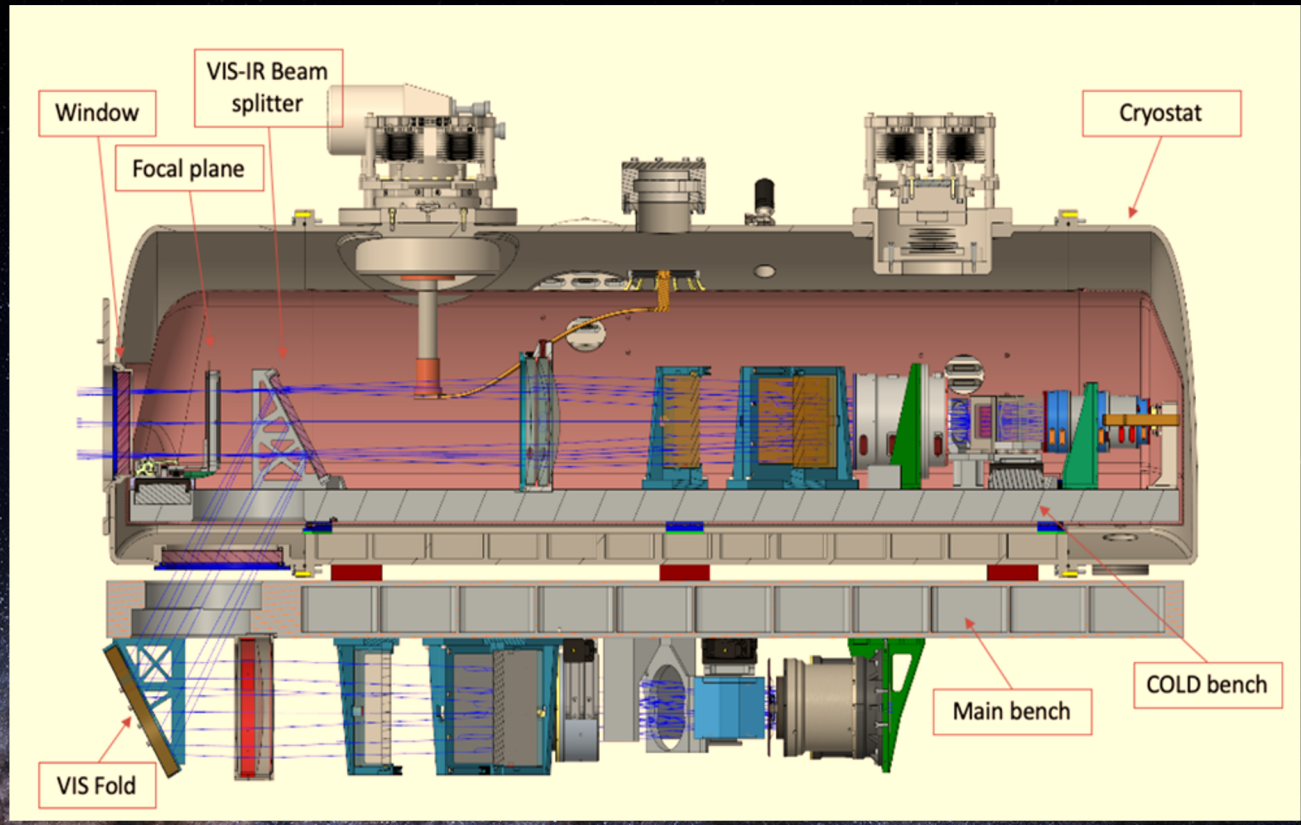
GPI is an extreme adaptive-optics imaging polarimeter/integral-field spectrometer, which provides diffraction-limited data between 0.9 and 2.4 microns. After completing its base science objectives at GS is being **upgraded** by Notre Dame, UC San Diego and HAA to improve contrast ratio, sensitivity; move to GN by 2024. Funded by NSF, Heising-Simons, NRC.

Future Facility Instrument SCORPIO (2024)

- 8 band optical/NIR imager and spectrograph.
- Simultaneous coverage 385nm - 2.35µm:

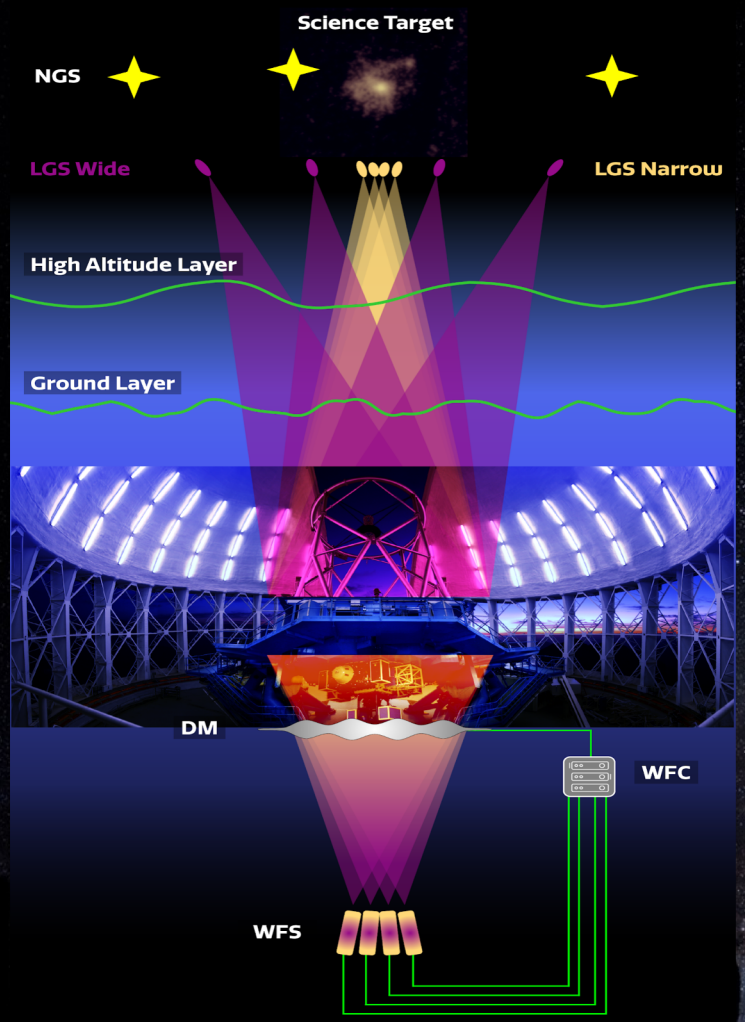
  grizYJHK 3'x3' imaging.

  R ~ 4000, 3' long slit spectroscopy.
- Designed for rapid acquisition and readout.
- Delivery in time for start of Rubin Observatory LSST.
- Integration will start soon, with the exception of the cryostat, all other vendor parts including optics have now been delivered.



SwRI: prime contractor, management, electronics, detectors, and final integration and testing);
STScI: Principal Investigator); FRACTAL (optomechanical work packages, initial integration);
GWU: Project Scientist and data reduction); JHU: engineering support and slit viewing camera study).

GNAO + GIRMOS (2027)



GNAO Facility, part of NSF's GEMMA award "Gemini in Era of Multi-Messenger Astronomy"

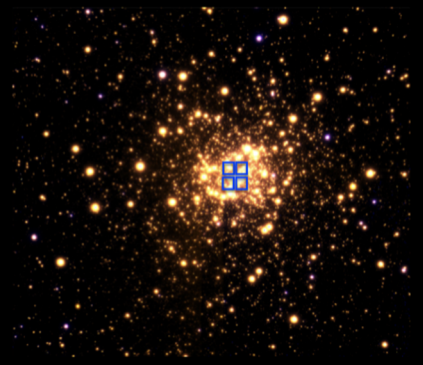
GNAO includes four side-launched laser beams supporting the two primary AO modes:

- Wide-field mode providing an improved image quality over natural seeing for a 2-arcmin circular FOV.
- Narrow-field mode providing near diffraction-limited performance over a 20 x 20 arcsec square FOV.

PI Gaetano Sivo

Multiple Objects

Pick-off System



Single Object

Tiled Super-IFU

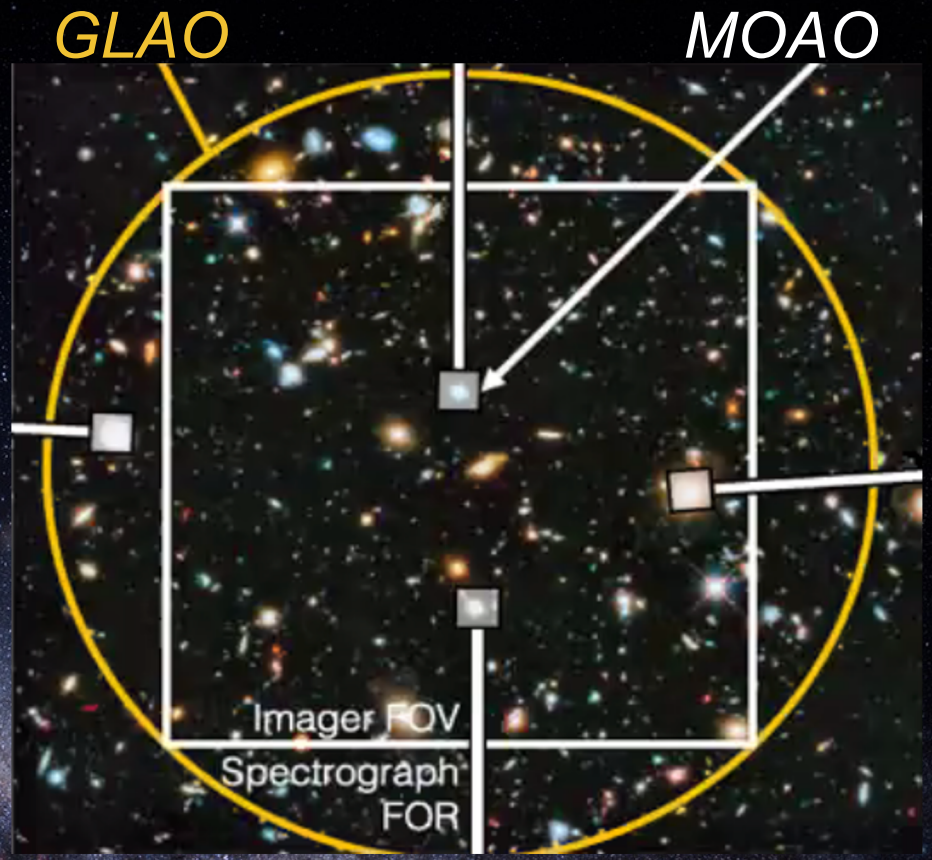
GIRMOS (MOAO)
Community project lead by PI Suresh Sivanandam, funded by Canadian Innovation Fund

GIRMOS

Wide-field MOAO ~2' FOV for multiple IFUs, or tiled LTAO mode (~20" sq). R~3000,8000.

Imaging YJHK$_s$ and assorted filters.

- The project had a successful PDR in May 2022.
- Although it is community lead, the design phase has significant involvement of Gemini, with the expectation of becoming resident or facility instrument.
- **GIRMOS is forecasted to arrive at Gemini North in mid-2026, with the final ATR coupled with GNAO's schedule.**



GIRMOS imager FOV, and the 4 MOAO IFU arms FOR.

Visiting Instruments

Frequent or resident visiting instruments.

The VI Program offers PIs the opportunity to use their own instruments, with support from Gemini engineering and operations staff.

- With the help of the instrument teams, these instruments can be made available to the larger user community as well.
- In recent years, some of these Visiting Instruments have been much sought after.

Instrument Capability	‘Alopeke & Zorro	Instrument Capability	GRACES (GN)	MAROON-X (GN)	IGRINS (GS)	TEXES (GN)
Bands	u, g, r, i, z, H_α (350–1070 nm)	Spectral range (μm)	0.4–1.0	0.5–0.92	1.45–2.45	5–25
FOV (circular)	6.7" or 60"	Fiber/Slit	1.2"	0.77"	0.34"x 5"	0.5"x4"
Spatial resolution	0.016" or seeing lim.	Max. spec. resolution	60,000	85,000	45,000	80,000
Additional Capability	Dual camera, subarray fast readout	Additional Capability	Does not use a port	RV precision ~20 cm/s	Slit viewing camera	8” slit & lower res.

The VIP currently expands Gemini capabilities to R~88,000 optical/MIR and R~45,000 NIR spectroscopy, diffraction limited spatial resolution down to 0.016" by means of speckle imaging, high speed imaging, and high precision polarimetry.

More about Gemini future capabilities

Monday:	Jeffrey Chilcote – **GPI 2.0**
	Garima Singh – **GPI 2.0 CAL**
	Heeyoung Oh – **IGRINS-2**
Wednesday:	Chris Hayes – **GHOST**
Thursday:	Massimo Roberto – **SCORPIO**
	Gaetano Sivo – **GNAO**
	Suresh Sivanandam – **GIRMOS**
	Paul Hirst – **GLAO Feasibility**
	Brian Miller – **Next Gen TDA**
Posters by	Christian Marois – **GPI 2.0 CAL**
	Rodolfo Angeloni – **SCORPIO**
	Mark Rawlings – **GPOL+NIRI**

Gemini Instruments

I will be available the whole week, please bring me your questions and ideas about Gemini instruments and capabilities. You will be able to talk with several of our instrument scientists too.

Thank you!