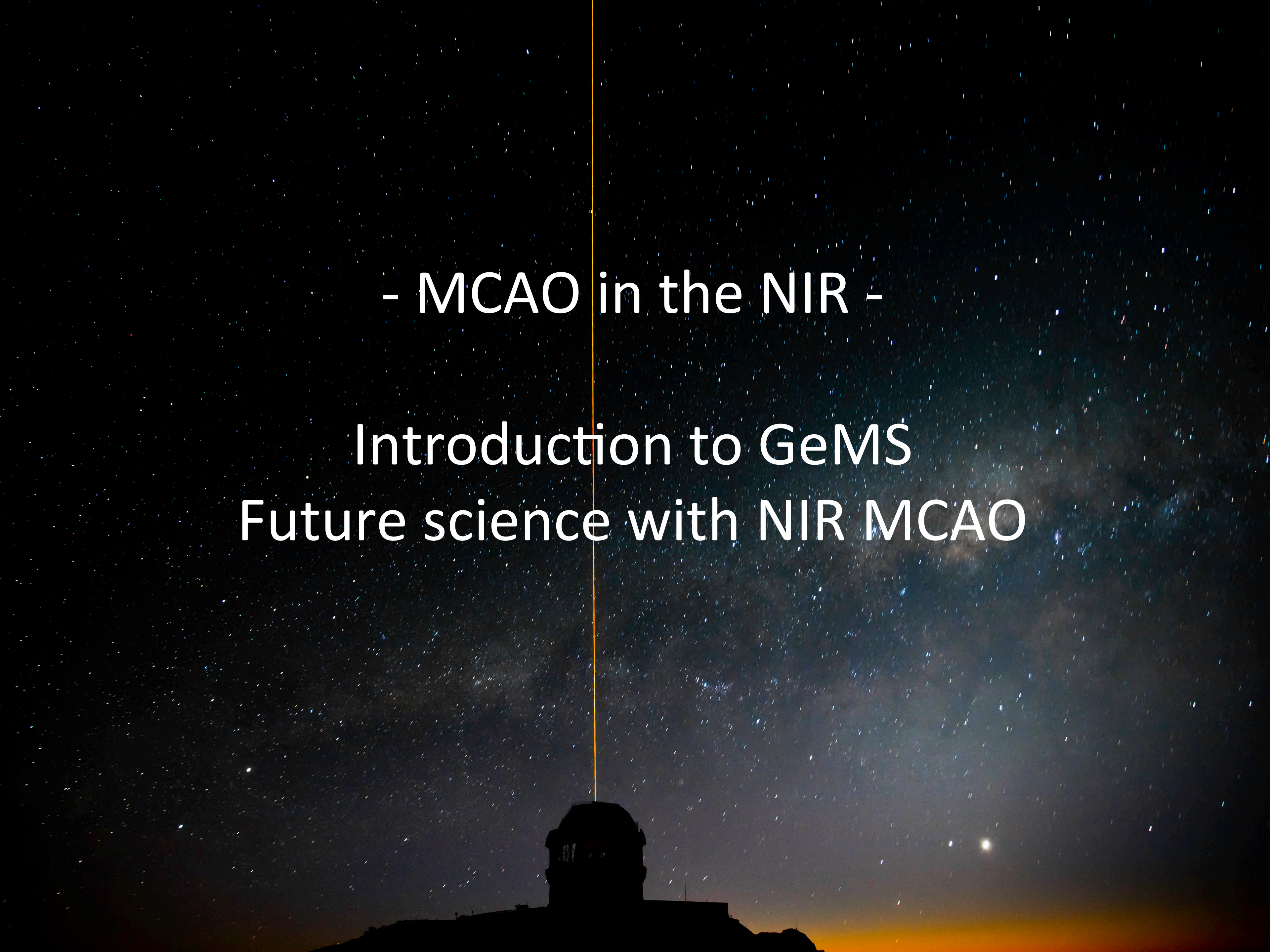
- MCAO in the NIR -

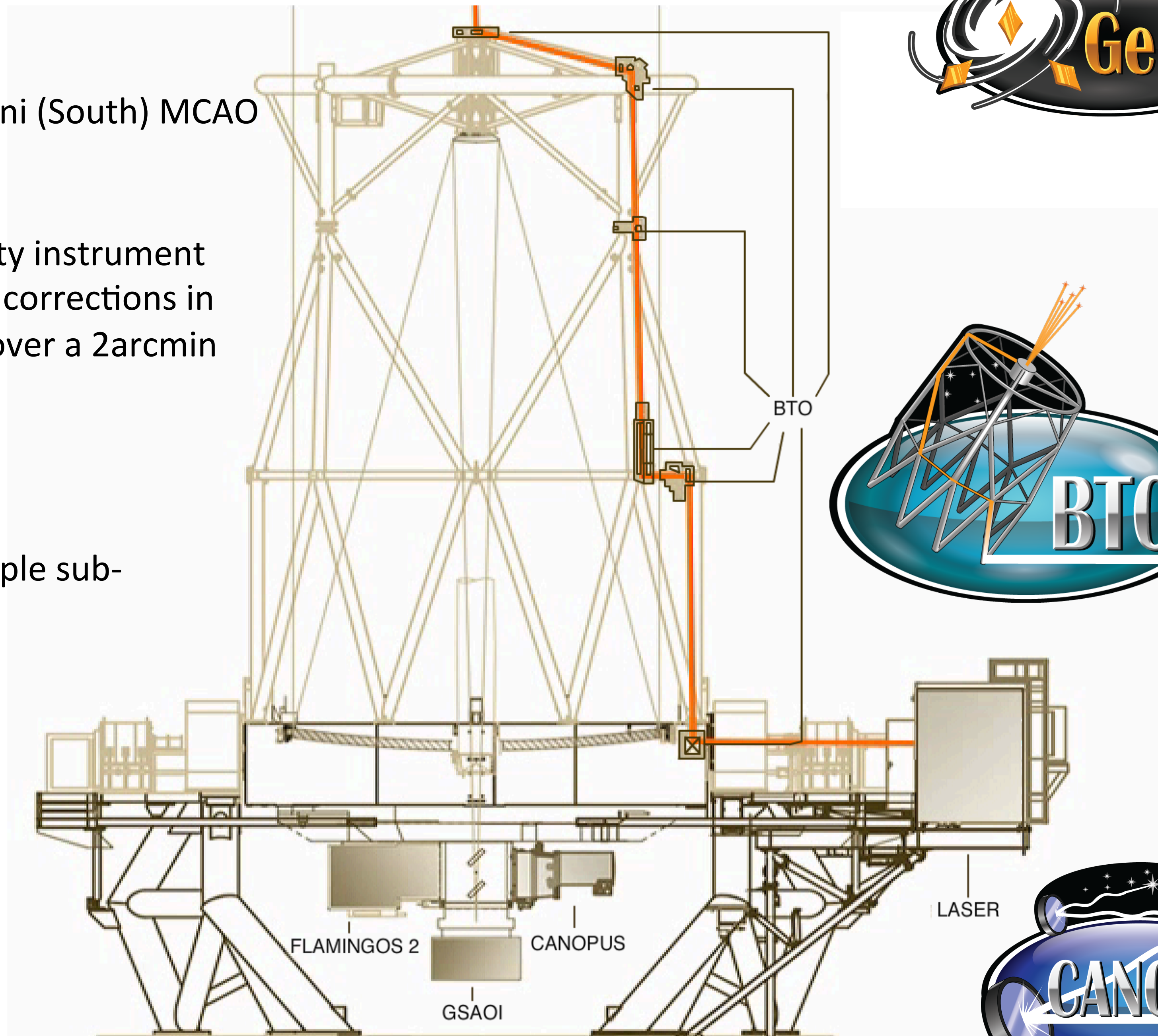
Introduction to GeMS
Future science with NIR MCAO



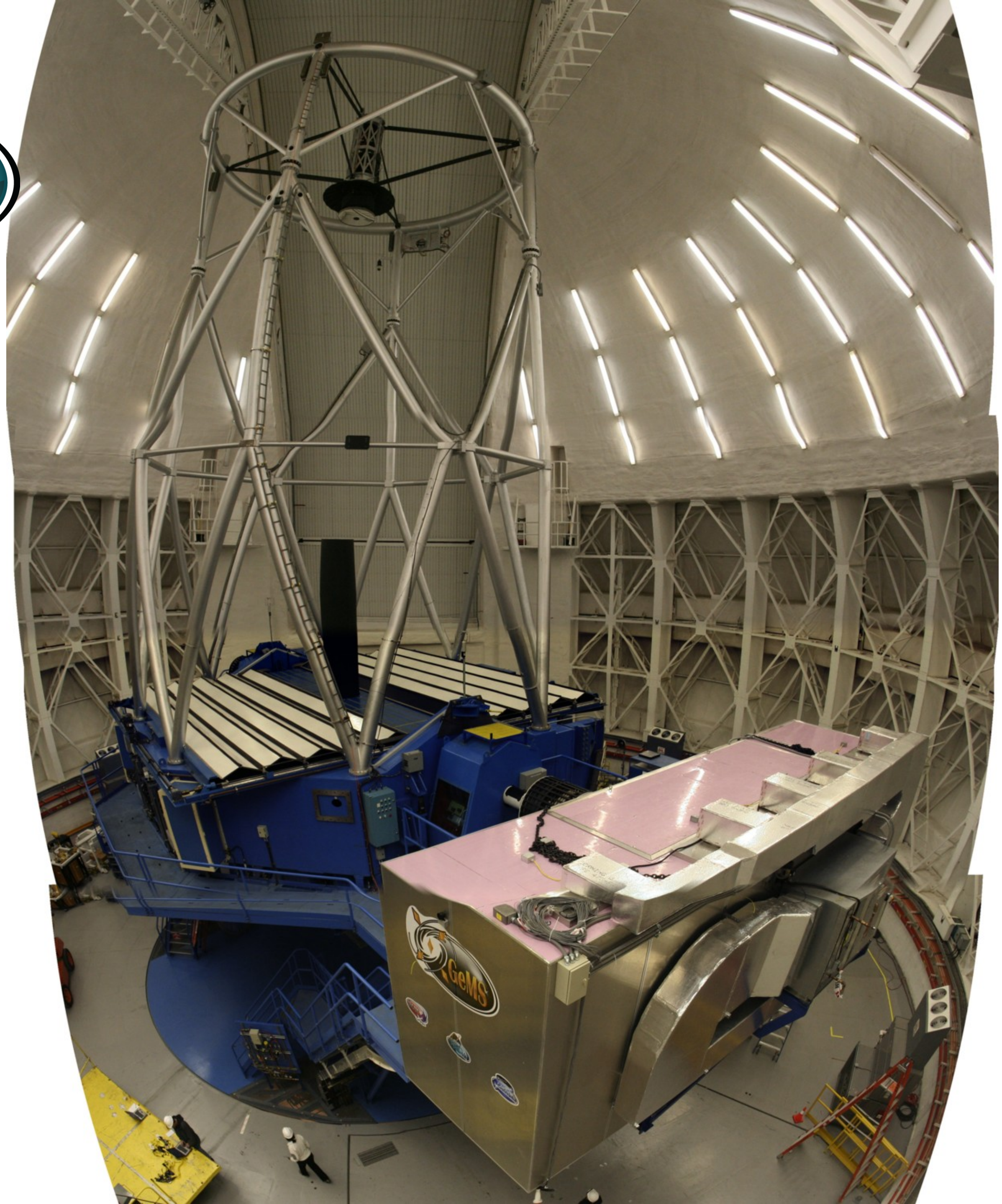
GeMS = Gemini (South) MCAO system

GeMS = Facility instrument delivering AO corrections in the NIR, and over a 2arcmin diameter FoV

GeMS = Multiple sub-systems.



BTO



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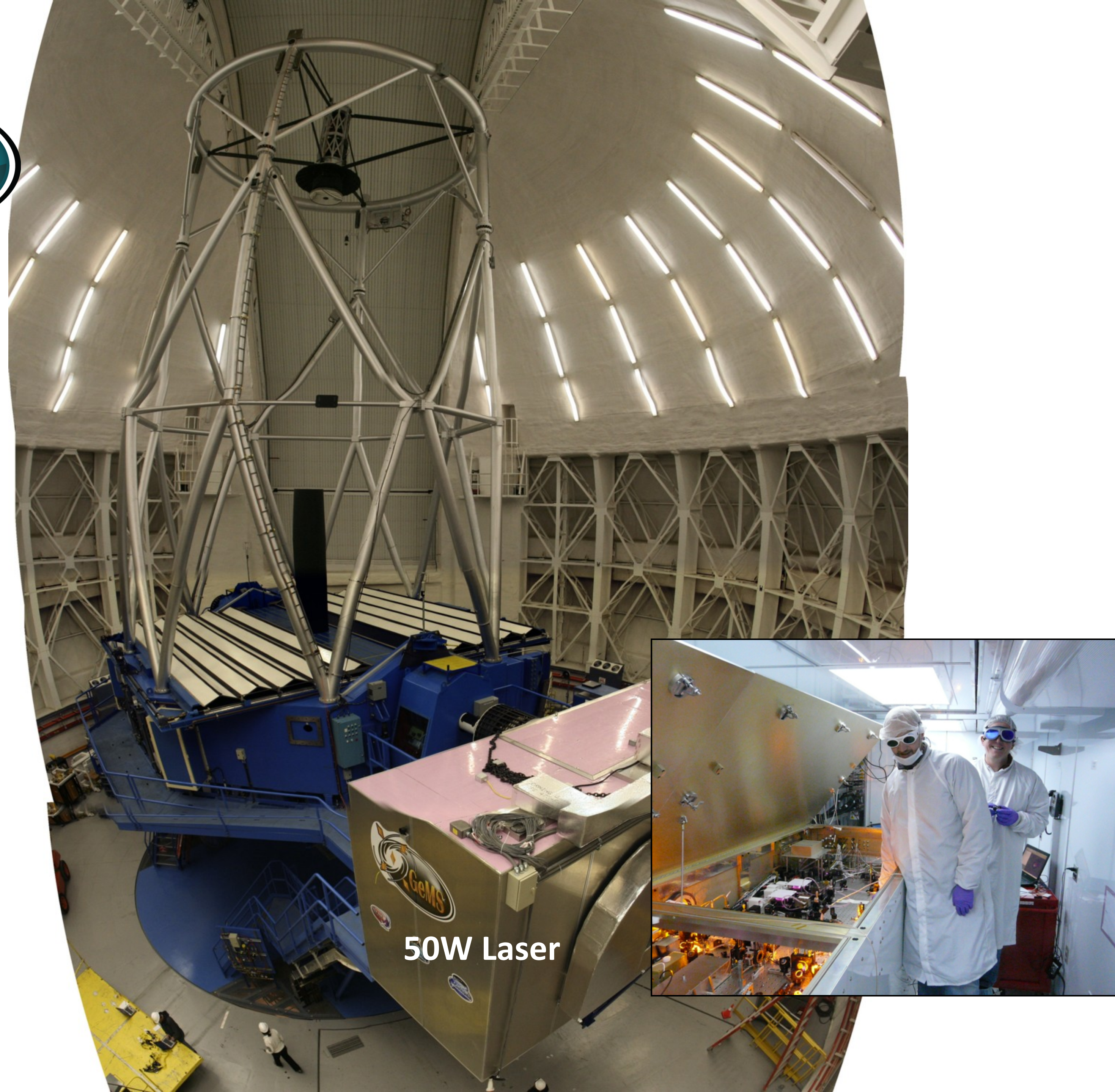

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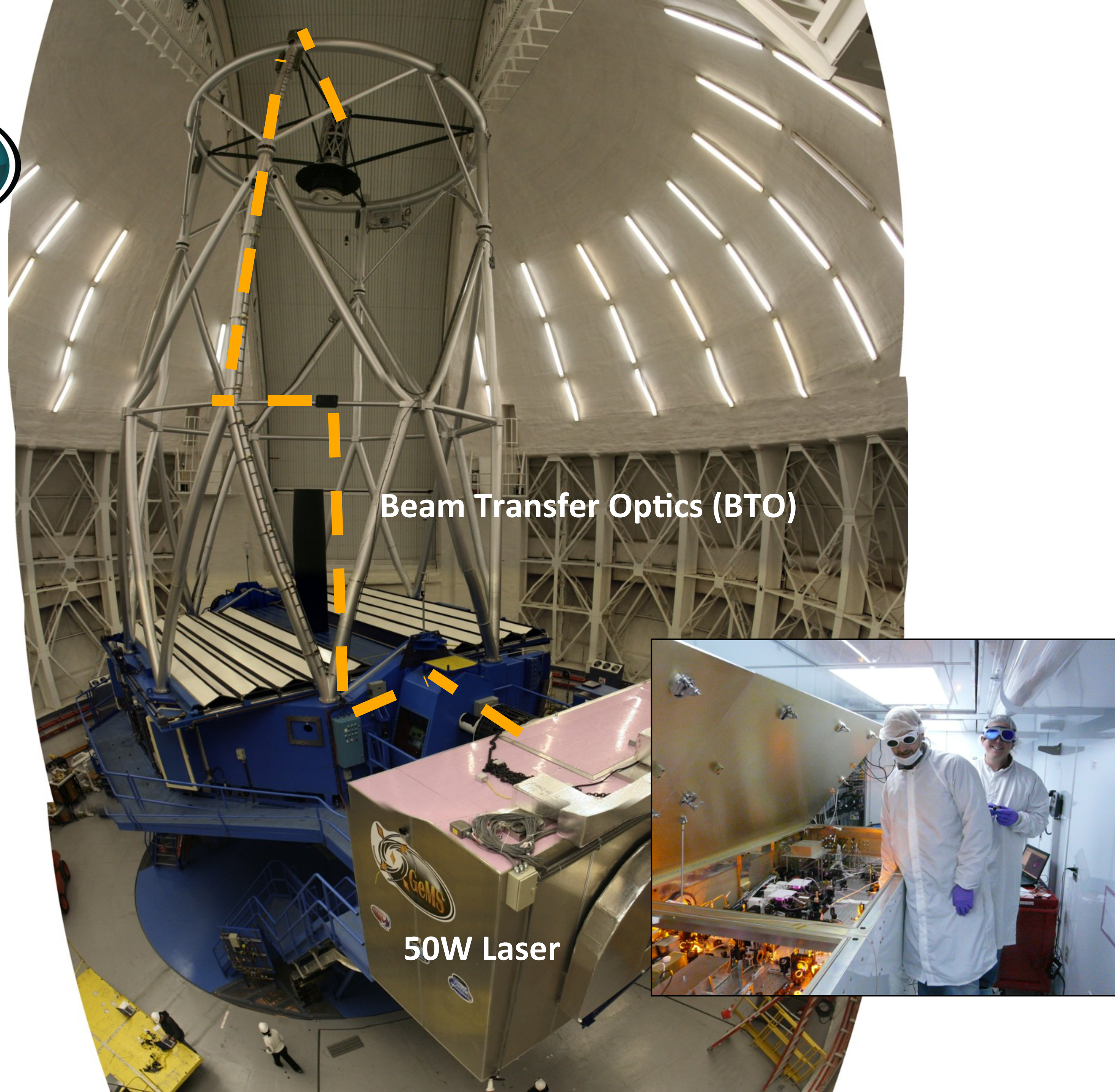

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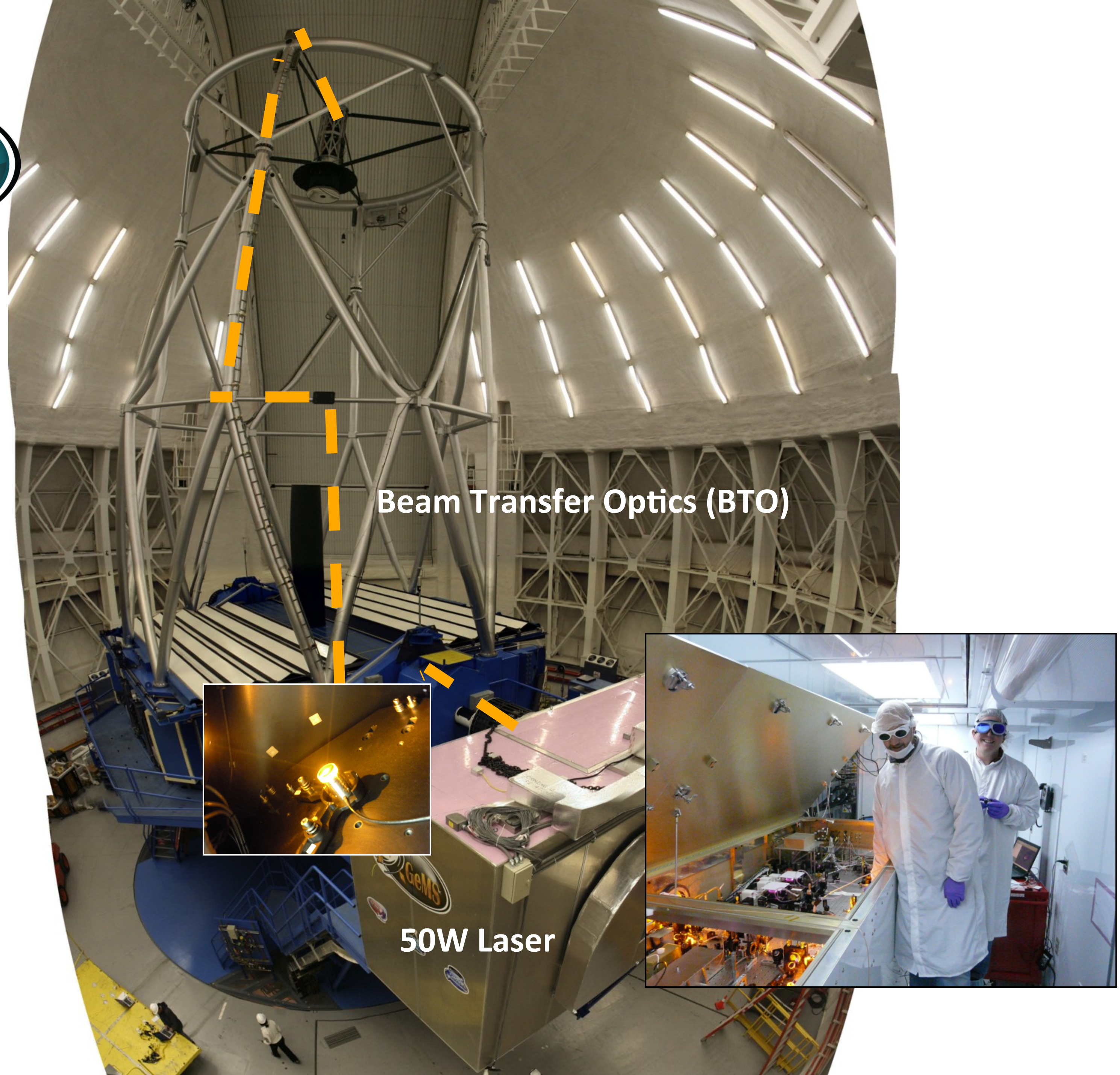
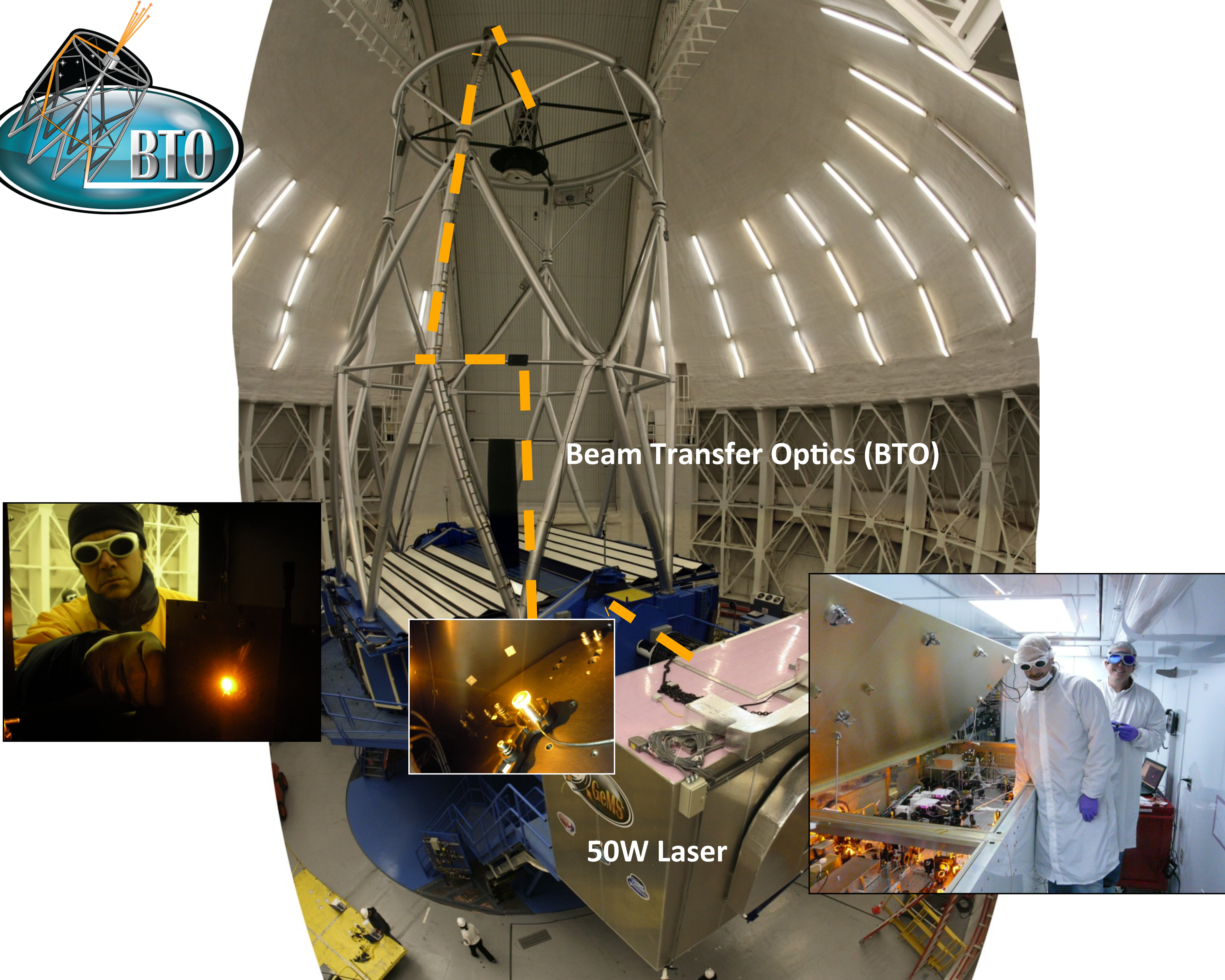
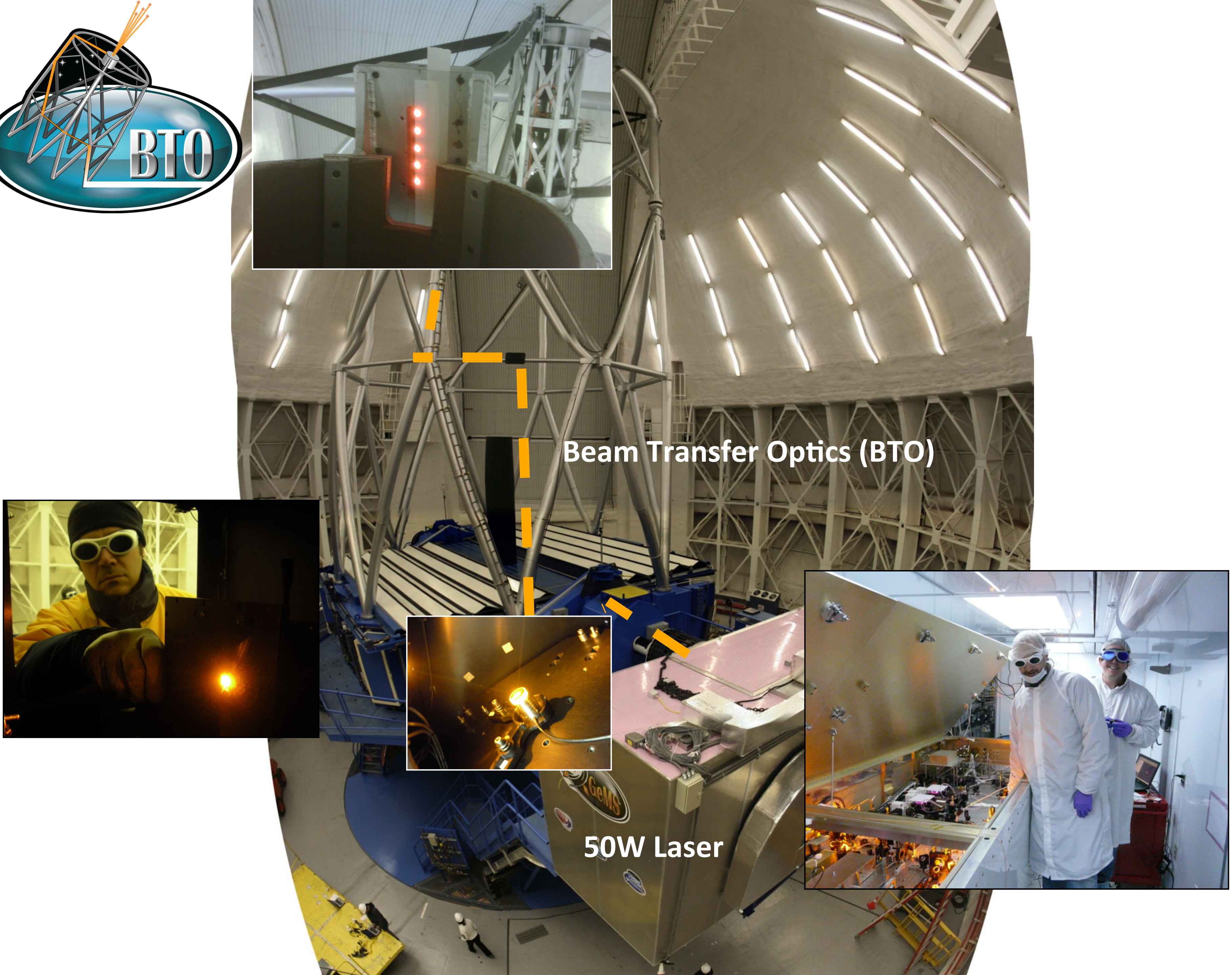
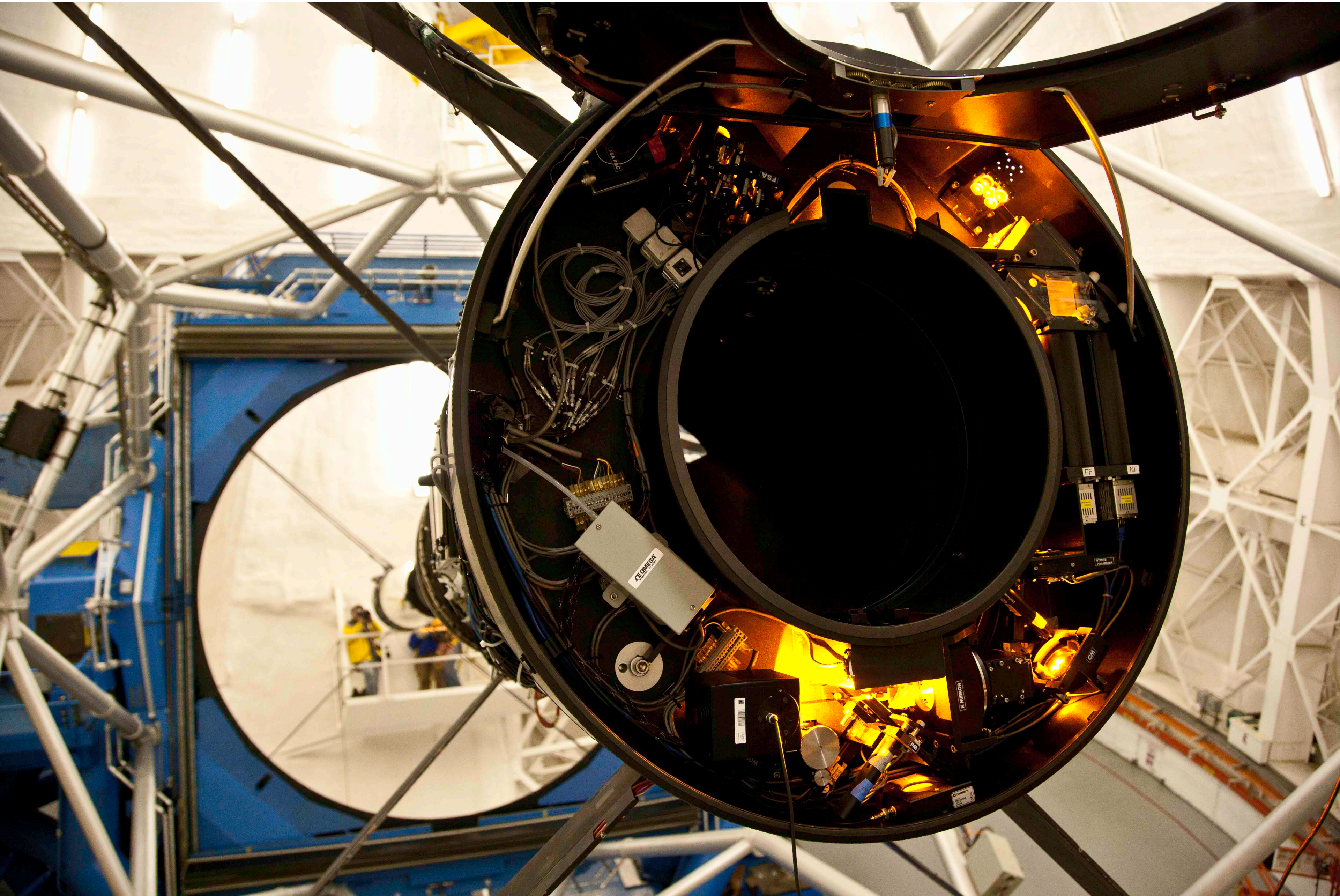
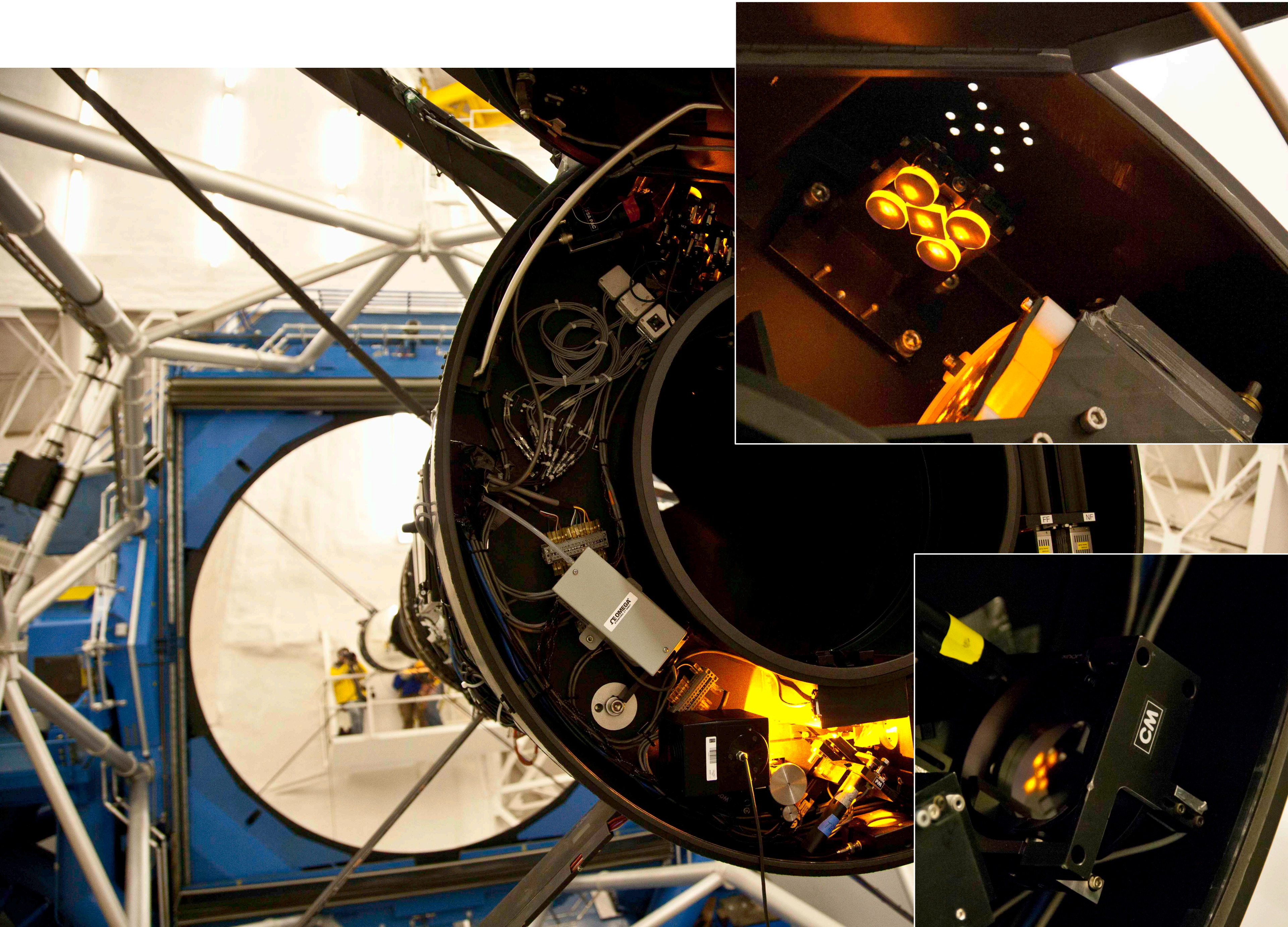


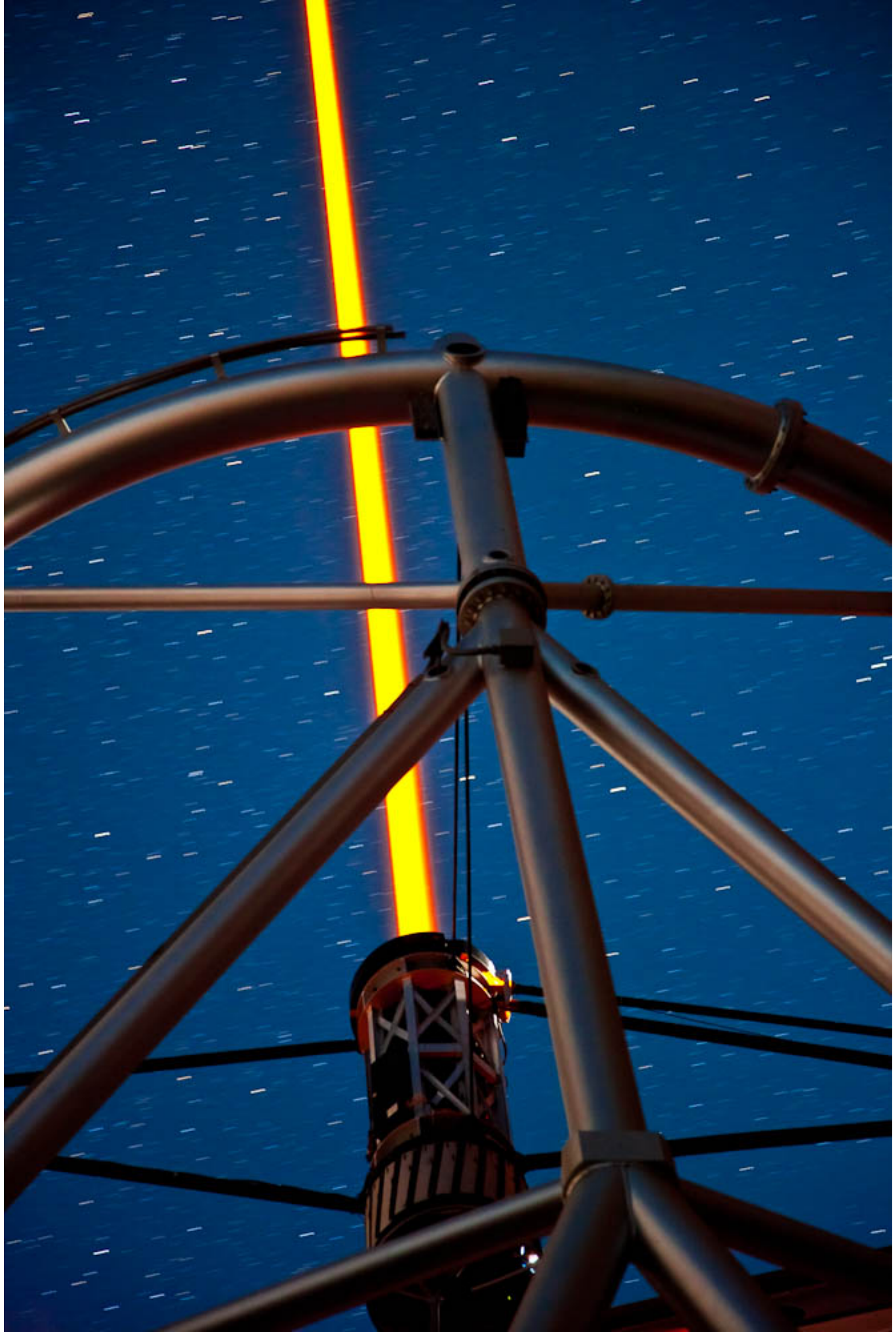

Beam Transfer Optics (BTO)
50W Laser
GeMS


Beam Transfer Optics (BTO)
50W Laser

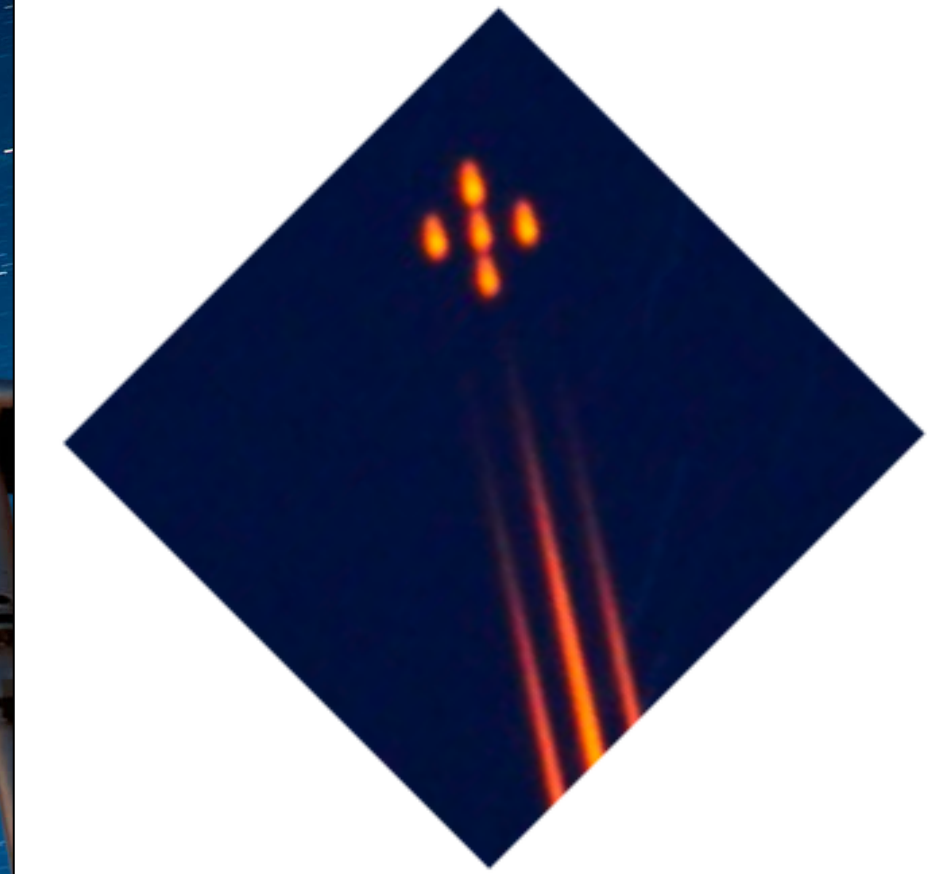

OMEGA
FF
NF
K MIRROR


OMEGA
FF
NF
CM

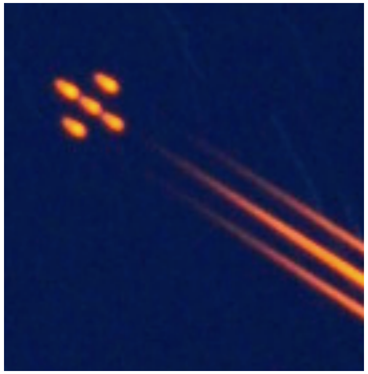
BTO

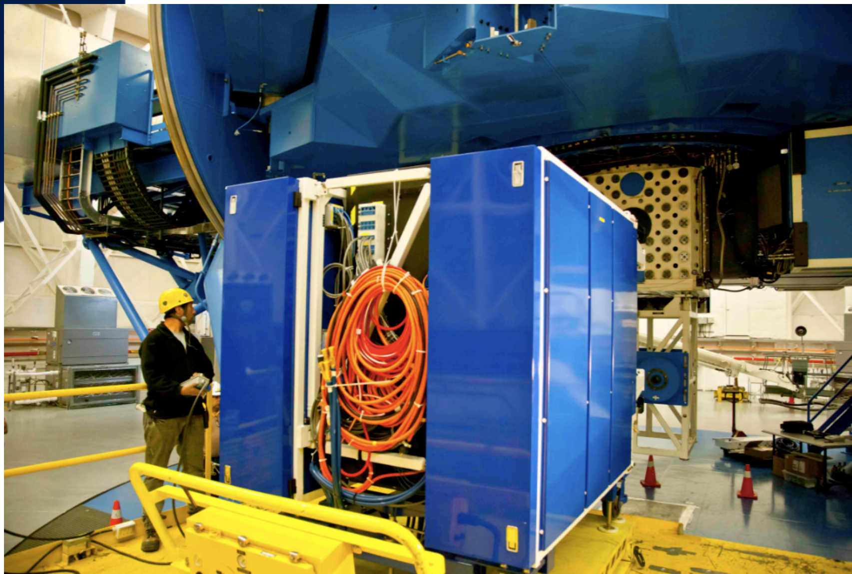


BTO




DM9
DM0
NIR
TTM
DM4.5
VISIBLE





Instruments fed by GeMS

GSAOI

Near-Infrared wide field imager

2 x 2 mosaic Rockwell HAWAII-2RG 2048 x 2048 arrays

0.9 - 2.4 µm wavelength

85" x 85" field-of-view

Pix. scale of 0.02"/pixel

Flamingos-2

Near-Infrared wide field imager and multi-object spectrometer

0.95-2.4 µm wavelength

FoV = 120" diameter

Pix. Scale 0.09 arcsec/pix

Long Slit (slit width from 1 to 8 pixels)

MOS (custom masks)

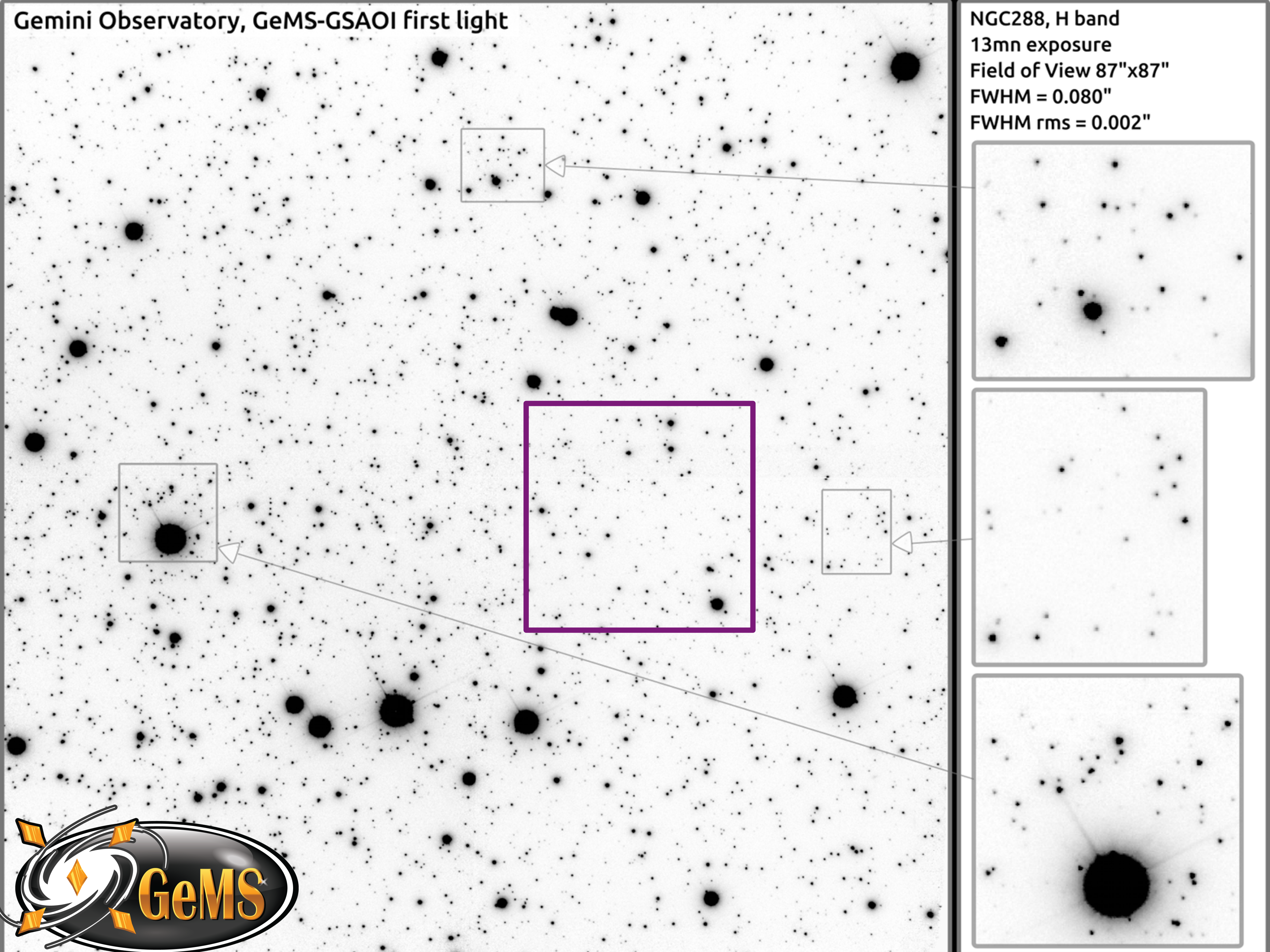
R = 1200-3000

GMOS

0.36-0.94 µm (New Hamamatsu-Red-Sensitive CCDs)
Imaging, long-slit and multi-slit spectroscopy

FoV = 2.4 arcminute diameter.

Integral Field Unit (IFU) - pix = 0.1arcsec - FoV = 17arcsec - R150 to 1200


Gemini Observatory, GeMS-GSAOI first light
NGC288, H band
13mn exposure
Field of View 87"x87"
FWHM = 0.080"
FWHM rms = 0.002"
GeMS

Science with NIR MCAO

Future Science with MCAO in the NIR (For VLT3)

Some examples of “current science”
What to expect in 8/10 years from now

NIR MCAO systems

MAD

2007 - 2008

Telescope:VLT
2 deformable mirrors (0 and 8.5km)
Pix Scale=0.028''/pix

(Marchetti et al., SPIE, 2008)

GeMS

2012 ->

Gemini-South
2 (3) DMs at 0, (4.5) and 9km
Works with GSAOI (NIR camera)
On-going commissioning for Flamingos 2
Potential commissioning with GMOS

See F. Rigaut / Hibon presentations

LINC NIRVANA

(2017 ?)

LBT
2DMs / path
Provide 2arcmin NIR imaging

Current MCAO is almost exclusively coupled with imagers
GeMS may get spectroscopy with F2 in a couple of years

Current Science with MCAO in the NIR

(examples from MAD and GeMS)

Main science cases:

1. Star Clusters
2. Astrometry

} **60 to 80% of the proposals**

3. A bit of extra-galactic (but difficult to compete with HST)
4. A bit of everything else

Current Science with MCAO in the NIR
(examples from MAD and GeMS)

Main science cases:

1. **Star Clusters**
   1. Globular clusters
   2. Star forming regions

Dense as a Globular cluster...

Scientific interests

- Fossils of galaxy archaeology
- Chronology of the Galactic halo and bulge assembly
- Testing ground for stellar evolutionary theory
- Tracers of chemical evolution
- Laboratory for dynamical stellar interaction
- The place to study *exotica* objects as Blue Stragglers and Black holes
- Basis for our understanding of any stellar system in the Universe
- Lower limit to the age of the Universe

(Slide from G. Fiorentino)

MCAO, by providing 1-2 arcmin FoV is ideal for GC

⇒ Gain in sensitivity / crowding vs. seeing limited

⇒ 8m NIR MCAO FWHM (~60-80mas) matches HST visible

Star Clusters, the MAD experience

MAD

A&A 483, L5–L8 (2008)
DOI: 10.1051/0004-6361:200809631

Astronomy & Astrophysics

LETTER TO THE EDITOR

Resolving stellar populations outside the Local Group: MAD observations of UKS 2323-326*

M. Gullieuszik[1], L. Greggio[1], E. V. Held[1], A. Moretti[1], C. Arcidiacono[1], P. Bagnara[1], A. Baruffolo[1], E. Diolaiti[2], R. Falomo[1], J. Farinato[1], M. Lombini[2], R. Ragazzoni[1], R. Brast[3], R. Donaldson[3], J. Kolb[3], E. Marchetti[3], and S. Tordo[3]

A&A 535, A63 (2011)
DOI: 10.1051/0004-6361/201016094

Astronomy & Astrophysics

MAD about the Large Magellanic Cloud*

Preparing for the era of Extremely Large Telescopes

G. Fiorentino[1,2], E. Tolstoy[1], E. Diolaiti[2], E. Valenti[3], M. Cignoni[2], and A. D. Mackey[4]

DOI: 10.1051/0004-6361/200913688

Astrophysics

A MAD view of Trumpler 14*,**

H. Sana[1,2], Y. Momany[1,3], M. Gieles[1], G. Carraro[1], Y. Beletsky[1], V. D. Ivanov[1], G. De Silva[4], and G. James[4]

The Astrophysical Journal, 737:31 (9pp), 2011 August 10
doi:10.1088/0004-637X/737/1/31

A FOSSIL BULGE GLOBULAR CLUSTER REVEALED BY VERY LARGE TELESCOPE MULTI-CONJUGATE ADAPTIVE OPTICS*

Sergio Ortolani[1], Beatriz Barbuy[2], Yazan Momany[3,4], Ivo Saviane[3], Eduardo Bica[5], Lucie Jilkova[3,6], Gustavo M. Salerno[5], and Bruno Jungwiert[7,8]

The Astrophysical Journal Letters, 708:L74–L79, 2010 January 10
doi:10.1088/2041-8205/708/2/L74

ON A NEW NEAR-INFRARED METHOD TO ESTIMATE THE ABSOLUTE AGES OF STAR CLUSTERS: NGC 3201 AS A FIRST TEST CASE*

G. Bono[1,2], P. B. Stetson[3], D. A. VandenBerg[4], A. Calamida[5], M. Dall'Ora[6], G. Iannicola[2], P. Amico[5], A. Di Cecco[1], E. Marchetti[5], M. Monelli[7], N. Sanna[1], A. R. Walker[8], M. Zoccali[9], R. Buonanno[1,10], F. Caputo[2], C. E. Corsi[2], S. Degl'Innocenti[11,12], S. D'Odorico[5], I. Ferraro[2], R. Gilmozzi[5], J. Melnick[5], M. Nonino[13], S. Ortolani[14],

Mon. Not. R. Astron. Soc. 418, 949–959 (2011)
doi:10.1111/j.1365-2966.2011.19561.x

A benchmark for multiconjugated adaptive optics: VLT–MAD observations of the young massive cluster Trumpler 14*

B. Rochau,[1]† W. Brandner,[1] A. Stolte,[2] T. Henning,[1] N. Da Rio,[1,3] M. Gennaro,[1] F. Hormuth,[1] E. Marchetti[4] and P. Amico[4]

Mon. Not. R. Astron. Soc. 408, 731–751 (2010)
doi:10.1111/j.1365-2966.2010.17167.x

The R136 star cluster hosts several stars whose individual masses greatly exceed the accepted 150 $M_\odot$ stellar mass limit

Paul A. Crowther,[1]* Olivier Schnurr,[1,2] Raphael Hirschi,[3,4] Norhasliza Yusof,[5] Richard J. Parker,[1] Simon P. Goodwin[1] and Hasan Abu Kassim[5]

Nature **462**, 483-486 (26 November 2009) | doi:10.1038/nature08581; Received 20 August 2009; Accepted 8 October 2009

The cluster Terzan 5 as a remnant of a primordial building block of the Galactic bulge

F. R. Ferraro[1], E. Dalessandro[1], A. Mucciarelli[1], G. Beccari[2], R. M. Rich[3], L. Origlia[4], B. Lanzoni[1], R. T. Rood[5], E. Valenti[6,7], M. Bellazzini[4], S. M. Ransom[8] & G. Cocozza[4]

Mon. Not. R. Astron. Soc. 391, 1650–1658 (2008)
doi:10.1111/j.1365-2966.2008.14019.x

Multi-Conjugate Adaptive Optics VLT imaging of the distant old open cluster FSR 1415

Y. Momany,[1,2]* S. Ortolani,[3] C. Bonatto,[4] E. Bica[4] and B. Barbuy[5]

A&A 493, 539–546
DOI: 10.1051/0004-

Astrophysics

MCAO near-IR photometry of the globular cluster NGC 6388: MAD observations in crowded fields*

A. Moretti[1], G. Piotto[2], C. Arcidiacono[1], A. P. Milone[2], R. Ragazzoni[1], R. Falomo[1], J. Farinato[1], L. R. Bedin[3], J. Anderson[3], A. Sarajedini[4], A. Baruffolo[1], E. Diolaiti[5], M. Lombini[5], R. Brast[6], R. Donaldson[6], J. Kolb[6], E. Marchetti[6], and S. Tordo[6]

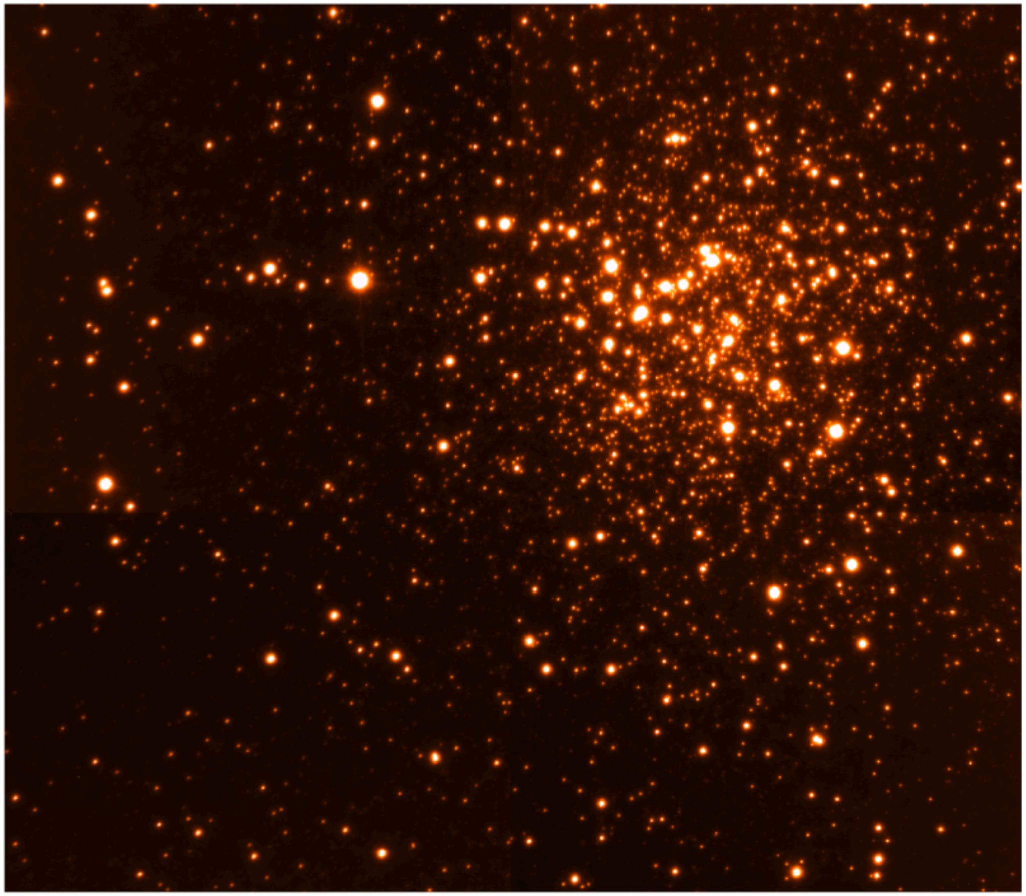
Mon. Not. R. Astron. Soc. 405, 421–435 (2010)
doi:10.1111/j.1365-2966.20

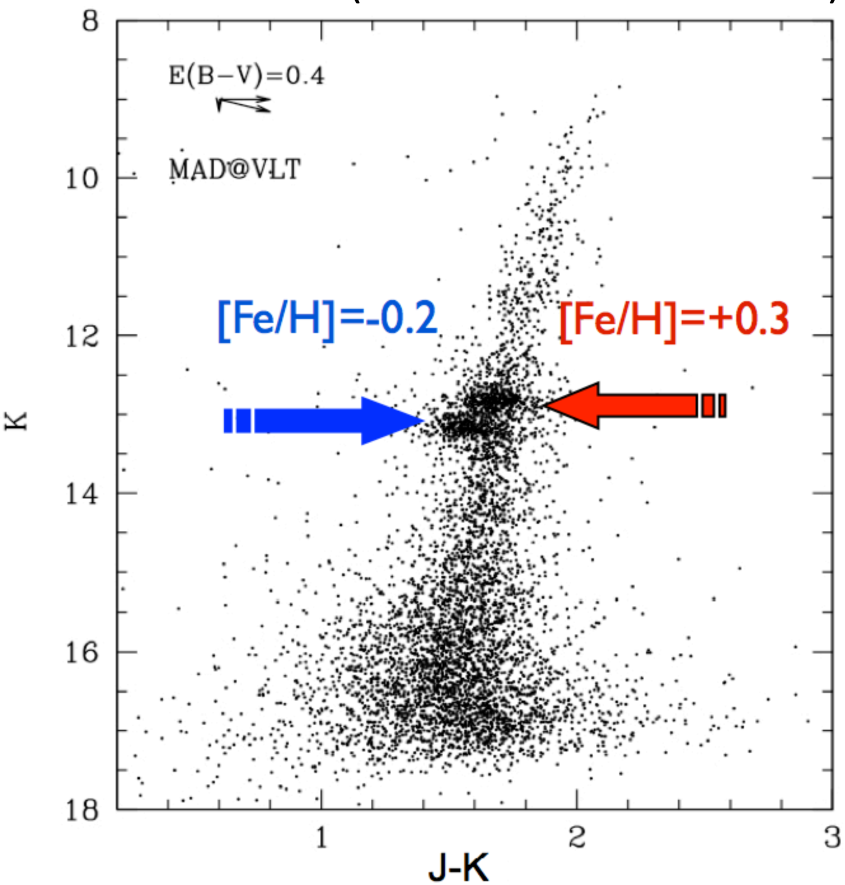
VLT-MAD observations of the core of 30 Doradus

M. A. Campbell,[1]* C. J. Evans,[2,1] A. D. Mackey,[1] M. Gieles,[3] J. Alves,[4] J. Ascer N. Bastian[6] and A. J. Longmore[2]

Ferraro et al. (2009, Nature)

(Slide from G. Fiorentino)





Ter 5 hosts two different populations (confirmed by spectroscopic follow-up):

1)one metal-poor and possibly old (12Gyr) that traces the early stage of the bulge formation

2)one metal-rich and possibly young (6Gyr) that could contain important information about the metal-enrichment and the dynamical evolution.

Star Clusters

TOWARDS PRECISION PHOTOMETRY WITH EXTREMELY LARGE TELESCOPES: THE DOUBLE SUBGIANT BRANCH OF NGC 1851

P. TURRI[1]
Department of Physics and Astronomy, University of Victoria,
3800 Finnerty Road, Victoria, BC V8P 5C2, Canada

HAFFNER 16: A YOUNG MOVING GROUP IN THE MAKING

T. J. Davidge

Dominion Astrophysical Observatory,
National Research Council of Canada, 5071 West Saanich Road,
Victoria, BC Canada V9E 2E7

GeMS MCAO observations of the Galactic globular cluster NGC 2808: the absolute age

D. Massari[1,2], G. Fiorentino[1], A. McConnachie[3], G. Bono[4,5], M. Dall'Ora[6], I. Ferraro[5], G. Iannicola[5], P.B. Stetson[3], P. Turri[7], and E. Tolstoy[2]

Ultra-deep GEMINI near-infrared observations of the bulge globular cluster NGC 6624[1]

S. Saracino[1,2], E. Dalessandro[1,2], F. R. Ferraro[1], D. Geisler[3], F. Mauro[4,3], B. Lanzoni[1], L. Origlia[2], P. Miocchi[1], R. E. Cohen[3], S. Villanova[3], C. Moni Bidin[5]

GEMINI/GeMS observations unveil the structure of the heavily obscured globular cluster Liller 1

S. Saracino, E. Dalessandro, F. R. Ferraro, B. Lanzoni, D. Geisler, F. Mauro, S. Villanova, C. Moni Bidin, P. Miocchi, D. Massari

GeMS in the Outer Galaxy: Near-infrared Imaging of Three Young Clusters at Large Galactic Radii

Year	2014
Journal	The Astrophysical Journal
Author	Davidge, T. J.

Resolving the low-mass content of Westerlund 1 using MCAO

M. Andersen[a], B. Neichel[b], A. Bernard[b], and V. Garrel[a]

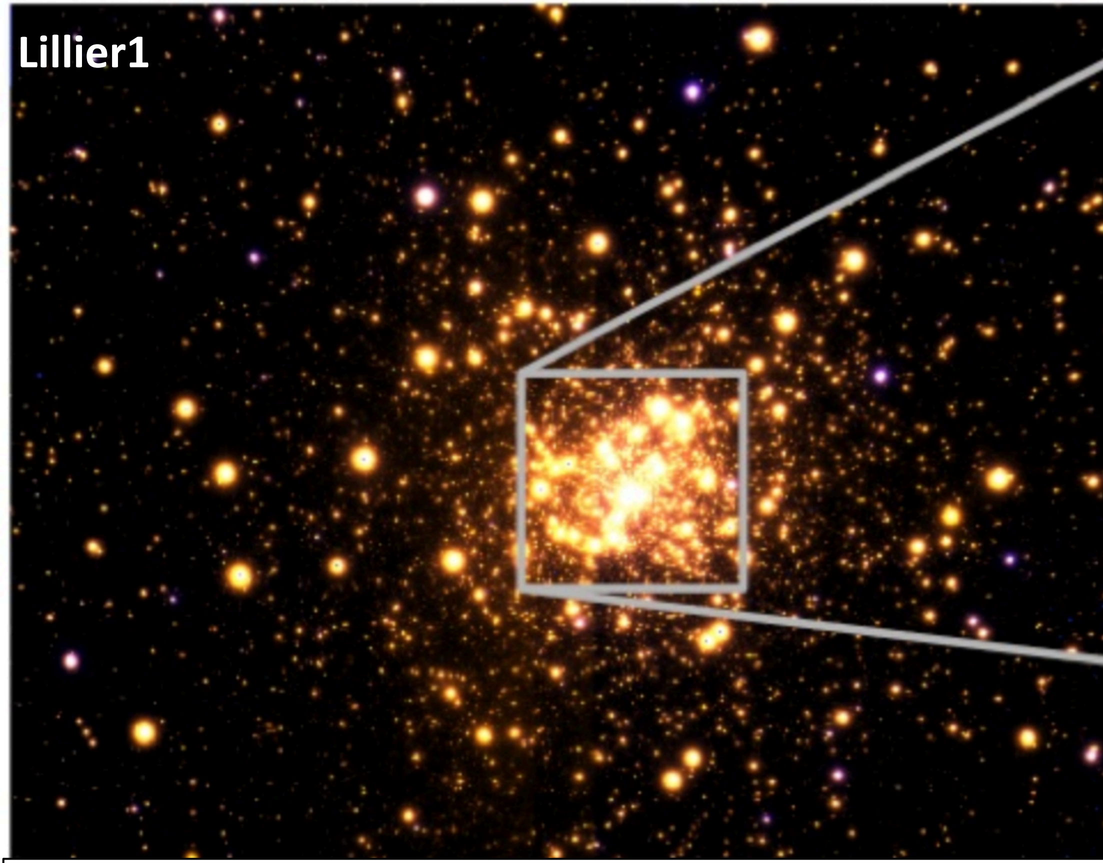
[a]Gemini Observatories, Casilla 603 La Silla, Chile
[b]Aix Marseille Université, CNRS, LAM (Laboratoire d'Astrophysique de Marseille) UMR 7326, 13388 Marseille, France

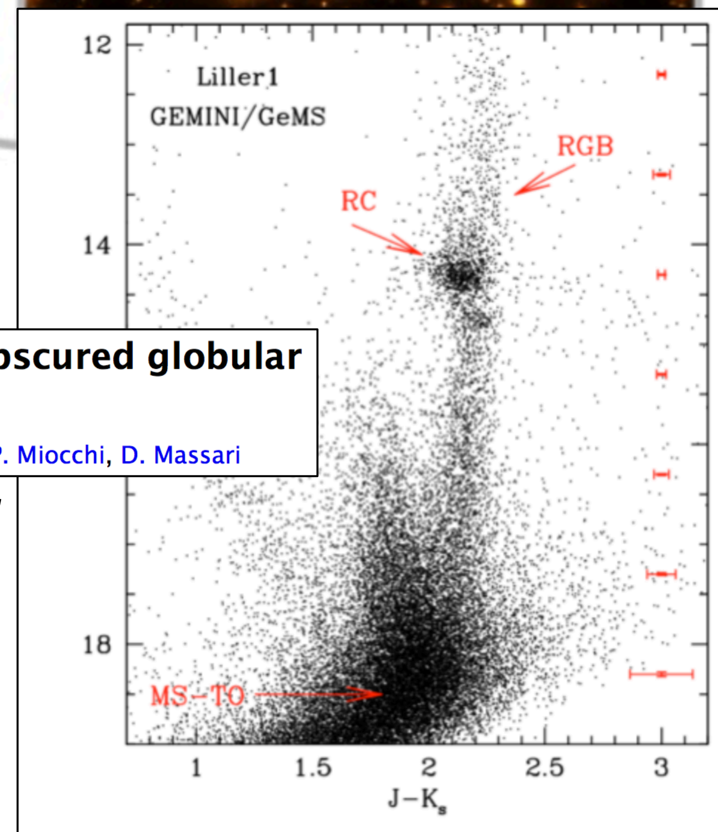
The Orion Fingers: Near-IR Adaptive Optics Imaging of an Explosive Protostellar Outflow

John Bally[1], Adam Ginsburg[2], Devin Silvia[3], and Allison Youngblood[1]

GeMs/GSAOI observations of La Serena 94: an old and far open cluster inside the solar circle

J. F. C. Santos Jr. (DF/UFMG, Brazil), A. Roman-Lopes (ULS, Chile), E. R. Carrasco (Gemini Observatory), F. F. S. Maia (IPAG, France), B. Neichel





GEMINI/GeMS observations unveil the structure of the heavily obscured globular cluster Liller 1

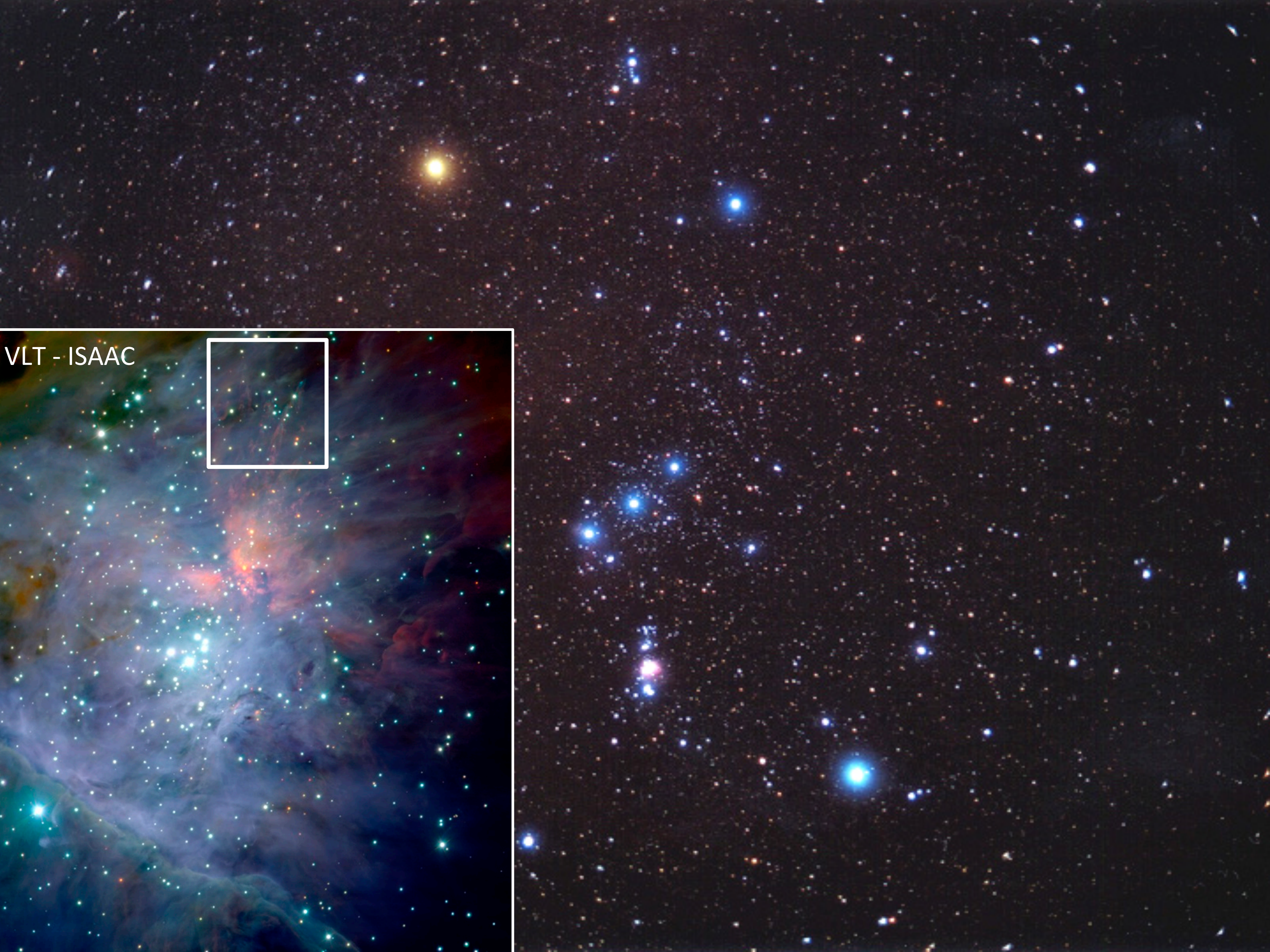
S. Saracino, E. Dalessandro, F. R. Ferraro, B. Lanzoni, D. Geisler, F. Mauro, S. Villanova, C. Moni Bidin, P. Miocchi, D. Massari

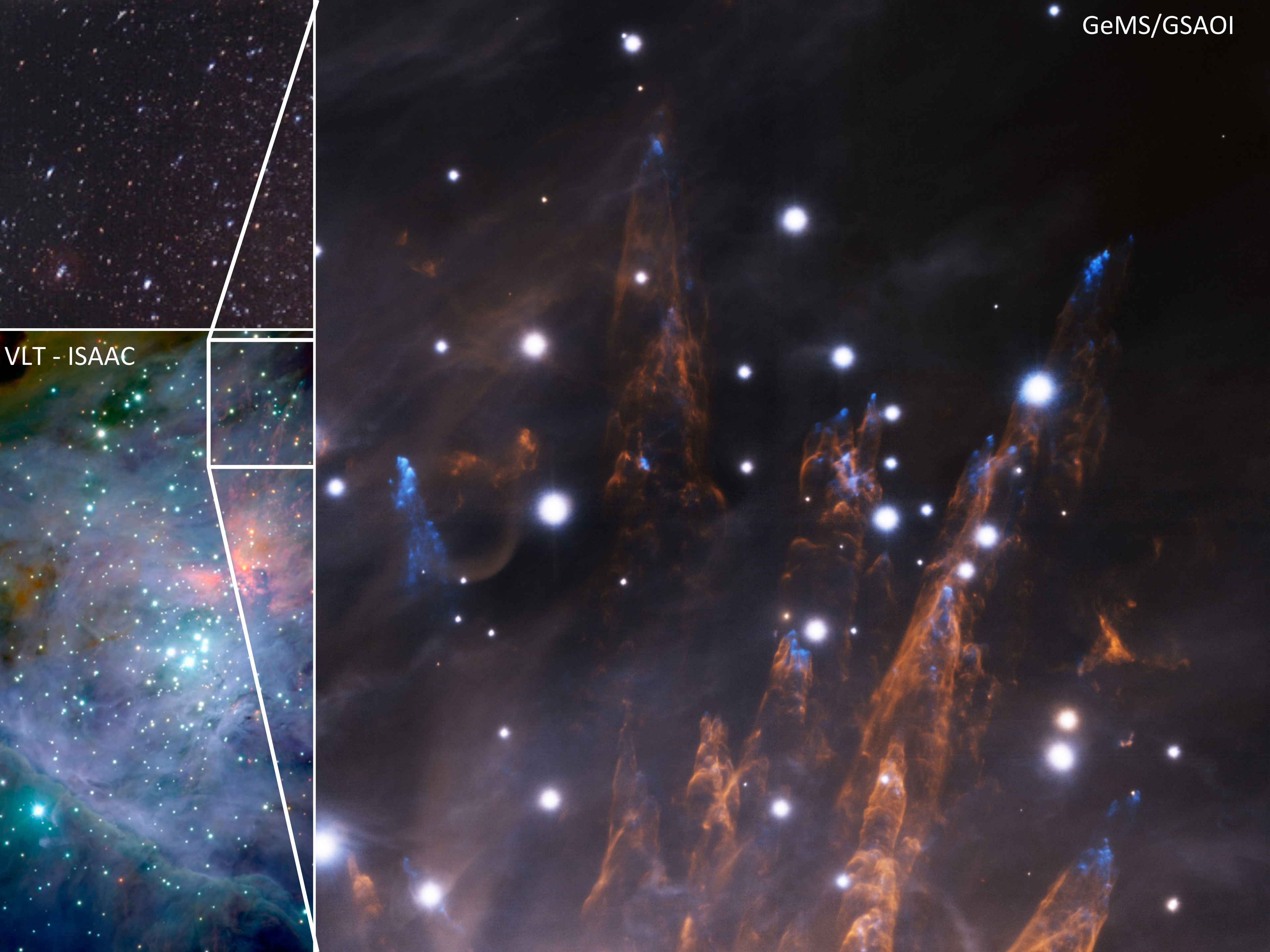
"We find that Lillier1 is significantly less concentrated and less extended than previously thought. The mass of Lillier1 is comparable to that of the massive clusters in the galaxy. Lillier1 has the second highest collision rate (after Ter5), confirming that is is an ideal environment for the formation of objects such as ms pulsar."

Current Science with MCAO in the NIR
(examples from MAD and GeMS)

Main science cases:

1. **Star Clusters**
    1. ~~Globular clusters~~
    2. Star forming regions

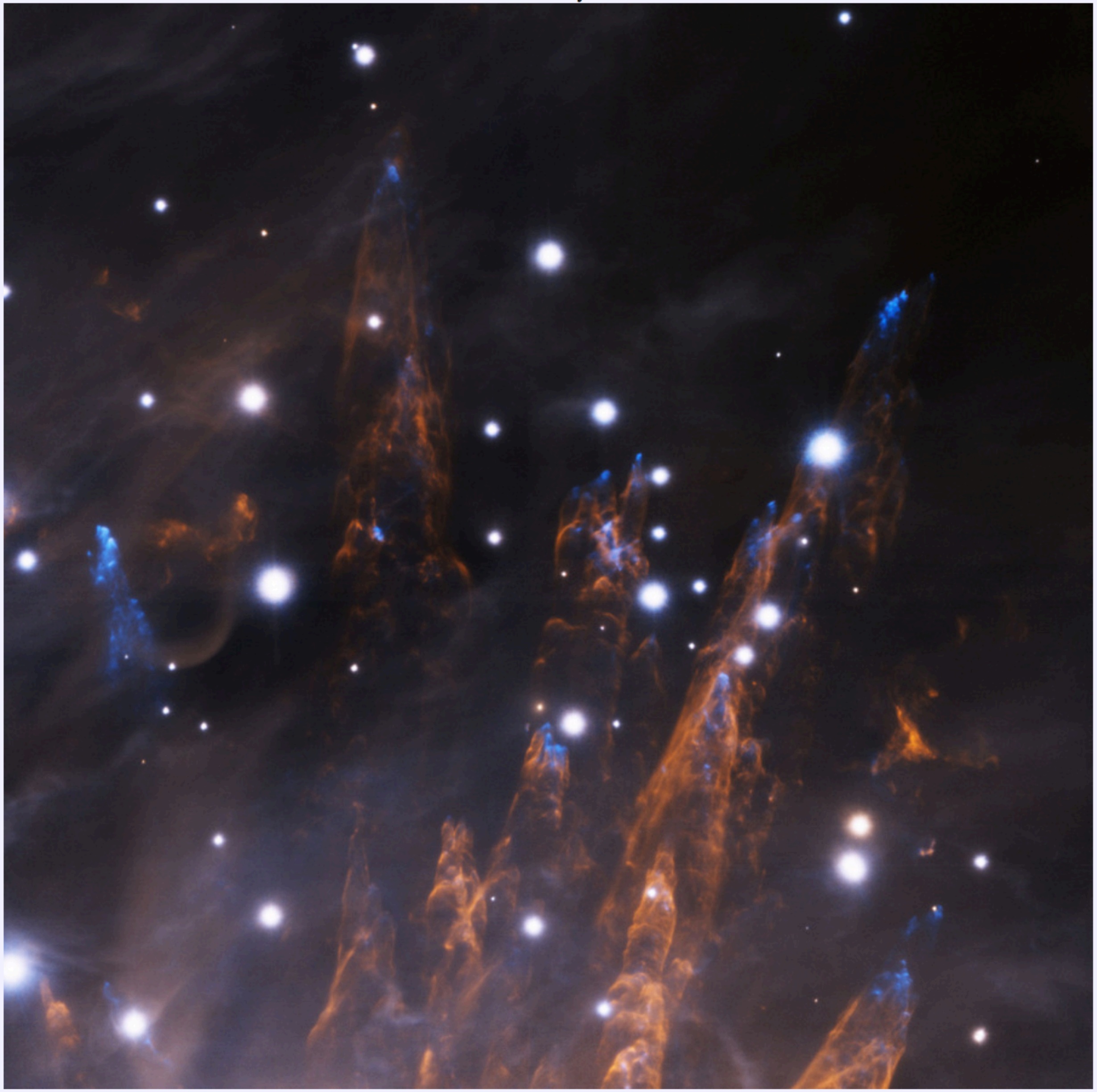

VLT - ISAAC


VLT - ISAAC
GeMS/GSAOI

Astronomy Picture of the Day

Discover the cosmos! Each day a different image or photograph of our fascinating universe is featured, along with a brief explanation written by a professional astronomer.

2013 January 10



The Orion Bullets
Image Credit: GeMS/GSAOI Team, Gemini Observatory, AURA

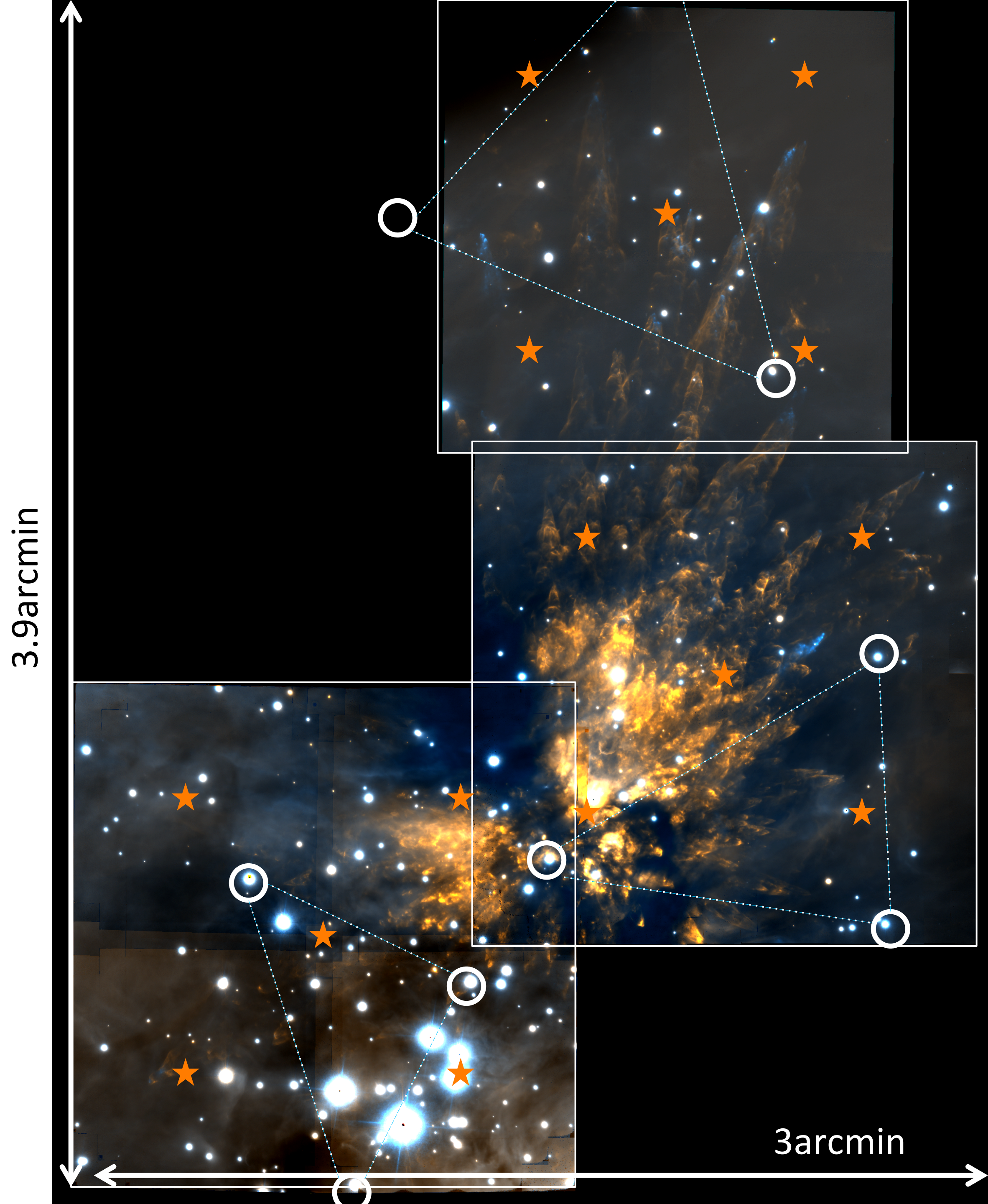
3 Fields:
OMC1 – North
OMC1 – Center
OMC1 – South-East

Filters:
Mol. Hydrogen (H2) - 2.122 µm (orange)
[Fe II] - 1.644 µm (blue)
Ks continuum - 2.093 µm (white)

Exposure Time per field:
H2 = 12min
[Fe II] = 10min
Ks continuum = 10min

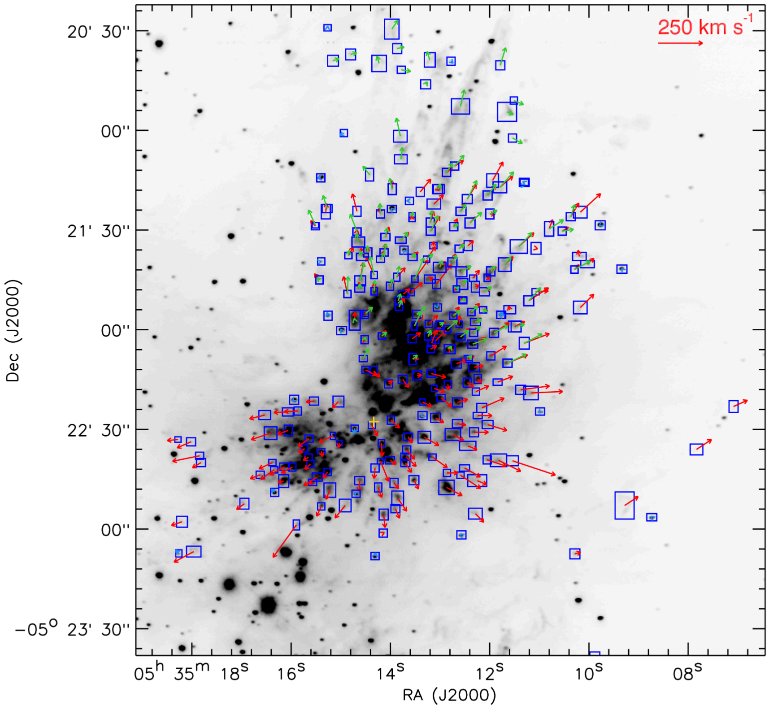
<FWHM> :
H2 = 90mas
[Fe II] = 100mas
Ks continuum = 90mas

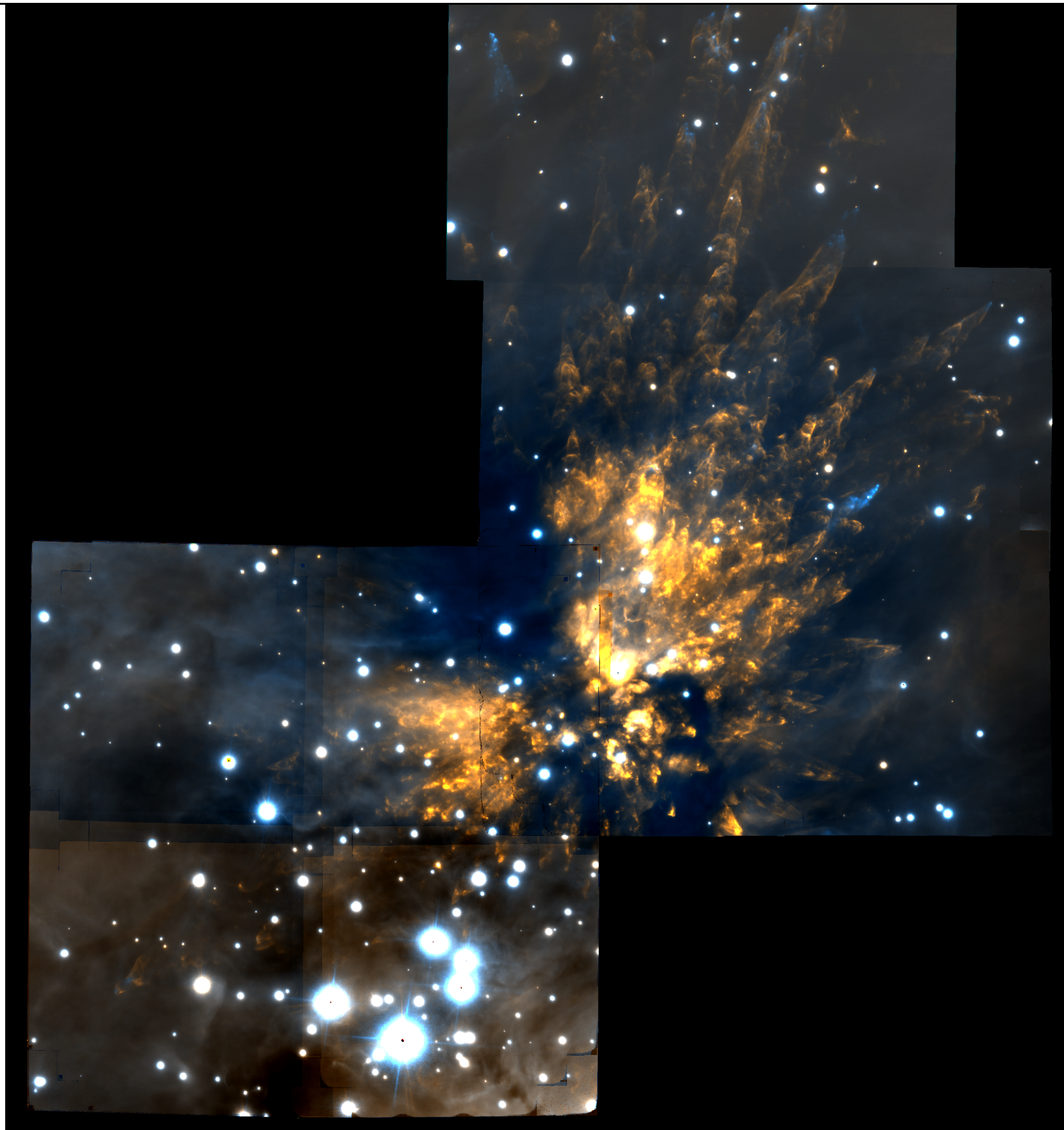
Natural seeing:
0.6” to 1.1” @ 550nm



The Orion Fingers: Near-IR Adaptive Optics Imaging of an Explosive Protostellar Outflow

John Bally[1], Adam Ginsburg[2], Devin Silvia[3], and Allison Youngblood[1]



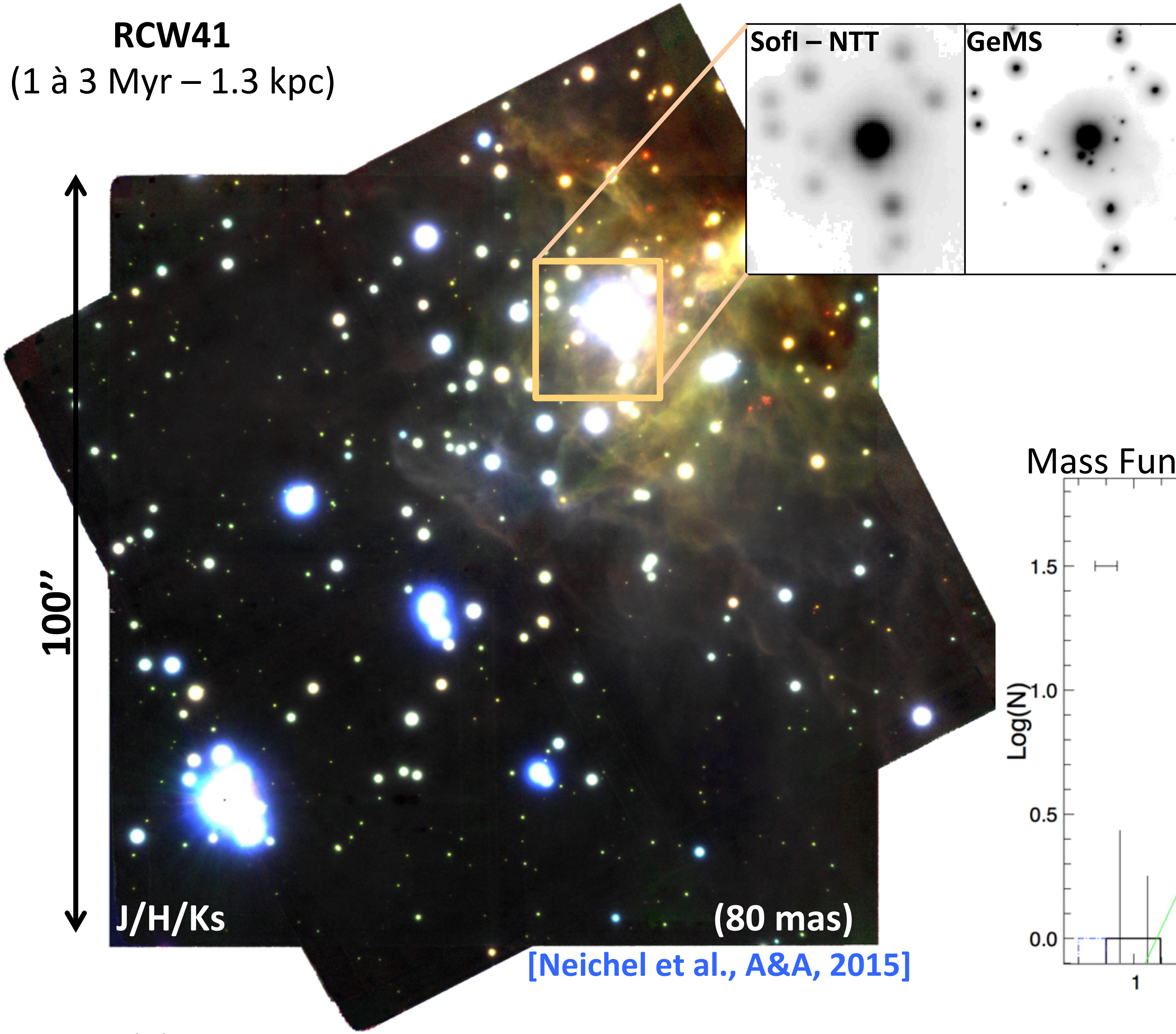


<u>Team:</u>

J. Bally, A. Ginsburg

Univ. of Colorado

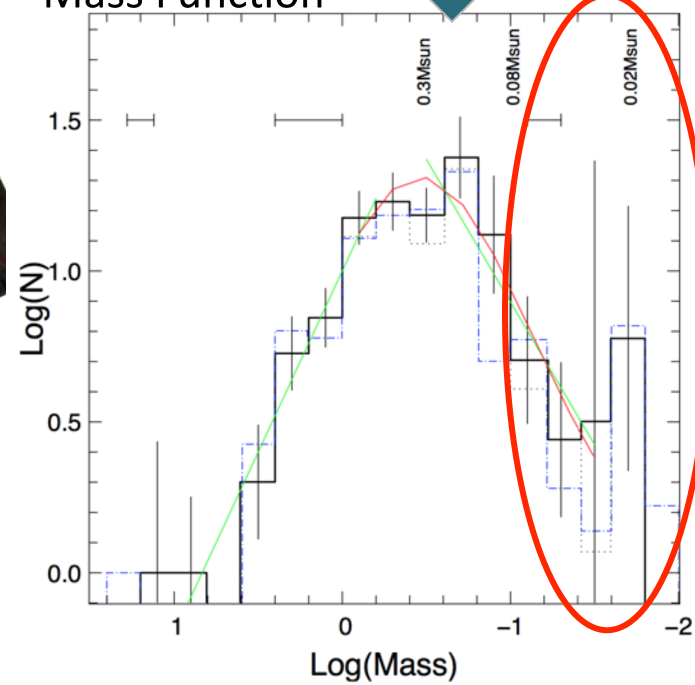
RCW41
(1 à 3 Myr – 1.3 kpc)



[Neichel et al., A&A, 2015]

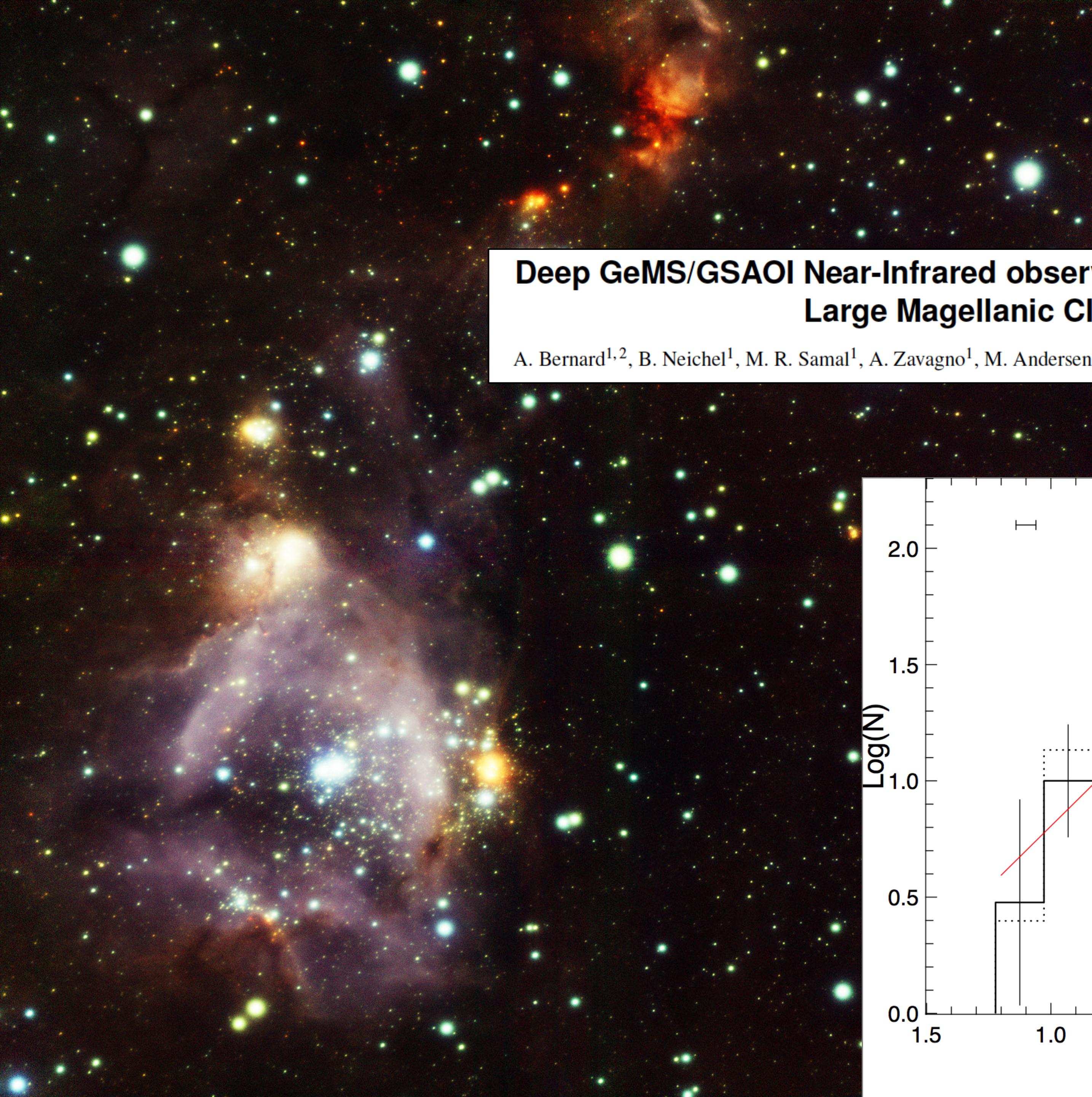
Brown dwarf detection

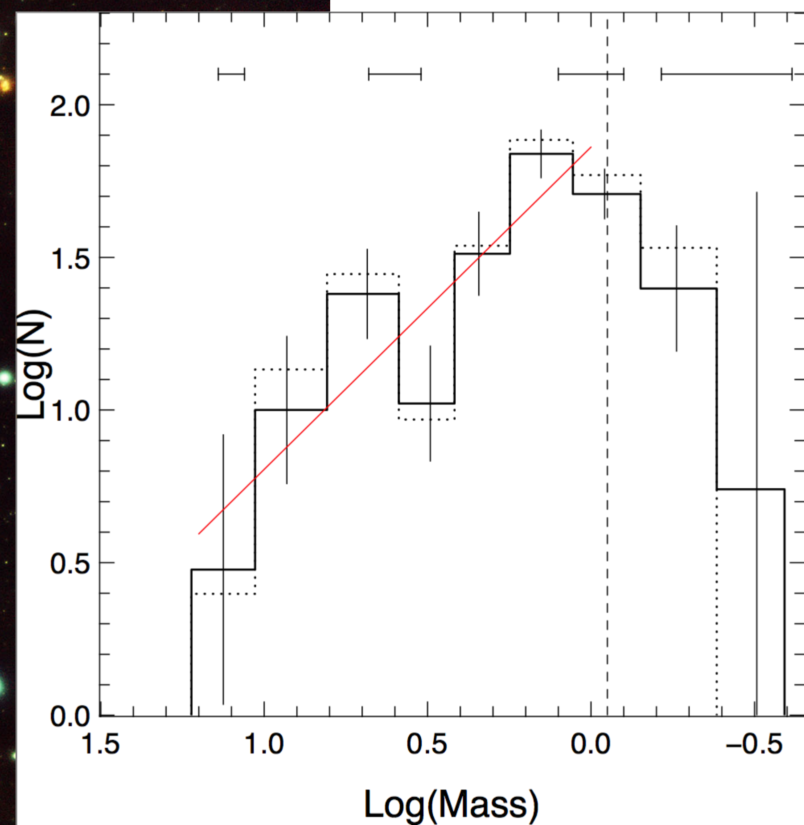
Mass Function



Deep GeMS/GSAOI Near-Infrared observations of N159W in the Large Magellanic Cloud

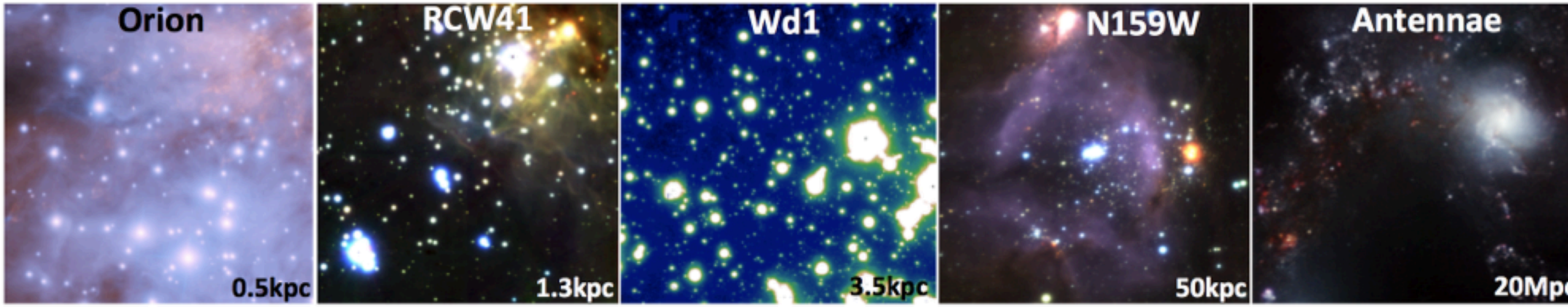
A. Bernard[1,2], B. Neichel[1], M. R. Samal[1], A. Zavagno[1], M. Andersen[3], C. J. Evans[4], H. Plana[5], and T. Fusco[1,2]



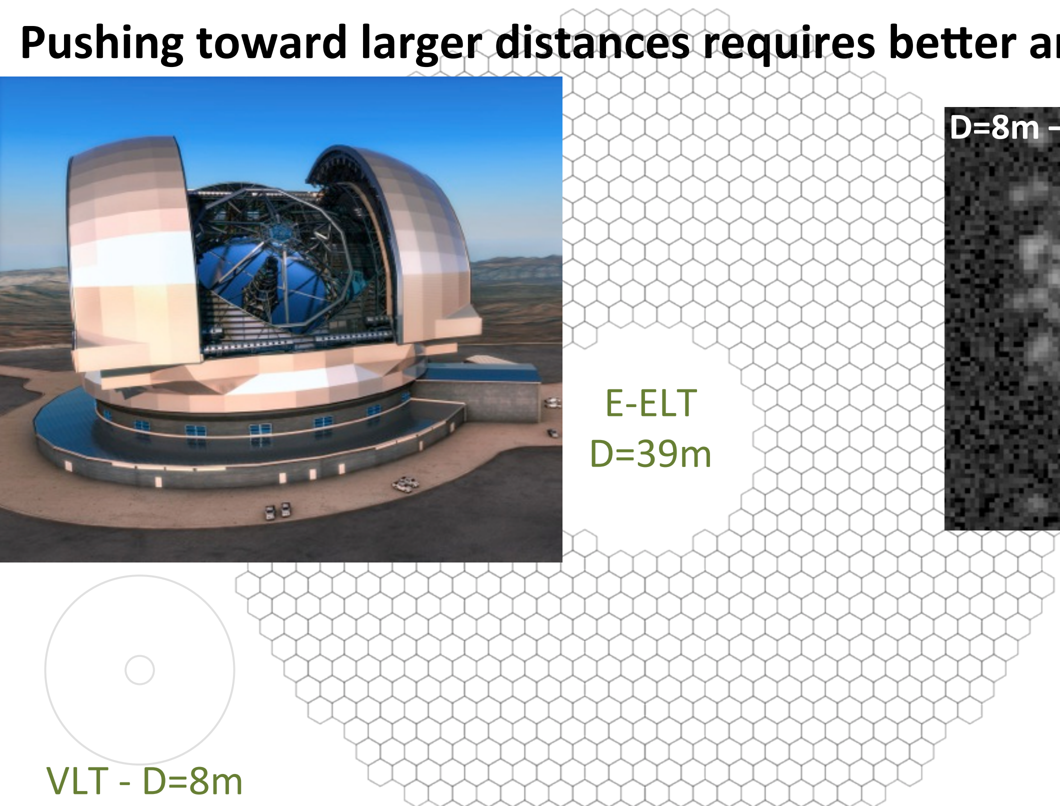


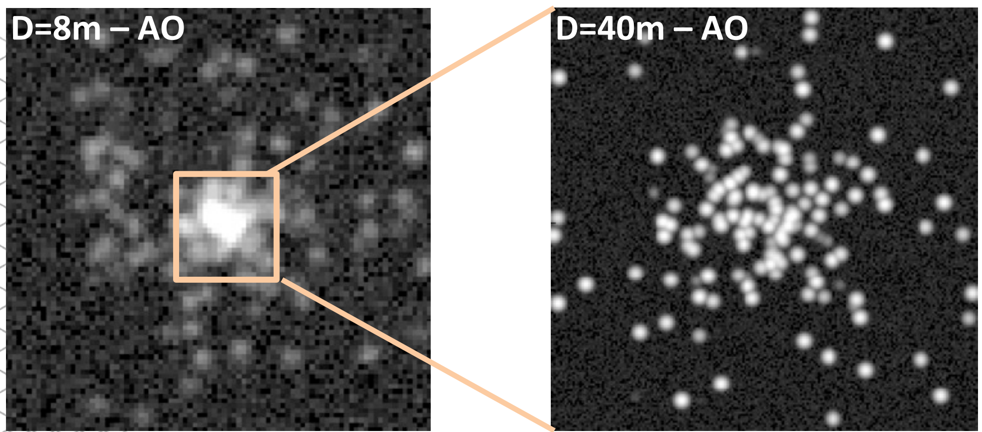
What's next for MCAO star cluster science ?

Pushing to larger distances:



Pushing toward larger distances requires better angular resolution and better sensitivity





Gain in resolution x 5
Gain in sensitivity x 5^4

What's next for MCAO star cluster science ?

In the time frame of VLT3 both E-ELT and TMT will be equipped with NIR MCAO systems

E-ELT

Name	1st light	Modes	FoV & OA	Comments
MICADO + MAORY	2024	Imager 0.8 -> 2.4 microns Single slit @ R=8000	Imaging ~40" SCAO + MCAO	8 / 10 mas resolution

TMT

Name	1st light	Modes	FoV & OA	Comments
IRIS	2024+	Equivalent to MICADO + HARMONI	MCAO	
IRMS	2024+	Equivalent to Keck MOSFIRE = multislit Spectro (46 slits) Slit = 160mas	MCAO FoV = 2.3' R=5000 0.8 -> 2.5microns	

(Slide From R. Davies)

What will the E-ELT be able to detect?

H_{AB} ~ 31mag for isolated sources after several hours.

from Deep+ 11 & Greggio+ 12:

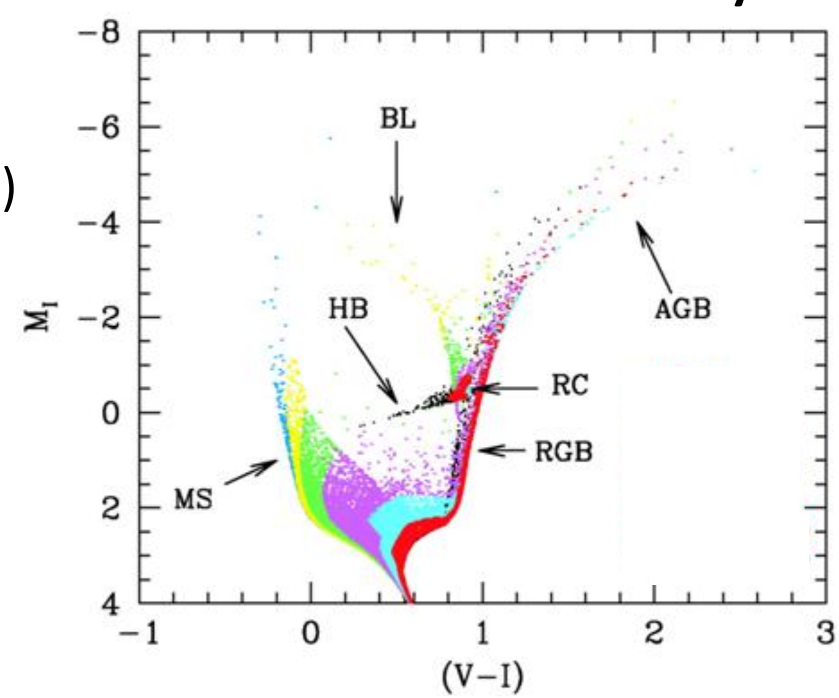
old Main Sequence Turnoffs out to ~2 Mpc
Local Group, Sculptor & M81 groups:
several large spirals

Horizontal Branch out to ~10 Mpc
Cen A: closest peculiar elliptical
Leo Group: closest normal elliptical (NGC3379)

Red Giant Branch
Virgo Cluster: many large galaxies

tip of Red Giant Branch & luminous variable stars out to >100Mpc

- < 0.1 Gyr
- 0.1 – 0.4 Gyr
- 0.4 – 1.0 Gyr
- 1.0 – 3.0 Gyr
- 3.0 – 6 Gyr
- 6 – 10 Gyr
- 10 – 13 Gyr



Aparicio & Gallart (2004)

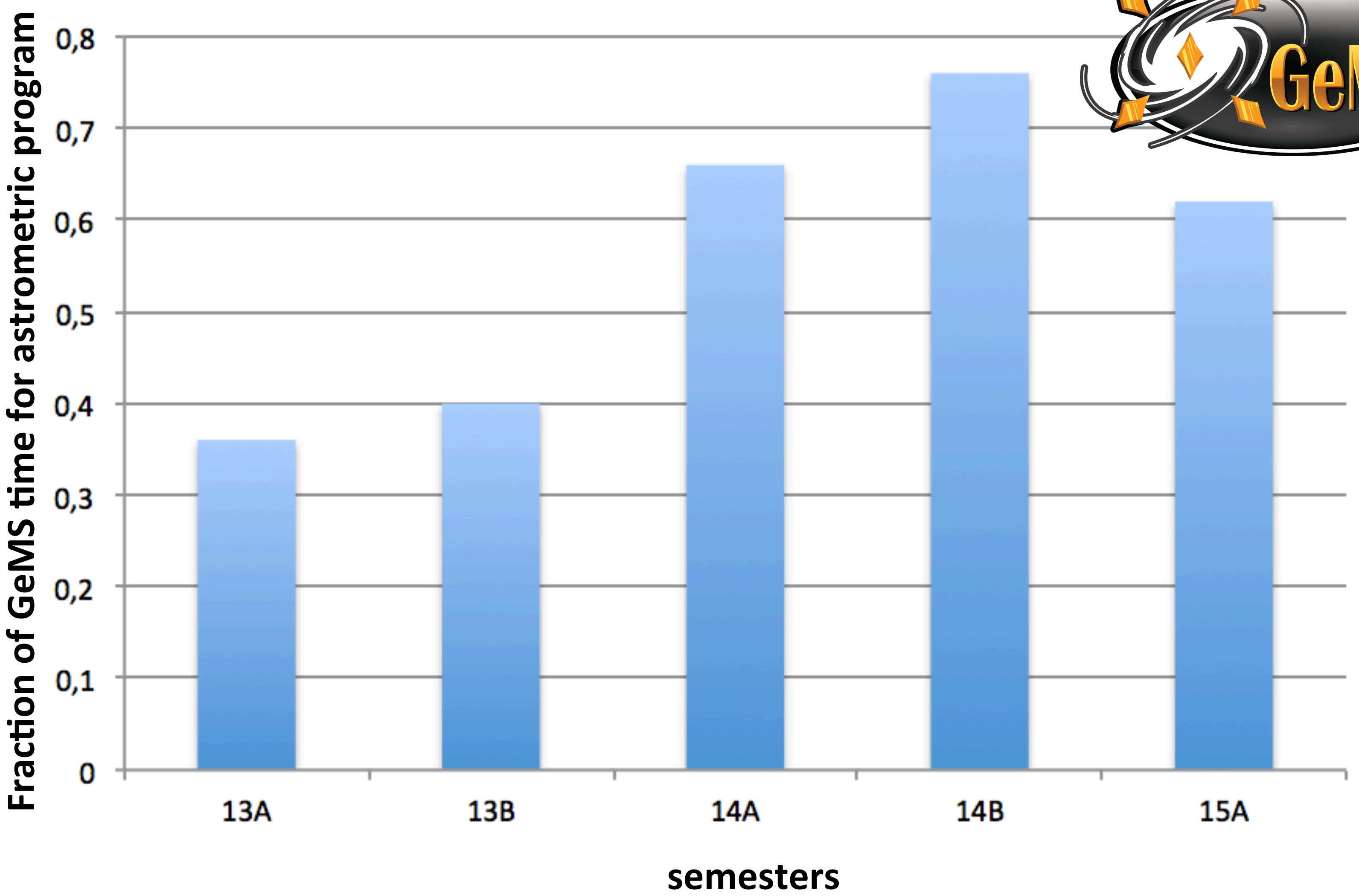
Current Science with MCAO in the NIR

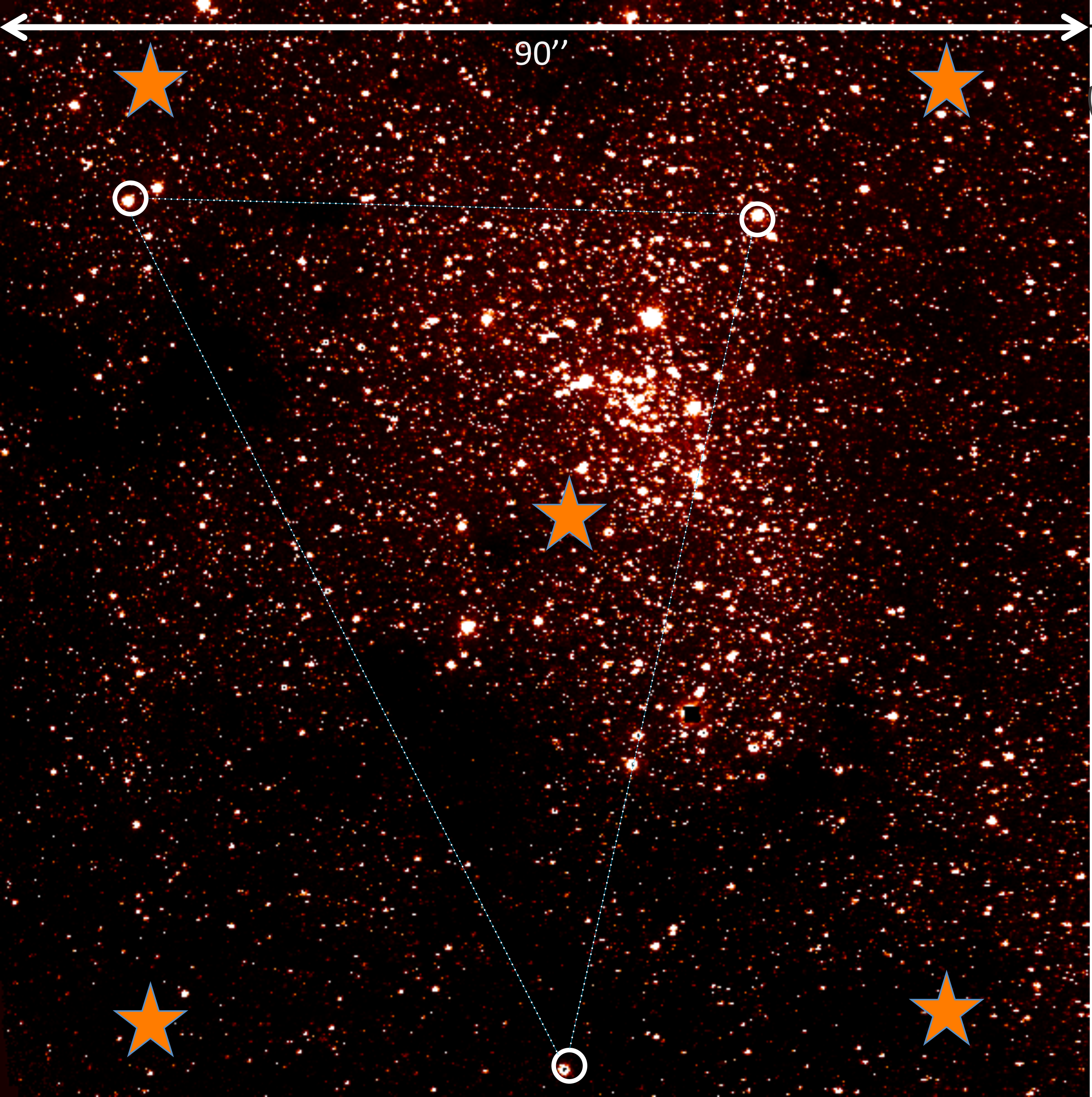
(examples from MAD and GeMS)

Main science cases:

1. Star Clusters
2. **Astrometry**
3. A bit of extra-galactic
4. A bit of everything else

Science cases for astrometry



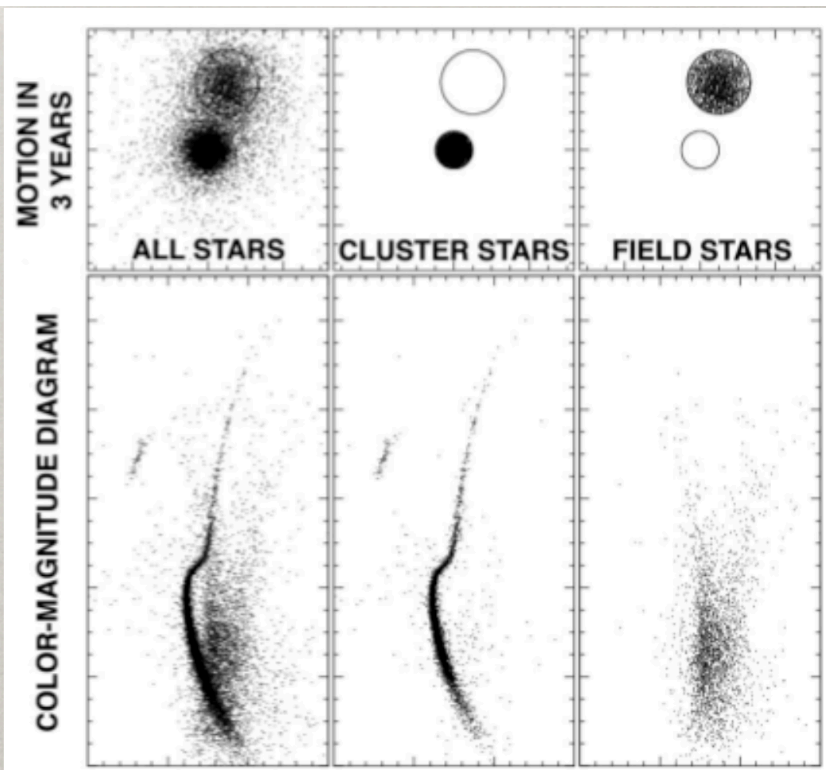


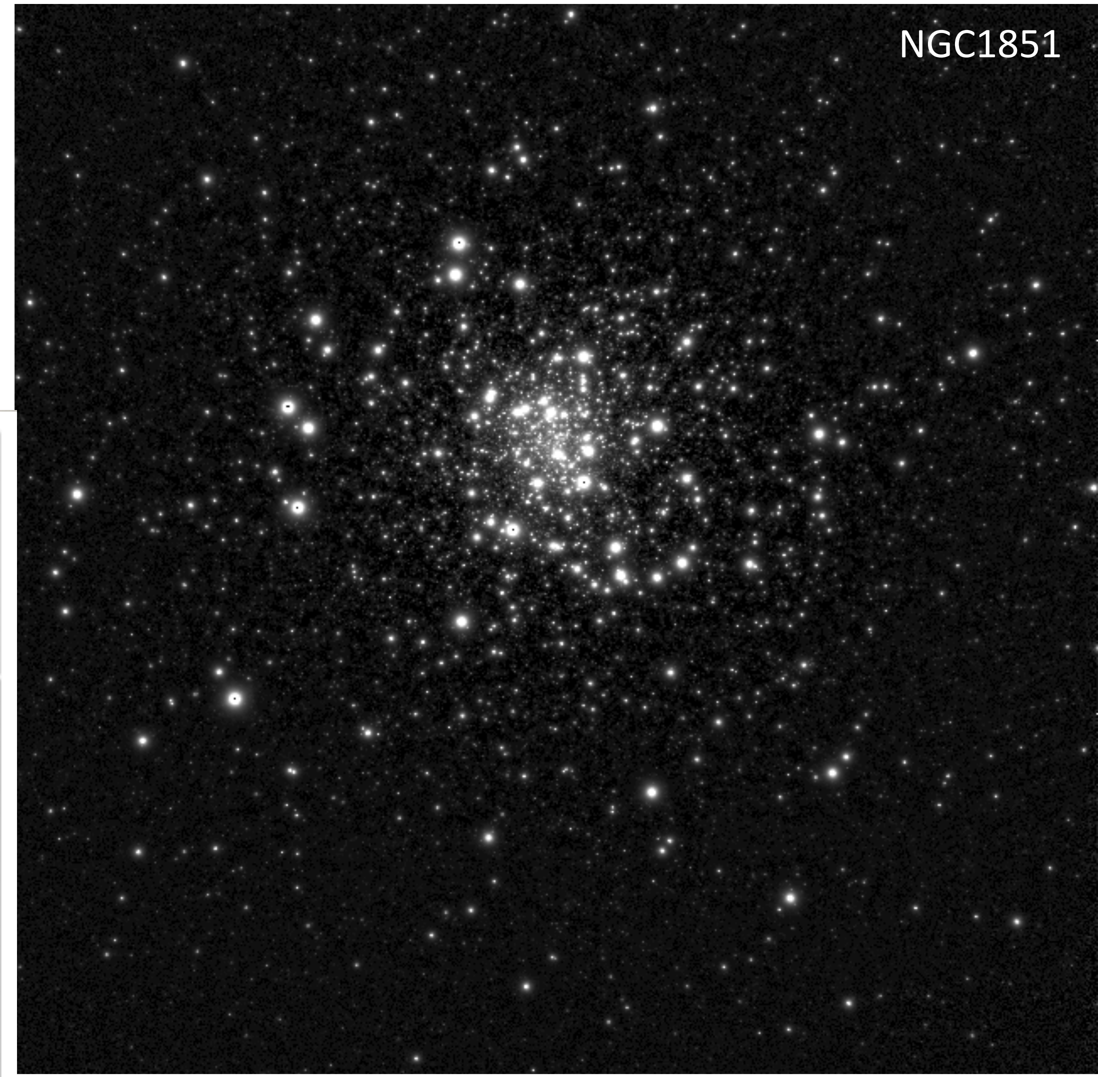
Galactic Center

Filter = Ks
Exposure Time = 5min
<FWHM> = 90mas

Multi-epoch observations of star clusters:

- Foreground / Background contamination
- Proper motions: trace the GGCs in space an time (using cluster age) providing a link to their birthplace.
- Internal dispersion: Occurrence of IMBH at the center of GGC.





Paolo Turri et al.

Open questions in near field cosmology

- **Mass** of the **Milky Way** uncertain, e.g. compare
  - $1.6\pm0.4*10^{12}$ M_{sol} (Boylan-Kolchin et al. 2013)
  - $0.56\pm0.12*10^{12}$ M_{sol} (Gibbons et al. 2014)
- **Too big to fail**:
  - There are too few dwarf galaxies with central dispersion of 30~<v~<60 km/s. (Zavala et al 2009, Boylan-Kolchin et al. 2012)
    - Are such dwarf galaxies missing?
    - Or have dwarfs less dense cores?
    - Less massive Milky Way could be (part of) the solution (Wang et al 2012)
- **Shape of the halo uncertain**:
  - Oblate but edge on the disk? (Law & Majewski 2010)

- We address these points with **absolute proper motions** in the halo of the Milky Way.

(Slide from Tobias Fritz)

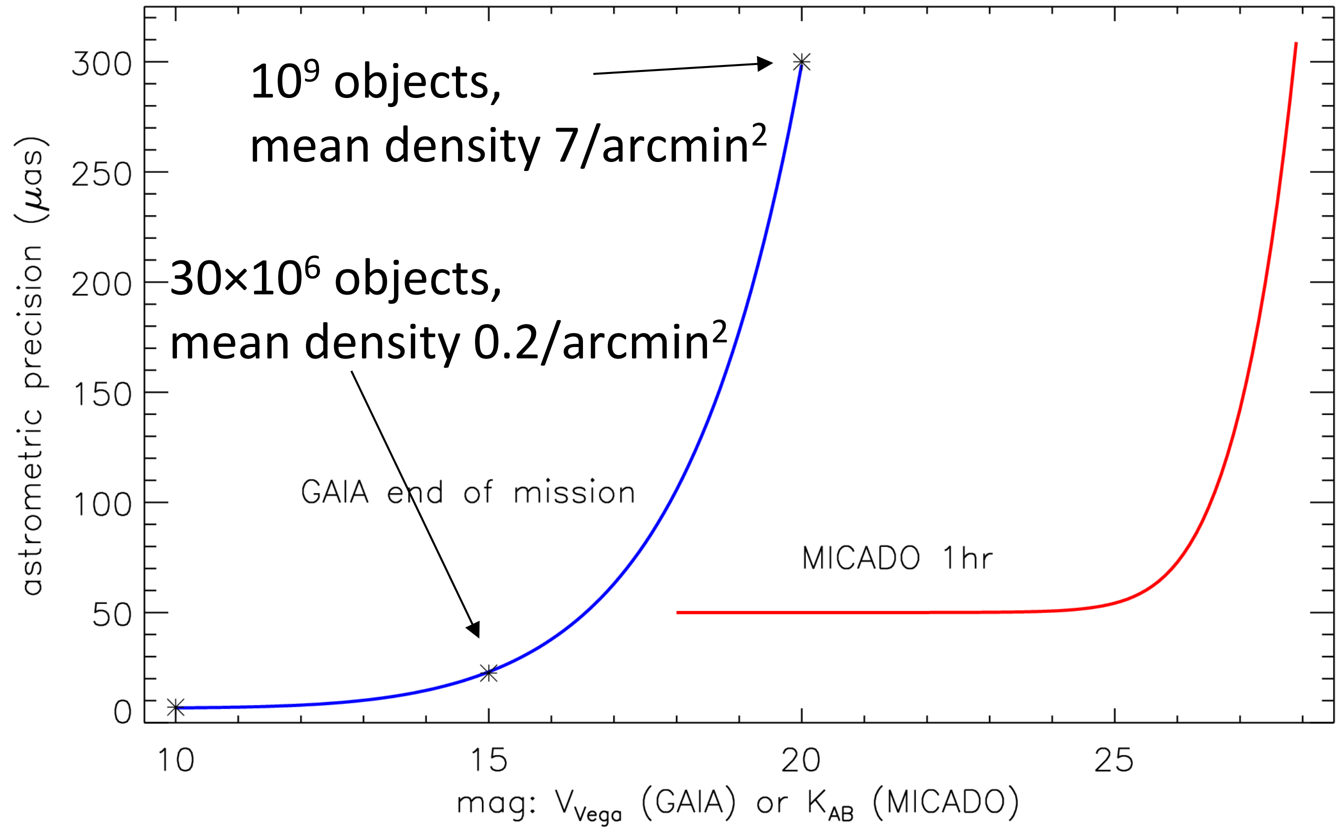
(Slide From R. Davies)

Astrometry: GAIA & MICADO

Relative vs Absolute astrometry.

MICADO & GAIA have different sensitivity & crowding limits:

- GAIA: Milky Way structure & evolution, exoplanets, solar system minor bodies
- MICADO: dense &/or dusty regions, IMBHs, star clusters, dwarf galaxies



V_{Vega} and K_{AB} magnitudes are roughly equivalent

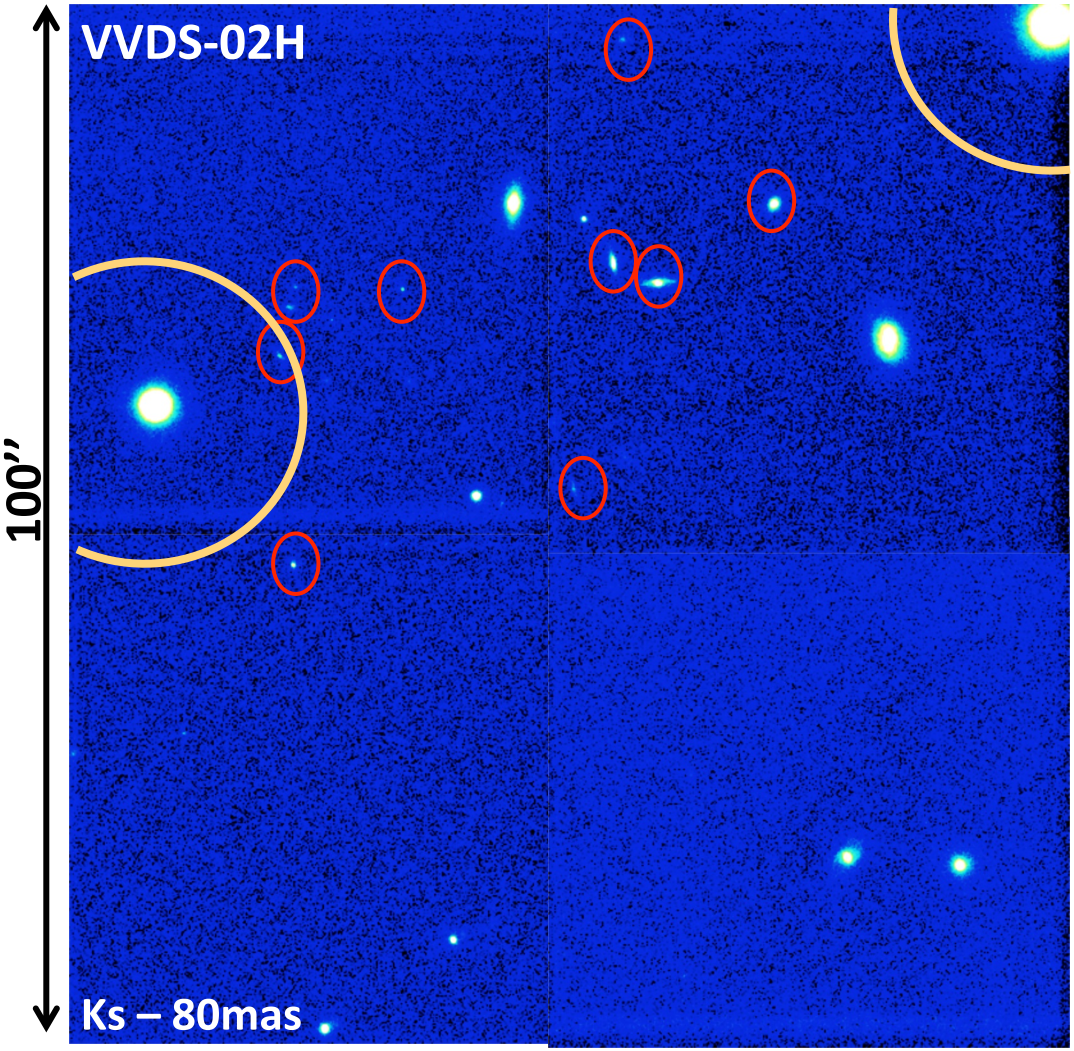
Current Science with MCAO in the NIR

(examples from MAD and GeMS)

Main science cases:

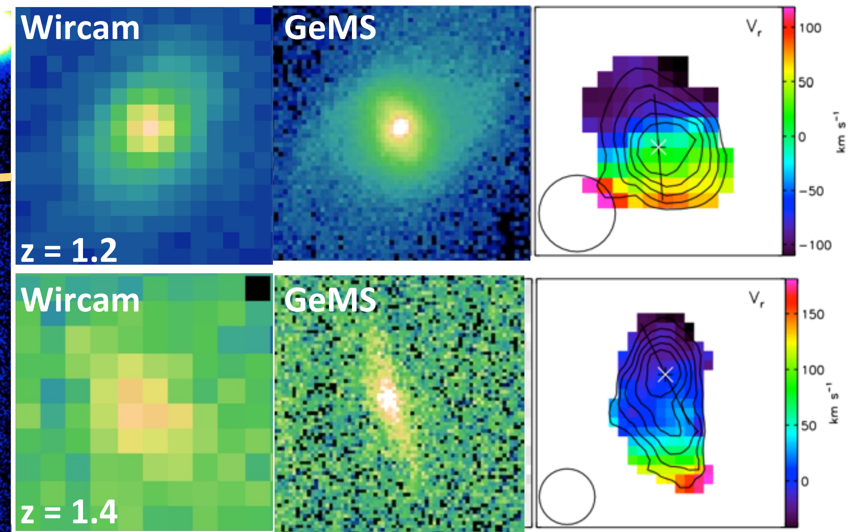
1. Star Clusters
2. Astrometry
3. **A bit of extra-galactic**
4. A bit of everything else

Morpho-dynamics of galaxies



[Epinat, Contini et al.]

Échantillon MASSIV – SINFONI (ESO)



Collab.: B. Epinat, P. Amram (LAM), T. contini (IRAP)

Perspective: Follow-up of in the NIR of MUSE observations

Scientific Context in ~8/10 years

Space instrumentation: **JWST**

Name	1st light	Modes	Comments
NIRCam	2018	Imager 0.6 to 5microns	FoV = 2'x2' Nyquist /2;/4
NIRSpec	2018	Multi-slit spectro 1-5 microns 0.6-1micron	FoV = 3'x3' Slit = 200mas R = 100 (< 1mic) R < 3000 (>1mic)
NIRISS	2018	Imager + Spectro R=700 (0.6 -> 3mic) R=150 (1-> 2.5mic)	FoV = 2.2' x 2.2'

(Slide From R. Davies)

Galaxies at High Redshift

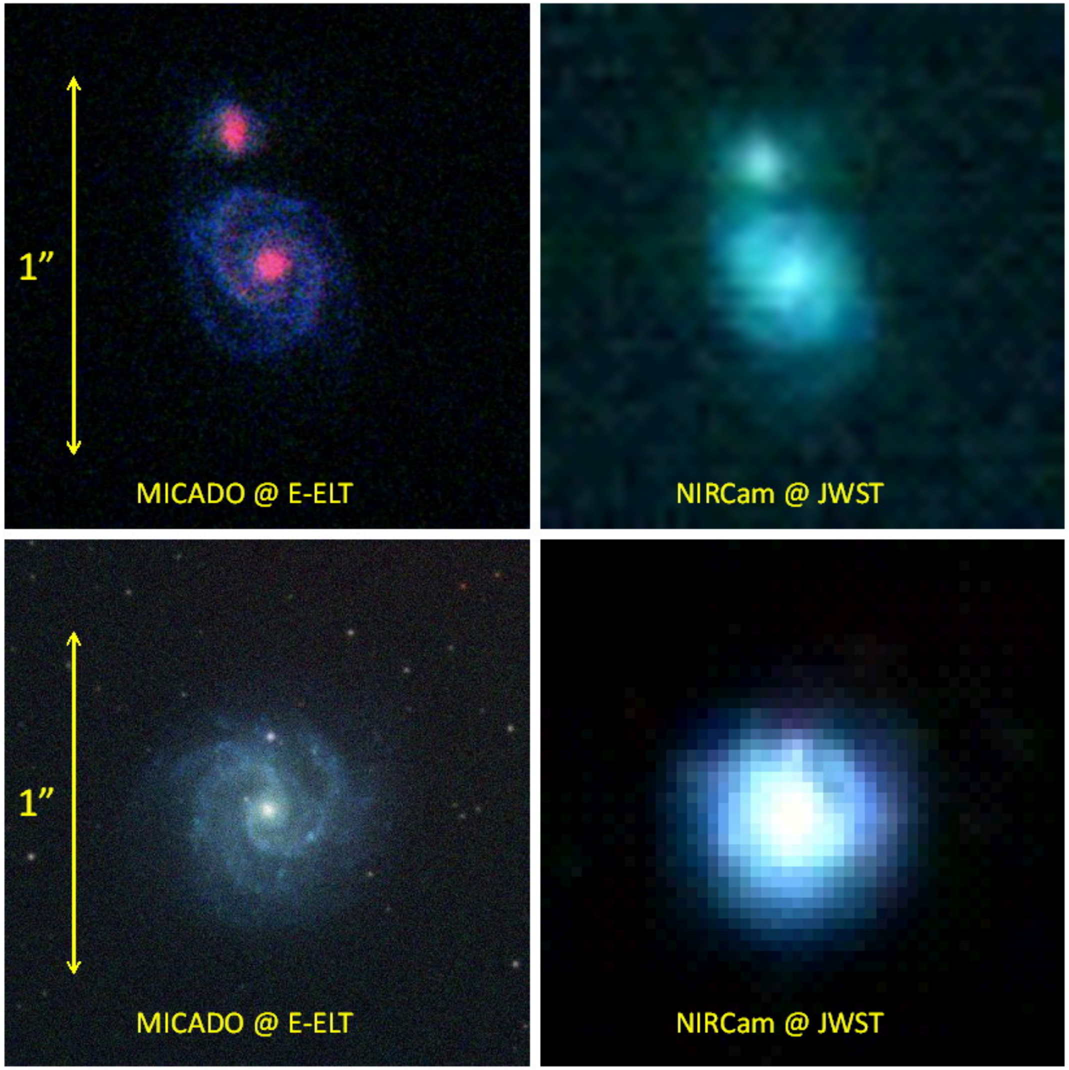
JWST will select samples & measure basic galaxy properties

MICADO will trace stellar continuum & provide detailed structure

HARMONI will give kinematics & emission line distribution (but more limited spatial sampling)

ALMA will trace molecular component

All are needed to answer:
What are the physical processes driving their evolution?



combined JHK images of local templates (BVR bands) shifted to z=2 (top) and z=1 (bottom), with R_{eff}=0.5” and Mv=-21. 5hrs integration.

Intermediate-Conclusion:

What is done currently by 8/10m MCAO NIR (MAD/GeMS/Linc Nirvana) will be fully covered by MICADO / JWST / TMT-NFIRAOS

So what's left for an 8m MCAO NIR ?

Current MCAO NIR are imaging only.
(Except GeMS that will provide MOS with Flamingos 2 in a couple of years)

Multiple Object Spectroscopy (IFUs ?), or spectro-imaging behind an MCAO NIR might be appealing

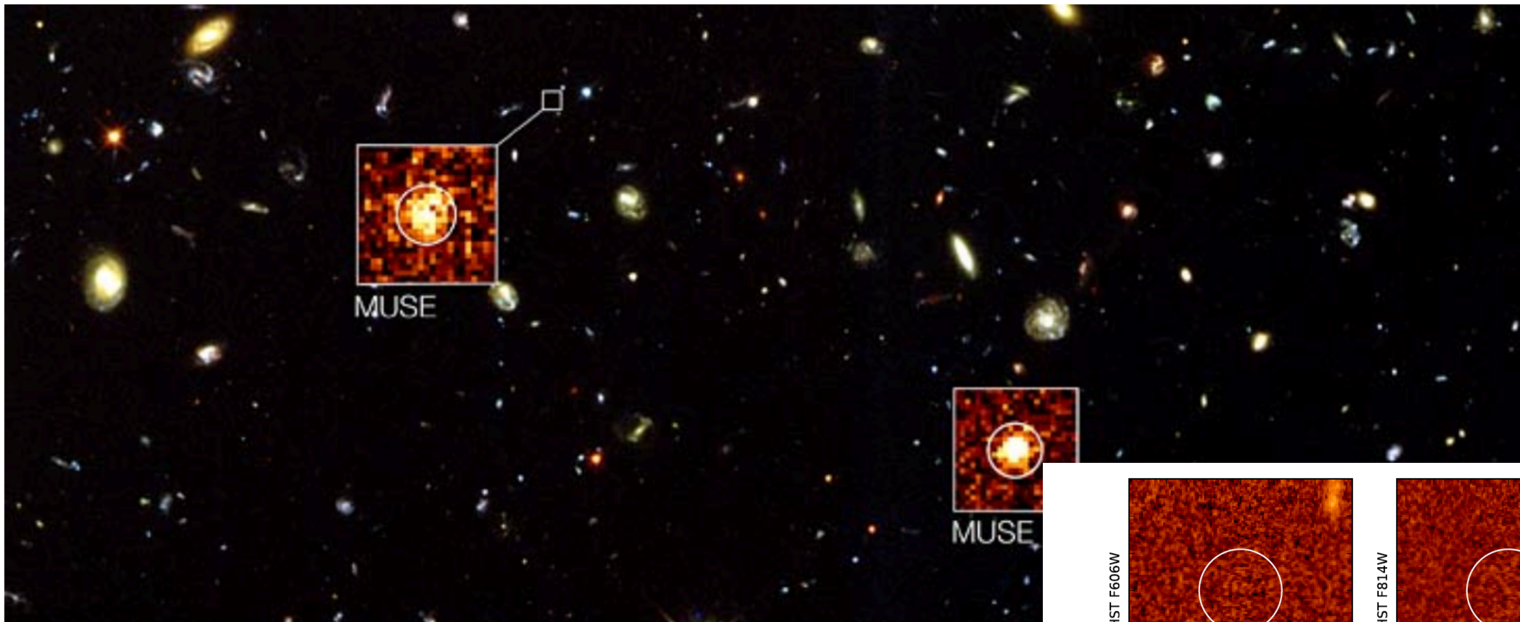
Can we build a NIR MUSE ?

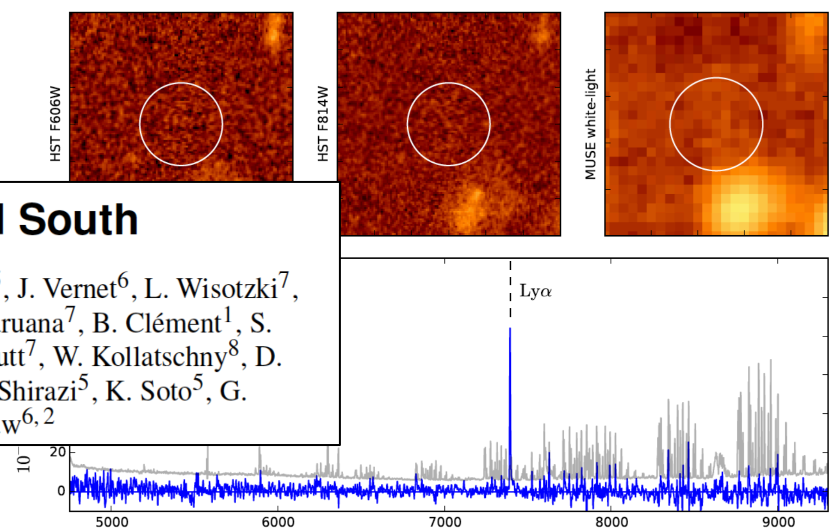
See J. Vernet Presentation

Looking Deeply into the Universe in 3D

MUSE goes beyond Hubble

26 February 2015

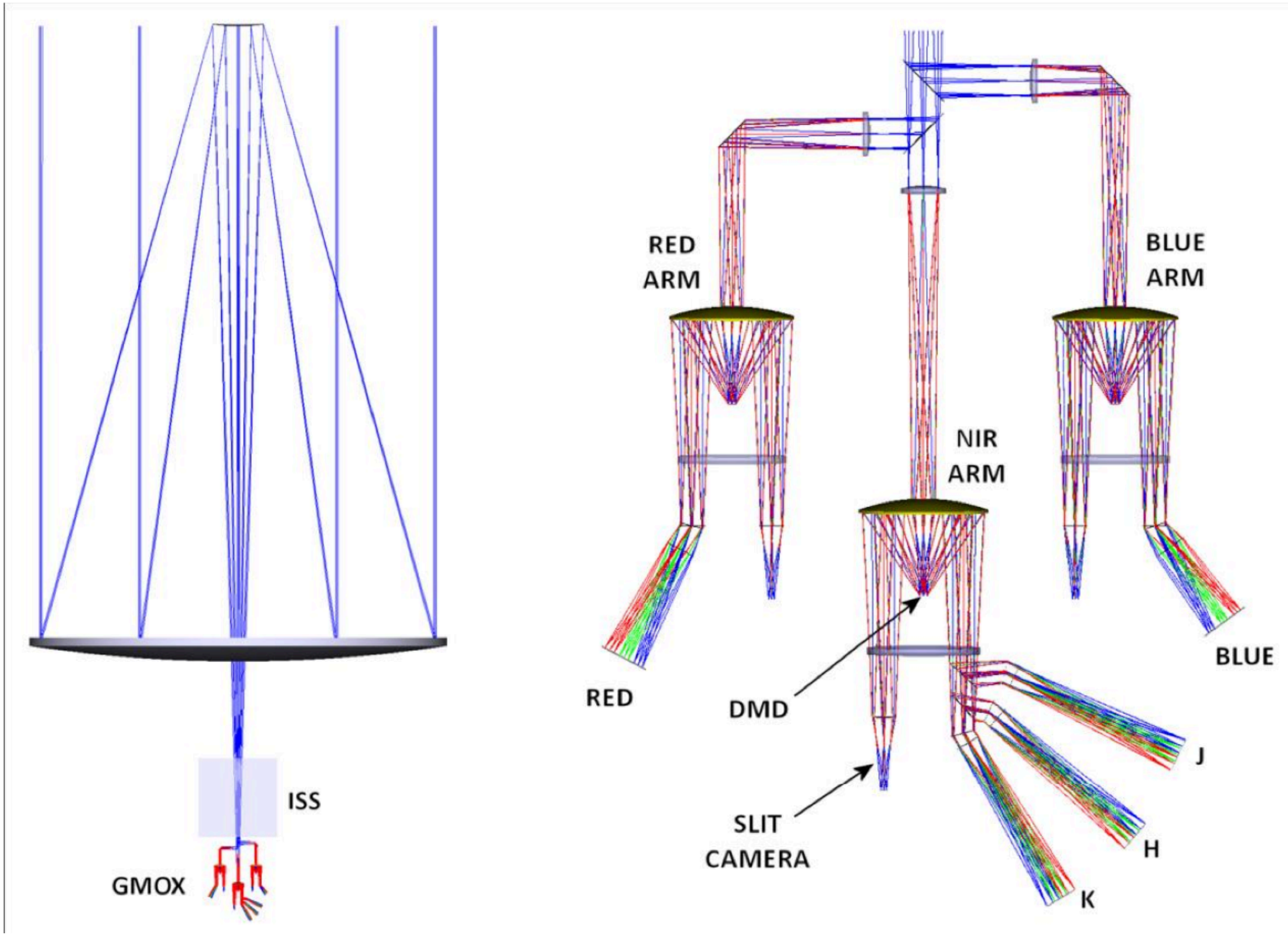




The MUSE 3D view of the Hubble Deep Field South

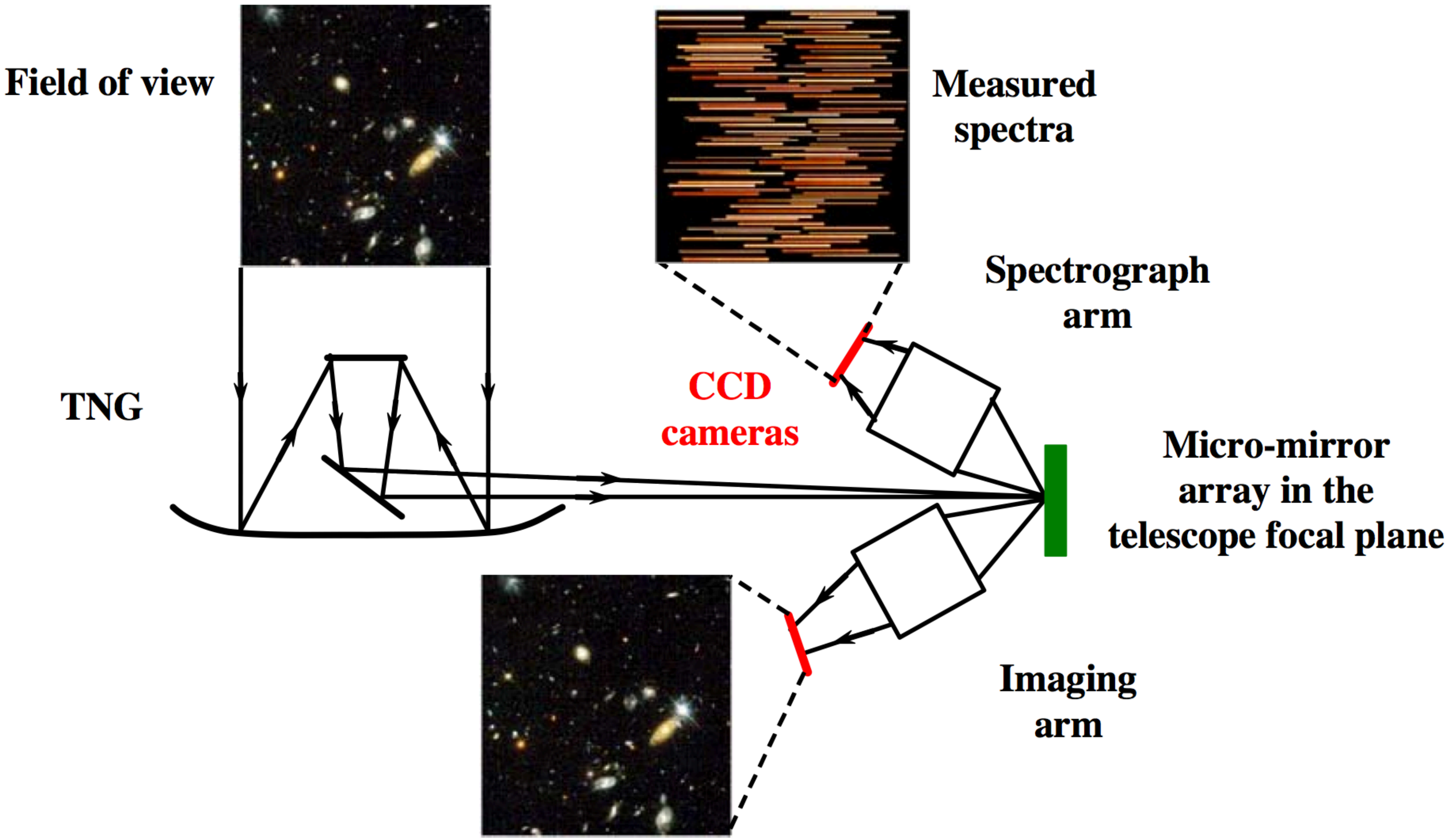
R. Bacon[1], J. Brinchmann[2], J. Richard[1], T. Contini[3,4], A. Drake[1], M. Franx[2], S. Tacchella[5], J. Vernet[6], L. Wisotzki[7], J. Blaizot[1], N. Bouché[3,4], R. Bouwens[2], S. Cantalupo[5], C.M. Carollo[5], D. Carton[2], J. Caruana[7], B. Clément[1], S. Dreizler[8], B. Epinat[3,4,9], B. Guiderdoni[1], C. Herenz[7], T.-O. Husser[8], S. Kamann[8], J. Kerutt[7], W. Kollatschny[8], D. Krajnovic[7], S. Lilly[5], T. Martinsson[2], L. Michel-Dansac[1], V. Patricio[1], J. Schaye[2], M. Shirazi[5], K. Soto[5], G. Soucail[3,4], M. Steinmetz[7], T. Urrutia[7], P. Weilbacher[7], and T. de Zeeuw[6,2]

GMOX



- **Wide-bandwith spectrograph: 0.32 – 2.4µm**
- **Moderate resolution: R ~ 5,000**
- **Multi-object spectrograph: 2.1M selectable slits over a few arcmin field.**
- **Excellent follow-up capabilities: <u>wide-band spectroscopy</u> <u>and parallel imaging</u>.**

BATMAN



See Presentation by Frederic Zamkotsian

Conclusions

The performance provided by a MCAO NIR instrument will be in direct competition with JWST/EELT/TMT.

A competitive instrument for an MCAO-VLT, in the NIR, would have to provide unique capabilities:

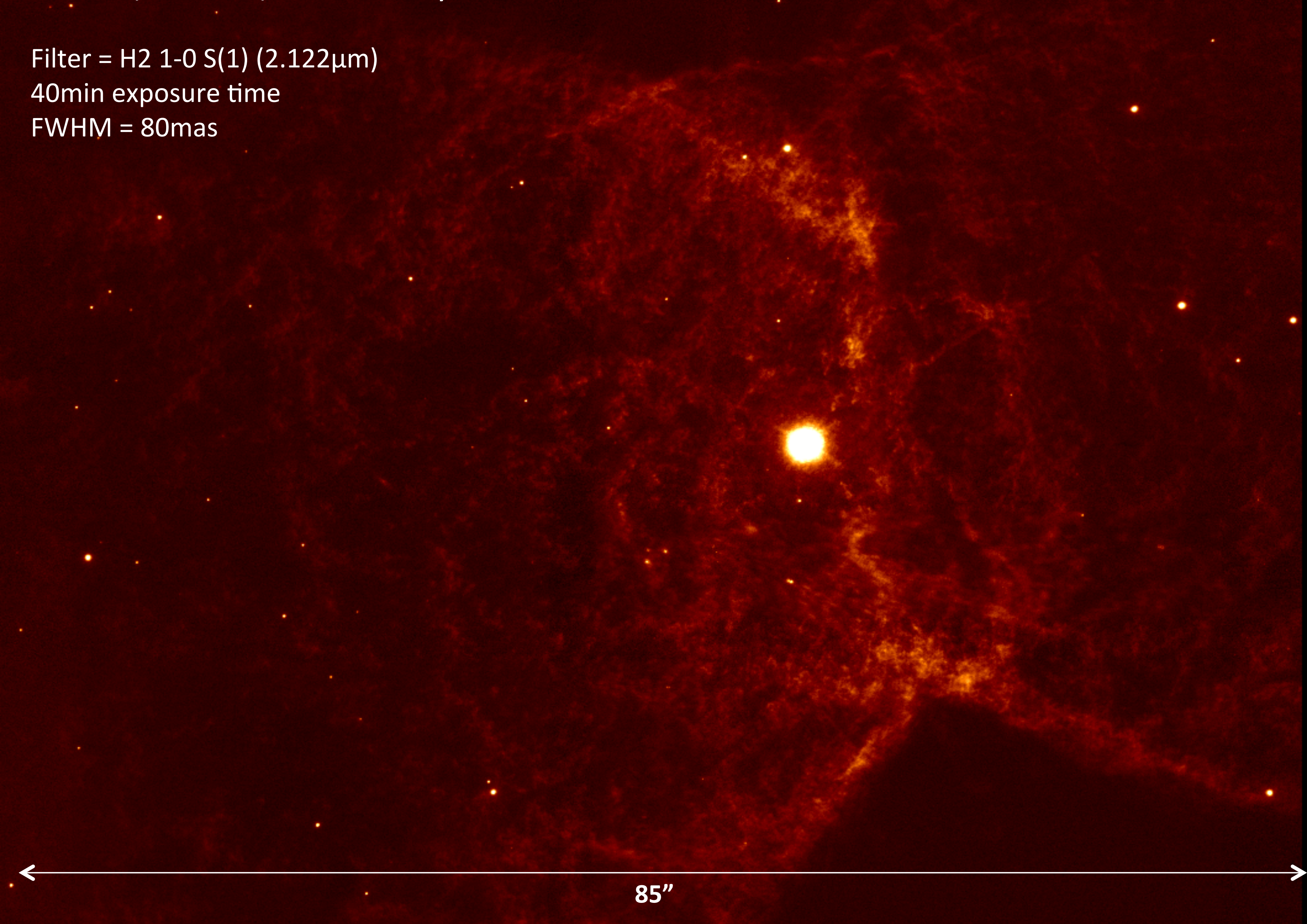
- Wide Field IFUs (MUSE-like)
- Parallel observations (e.g. Spectro + imaging, NIR+Visible, …)

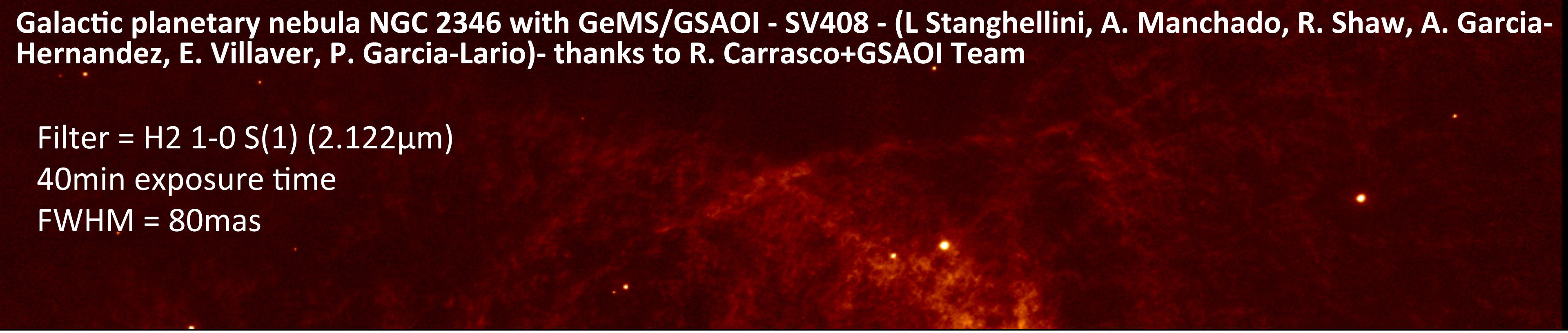
- Announcement -

- Looking for a post-doc to work on VLT3 instrument at LAM
- 2 years
- Start date can be any time from now to mid-2017
- Can be more technological, or more “astro”

If you know good candidates, please forward the information !!

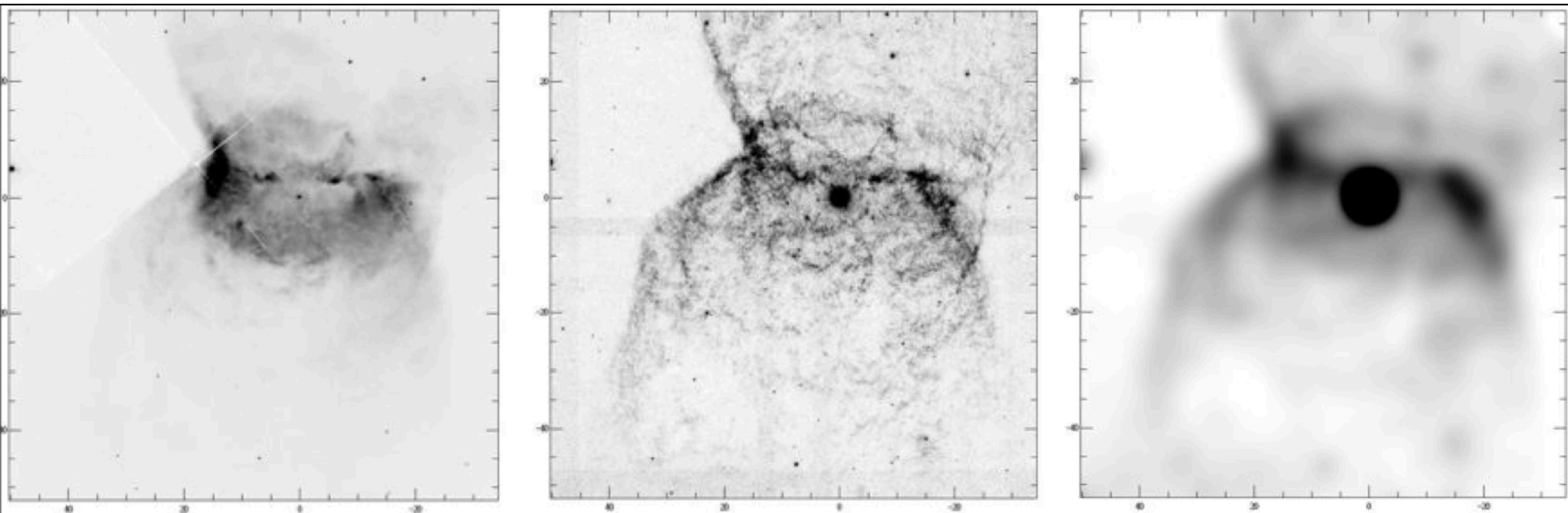
Galactic planetary nebula NGC 2346 with GeMS/GSAOI - SV408 - (L Stanghellini, A. Manchado, R. Shaw, A. Garcia-Hernandez, E. Villaver, P. Garcia-Lario)- thanks to R. Carrasco+GSAOI Team





High resolution imaging of NGC 2346 with GSAOI/GeMS: disentangling the planetary nebula molecular structure to understand its origin and evolution.

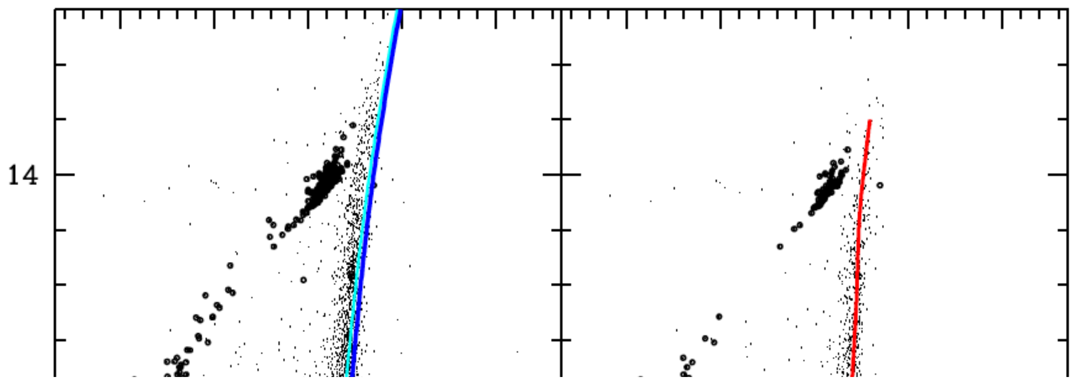
Arturo Manchado[1,2,3], Letizia Stanghellini[4], Eva Villaver[5], Guillermo García-Segura[6], Richard A. Shaw[4] & D. A. García-Hernández[1,2]



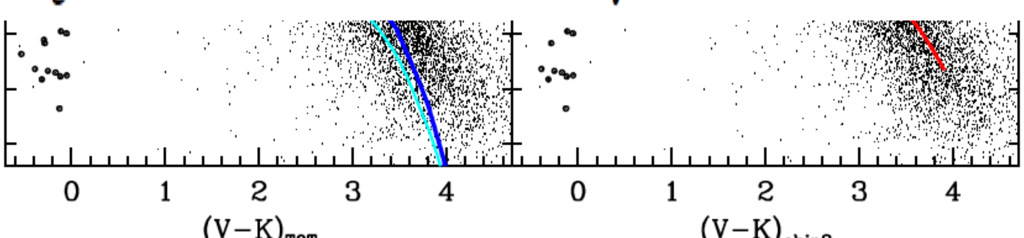
HST H image | GeMS H_2 image | low seeing image

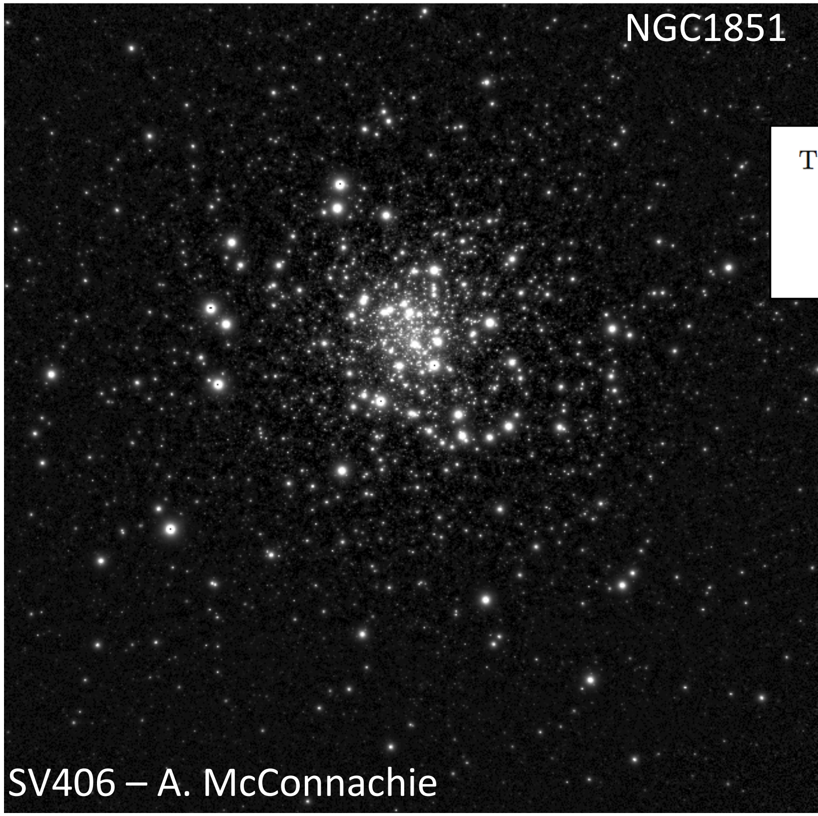
GeMS MCAO observations of the Galactic globular cluster NGC 2808: the absolute age

D. Massari[1,2], G. Fiorentino[1], A. McConnachie[3], G. Bono[4,5], M. Dall'Ora[6], I. Ferraro[5], G. Iannicola[5], P.B. Stetson[3], P. Turri[7], and E. Tolstoy[2]



Results. We found that NGC 2808 has an age of t= 10.9 ± 0.7 (intrinsic) ±0.45 (metallicity term) Gyr. A possible contamination by He-enhanced population could make the cluster up to 0.25 Gyr older. Although this age estimate agrees with the age coming from the classical turn off method (t= 11.0 Gyr), its uncertainty is a factor ~ 3 better, since it avoids systematics in reddening, distance assumptions and photometric zero points determination. The final absolute age indicates that NGC 2808 is slightly younger than other Galactic globular clusters with similar metallicity.

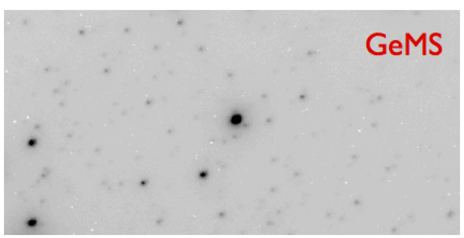




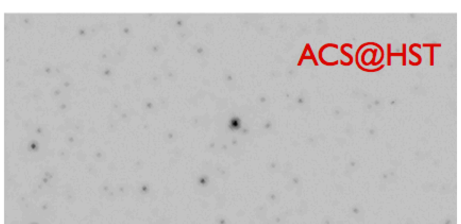
TOWARDS PRECISION PHOTOMETRY WITH EXTREMELY LARGE TELESCOPES: THE DOUBLE SUBGIANT BRANCH OF NGC 1851

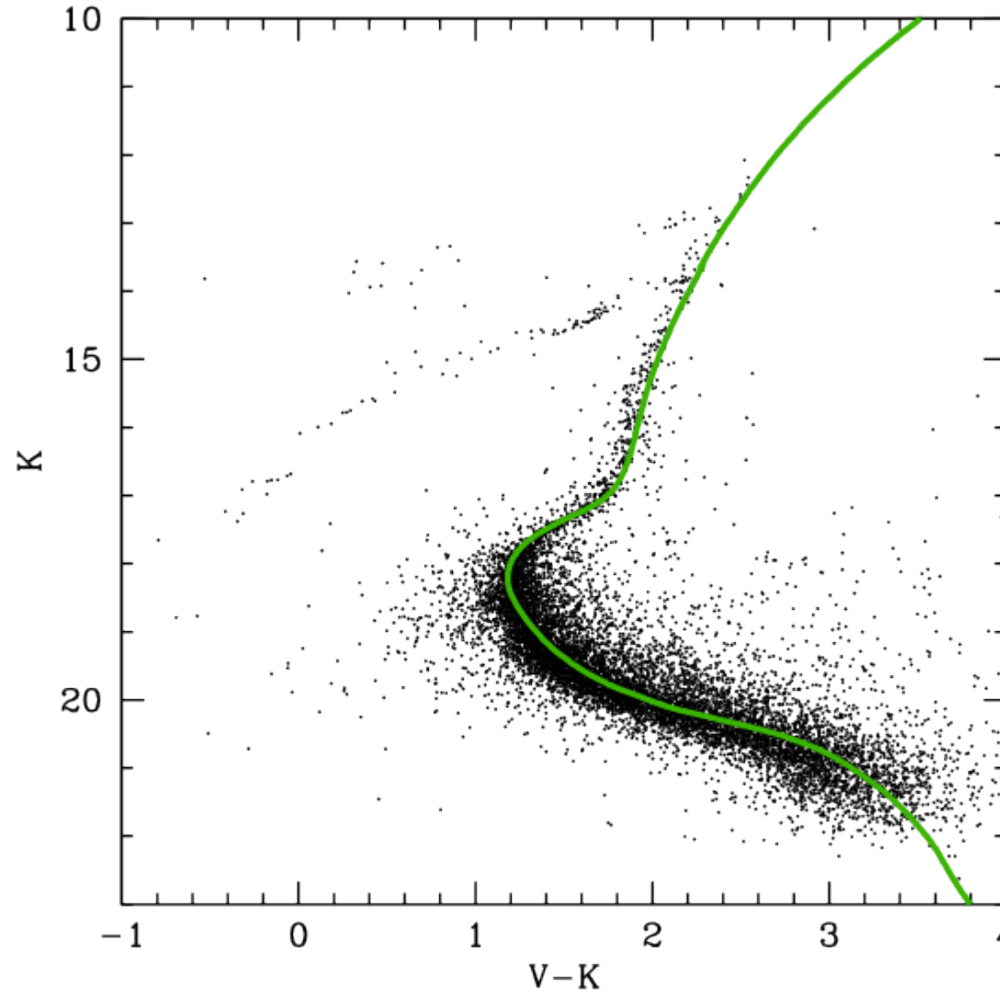
P. Turri[1]
Department of Physics and Astronomy, University of Victoria, 3800 Finnerty Road, Victoria, BC V8P 5C2, Canada

80mas



50mas

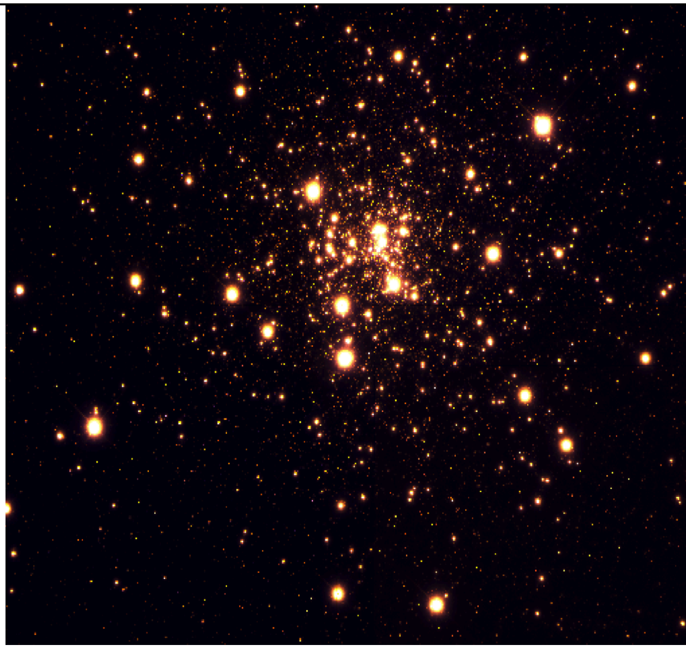




P. Turri – PhD thesis

Ultra-deep GEMINI near-infrared observations of the bulge globular cluster NGC 6624[1]

S. Saracino[1,2], E. Dalessandro[1,2], F. R. Ferraro[1], D. Geisler[3], F. Mauro[4,3], B. Lanzoni[1], L. Origlia[2], P. Miocchi[1], R. E. Cohen[3], S. Villanova[3], C. Moni Bidin[5]



"By adopting the MS-TO fitting method, we determined an absolute age of about 12.0+/-0.5 Gyrs.
The LF and MF show significant signatures of mass segregation. The number of low-mass stars gradually increases from the innermost to the outskirts. This confirms that NGC6624 is a dynamically old cluster, already relaxed"

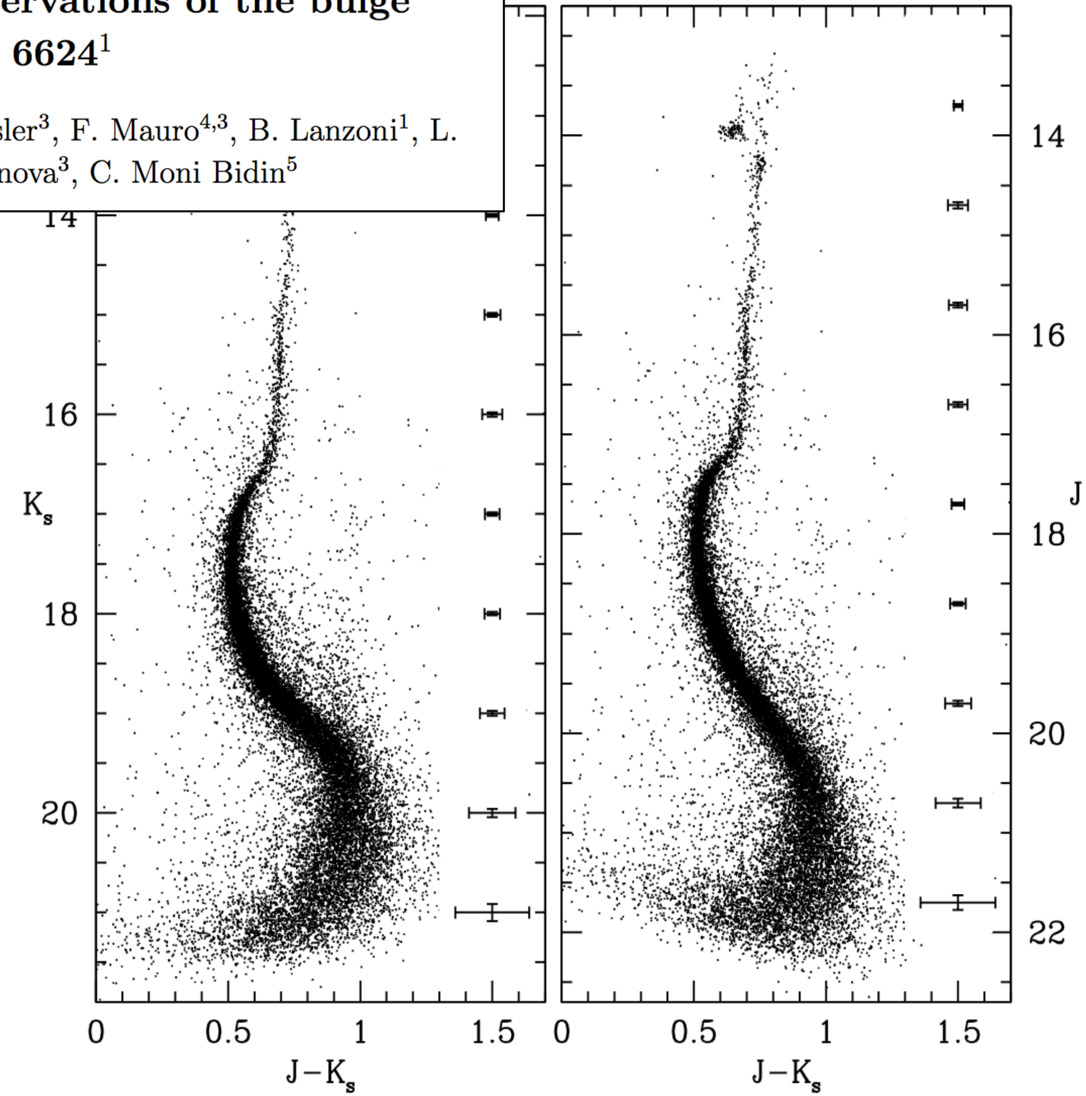
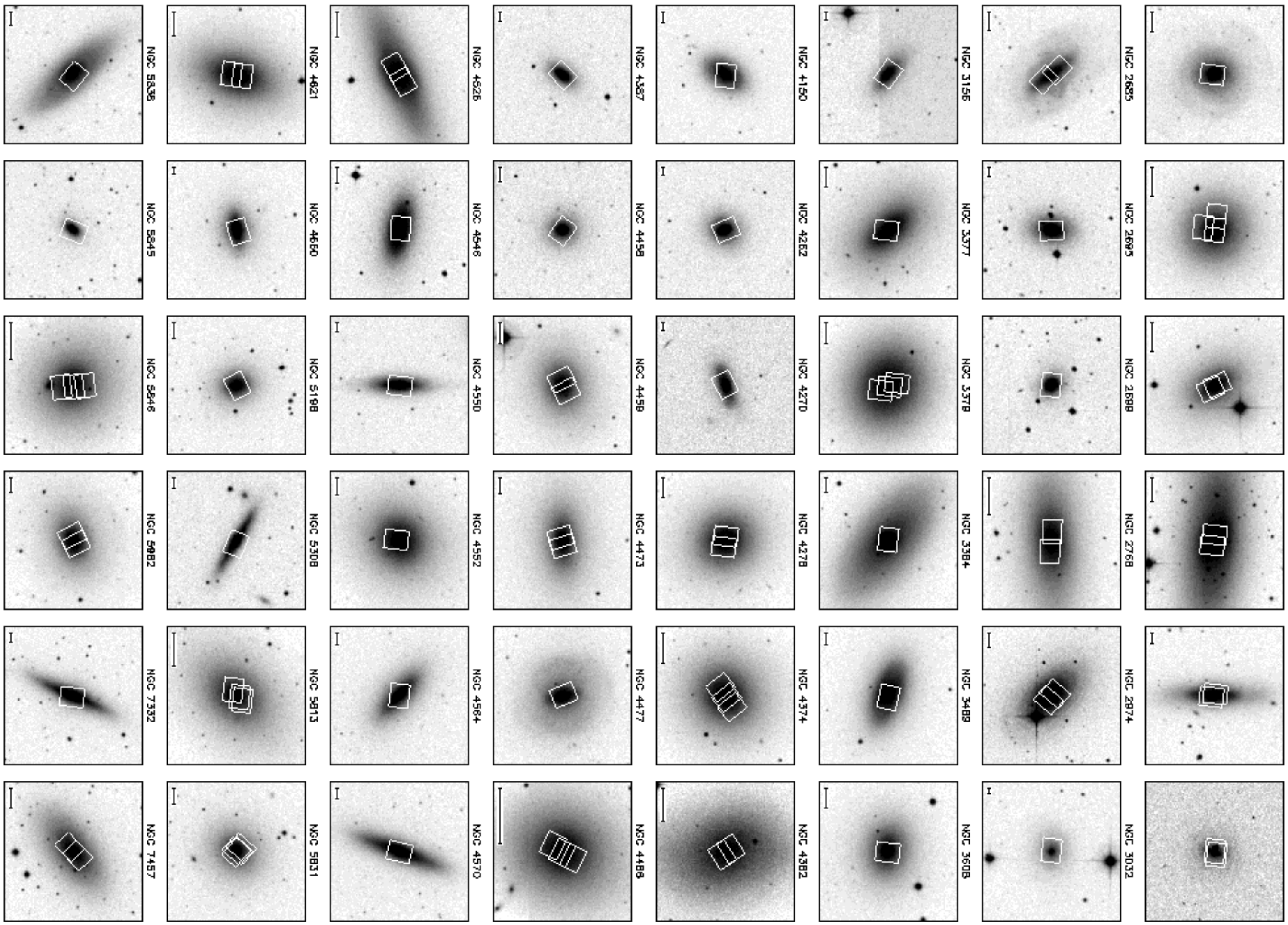


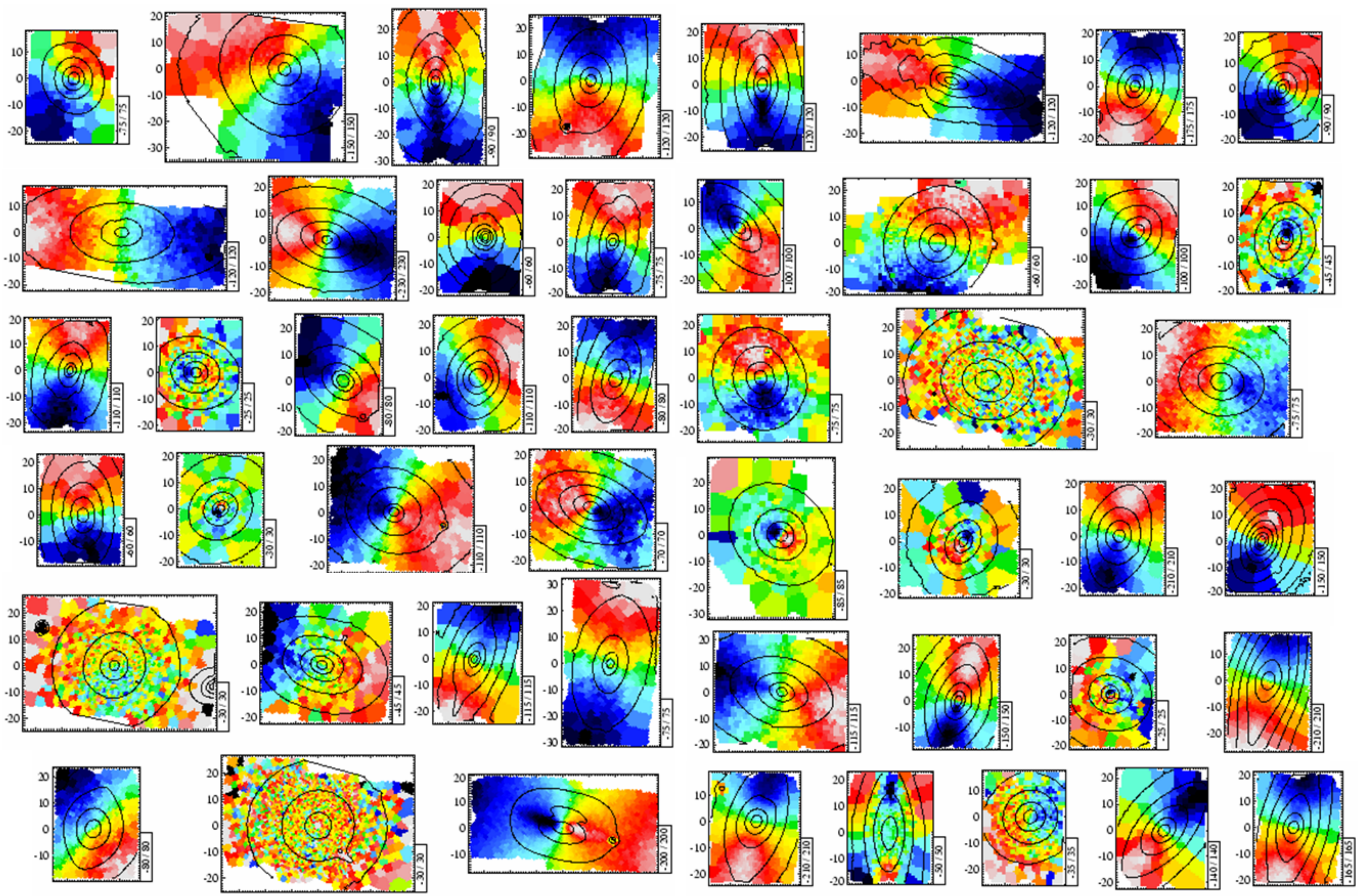
Fig. 5.— $(K_s, J-K_s)$ and $(J, J-K_s)$ CMDs of NGC 6624 obtained from the GEMINI observations discussed in the paper. All the main evolutionary sequences of the cluster are well visible, from the RGB, HB, MS-TO down to the MS-K. These NIR diagrams turn out to be comparable to the HST optical ones, both in depth and in photometric accuracy. The photometric errors for each bin of K_s and J magnitudes are shown on the right side of the panels.

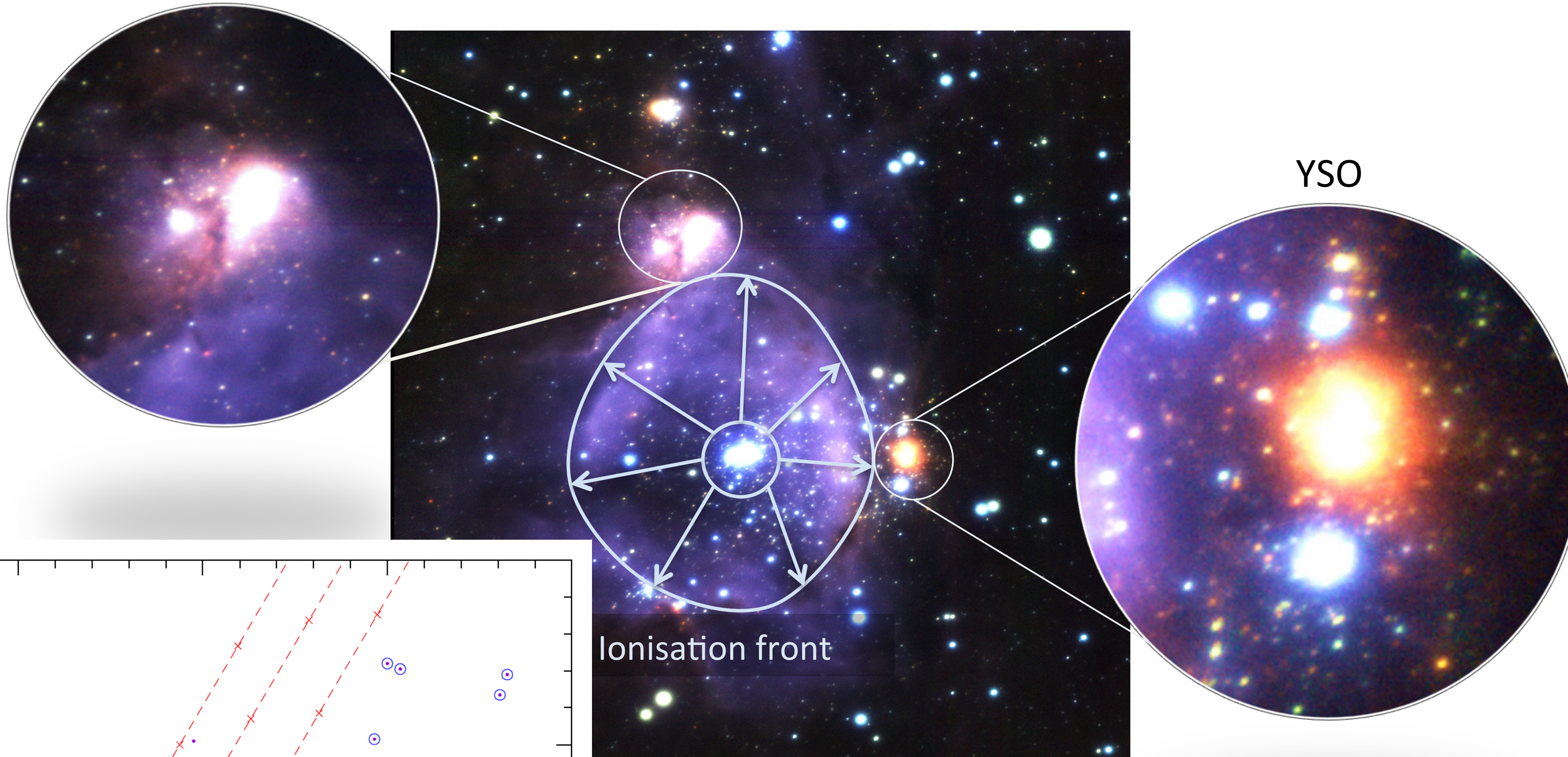
SAURON Survey: 48 ETGs

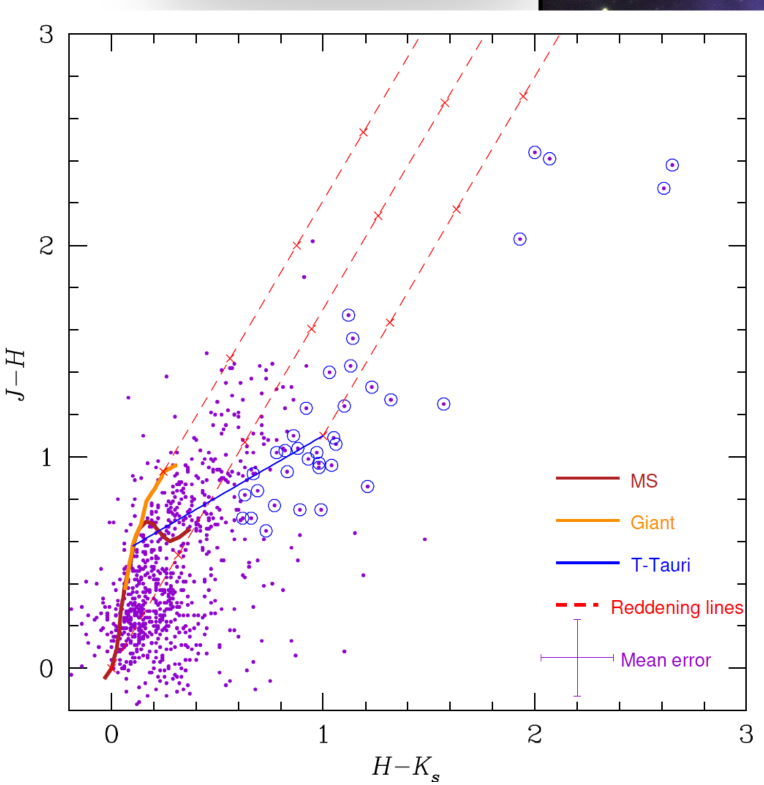
Aim: Cover one effective radius = half the light



SAURON Survey: 48 ETGs







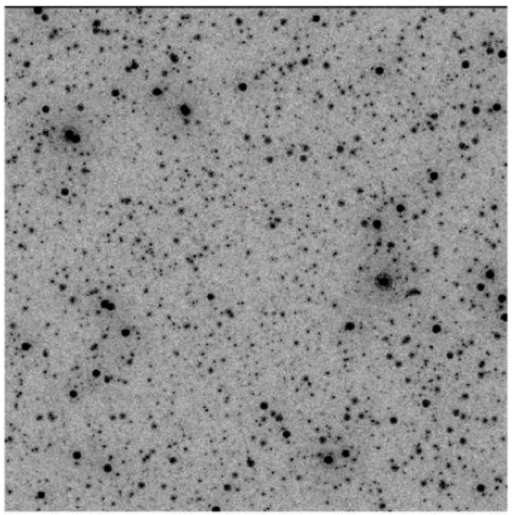
"The YSO distribution, preferentially distributed around the ionisation front suggest that this second generation of stars has been triggered"

Anticipating the ELTs

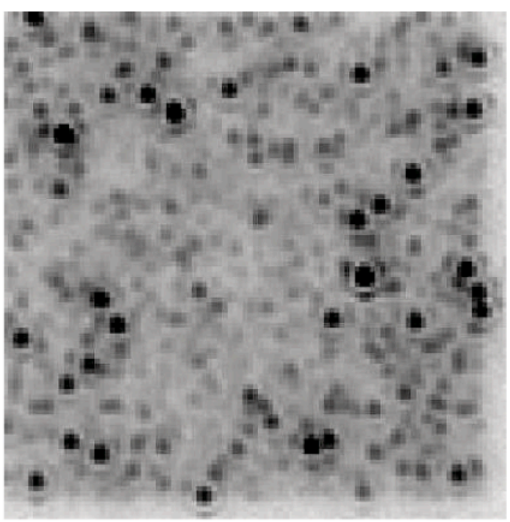
Resolution gives an effective sensitivity gain wrt JWST – cf. 3mag for MAD vs ISAAC.

Can probe tip of RGB out to Virgo (δ_{Virgo} = +12.5°, zd at transit is 37° -> seeing ~0.1" worse)

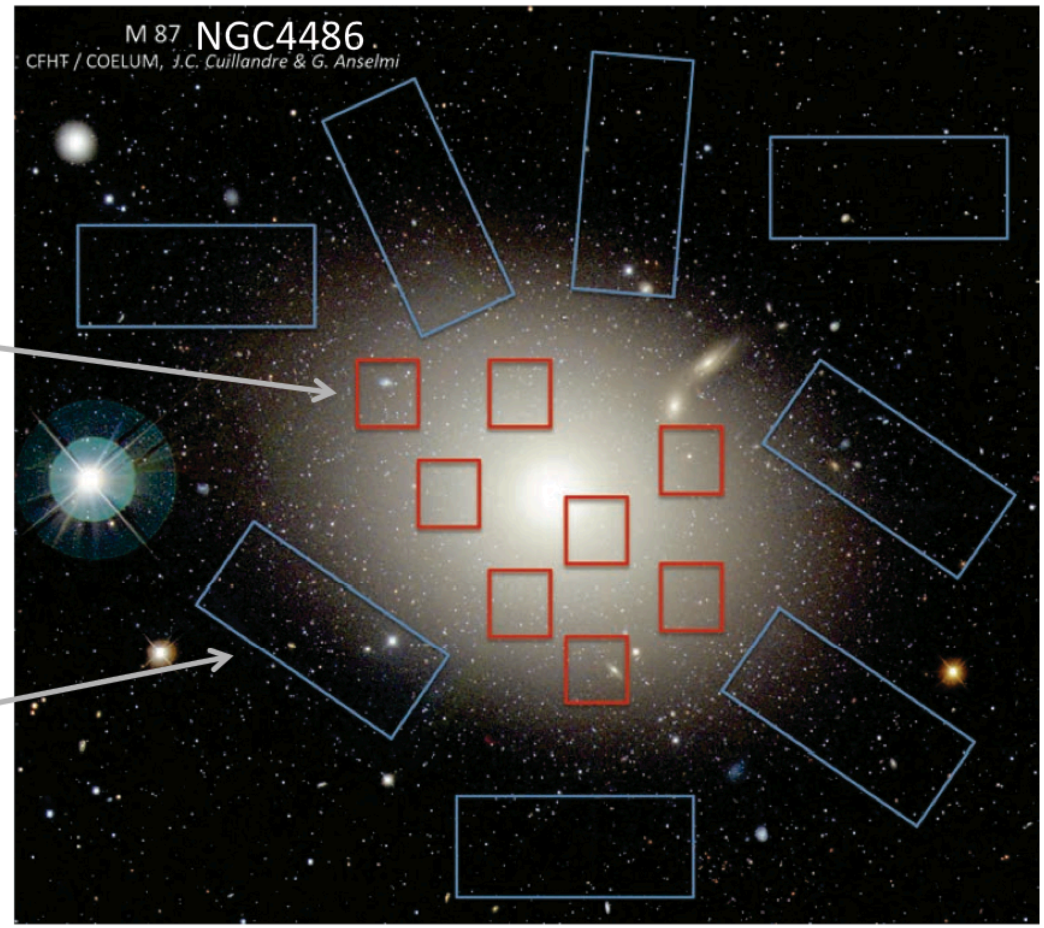
5-hr K-band simulated exposures



MICADO @ E-ELT

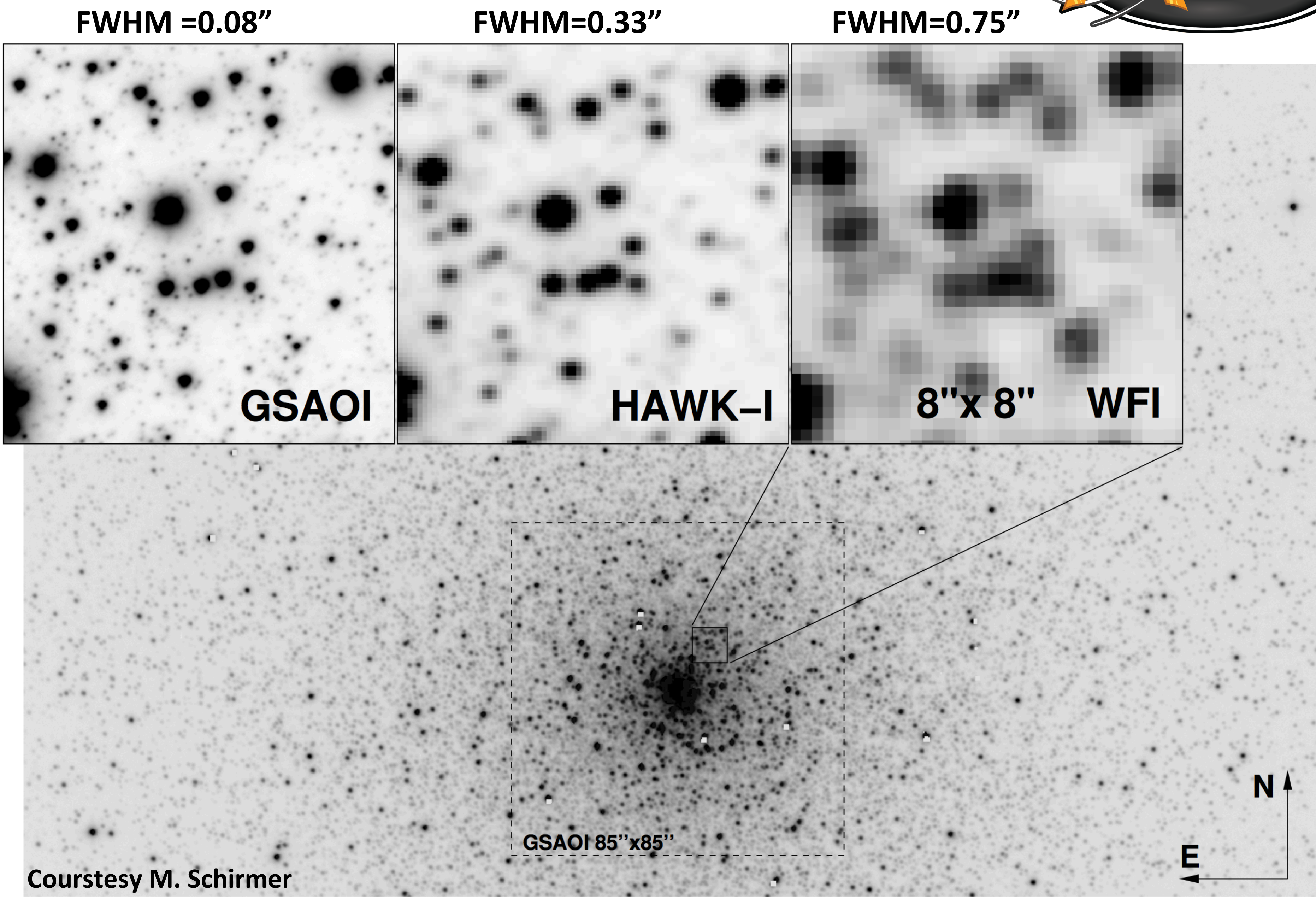


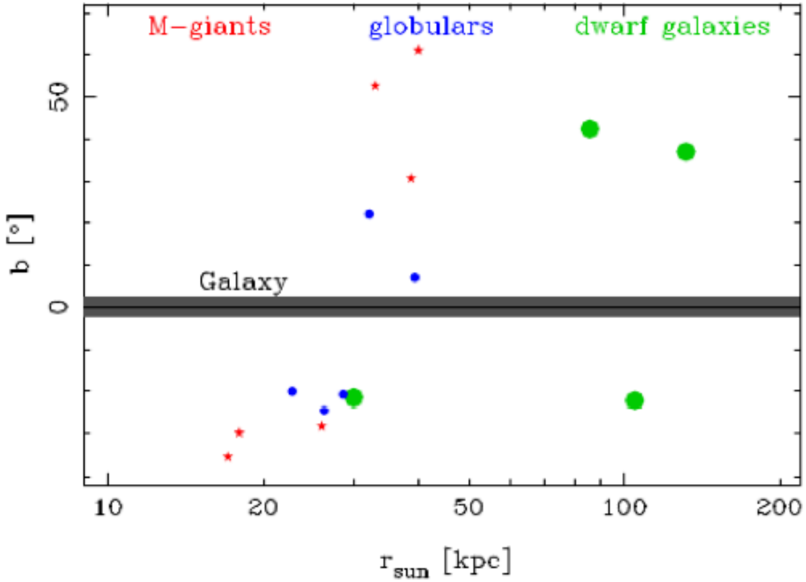
NIRCAM @ JWST



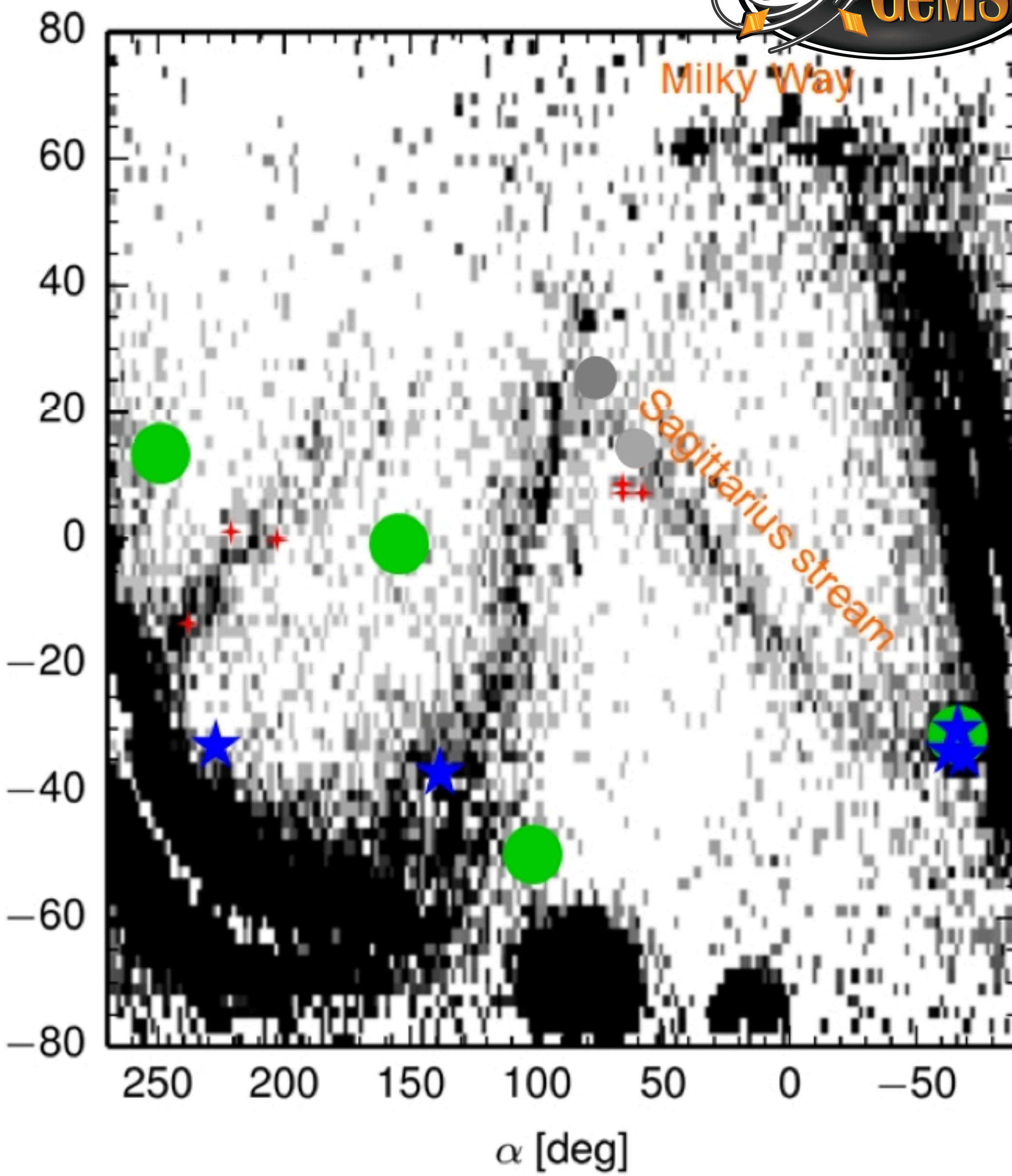
(Slide from Ric Davies)

Star Clusters





- **15 targets**
- **6 M-giants** in the Sagittarius stream
- **5 globulars**
  - 3 possible members of Sagittarius system: Arp 2, Terzan 7, Terzan 8
  - 2 others in outer halo: NGC5824, Pyxis
- **4 dwarf galaxies**:
  - Sagittarius, Hercules, Sextant, Carina

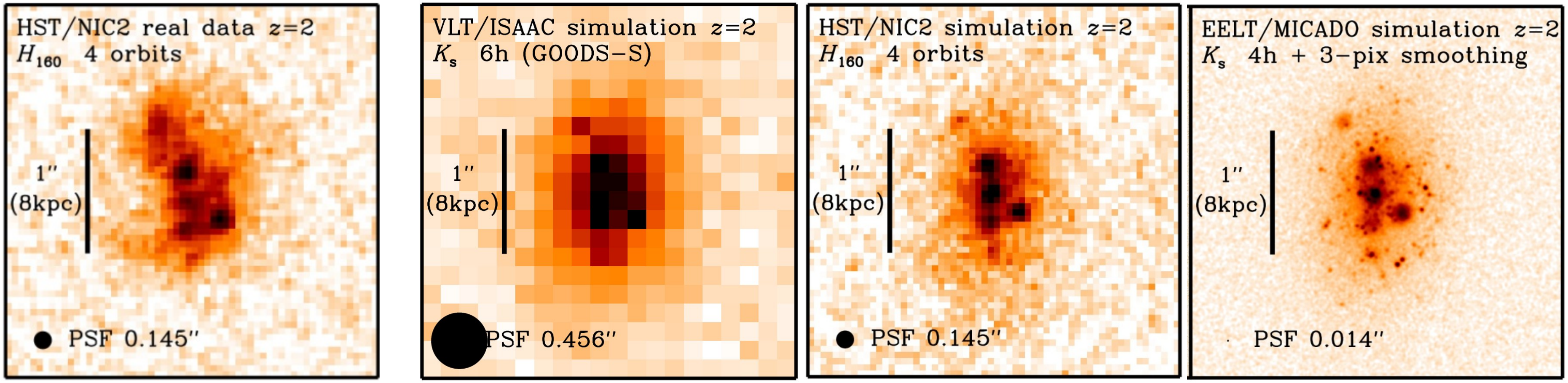


M-giant density map from Koposov et al. 2015

(Slide from Tobias Fritz)

(Slide From R. Davies)

Galaxies at High Redshift



simulation of a large bright disk galaxy at z = 2.3 ($R_{1/2}$ = 5 kpc, K_{AB} = 21.3), showing that one can measure sizes, distribution and luminosity functions of compact clusters to K_{AB} ~ 28.5

spectroscopy: - metallicity, extinction, stellar populations, outflows (AGN)
- relations between mass, SFR, metallicity

NIR IFU science cases

Absorption line diagnostics of early type galaxies at z ~ 0.5 to 1.0

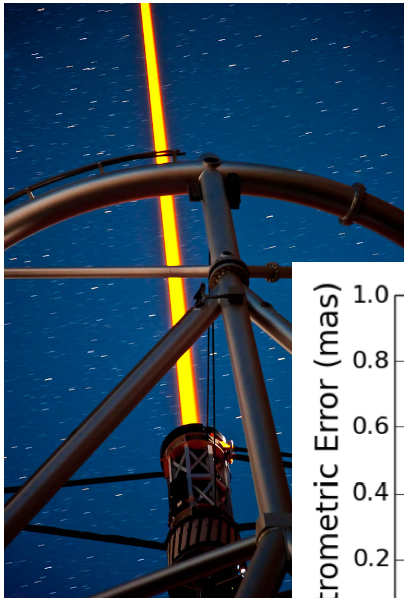
- Target clusters of galaxies, with high number density
- Well understood Lick indices redshifted into 0.8 to 1.3 micron region
- Chemical abundance evolution (and gradients) as well as IMF variation with formation process and cosmic epoch are key goals
- Kinematics of stars allows classification into fast and slow rotators (widely believed to be well connected to formation processes).

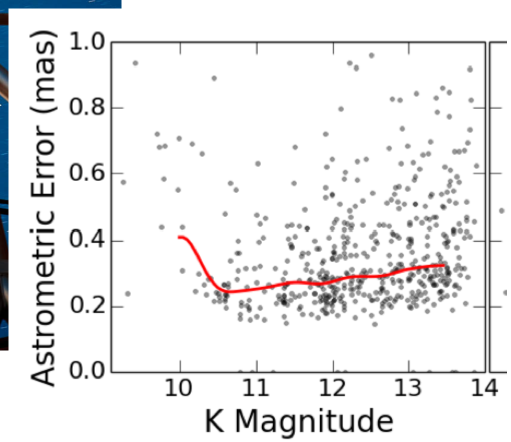
Emission line galaxies at higher redshift

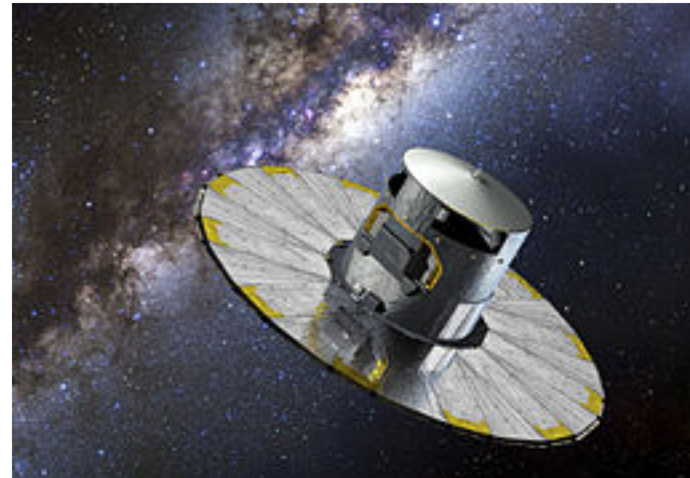
- Galaxy assembly at z > 2 and test early stellar formation of massive galaxies at z = 1
- Internal properties such as dynamical state, distribution of mass, star formation regions provide test for models
- Distinguish between chaotic or well-ordered velocity fields

(Slide from Niranjan Thatte)

Ground based AO vs. GAIA



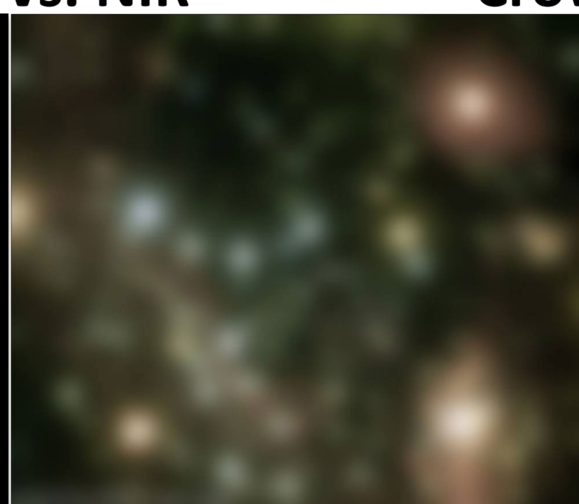




Bright stars	5-16 μas (3 mag < V < 12 mag)
V = 15 mag	26 μas
V = 20 mag	600 μas

Visible vs. NIR

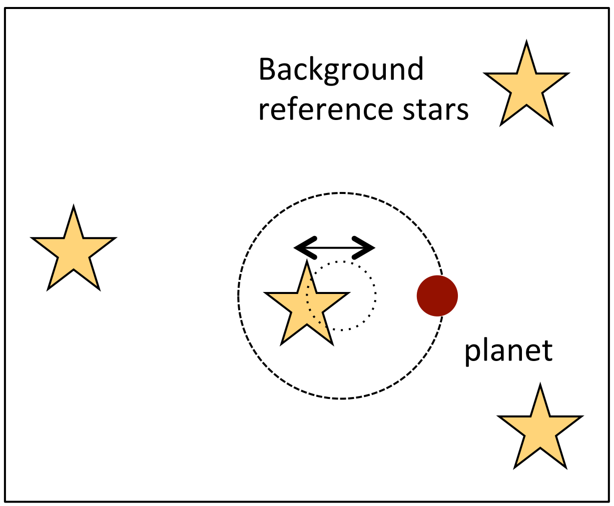
Crowding

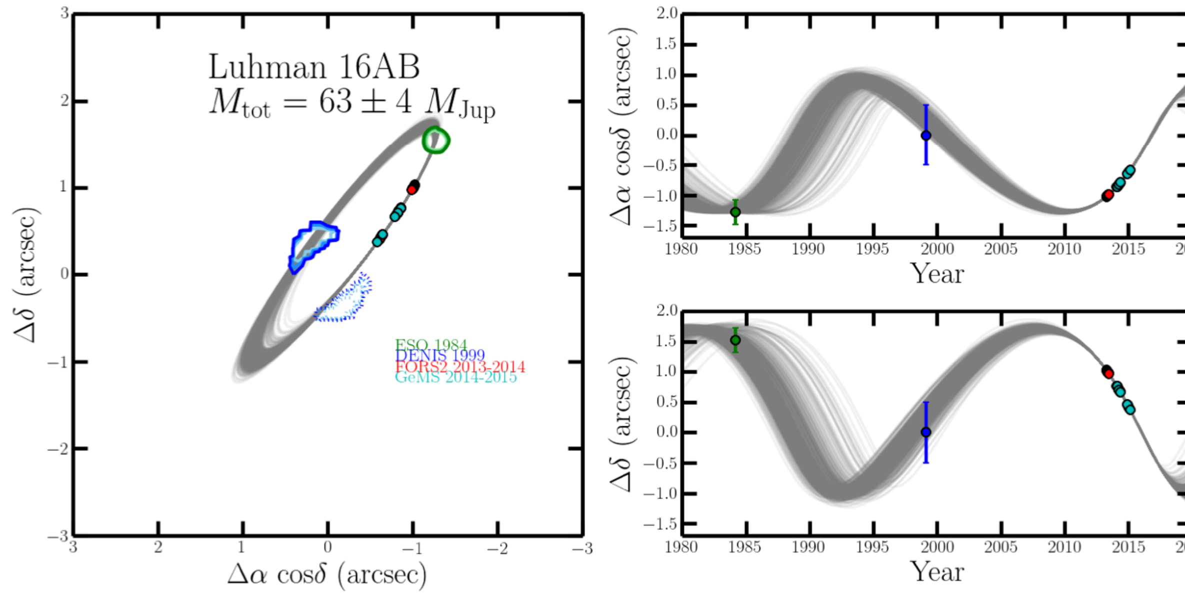


Astrometry for exo-planets / binary systems

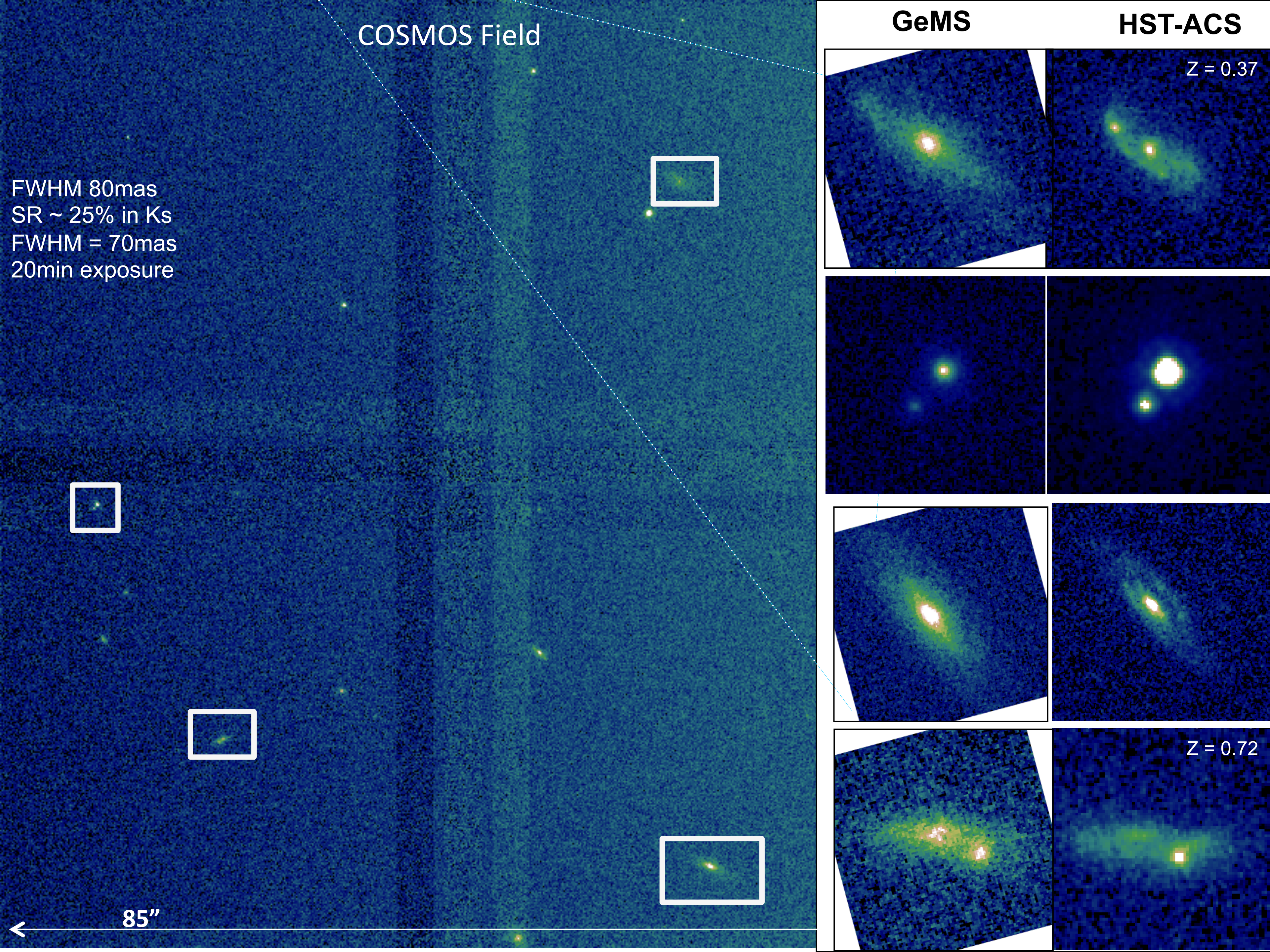
Individual, Model-Independent Masses of the Closest Known Brown Dwarf Binary to the Sun

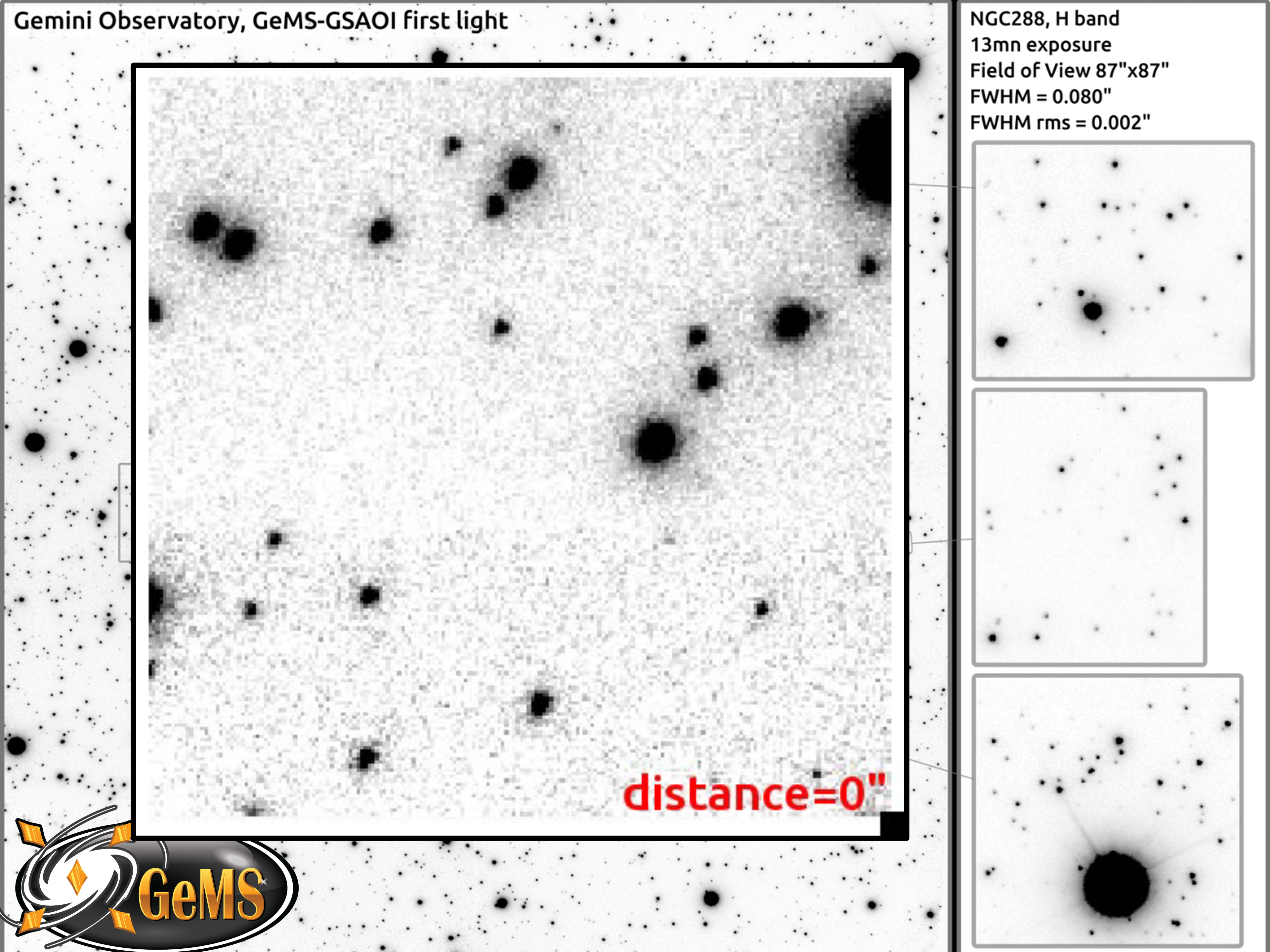
E. Victor Garcia[1], S. Mark Ammons[1], Maissa Salama[2], Jeff Chilcote[3], Vincent Garrel[4], James R. Graham[5], Paul Kalas[5], Quinn Konopacky[6], Jessica R. Lu[2], Bruce Macintosh[7], Eduardo Marin[4], Christian Marois[8,9] Eric Nielsen[7,10], Benoît Neichel[11], Don Pham[1], Robert J. De Rosa[5], Dominic M. Ryan[5], Maxwell Service[2], Gaetano Sivo[4]





"We constrain the individual masses and mutual orbit parameters of the Luhman 16 AB binary brown dwarf system. The masses are constrained to be 0.025+/- 0.0020 for the northwest T dwarf and 0.033 +/- 0.0020 for the southeastern L dwarf. Luhman 16 AB represents the second individual mass measurement for any L or T field brown dwarfs."


COSMOS Field
FWHM 80mas
SR ~ 25% in Ks
FWHM = 70mas
20min exposure
85”
GeMS
HST-ACS
Z = 0.37
Z = 0.72



Gemini Observatory, GeMS-GSAOI first light
NGC288, H band
13mn exposure
Field of View 87"x87"
FWHM = 0.080"
FWHM rms = 0.002"
distance=0"

Can we build a NIR MUSE ?

- Desire 0.1” resolution (100 mas), so 50 mas sampling.
- If we cover a field of 32” x 16” = 640 x 320 pixels = 204800 spatial elements.
- R = 3000
- 30 H4RG (4k x 4k) detectors (!!) May be too expensive…

Can we build a NIR MUSE ?

- Desire 0.1” resolution (100 mas), so 50 mas sampling.
- If we cover a field of 32” x 16” = 640 x 320 pixels = 204800 spatial elements.
- R = 3000
- 30 H4RG (4k x 4k) detectors (!!) May be too expensive…

Another approach would be to use multi-IFUs, but we loose the “blind discovery”

Multi-IFUs:

- Desire 0.1” resolution (100 mas), so 50 mas sampling. 64 x 32 = 2048 spatial elements per IFU, results in **3.2” x 1.6” FoV per IFU**.
- A single 4K x 4K detector can accommodate 4 IFU, 2 in spatial direction, and 2 in spectral direction.
- 3 detectors gives **multiplex of 12**

How competitive would that be compared to JWST IFU ? And MOSAIC ?