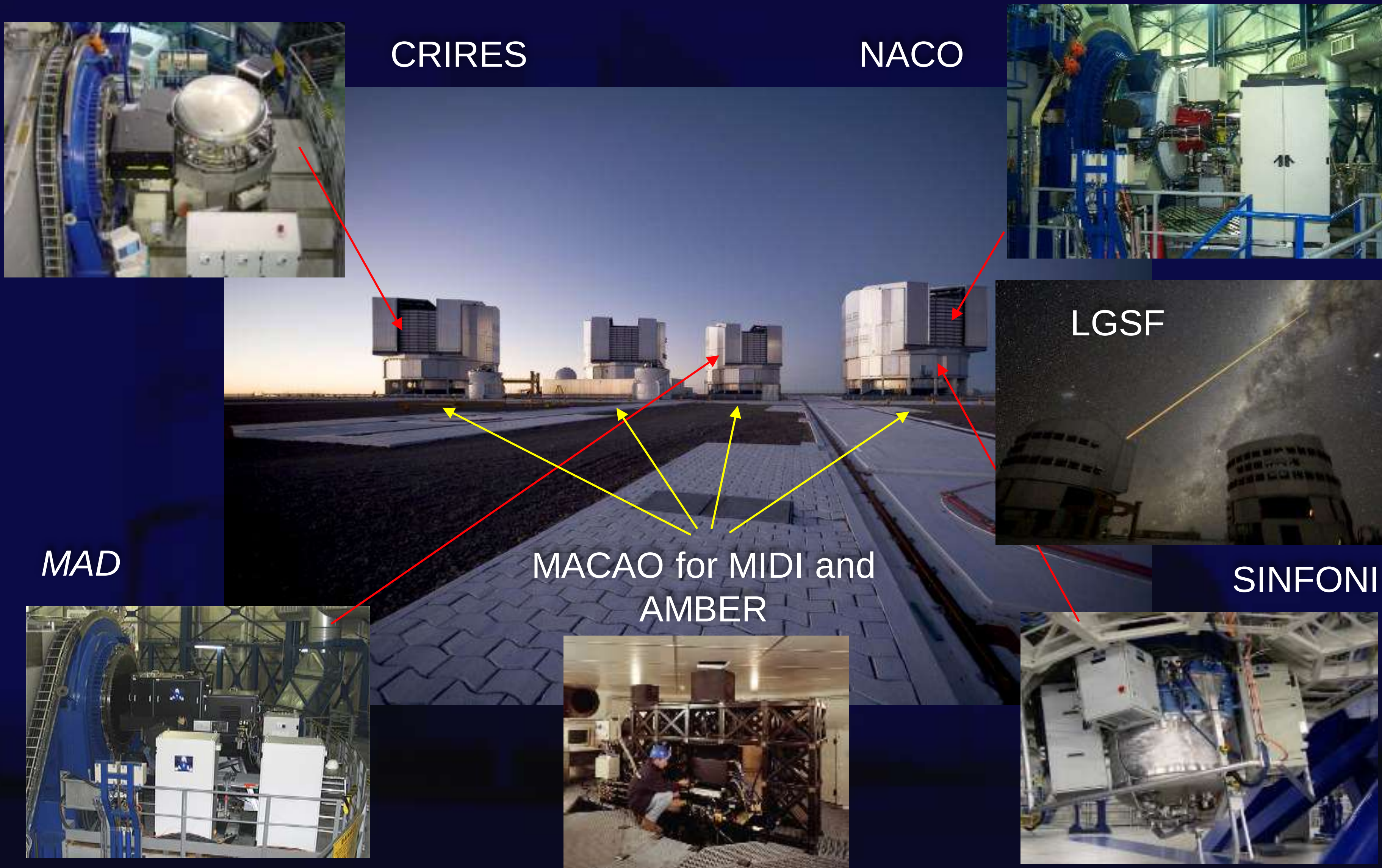
AO@ESO

Adaptive Optics Facilities at ESO

C. Lidman

NACO, SINFONI, CRIRES and *MAD*



NACO = NAOS + CONICA

ESO's multi-purpose AO facility

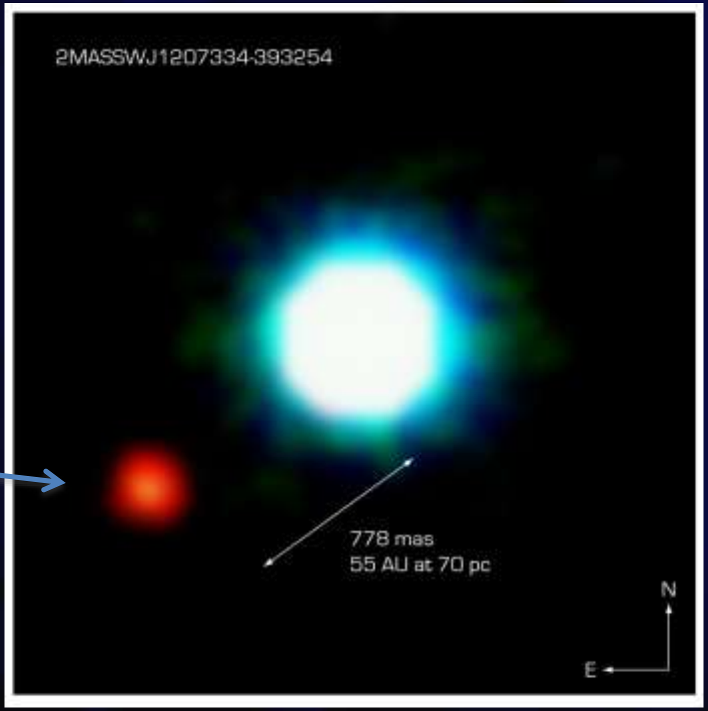
- Shack-Hartmann wave-front sensing - in the visible and near-IR
- Uses natural guide stars (R=16,K=13) or the laser guide star (R=19)
- CONICA has many Modes covering the 1 – 5 micron spectral range
  - Imaging
  - Coronography
  - Polarimetry
  - Spectroscopy
  - *SAM – Sparse Aperture Masking*
  - *SDI – Simultaneous Differential Imaging*
  - 4QPM, Cube mode, ADI – Angular differential imaging, …

NACO - Imaging

Near-IR WFS

- For red objects that are too faint for the visible WFS, e.g. brown dwarfs

4 to 8 Jupiter masses

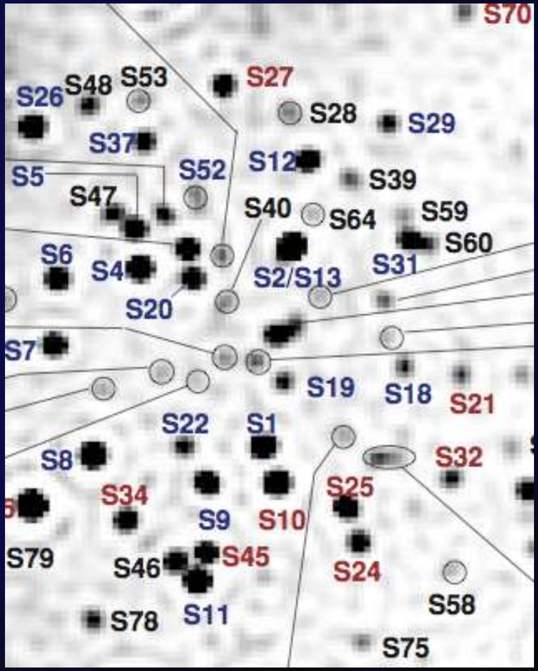


Chauvin et al (2004)

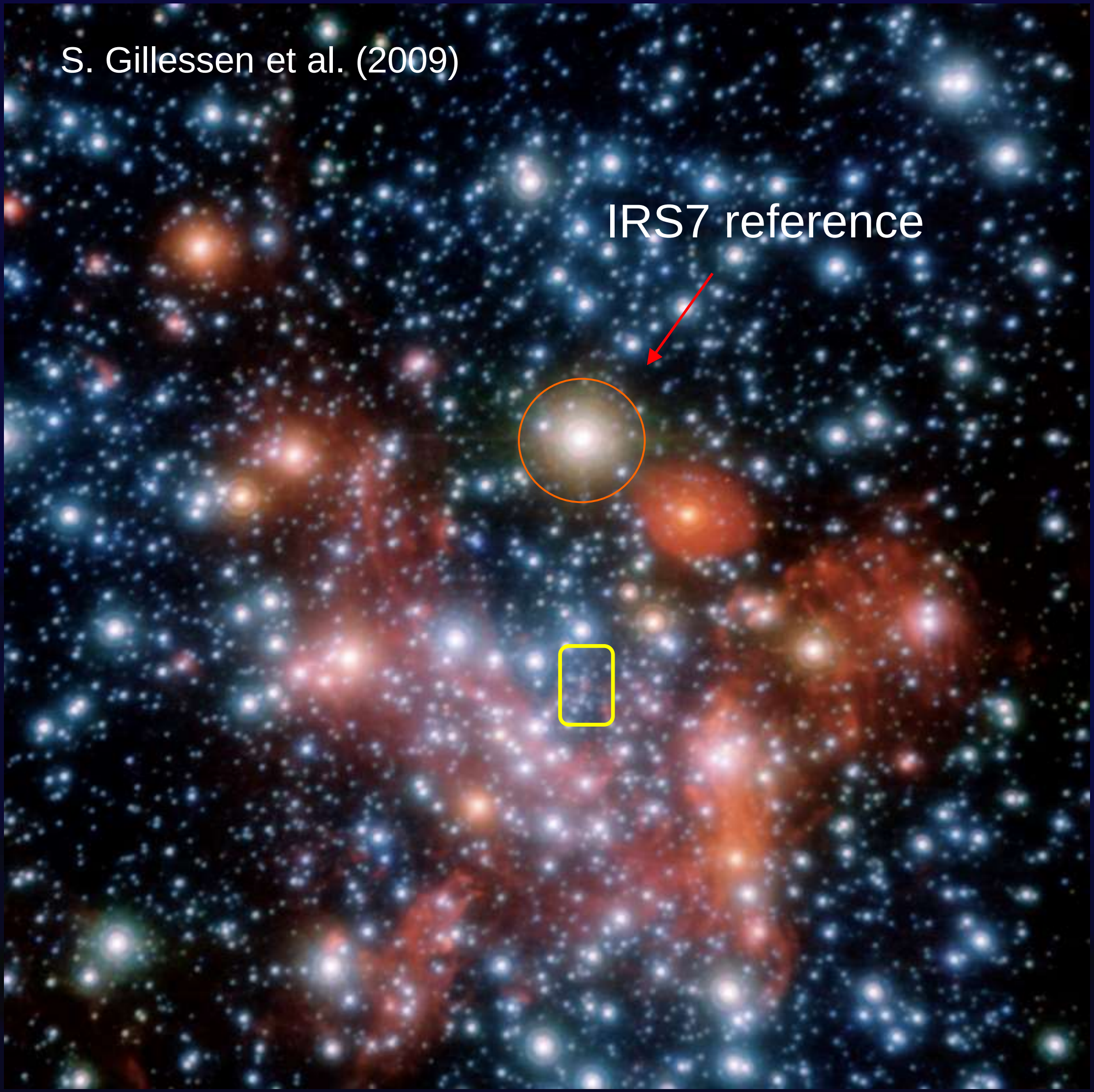
NACO - Imaging

Near-IR WFS

- For highly obscured objects, e.g. The Galactic Center

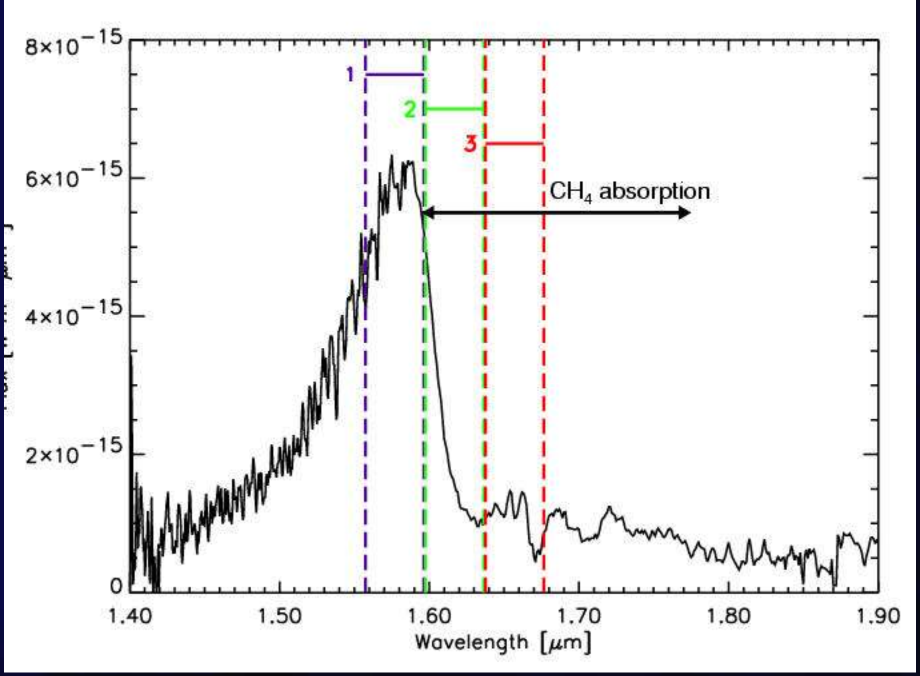


1"



NACO - SDI

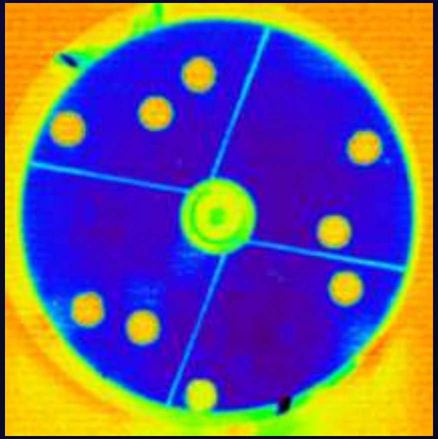
Simultaneous differential imaging (SDI)



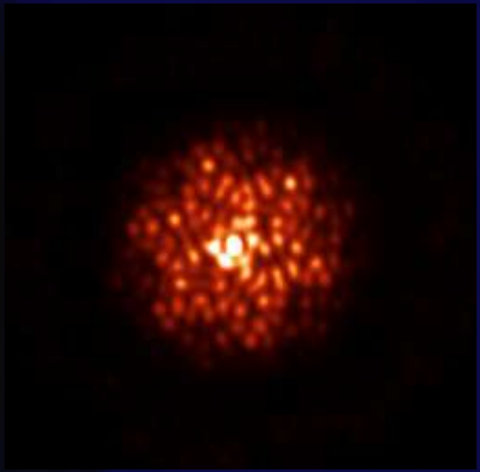
NACO - SAM

Sparse Aperture Masking (SAM)

What is it?



Pupil plane



PSF in image plane (snowflake)

What is it used for?

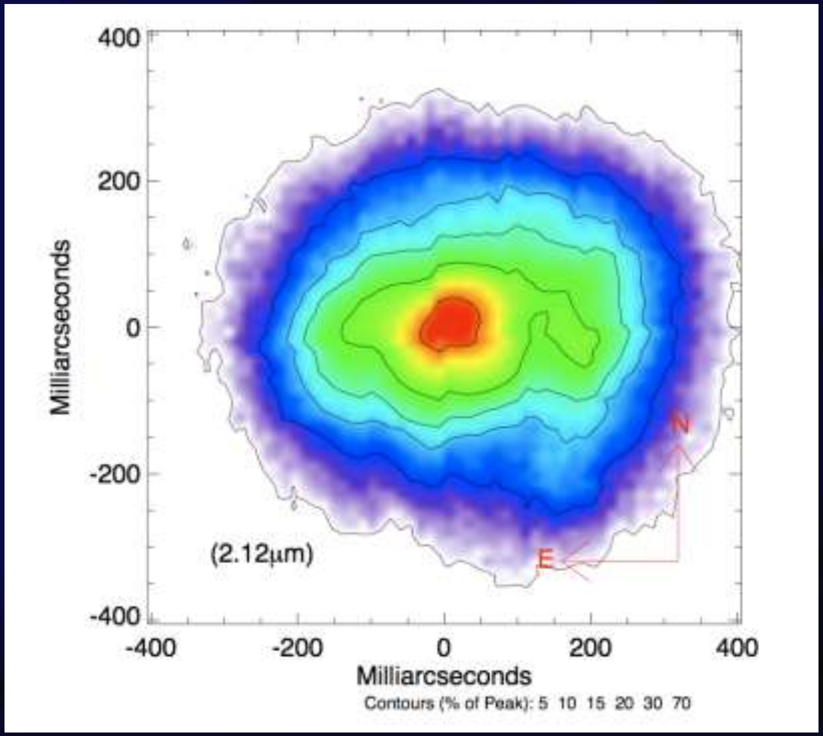
- High contrast and high angular resolution imaging.
- Narrow fields of view (few 100 mas)
- Relatively bright targets

SAM – a second example

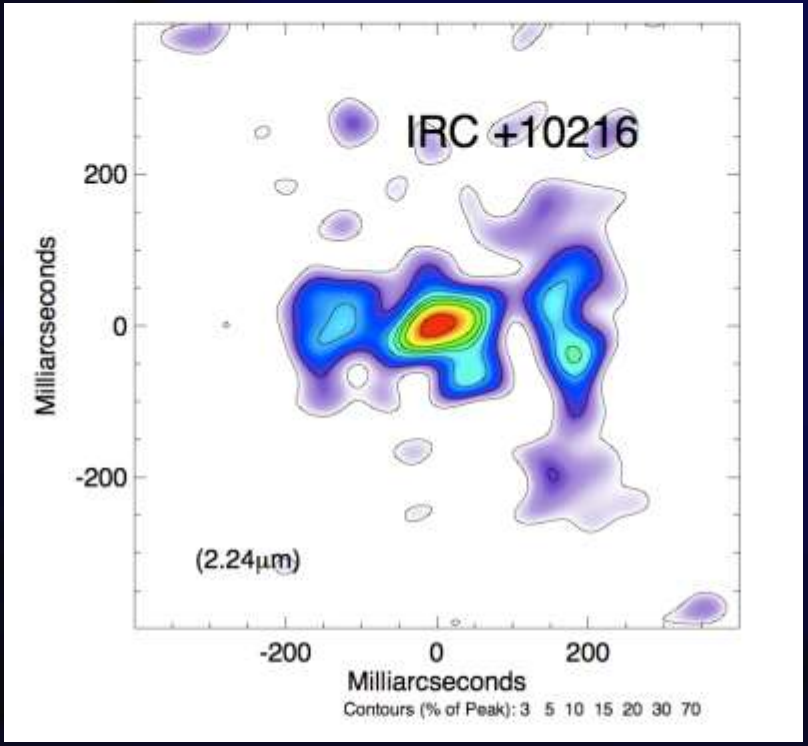
IRS +10216

- A clumpy carbon star

Full AO and full pupil



Full AO + SAM

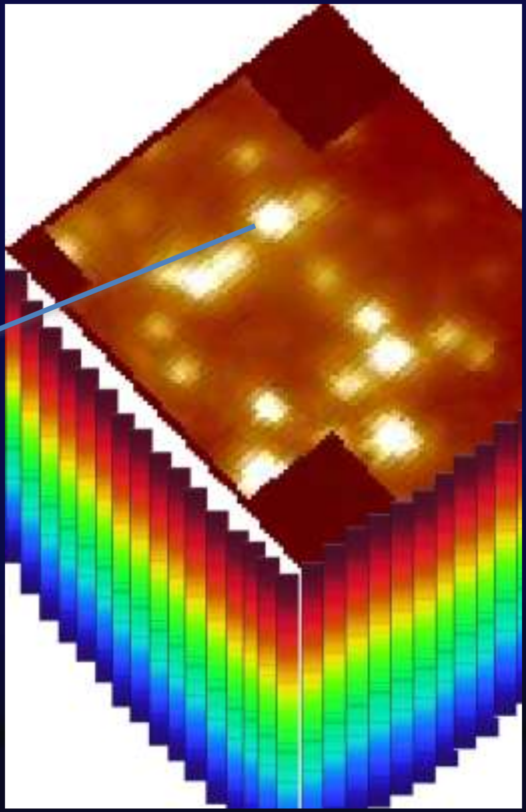


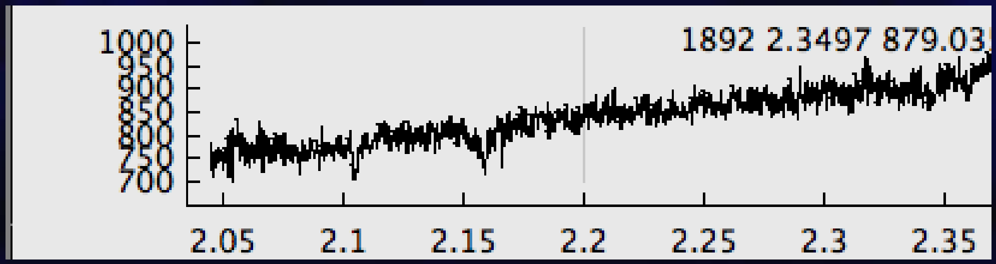
Courtesy of Peter Tuthill

SINFONI – 3D spectroscopy

An AO fed near-IR integral field unit (IFU)

- Uses natural guide stars (R=16) or laser guide stars (R=19)
- Curvature AO system
- Natural seeing mode
- Seeing enhancer mode - new
- A lot more extragalactic science

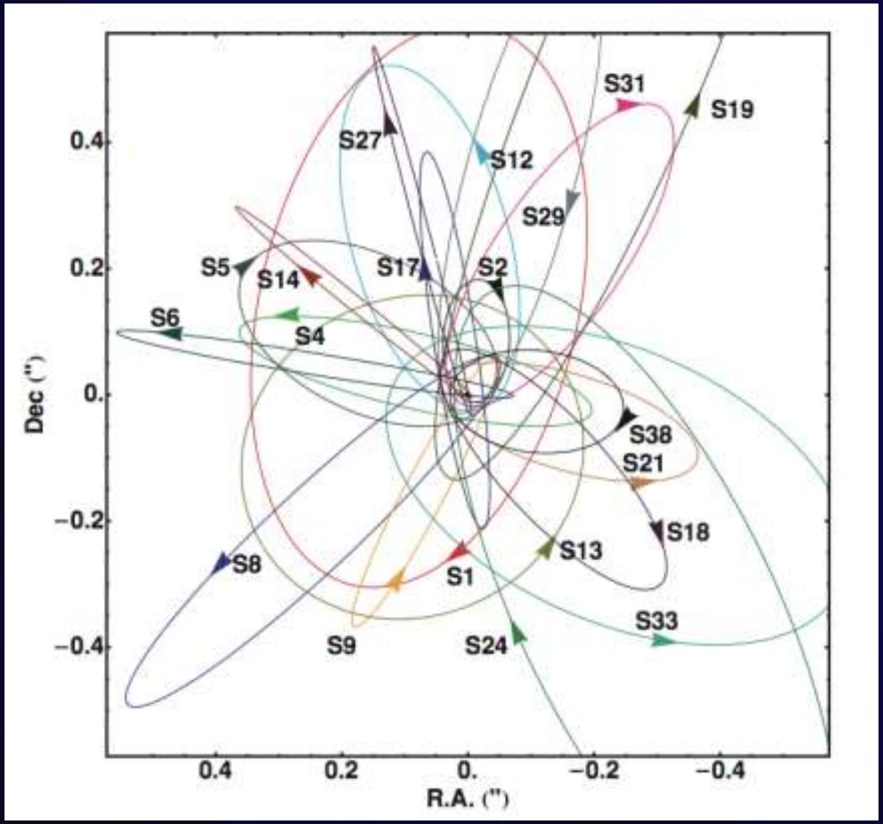




Science with SINFONI

Galactic Center Studies

- Orbits
- Stellar populations
- Super massive black hole

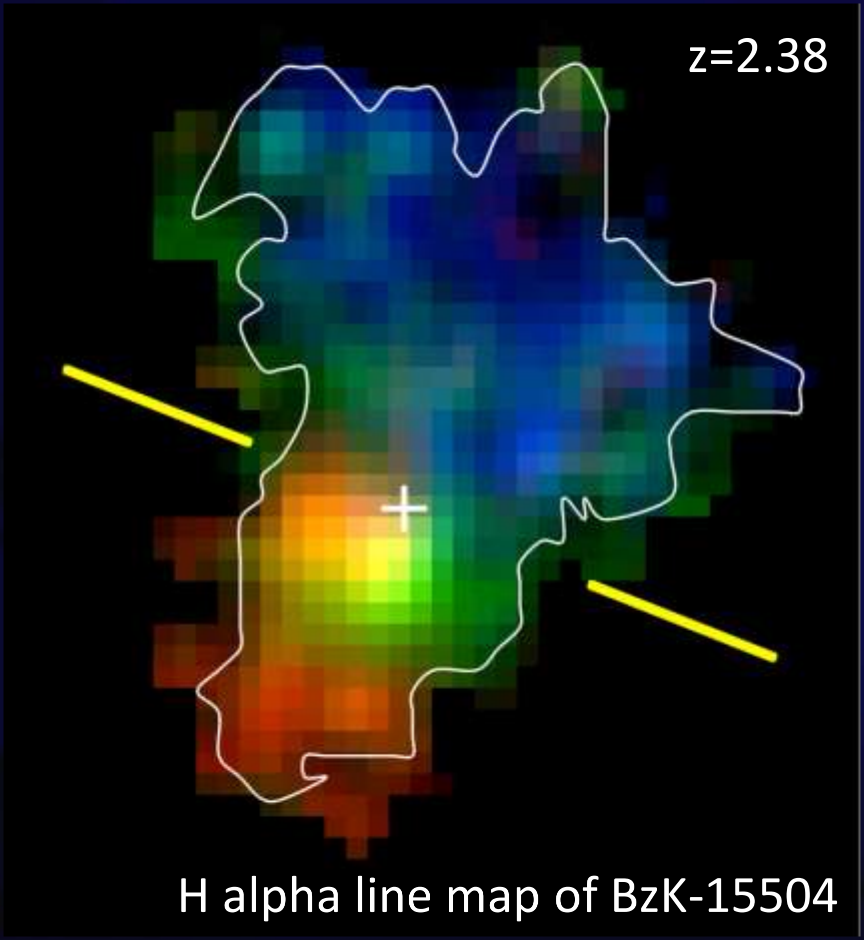


S. Gillessen et al. (2009)

Extragalactic Science with SINFONI

Much more done with SINFONI than NACO

Velocity fields of distant galaxies



Förster Schreiber et al.

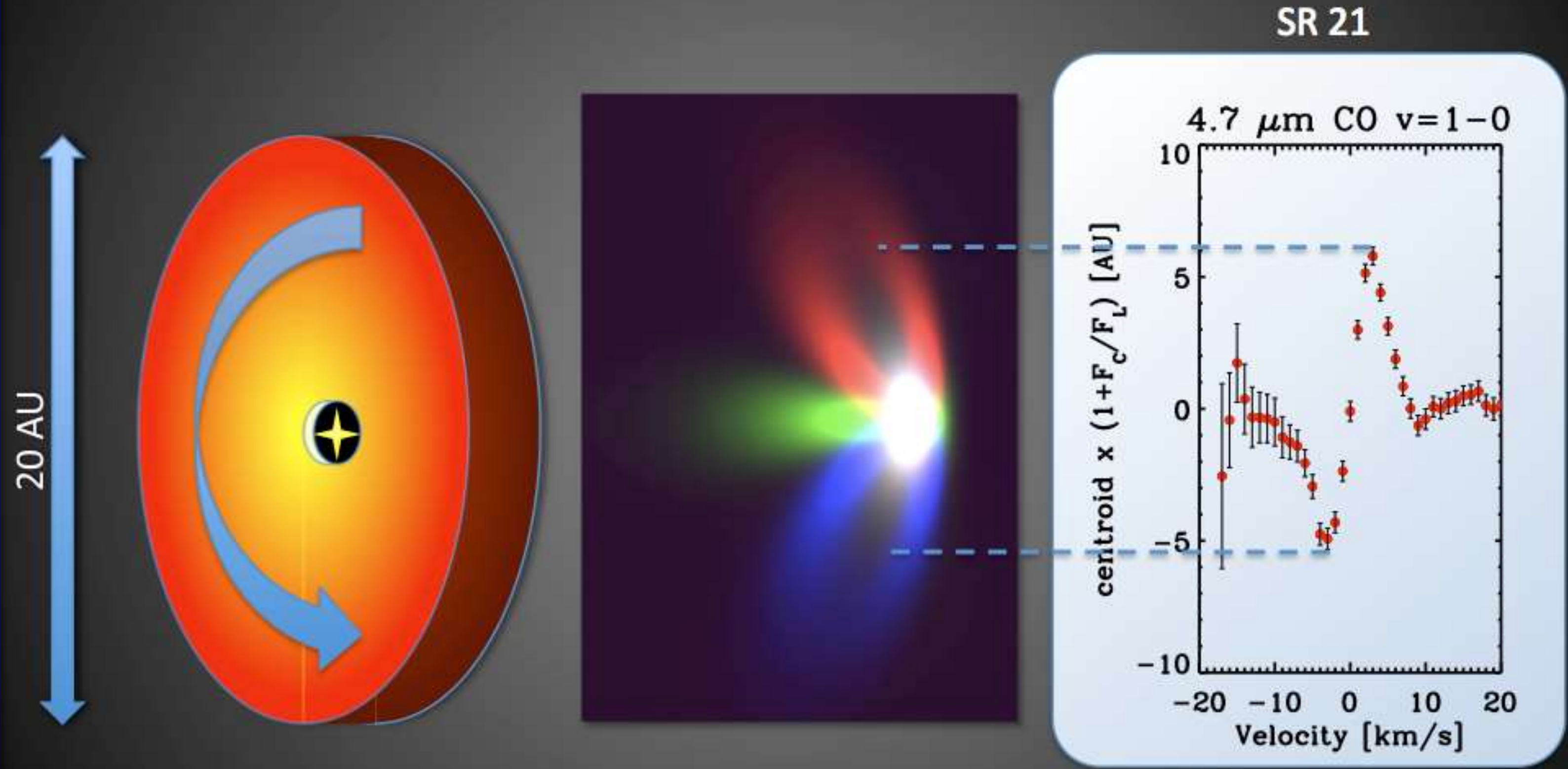
CRIRES

ESO's AO fed high resolution (R=100,000) 1-5 micron spectrograph

- Uses natural guide stars
- Natural seeing mode
- Curvature system
- Mostly stellar astronomy

CRIRES – Spectroastrometry

Milli-arcsecond imaging of molecular gas in protoplanetary disks

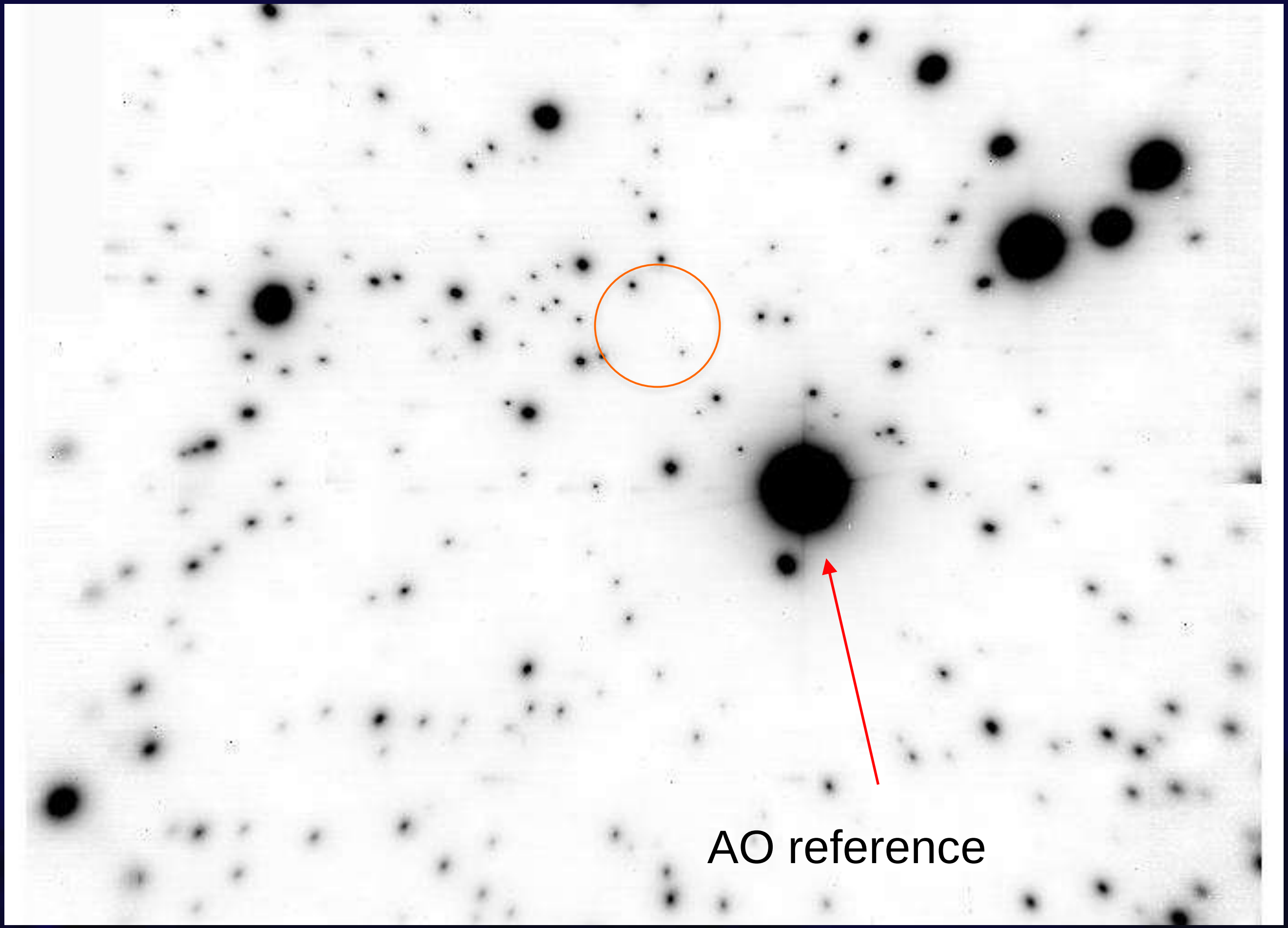


Pontoppidan et al.

Radiative transfer model

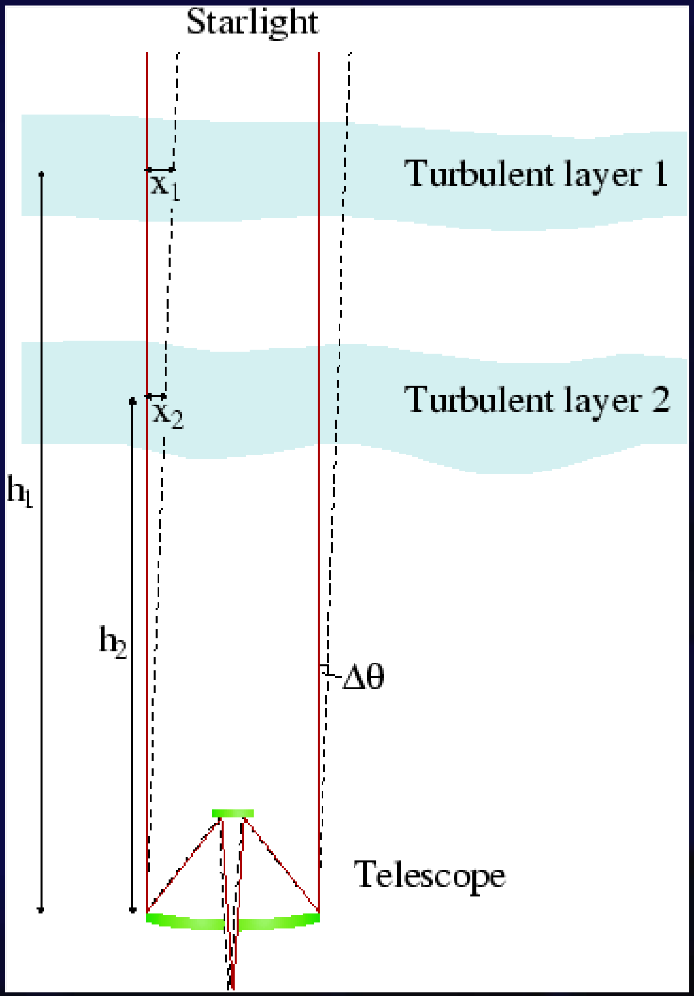
CRIRES Spectro-astrometry

Anisoplanatism



Even relative photometry is difficult!

What is anisoplanatism?



Decorrelation of the wavefront for an off axis source.

Characterized by the isoplanatic angle – ❑

Depends on the height of the turbulence layers ❑ ~ 1/h

Strong dependence on airmass

❑ ”

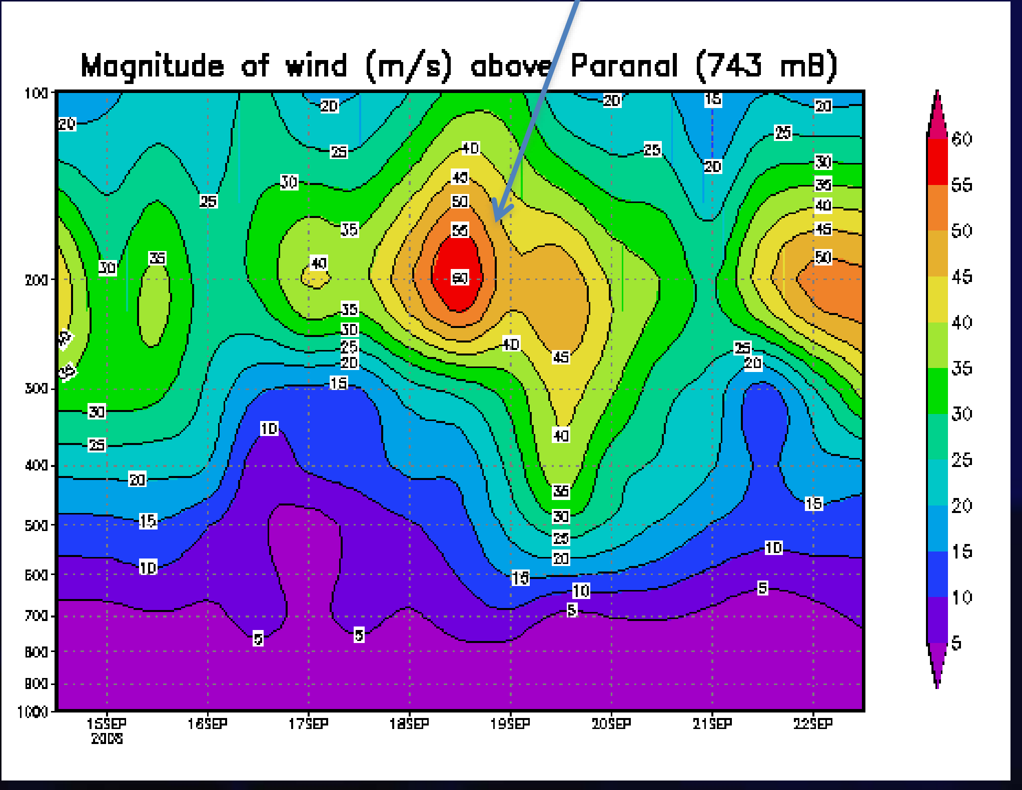
(airmass)$^{-8/5}$

Jet streams

The jet stream is time variable

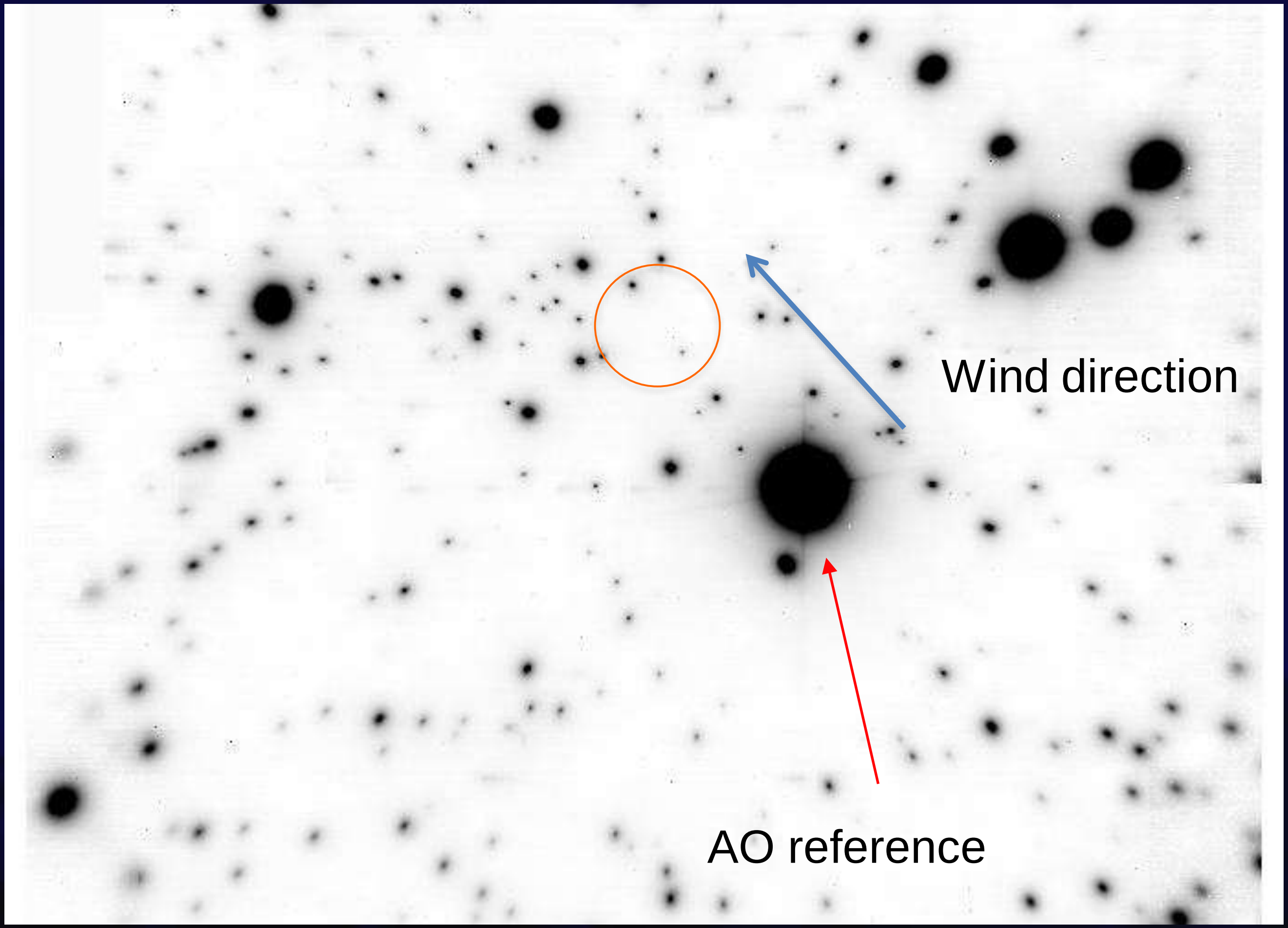
Strong Jet Stream (60 m/s) on the 18th

Height

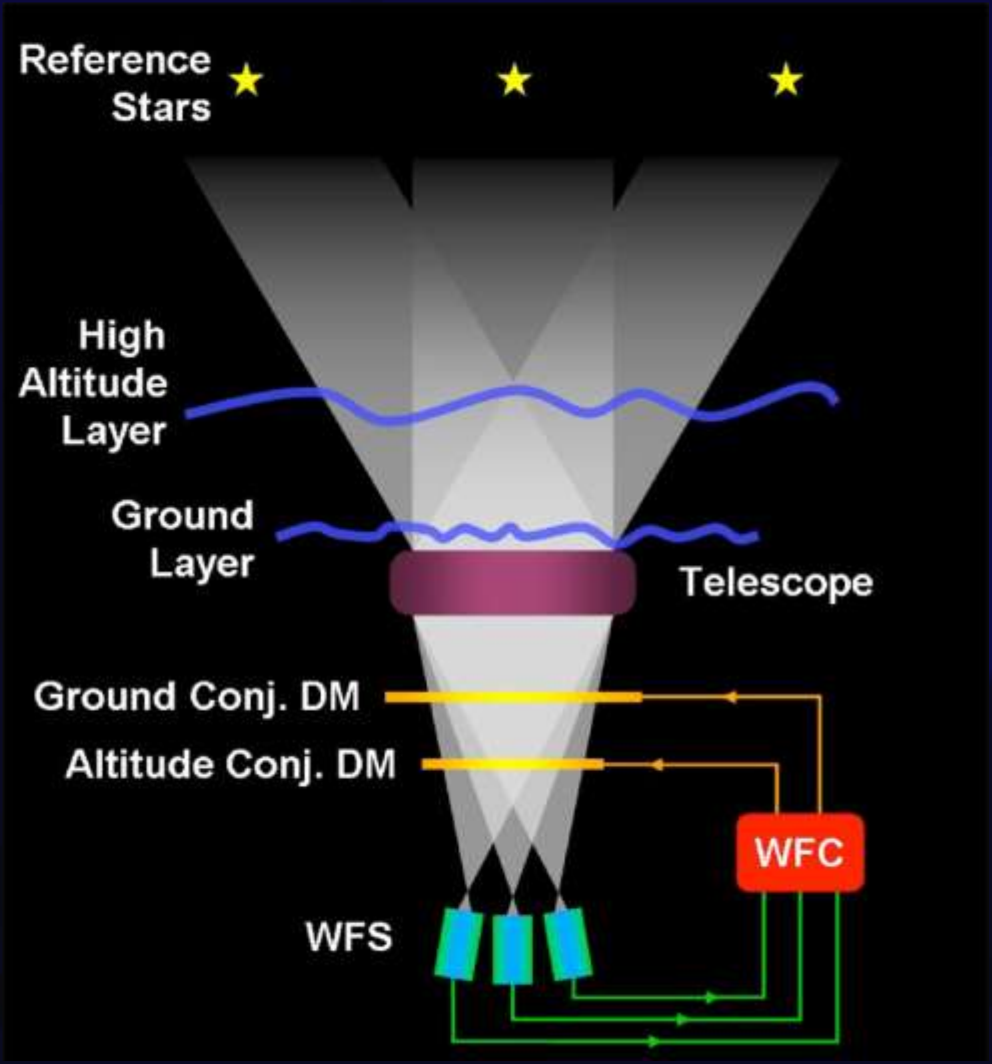


1 week

Anisoplanatism



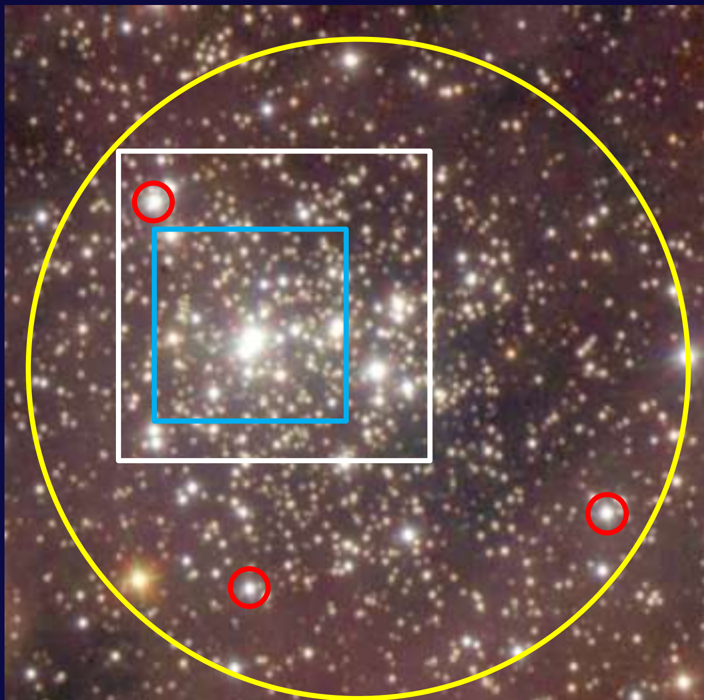
Multi-Conjugate AO - MCAO



The MAD experiment

- Multi-Conjugate Adaptive Optics (MCAO)
- MAD Star Oriented system
  - Wavefront sensing on 3 Natural Guide Stars in 2 arcmin FoV
  - Correcting with 2 deformable mirrors (0 & 8.5 Km)
  - IR camera imager CAMCAO
- Three science demonstration runs (Nov’07-Jan’08-Aug’08)

Trumpler 14



MAD [H] 0.028”/px

T_{epx}: 1680s

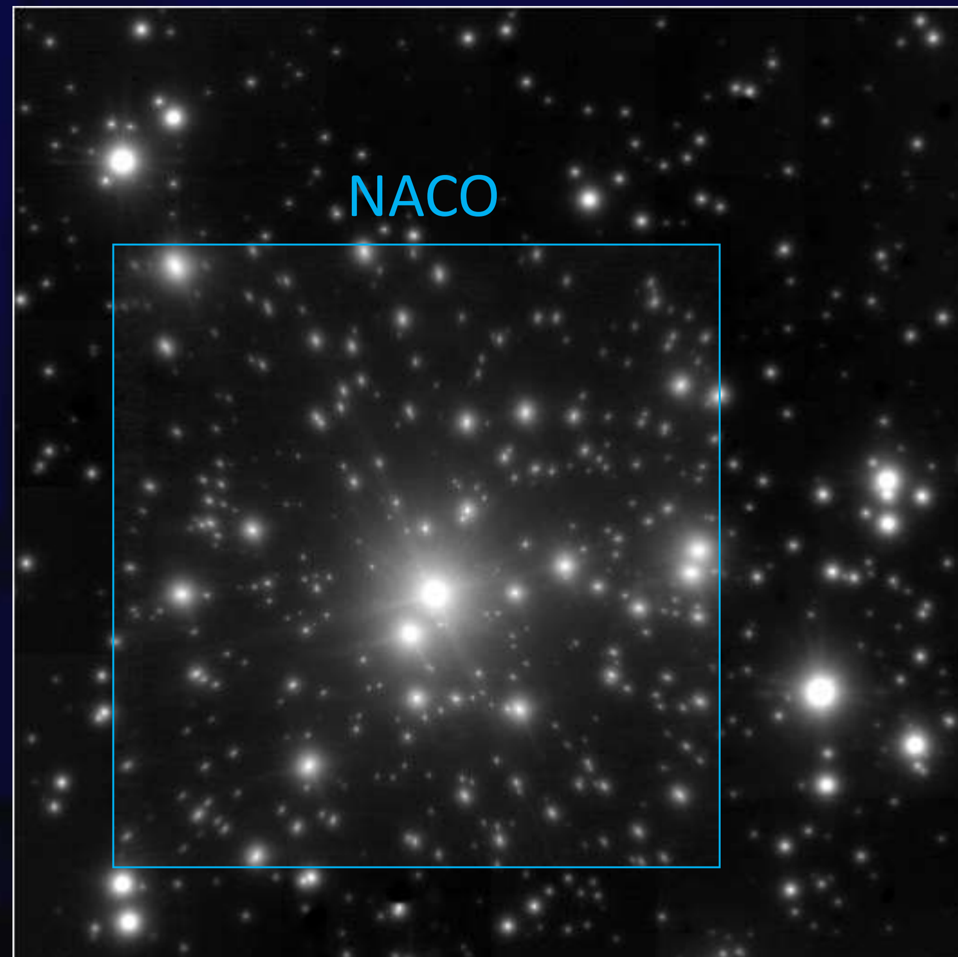
DIMM: 1.20”

NACO [H] 0.054”/px

T_{exp}: 690s

DIMM: 0.85”

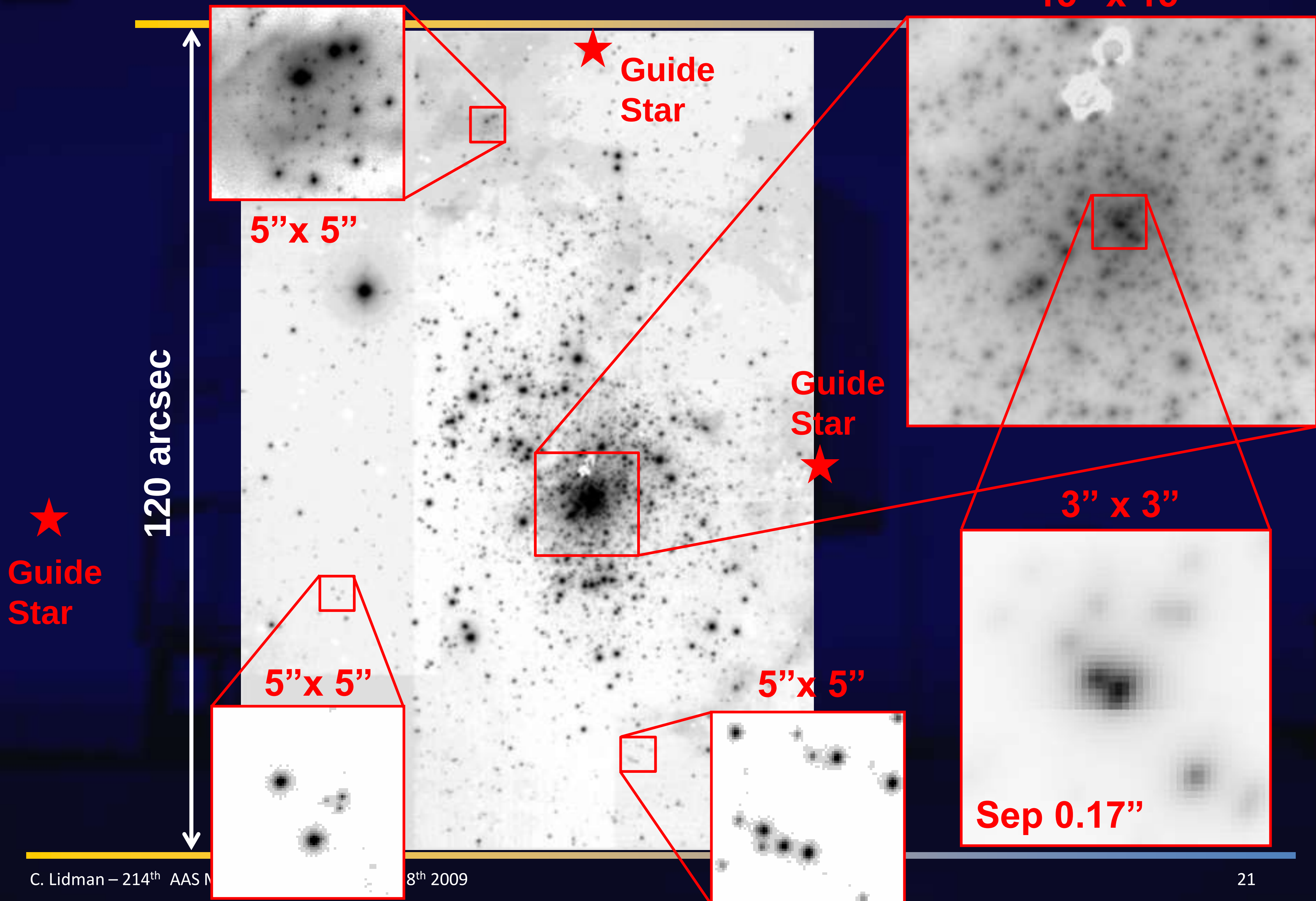
MAD



60” x 60”

Courtesy: J.Ascenso

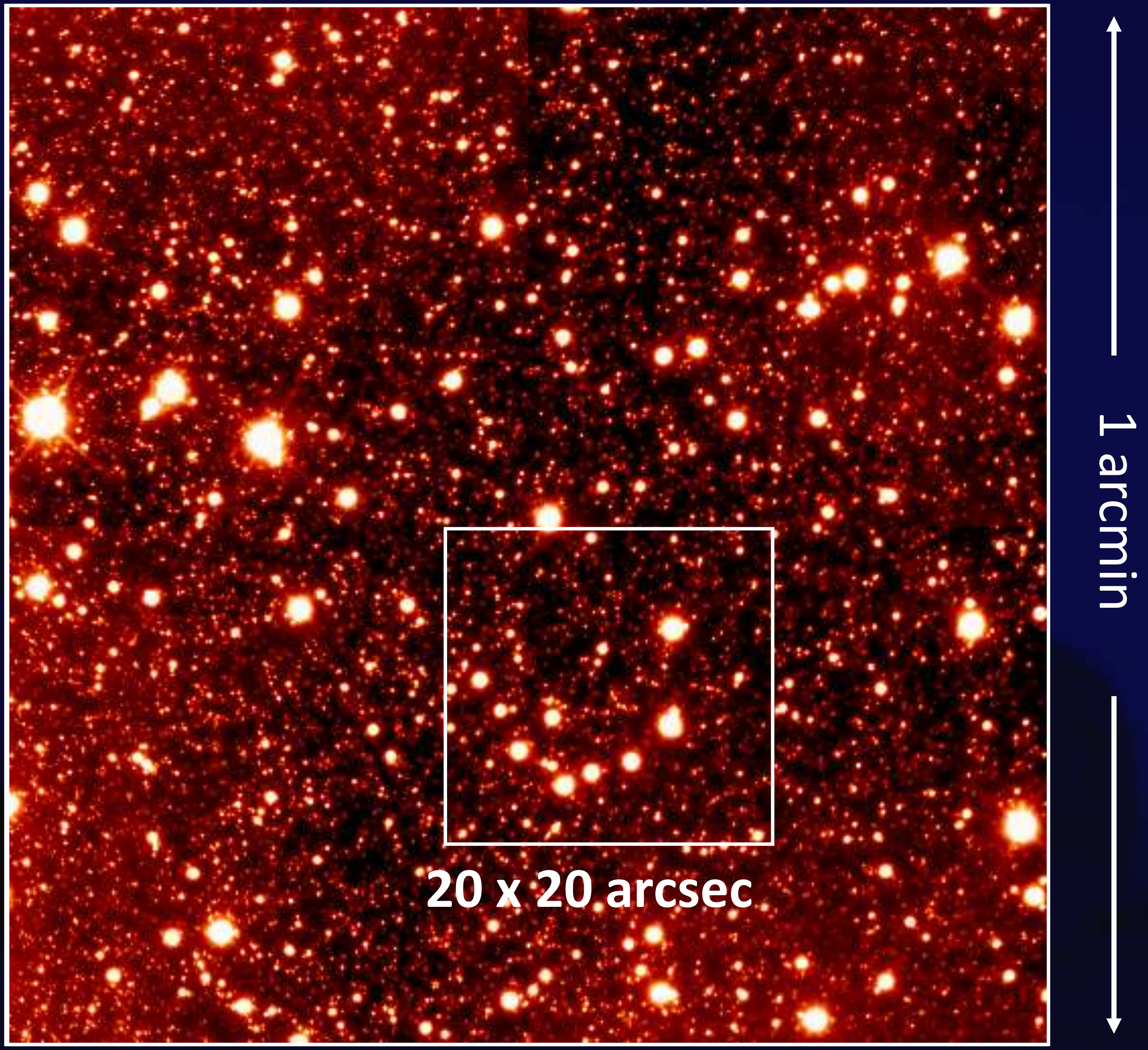
30 Doradus


15” x 15”
Guide Star
Guide Star
Guide Star
5”x 5”
5”x 5”
5”x 5”
120 arcsec
3” x 3”
Sep 0.17”

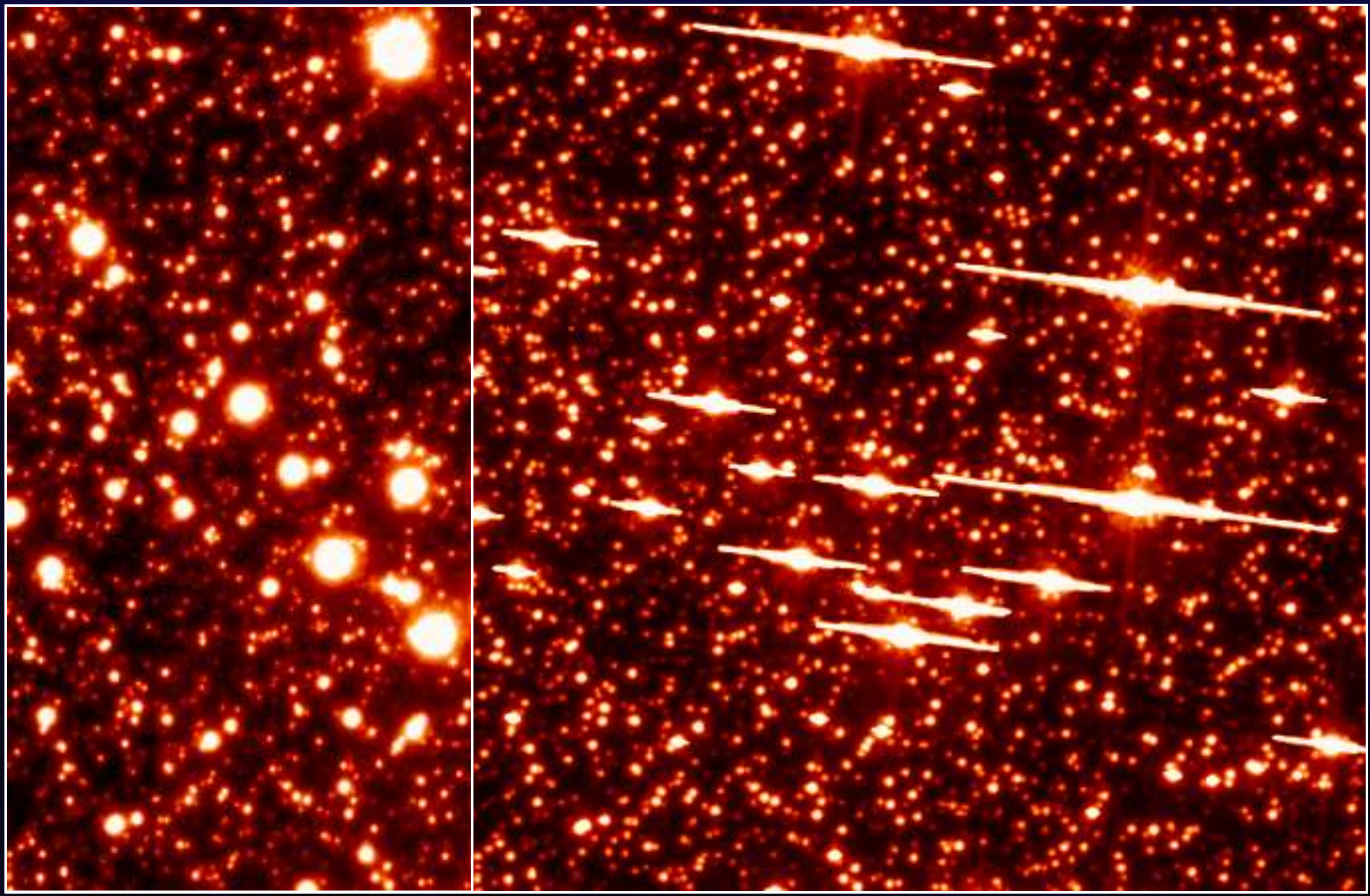
Omega Centauri

ISAAC: 1600s
FWHM: 400mas

MAD Ks 600s
FWHM: 100mas
K~20.5
DIMM: 0.69”



Guide stars @ 60” 20” x 20”



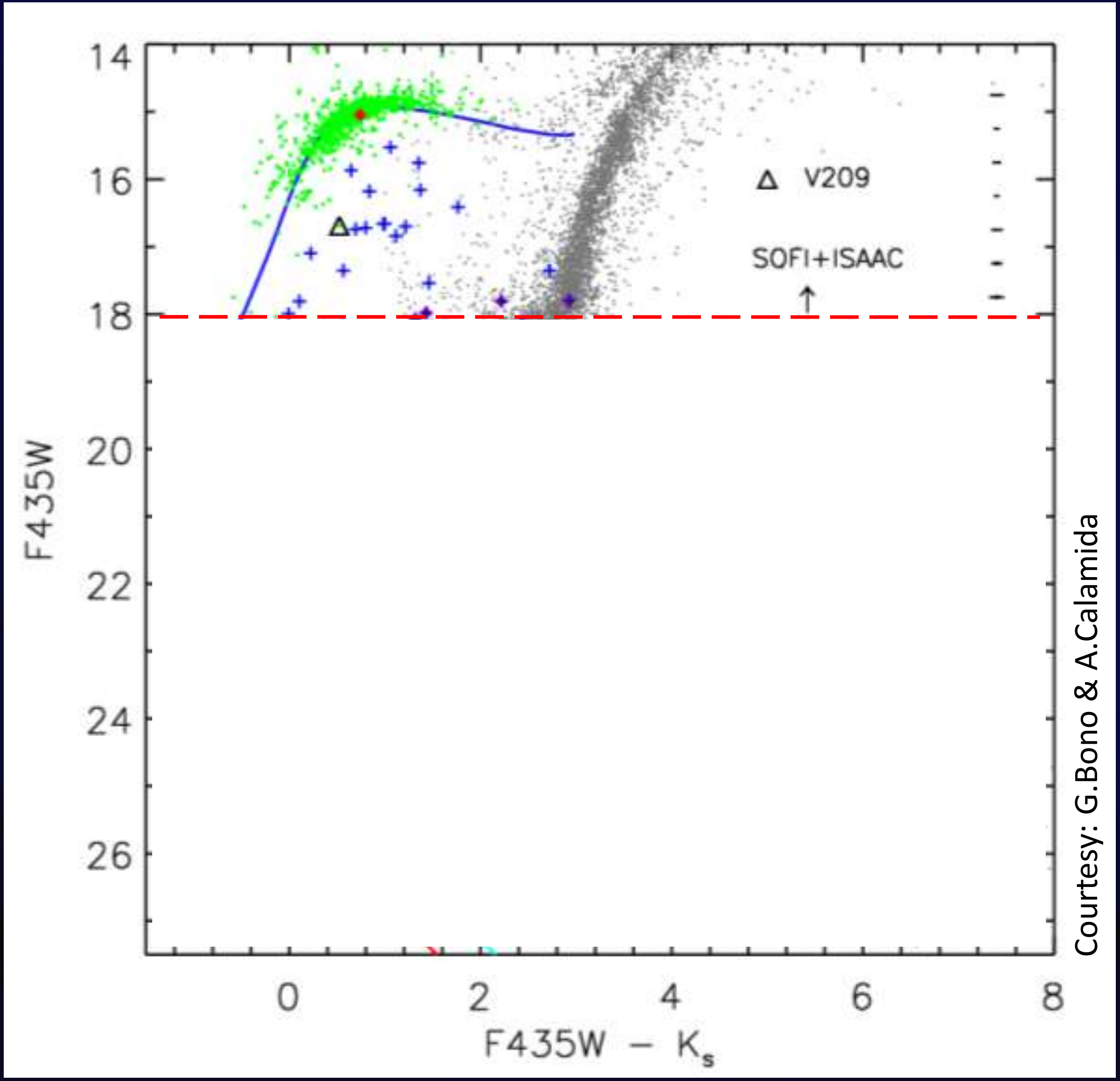
MAD [Ks] (0.028”/px) … [F435W] (0.050”/px)

FWHM: 100mas – T_{exp}: 340s

Omega Centauri

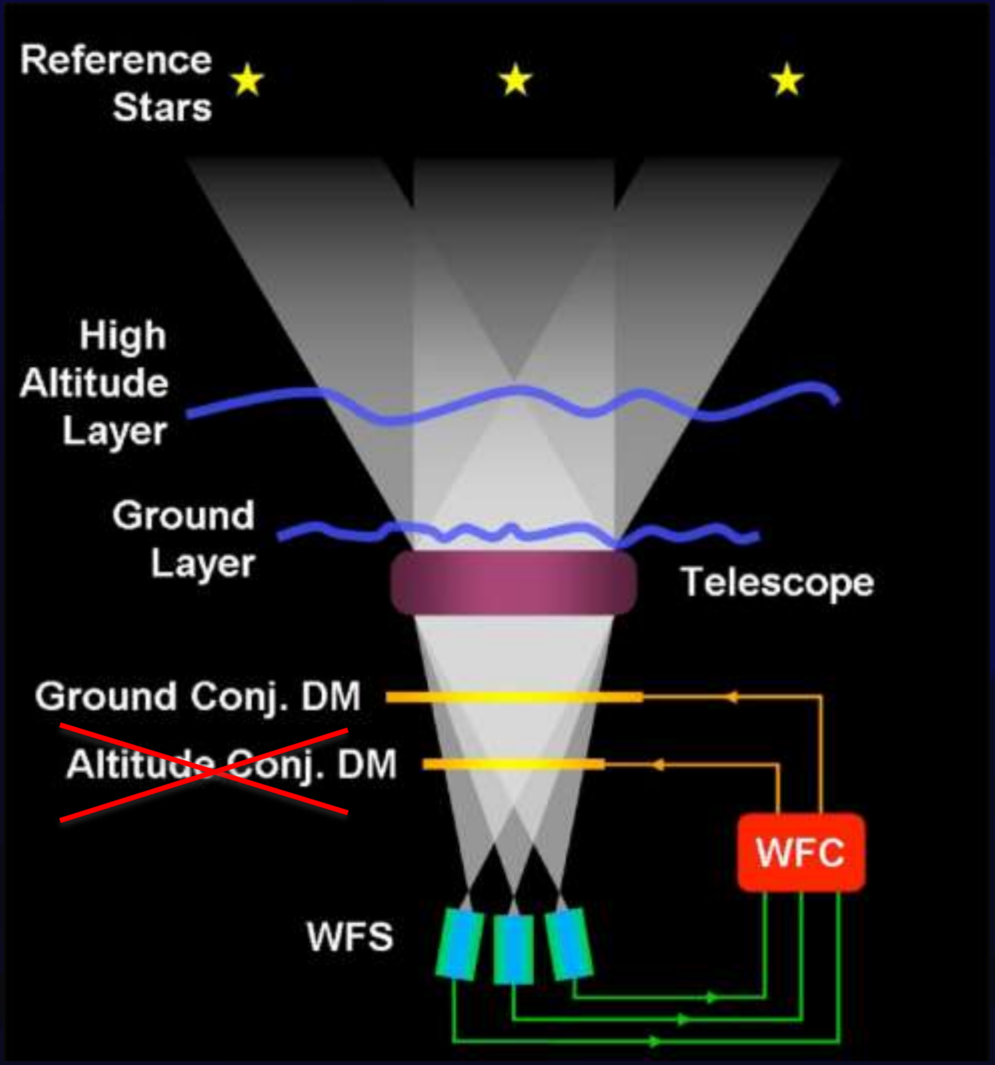
MAD completeness
w.r.t. HST/ACS
Ks: 90%

~10 White Dwarfs detected in Ks all having IR excess

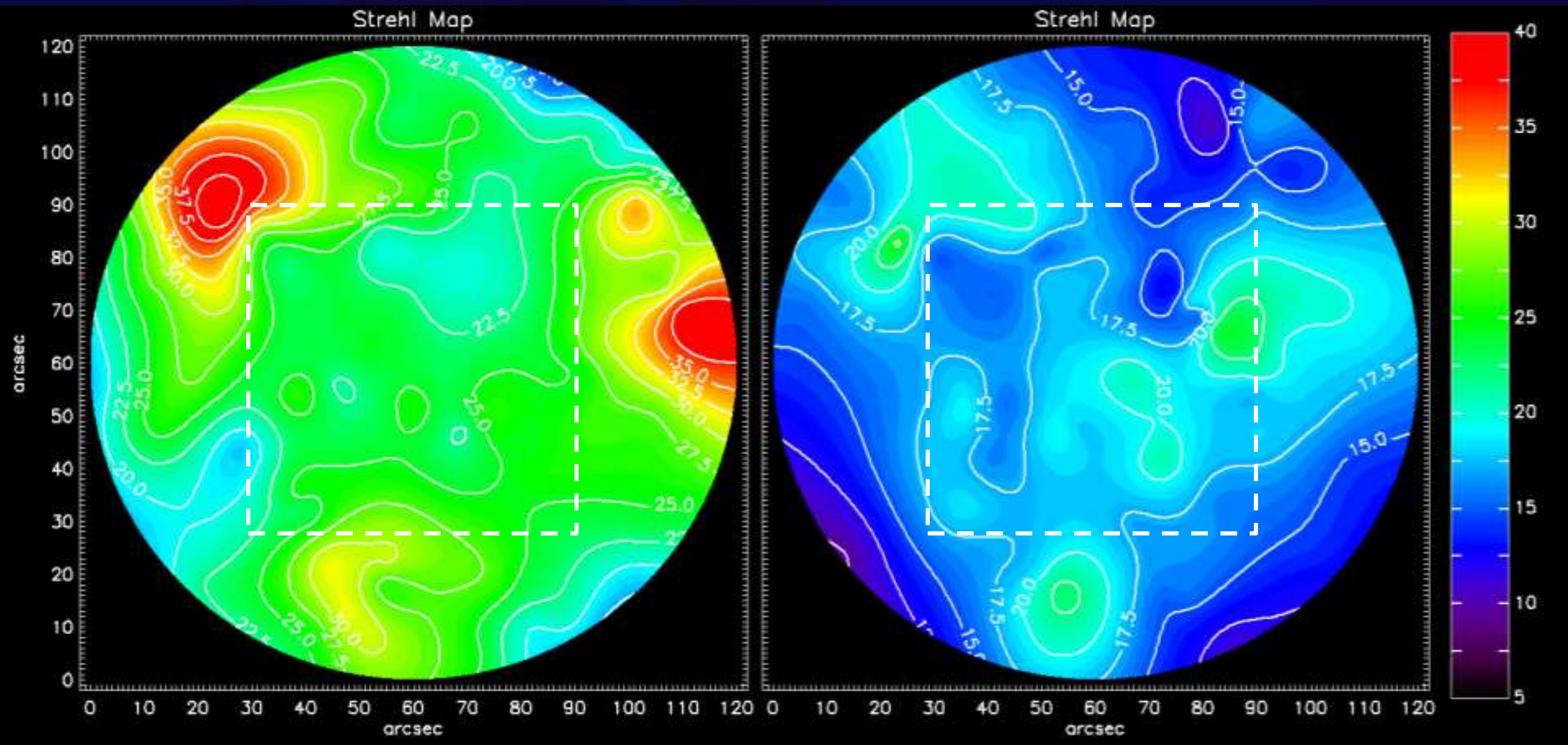


Courtesy: G.Bono & A.Calamida

Ground layer AO - GLAO



Ground Layer AO - GLAO

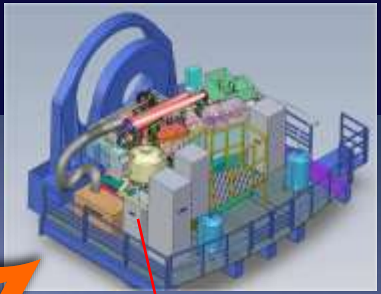


MCAO

GLAO

2013?

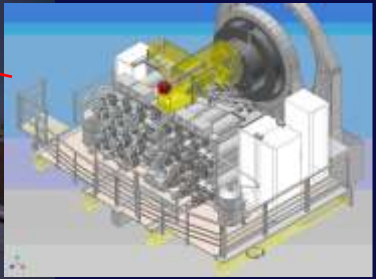
SPHERE



HAWK-I

CRIRES

Thank You



MUSE

Beyond MAD ?

VLTI MACAO x 4

SINFONI