

Gemini in the Era of Multi- Messenger Astronomy

*Developing an
advanced multi-
conjugate adaptive
optics system for
high-resolution
astronomy & a rapid
response system for
time domain science.*

GEMMA



Gemini in the Era of Multi-Messenger Astronomy: High Image Quality & Rapid Response

\$26M Award from U.S. National Science Foundation

- New **Multi-Conjugate Adaptive Optics** at Gemini-North (**GNAO**), with route to an adaptive secondary [synergy with JWST]
+ New **Real-Time Computer** for AO system at Gemini-South.
- **Operations software** and **data pipeline developments** for **rapid follow-up Time Domain Astronomy (TDA)** [synergy with LSST]
- **Public outreach & education** programs on the general themes of Time-Domain & Multi-Messenger Astronomy
- All funds must be spent by 30 Sep 2024.

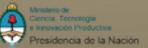


NRC·CNR



Ministry of
Science, Technology
and Innovation

BRAZIL



한국천문연구원
KASI

Gemini North Adaptive Optics (GNAO) upgrade

Baseline requirements in proposal:

- MCAO system with 2-arcmin field of view:
 - physical limitation set by size of the AO Fold mirror
- 30% Strehl correction in K at median seeing
 - GNAO should at least match the performance of GeMS, and take full advantage of Maunakea. *Goal is 50% Strehl.*
- PSF astrometry better than 1 mas across field (single detector)
- Operable by standard Gemini night crew (one telescope operator + one queue observer), so available every suitable night.



Gemini North Adaptive Optics (GNAO) upgrade

GNAO scope does *not* include Adaptive Secondary Mirror (ASM)

- ASM technology becoming cheaper and more robust, however...
 - still doesn't fit within available GEMMA budget for GNAO.
- **But**, Gemini Science & Technology Advisory Committee (STAC) report:
 - "We see the ASM as a critical part of the GNAO system. The STAC strongly recommends including the incorporation of an ASM within the GNAO design from the beginning. A future GLAO system could feed all the other back-end instruments, as well as improve their performance and efficiency."
- Thus, an Adaptive Secondary is part of the overall plan, funded outside of GEMMA, for enabling GLAO and a broad range of wide-field high-resolution science in the 2020s. GNAO is designed to be compatible with this.

GNAO is an improved version of GeMS – some recent refereed papers based on GeMS/GSAOI data:

- A Subarcsecond Near-infrared View of **Massive Galaxies at $z > 1$** with Gemini Multi-conjugate Adaptive Optics
- First results from GeMS/GSAOI for project SUNBIRD: **Supernovae** Unmasked by Infra-Red Detection
- **Proper Motion of Pyxis**: First Use of Adaptive Optics in Tandem with HST on a Faint Halo Object
- Individual, Model-independent Masses of the Closest Known **Brown Dwarf Binary** to the Sun
- Multi-conjugated adaptive optics imaging of **distant galaxies**: A comparison of Gemini/GSAOI and VLT/HAWK-I data
- The stellar **mass-size relation for cluster galaxies at $z = 1$** with high angular resolution from the Gemini/GeMS multiconjugate adaptive optics system
- Optimal **Stellar Photometry** for Multi-conjugate AO Systems Using Science-based Metrics
- Deep GeMS/GSAOI near-infrared observations of **N159W in the Large Magellanic Cloud**
- **Protoplanetary Disks** in the Orion OMC1 Region Imaged with **ALMA**
- Astrometry with MCAO: **HST-GeMS proper motions** in the globular cluster NGC 6681
- GeMS MCAO observations of the **Galactic globular cluster** NGC 2808: The **Absolute Age**
- Searching for **Binary Y Dwarfs** with the Gemini Multi-conjugate Adaptive Optics System
- Detailed **Abundance Analysis** of a Metal-poor Giant in the **Galactic Center**
- The **Orion fingers**: Near-IR adaptive optics imaging of an **explosive protostellar outflow**



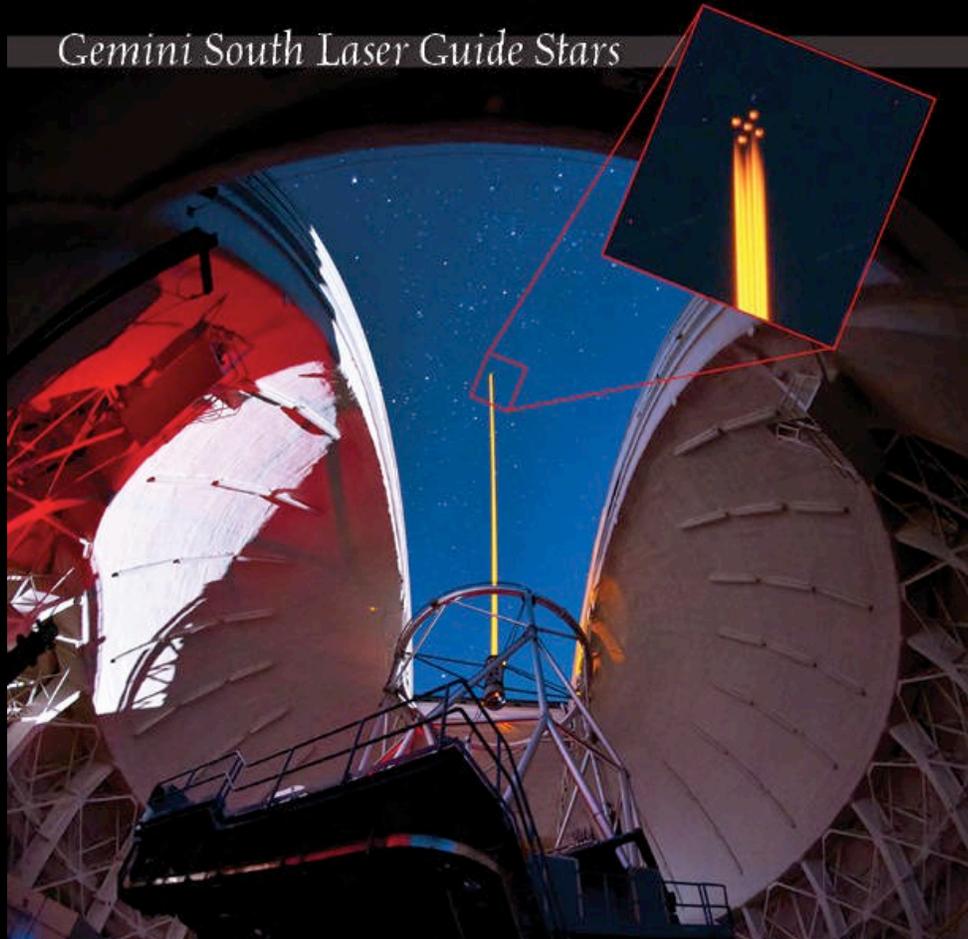
NRC · CNRC



GeMS/GSAOI

Gemini Multi-Conjugate AO System (GeMS) delivers images with FWHM $< 0.09''$ over the $1.4'$ field of the Gemini South AO Imager.

Gemini South Laser Guide Stars



Bullets Rip Through Orion Nebula



Gemini Observatory
Legacy Image

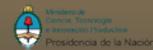
Gemini Observatory/AURA/J. Bally (University of Colorado)
(Background Images: Space Telescope Science Institute/NASA)



NRC-CARC

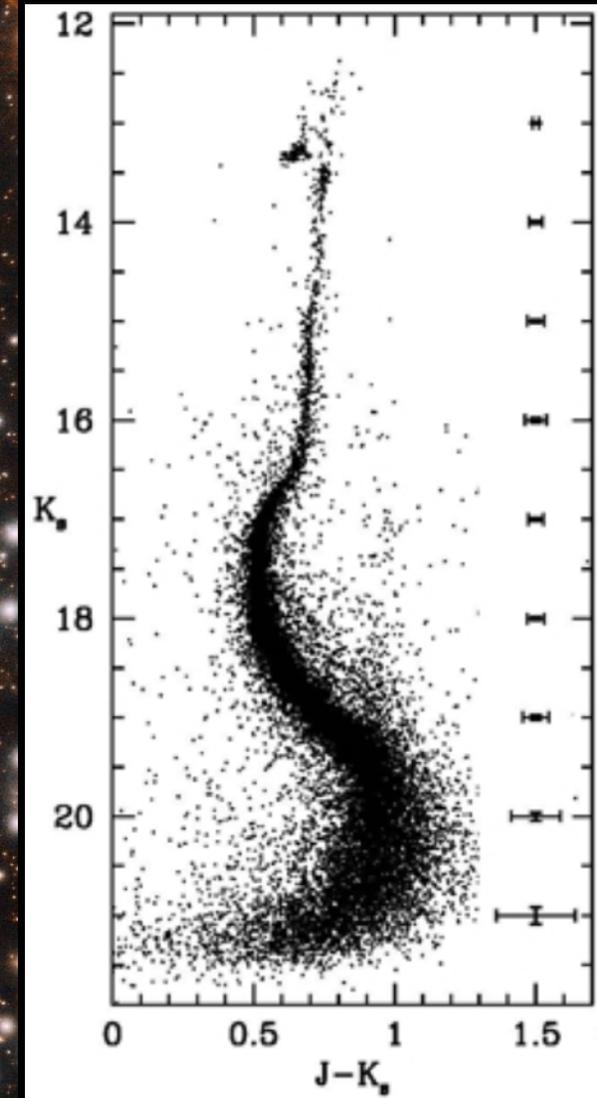
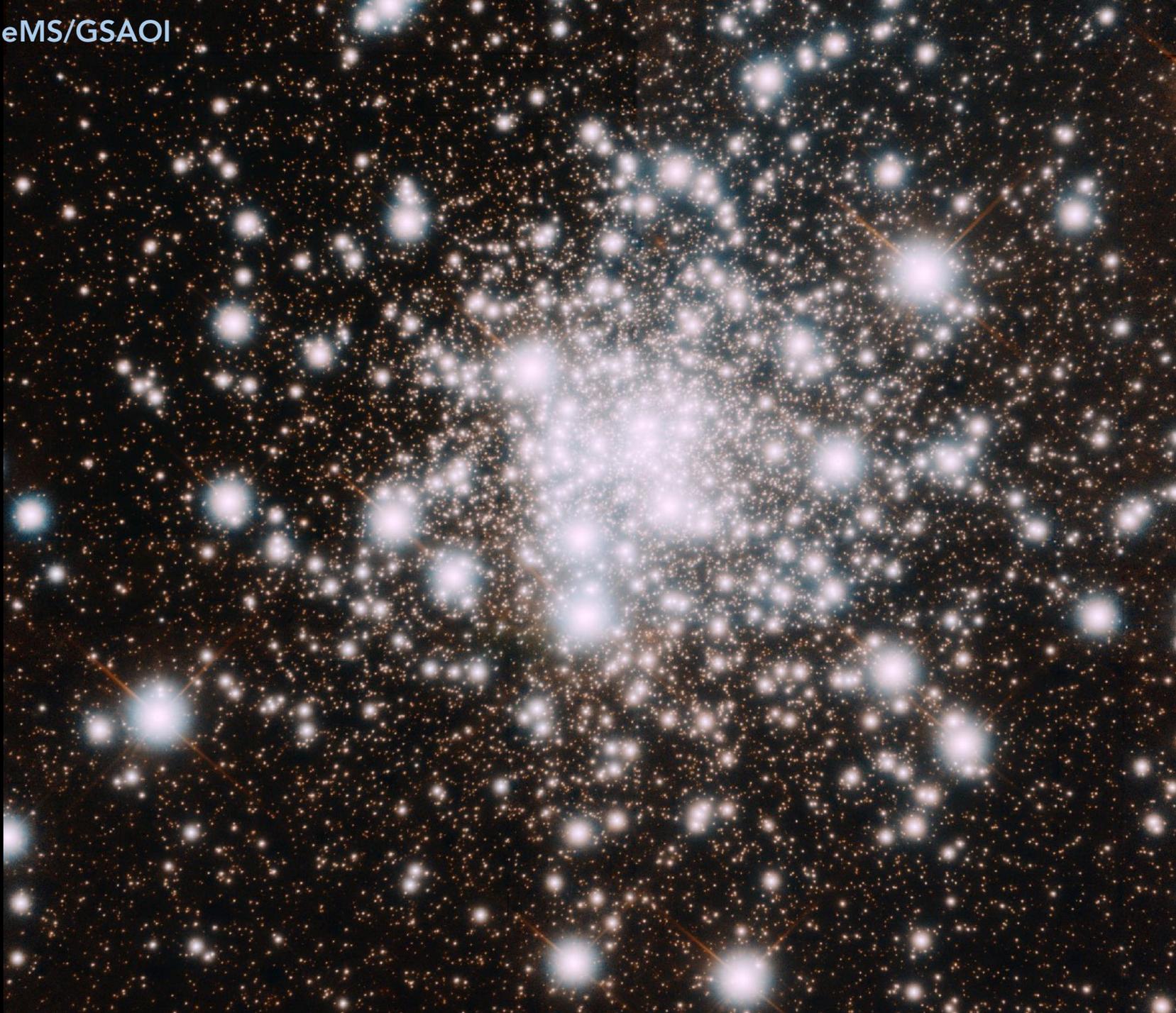


Ministry of
Science, Technology
and Innovation
BRASIL

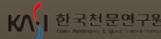
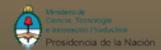


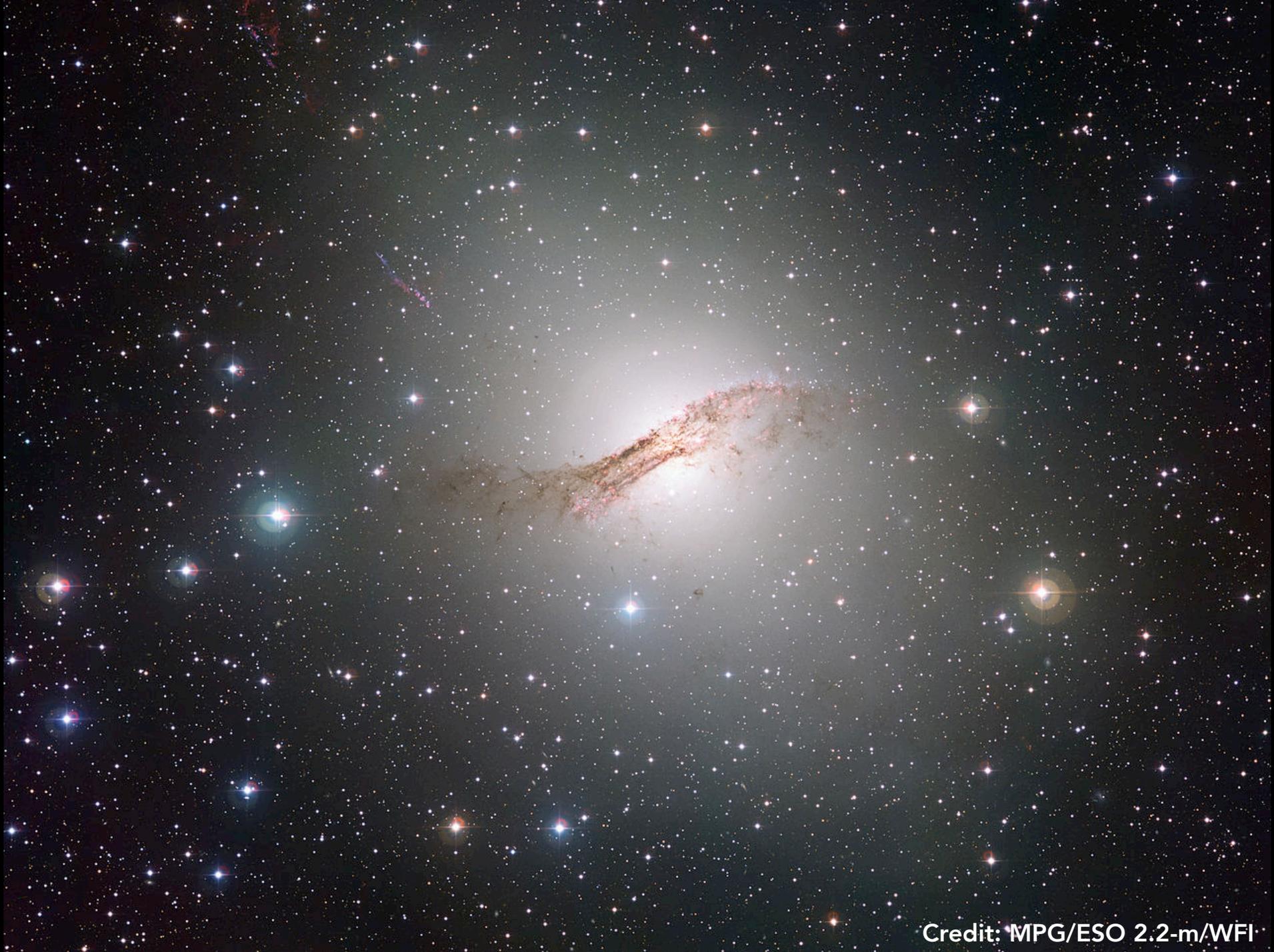
KASI 한국천문연구원



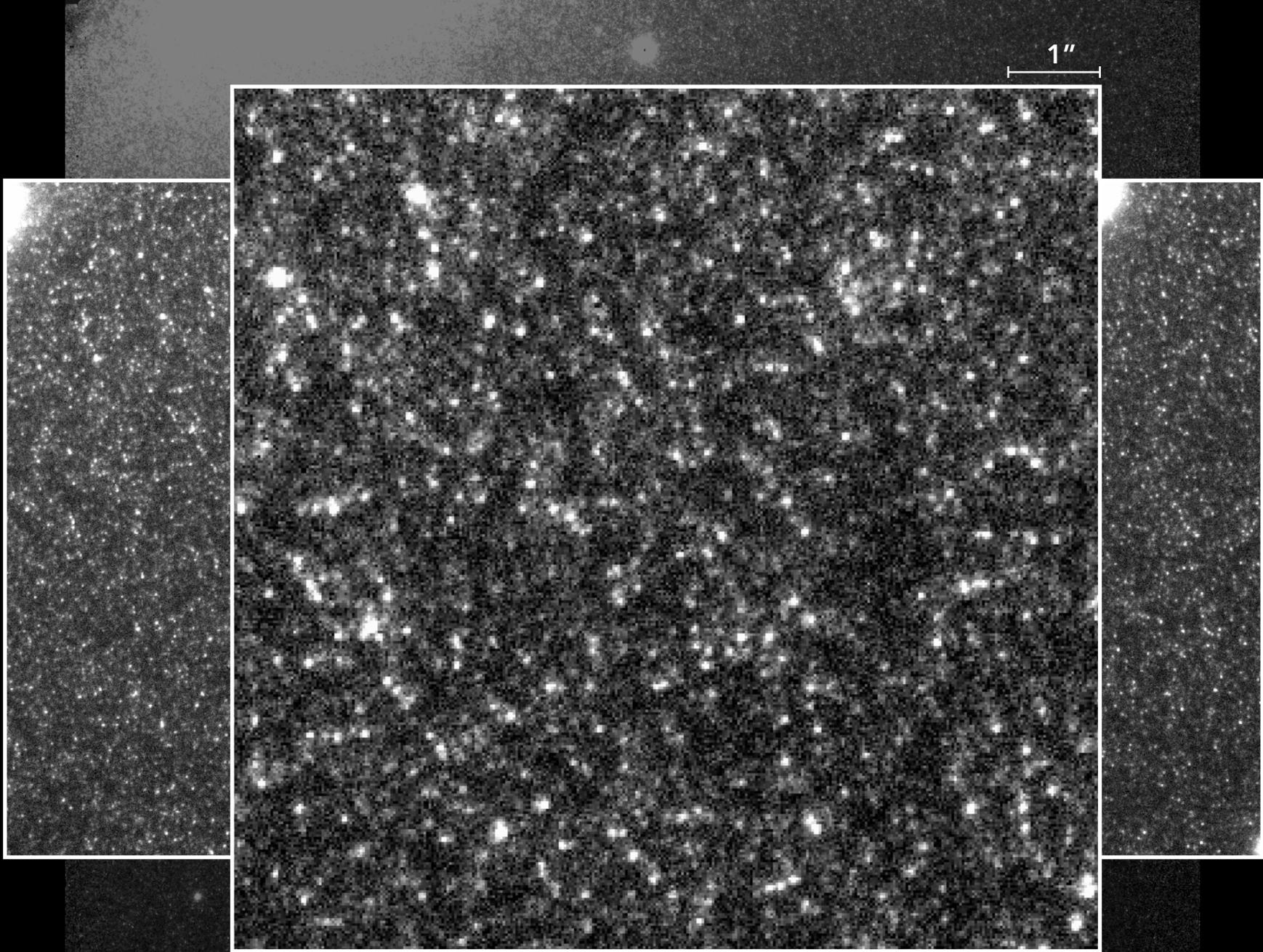


Deepest near-IR
CMD for any bulge
globular cluster.

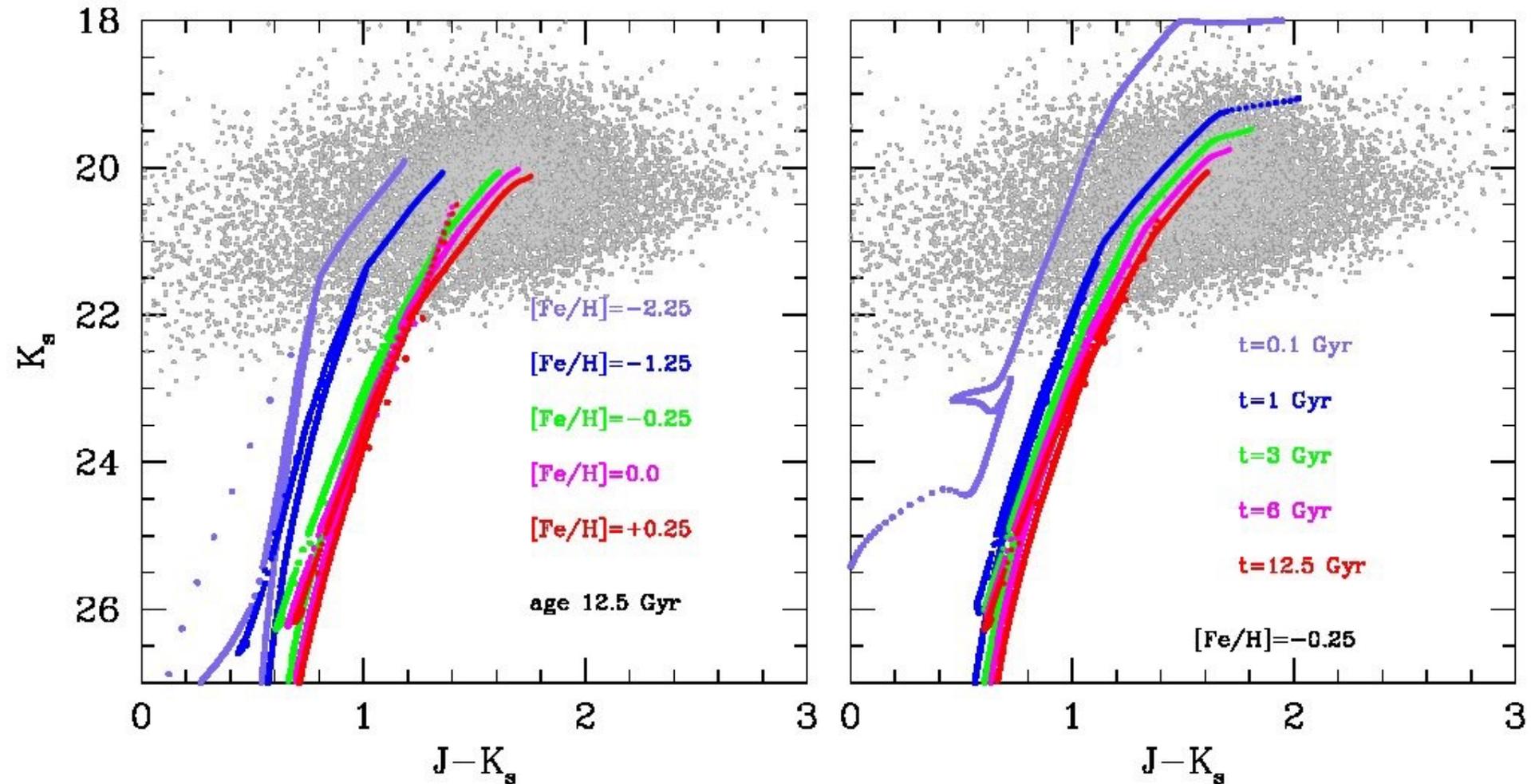




Credit: MPG/ESO 2.2-m/WFI

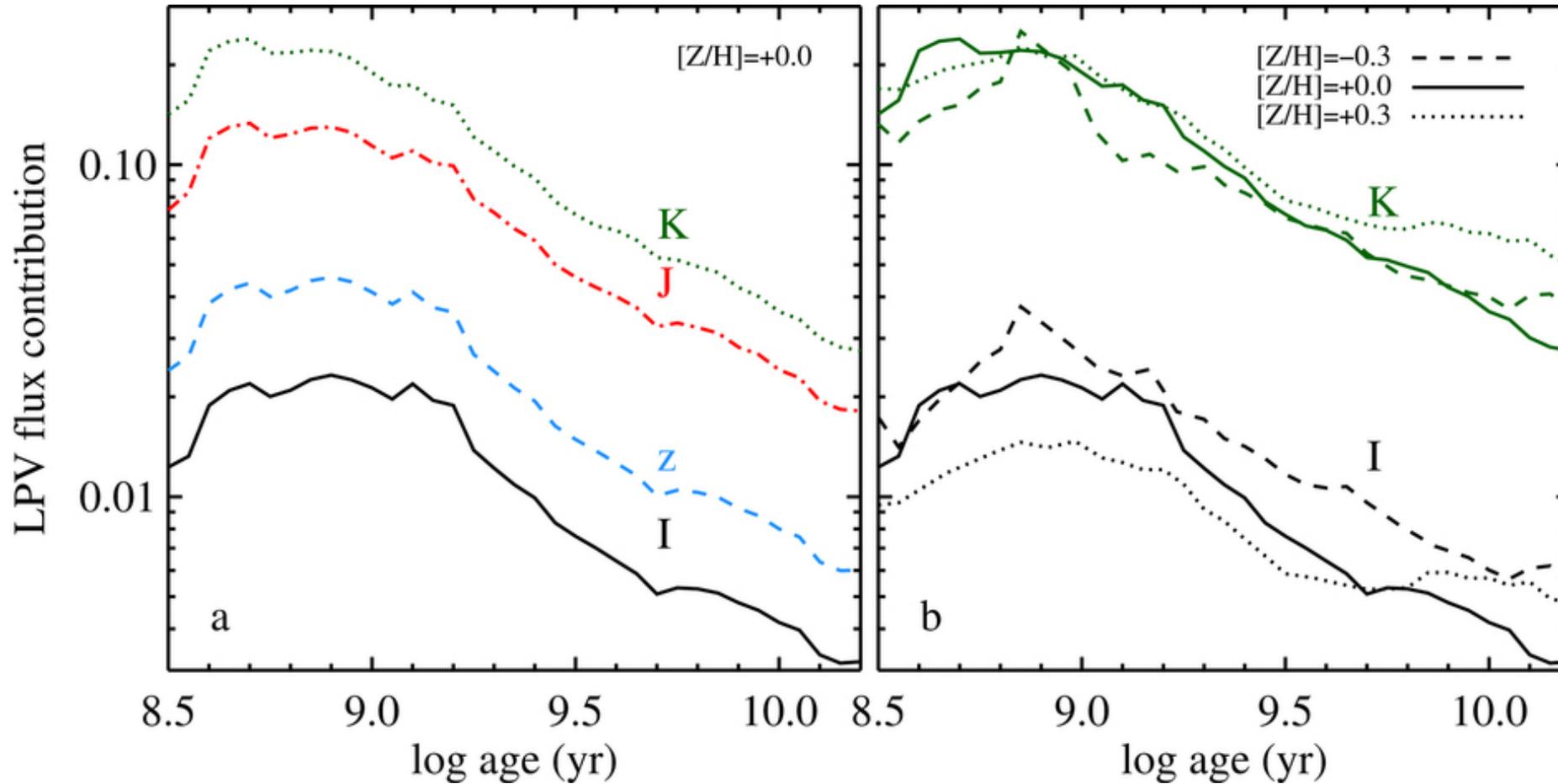


GeMS/GSAOI preliminary CMDs for inner regions of NGC5128 at 4 Mpc (in < 5 mins)



(Limited mainly by J photometry)

Contribution of Long Period Variables to total light in various bandpasses...



Potentially important for estimating galaxy ages from SED fits (models from Conroy et al. 2015)

Gemini InfraRed Multi-IFU Spectrograph (GIRMOS)

High angular resolution, multi-integral-field spectrograph and imager, employing a Multi-Object Adaptive Optics (MOAO) system behind Gemini MCAO

Four IFU arms: deployable over full 120" diameter field of regard

Spatial Sampling: 25×25 mas, 50×50 mas, 100×100 mas.

IFU field of view: 1.0×1.0 , 2.0×2.0 , or 4.0×4.0 arcsec
 8.0×8.0 arcsec (all IFUs combined)

Spectral Coverage: $1.1 - 2.4 \mu\text{m}$

Spectral Resolution: $R = 2500 - 3000$ (all samplings)
 $R = 5000 - 6000$ (50 & 100 mas sampling)

Science: galaxy mass assembly & evolution, galaxy groups, reionization, AGNs, star formation; stellar populations; near field cosmology, proto-planetary disks.

Conceptual Design Review scheduled for March 2019

Commissioning planned for early 2024

Originally intended for GeMS at GS, but GIRMOS team now considering for GNAO.

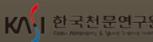
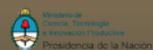
PI: Suresh Sivanandam,
(U. Toronto, Dunlap Institute)
<https://arxiv.org/abs/1807.03797>



NRC-CARC

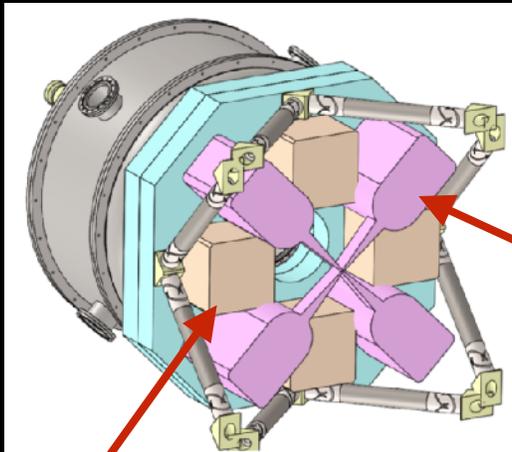


Ministry of Science, Technology and Innovation



GIRMOS Architecture

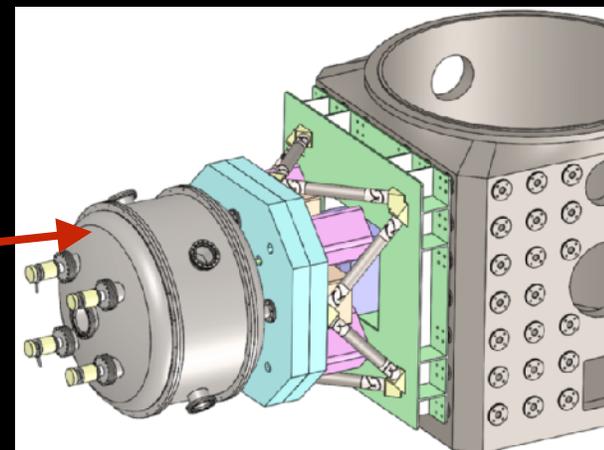
PI: Suresh Sivanandam, U. Toronto



MOAO System

Object Selector

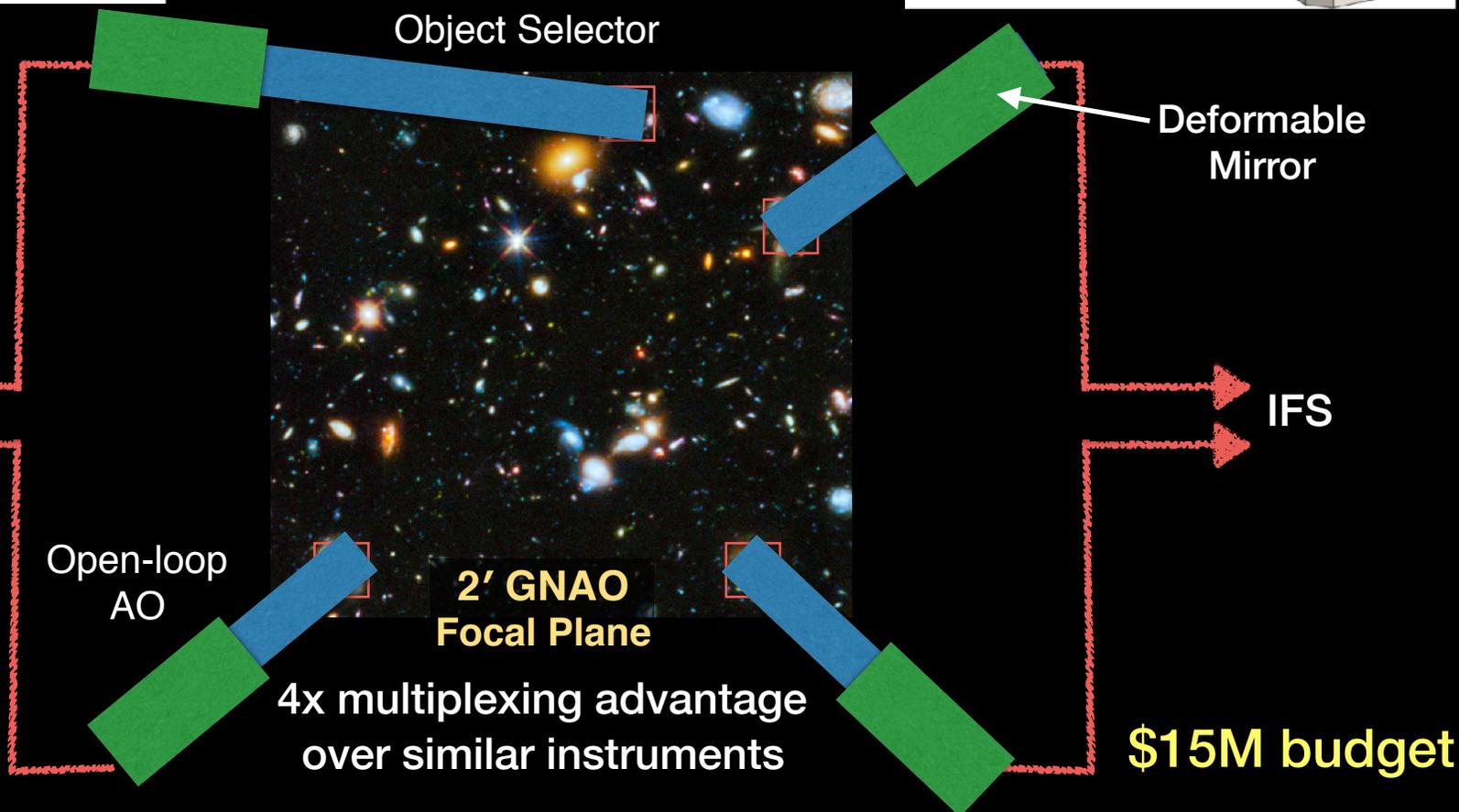
Spectrographs



Deformable Mirror

Funding from the Canadian Foundation for Innovation (CFI)

Broad range of science cases that can benefit from these capabilities



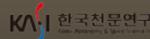
Time-Domain Astronomy in GEMMA

Strategic Vision: “Beyond 2021, Gemini should exploit its geographical location & agile operational model in order to be the premier facility for the follow-up investigation of targets identified by the LSST.”

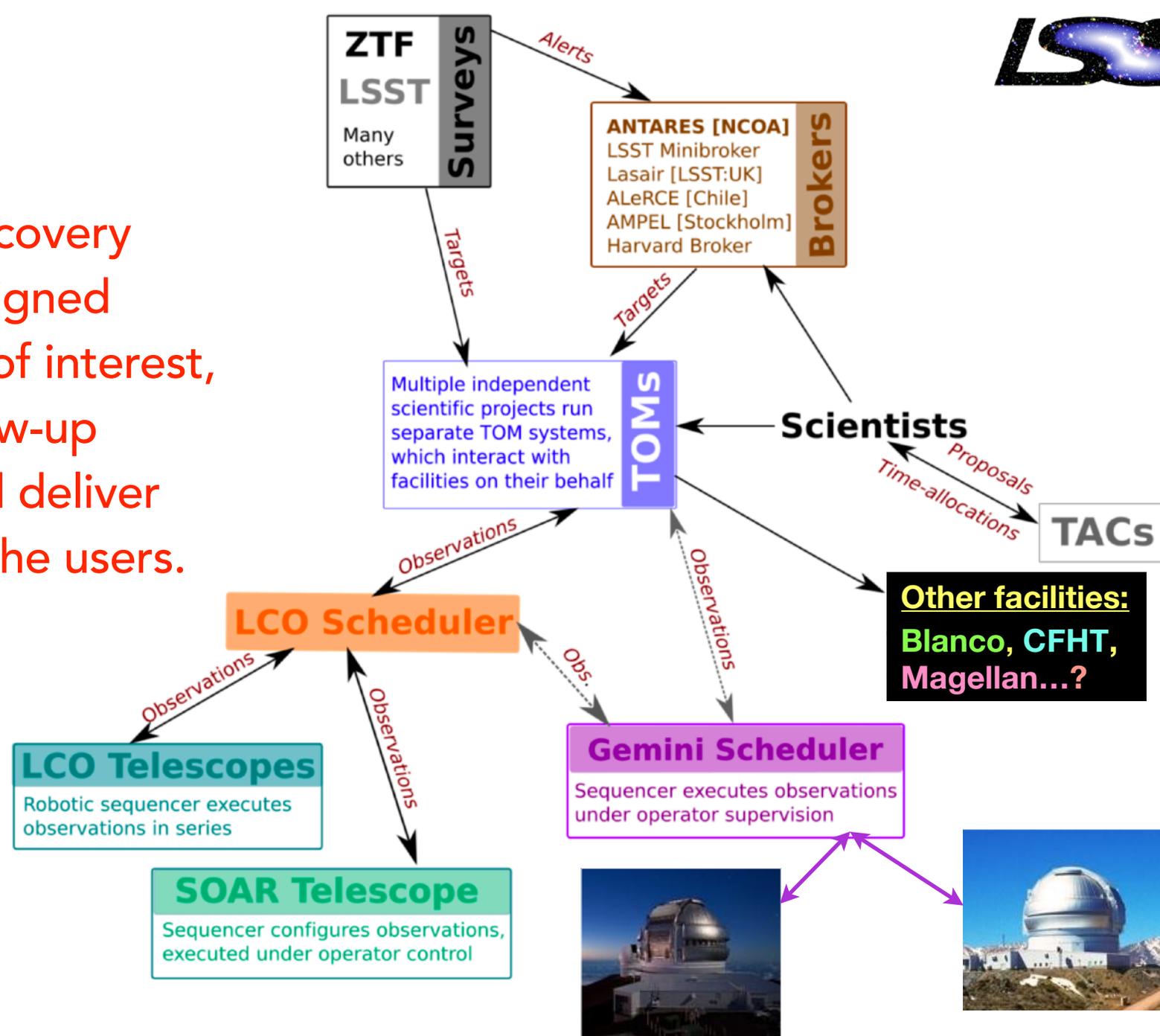
- Collaboration on the new Astronomical Event Observatory Network (“AEON”) involving Gemini, Las Cumbres, SOAR, and possibly other facilities (Blanco, Magellan, CFHT?) fed by ANTARES event broker, initially for ZTF, LIGO, etc.
- The effort at Gemini is closely linked to the Observatory Control System (OCS) upgrade, a project being undertaken to modernize Gemini’s proposal, scheduling, and operations software.
- We are developing a plan for how the Transient Follow-up Network will work in practice, but full partnership will have access to all; we welcome feedback & involvement (TDA advisory group forming)!



NRC-CARC



AEON: a new discovery "ecosystem" designed to identify alerts of interest, obtain rapid follow-up observations, and deliver reduced data to the users.



AEON = NOAO/SOAR/Las Cumbres/Gemini collaboration to enable dynamic scheduling of targets from TOMs on SOAR, Gemini,... others welcome.



Gemini is now forming a community group of ToO users to advise us on strategies and policies for rapid follow-up in the Time-Domain Era.

Please talk to us if you're interested!

Goal: Gemini/AEON ready for rapid response by 2022

LC  gtn

 **GEMINI**
OBSERVATORY
Exploring the Universe, Sharing its Wonders

 **AURA**



NRC · CNRC



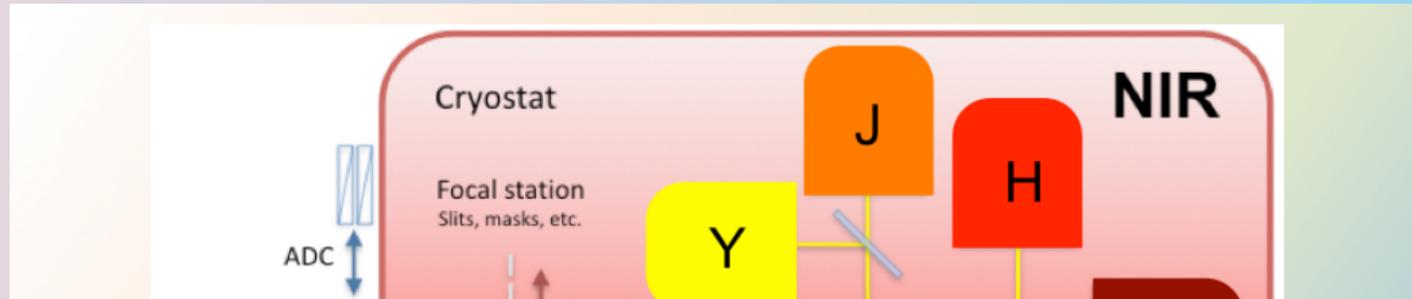
Ministry of
Science, Technology
and Innovation
BRASIL



KASI 한국천문연구원
Korea Astronomy & Space Science Institute



SCORPIO: Key Part of Gemini's follow-up plans



For details, attend the special session
“Science with SCORPIO on Gemini” on
Weds, January 9th, 2-3:30pm in Room 310.



- Simultaneous 8-band photometry or spectroscopy over 3.3' field
- Rapid identification, and characterization of transients
- High-time resolution follow-up, from minutes to years
- Also a panchromatic workhorse instrument for static sources

<https://www.gemini.edu/gemma>

GEMMA

Projects

Submit Your Input

GEMMA

Gemini in the Era of Multi-Messenger Astronomy

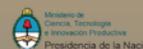
GEMMA



NRC-CMRC



Ministry of
Science, Technology
and Innovation
BRAZIL



한국천문연구원
KASI Korea Astronomy & Space Science Institute



GEMMA

Gemini In The Era of Multi-Messenger Astronomy



The GEMMA program is funded by a multi-million dollar award from the National Science Foundation to advance the leadership role of Gemini Observatory in the era of Multi-Messenger Astronomy. The program has been designed to maximize synergies with the transformative facilities coming online in the near future. The projects within GEMMA specifically focus on the areas of high spatial resolution and rapid-response astronomy.

Projects



NRC-CARC



Ministry of
Science, Technology
and Innovation

BRASIL



한국천문연구원
KASI Korea Astronomy & Space Science Institute



Projects



Adaptive Optics

The Gemini North Adaptive Optics (GNAO) upgrade project will deliver the first queue-operated multi-conjugate adaptive optics (MCAO) system in the northern hemisphere. The GNAO effort will build on experience with the Gemini Multi-conjugate System (GeMS) at Gemini South, but it will employ the latest technologies for improved performance in support of the next generation of AO-assisted instruments at Gemini North. With a corrected field-of-view of about 2 arcmin and spatial resolution similar to that of JWST, GNAO will take advantage of Maunakea's outstanding conditions for AO performance and establish GN as the premier ground-based facility for wide-field AO studies.



Time Domain

The Time Domain Astronomy (TDA) project will develop the infrastructure for incorporating Gemini's telescopes into the Astronomical Event Observatory Network (AEON), an efficient new system for following up transients identified by LSST, LIGO, and other time-domain and multi-messenger surveys. The goal of this effort is to maximize Gemini's contributions to discoveries in the TDA era, and Gemini will provide the largest aperture within AEON to enable studies of the faintest, highest priority targets. The TDA project also includes development of automated data pipelines for rapid delivery of science-quality reduced data so that users can assess the outcome of their observations in real time.



Outreach

GEMMA enables Gemini Observatory to expand on its legacy of ambitious Public Information and Outreach (PIO) initiatives. The basis for this expanded outreach is multi-messenger astronomy (MMA) and the role of Gemini and other ground-based facilities in this new discovery arena. Specifically, the GEMMA PIO initiatives include a multimedia planetarium program to illustrate MMA concepts, classroom materials to promote careers in related science and technology fields, training workshops for science writers, and an ambitious "MMA summit" to establish a charter for the public communication of MMA concepts and discoveries.

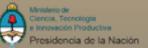


NRC-CARC



Ministry of
Science, Technology
and Innovation

BRAZIL



KASI 한국천문연구원
Korea Astronomy & Space Science Institute

AURA

Big Ideas

Tell us about your ideas for scientific studies that may be enabled by the GNAO and TDA efforts described above, and any specific requirements that must be met (particularly in the case of GNAO) to make those studies possible.

Remember to send us your ideas for science with GEMMA so we can optimize the design of GNAO and TDA!

GEMMA Big Ideas

Gemini In The Era of Multi-Messenger Astronomy

* Required

Email address *

Your email

What science goals do you want to pursue?

Your answer

If your science goals involve GNAO, what instrument requirements must be met to achieve these goals?

Your answer

What observations would you propose to pursue these goals?



NRC-CARC



Ministry of Science, Technology and Innovation
BRAZIL



KARI 한국천문연구원
Korea Astronomy & Space Science Institute



Remember to send us your ideas for science with GEMMA so we can optimize the design of GNAO and TDA!

<https://www.gemini.edu/gemma>

What observations would you propose to pursue these goals?

Your answer

Do you have any other GEMMA-related Big Ideas?

Your answer

Your Name *

Your answer

Your Institution *

Your answer

SUBMIT

Never submit passwords through Google Forms.

Google Forms

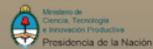
This form was created inside of Gemini Observatory.



NRC-CARC



Ministry of Science, Technology and Innovation
BRAZIL



KASI 한국천문연구원
Korea Astronomy & Space Science Institute

GEMINI'S FUTURE

Gemini South: *the premier facility for rapid response*

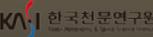
- Instrumentation: GHOST, SCORPIO, GMOS-S, IGRINS-2, GeMS/GSAOI
- Operations: flexible queue scheduling, minimal overhead, rapid switch between instruments.
- Scheduling: pre-defined filtering of transients via event broker and optimized scheduling via a Target Observation Manager
- Delivery: develop robust, automated data reduction pipelines
- Also provides upgraded wide-field AO capabilities for Galactic center science, and other applications

Gemini North: *the premier facility for AO Science*

- Instrumentation: GNAO, GMOS-N, GIRMOS, GPI-2, ASM, visitor instruments
- Maximize synergies with JWST
- Capitalize on complementarity with the family of Maunakea Observatories
- Also benefits from Operations & Scheduling improvements for greater efficiency in rapid follow-up in Time Domain and the development automated data reduction pipelines



NRC-CARC



GEMINI'S FUTURE

Gemini South:
the premier facility for rapid response

Gemini North:

- Instrumental IGRIN
- Operations: minir betw
- Scheduling: via e sche Man
- Delivery: de redu
- Also provides upgraded wide-field AO capabilities for Galactic center science, and other applications

Consider submitting an ASTRO2020 white paper related to science that can be enabled by Gemini's capabilities in the coming decade – due Feb 19 – *we are eager to help!*

reduction pipelines

Science

J, GIRMOS, ents

with the family es

Scheduling efficiency in main and ted data



NRC-CARC

