NSF's National Optical-Infrared Astronomy Research Laboratory

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GNAO Science Cases

Morten Andersen, Julia Scharwächter, Gaetano Sivo
With the GNAO science team

GEMINI OBSERVATORY
Exploring the Universe, Sharing its Wonders

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MINISTRY OF SCIENCE, TECHNOLOGY, INNOVATION AND COMMUNICATION
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Presidencia de la Nación

KASI 한국천문연구원 Korea Astronomy & Space Science Institute

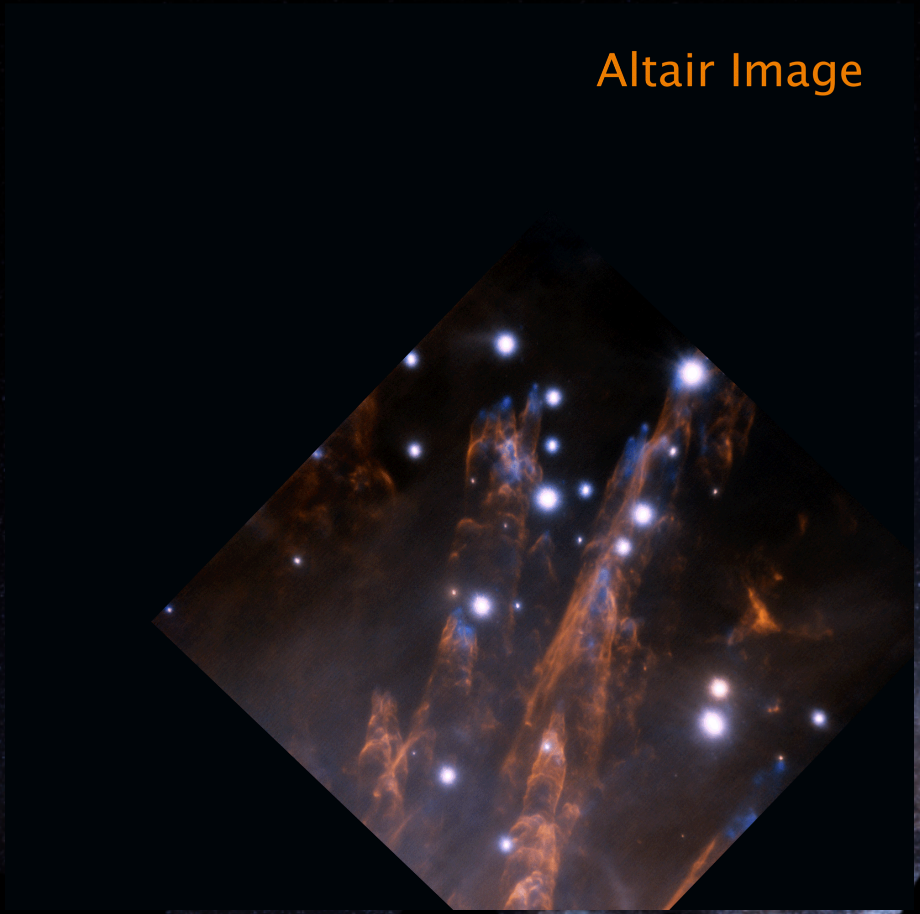
Why GNAO?

- GN ALTAIR system aging
- GeMS has shown the science capable with MCAO
- MK excellent site for an MCAO system

GeMS lessons learned

- GeMS+GSAOI provide exquisite image quality
- Instrumental for e.g. crowded fields
- Astrometric stability crucial for proper motion studies
- Relatively large field of view great asset.

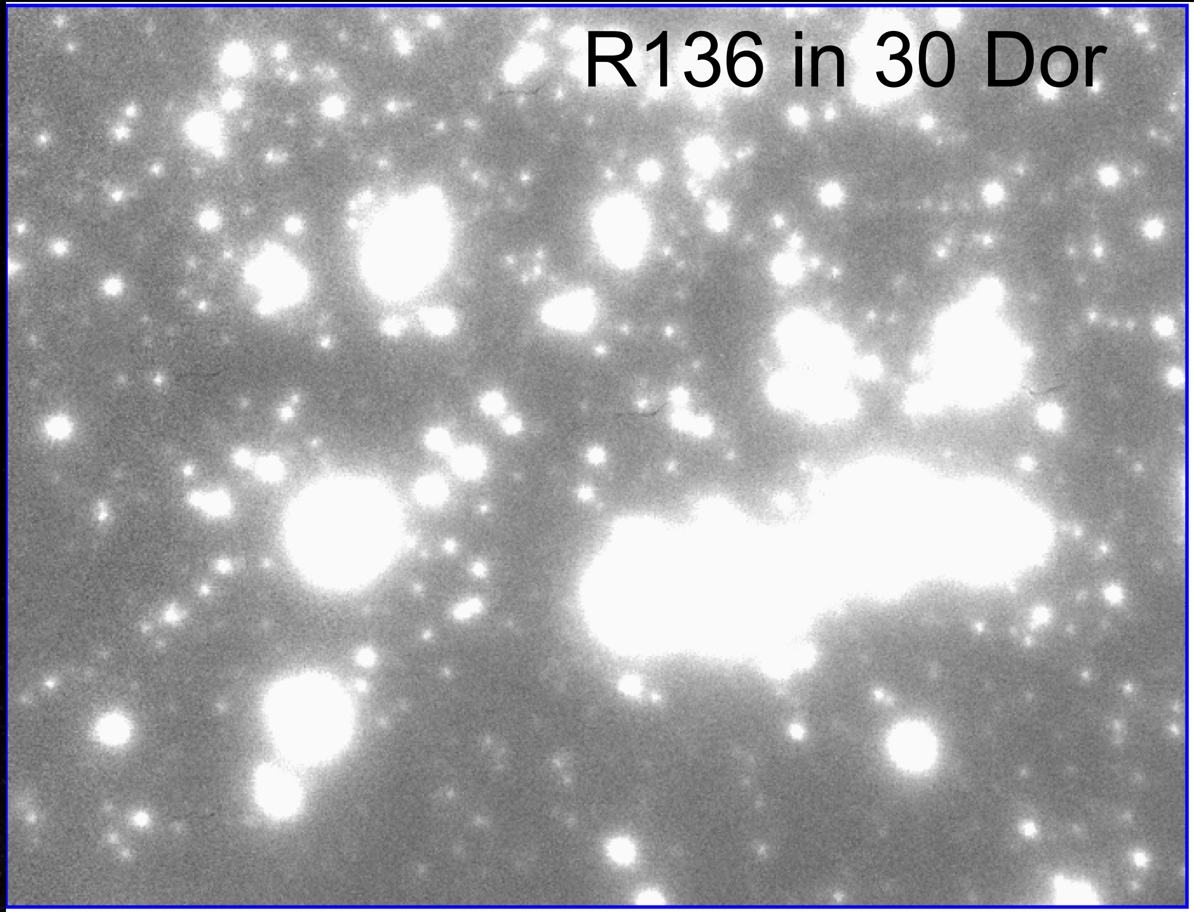
Explosive outflows

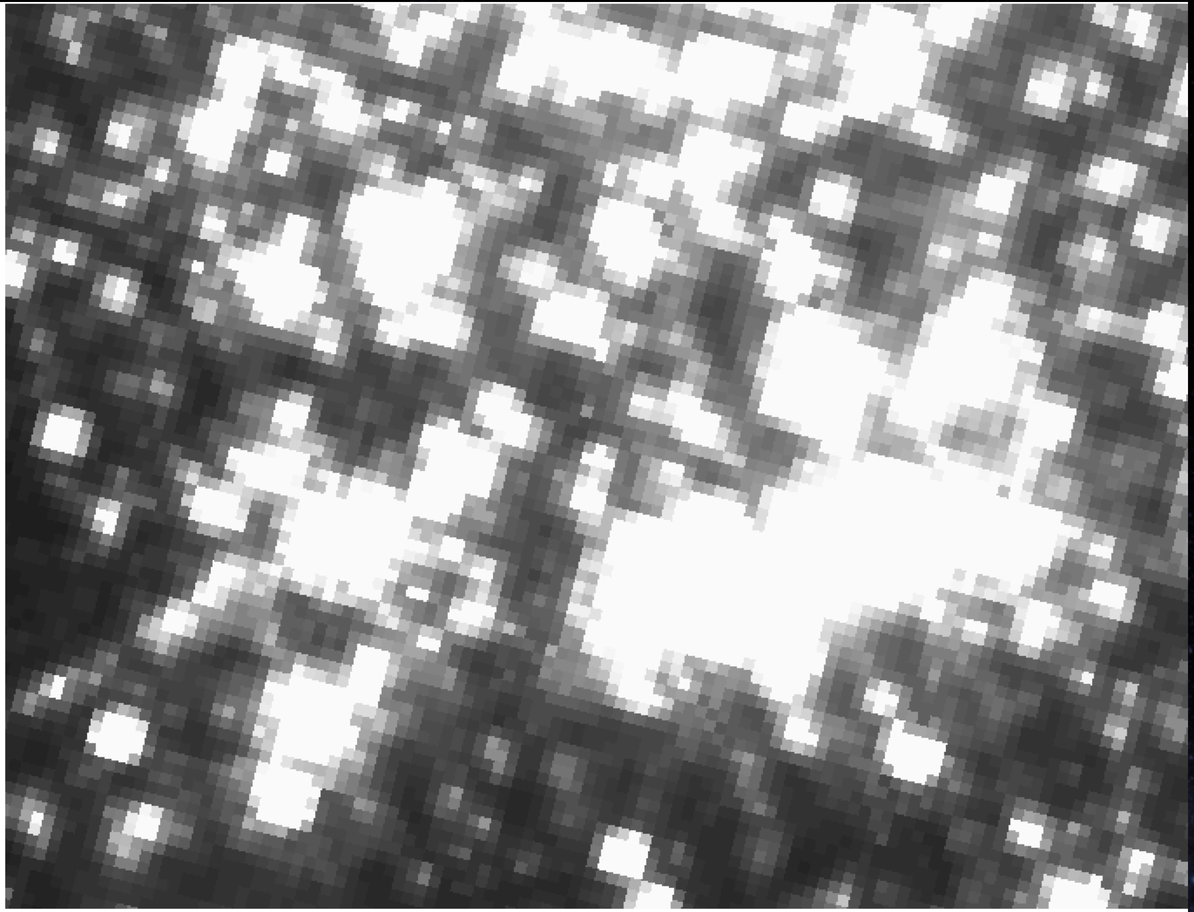


Bally et al. 2015

NIRI Field of view 20”
Multi-epoch data shows material moving

High Spatial resolution



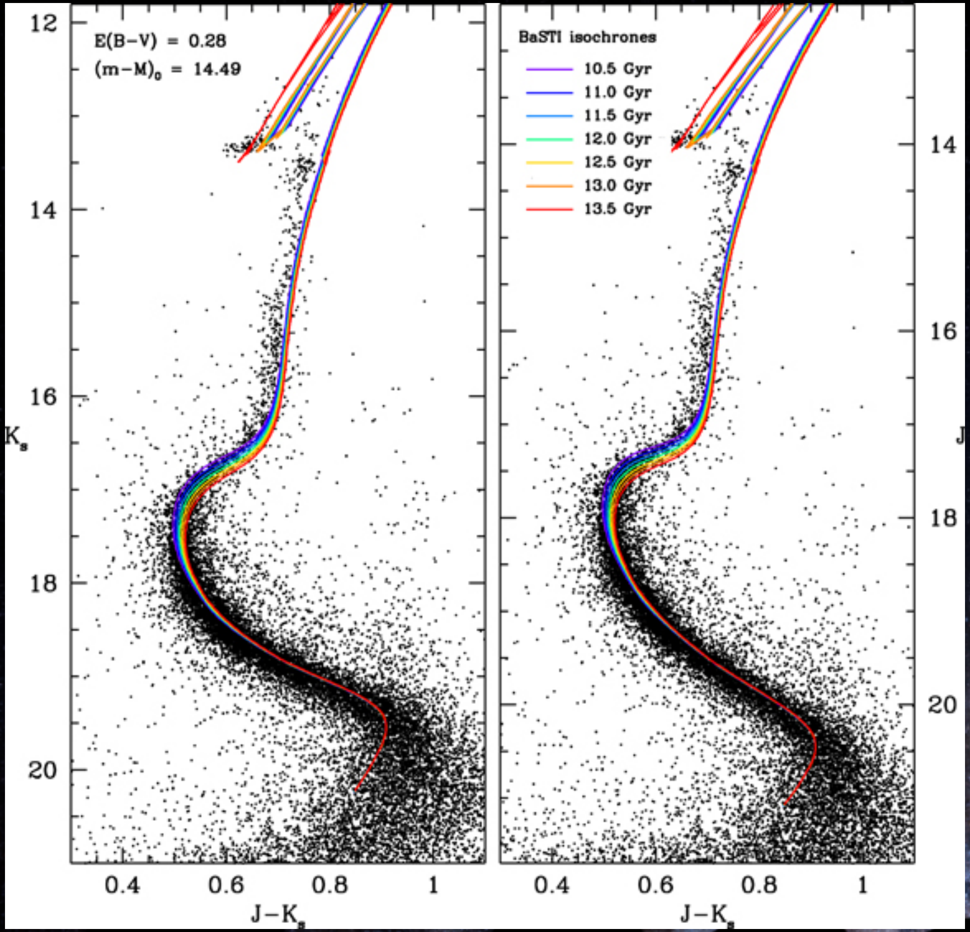


GeMS/GSAOI K band 15”x10”

HST NICMOS2 F160W (Andersen et al. 2009),

Lawrence, Andersen et al. in prep

Accurate CMDs

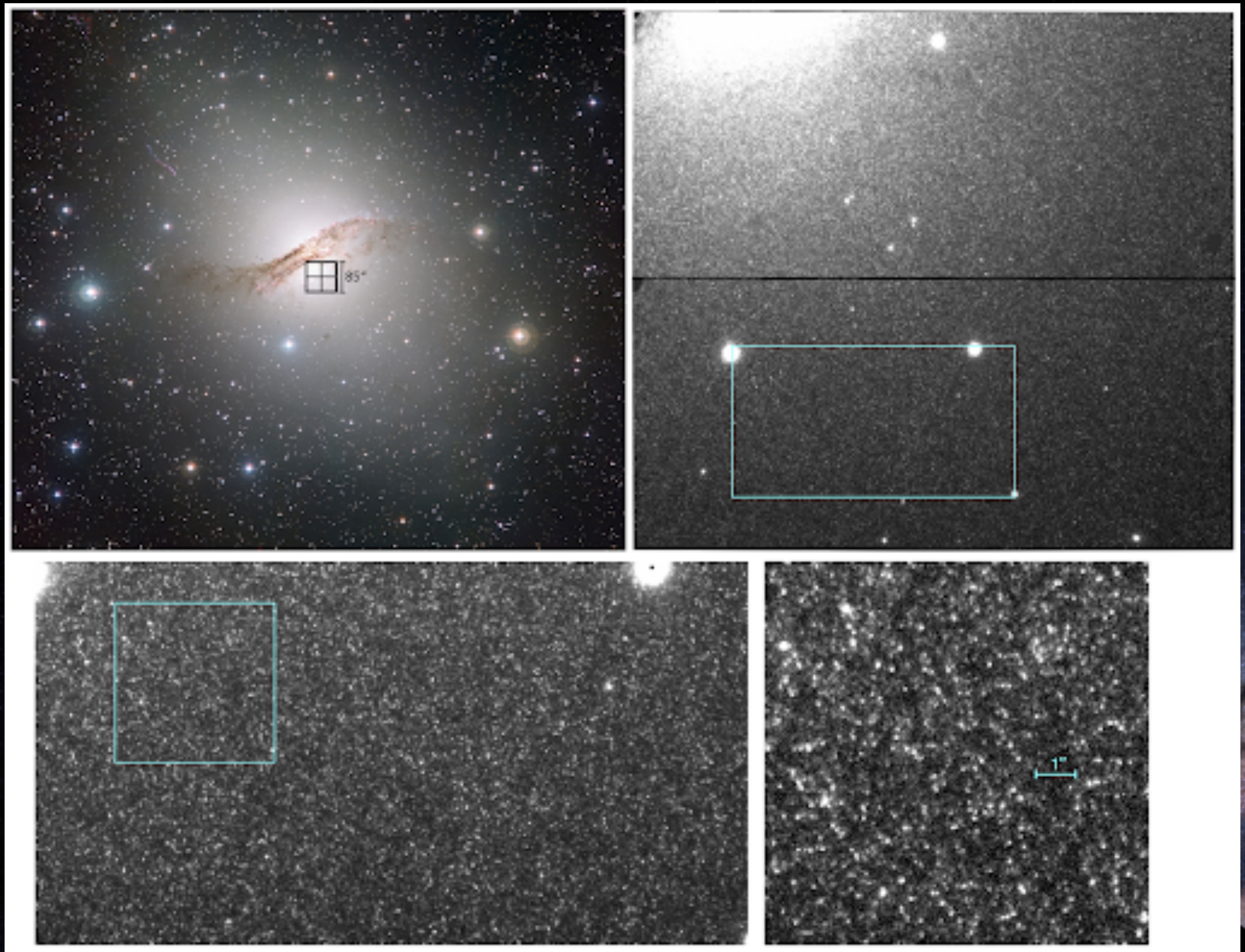


J,K CMD of NGC 6624 with GeMS/GSAOI

Deep accurate photometry allows age determination 12+-0.5 Gyr

Saracino et al. 2016

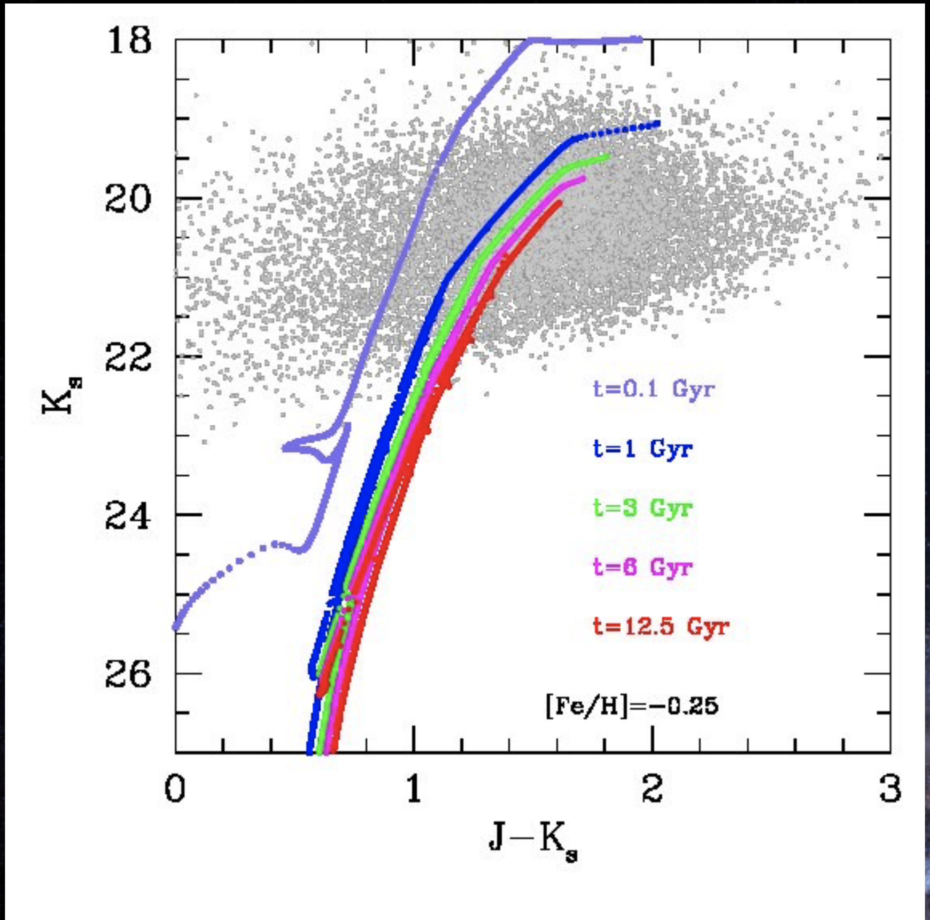
Faint variable studies



GeMS/GSAOI imaging of CenA. Multi-epoch data will identify variable stars (LPVs)

Blakeslee et al. in prep

Faint variable studies



GeMS/GSAOI imaging of CenA. Color-magnitude diagram

Blakeslee et al. in prep

The Science team:

- Combination of Base of Gemini staff and external expertise for key areas
- Not exhaustive collection of science cases
- To explore which parameters are critical

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Science team Members

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J. Blakeslee (Gemini), R. Carasco (Gemini)
R. Diaz (Gemini), T. Dupuy (Gemini)
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M. J. Jee (Yongsei), H. Kim(Gemini)
M. Lemoine-Busserolle (Gemini), F. Marchis (SeTI)
C. Packham (San Antonio), M. Pierce (Wyoming)
T. Puzia (Univ. Catholica), J. Scharwächter (Gemini)
S. Sivanandam (Toronto), G. Sivo (Gemini)
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Science cases:

Driving science cases expected to define the design
Return timely science made capable by an MCAO system

Enabling science cases expected to take advantage of an MCAO system

The driving science cases are discussed in this talk
Separate talks by Michael Pierce and Jessica Lu

Extragalactic Science cases :

- Central parsecs around AGNs
- AO assisted survey of 0.7 <z < 2.7 field galaxies
- Gravitationally lensed transients
- Nuclear star clusters in local and nearby galaxies

Central parsecs around AGNs

- The interplay between SMBHs and their immediate environment
- How is Star Formation enhanced/quenched?
- Spatial resolution of <~0.1" allows to resolve ~100pc scale
- Near-IR to compensate for extinction
- Emission lines to trace inflow/outflow and velocity flow.
- R~5000 to resolve emission lines and obtain v~100km/s

Survey of 0.7 < z < 2.7 field Galaxies

- Period of peak of cosmic Star Formation
- Crucial to understand the SF enhancement and quenching
- Major and minor mergers play large role
- Emission lines and velocity structure crucial

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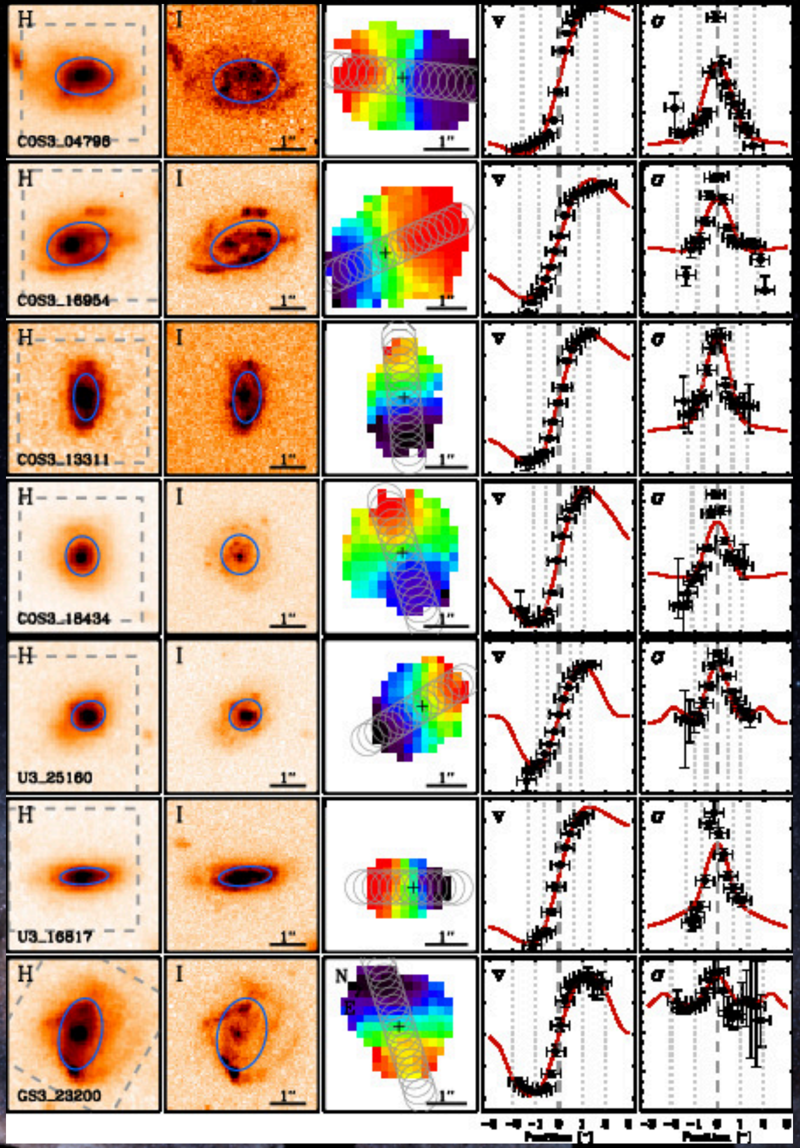
Natural seeing KMOS IFU obs. of a sample of z~2 field galaxies

Although spatial gradients can be measured with this resolution there is no information about mergers.



Wuyts et al. 2016

Gravitational lensed transients

- Deep HST surveys found new transient phenomena,
- Cluster dark matter studies,
- Massive star studies,
- Expansion rate of the universe
- Regular temporal sampling is crucial for these studies

Gravitational lensed transients

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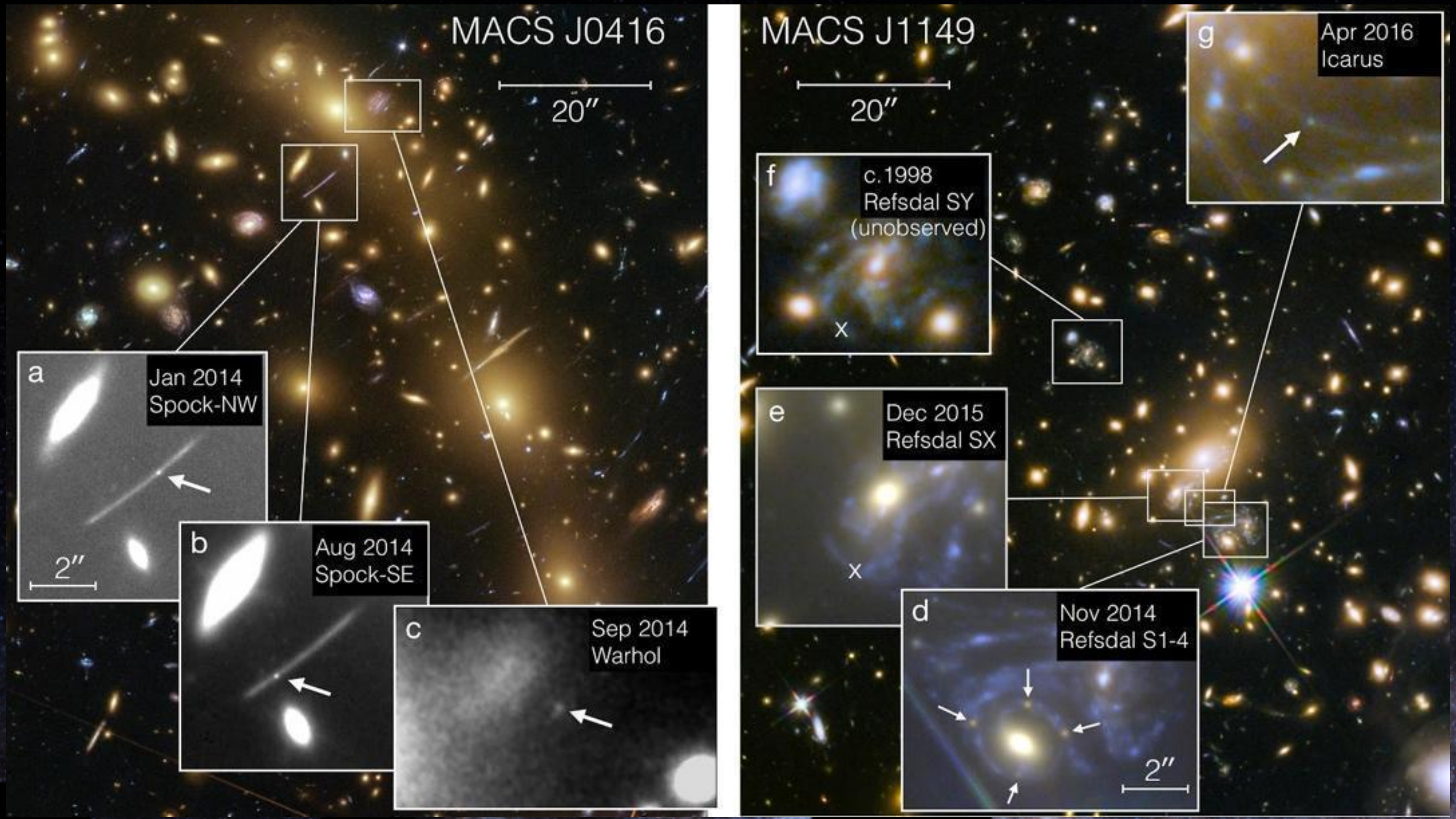

Lensing and temporal sources in two clusters

Kelly et al. 2018

Nuclear star clusters in nearby galaxies

- Nuclear Star clusters common in Galaxies
- What is their origin?
- Often deeply embedded => high spatial resolution near-IR

Galactic Science cases:

- Galactic Young Massive Star Clusters
- The Galactic Nucleus
- Chemodynamics of Galactic Globular Clusters

Galactic Young Massive Star Clusters

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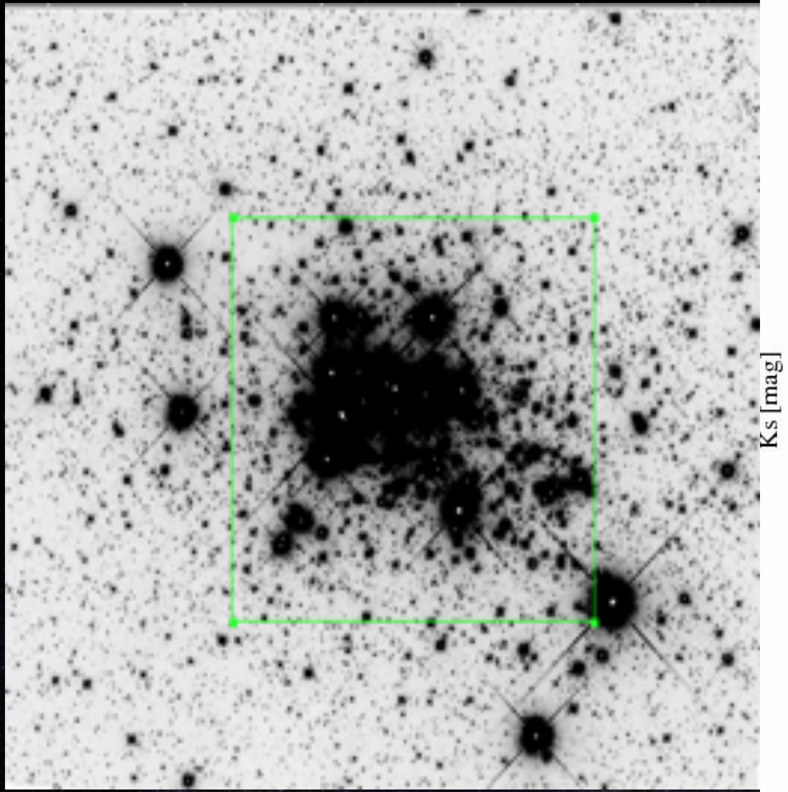
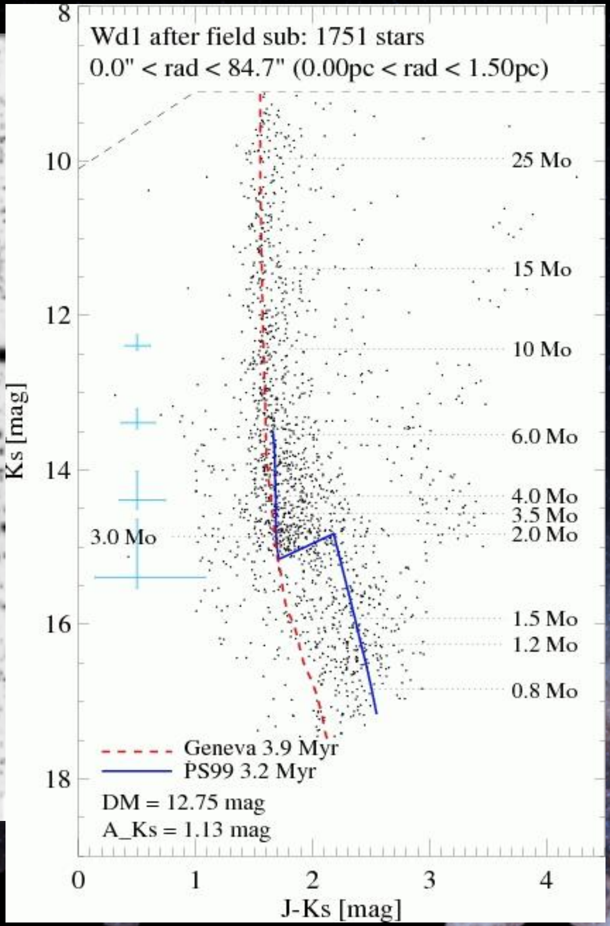
- Rare local analogues to distant star bursts.
- Key regions to search for variations in the IMF
- The formation of the clusters poorly known
- Can they remain bound or disperse into the field?
- More details in the talk by J. Lu.

• Galactic Young Massive Star Clusters



Andersen et al. 2017



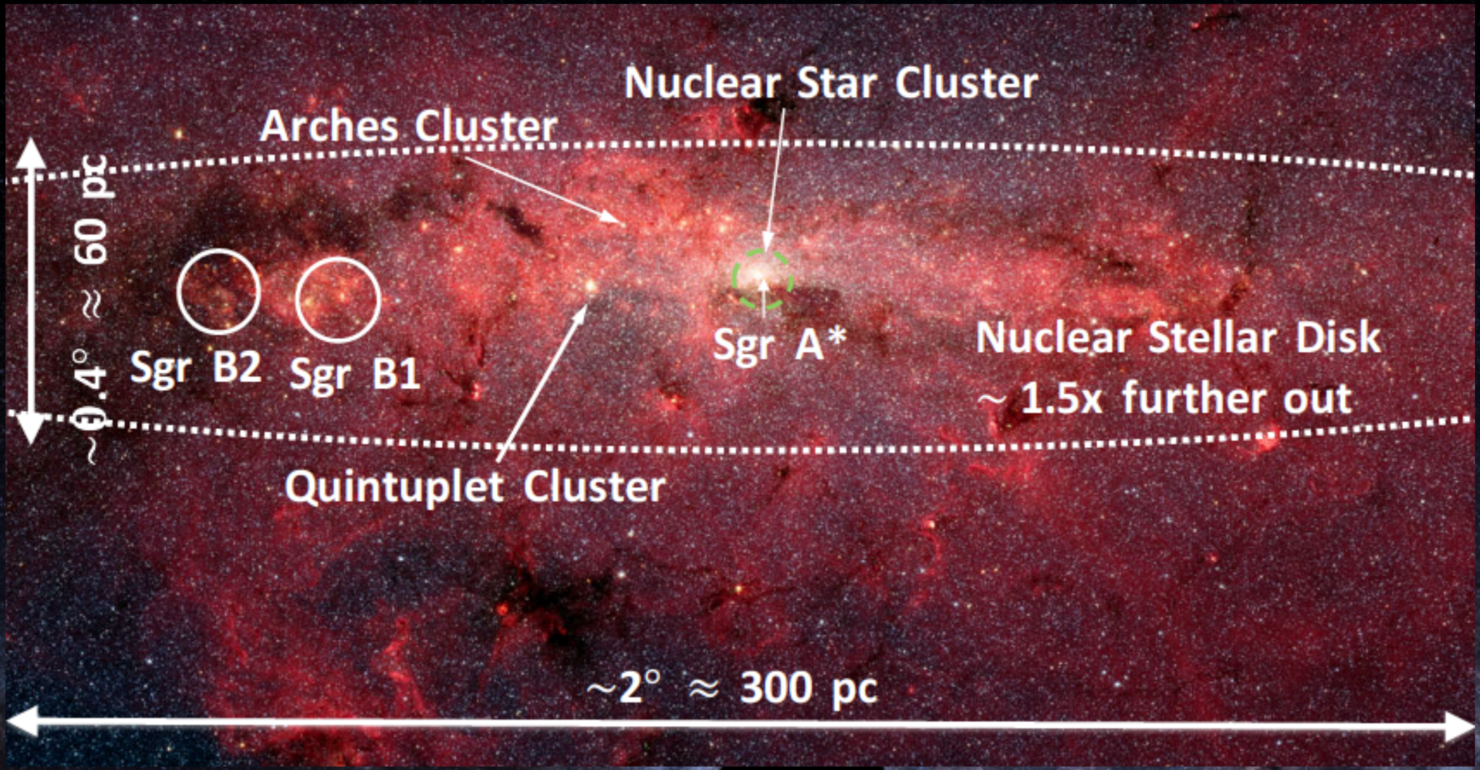
Brandner et al. 2008

F160W image of Westerlund 1 and a ground-based color-magnitude diagram. The HST observations reaches down to 0.25 Msun whereas the ground-based color-magnitude diagram only reaches 2 Msun (50% completeness). GNAO can reach the brown dwarf limit (0.08Msun)

Galactic Center:

- Unique target, only central region to be studied in
- Star formation in an extreme environment
- How was the Galactic Center formed?

Galactic Center:



Schematic of the Galactic Center region. Most notable clusters and objects are marked.

Feldmeier-Krause

Chemodynamics of Globular Clusters:

- How did Globular clusters form? Do they contain a black hole?
- AO assisted NIR IFU observations:
- Determine the velocity dispersion
- Determine the chemical abundance of each star
- Thus probe for any IMBH in the center of the GC and
- Correlate velocity dispersion with the chemical abundances

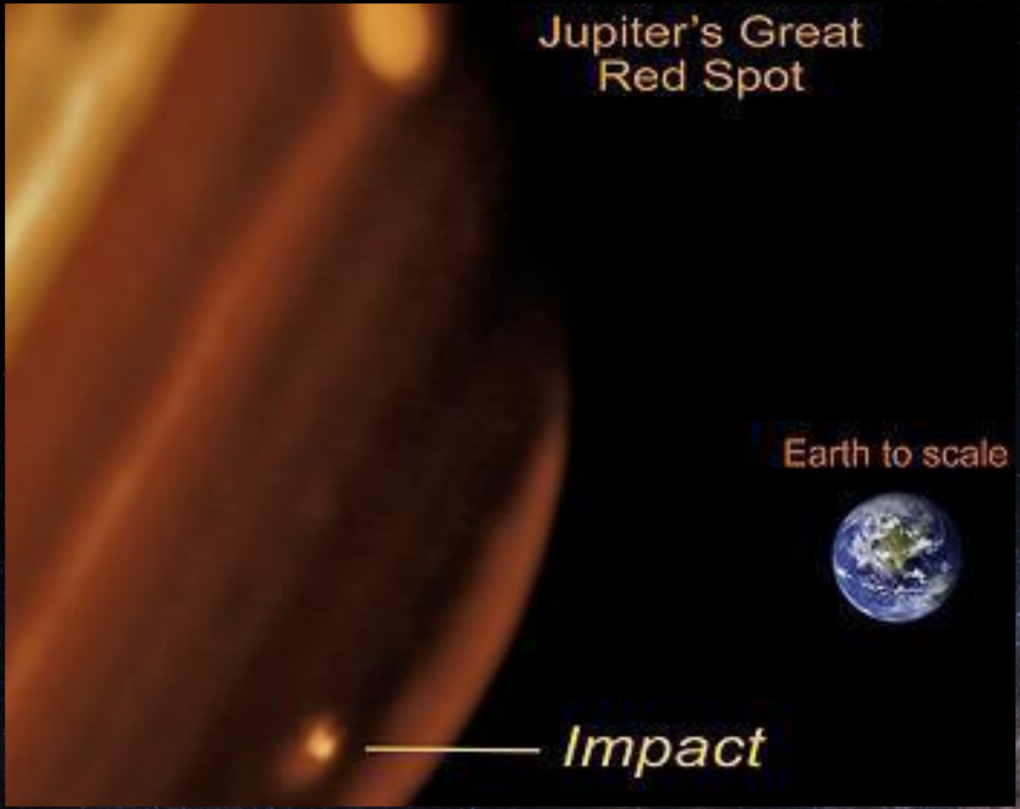
Solar system and brown dwarfs

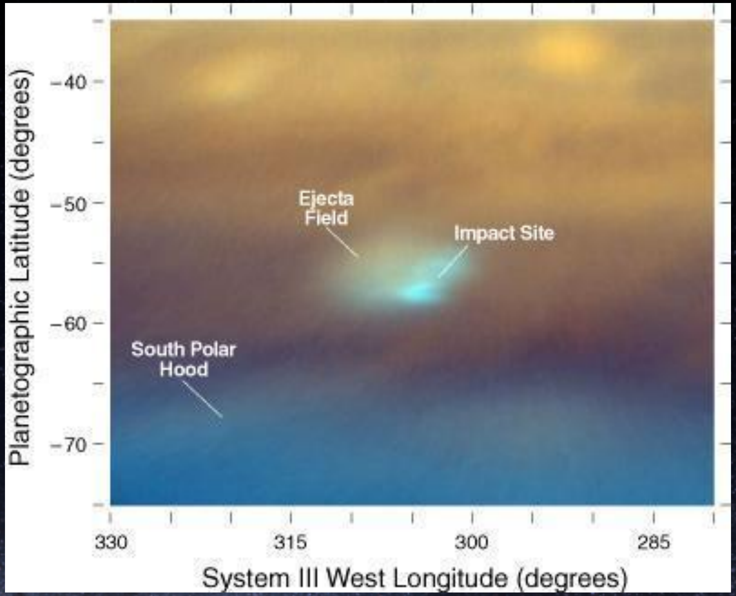
- Giant Planet Atmospheres and their disks
- Lowest-mass products of star formation

Giant Planet Atmospheres and their disks

- Wind and turbulence phenomena on giants common.
- Opportunity to look into the atmosphere
- Ice giants analogues to many extra solar planets

Gaseous planets:



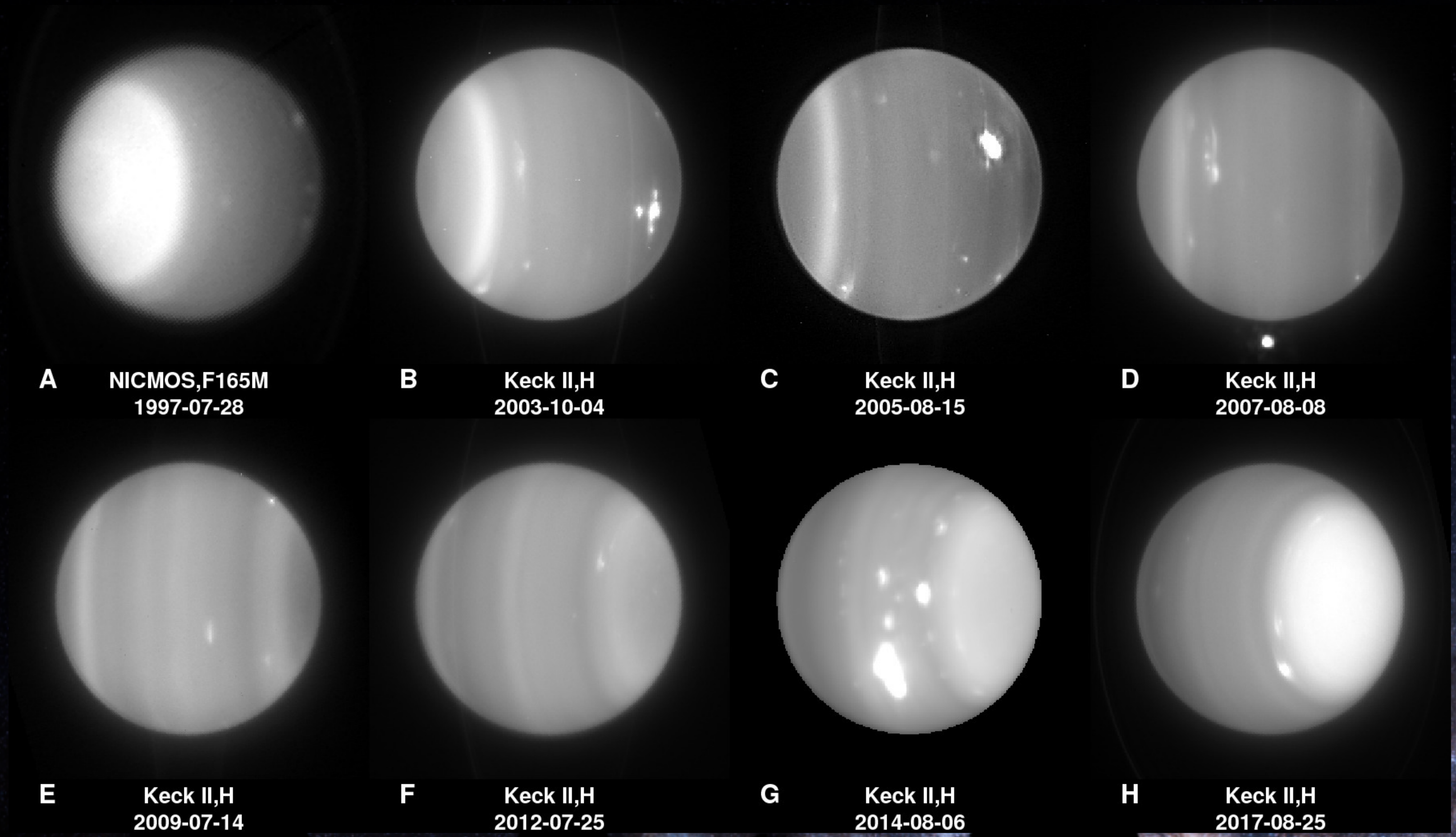


The scar. Image taken with Keck II.
Right: JHK image of the impact site in Jupiter's southern hemisphere.

Gaseous planets

- Due to their size MCAO important
- SCAO images often distorted
- Moons sufficiently bright to use as WFS
- But requires non-sidereal tracking

Icy Planets



Uranus over time in the near-IR
Sromovsky & Fry

Lowest-mass products of star formation

- What is the shape of the low-mass IMF?
- Necessary to target large samples of objects, NIR, Spec. and astrometry.
- Characterize their atmosphere, comparison with giant planets
- Proper motion crucial to associate membership

Summary

- GNAO will enable a range of science , From solar system, planets, TNOs etc, over Galactic astronomy, Star Formation, Globular clusters, to extragalactic astronomy.
- High Strehl and a large field of view crucial for science cases
- Flexibility of MCAO over SCAO important
- In particular, nimble use and flexible scheduling allow new high resolution possibility in transient astronomy.

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Summary of requirements

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Science case	Spectral range [µm]	Field of view	Strehl ratio	Astrometric accuracy [mas]	Photometric accuracy
Extragalactic and cosmology					
High-z galaxies	0.9-2.5	3" (multi-IFU)		<100	~10%
Nuclear star clusters & disks	0.9-2.5	20"			
Central parsecs around AGN	0.9-2.5	<~ 10"	60% (K)		~10%
Gravitationally lensed transients	0.7-2.5	2'	>30% (K)	10	2%
Galactic and nearby extragalactic					
Galactic young massive star clusters	1-2.4	>2'	50% (K)	<0.3	few %
Globular clusters	1.5-2.4	Multi-IFU patrol field 2'	>50% (K)	<10	<20%
Galactic Center	1-2.4	>2'		<0.2	few %
Brown dwarfs, solar system					
The lowest-mass products of star formation (astrometric orbits & resolved spectra)	1-2.5	~1" | ~10'	FWHM/stable PSF more important	n/a | ~1	n/a
Giant planet atmospheres and their disks	1-2.4	1'	30% (JHK)	<1	few %