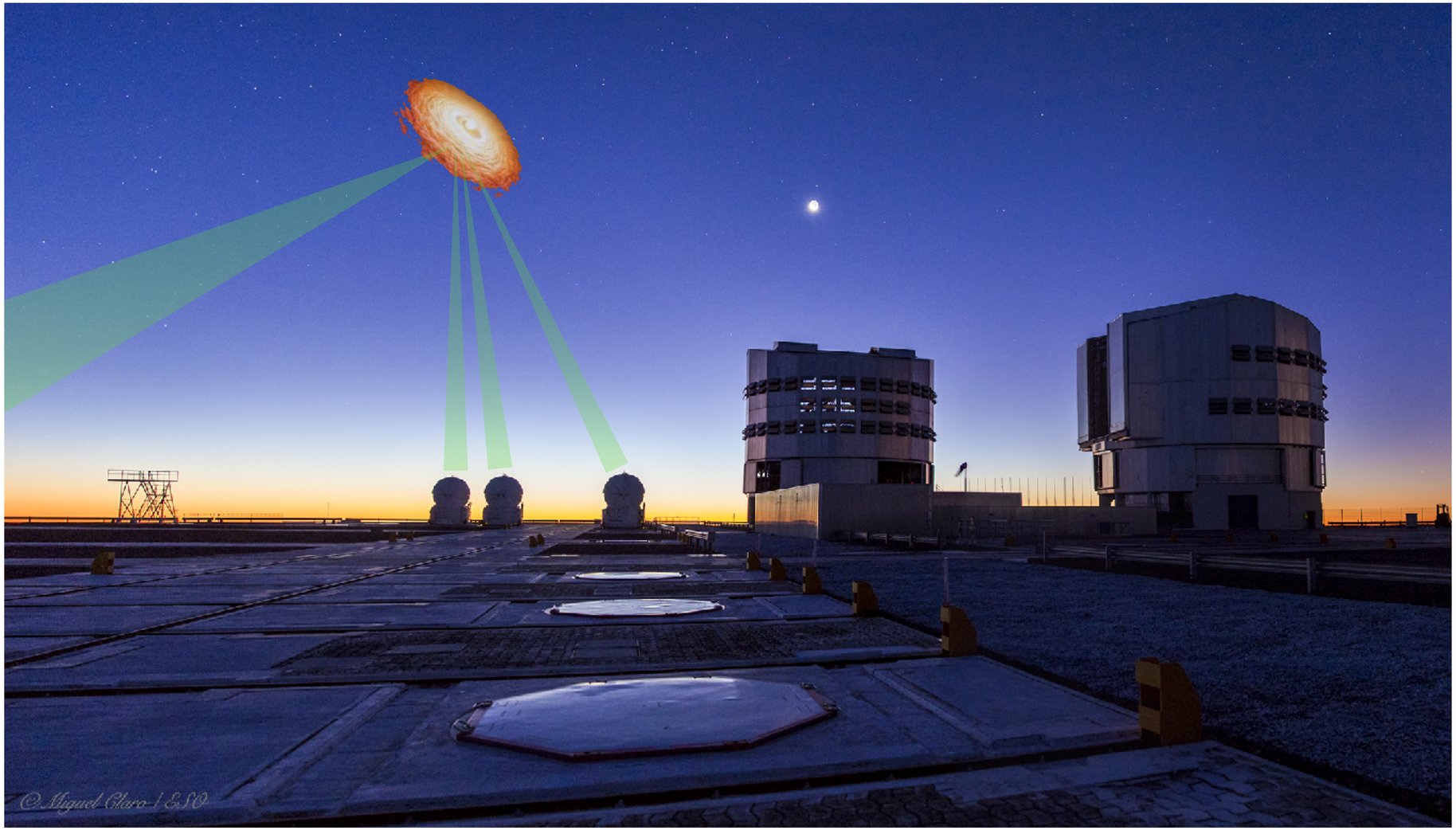
the MATISSE YSO survey



Presenter: Paul Boley, MPIA (filling in for Roy van Boekel)

MATISSE YSO Team

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MATISSE vs MIDI

- **6 baselines** for a single observation
  - 6 measurements of V^2 (vs 1)
  - 4 measurements of CP (vs 0)
- Addition of ***L* and *M* bands**
  - Continuum from **500-700 K dust**
  - **More dust species** accessible
  - Spatial resolution ~3 times better
- Much higher spectral resolution available (max R=230 with MIDI in *N*)
- *N*-band performance not as sensitive as MIDI

MATISSE the instrument

MATISSE : a spectro-interferometer

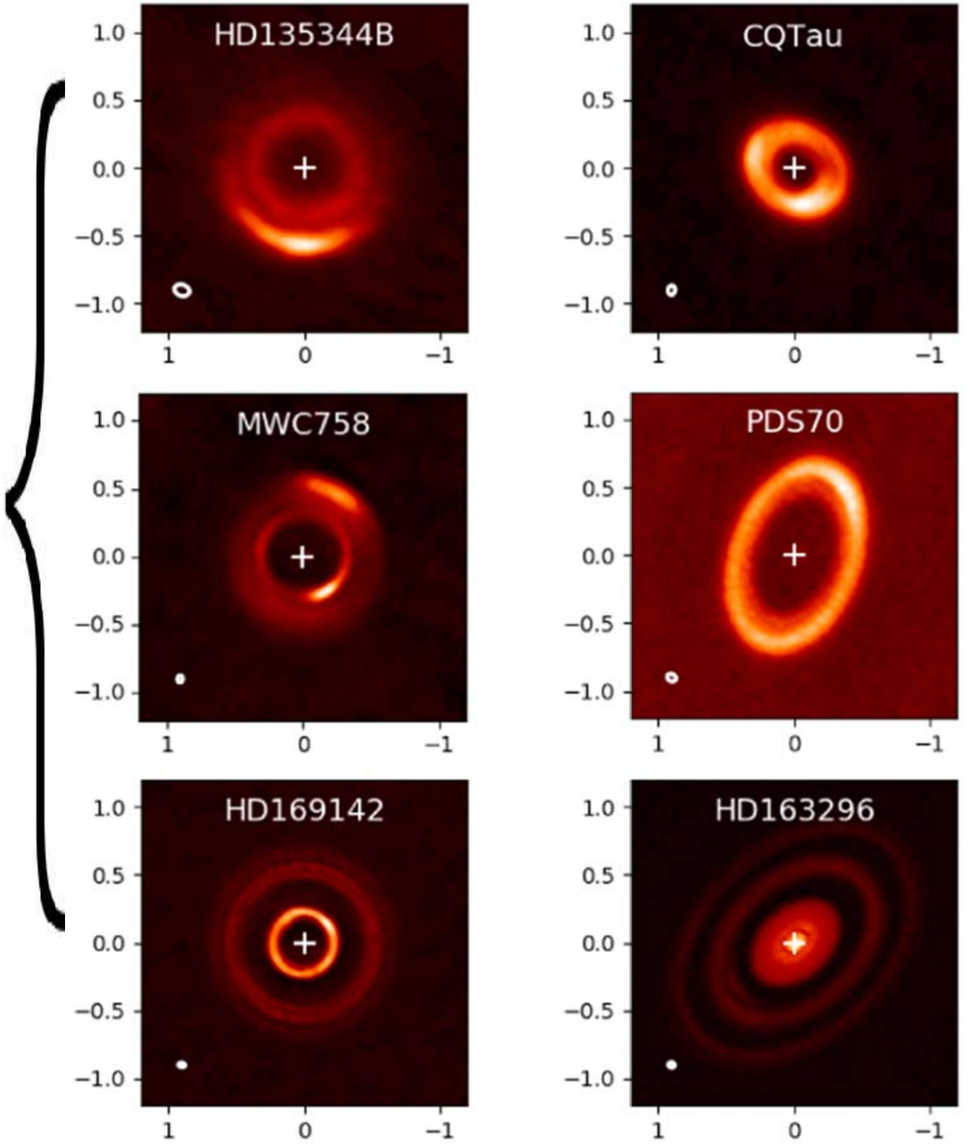
	Feature	Wavelength (μm)
	L- and *M*-bands (~ 2.8–5.0 μm)	
L/M band instrument R ~ 30 R ~ 500 R ~ 900 (only L-band) R ~ 5000	H_2O (ice)	3.14
	H_2O (gas)	2.8–4.0
	H lines (Br-α, Pf-β)	4.05, 4.65
	PAHs	3.3, 3.4
	Nano-diamonds	3.52
	CO fundamental transitions	4.6–4.78
	CO (ice)	4.6–4.7
	N-band (~ 8.0–13.0 μm)	
N band instrument R ~ 30 R ~ 220	Amorphous silicates	9.8
	Crystalline silicates (olivines and pyroxenes)	9.7, 10.6, 11.3, 11.6
	PAHs	8.6, 11.4, 12.2, 12.8
	Fine structure lines (e.g., [S IV], [Ne III], [Ne II])	10.5, 10.9, 12.8

Science themes

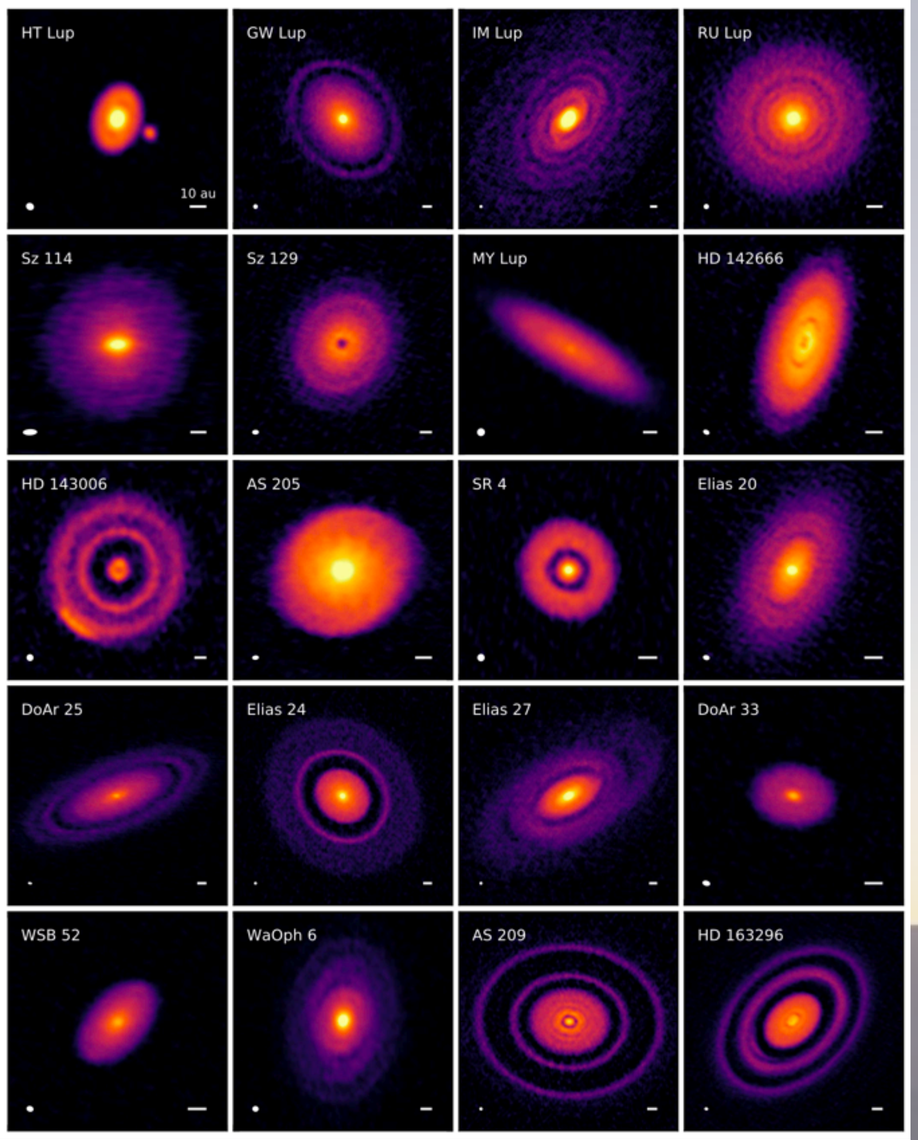
- disk structure on 1-10 au scale, same diversity in structure as seen on larger scales with ALMA / SPHERE & Co?
- silicate mineralogy in N-band, spatial variations in dust composition.
- carbonaceous material (PAHs, nano-diamonds)
- gaseous lines of water, CO, H-series
- Ices (water, CO)

Van der Marel+2021, AJ, 161, 33

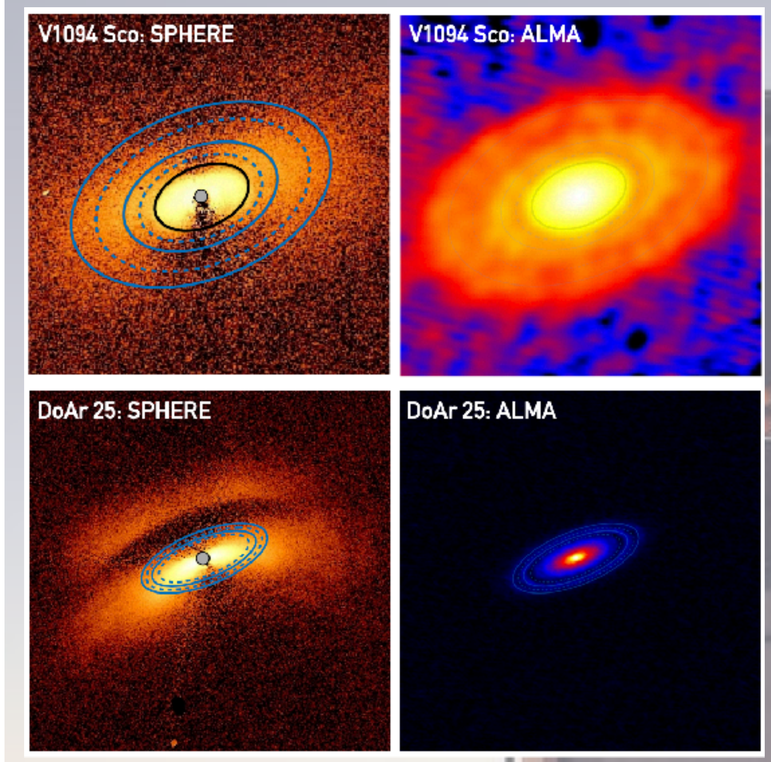
ALMA: huge diversity in geometry on scales of ≈5-100 AU

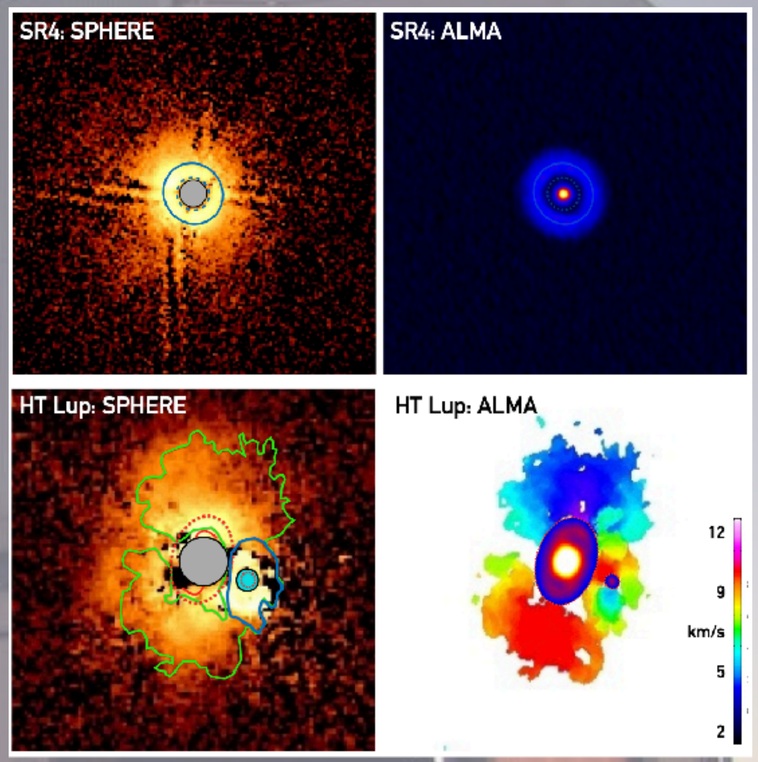


AO-assisted imaging & sub-mm interferometry



Andrews et al. (2018). ~50 mas resolution with ALMA.

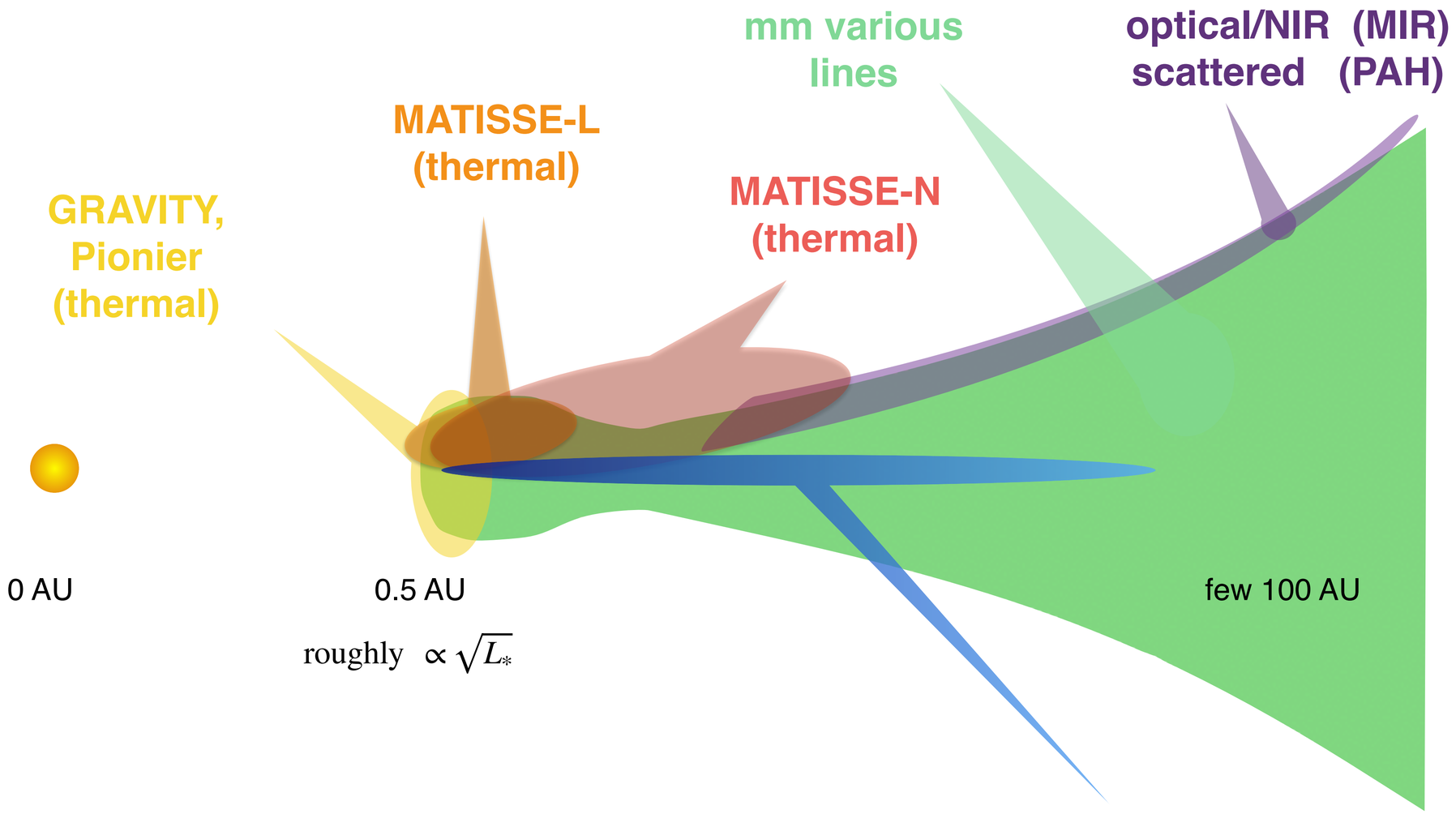




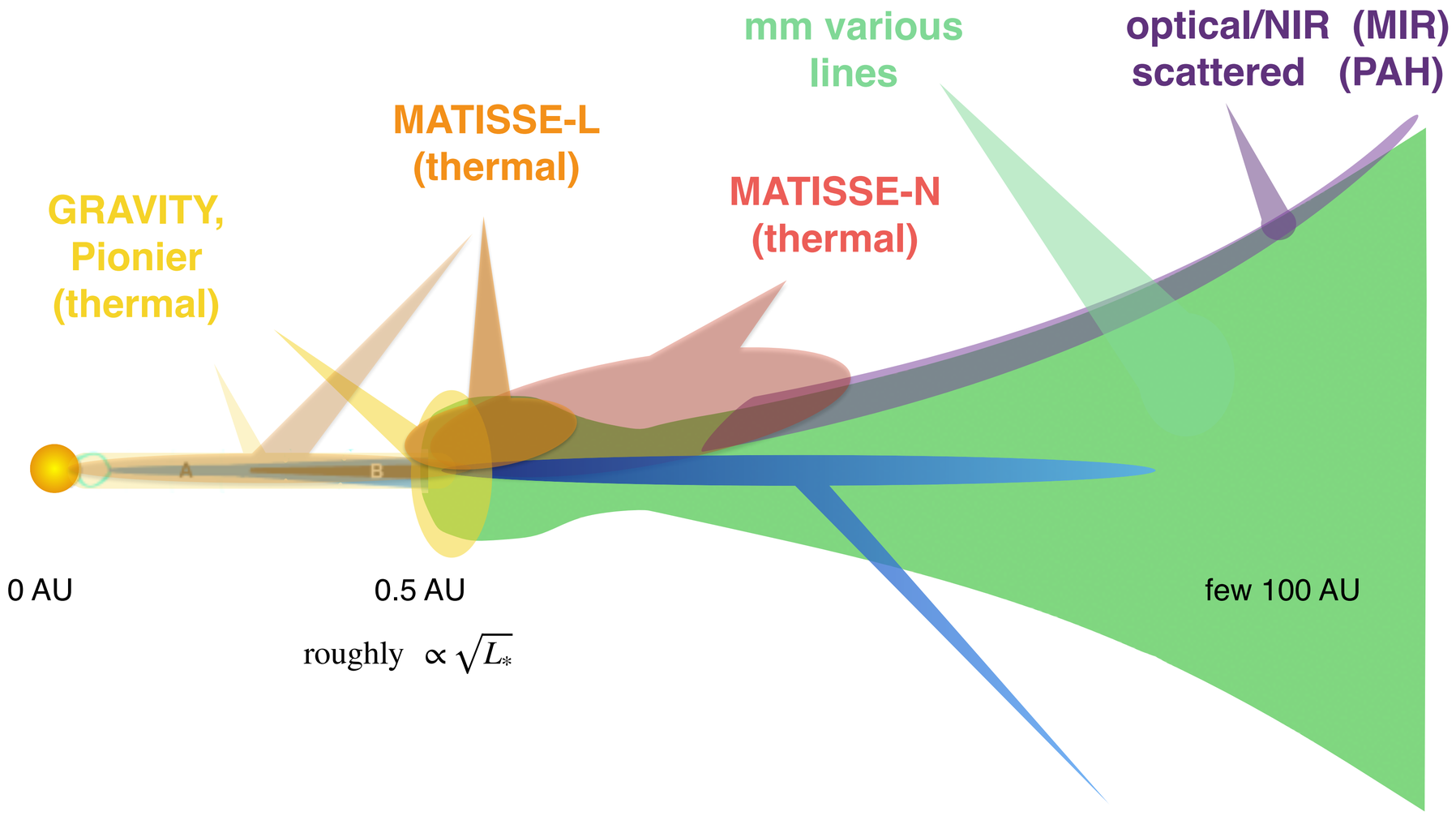
Garufi et al. (2020). ~30 mas resolution with SPHERE.

Access to inner disk regions (~0.1-10 au) requires spatial resolution of ≤10 mas.
Optical/IR interferometry is essential!

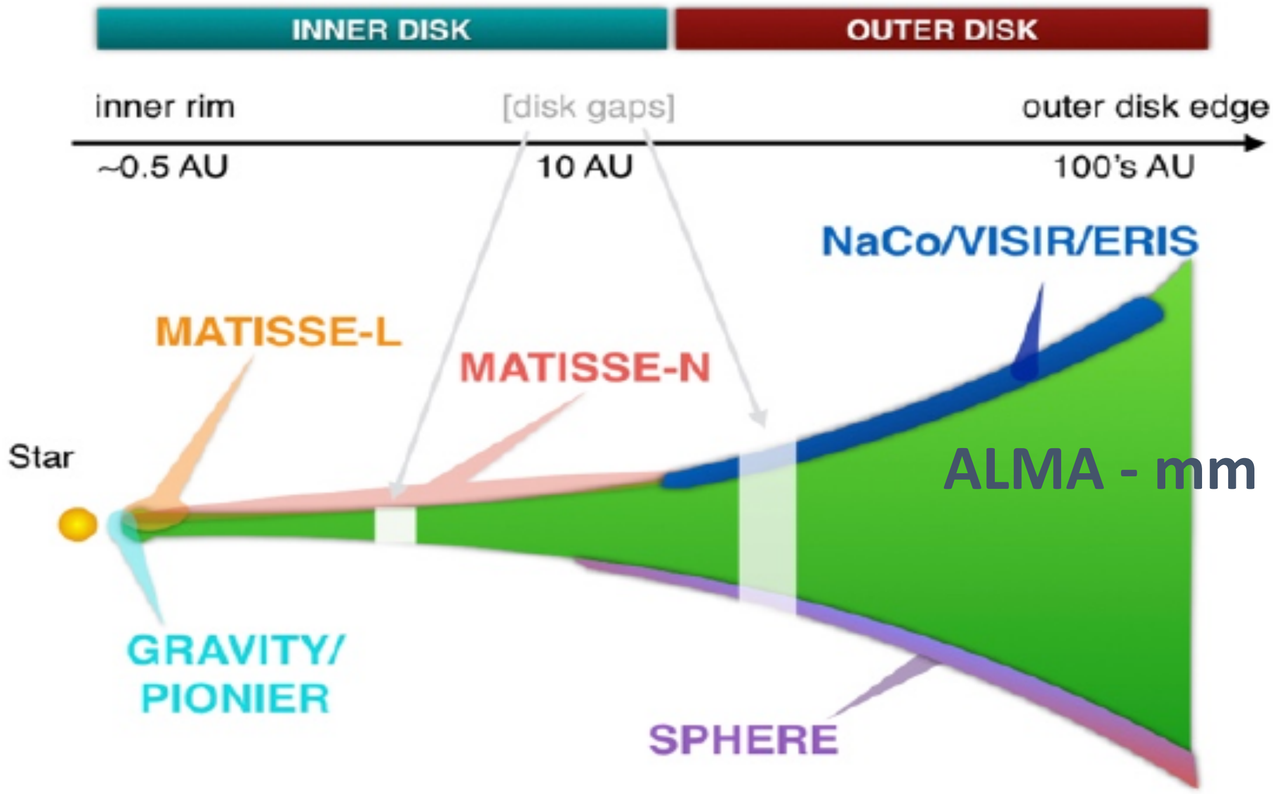
Disks: observational diagnostics

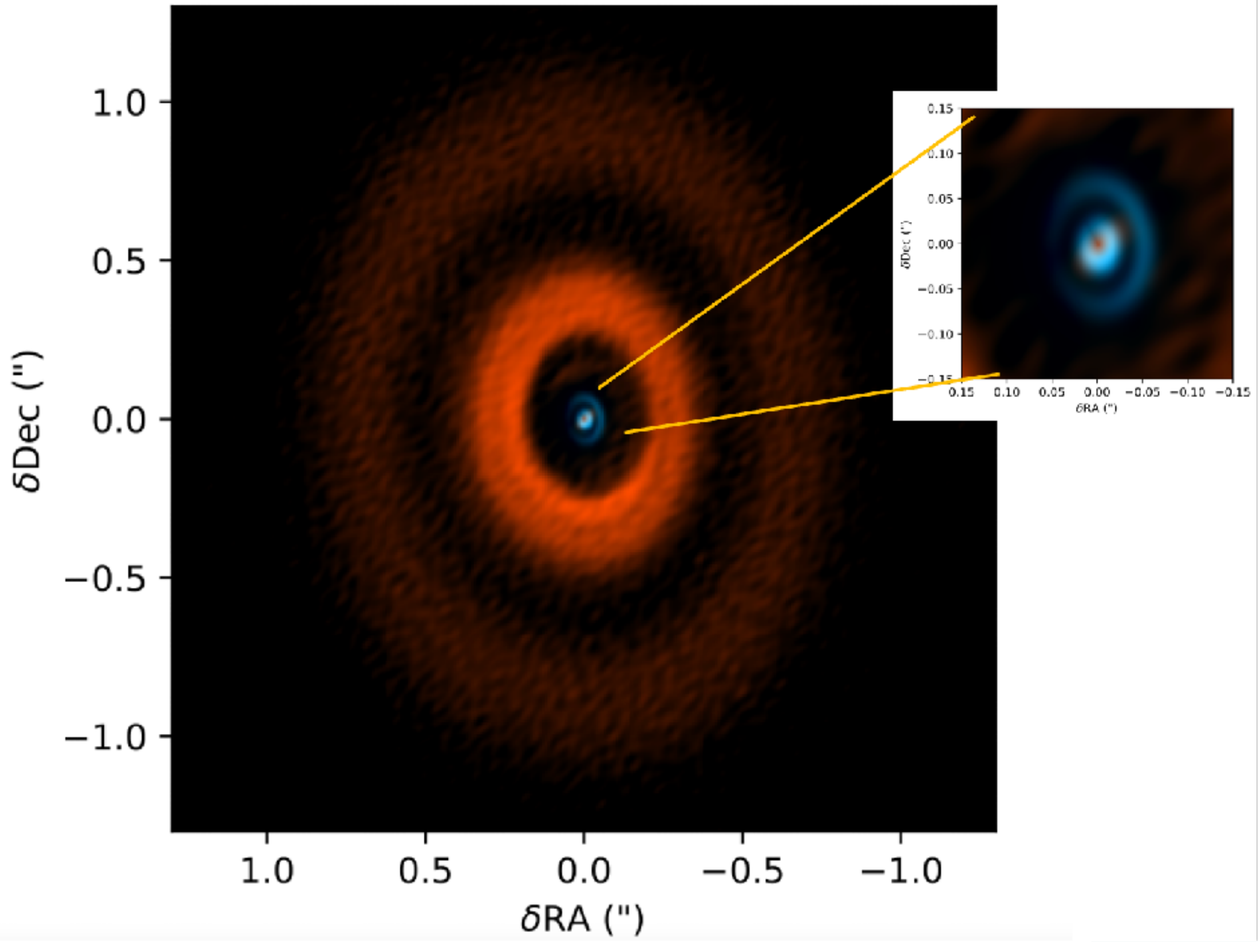


Disks: observational diagnostics



Survey - Sub-Structure





ALMA continuum from Francis & van der Marel (2020) and MATISSE model image Lopez et al. (in prep.) for HD 97048

Survey - Overview

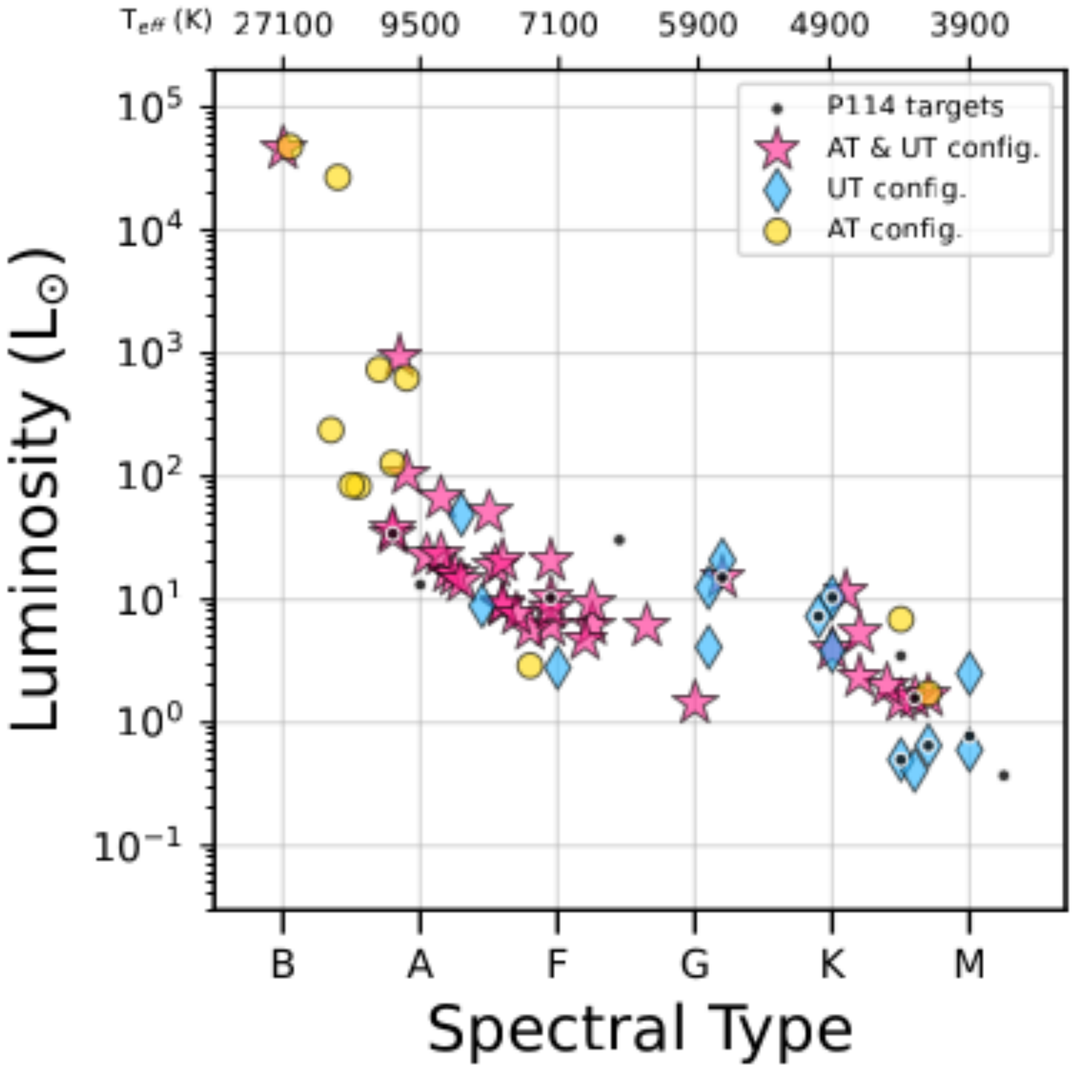
Aims

Characterize the Structure and Composition of the planet-forming regions in discs around a variety of young sources in the LM (3-5 μm) and N band (8-13 μm)

Overview

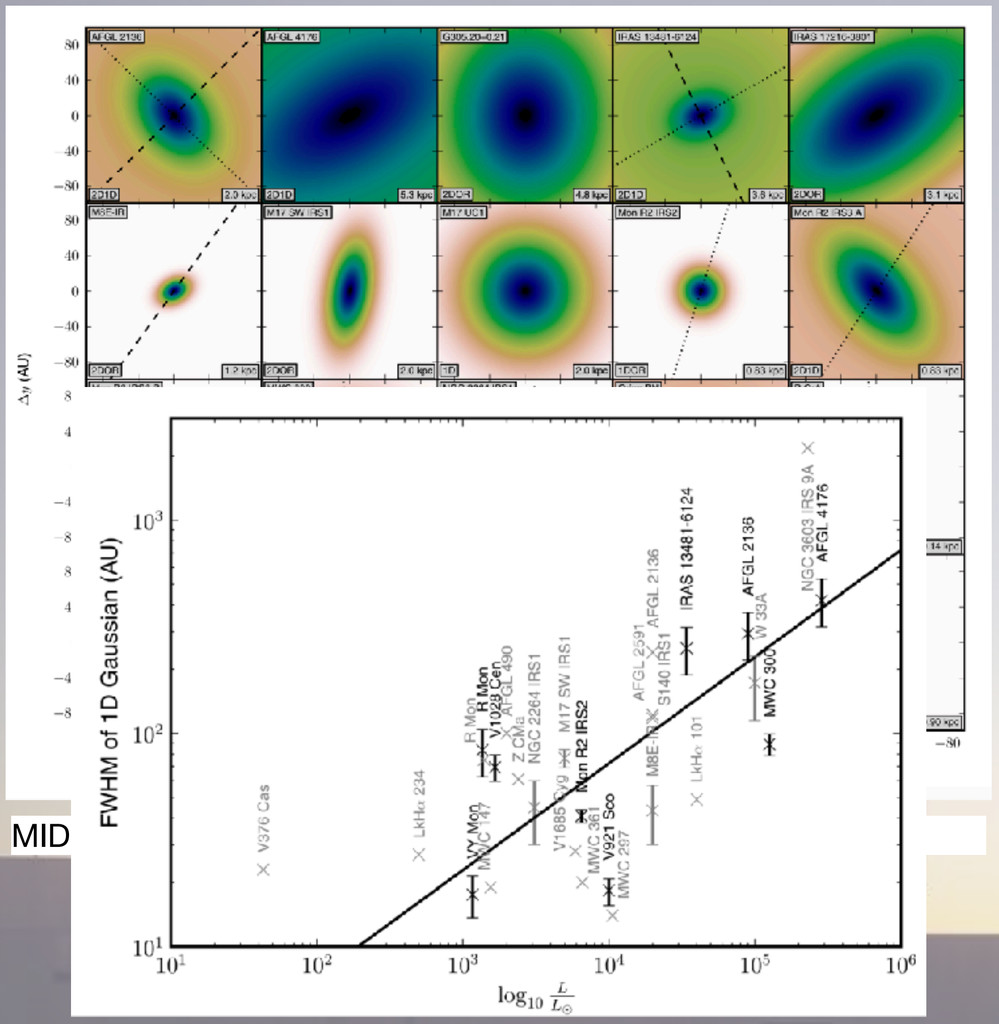
The Survey consists of relatively bright sources (mainly Herbig Ae/Be and MYSOs), augmented with weaker sources (T Tauri stars), and spectroscopic observations (silicate features, PAHs, carbonaceous grains, gas, etc.), based on the three MIDI “legacy” surveys of Boley+ (2013), Menu+ (2015), Varga+ (2018)

Observed in total ~90 stars (out of ~110) since 2019

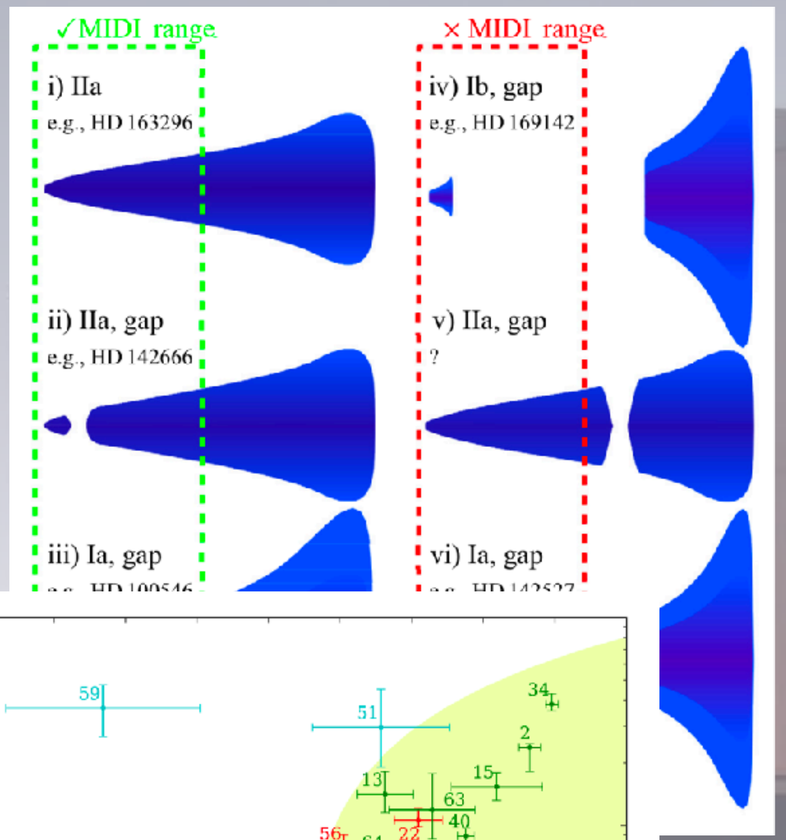


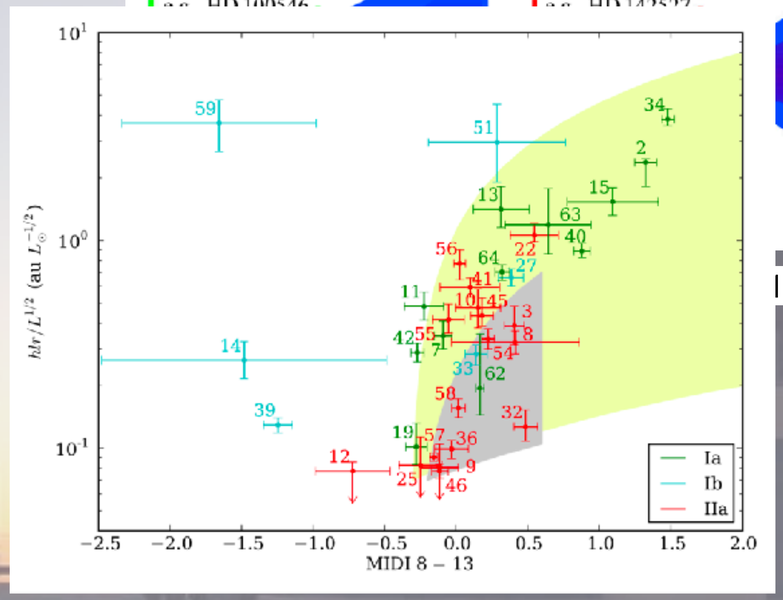
Graphic by L.N.A. van Haastere

Earlier YSO surveys



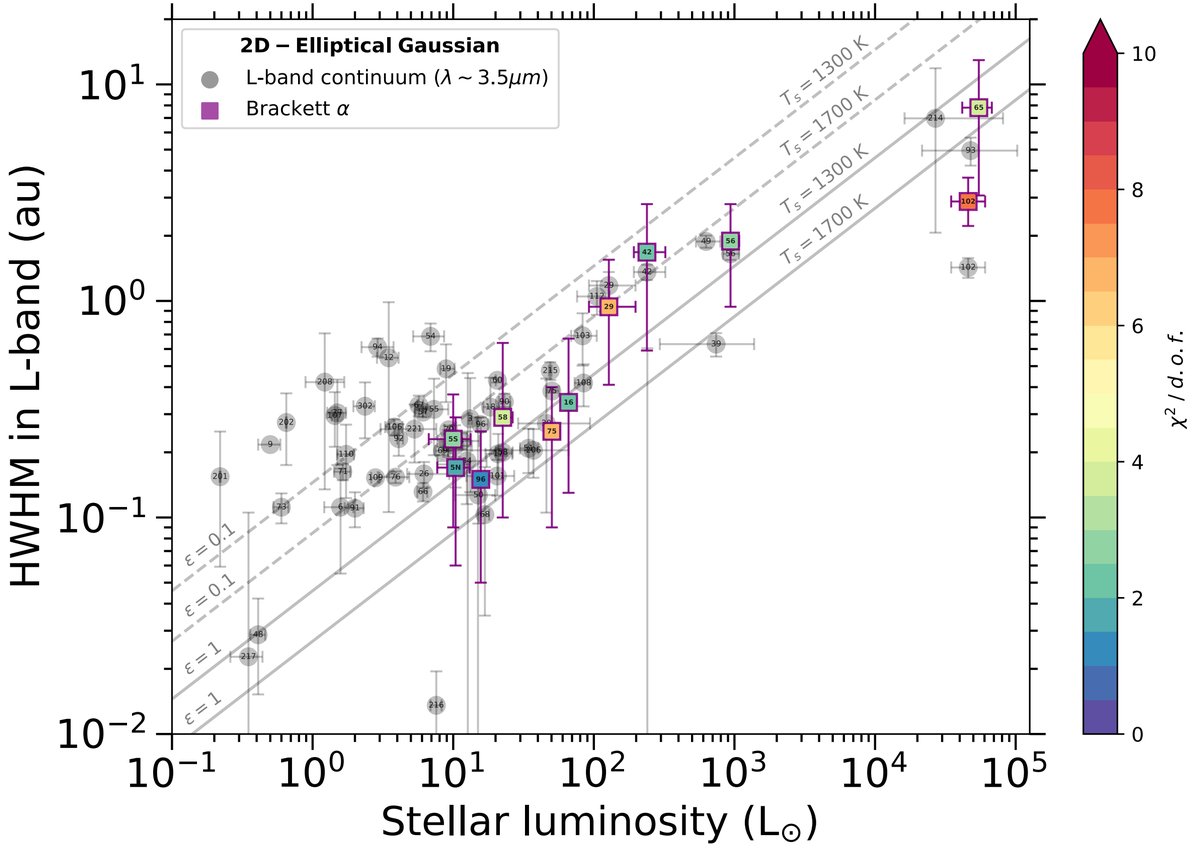
MIDI MYSO survey (Boley et al. 2013)

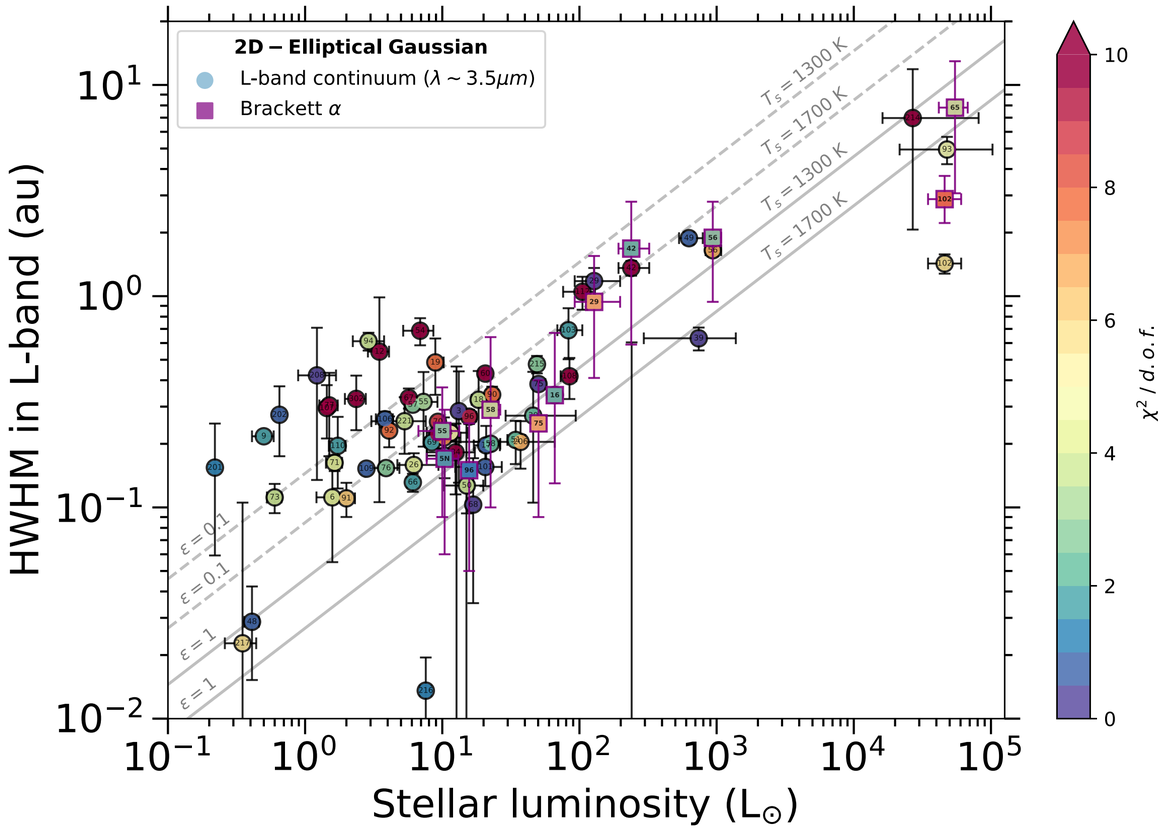




MIDI Herbig star survey (Menu et al. 2015)

With MATISSE and GRAVITY we have *KLMN* bands (2-13 μm) + much better *uv* coverage



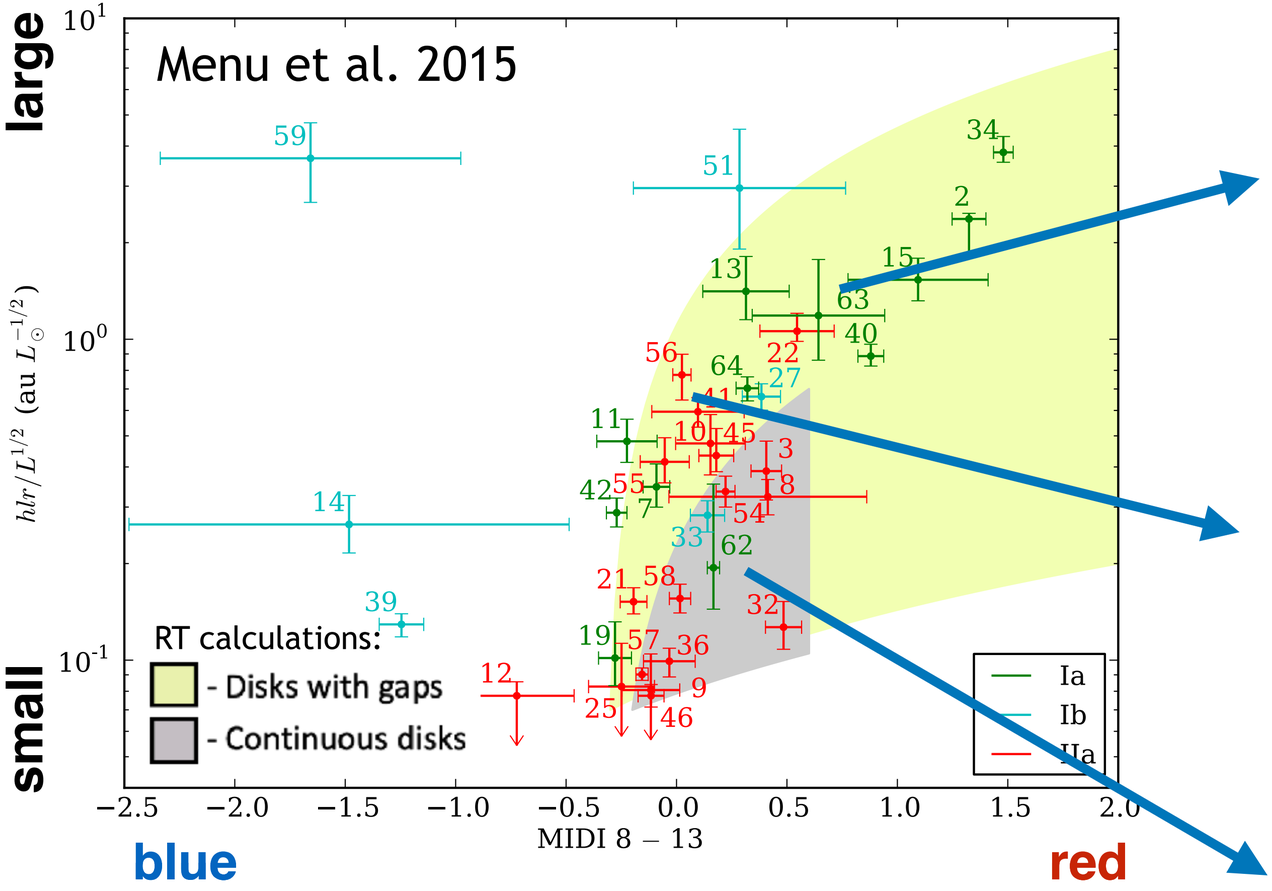


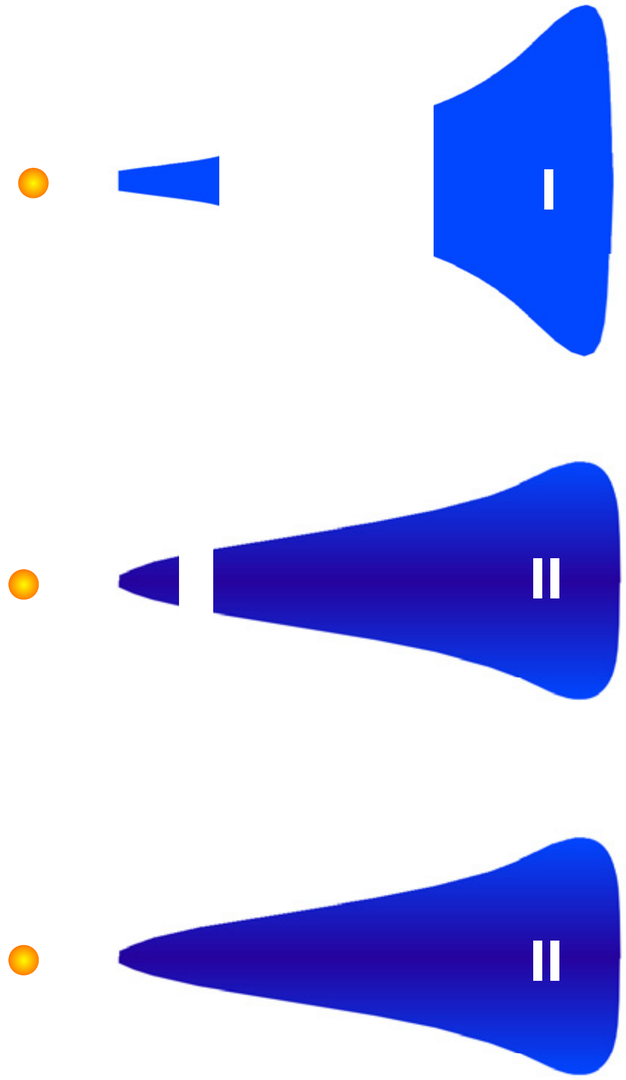
van Haastere+ 2025: L-band

L-band size vs luminosity (continuum and Br-alpha)

VLTI/MIDI: inner disk gaps in HAe stars

10+ years of data from MIDI (predecessor of MATISSE):





Menu et al. (2015, A&A, 581, 107)

see also Varga et al. (2018, A&A, 617, 83)

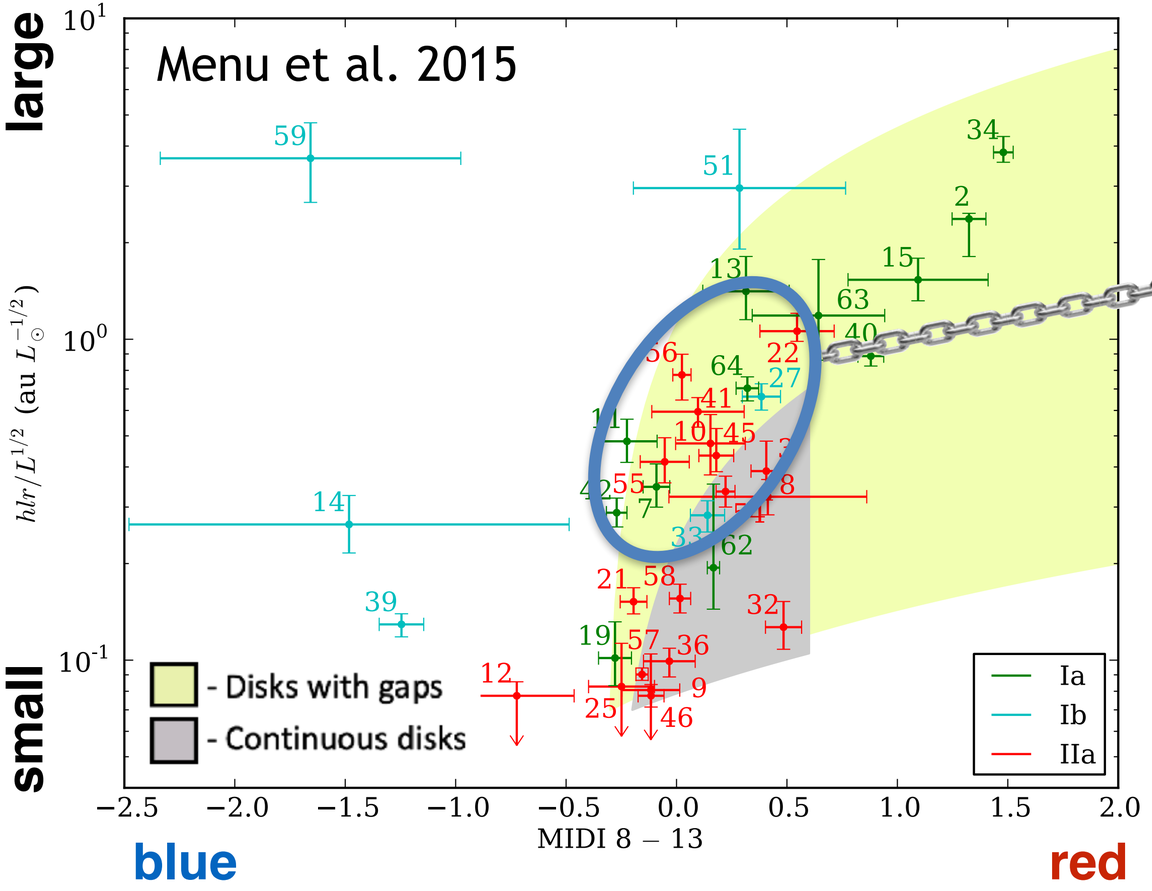
Jonathan Menu

Jozsef Varga

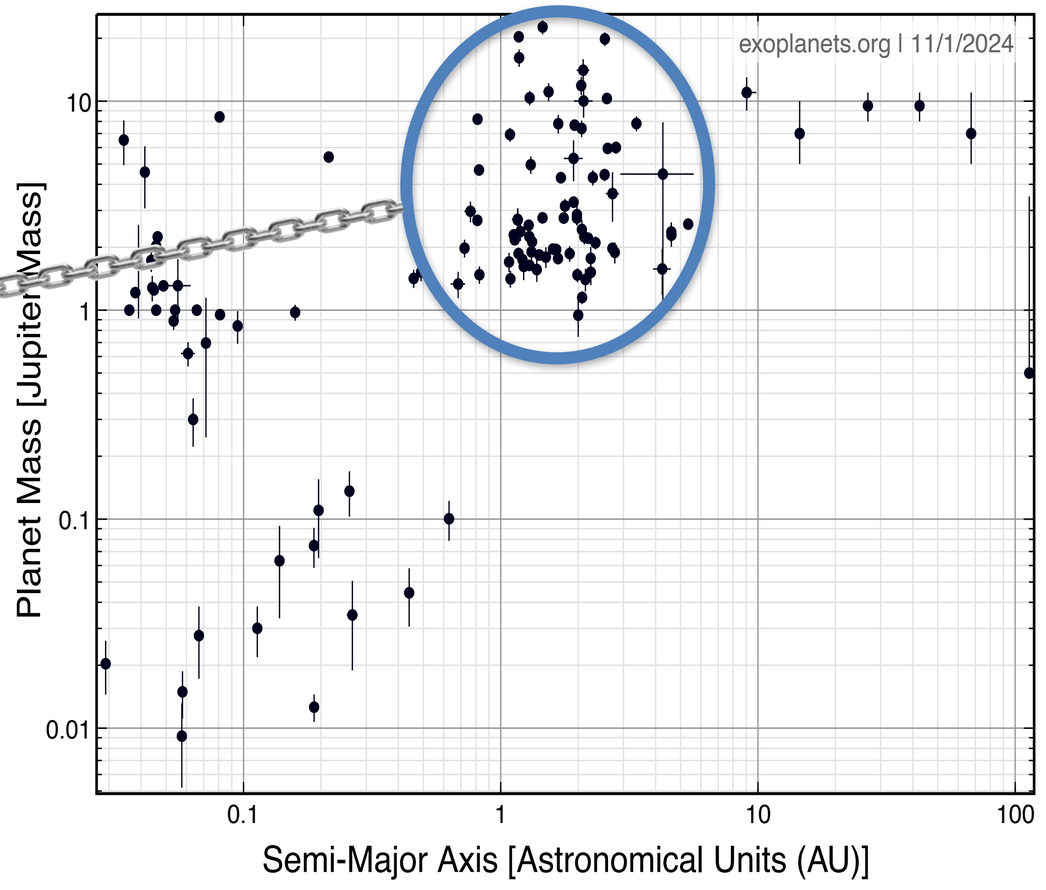
Marten Scheuck

MIDI size-color diagram

10+ years of data from MIDI (predecessor of MATISSE):



mature stars 1.5 $M_\odot$ < M_* < 3.0 $M_\odot$



Menu et al. (2015, A&A, 581, 107)

see also Varga+ (2018, A&A, 617, 83)

main sequence Spectral Type F2-B8

Jonathan Menu

Jozsef Varga

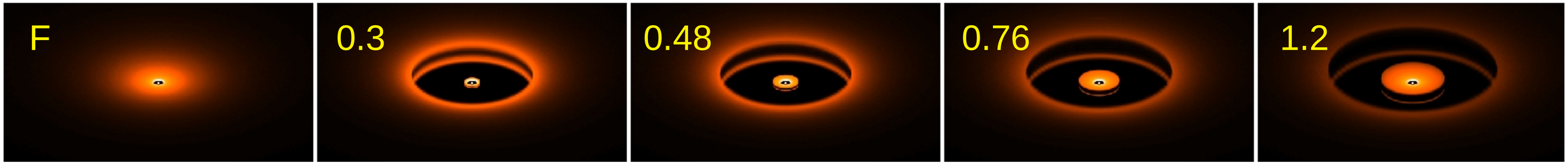
Marten Scheuck

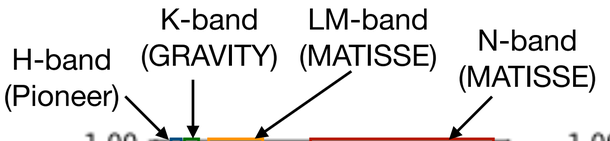
Disk gaps: N-band crucial

Lucia Klarmann

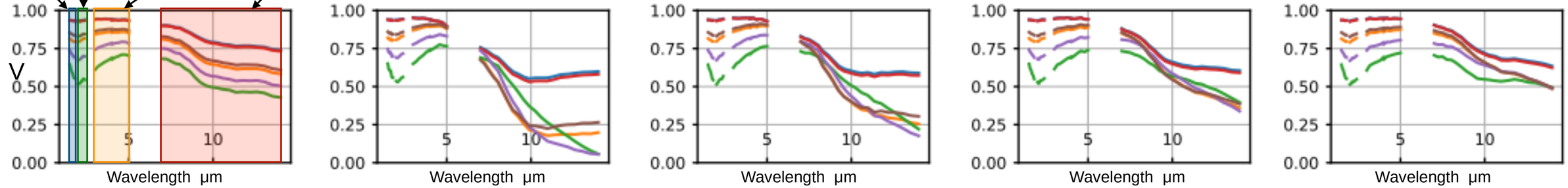
Radiative transfer calculations & simulated observations by Lucia Klarmann

<—— no gap ——> <—— 2 AU wide gap at range of locations ——>

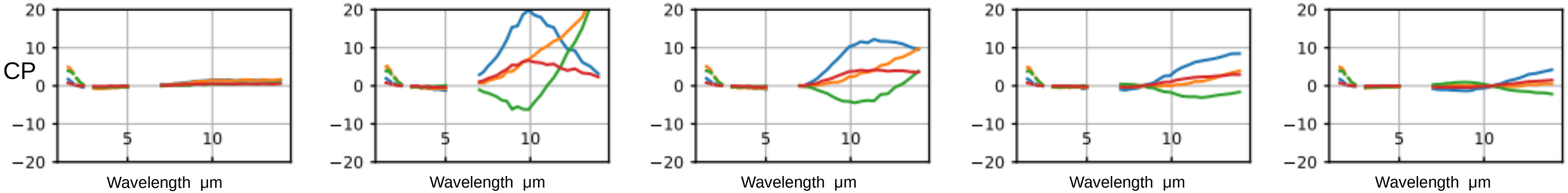




Visibility amplitudes on UT baselines

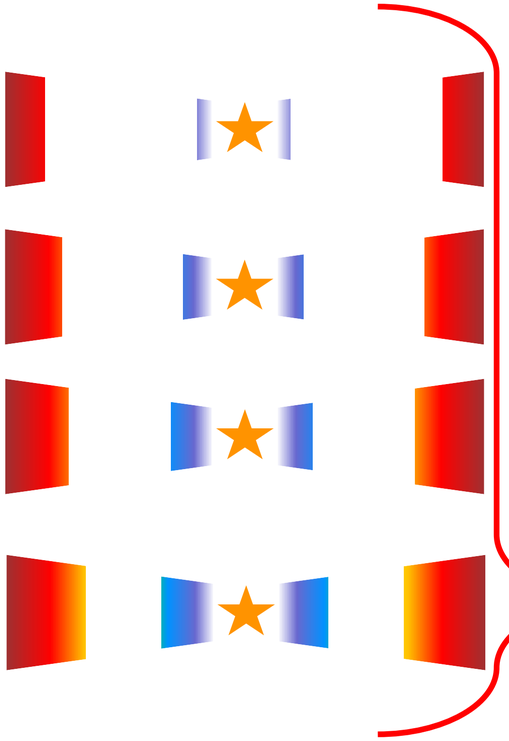


closure phases on UT baselines

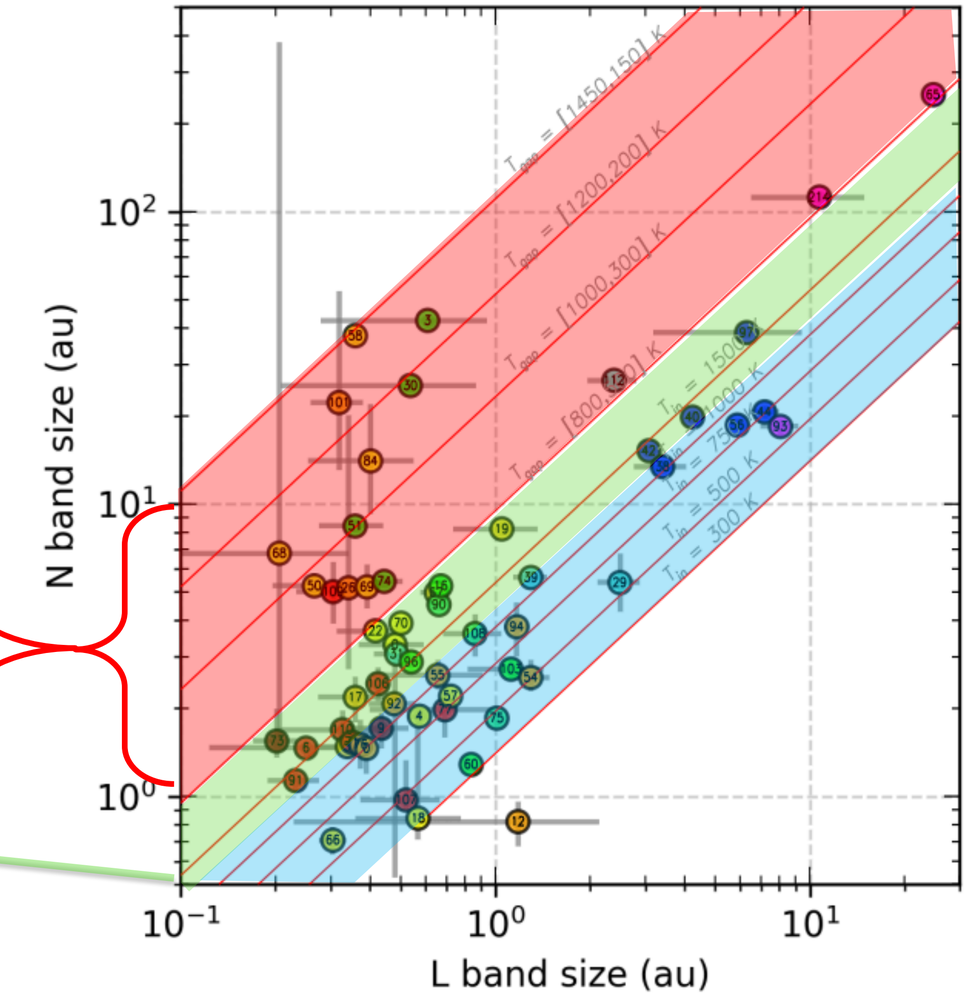


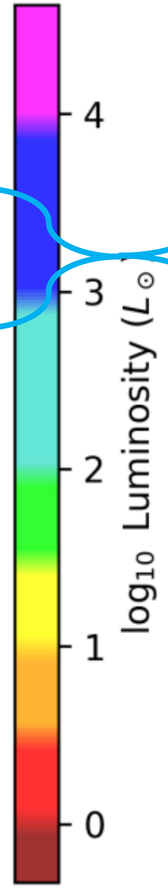
N vs. L size-size diagram

Gapped disks

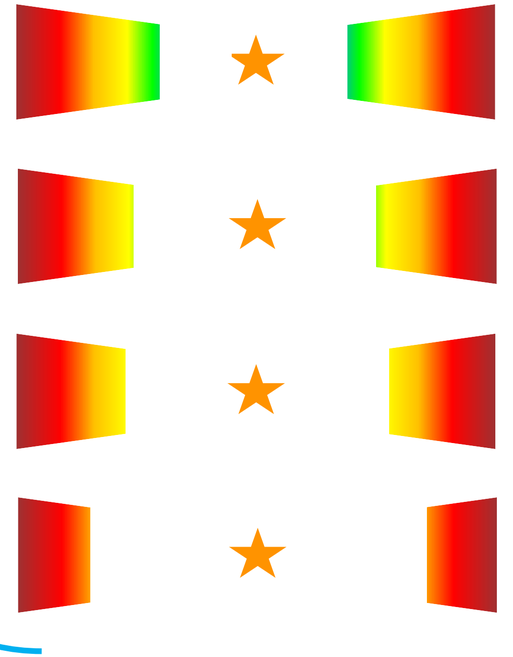


Full disk





Disks with cavity



Scheuck+2025

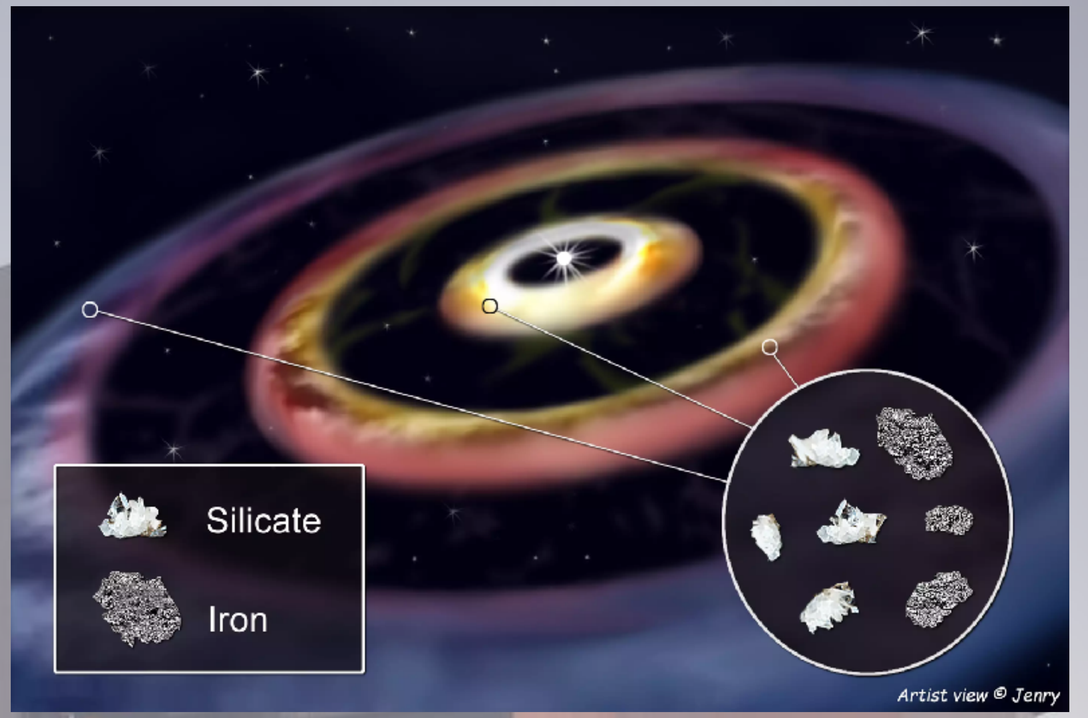
Size estimates from simple modeling with oimodeler

A&A, 681, A47 (2024)
https://doi.org/10.1051/0004-6361/202347535

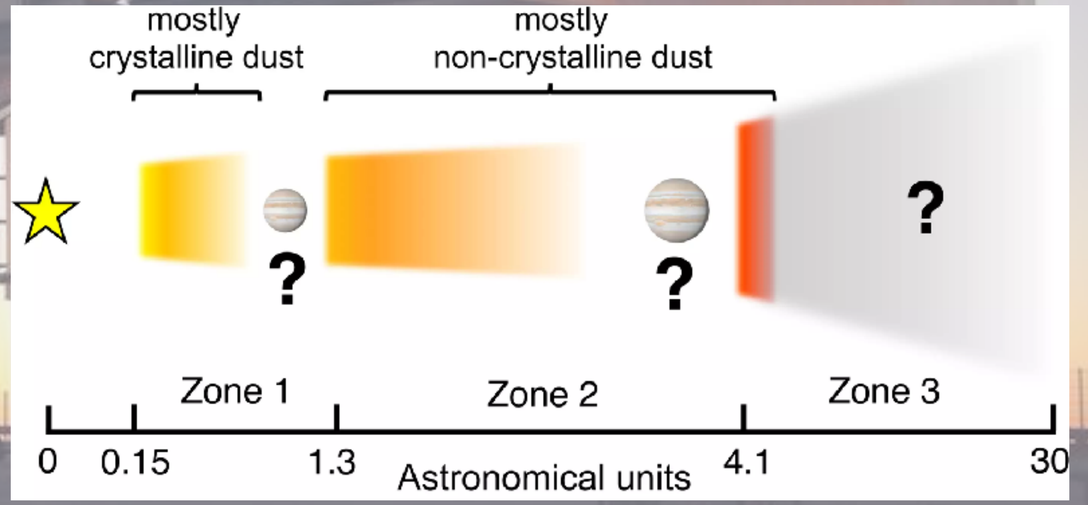
Astronomy & Astrophysics

Mid-infrared evidence for iron-rich dust in the multi-ringed inner disk of HD 144432★

J. Varga[1,2,3], L. B. F. M. Waters[4,5], M. Hogerheijde[3,6], R. van Boekel[7], A. Matter[8], B. Lopez[8], K. Perraut[9], L. Chen[1,2], D. Nadella[3], S. Wolf[10], C. Dominik[6], Á. Kóspál[1,2,7,11], P. Ábrahám[1,2,11], J.-C. Augereau[9], P. Boley[12], G. Bourdarot[13], A. Caratti o Garatti[7,14], F. Cruz-Sáenz de Miera[1,2,15], W. C. Danchi[16], V. Gámez Rosas[3], Th. Henning[7], K.-H. Hofmann[17], M. Houllé[8], J. W. Isbell[7], W. Jaffe[3], T. Juhász[1,2,11], V. Kecskeméthy[3], J. Kobus[10], E. Kokoulina[18,8], L. Labadie[19], F. Lykou[1,2], F. Millour[8], A. Moór[1,2], N. Morujão[20], E. Pantin[21], D. Schertl[17], M. Scheuck[7], L. van Haastere[3], G. Weigelt[17], J. Woillez[22], P. Woitke[23], and MATISSE & GRAVITY Collaborations



- Three rings in planet-forming disk
- Iron-rich dust in inner 5 au
- (Only?) way to probe future **compositions of rocky exoplanets**
  - Cannot “drill”!

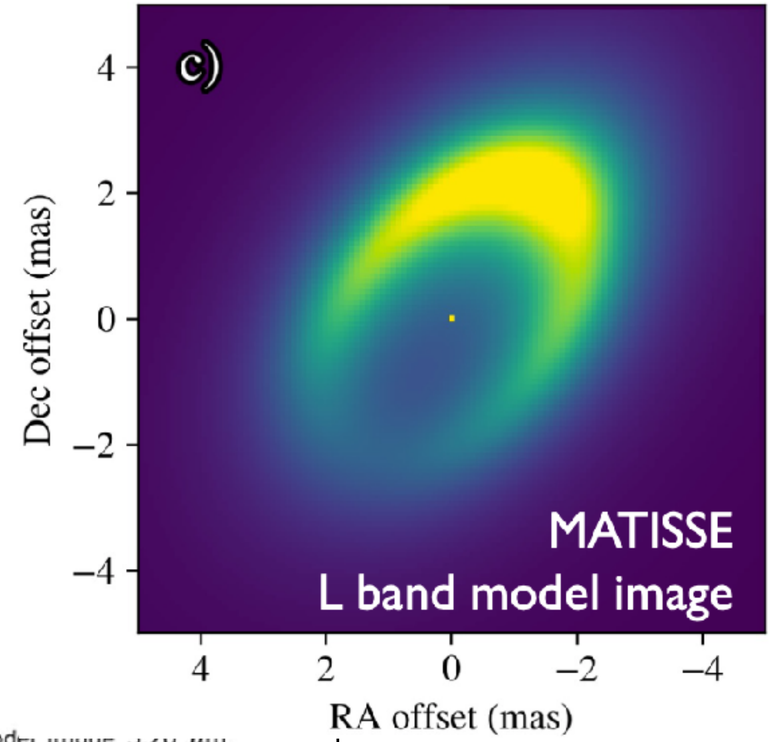


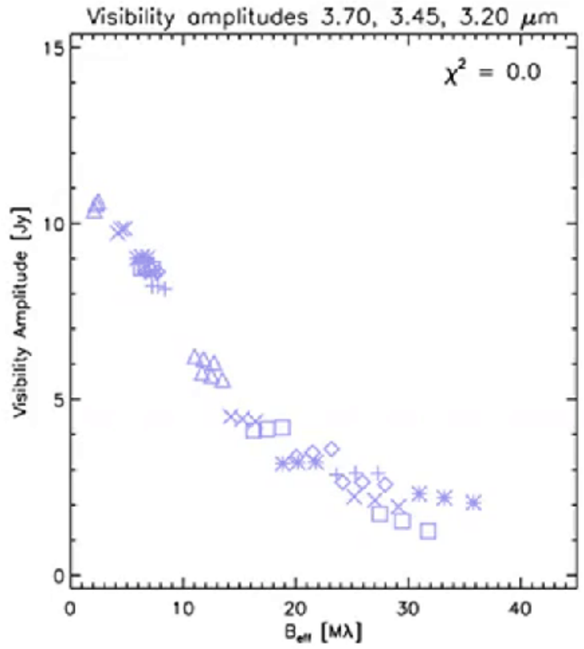
From press release, January 8 2024

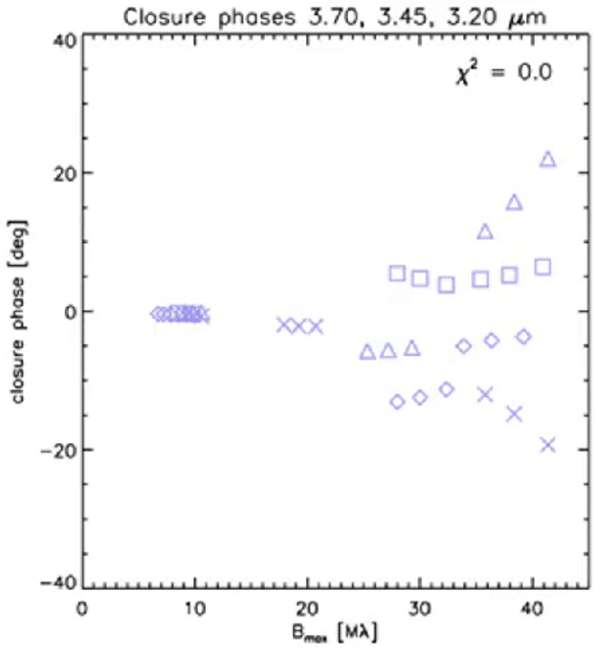
Temporal Variation - HD 163296

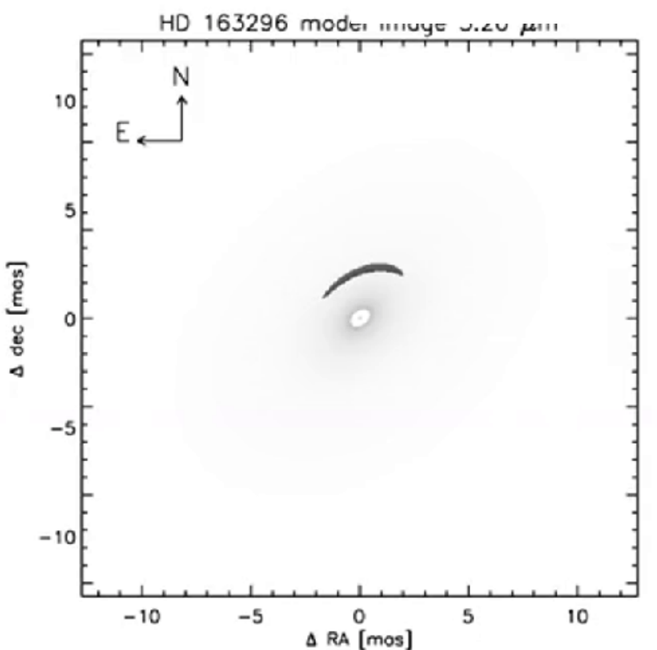
J. Varga et al. (2021)

- Asymmetric inner structure at r = 0.3 au
  - Strong indication for variable morphology
  - Possibly an orbiting clump
    - P ~ 20-42 Days
    - Possible dust trap
- Time-monitoring observations were done and are being evaluated







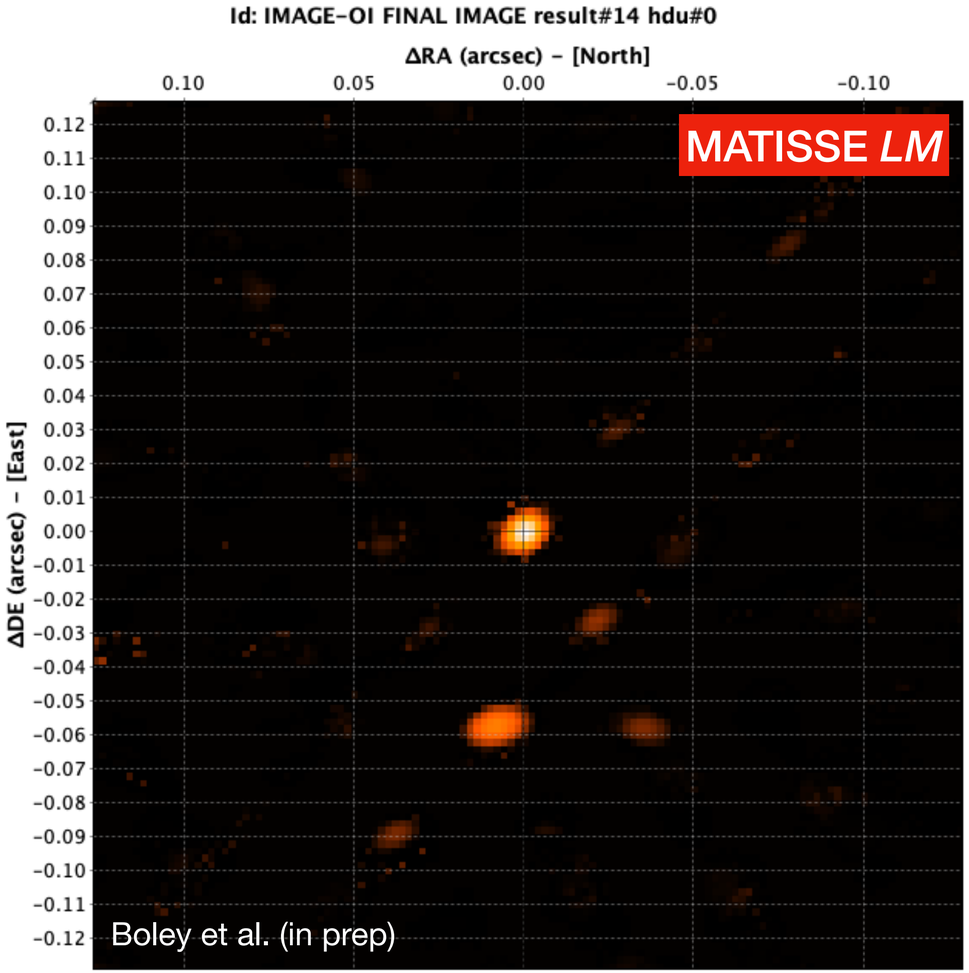


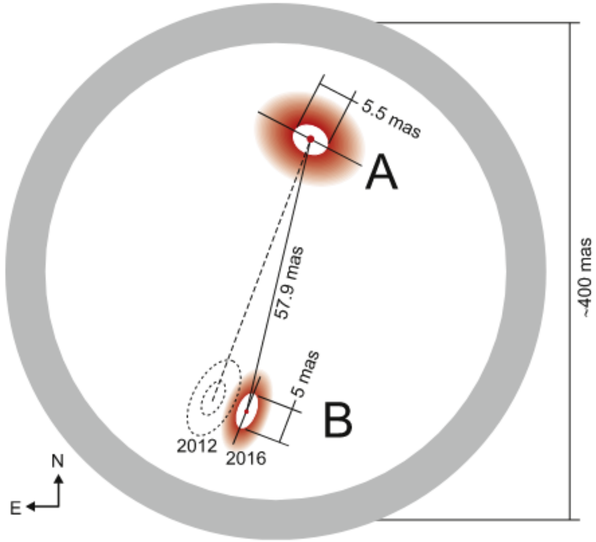
Animation credit:
R. van Boekel

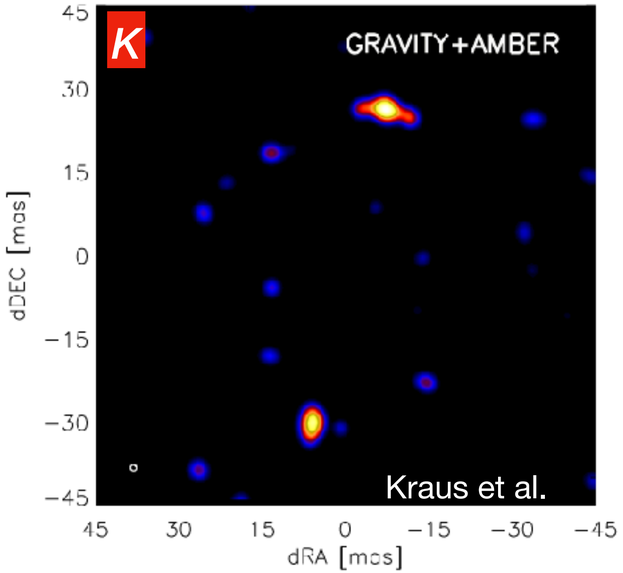
Survey - Ongoing Works

IRAS 17216-3801

MATISSE, ALMA





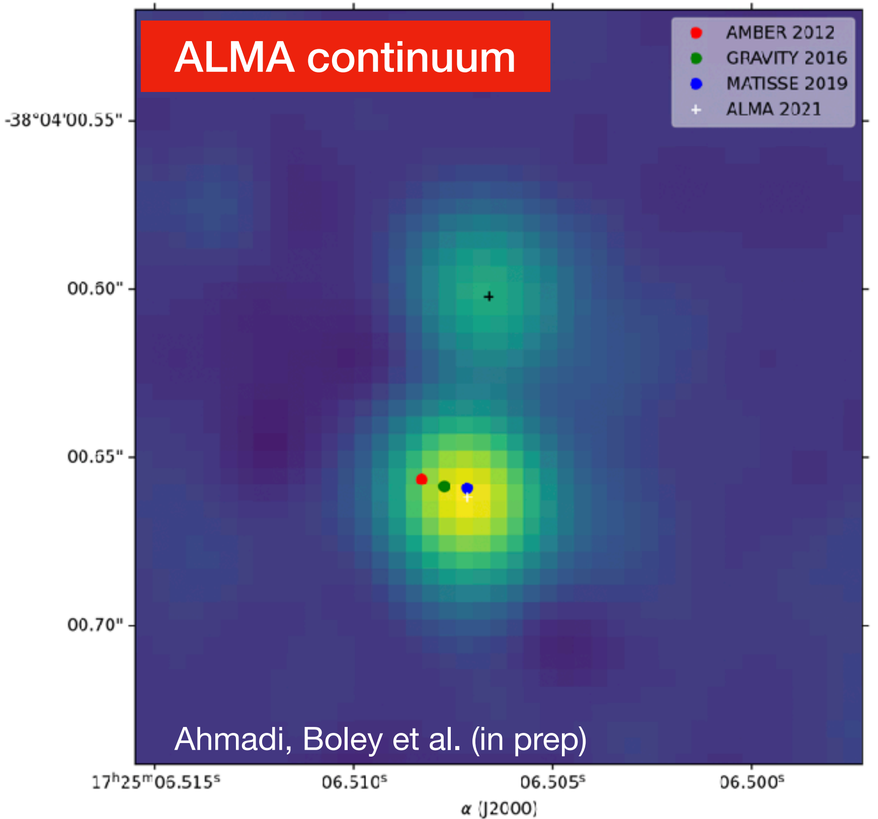


Most extensive interferometric data set for any MYSO to date (2-13 μm): **MIDI, AMBER, GRAVITY, MATISSE**

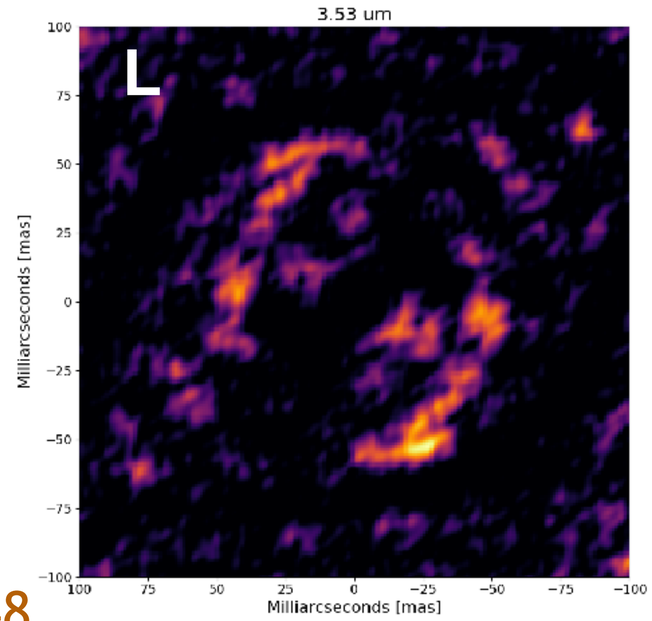
Wide range of dust temperatures (300-1500 K)

Resolve both the **binary** and **individual protostars**

Orbital motions over 10+ years



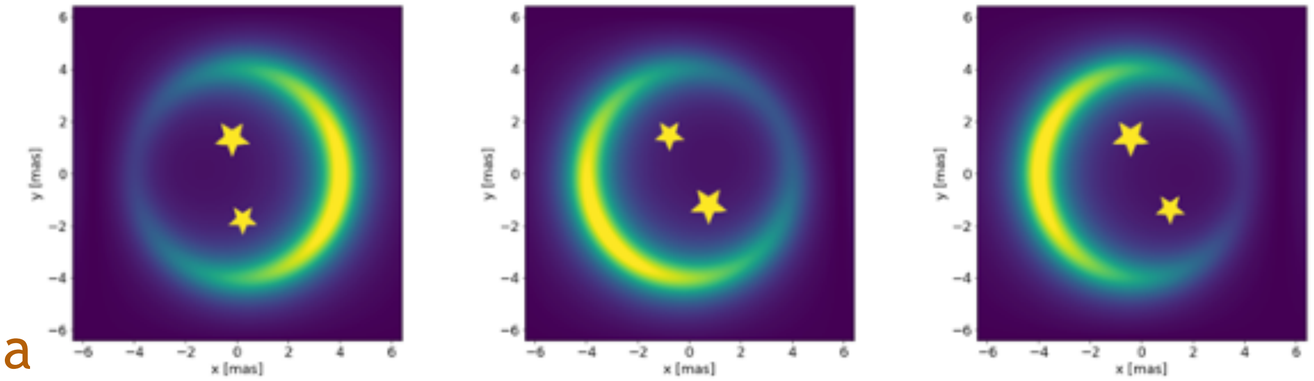
Survey - Ongoing Works



HD 97048

Lopez et al. (in prep.)

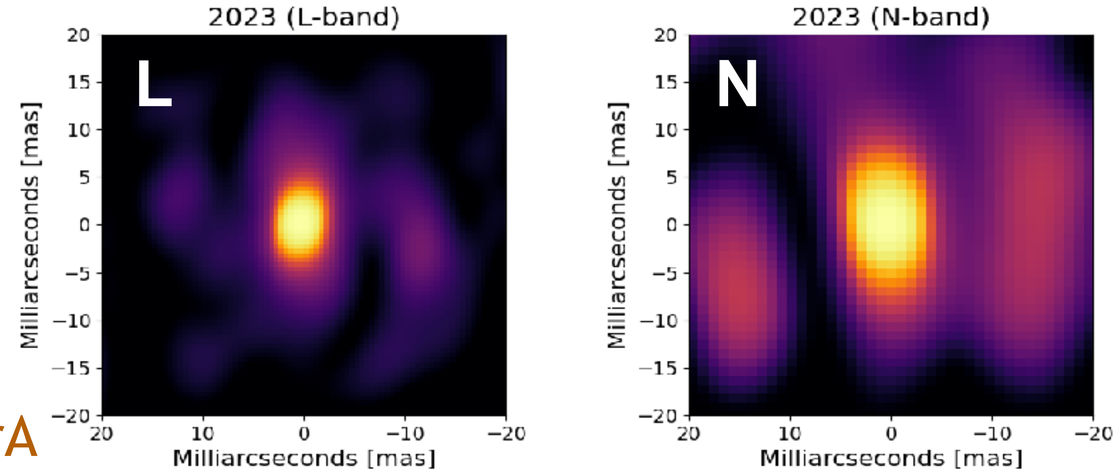
Image of nanodiamond emission



DX Cha

Juhász et al. (in prep.)

Emission perhaps from accretion funnels

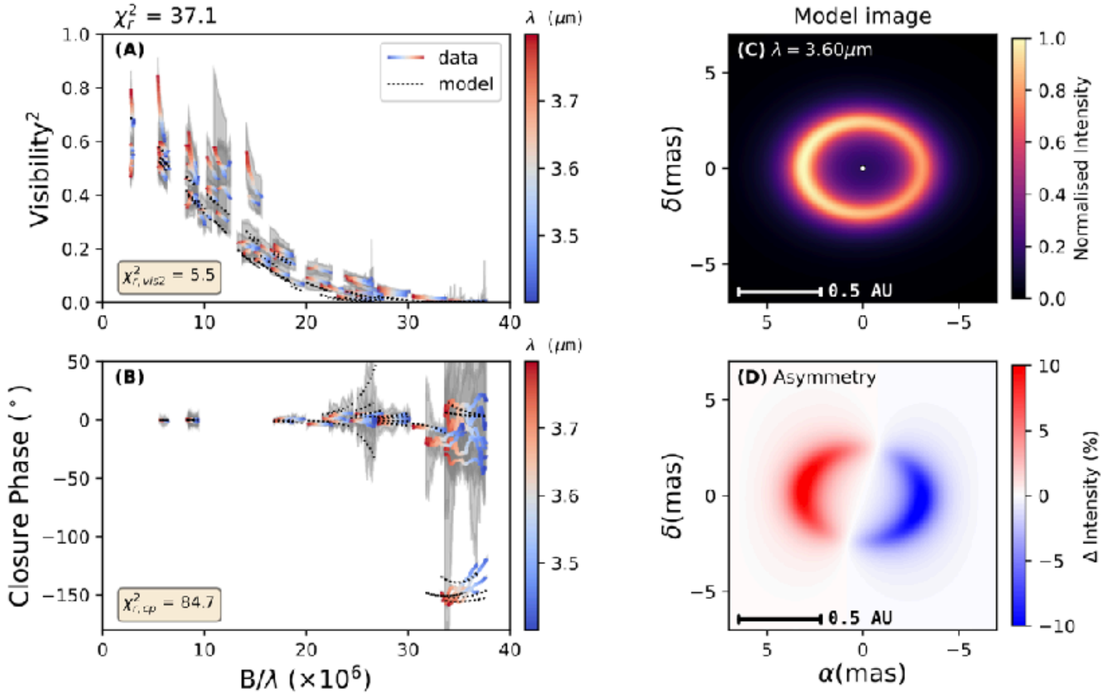


R CrA

Matter et al. (in prep.)

Image of complex inner disk structure

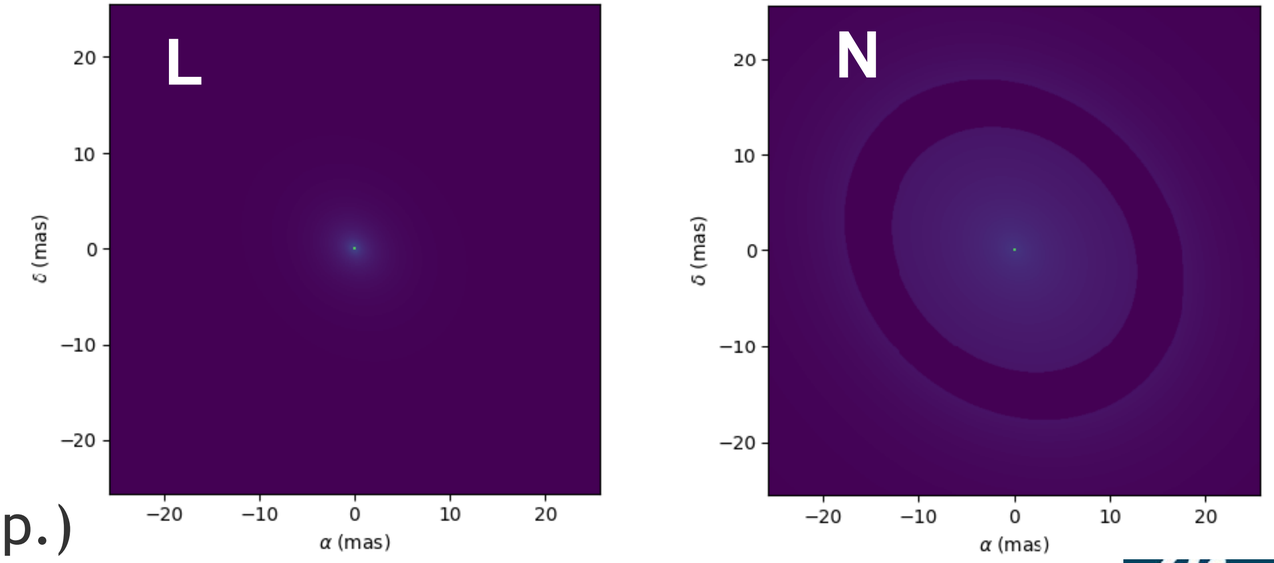
Survey - Ongoing Works



HD 100453

L.N.A. van Haastere et al. (in prep.)

Model of complex inner disk structure



HD 142527

Scheuck et al. (in prep.)

Model of complex inner disk structure

Thanks for your attention!