The Galactic Center with METIS

THE E-ELT DESIGN REFERENCE MISSION

DRM & DRSP Workshop

26 – 28 May 2009

ESO Garching

METIS
Mid-infrared
E-ELT Imager and
Spectrograph

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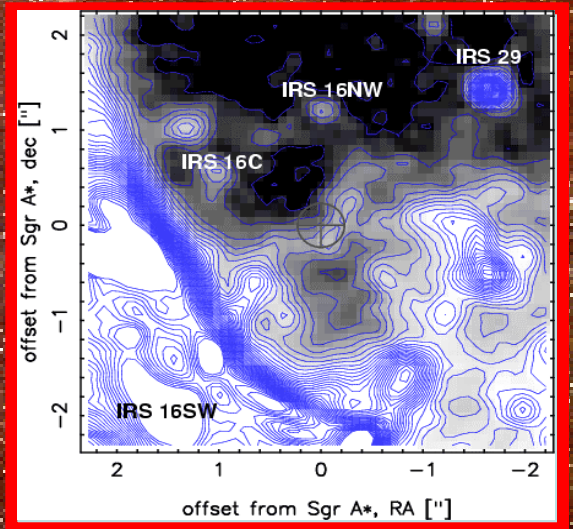
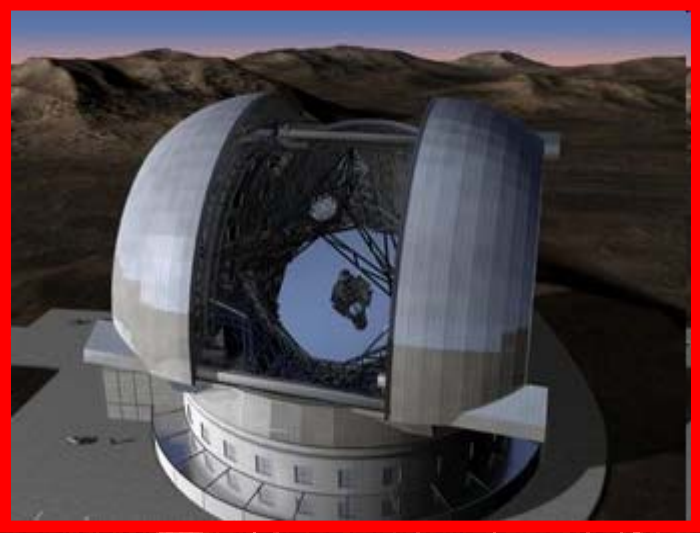
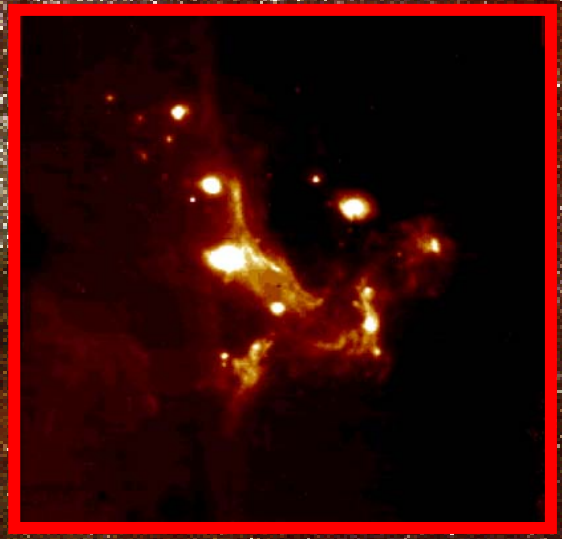
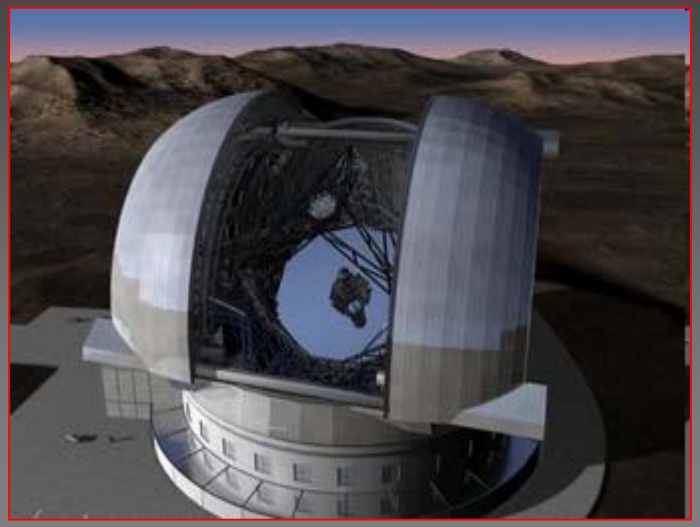
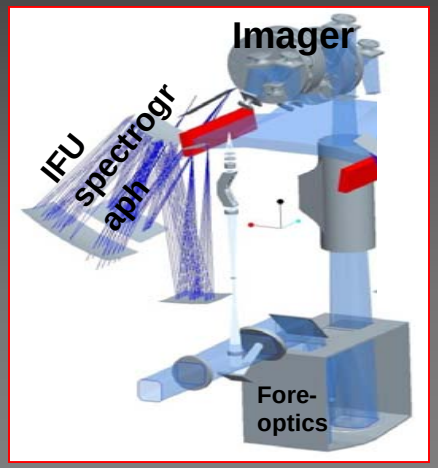


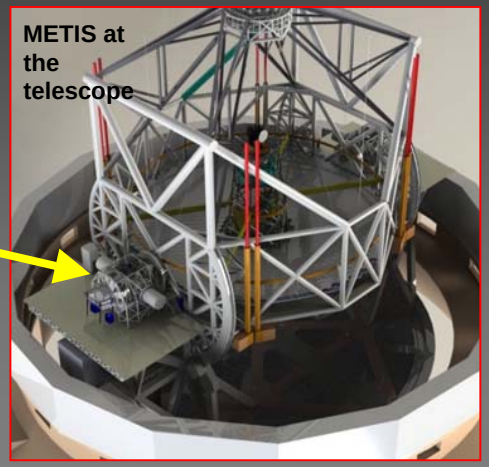




METIS is the E-ELT instrument for λ > 2.5μm







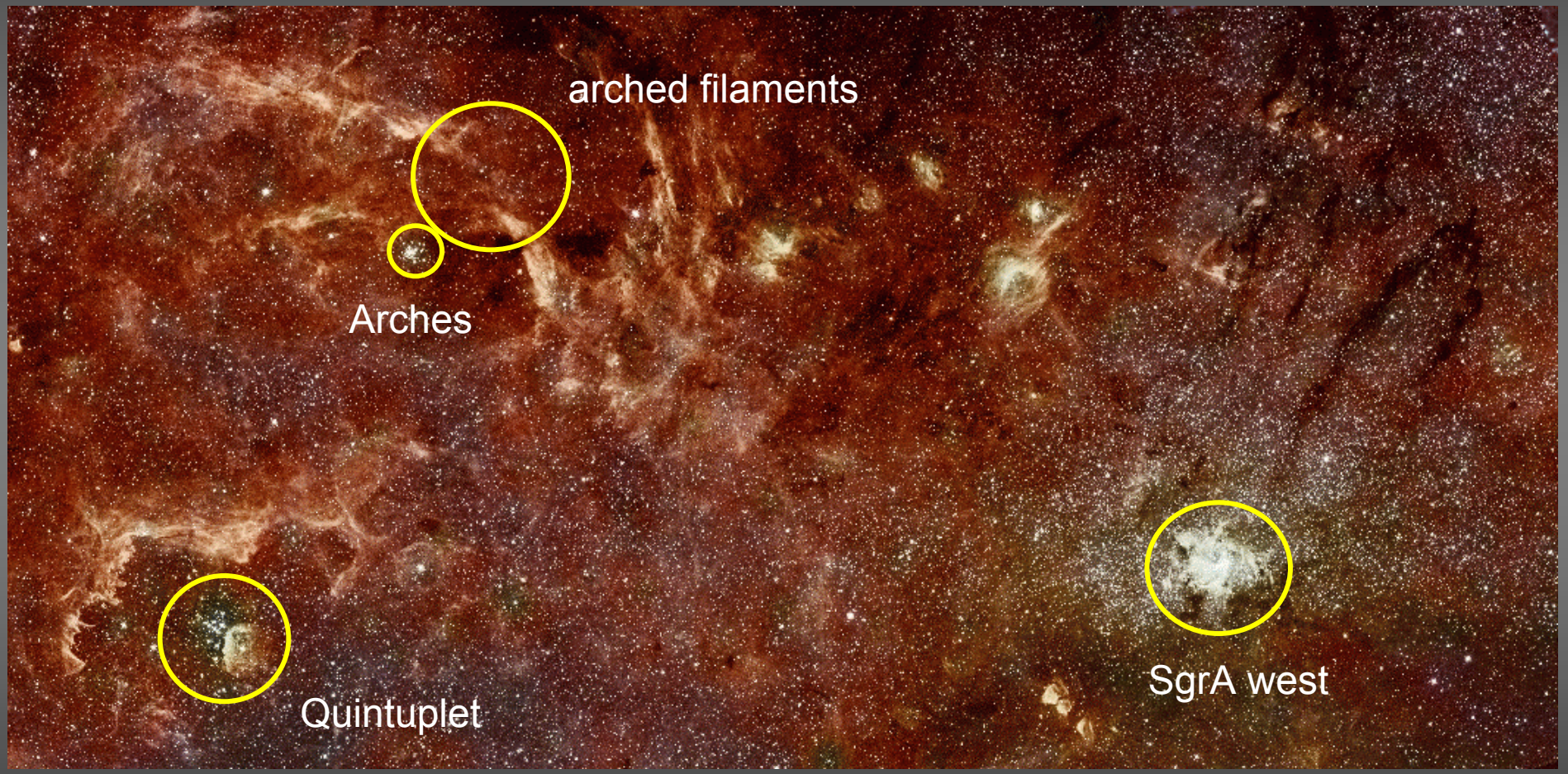
METIS Baseline:

- Diffraction limited **imager** [18″×18″] at L/M, N
  - incl. coronagraphy (N-band only)
  - incl. low-resolution (R ≤ 5000) long-slit
  - incl. polarimeter (N-band)
- High resolution [R ~ 100,000]

  IFU spectrograph [≥ 0.4″×1.6″] for L/M [2.9 – 5.3μm] band

PI: Bernhard Brandl

The Galactic Center as seen by SPITZER and HUBBLE



300 x 115 light years = 91 x 34.8 parsec = 38.3 x 14.7 arcmin

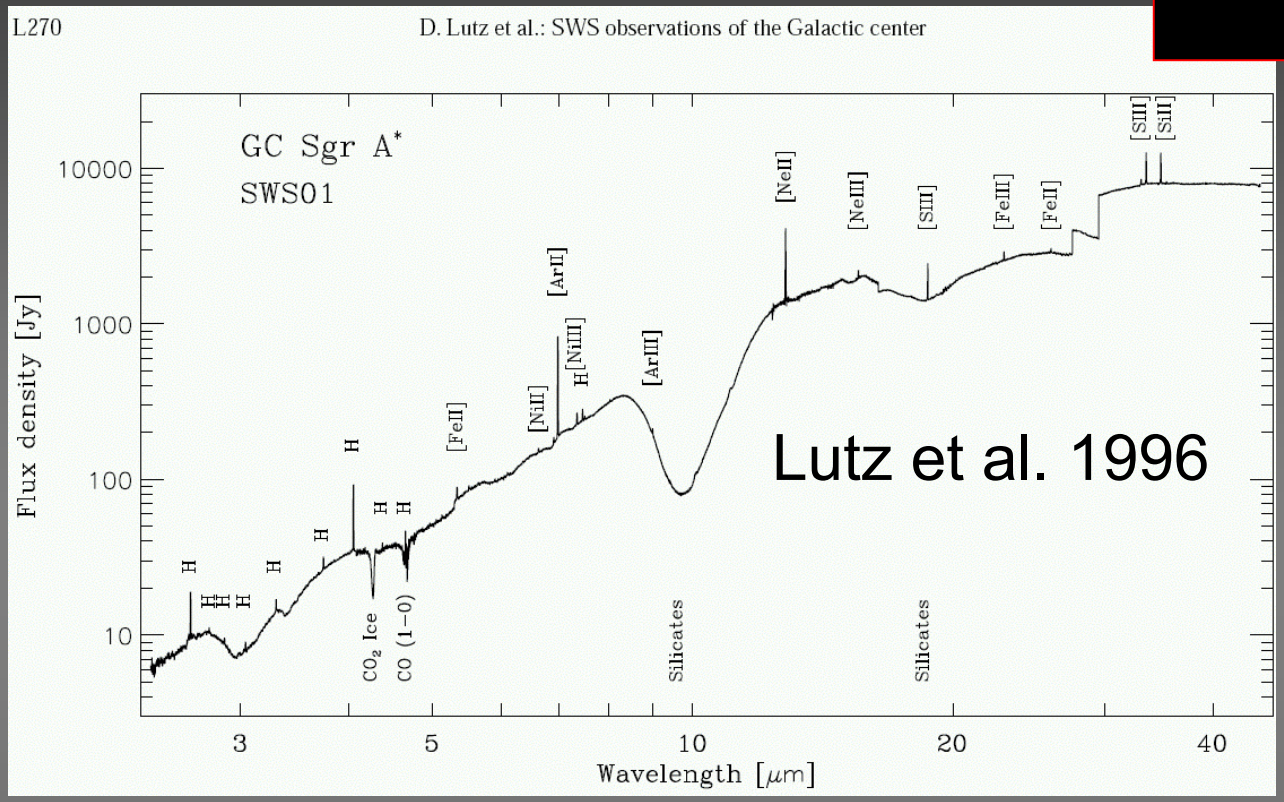
Hubble: NASA, ESA und D. Q. Wang (U. Mass, Amherst); Spitzer: NASA, JPL und S. Stolovy (SSC/Caltech)

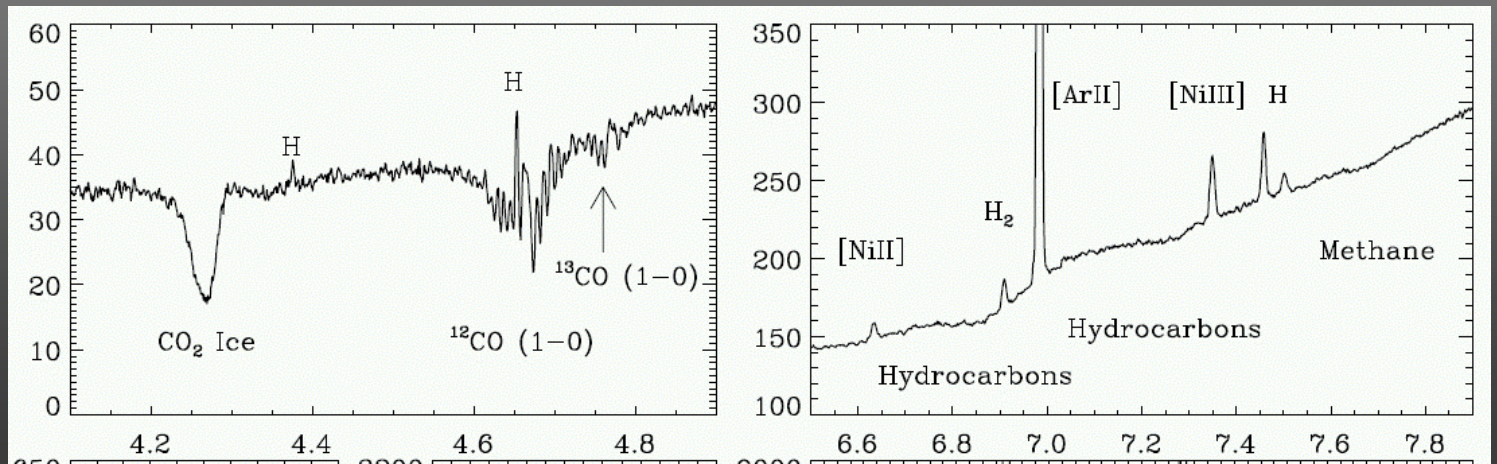
METIS observing the Galactic Center

Star Formation and Black Hole physics

- Central stellar cluster
  - IRS13N young star candidates
  - low luminosity bow shocks
  - dust filaments
  - cluster of high velocity stars
  - SgrA*
- Arches / Quintuplet cluster
  - young disk stars
  - arched interaction filaments
- Foreground ISM studies

Spectroscopic probes: ISO SWS





Spectroscopic probes

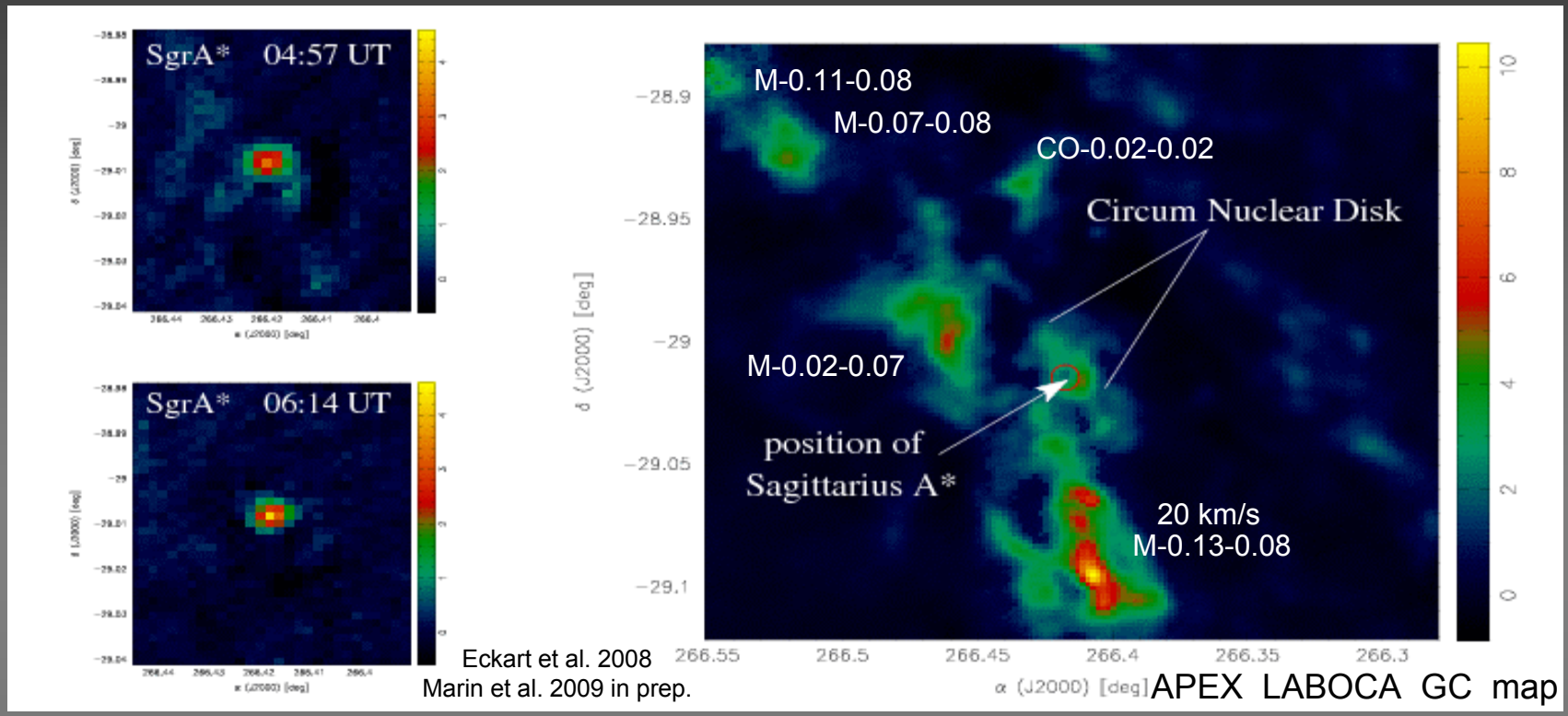
NH_3 (9um), CH_3OH (9.7um C-0 stretching) features
5.5-7.5 H_2O ice features as reported by
Boogert et al. 2008 (Spitzer) and Bottinelli et al. 2008

Shocked gas in arcs, bow shocks and interaction zones will be observed in emission through lines from neutral molecular and atomic hydrogen species

and fine structure lines from ionized species
[FeII], [NiII], [ArII], [NeII], [SiII], SIII], [FeIII], [ArIII], [NiIII]
(Lutz et al. 1996)

Arched shocked features and PDR regions will also show strong 6 and 8μm PAH emission (Archers/Spitzer Cotera et al. 2006)

Spectroscopic probes



Eckart et al. 2008
Marin et al. 2009 in prep.

APEX LABOCA GC map

The foreground absorption by the 20 km/s and 50 km/s cloud may be a problem for the tracers of cold gas and ices.

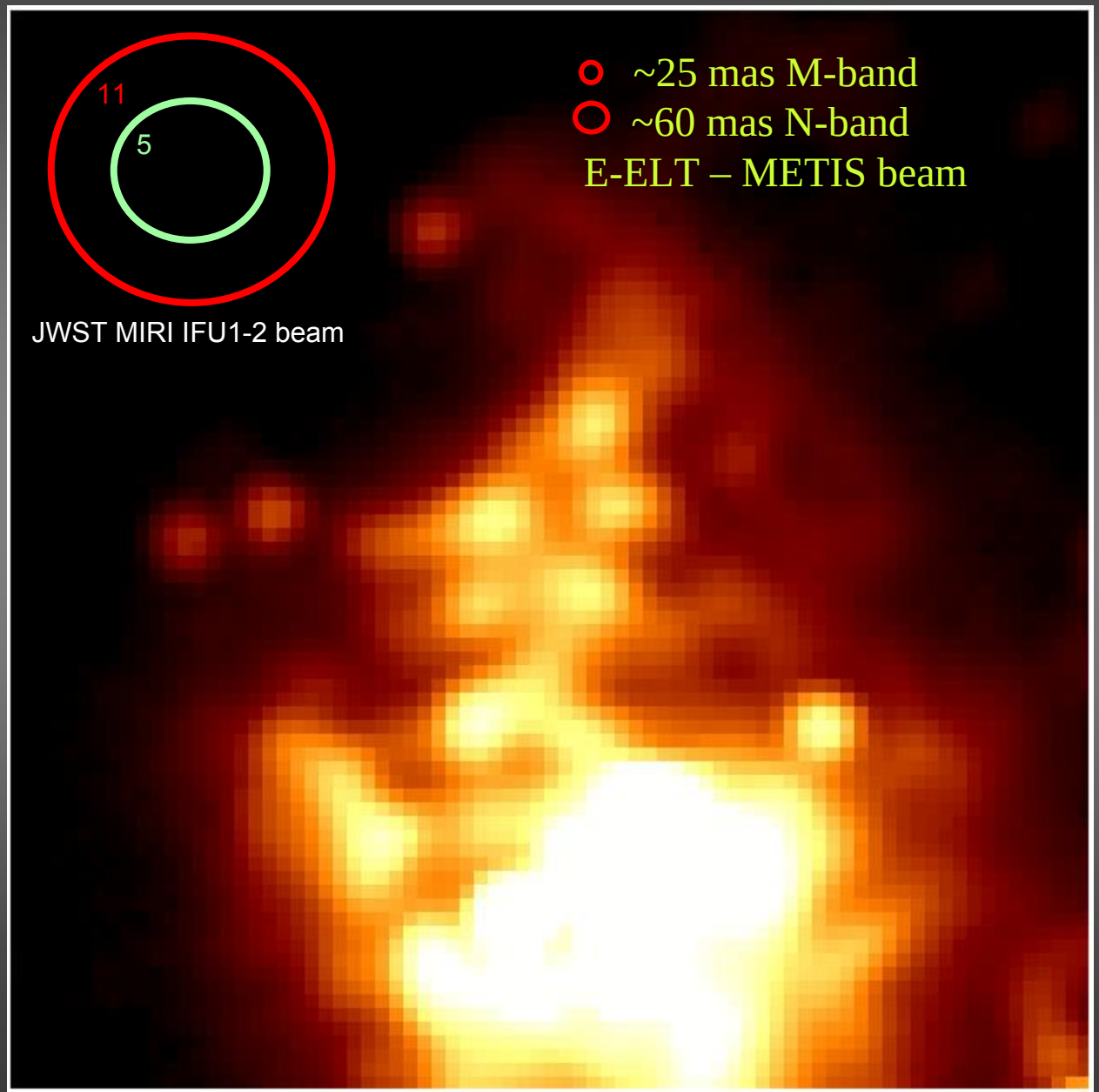
Close to the position of SgrA* this may in part be calibrated for using the spectra of the high velocity B-stars (see Moultaka et al. 2004, 2005).

For lines that trace higher excited gas in emission this is probably not a problem (see Spitzer work on larger scales towards the arched filaments (Simpson et al. 2007)

IRS13N

A Complex of Comoving IR Excess Soures

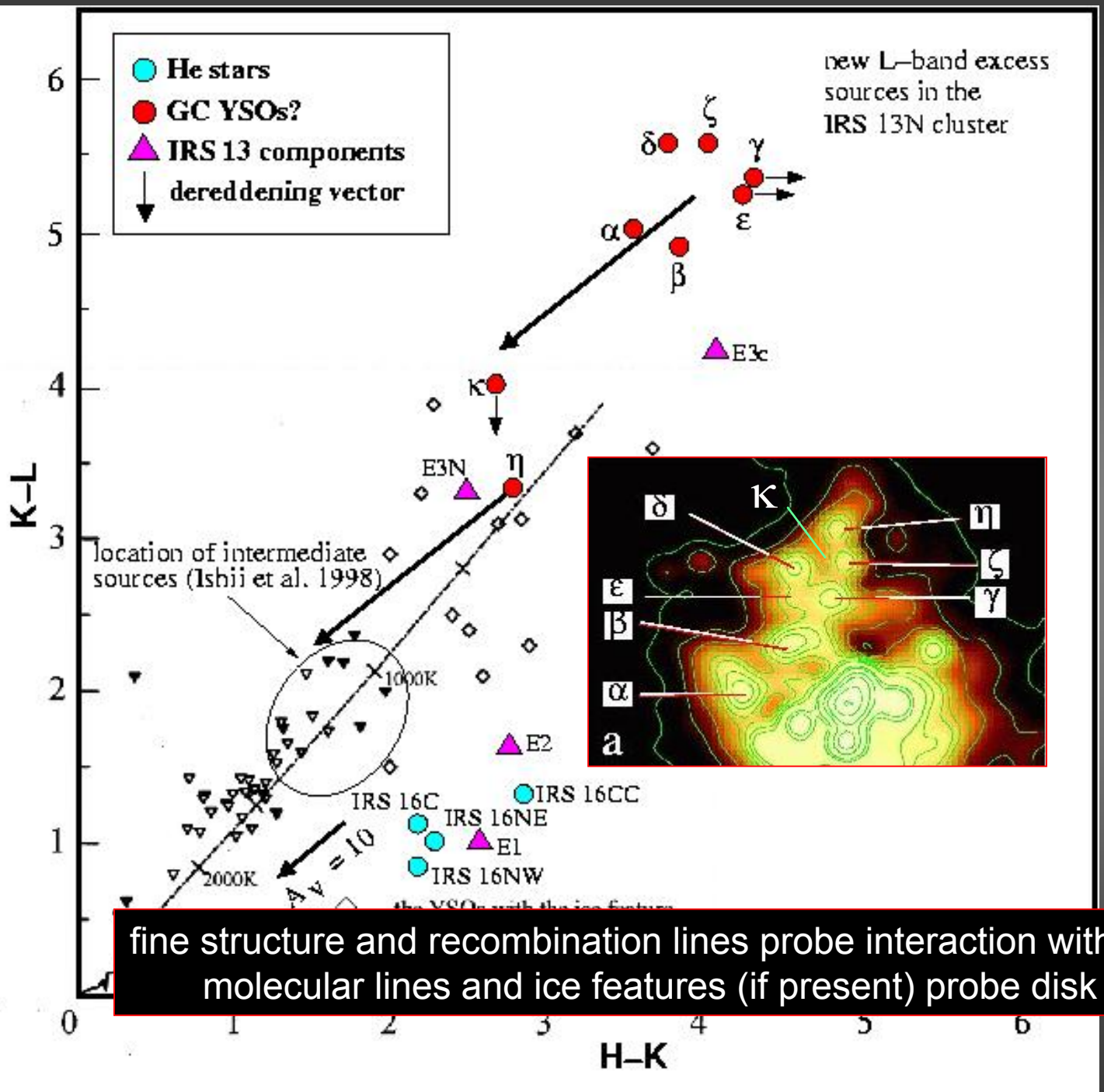
Zooming in – towards IRS 13N



NIR
3.8 μm
VLT
NACO

500mas
23 light days

HKL-colors of sources in the IRS13N complex



$L=10^{2}$ -10^{4} Lsol
M=2-8 Msol

Low luminosity bow shock sources.

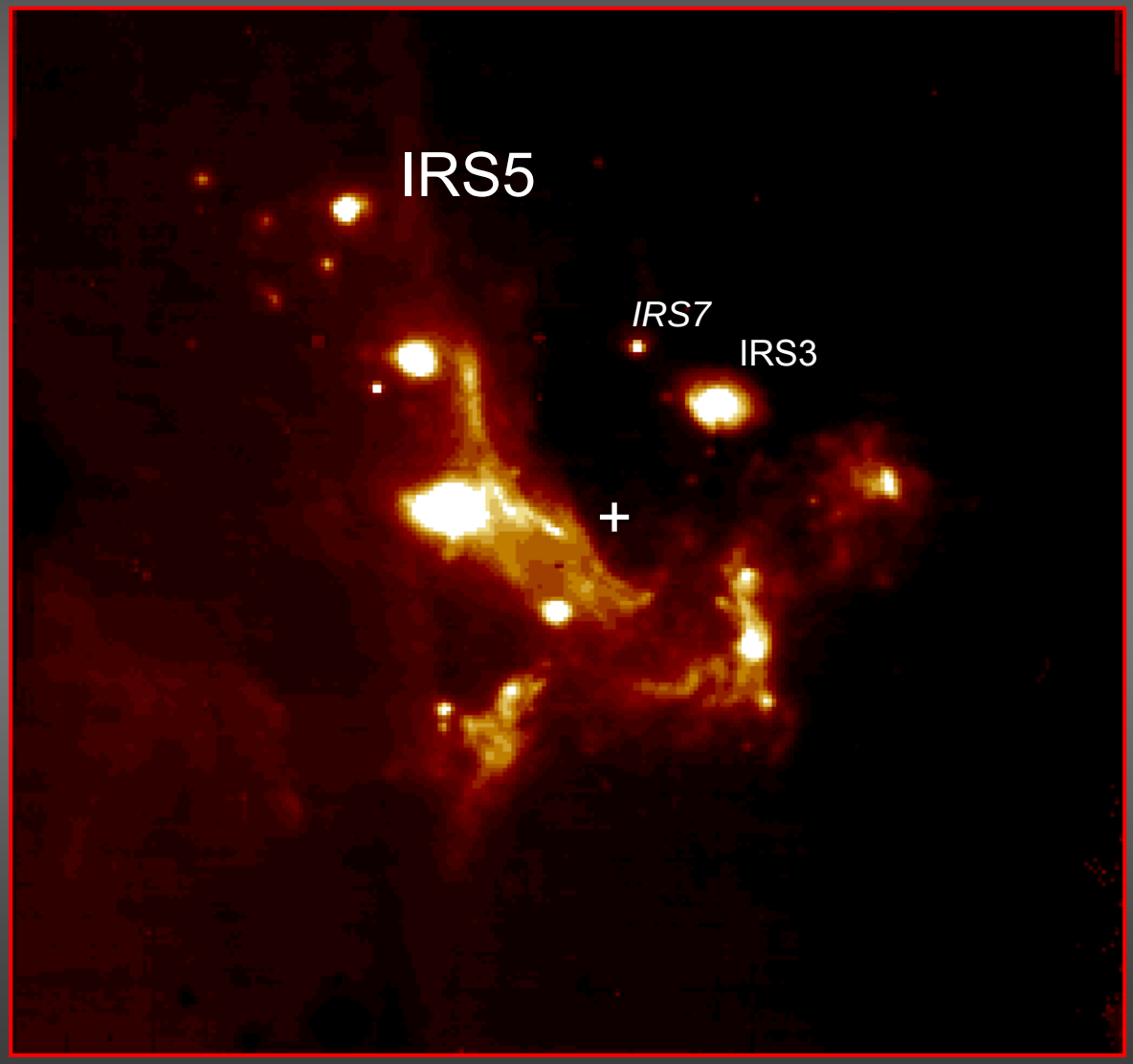
Are the IRS 13N sources at the GC Herbig Ae/Be stars? Co-moving group! IRS31N is also dynamically young!

fine structure and recombination lines probe interaction with radiation field
molecular lines and ice features (if present) probe disk properties

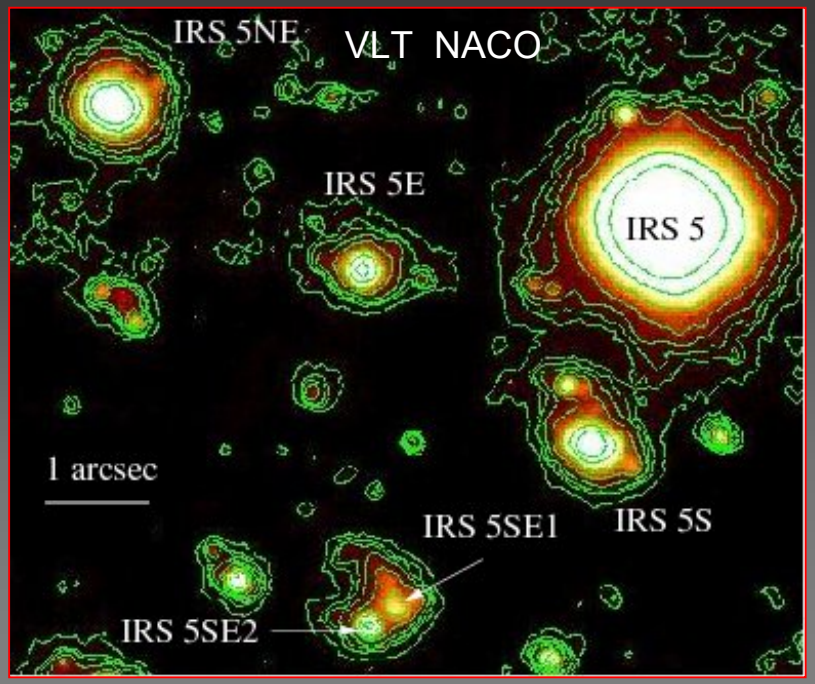
Eckart et al. 2003

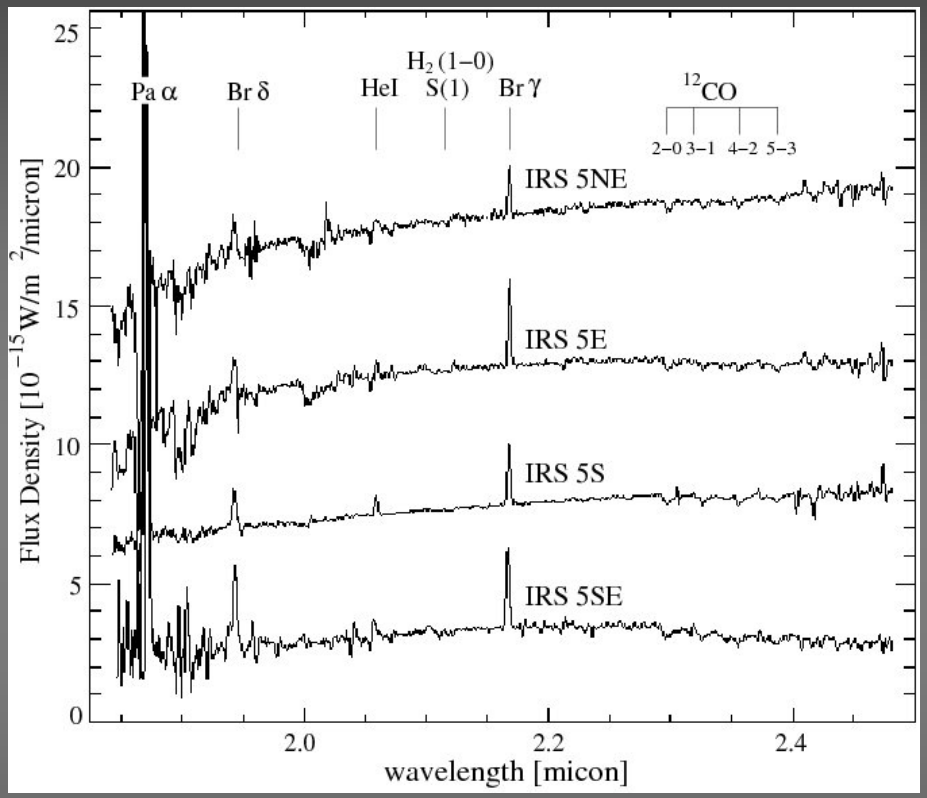
Low Luminosity Bow Shock Sources East of IRS5 in the Northen Arm

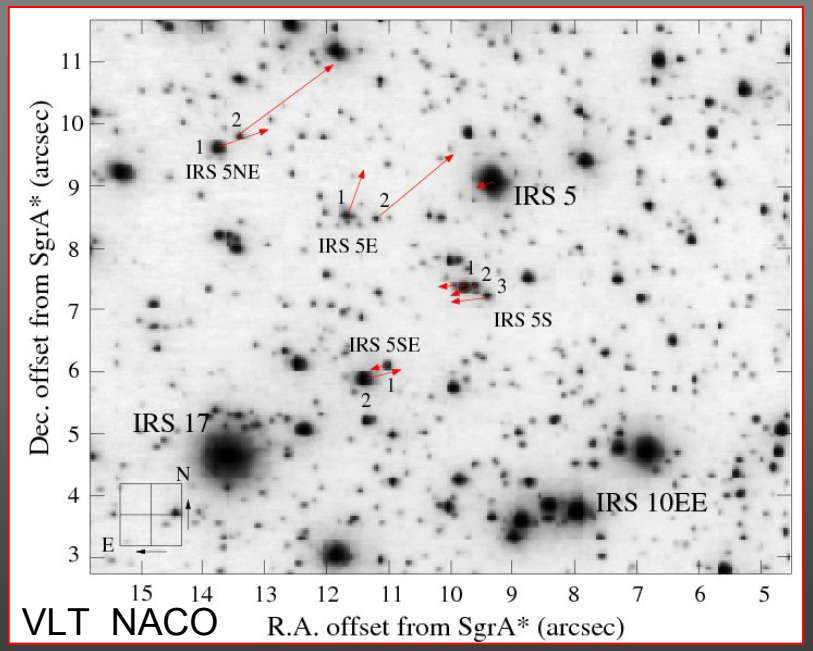
N-band
VISIR



Low Luminosity Bow Shock Sources East of IRS5 in the Northen Arm





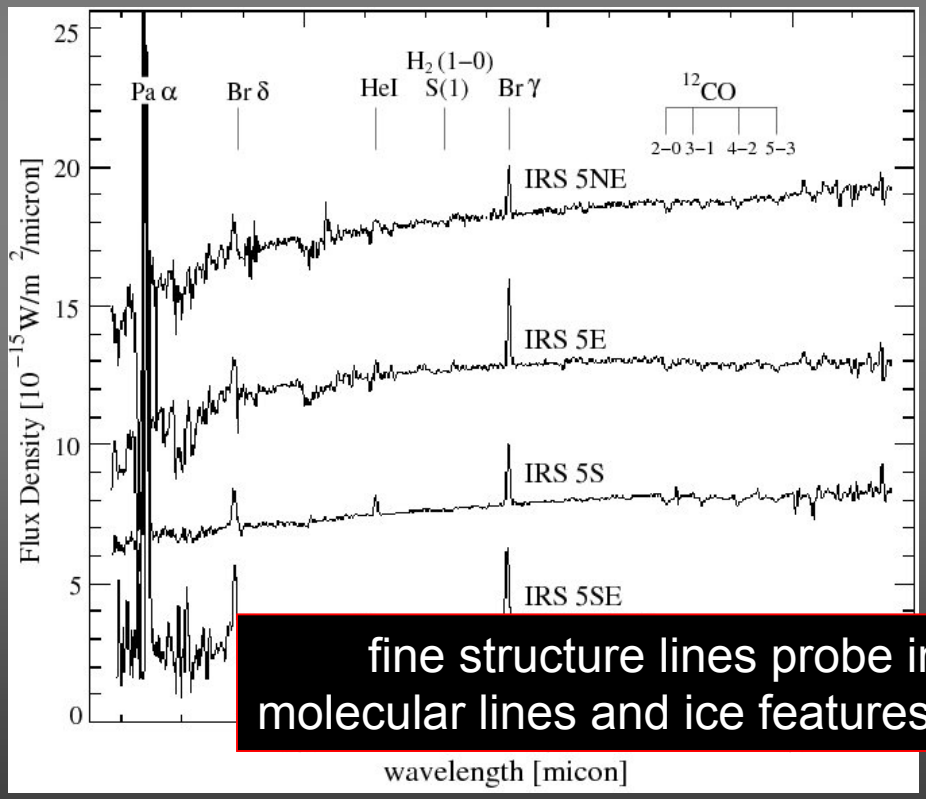


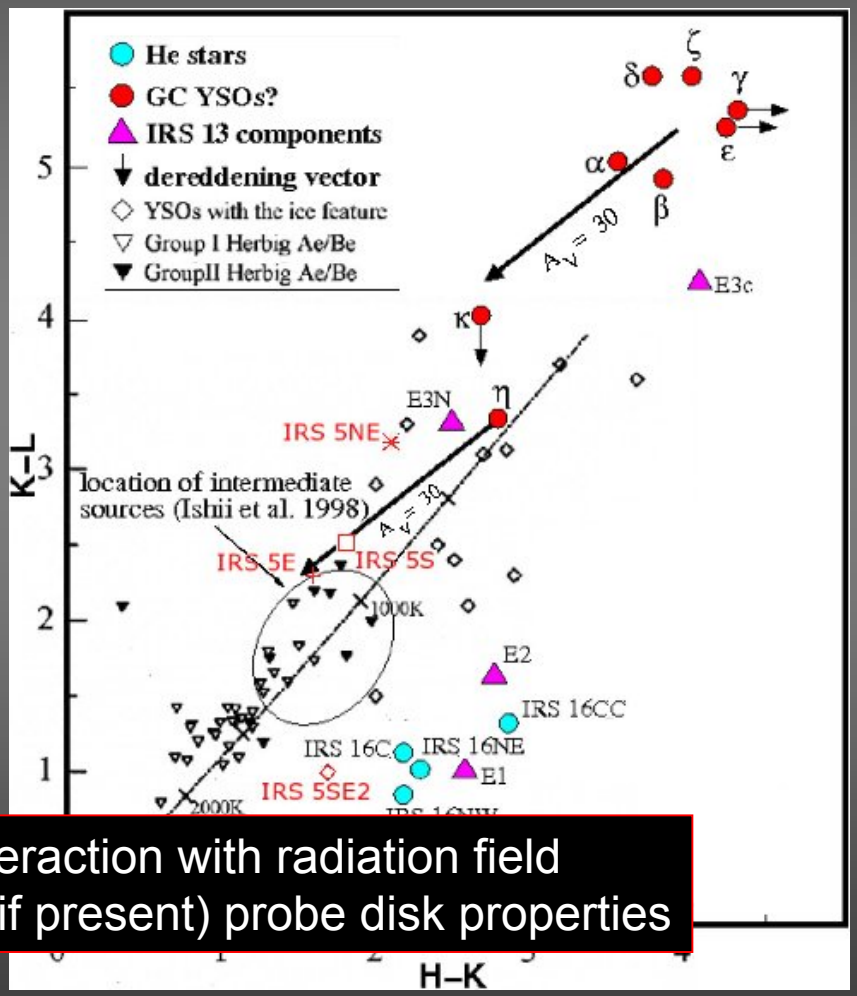
Compact MIR excess sources located in comoving small clusters as indicated by imaging and proper motion

Perger et al. 2008

Low Luminosity Bow Shock Sources East of IRS5 in the Northen Arm

NIR spectra, colors and absolute magnitudes and clustering indicate the presence of young stars. (see colors of sources east of IRS 5)





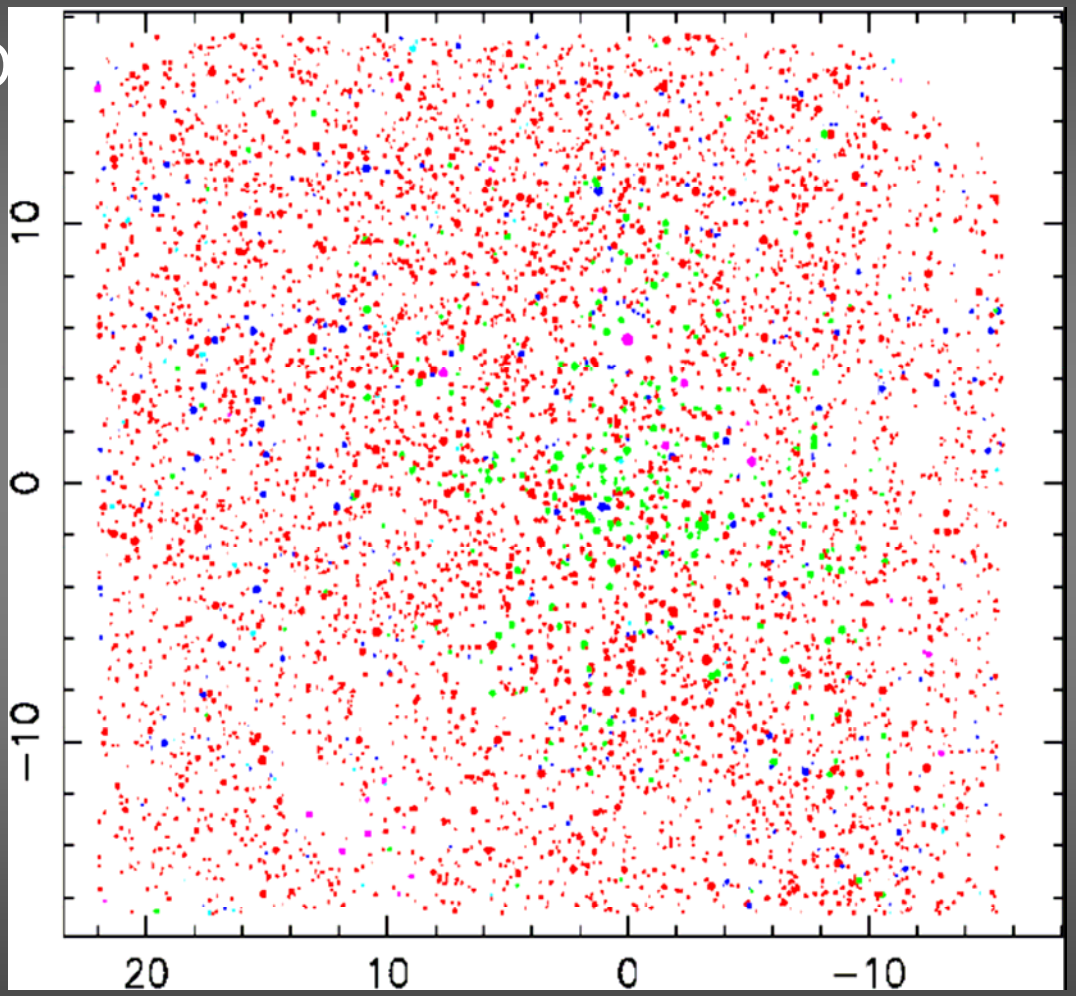
fine structure lines probe interaction with radiation field
molecular lines and ice features (if present) probe disk properties

Perger et al. 2008

Identification of Stellar Types through Spectroscopy and Narrow Band Imaging

Here: H,K band with NACO

METIS can do this in the MIR using ice and CO, PAH features as well as recombination and forbidden lines



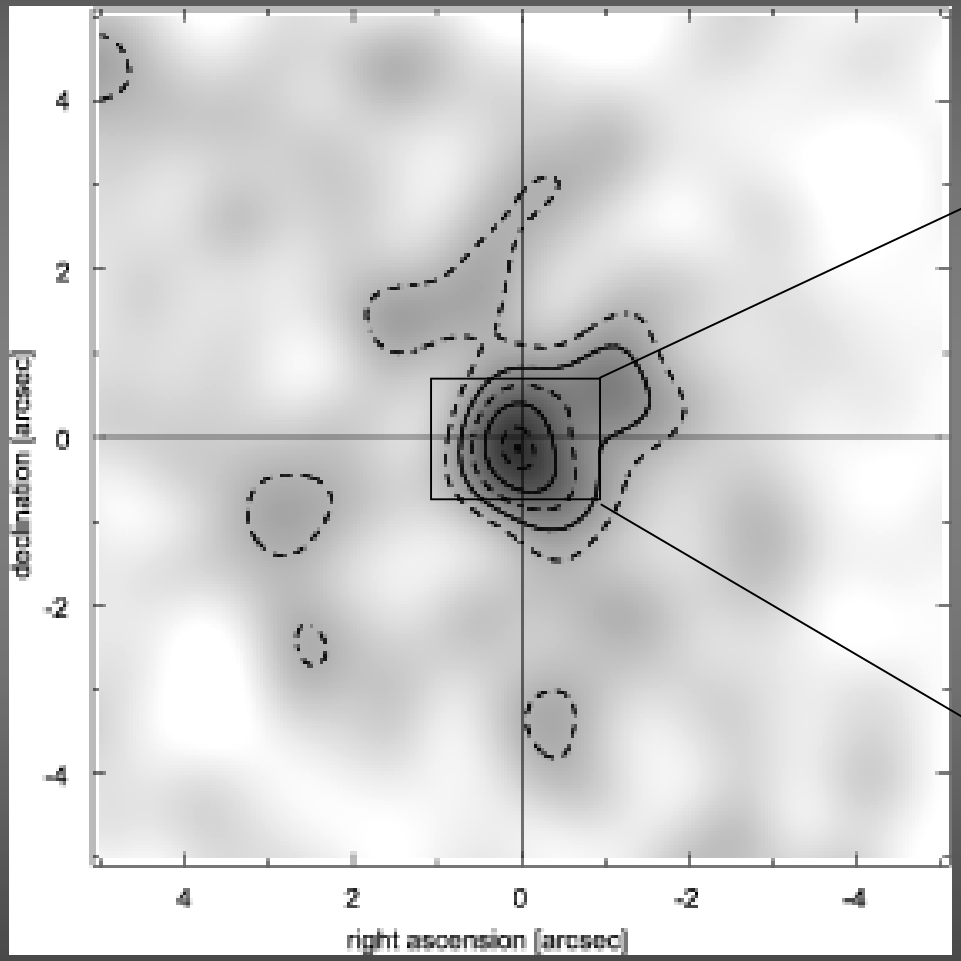
Narrow band identification of stars in the central stellar cluster

Buchholz, Schödel, Eckart 2009

The Central Arcsecond: A cusp of high velocity stars

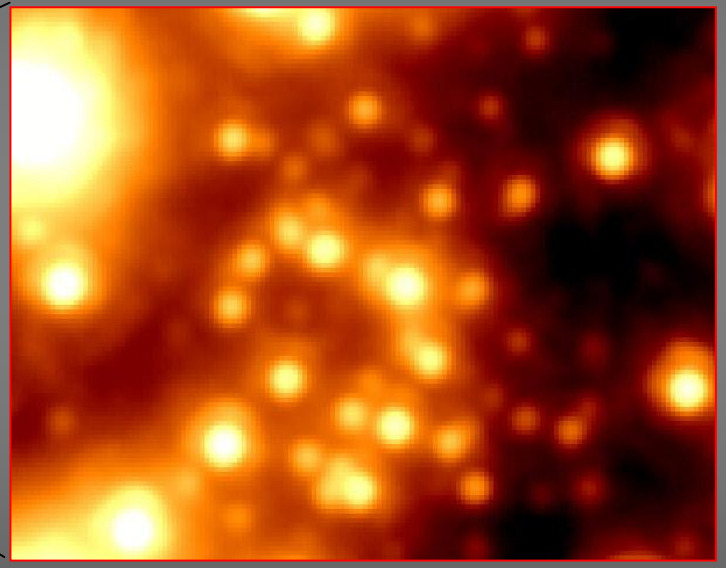
Identification and Variability of SgrA* at $\lambda > 5\mu m$

Distribution of stars: The central cusp



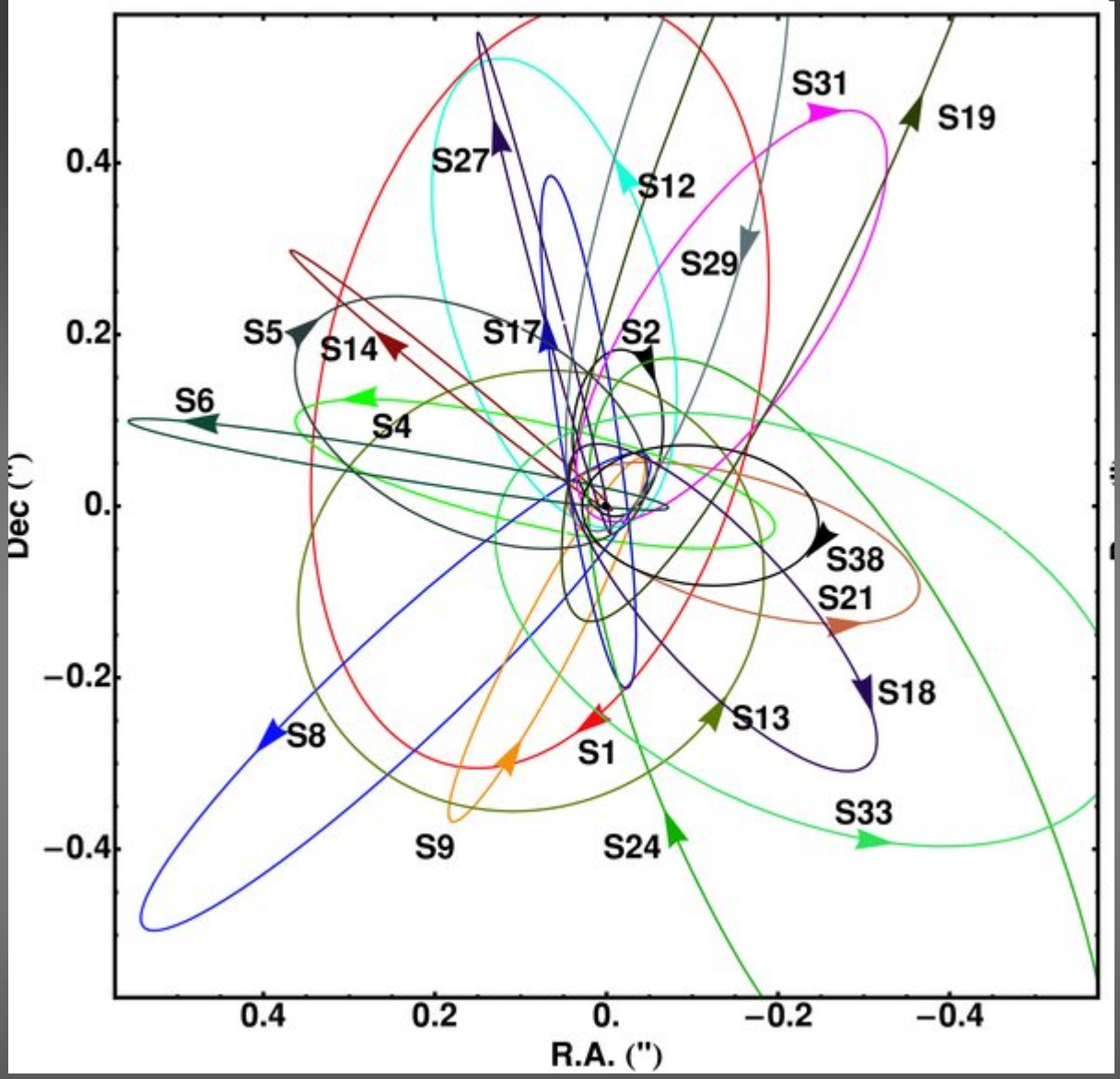
surface number density of stars
excess above mean density by 2, 3, 4, 5, 6.3 σ

- More than 90 sources can be detected in the central arcsecond in H-Band NACO/VLT images!
- A stellar cusp is clearly detected.



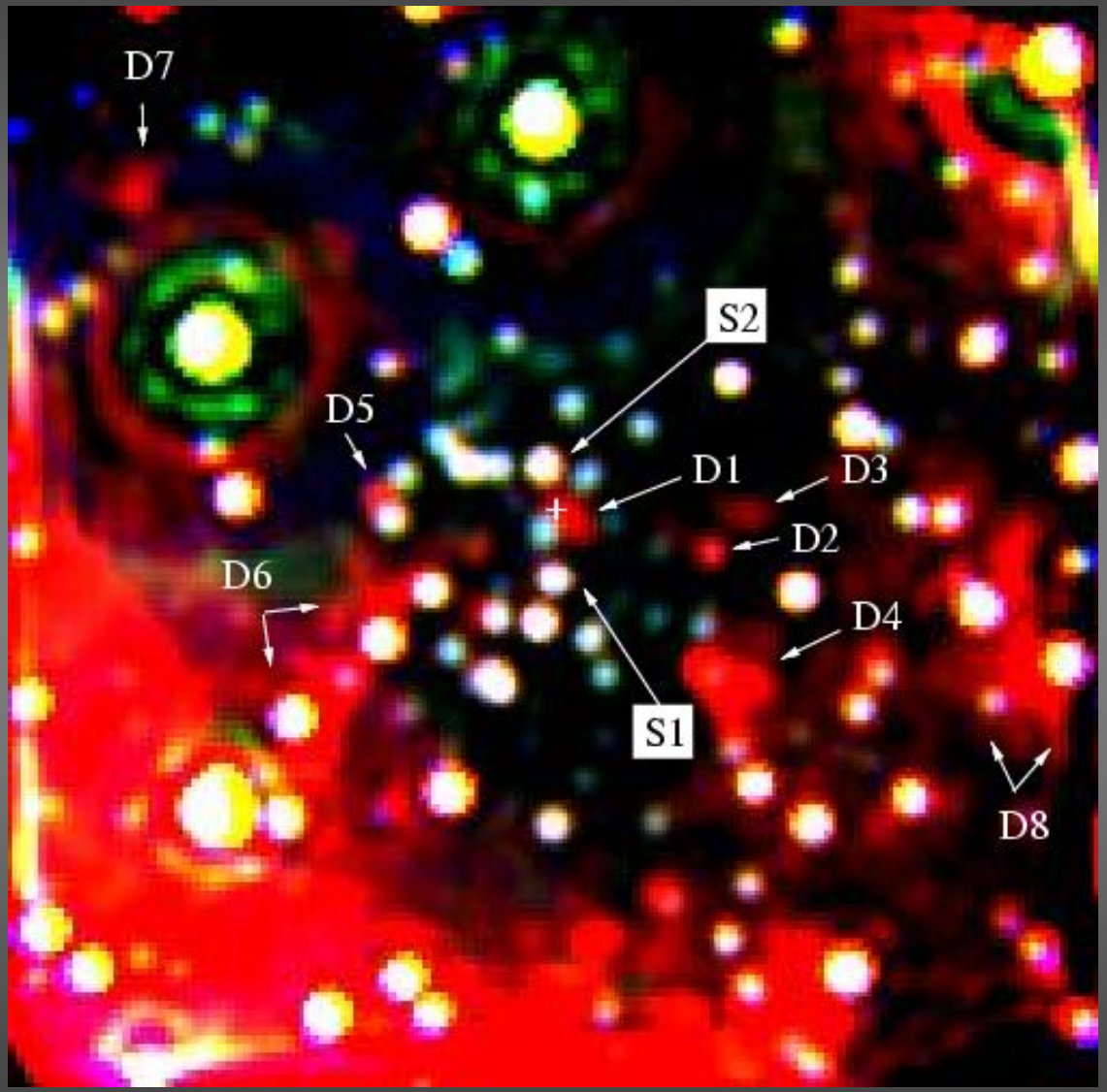
1“/46 light days

Schödel et al. 2003, 2007
Genzel et al. 2003
Eckart, Schödel, Straubmeier 2005
Mouawad, Eckart et al. 2003, 2005



Stellar orbits of the stars in the central arcsecond for which we were able to determine orbits.
Gillessen et al. 2009

Detection of a Dust Component along the Line of Sight towards SgrA*



5“x5“

HKL multi-color image of the central 5“x5“ taken with NACO. L-band is in red.

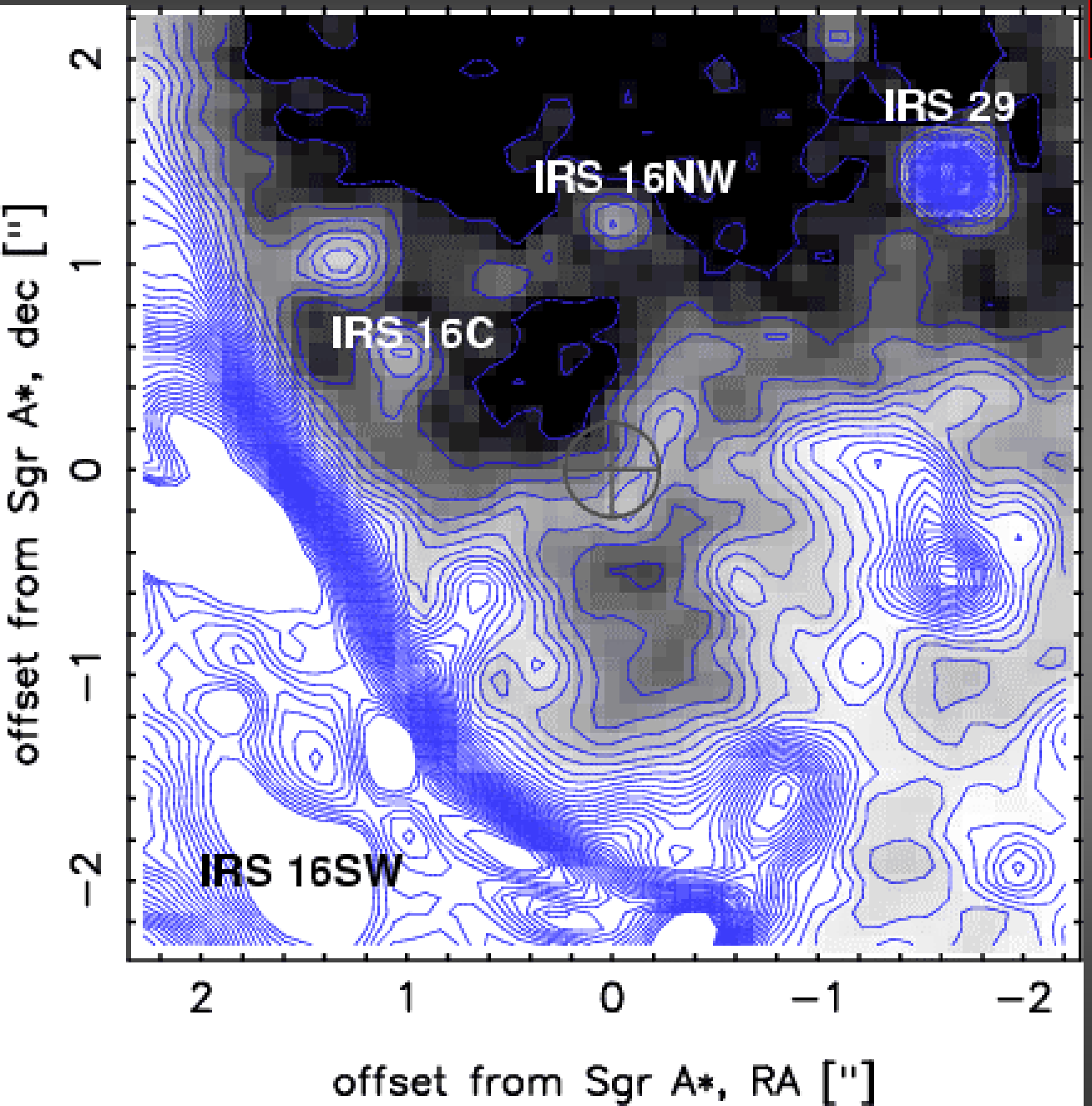
Fore-/Backgrond dust component 26mas west of SgrA*
~1000 AU at 8 kpc

High angular resolution required in the MIR!!

Several of those dust blobs are seen across the field

Eckart et al. 2005

Detection of of SgrA* longward of 5 microns



SgrA* position is indicated by the cross.

It is located close to the LOS of a dust component unknown distance to the center.

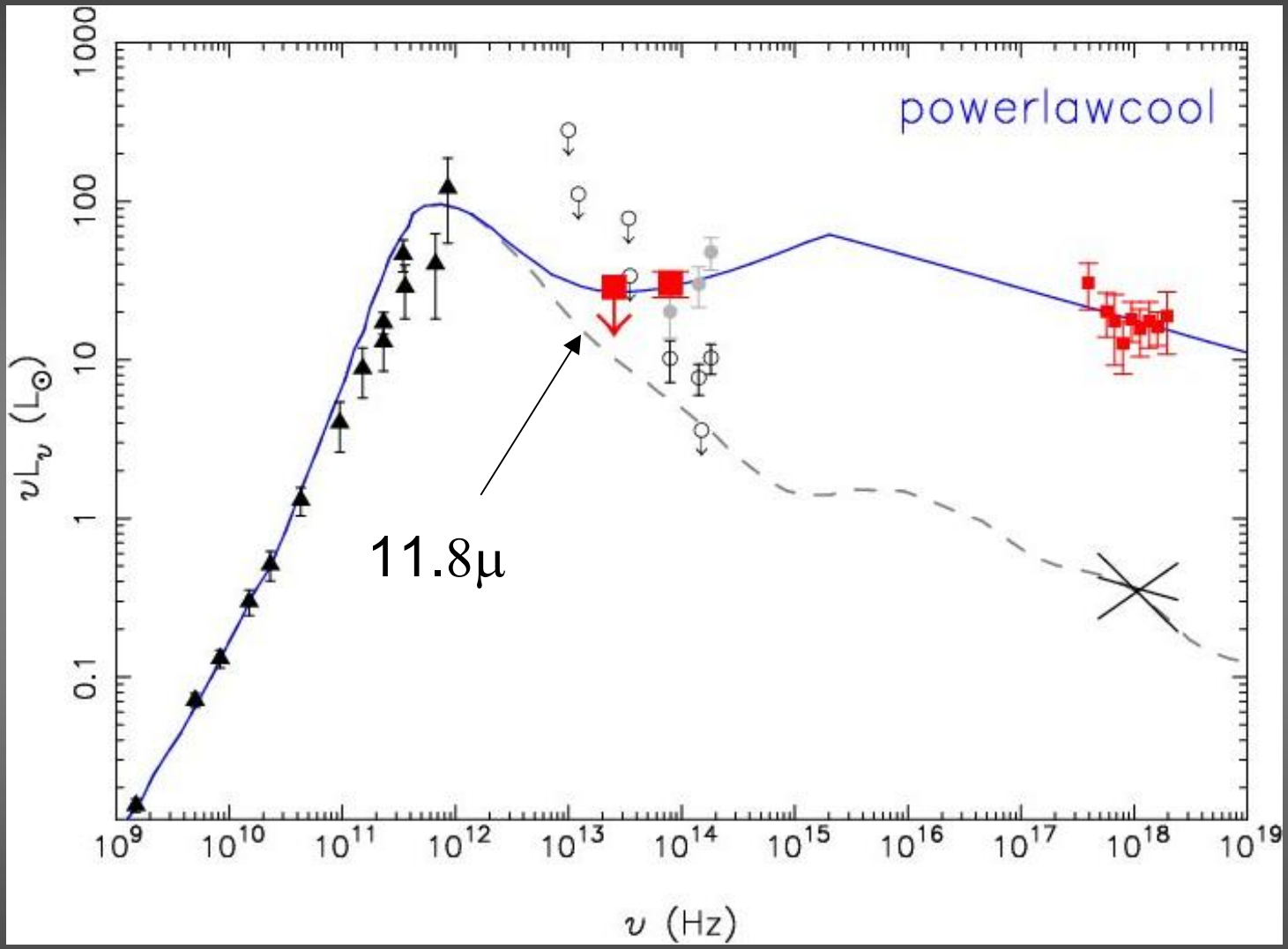
The dust component may be associated with the min-spiral.

Fluxes at 8.6 μ:

IRS16C 22+-5 mJy
IRS16NW 21+-5 mJy
IRS29 180+-20 mJy

Schödel et al. 2007

MIR flux of SgrA* ?

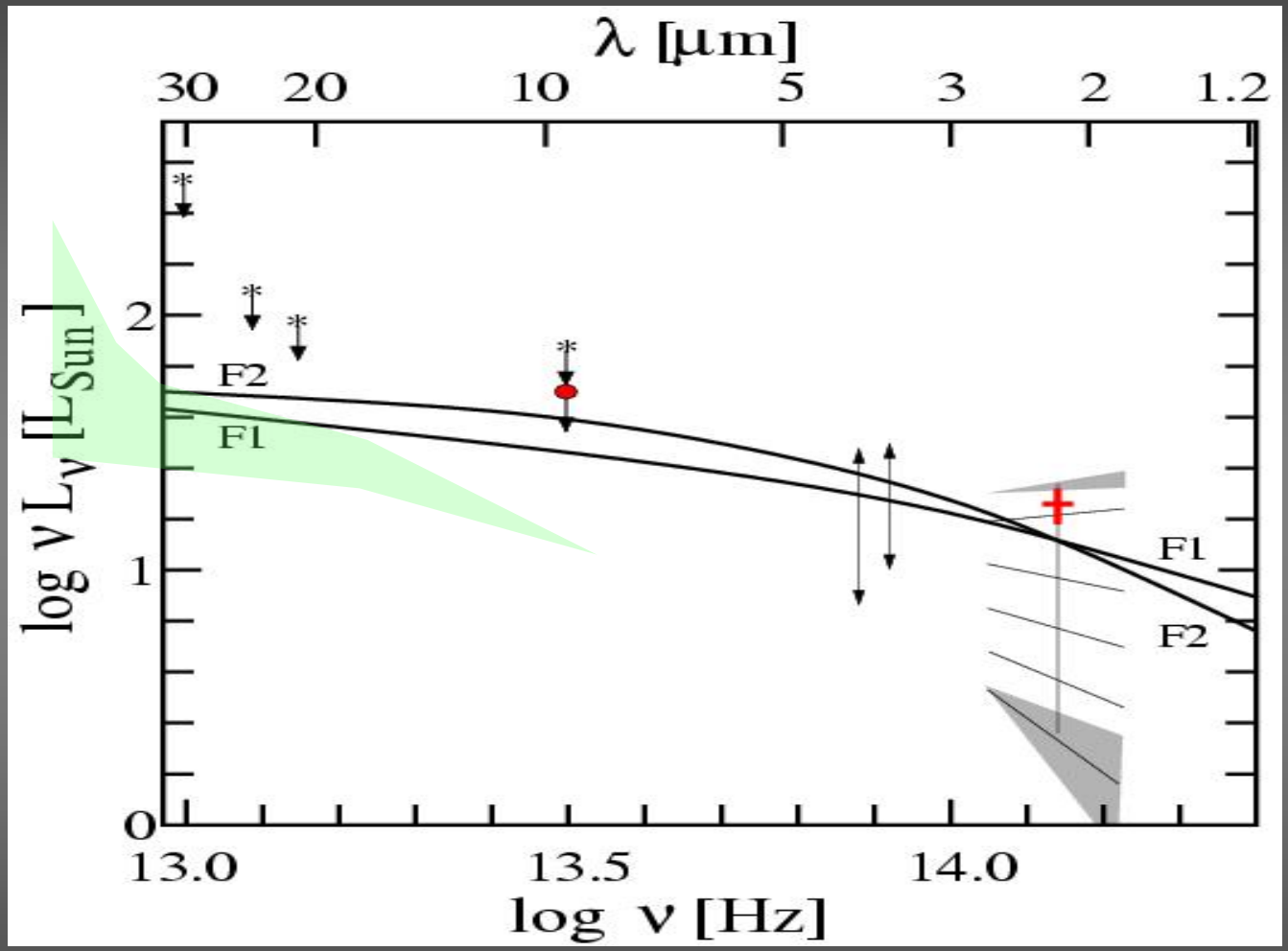


Dodds-Eden et al. 2009

Simultaneous weak flare models

NIR/MIR cutoff may shift towards shorter wavelength: NIR flare spectral index may be flatter

Model consistent with low upper limits in the MIR



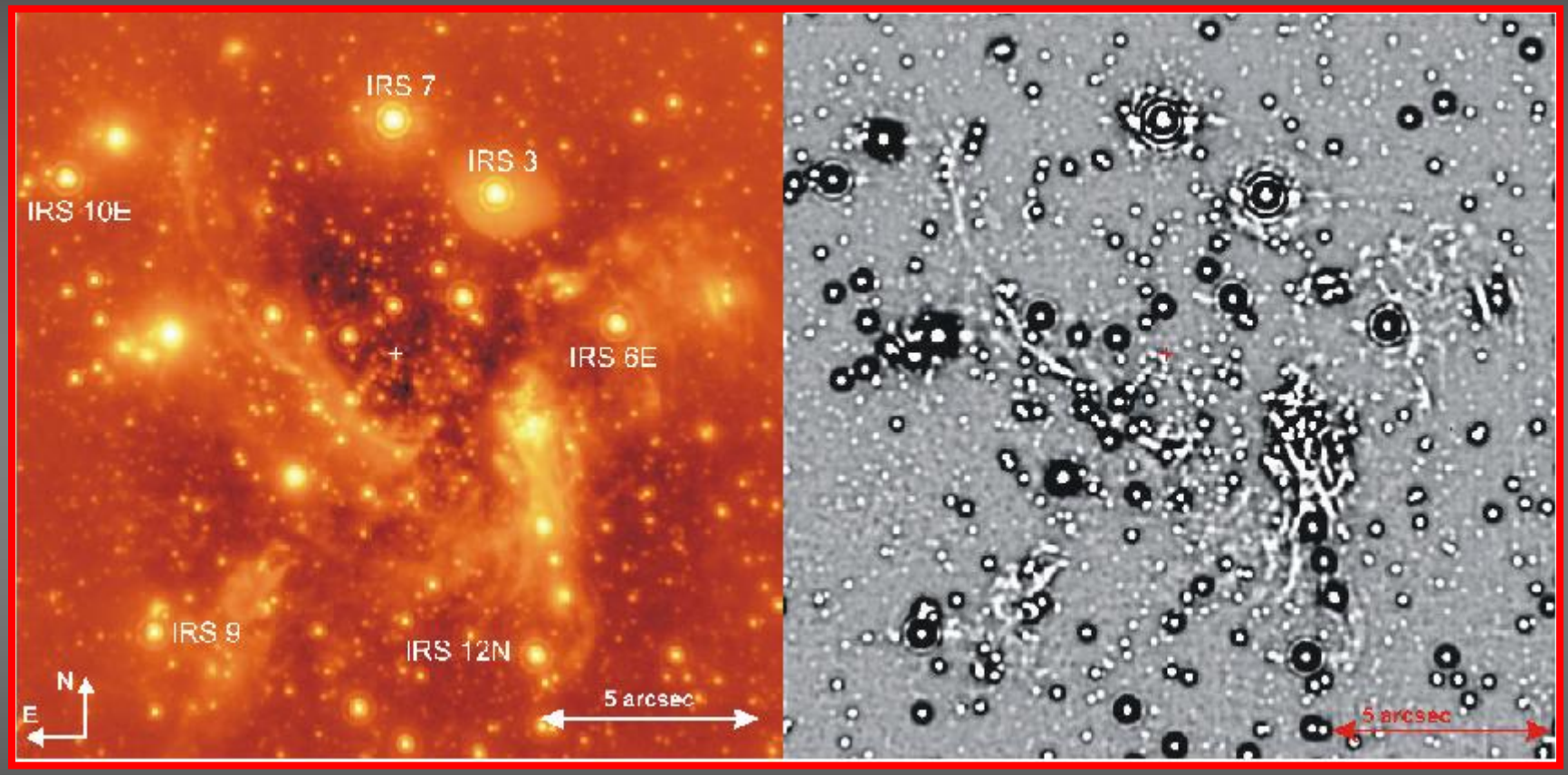
Eckart et al. 2006

Probing the wind from SgrA*

Compact Dusty Filaments in the Central Cluster

Bow Shock Stars: Tracing the interaction with a wind from the central half light year

The Detection of Thin Filaments in the Central Parsec

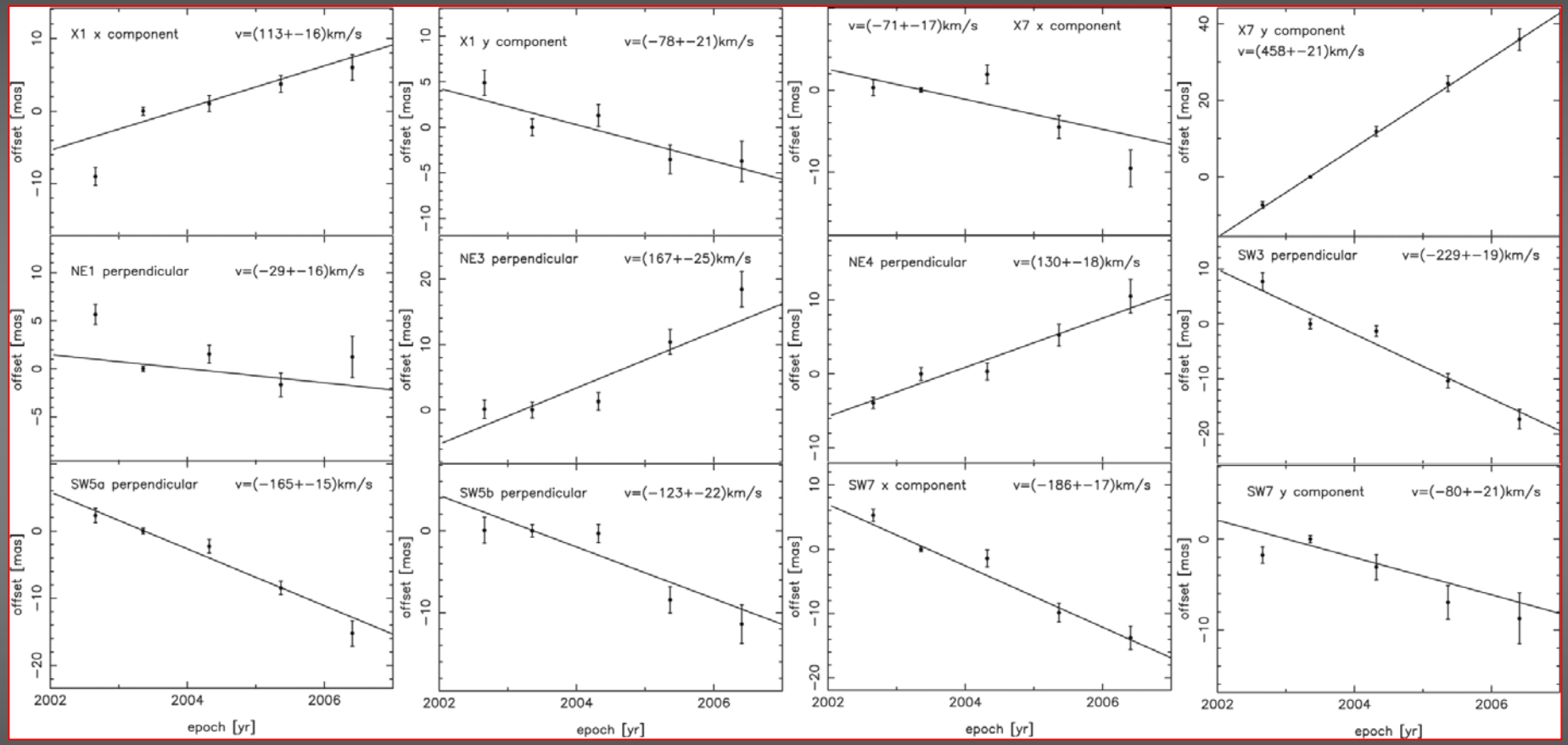


3.8 um NACO image;
100mas angular resolution

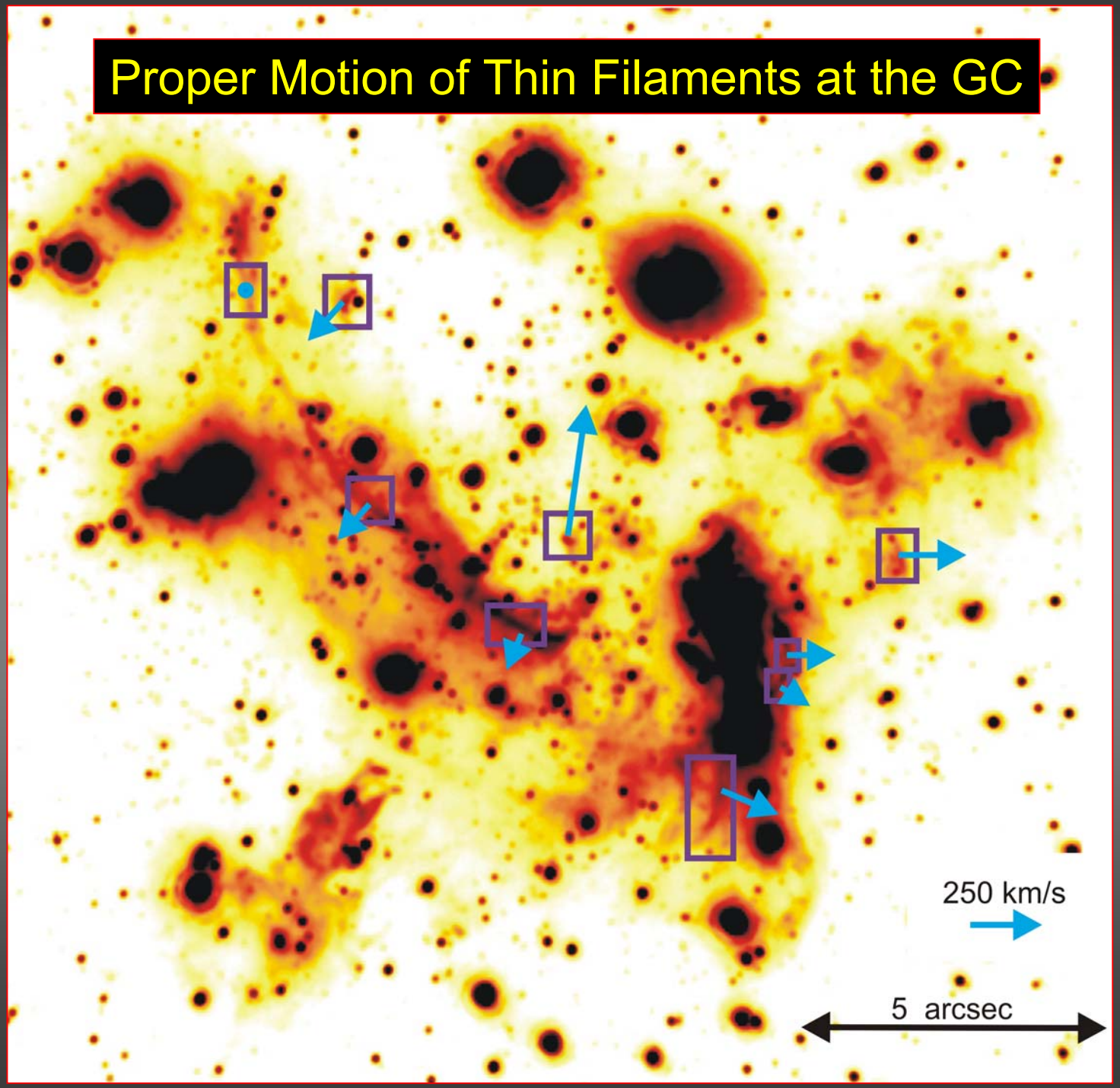
3.8 um NACO image;high pass filtered

Muzic,Eckart, Schödel et al. 2007

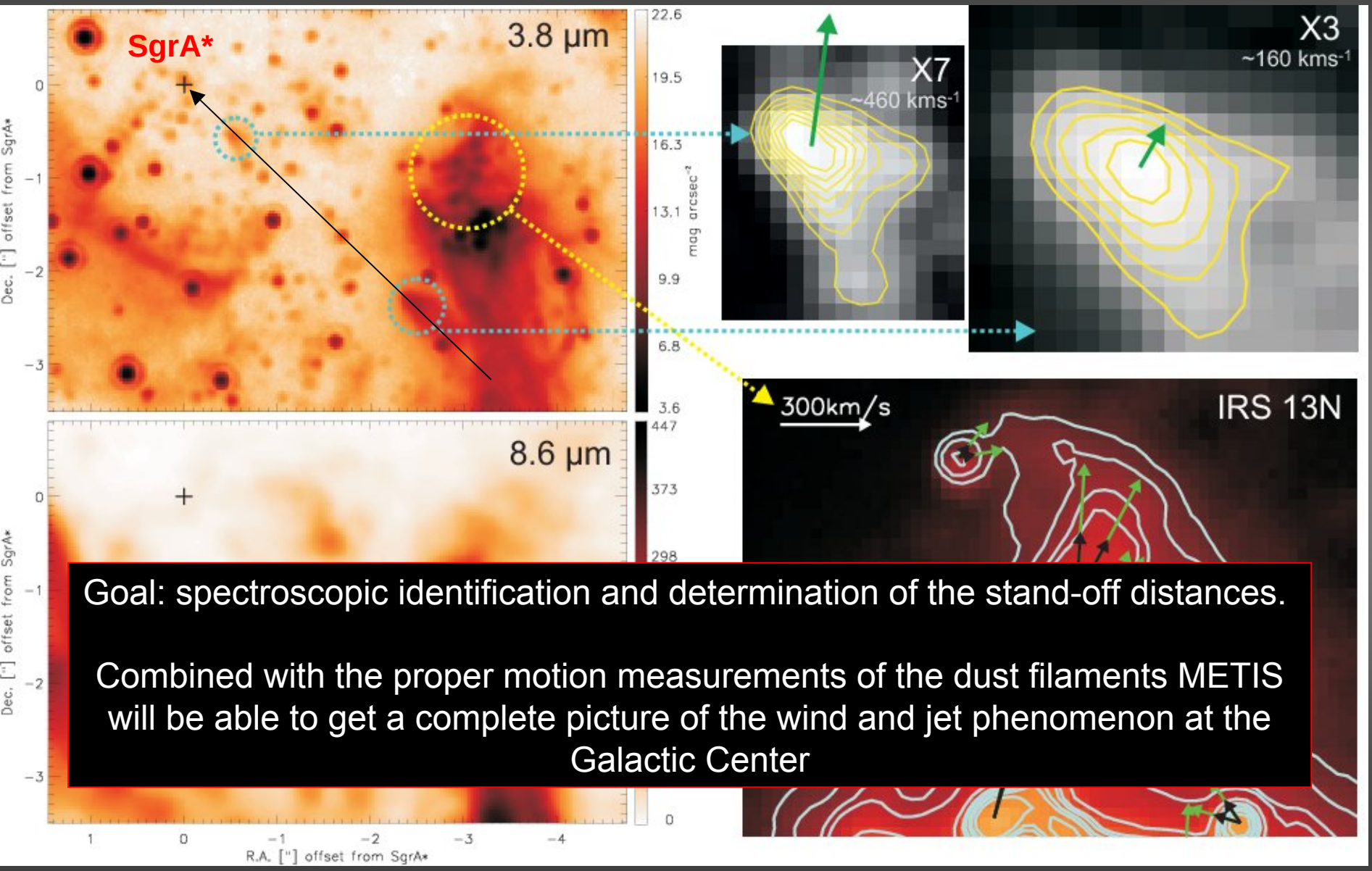
Proper Motion of Thin Filaments at the GC



Muzic,Eckart, Schödel et al. 2007


Proper Motion of Thin Filaments at the GC
250 km/s
5 arcsec

Cometary Sources and Wind Interaction mapped by METIS



Goal: spectroscopic identification and determination of the stand-off distances.

Combined with the proper motion measurements of the dust filaments METIS will be able to get a complete picture of the wind and jet phenomenon at the Galactic Center

Uniqueness

Uniqueness is given by
- use of full spectral range
- high angular resolution
- high Strehl ratio

METIS can trace 8 Myrs of star formation at the closest center of a galaxies!

ARCHES cluster	2-3 Myr	at ~95 km/s
QUINTUPLET	4-5 Myr	at ~113 km/s
GC stellar cluster	6-8 Myr	at ~ 0 km/s

Synergy with MIRI/JWST and ALMA

The Galactic Center observed with METIS at the E-ELT

Unique opportunity for METIS

- Dust enshrouded stars – 8 Myrs of star formation
- cometary shaped bowshock sources
- Proper motion of dust filaments
- MIR SgrA* detection and monitoring the accretion process
- Search for intermediate mass black holes

require highest angular resolution and can only be done with METIS at the E-ELT.

METIS
Mid-infrared
E-ELT Imager and
Spectrograph