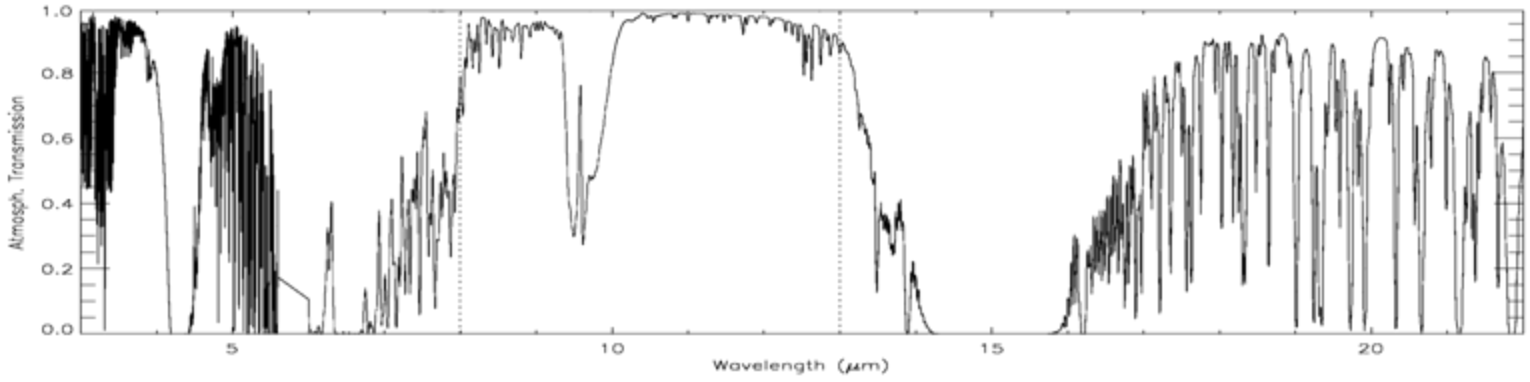
IR-Interferometry of AGNs

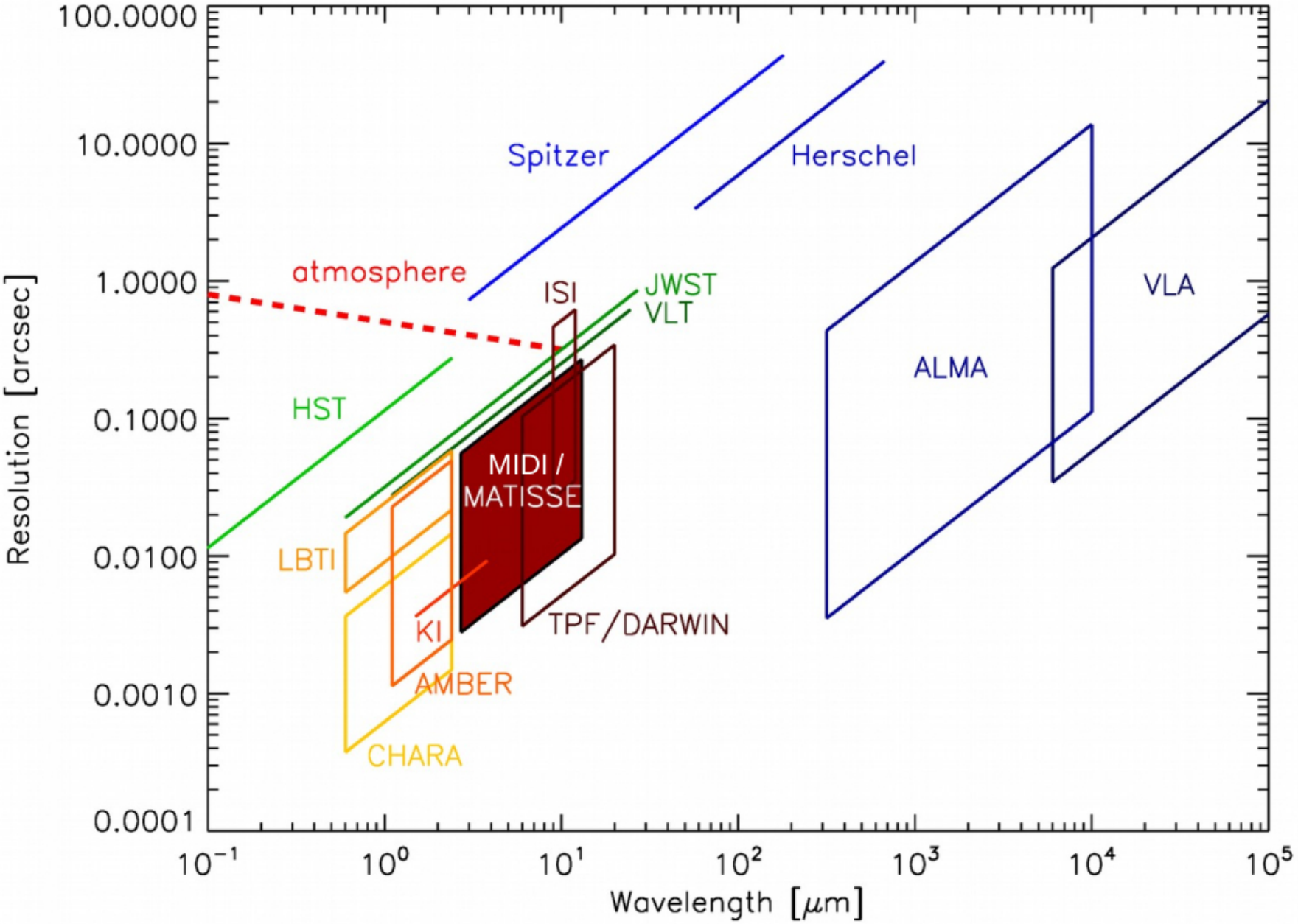
Basic Physics:

- **Temperatures 200-1500K + hotter material under special circumstances**
- **Continuum emission from dust**
- **Hydrogen Recombination lines (Pa/Br/Pfd)**
- **Molecular vibration/rotation CO/H2**
- **High ionization lines [SiIX], [ArVI]..**
- **Solid broad lines (SiO2, H2O, CO)**


1.0
0.8
0.6
0.4
0.2
0.0
Atmosph. Transmission
5
10
15
20
Wavelength (μm)

“long” baseline resolution

- Imaging- $\lambda/3B \sim$ 5-25 nanorad ~ 1-5 mas
- ~10 AU at Sgr A*, 0.1 pc at Virgo
- Phase/Astrometry ~1 μarcsec under very good conditions.


100.0000
10.0000
1.0000
0.1000
0.0100
0.0010
0.0001
Resolution [arcsec]
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
Wavelength [μm]
Spitzer
Herschel
atmosphere
ISI
JWST
VLT
HST
MIDI /
MATISSE
LBTI
KI
AMBER
CHARA
TPF/DARWIN
ALMA
VLA

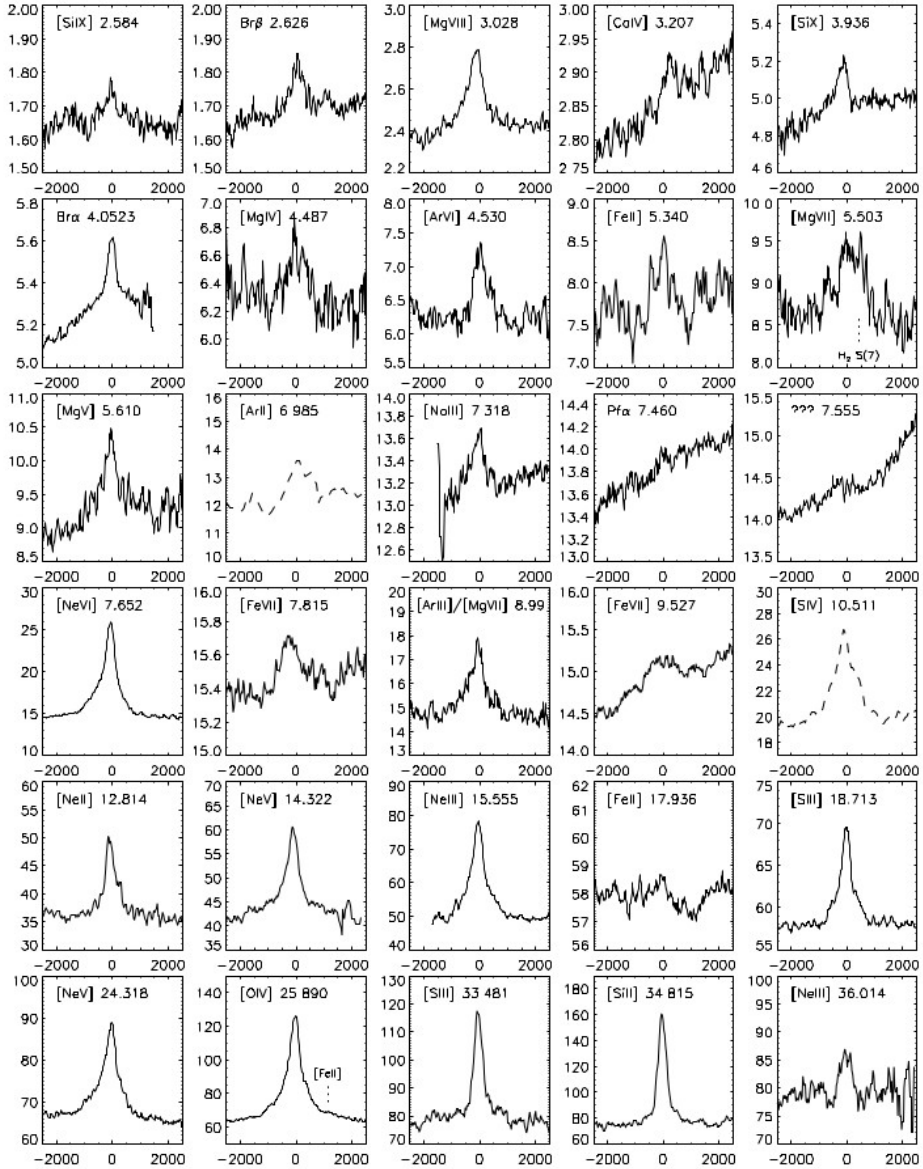
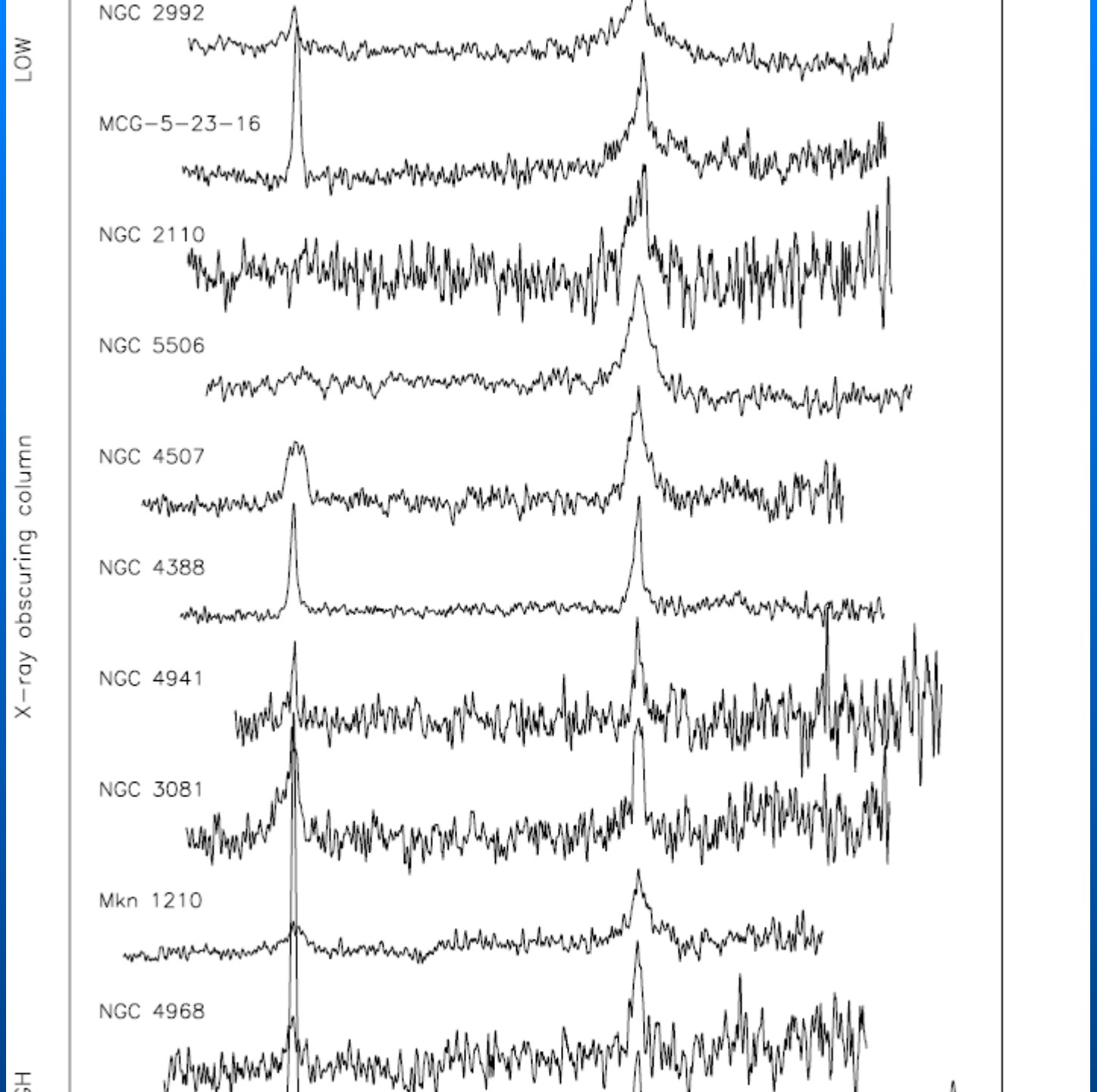


FIG. 2.—*ISO*-SWS spectra of lines emerging in the ionized medium of NGC 1068. Flux densities in janskys are shown for a range of ± 2500 km s^{-1} around systemic velocity. Most lines originate in the narrow-line region, but some low-excitation lines have a significant starburst contribution. The two lines shown dashed were observed in SWS01 mode, all others in full-resolution SWS06 mode.


LOW
X-ray obscuring column
NGC 2992
MCG-5-23-16
NGC 2110
NGC 5506
NGC 4507
NGC 4388
NGC 4941
NGC 3081
Mkn 1210
NGC 4968

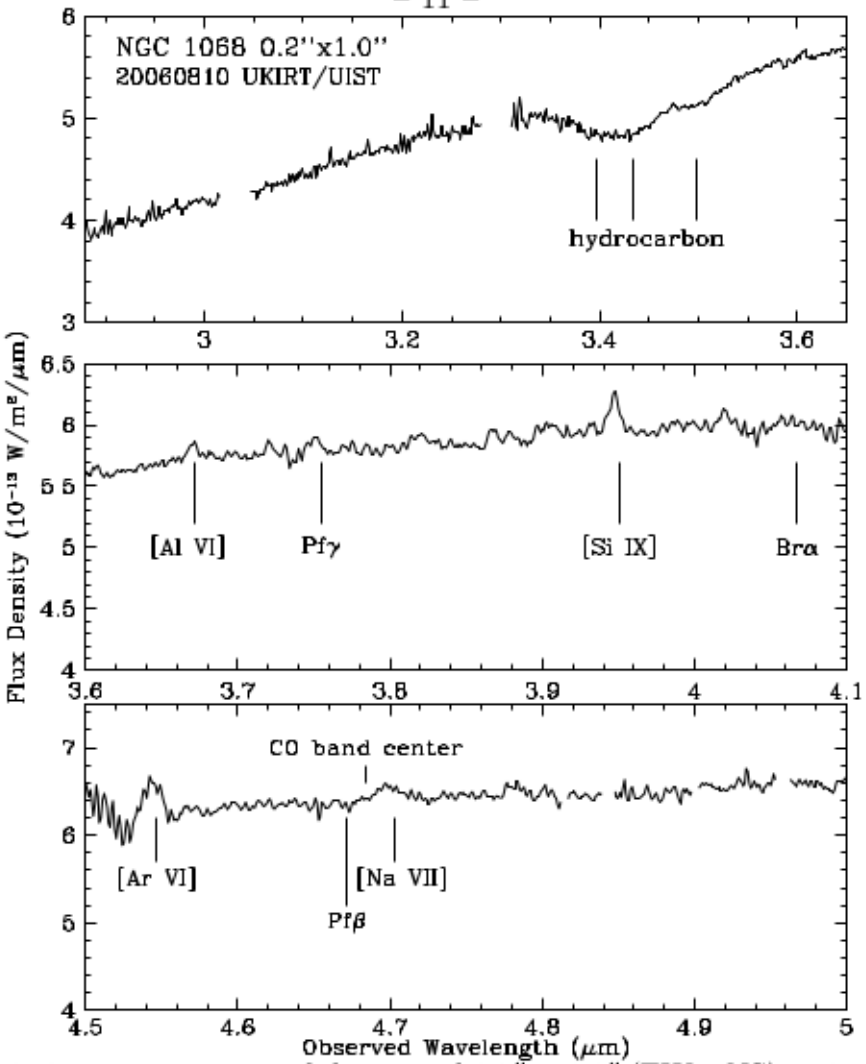
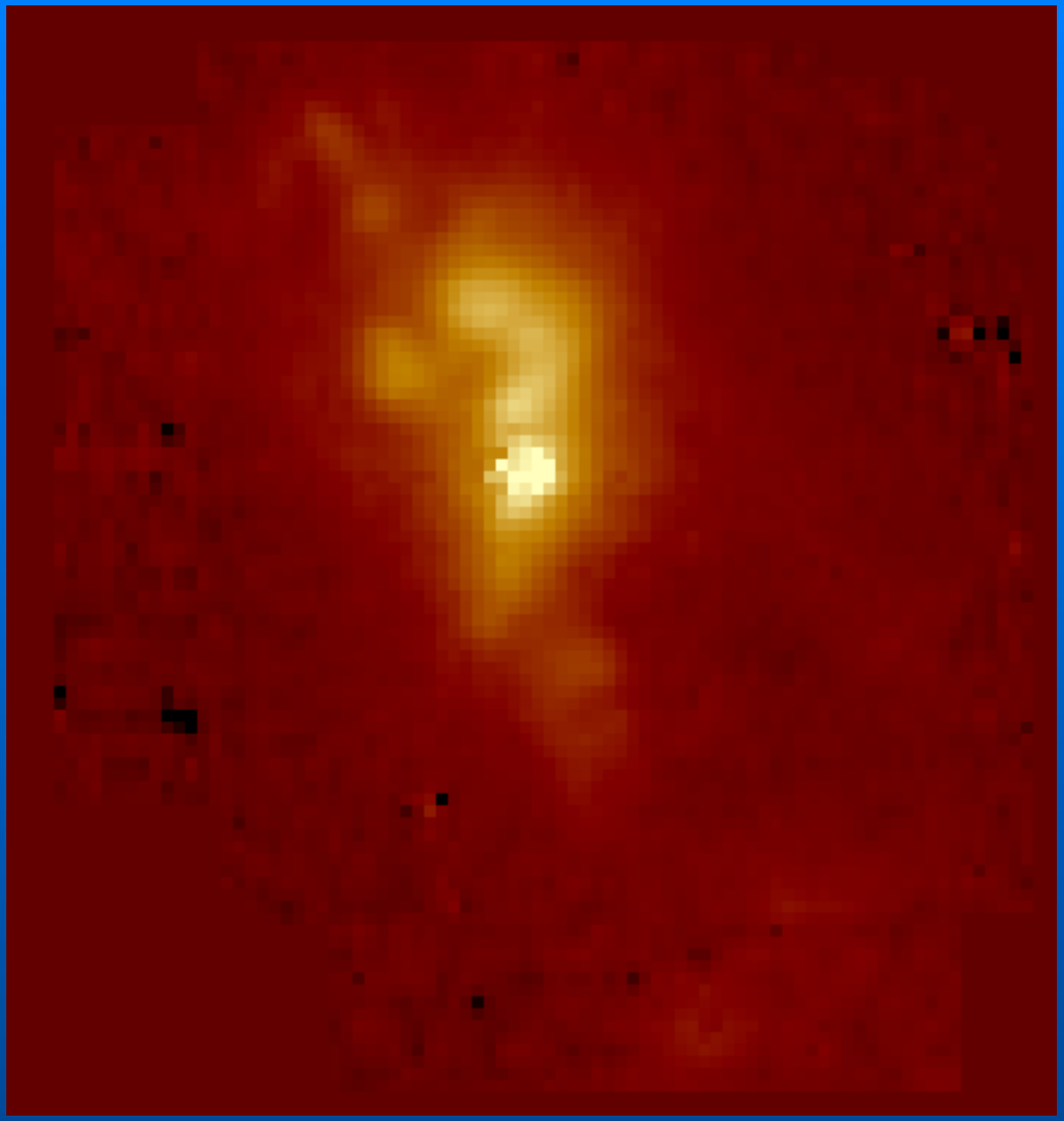


Fig. 2.— Fig. 1: 3–5 μm spectrum of the central $0.2'' \times 1.0''$ (EW x NS) region of NGC 1068. Wavelengths of atomic lines of interest are shown, as are the the three components of the 3.4 μm hydrocarbon feature (Pendleton et al. 1994) and the band center of CO, all at the systemic redshift of 0.003793. The noise level varies but can be estimated at each wavelength from the typical point-to-point fluctuations of the continuum in the vicinity. For simplicity the flux scale assumes that both NGC 1068 and the calibration star are unresolved point sources and that slit losses for them are equal; this is approximately correct for the continuum from NGC 1068, but not for the much more extended line emission.



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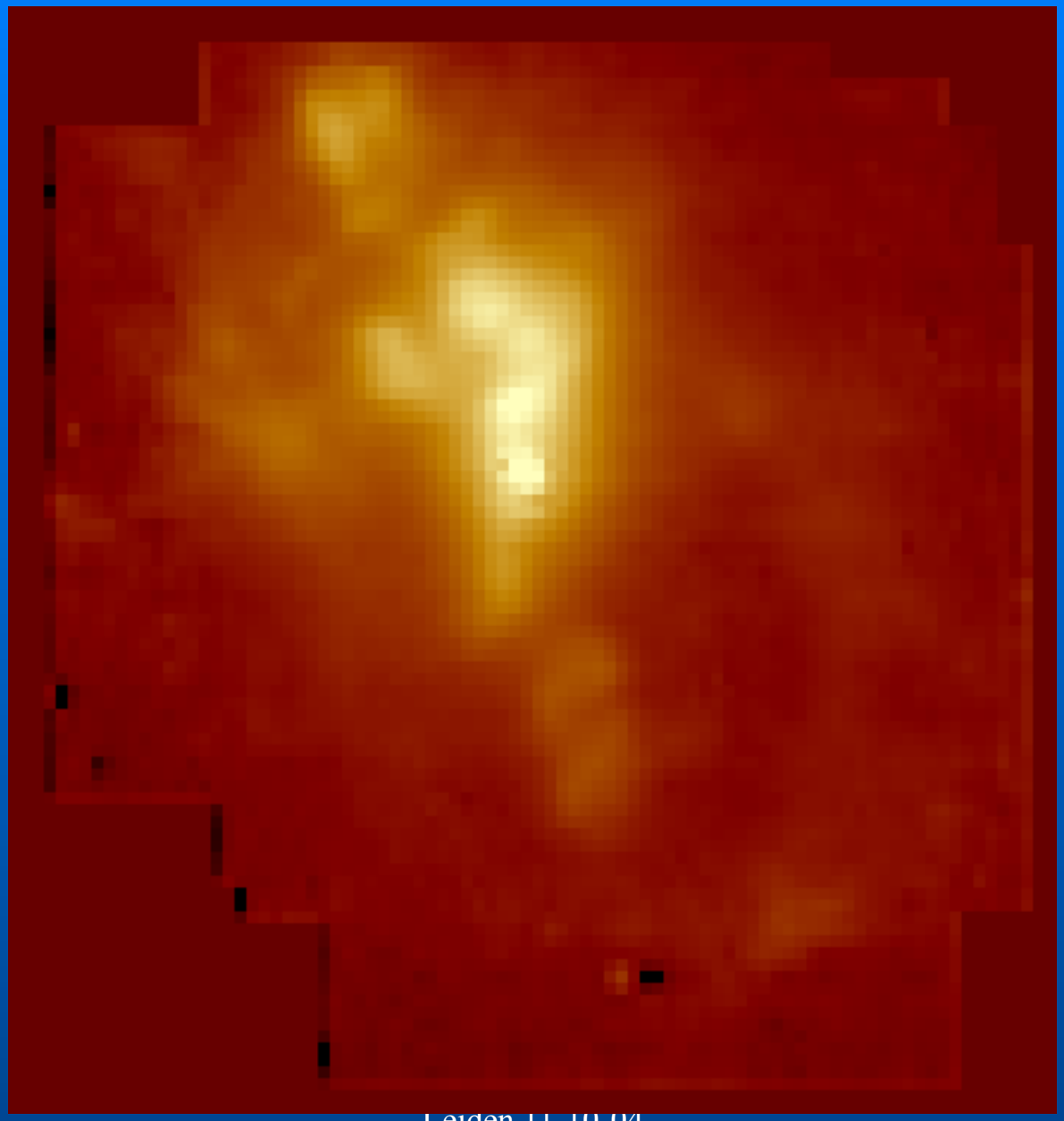
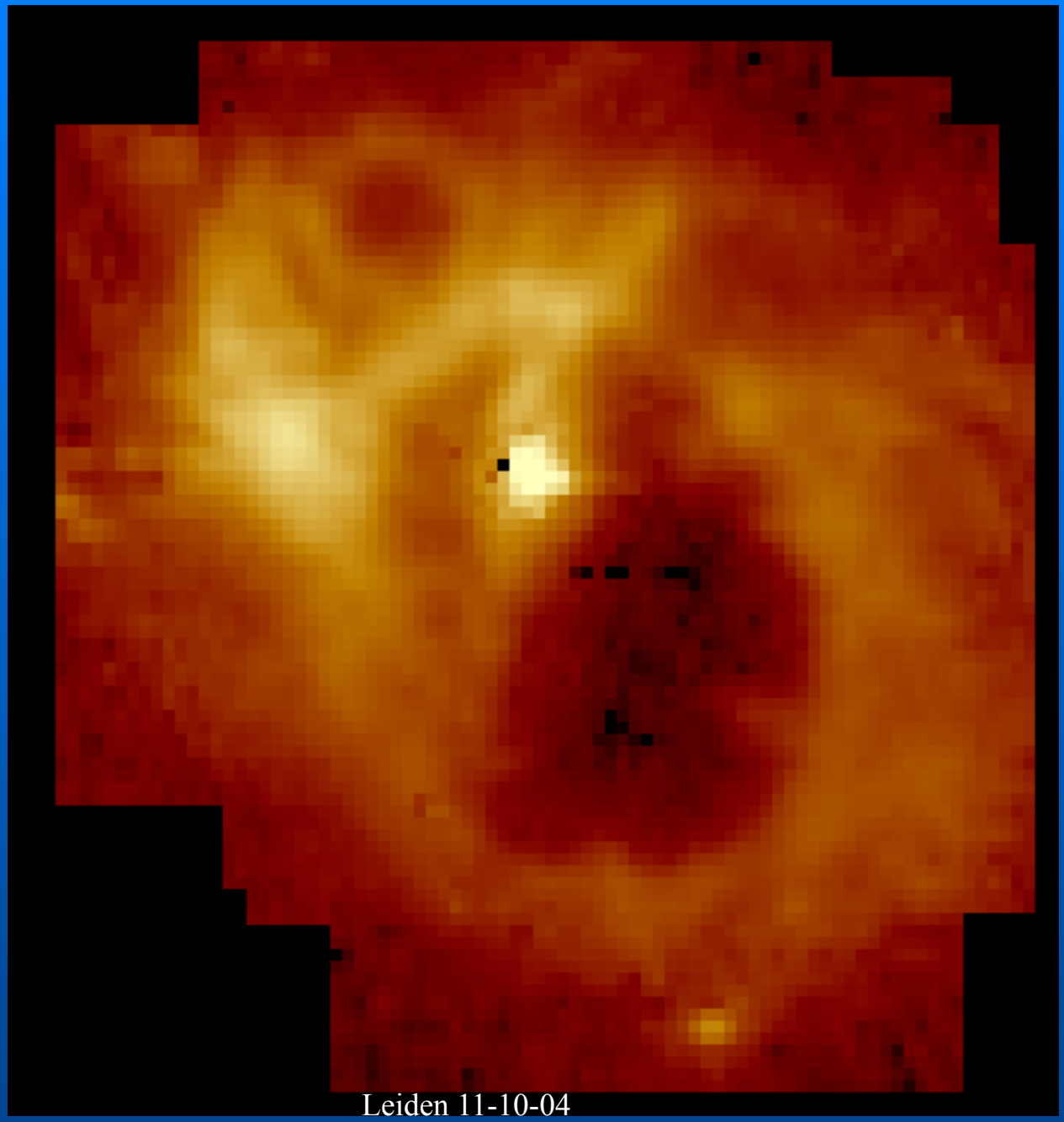
SiVI





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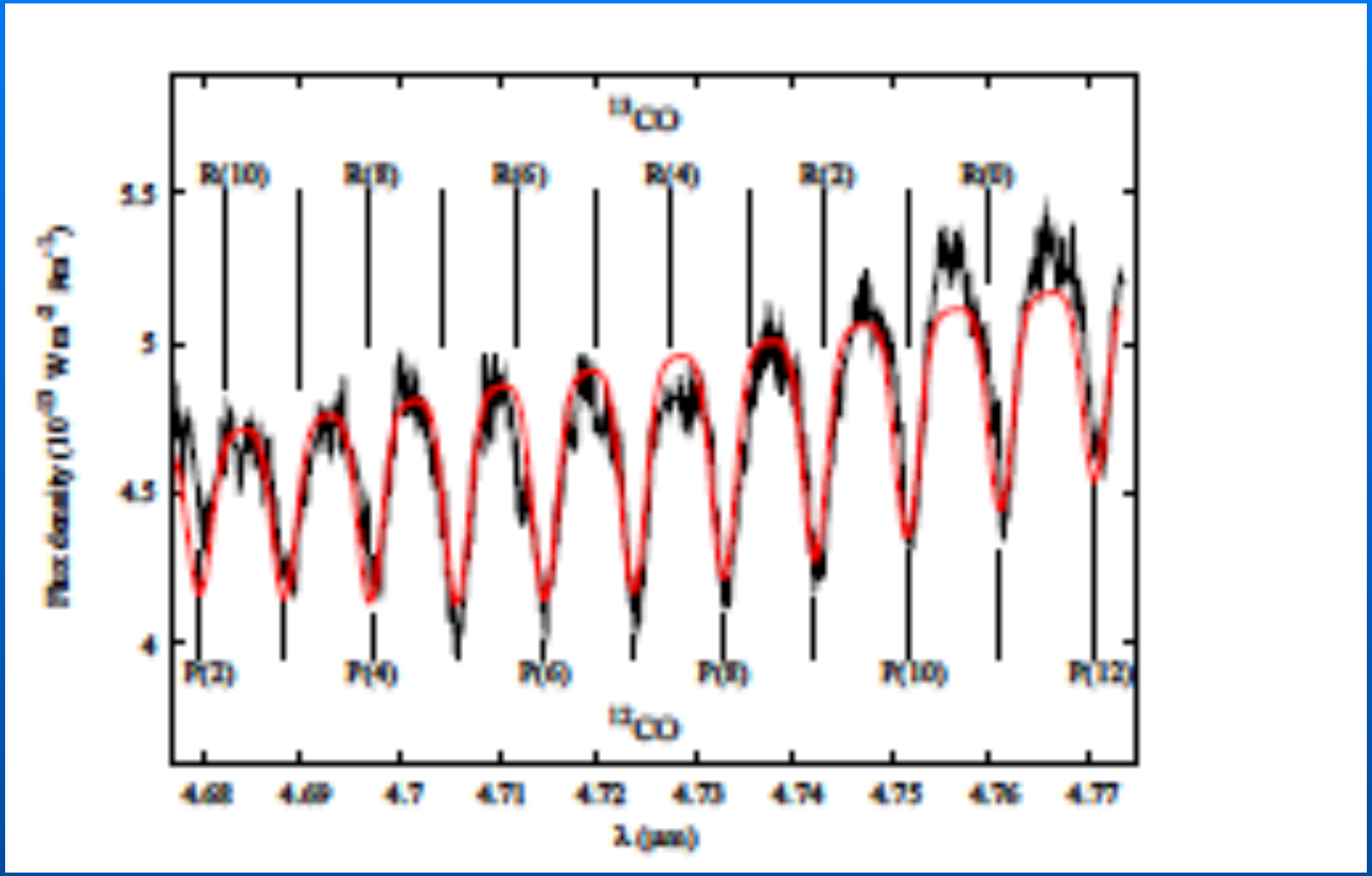
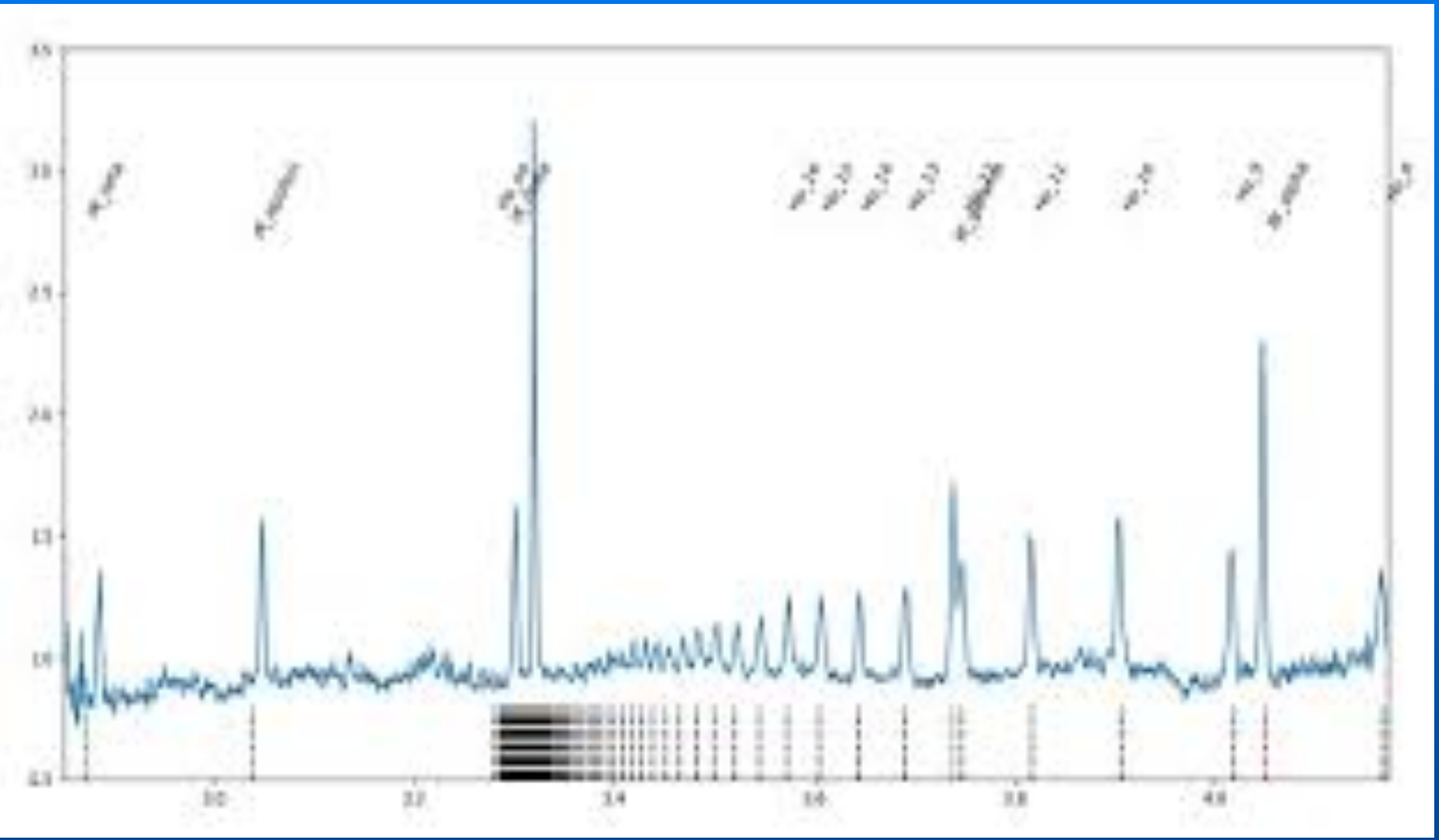
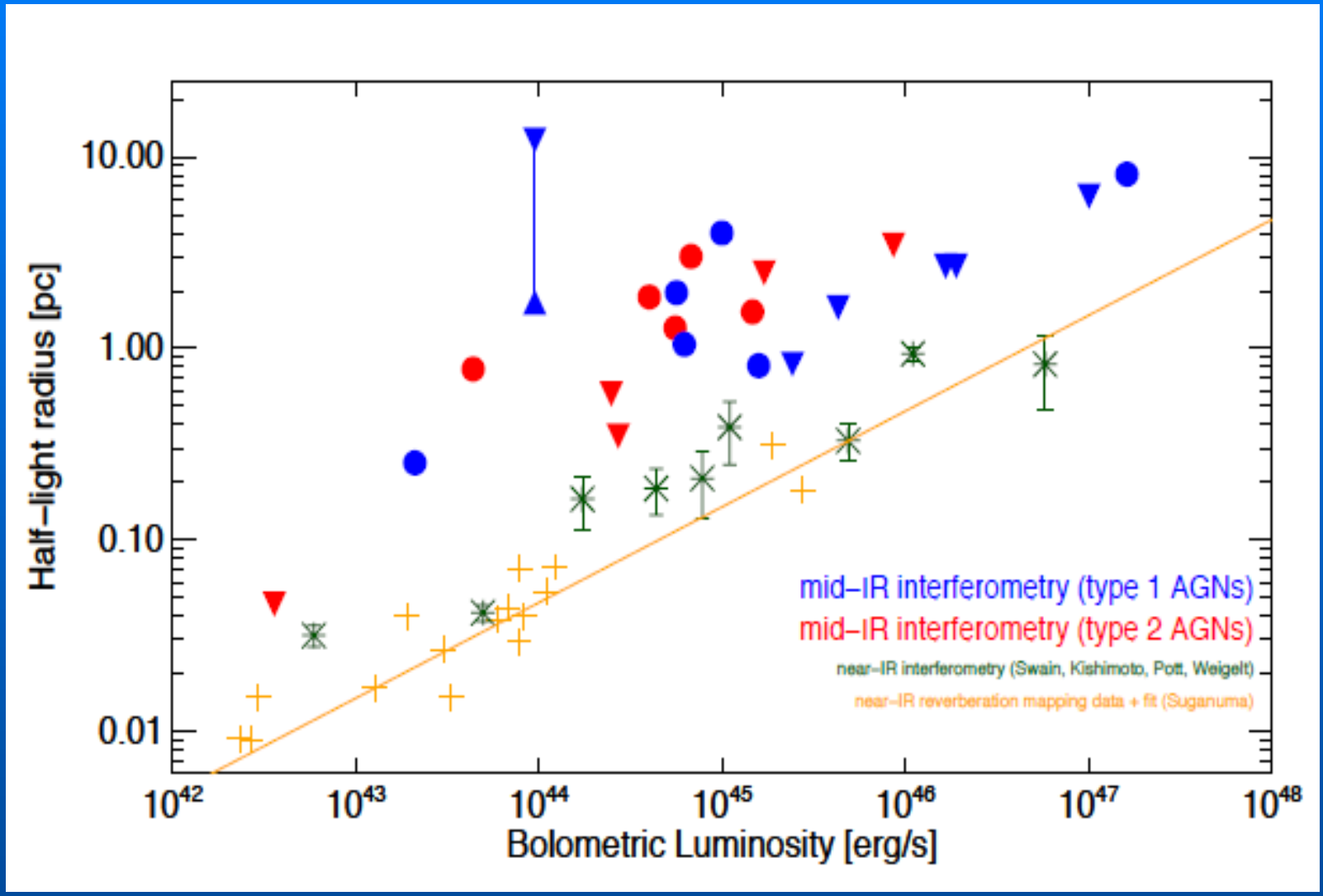

^{13}CO
R(10)
R(8)
R(6)
R(4)
R(2)
R(0)
P(2)
P(4)
P(6)
P(8)
P(10)
P(12)
^{12}CO
5.5
5
4.5
4
4.68
4.69
4.7
4.71
4.72
4.73
4.74
4.75
4.76
4.77
λ (μm)

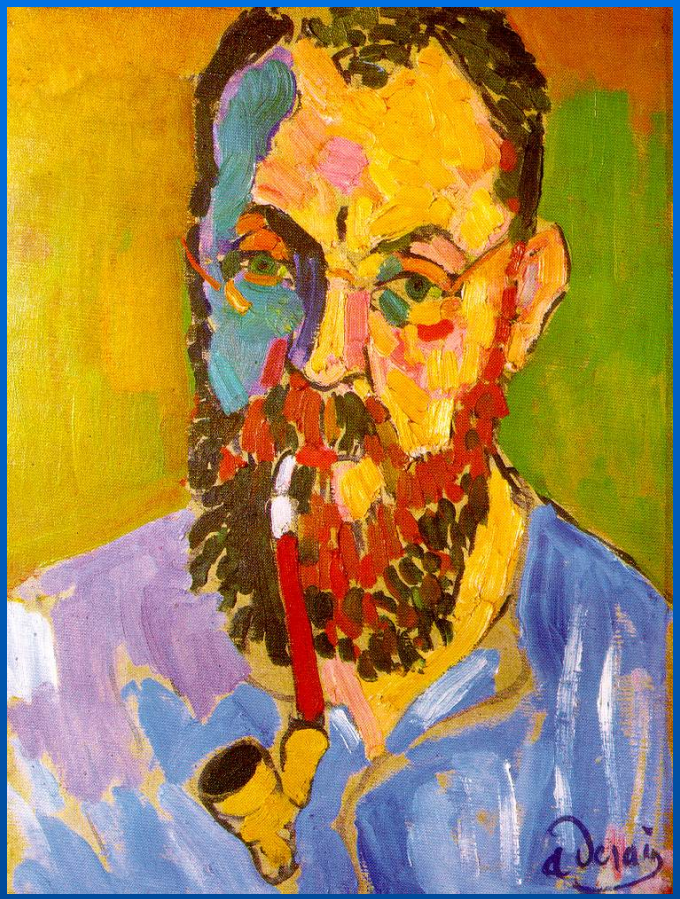


The Past (MIDI, PIONIER, AMBER)

- Dust Structures optically thick clumps
- At N-band highly variable structures, less so at K-band. Some misalignments, maybe some strange minerology.
- Uncertain geometries, no kinematics
- Non-unified models, misclassifications

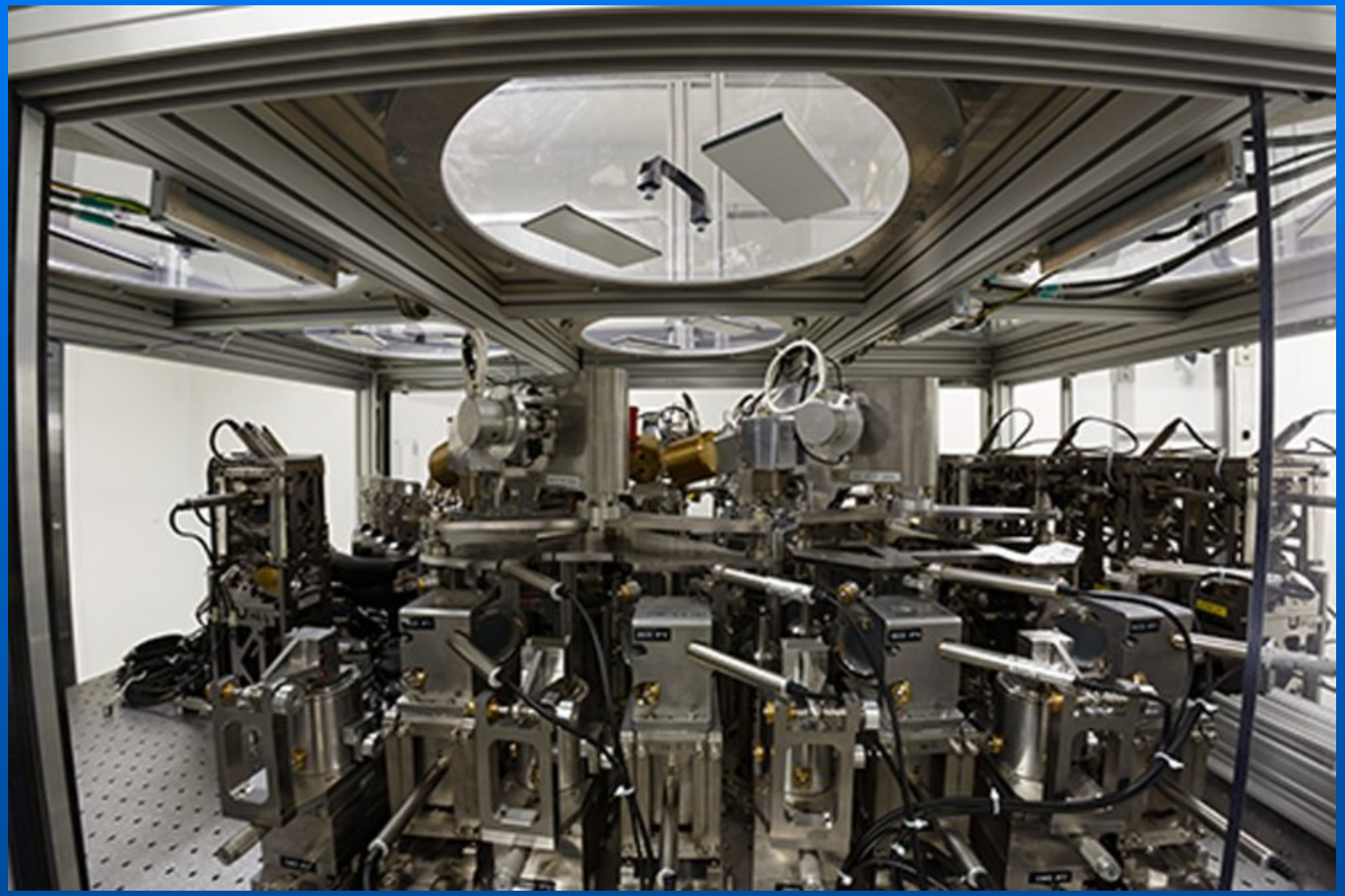

Half–light radius [pc]
10.00
1.00
0.10
0.01
10^{42}
10^{43}
10^{44}
10^{45}
10^{46}
10^{47}
10^{48}
Bolometric Luminosity [erg/s]
mid–IR interferometry (type 1 AGNs)
mid–IR interferometry (type 2 AGNs)
near–IR interferometry (Swain, Kishimoto, Pott, Weigelt)
near–IR reverberation mapping data + fit (Suganuma)

MATISSE:



MATISSE:

- designed for imaging with 4x8m or 4x1.8m tel
- Independent UV-points ~60 or ~200
- OCA+NOVA+MPIA+MPIfRA+ESO
- cost: ~13 MEu
- Wavelengths 3-13μ (with gaps)
- Resolutions 3-13 milliarcsec
- Field of view ~0.3-1" (8m) x 4.4 (1.8m)
- Sensitivity: complicated: low res. Continuum:
  - UTs: N-band ~0.3 Jy, L-band <~ 100mJy
  - ATs * 20 (?)



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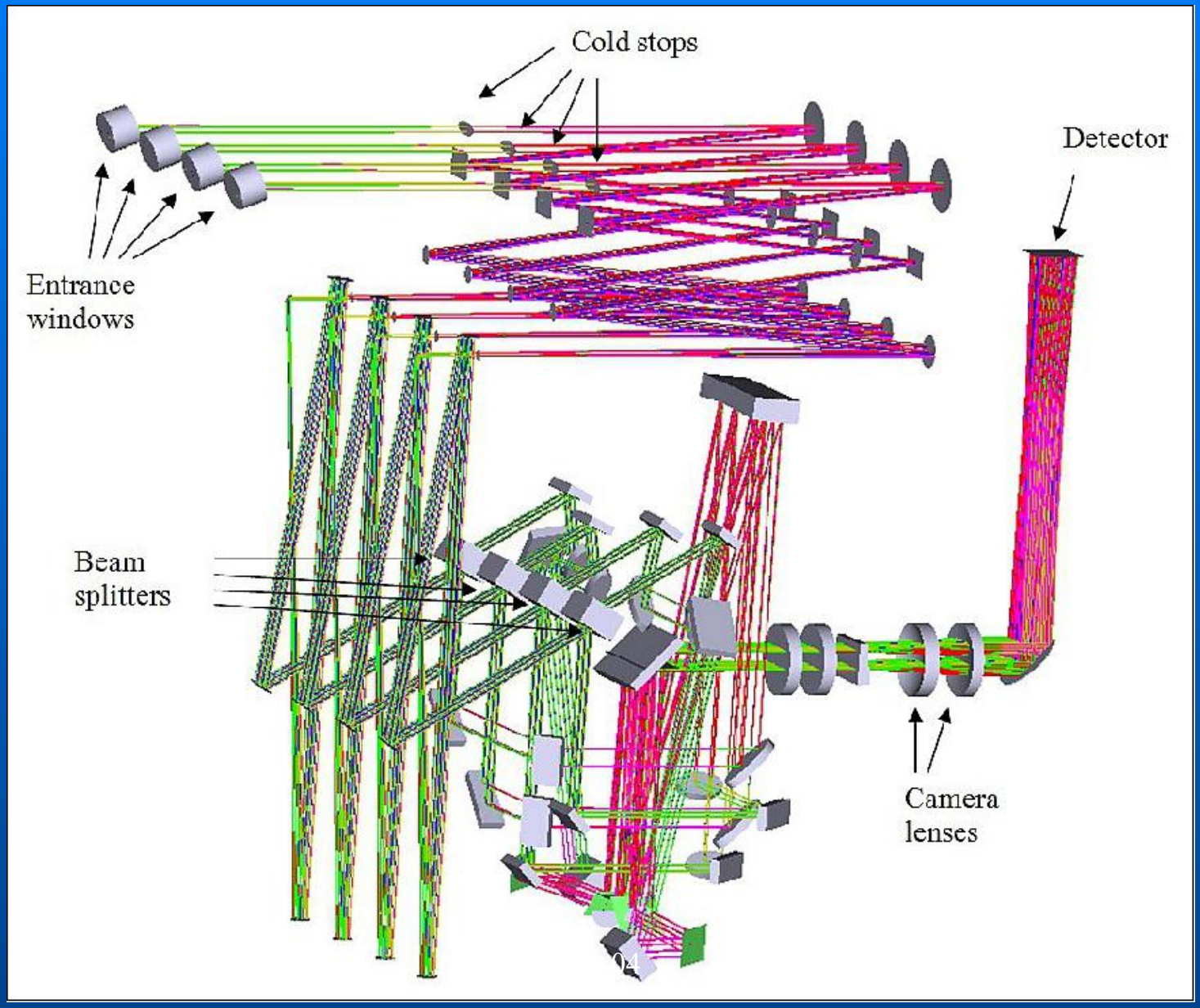
ESO
MATISSE
NOVA
ASTRON


Cold stops
Detector
Entrance windows
Beam splitters
Camera lenses

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File View Graphics Real-time Std. Options Help
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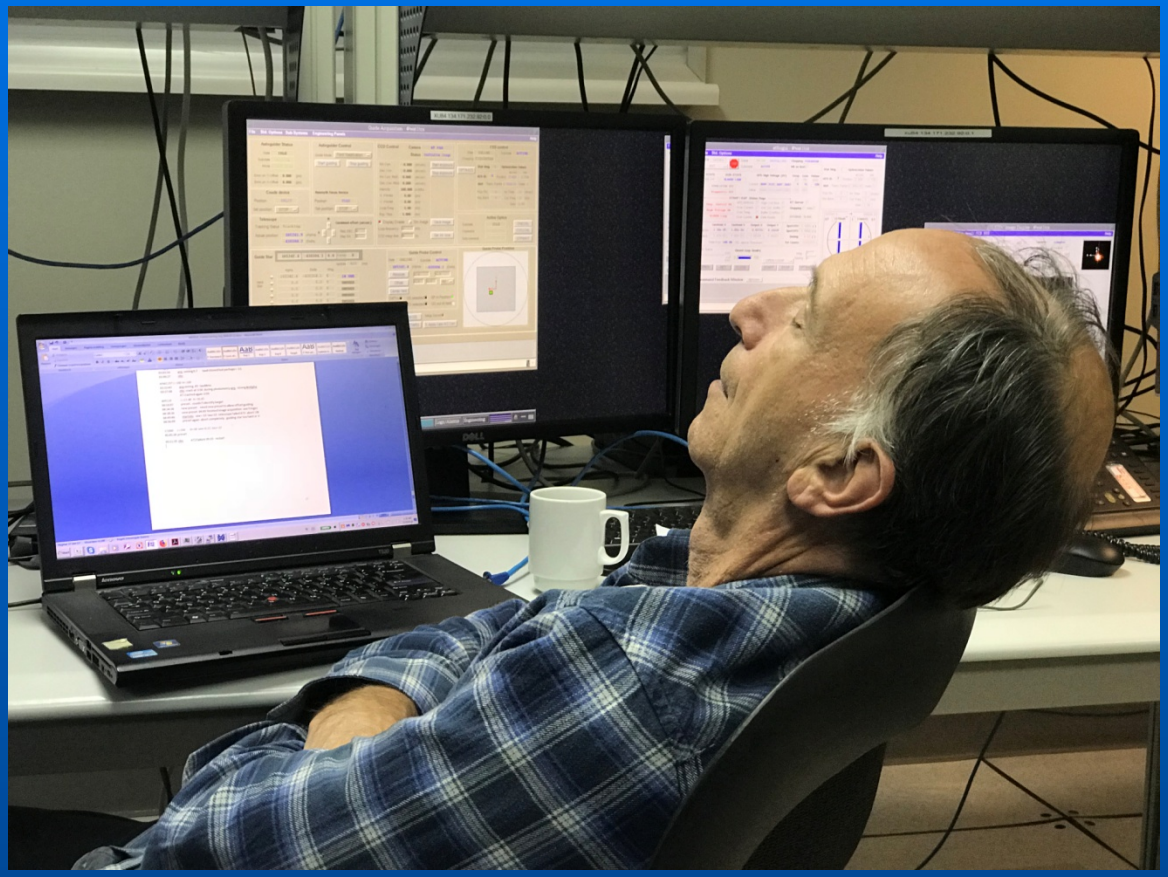
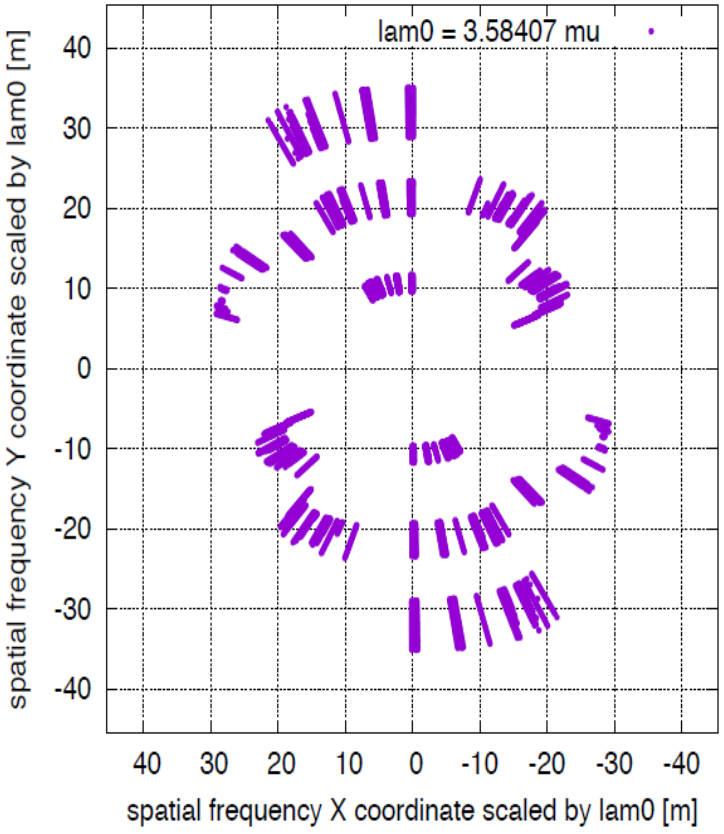
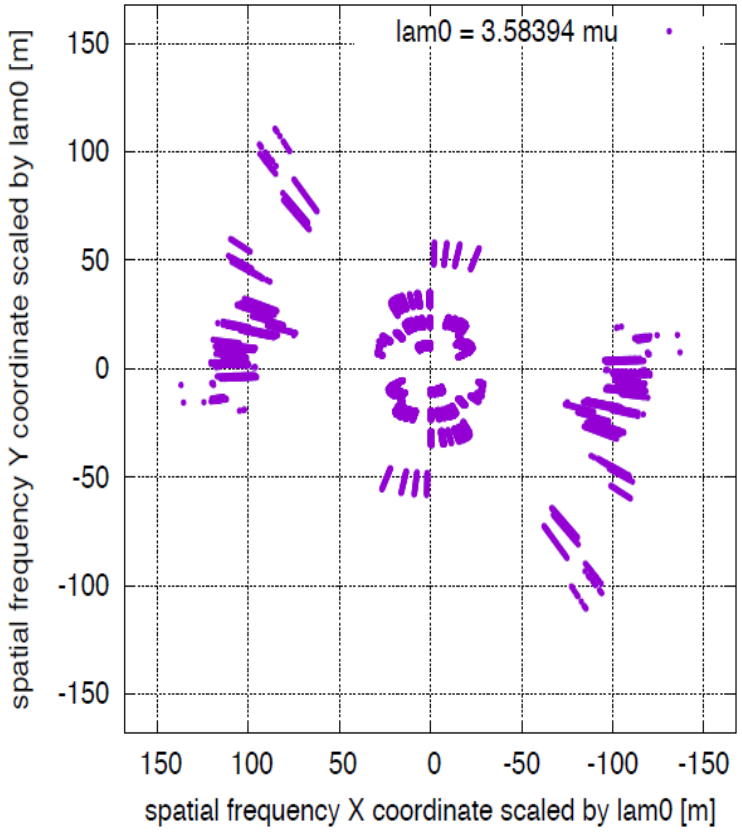


Dec 07+08



Dec 02+03+07+08+09



Relative Advantages

- GRAVITY/Kband:
  - Higher spatial resolution
  - Lower noise
  - Br γ, H2 1-0 rot/vib lines
  - Astrometry/polarization(?)
  - High T/dust-scattered light

Relative Advantages

- MATISSE LMN-band:
  - Lower temperature components
  - Broad spectral coverage
  - Brα, SiO2, CO(2-0), H2rot, ice lines, H2 polarization(???)
  - Low foreground absorption, mostly emission
  - Lower dust optical depths

Relative Advantages

- ALMA:
  - Low temperature components
  - Filled UV plane
  - CO rot lines, other molecular lines

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Relative Advantages

- One obvious division of focus:
- GRAVITY:Sy 1
- MATISSE:Sy 2

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Future IR-Interferometers

- **The European Interferometer Initiative is studying the feasibility of a exoplanetary interferometer, with (say) 27 10-meter telescopes with baselines of 1-10 km.**
- **MidIR resolution 20**μsec, **at 15 Mpc ~1 mPc , 200AU**
- **Image individual clumps, maybe BLR**
- **Surface brightness limited?** $\Omega/\mathrm{VLT} = 10^{-4}$, collecting area $= 10^{+1}$