Richard Davies

on behalf of nearly 50 people in Germany, the Netherlands, Italy, & France

MICADO: *M*ulti-AO *I*maging *C*amer*a* for *D*eep *O*bservations

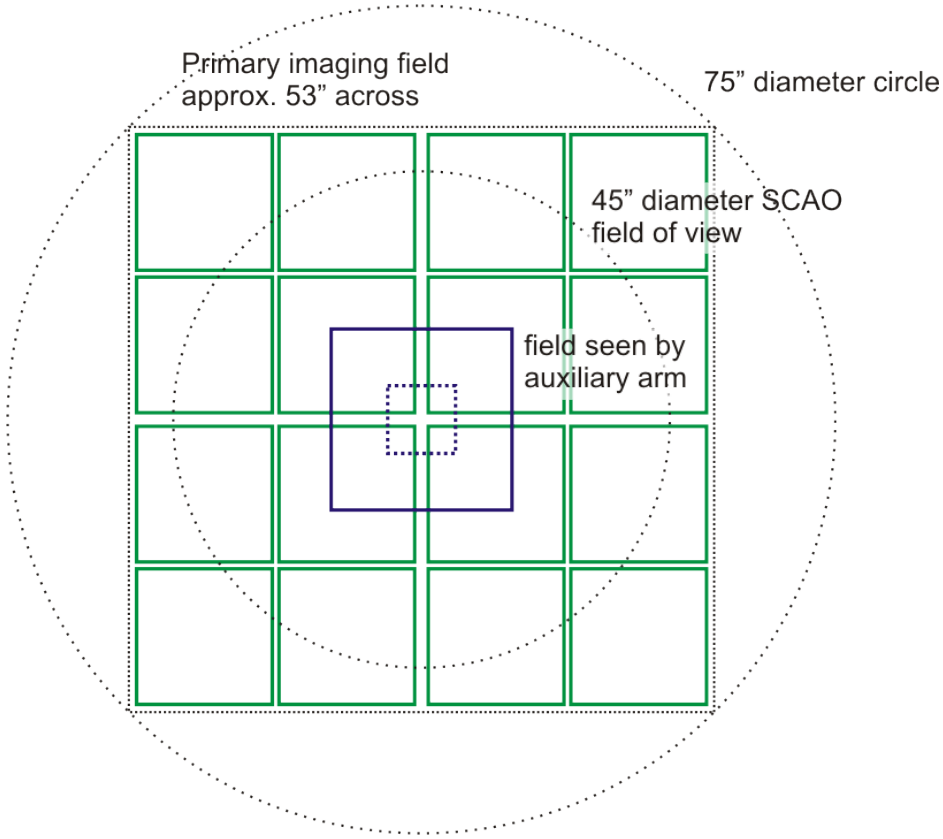
- 0.8-2.5µm

Primary Imaging Field

- 53” across, 3mas pixels
- high throughput (>60%)
- 4×4 HAWAII 4RG detectors
- 20 filter slots

Auxiliary Arm

- 1.5mas pixels for imaging
- 4mas pixels for spectroscopy
- 1 HAWAII 4RG detector
- 20 filter slots
- potential for additional options, e.g.
  - tunable filter (dual imager)
  - high time resolution



movable pick-off switches between Primary & Auxiliary arms

MAORY: Multi-conjugate Adaptive Optics RelaY

INAF + University of Bologna, ONERA, ESO

talk 7736-26 by Emiliano Diolaiti

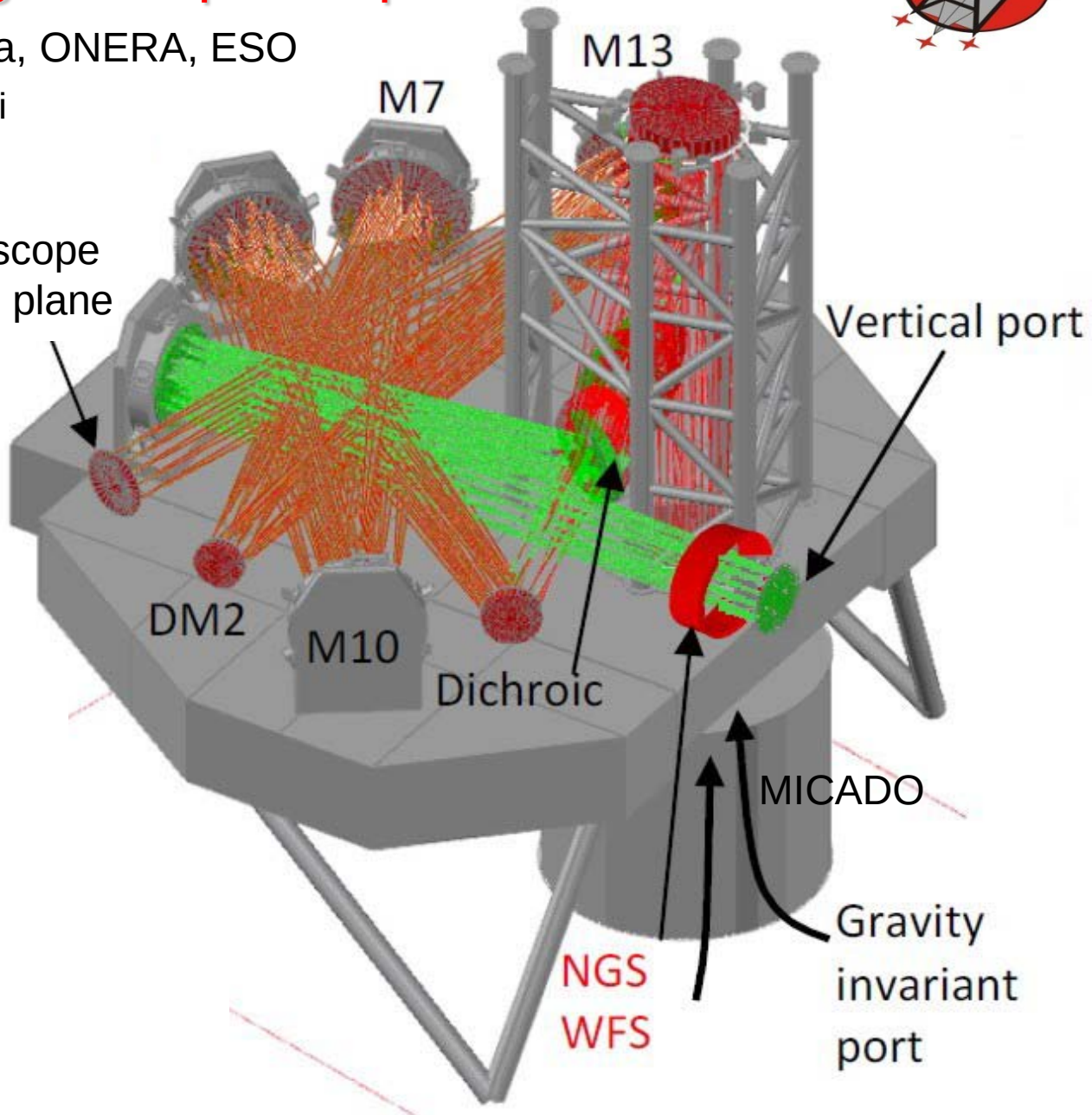
Performance in 0.8” seeing

sky coverage @ NGP:

	26%	48%

strehl ratio:

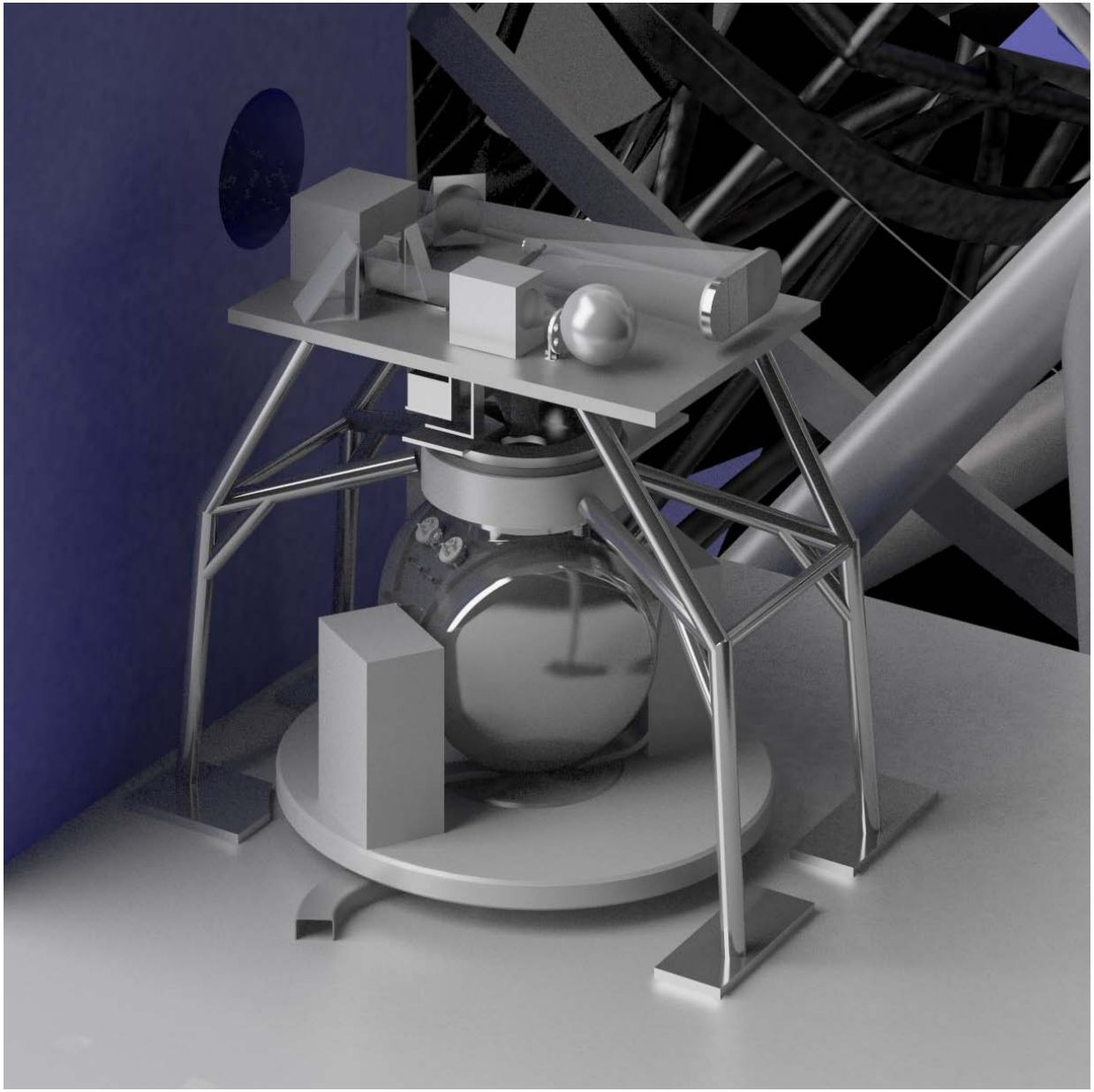
K	53%	41%
H	34%	22%
J	14%	6%



Phased Approach: using SCAO for initial operations

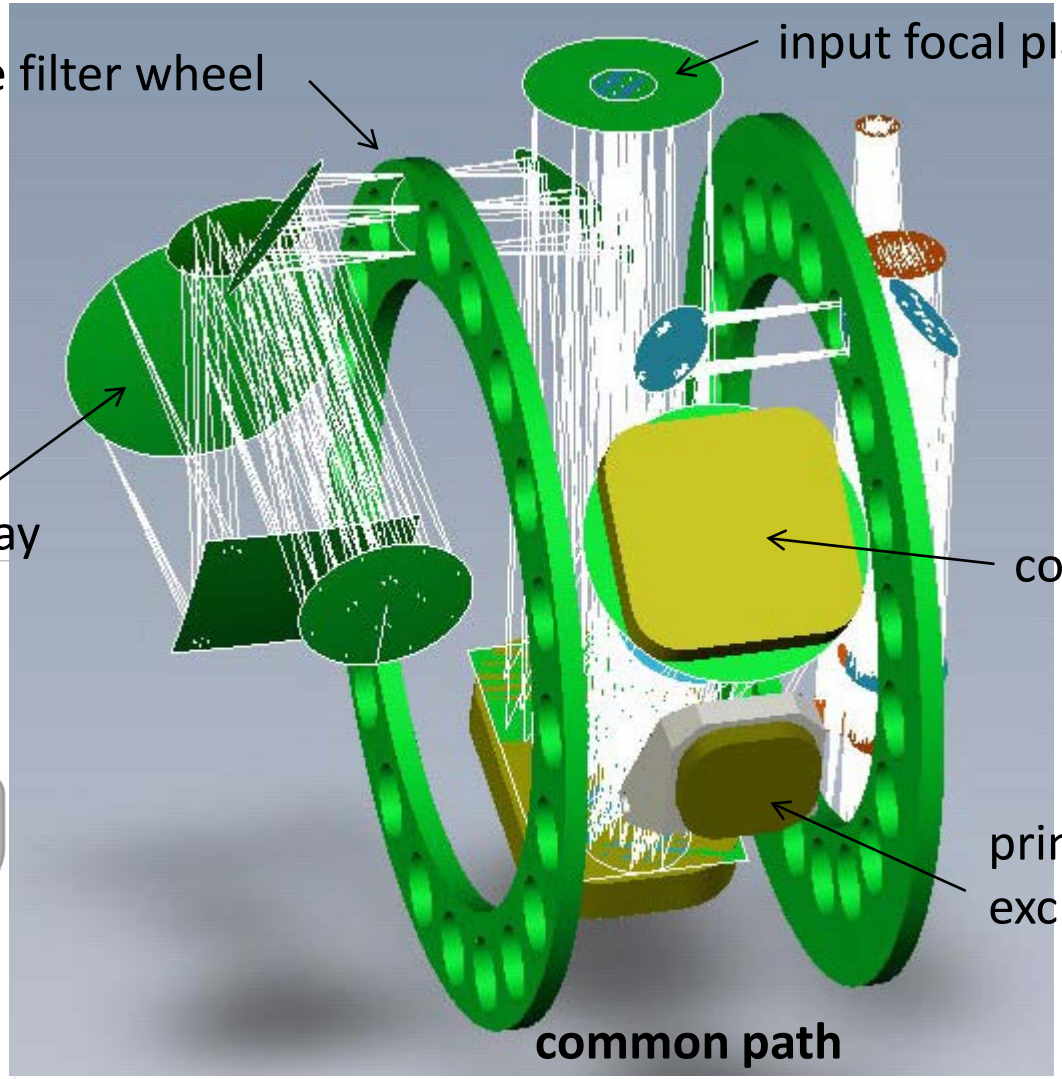
- simple robust AO using a single NGS
- sufficient science targets for 2-3 years
- optical relay can be used with other AO systems such as ATLAS until MAORY is available

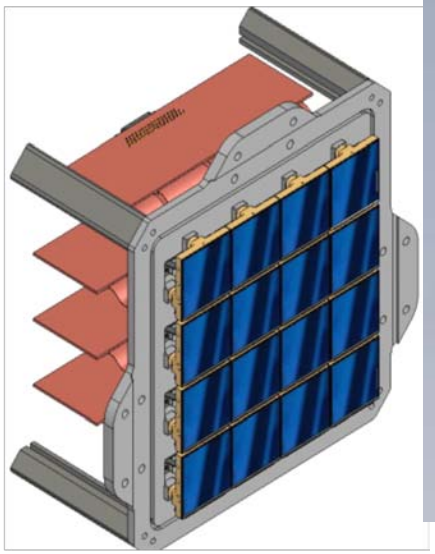
poster 7736-137 by Yann Clénet



MICADO opto-mechanics overview

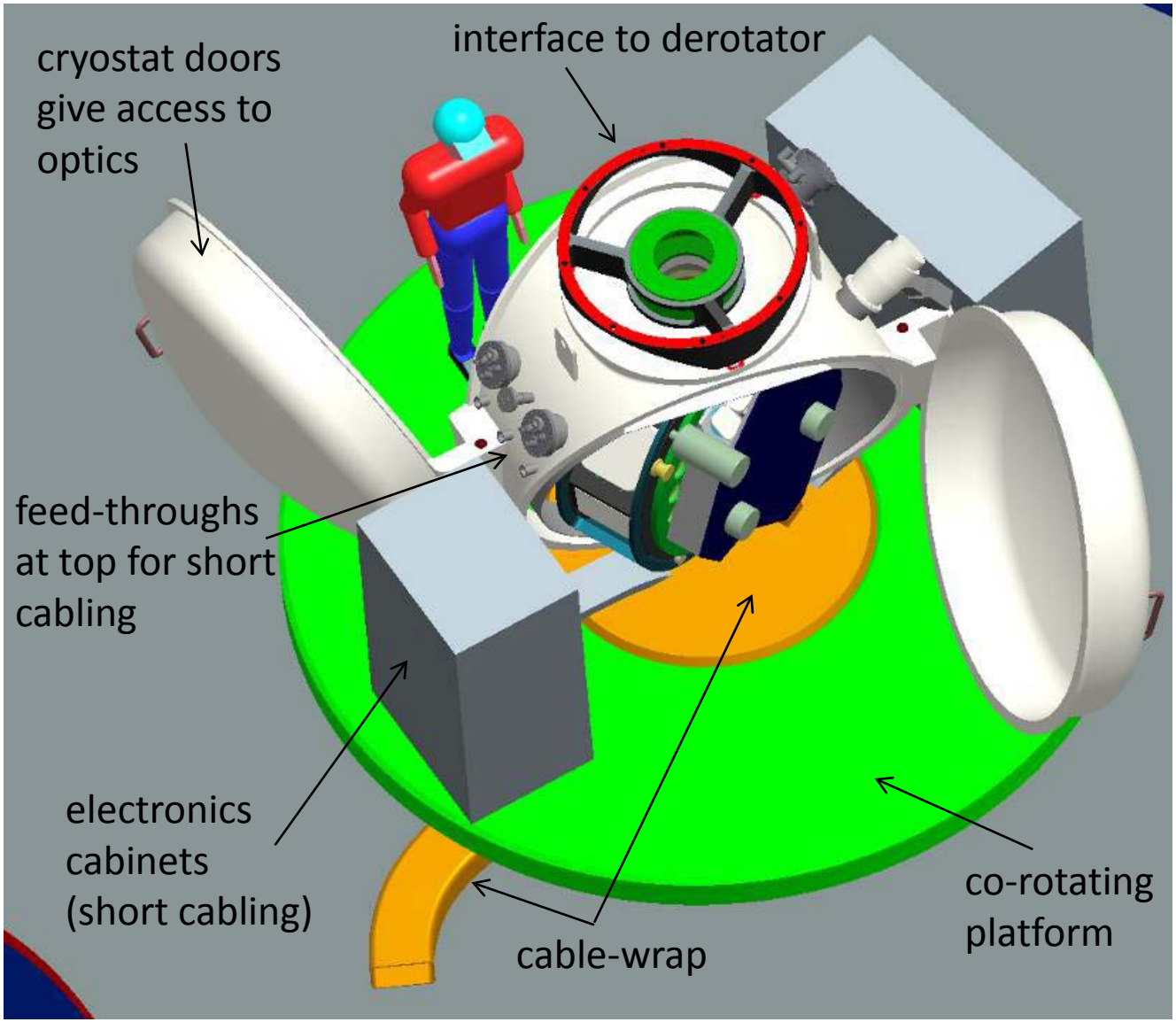
- gravity invariant high-throughput reflective design using only fixed mirrors; optimised for photometric & astrometric precision
- poster 7735-202 by Demetrio Magrin





Mechanics: instrument & cryostat

- cryostat ~2m across; mounts underneath SCAO & MAORY



Mass:

under derotator	3000 kg
on Nasmyth	2800 kg
calibration unit	500 kg

Operations, Data Rate, & Processing

Imaging & longslit spectroscopy are standard techniques

- use standard procedures for processing data
- astrometry is an exception; detailed astrometric calibration scheme developed

Operations: dithering scheme

- balances requirements of:
  - science (frequent dithering)
  - telescope (infrequent dithering)
  - AO (precision vs distance)

small dither	+/-0.3” from centre, accuracy <2mas, cadence 10-30sec
large dither	up to 10” from centre, cadence a few minutes
sky offset	up to 15arcmin, cadence 20-30mins

Data Rates & Volumes:

typical observation for a 1hr OB might be:

preset + [((3s exp. + 1s readout)×5 + 2s small dither)×10 + 20s large dither]×14

1 preset
14 telescope offsets
700 detector readouts (58% efficiency)
700GB raw data (i.e. 6-7TB per night)

MICADO Key Capabilities

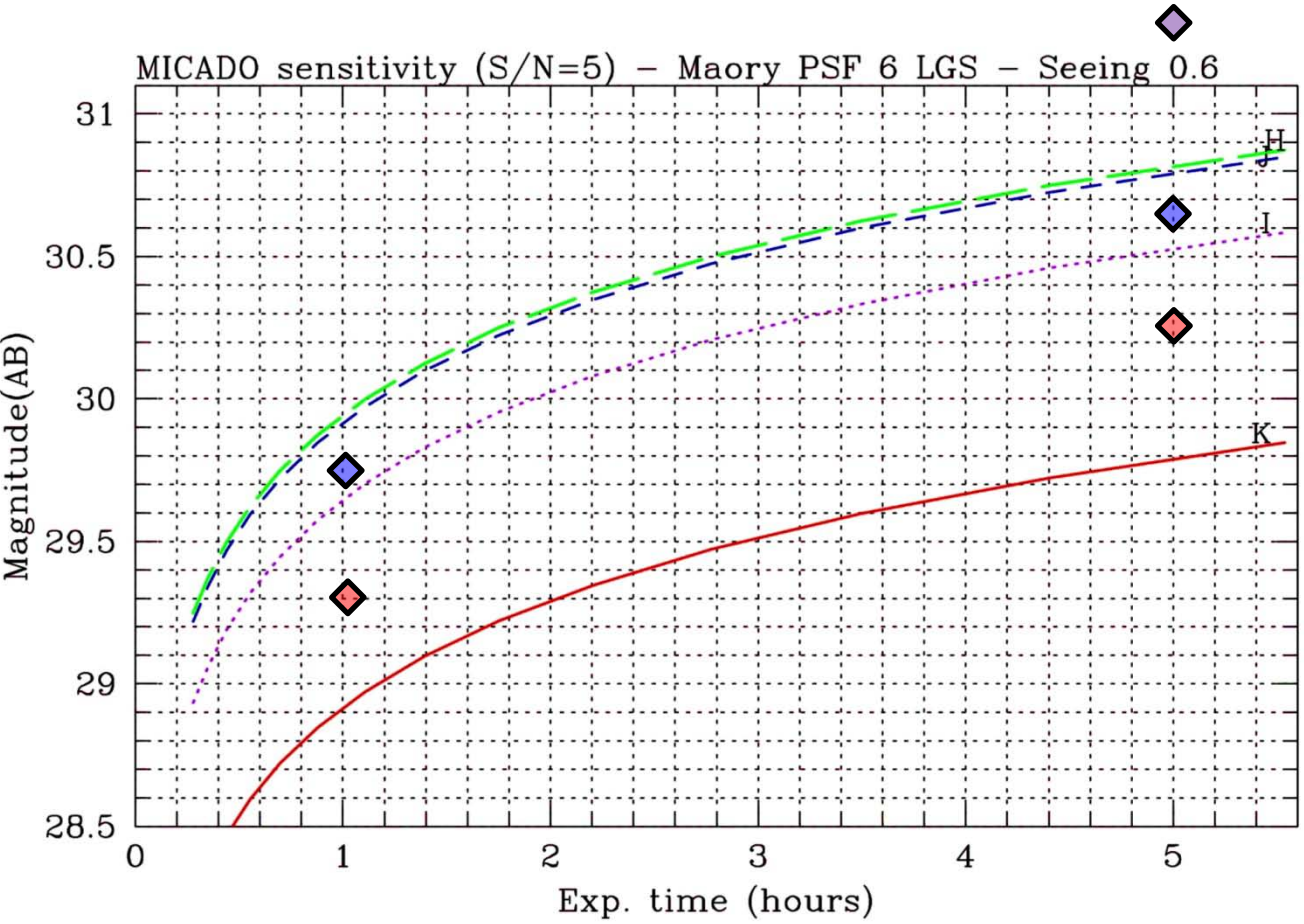
- **Sensitivity & Resolution**
  - 0.8-2.4µm; JH ~ 30.8mag AB in 5 hrs to 5σ
  - JH sensitivity comparable to JWST, up to 3mag deeper in crowded fields
  - resolution of 6-10mas over 1arcmin field
  - up to 0.5mag deeper with high efficiency broadband filters & OH suppression
- **Precision Astrometry**
  - <50µas over full 1arcmin field
  - 10µas/yr = 5km/s at 100kpc after 3-4 years
  - bring precision astrometry into mainstream
- **High throughput Spectroscopy**
  - simple high-throughput slit spectroscopy
  - ideal for compact sources
  - 12mas slit for maximum sensitivity, R~3000
  - JH ~ 27.2mag AB in 5 hrs to 5σ between OH
- **Simple, Robust, Available early**
  - optical & mechanical simplicity for stability
  - exemplifies most unique features of E-ELT
  - flexibility to work with SCAO, LTAO, MCAO

MICADO Science

- **Sensitivity & Resolution**
  - star formation history via resolved stellar populations to Virgo cluster
  - structure of high-z galaxies on 100pc scales: galaxy formation & evolution
  - environment and host galaxies of QSOs at high-z
  - nuclei of nearby galaxies (stellar cusps, star formation, black holes)
- **Precision Astrometry**
  - stellar motions within light hours of the Galaxy's black hole
  - intermediate mass black holes in stellar clusters
  - globular cluster proper motions: formation & evolution of the Galaxy
  - dwarf spheroidal motions test dark matter & structure formation
- **High throughput Spectroscopy**
  - Galactic Centre; stellar types & 3D orbits
  - stellar velocities in nearby galaxies: M_{BH}, extended mass distributions
  - absorption lines: ages, metallicities, central dispersions of first elliptical galaxies at z=2-3
  - spectra of first supernovae at z=1-6
  - emission lines: redshifts, velocities, metallicities of starburst galaxies at z=4-6

Sensitivity: imaging

Isolated Point Sources to 5σ

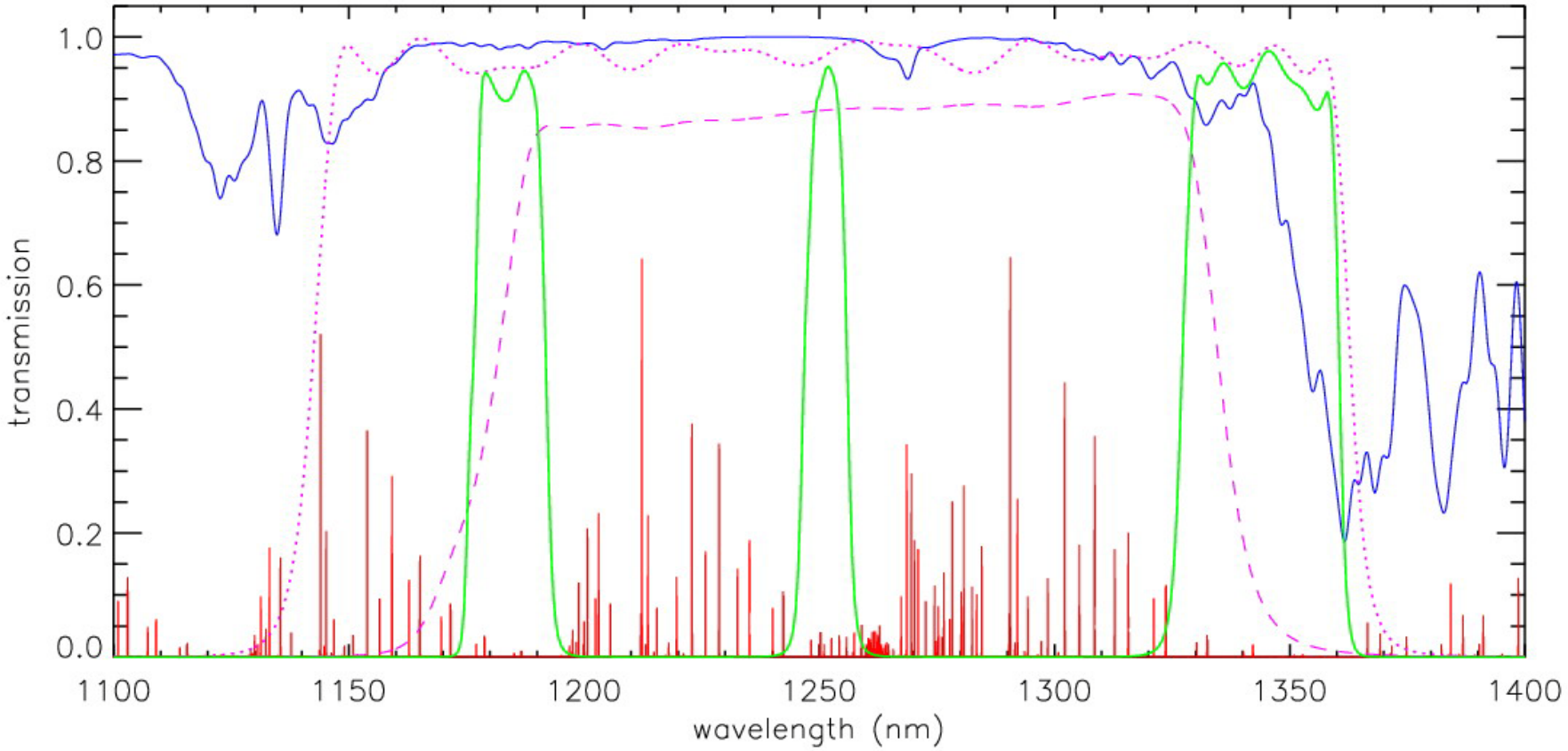


- JWST in J-band
- MICADO in J-band with high efficiency filter
- (i) JWST in K-band; (ii) MICADO with low telescope + AO background & a high efficiency filter

5hrs, 5σ	J_{AB}	H_{AB}	K_{AB}
Imaging	30.8	30.8	29.8
Imaging with advanced filters	31.3	31.3	30.2

High Efficiency Filters

- prototype filters have been manufactured by LZH
- broad J-band with 98% throughput; also OH suppression
  - ×1.34 increase in S/N wrt HAWK-I filters
  - ×1.8 more efficient in terms of observing time to reach same S/N
- technical developments in progress to reach MICADO requirements



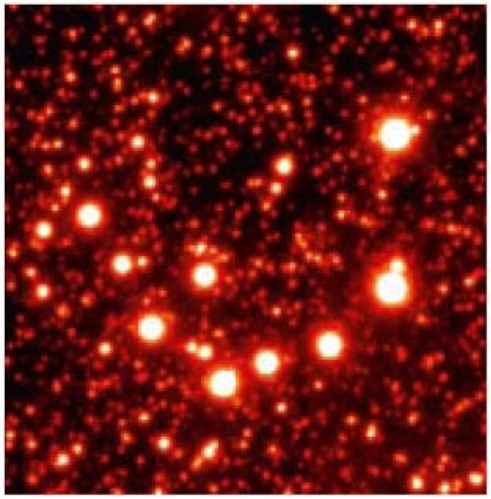
Impact of Crowding: MICADO vs JWST

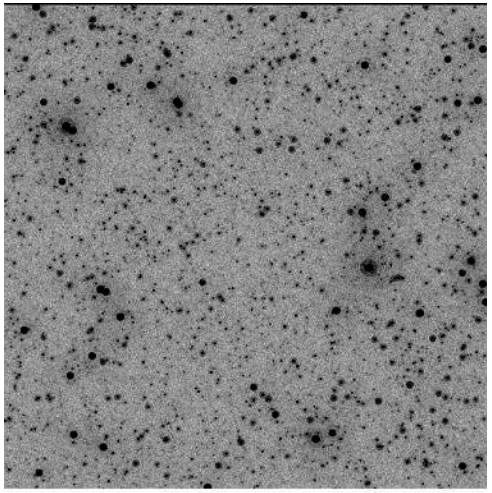
Resolution gives an effective sensitivity gain – cf. 3mag for MAD vs ISAAC.

Data for Omega-Cen
(Marchetti+ 07)

5-hr K-band simulated exposure

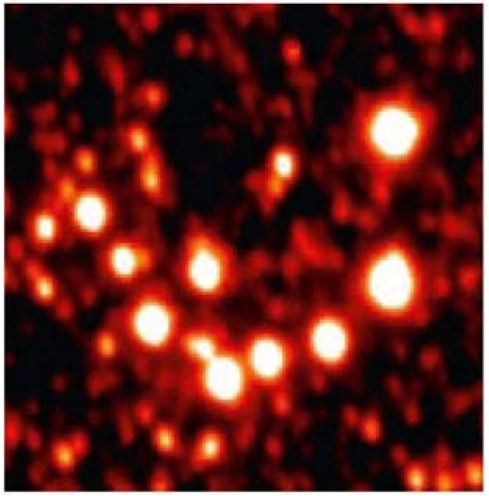
MAD

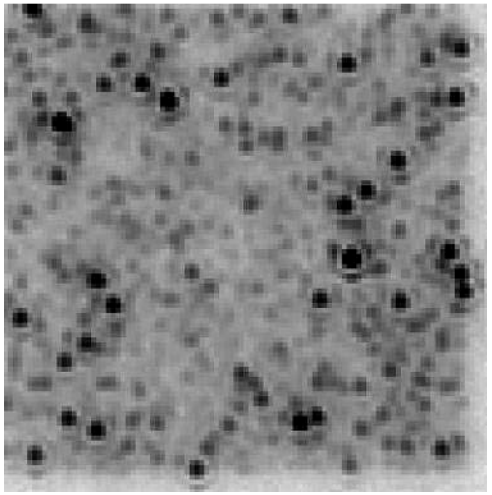




MICADO

ISAAC

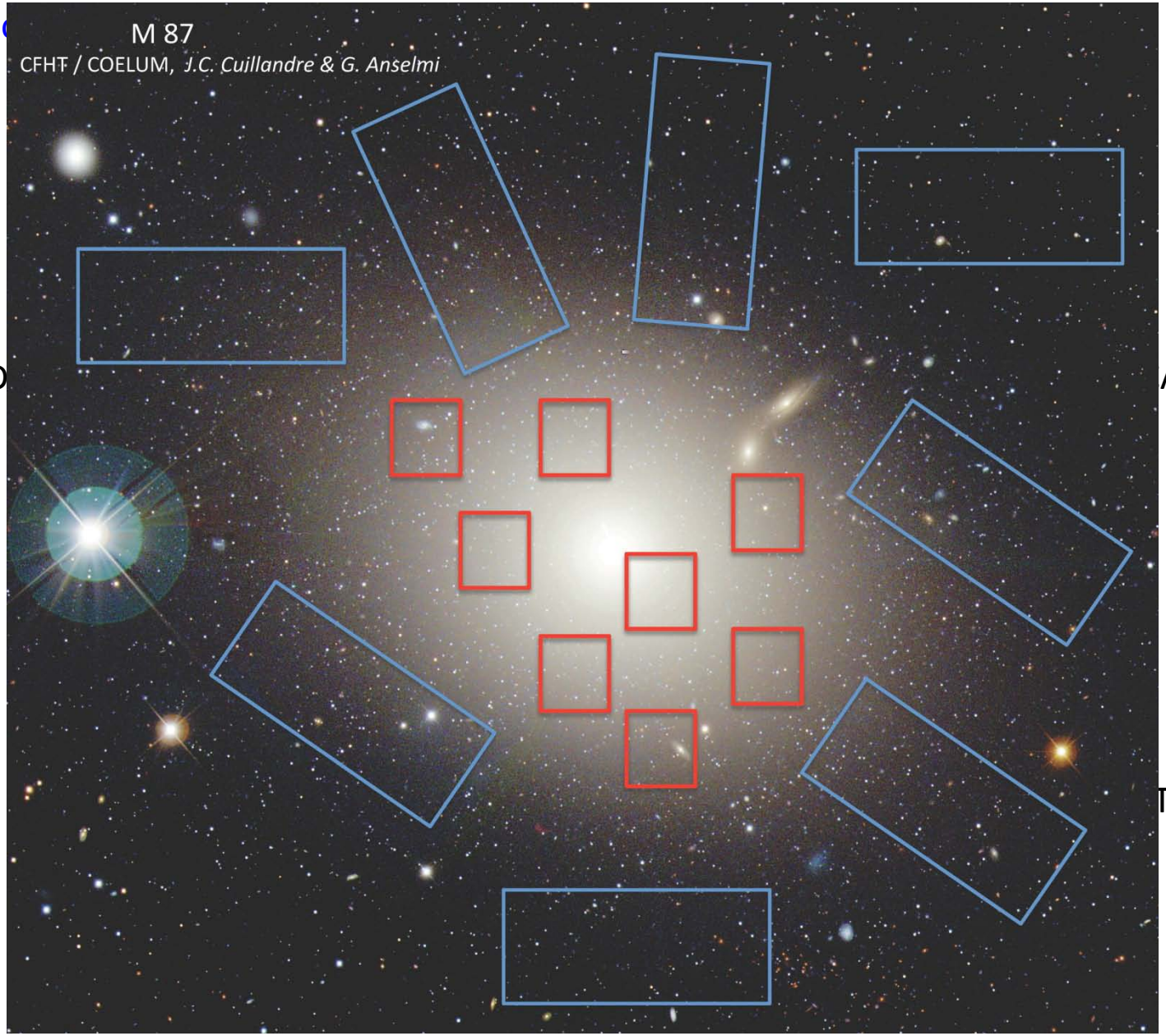




JWST

Impact of Crowding: MICADO vs JWST

Resolutio

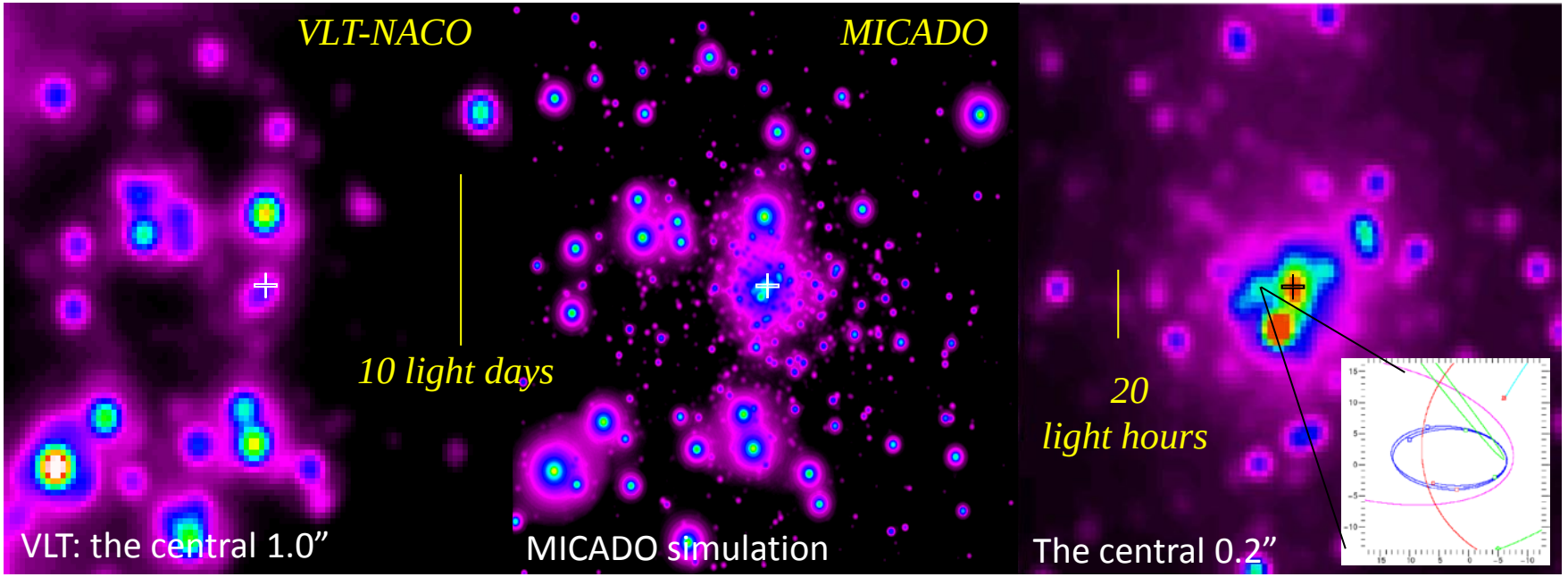


MAD ADO

ISAAC T

Galactic Centers near & far

- Unique laboratory for exploring strong gravity around the closest massive black hole
- Crucial guide for accretion onto black holes & co-evolution of star clusters and AGN
- Other galaxies possible, e.g. Cen A, M_{BH}=5 $10^7 M_{sun}$ velocities 1000km/s = 50µas/yr



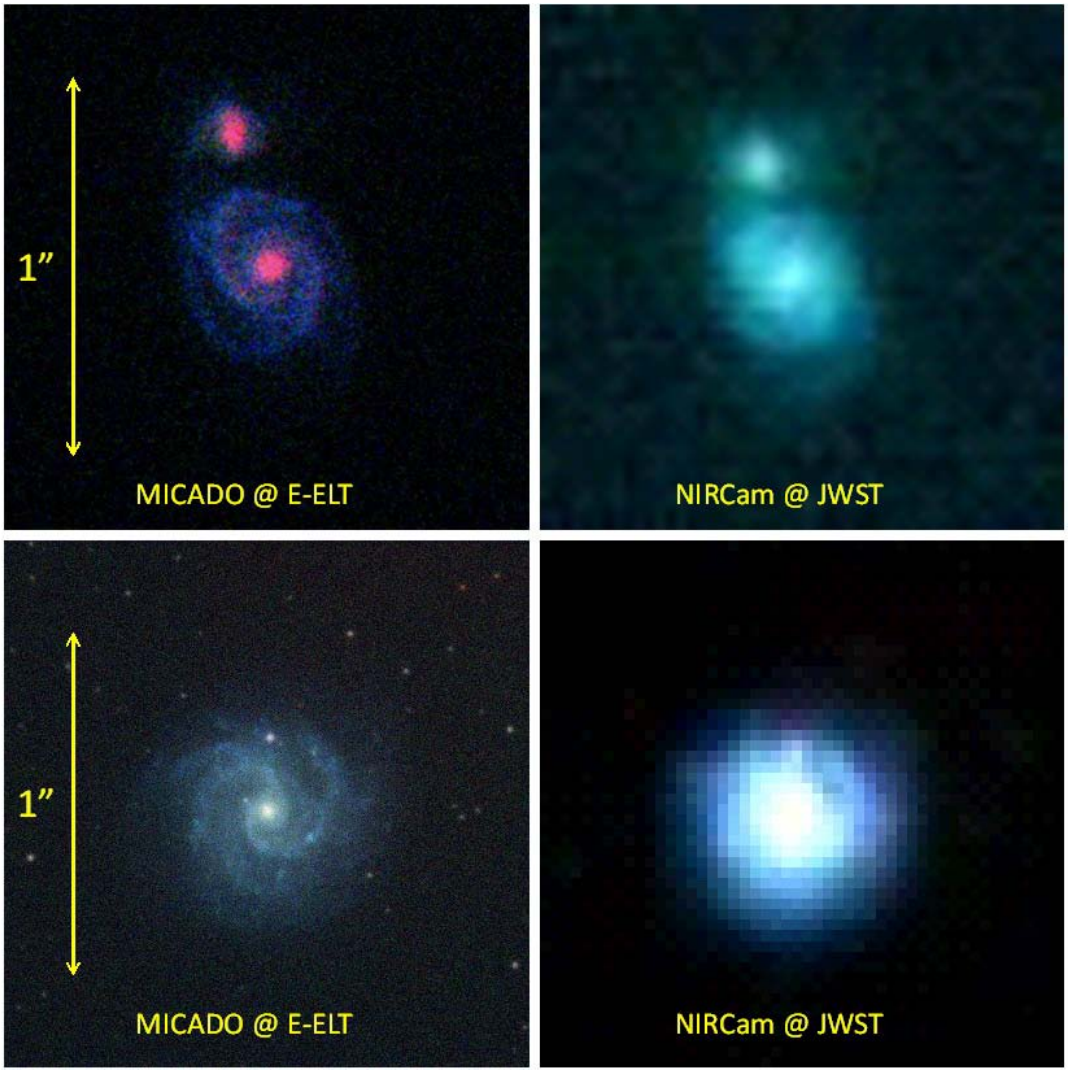
- sensitivity >5mag fainter, resolution & astrometry 5x better than NACO on VLT
- density profile, luminosity function to <1M_{sun}, shape of IMF
- orbits of stars closest to BH; prograde & retrograde precession
- proper motions of ~1000 stars: accurate distance, phase-space clumping (disks), binary fraction, intermediate mass BHs

Galaxies at High Redshift

JWST will select samples & measure basic galaxy properties

MICADO will provide the details of their structure to answer: What are the physical processes driving their evolution?

obvious synergies with ALMA, HARMONI, EAGLE for kinematics (rotation curves, clump dispersions) & gas content



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.

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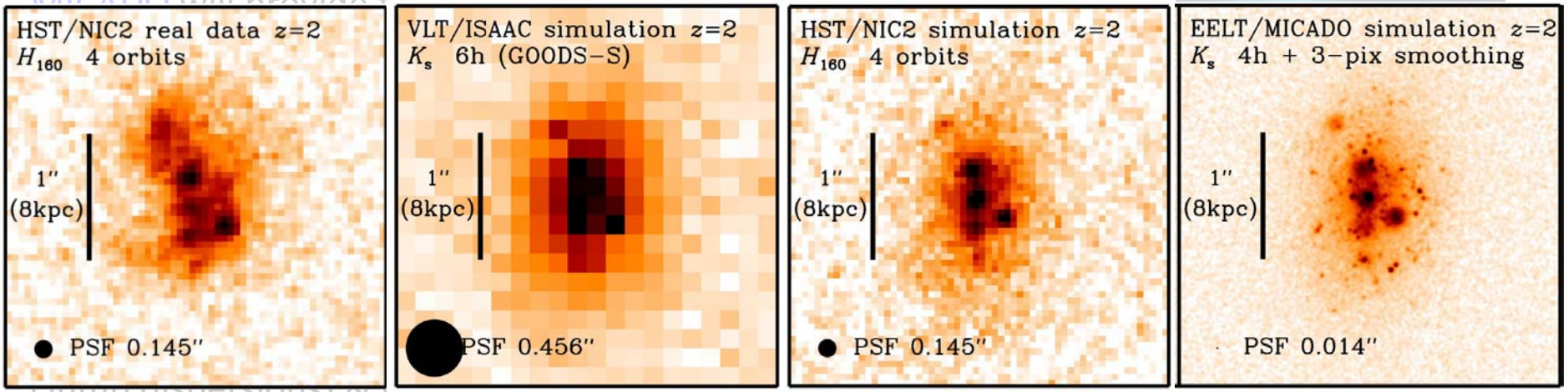
clump dispersions) & gas content

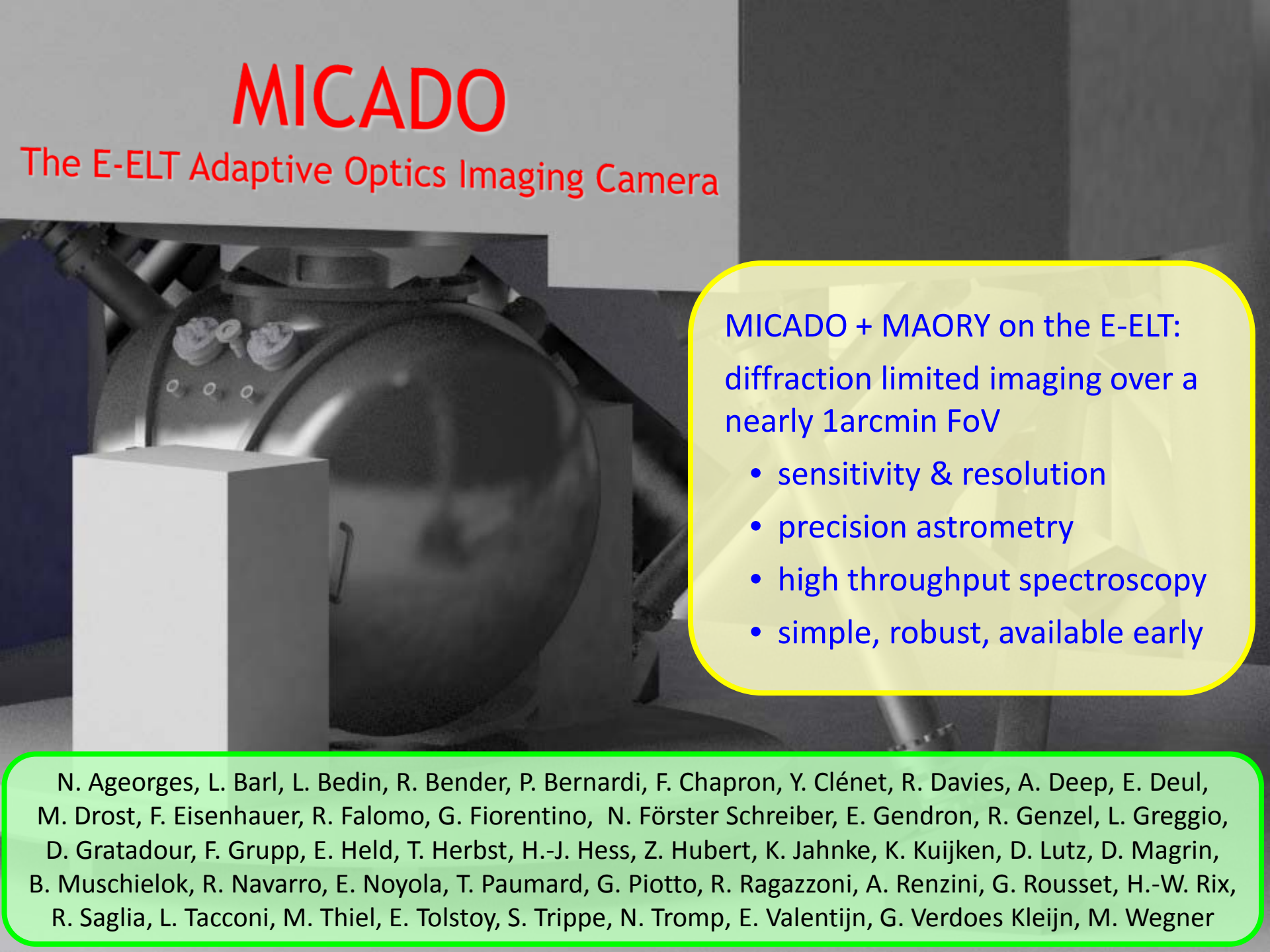


simulation of a large bright disk galaxy at z = 2.3 ($R_{1/2}$ = 5 kpc, K_{AB} = 21.3), showing that MICADO will be able to measure sizes, distribution and luminosity functions of compact clusters to K_{AB} ~ 28.5

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.

MICADO

The E-ELT Adaptive Optics Imaging Camera



MICADO + MAORY on the E-ELT:

diffraction limited imaging over a nearly 1arcmin FoV

- sensitivity & resolution
- precision astrometry
- high throughput spectroscopy
- simple, robust, available early

N. Ageorges, L. Barl, L. Bedin, R. Bender, P. Bernardi, F. Chapron, Y. Clénet, R. Davies, A. Deep, E. Deul, M. Drost, F. Eisenhauer, R. Falomo, G. Fiorentino, N. Förster Schreiber, E. Gendron, R. Genzel, L. Greggio, D. Gratadour, F. Grupp, E. Held, T. Herbst, H.-J. Hess, Z. Hubert, K. Jahnke, K. Kuijken, D. Lutz, D. Magrin, B. Muschielok, R. Navarro, E. Noyola, T. Paumard, G. Piotto, R. Ragazzoni, A. Renzini, G. Rousset, H.-W. Rix, R. Saglia, L. Tacconi, M. Thiel, E. Tolstoy, S. Trippe, N. Tromp, E. Valentijn, G. Verdoes Kleijn, M. Wegner