VLTI+ALMA imaging of potential planet-forming processes in the pre-transitional disk of V1247 Ori

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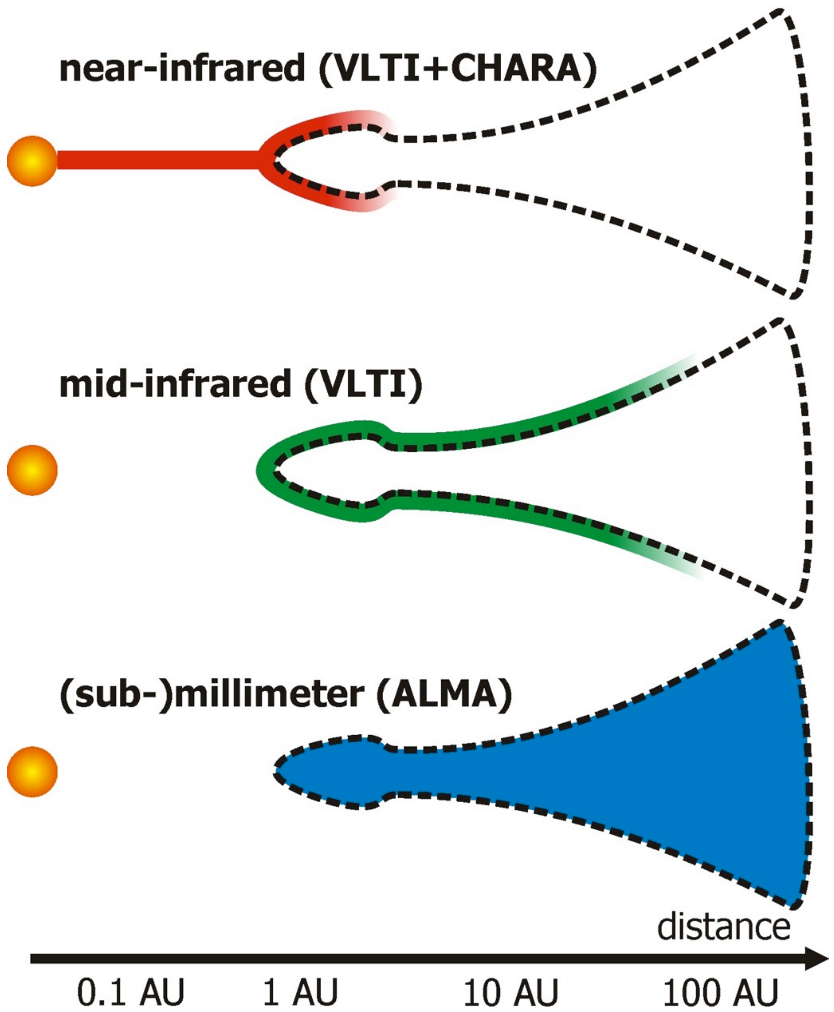
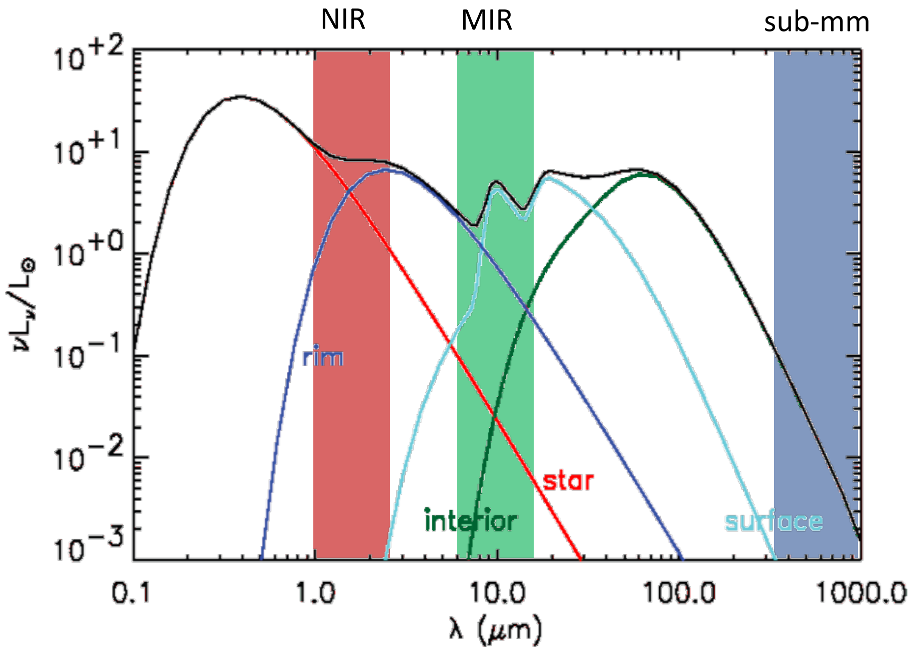
Oct. 15, 2018, Take a Closer Look, ESO, Garching

Outline

- Multi-wavelength interferometry
- Radial drift problem & Dust trapping
- V1247 Ori: Potentially planet-triggered dust trap

Multi-wavelength interferometry

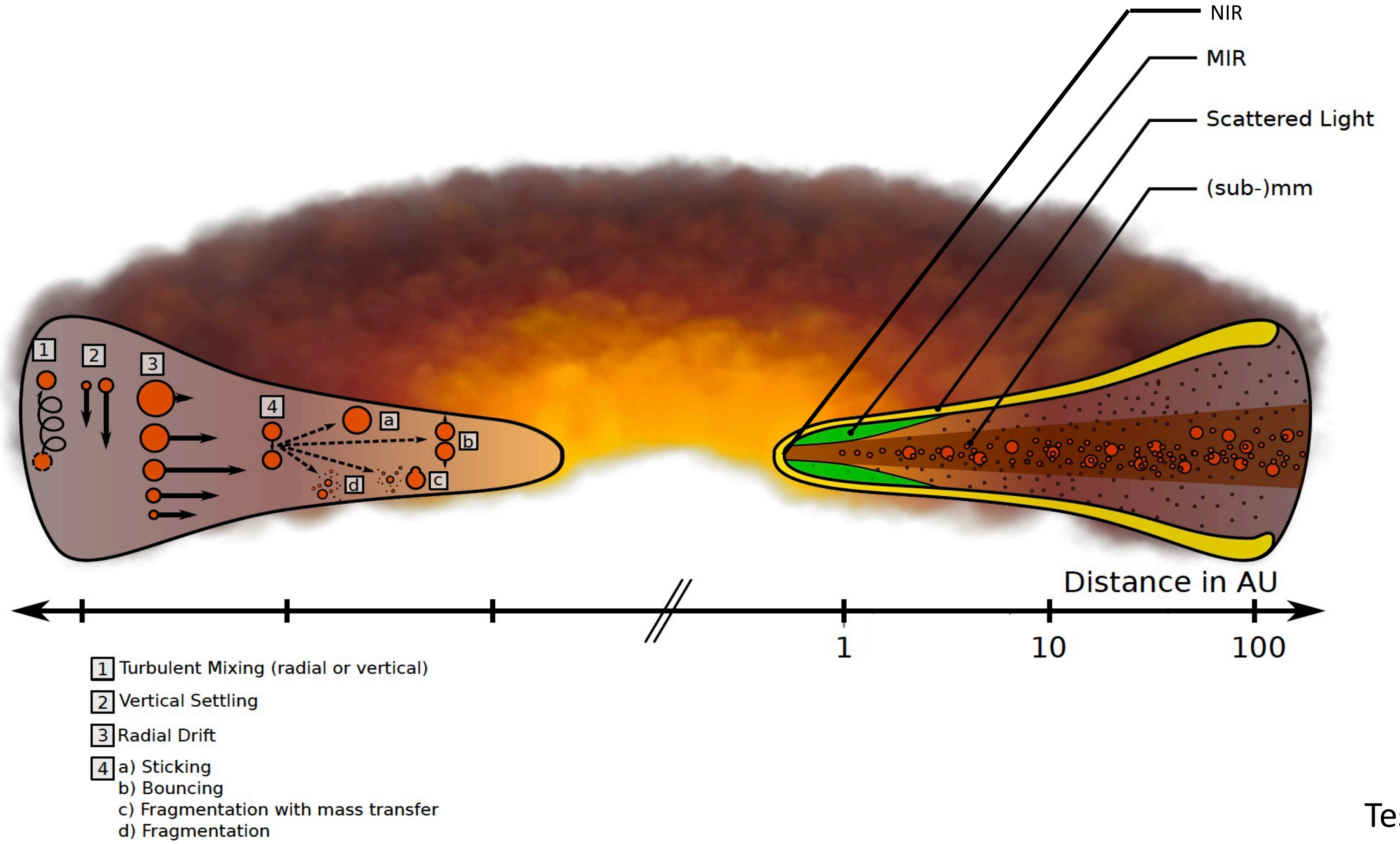




Combined NIR+MIR+sub-mm interferometry:

- **Solves ambiguities** of SED modelling
- Traces **all disk radii**
- Traces **disk surface & interior**
- Reveals variations in **dust mineralogy** (dust filtration, dust traps, …)

Dust evolution: The key to planet formation



Testi et al. 2014

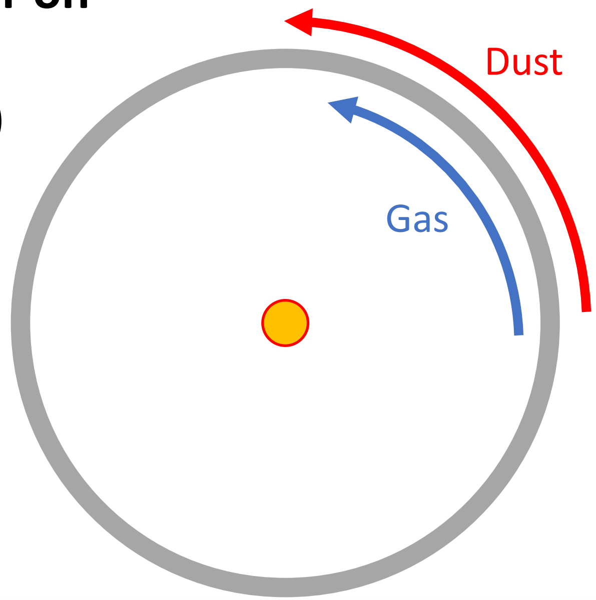
Radial Drift Problem

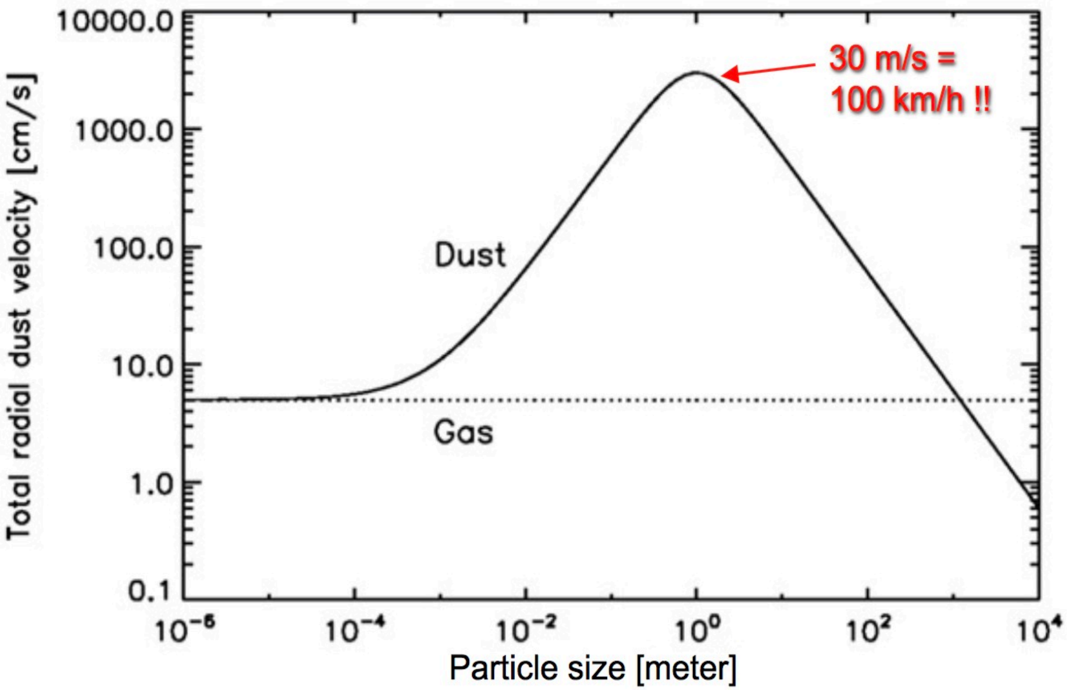
Dust particles: Keplerian

Gas: slightly sub-Keplerian, due to pressure gradient

➜ Particles feel head-wind, loose angular momentum to gas, drift towards pressure maximum (Whipple 1972, Weidenschilling 1977, Brauer et al. 2007, …)

➜ **Dust should drift into the star on time scales of $10^{2…3}$ years**
("metre size barrier" at 1 AU)





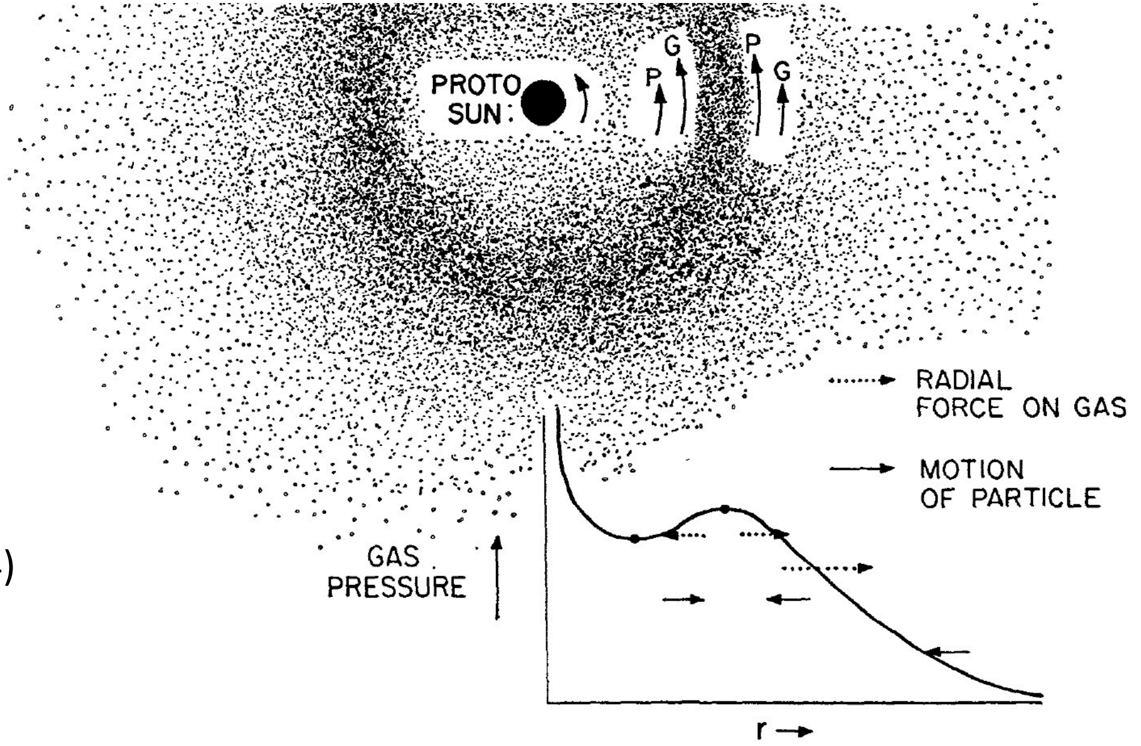
Credit: Dullemond

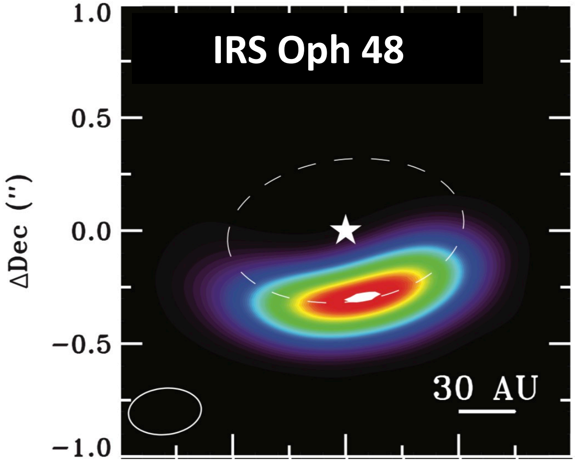
Dust Trapping

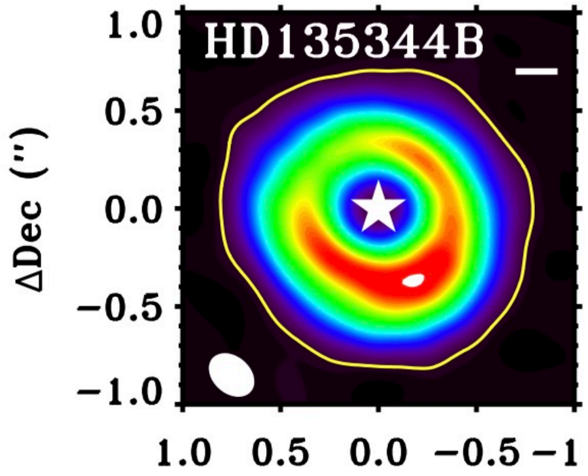
Potential solution:
Dust trapping in pressure bump
(Whipple 1972, …)

Possible mechanisms for creating pressure bump:

- Vortices (e.g. Klahr & Henning 1997)
- Ice lines (e.g. Kretke & Lin 2007)
- Dead zones (e.g. Lyra et al. 2009)
- Edges of planet-cleared gaps (e.g. Zhu et al. 2012, Meru et al. 2014)



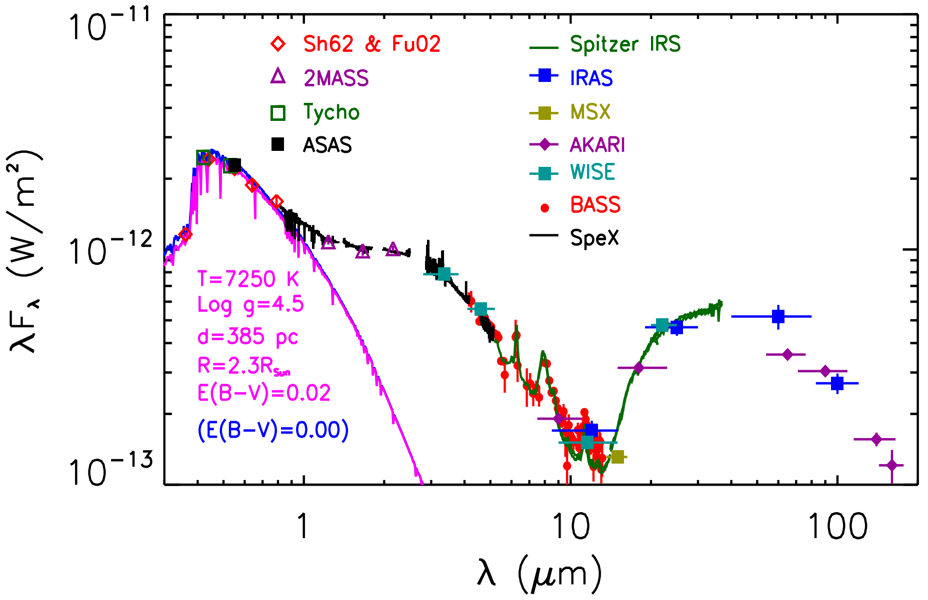




Dust trapping might explain some asymmetric disk features observed with ALMA

van der Marel et al. 2013, 2015

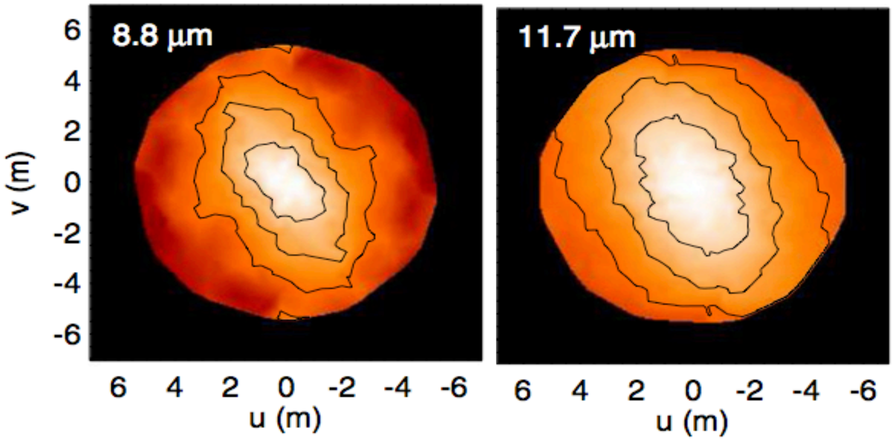
V1247 Ori



V1247 Ori exhibits MIR flux deficit compared to typical protoplanetary disks

➜ **Indirect evidence for a gapped disk structure**

Spectral type F0V
T_{eff} = 7250±100 K
D = 385±15 pc
M = 1.86 $M_\odot$
Age = 7.4±0.4 Myr



Gemini/TReCS speckle interferometry yields MIR 2-D power spectra

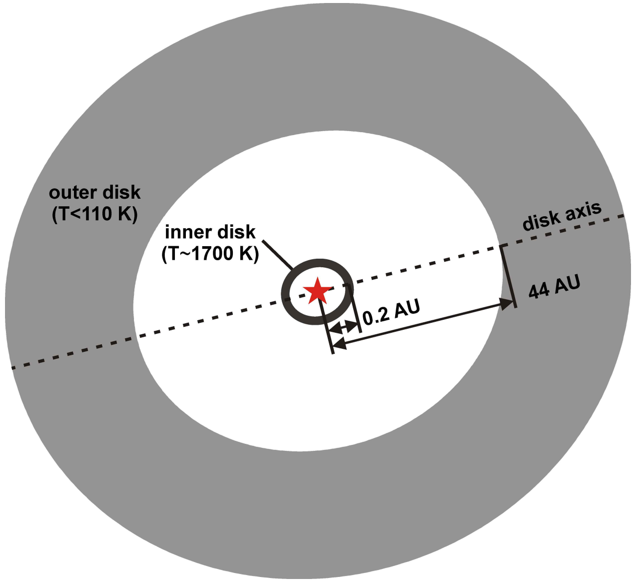
➜ **Inclination: 31±7°**
PA: 104±15°

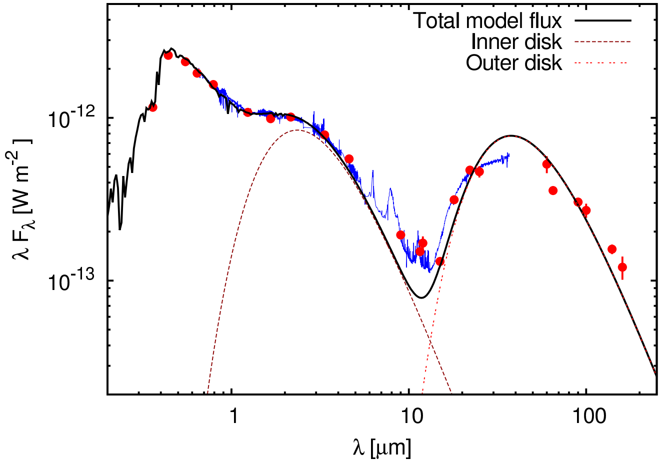
Kraus et al. 2013

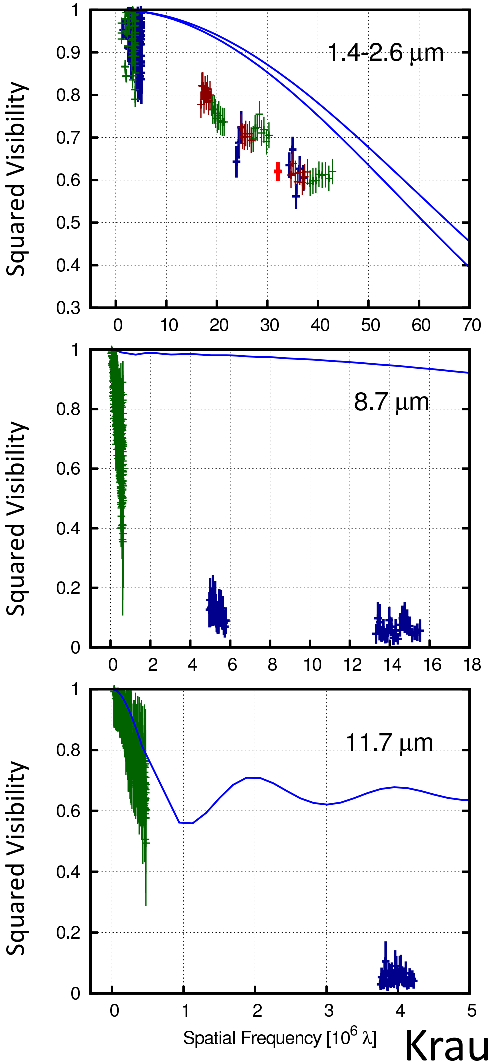
V1247 Ori: Disk structure constraints

Scenario 1:

Gapped disk







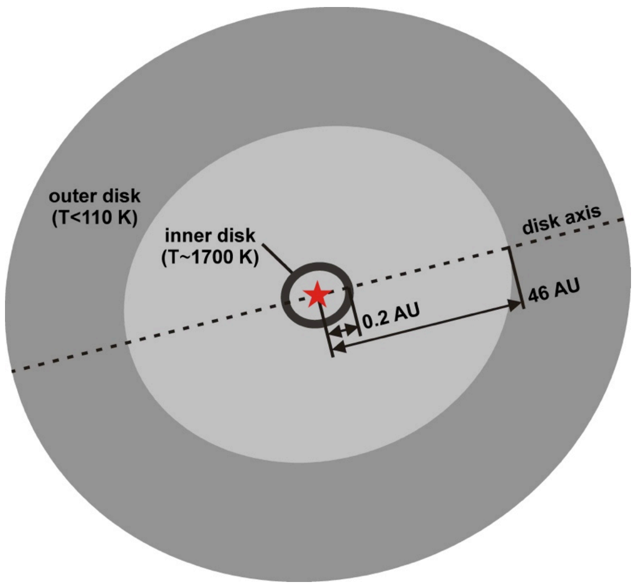
Kraus et al. 2013

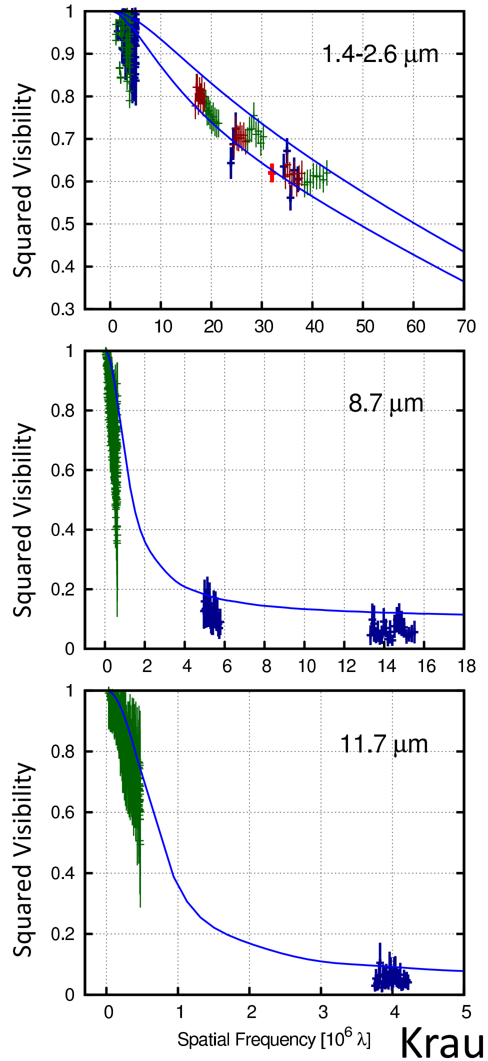
➜ **Model underpredicts MIR size by order of magnitude**

V1247 Ori: Disk structure constraints

Scenario 2:

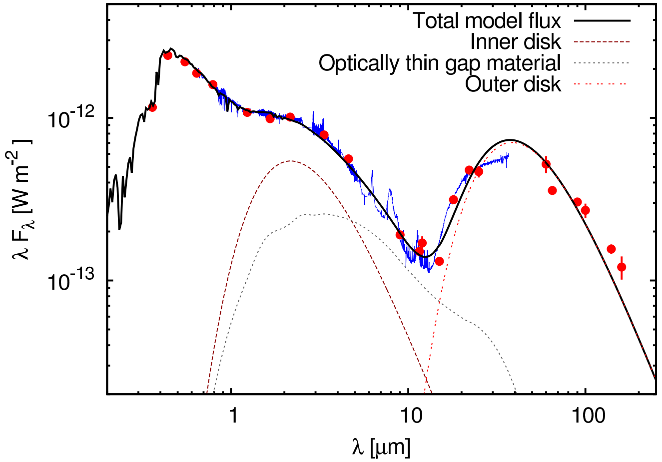
Gapped disk + optically thin gap material





➜ **Gap filled with optically thin dust**
$\Sigma_{gap}=9 \times 10^{-6}$ g/cm²

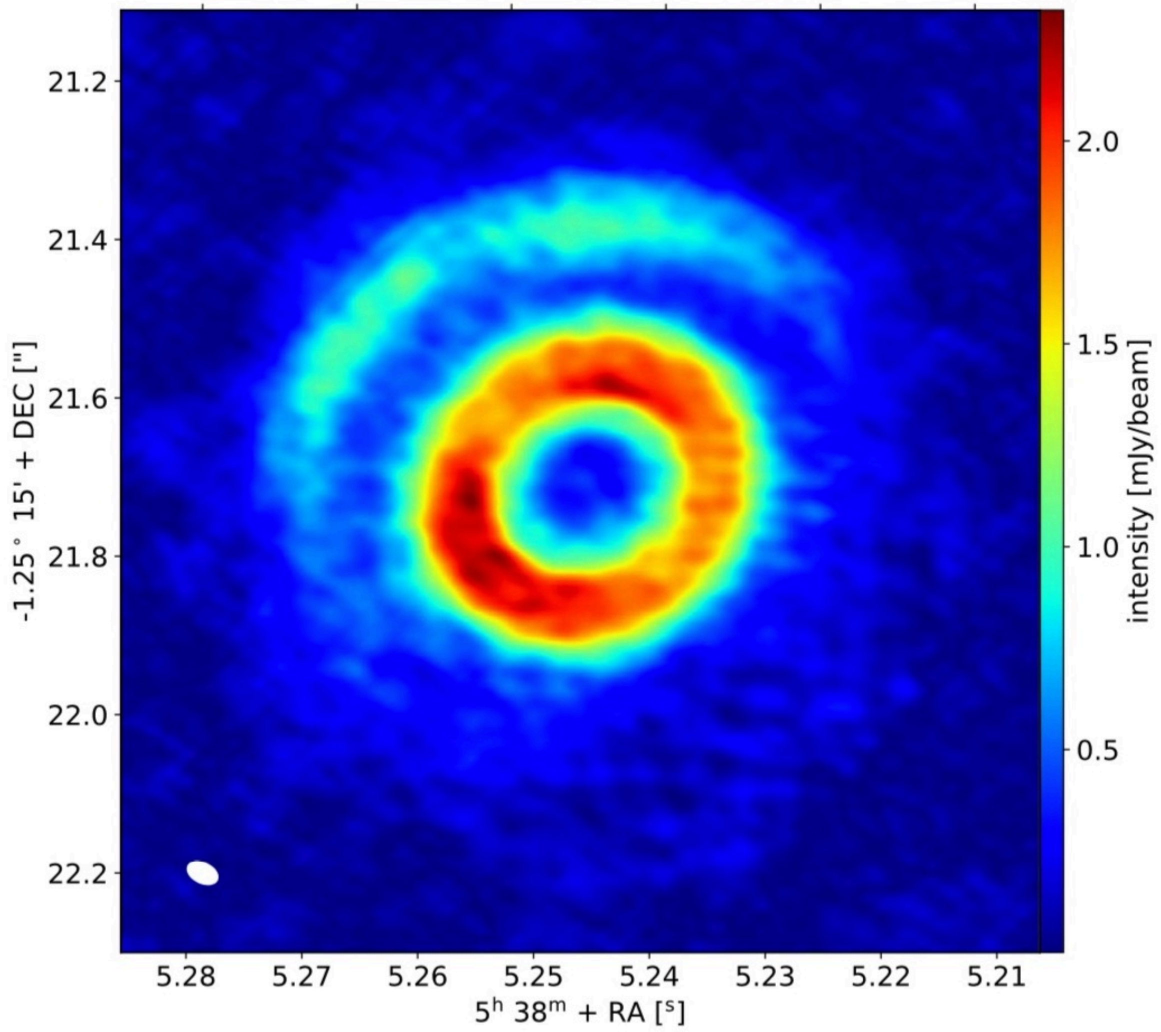
➜ **Gap material dominates MIR emission**



Kraus et al. 2013

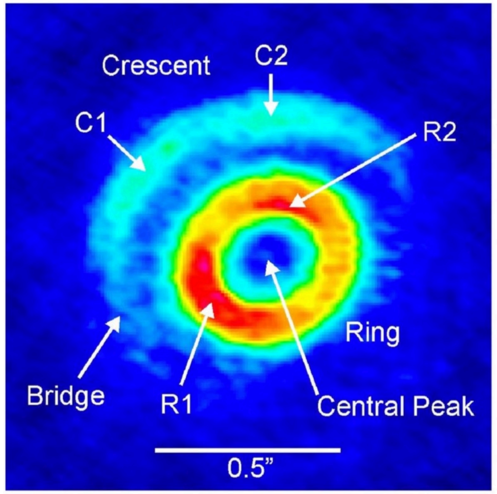
V1247 Ori

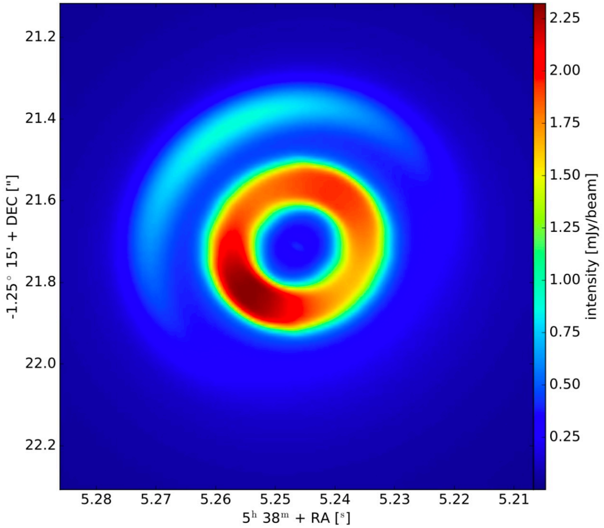
Cycle 3 image including 11km baseline (0.04” resolution):

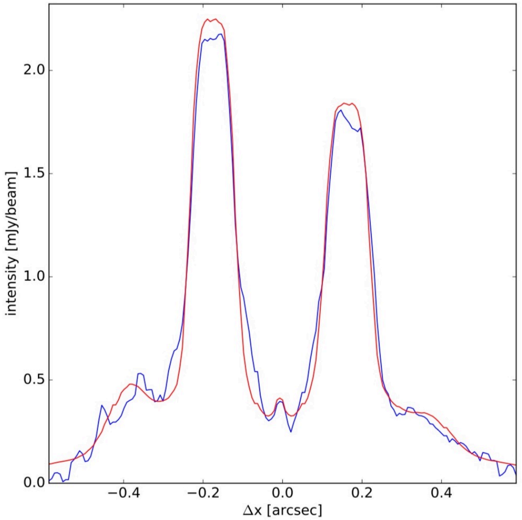


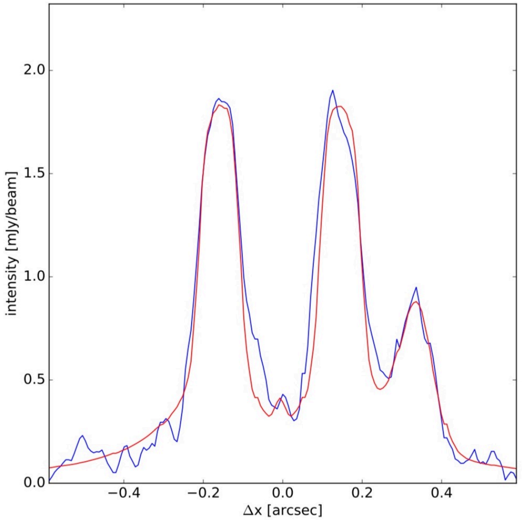
Kraus et al. 2017

V1247 Ori: ALMA 870µm image





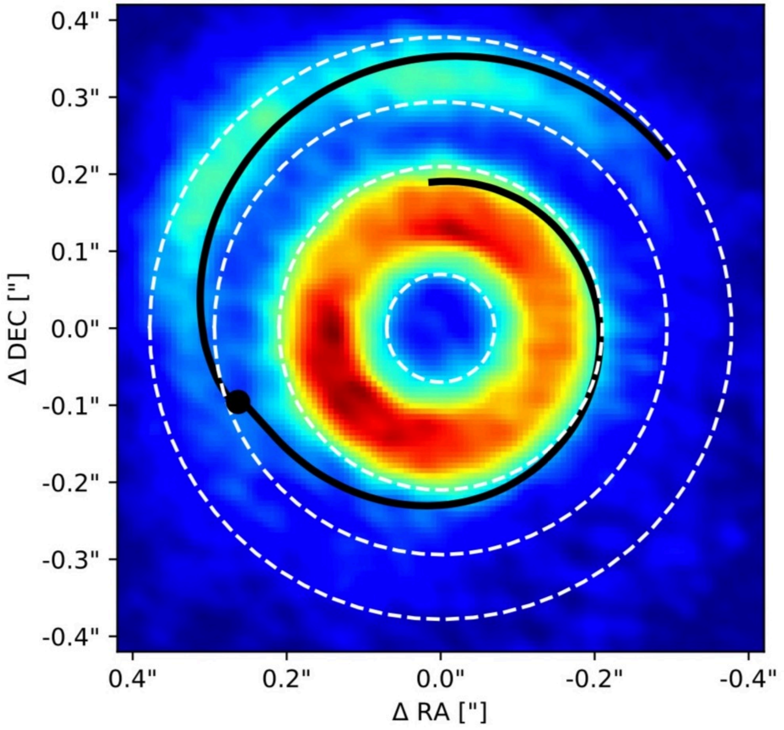


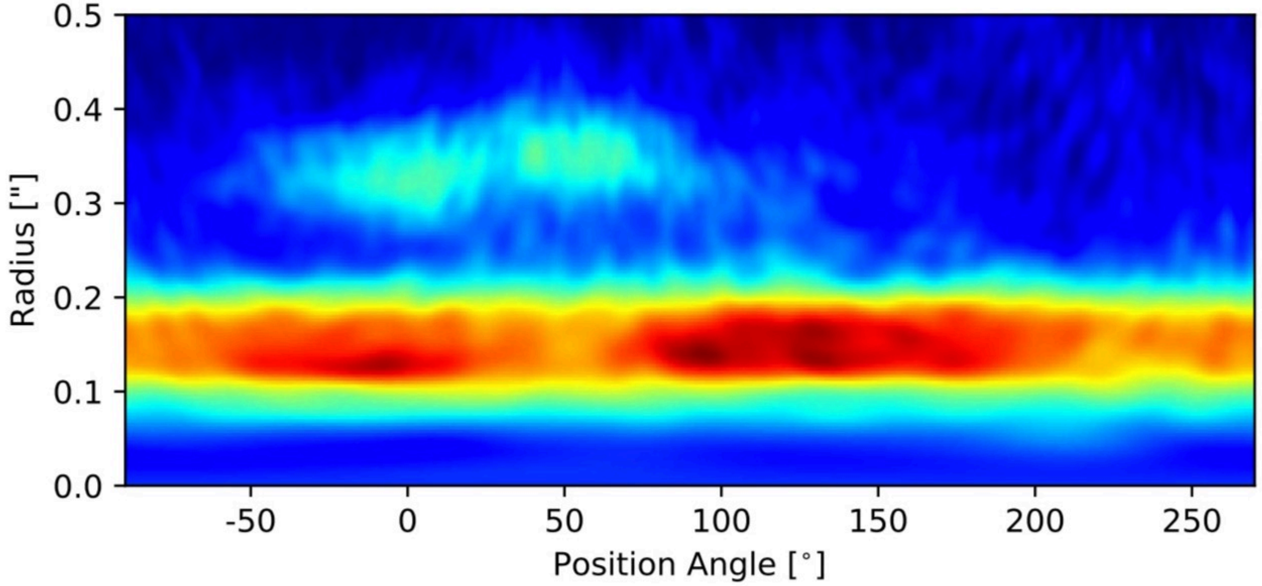


- Ring of emission ~ 0.15..0.25"
- Crescent-shaped structure (radii ~ 0.3…0.4")
- Extended flux with a Gaussian HWHM ~ 0.3"

Kraus et al. 2017

V1247 Ori: Is the crescent part of a spiral arm?



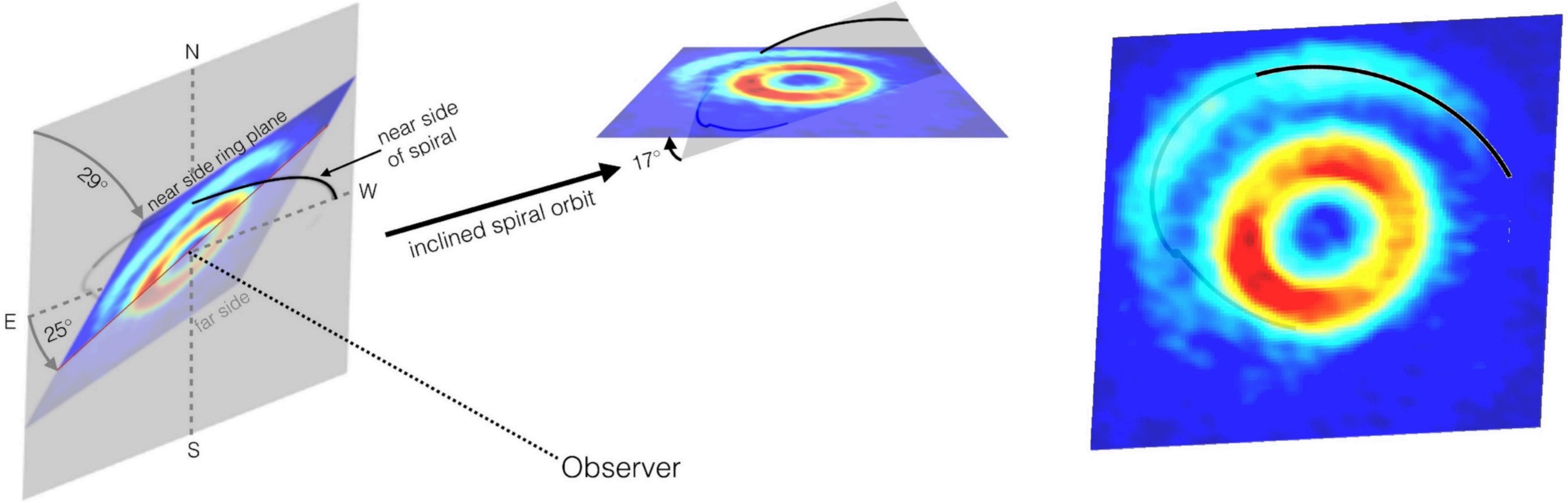


Kraus et al. 2017

The observed crescent structure is co-radial

(i.e. does not follow the pitch angle expected for a planet-triggered spiral wake; Ogilvie & Lubow 2002)

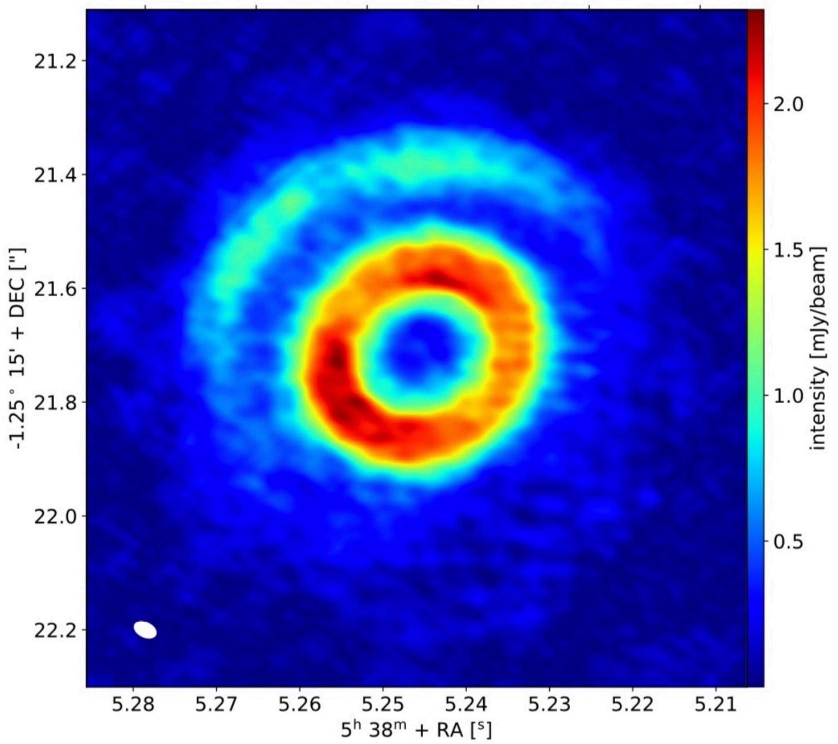
V1247 Ori: Is the crescent part of a spiral arm?

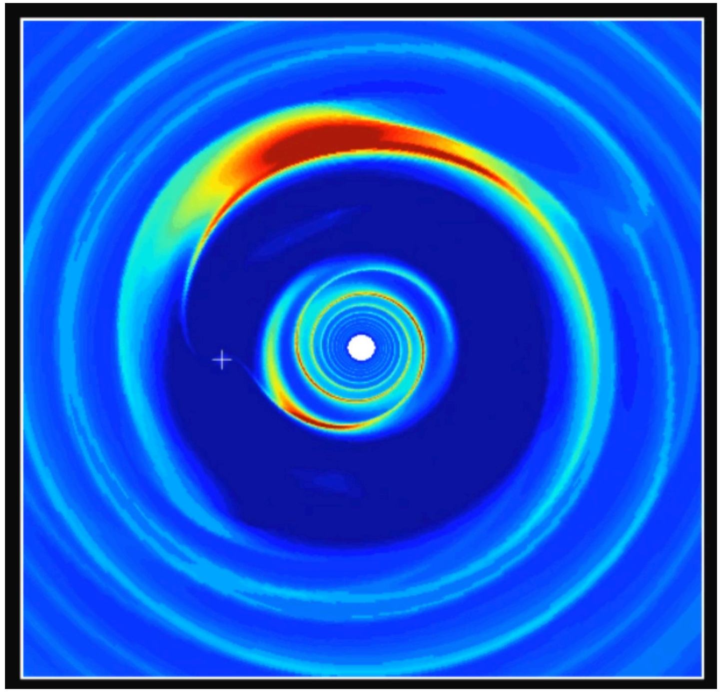


The spiral arm interpretation works if one assumes that the disk plane and spiral arm-plane are misaligned.

Kraus et al. 2017

V1247 Ori: Crescent + ring as a dust-trapping vortex





The crescent and ring asymmetry might constitute dust-trapping vortices

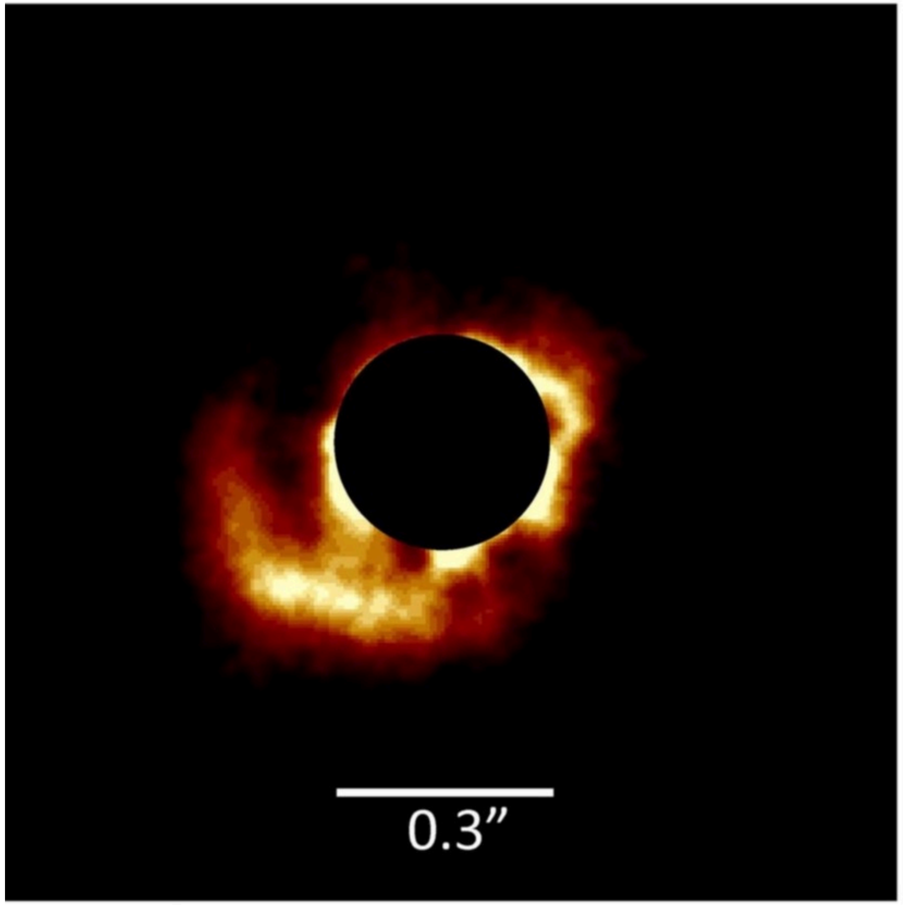
➜ **First case where dust trap observed at inner + outer edge of gap**
(e.g. predicted by Rossby Wave instability; Li et al. 2005)

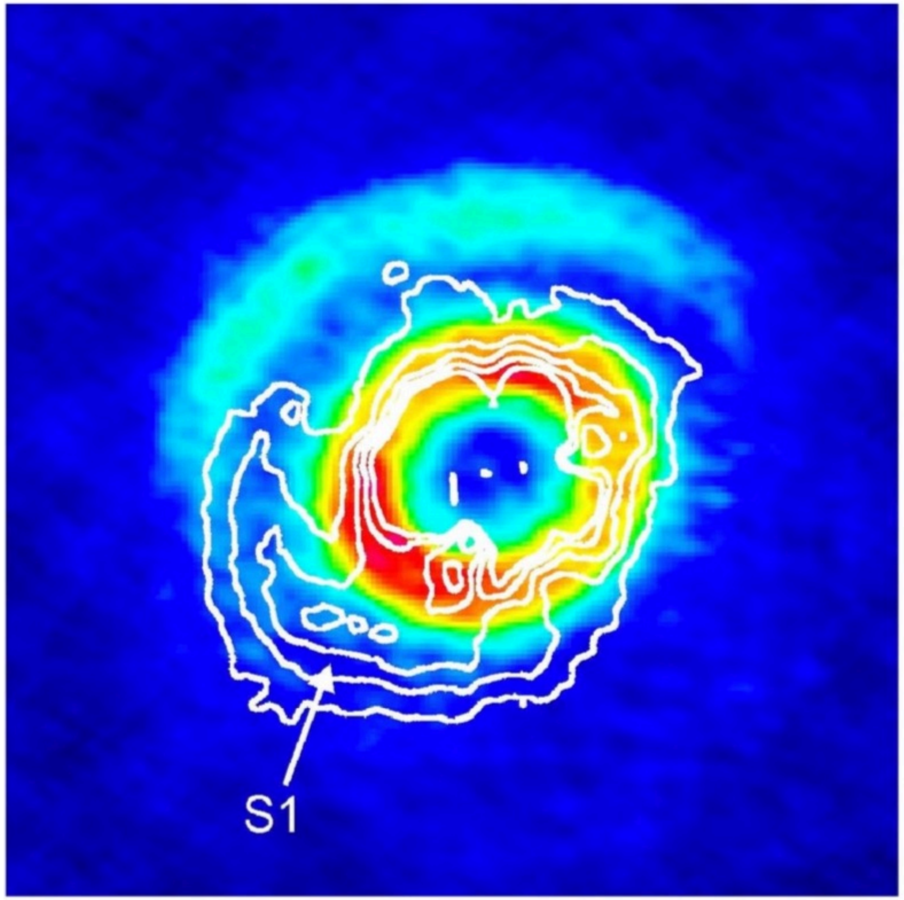
➜ 0.04" resolution allows us for the first time to resolve
azimuthal + radial structure of potential dust trap

Kraus et al. 2017; van der Marel et al. 2015 (Pinilla simulation)

V1247 Ori: Spiral arm in scattered light

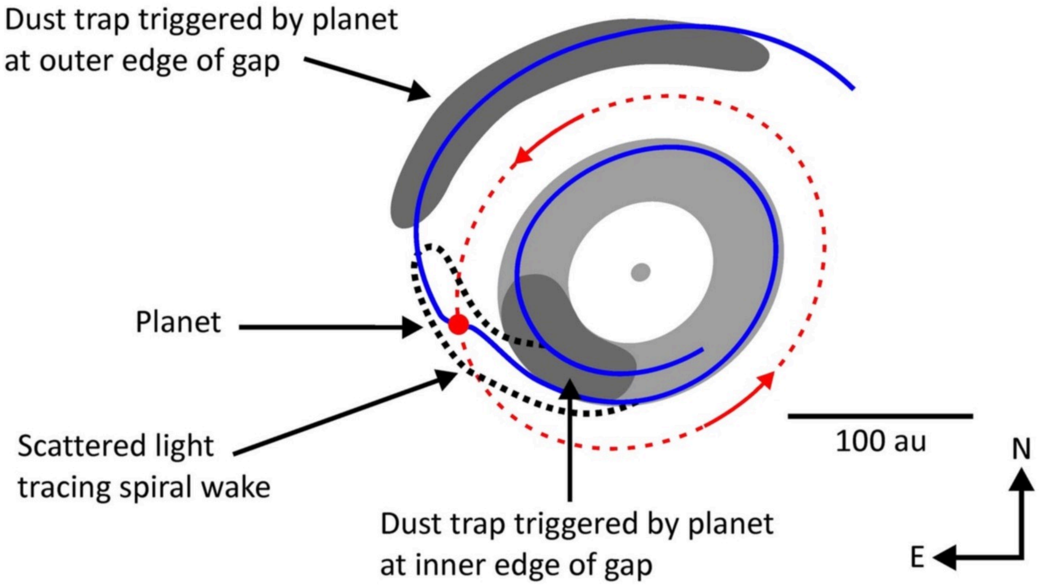
Subaru/HiCIAO H-band scattered light image

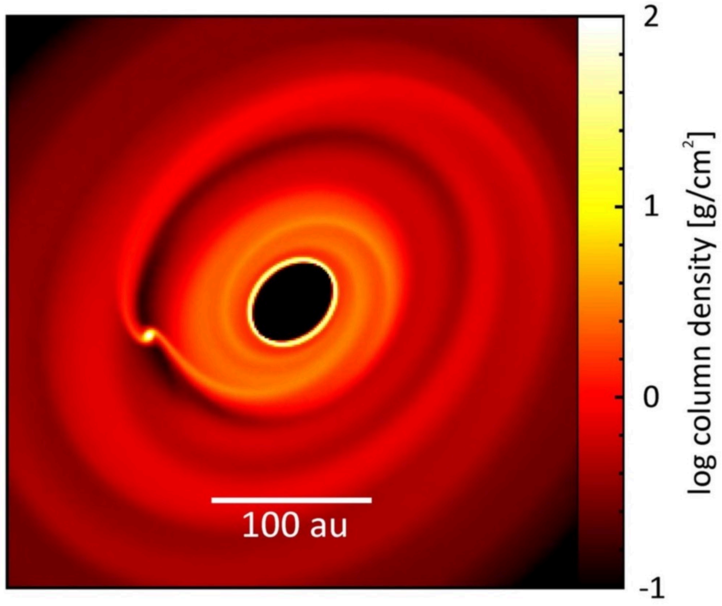


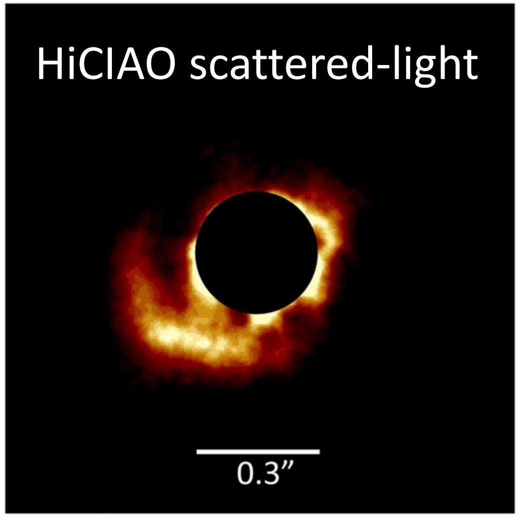


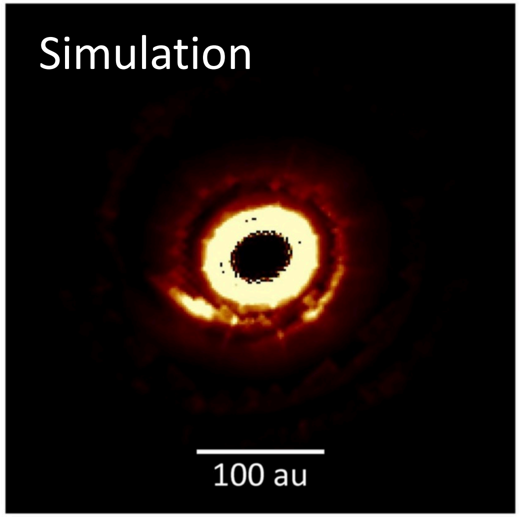
Ohta et al. 2015, Kraus et al. 2017

V1247 Ori: Hydrodynamic simulations of spiral wake









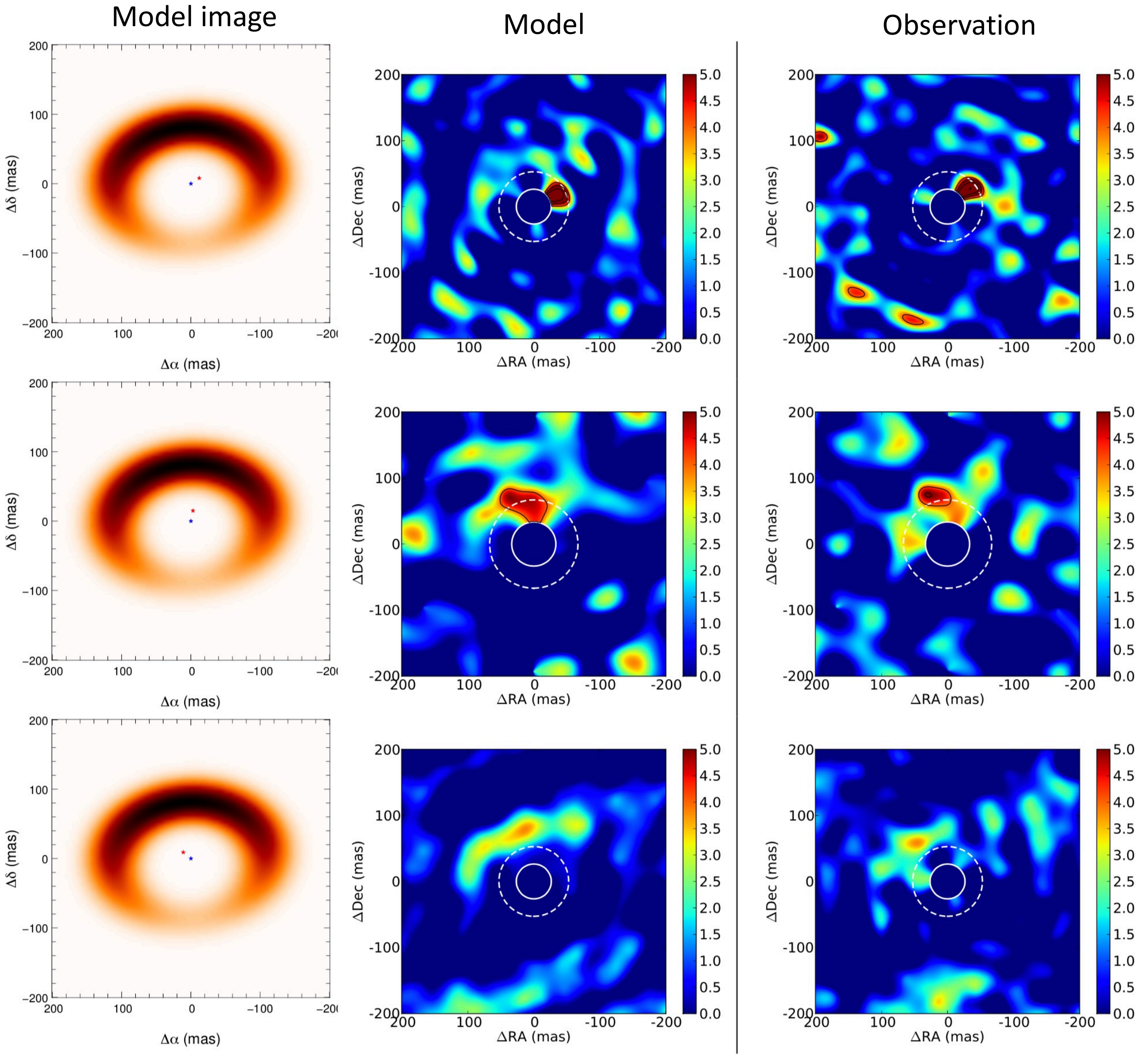
Kraus et al. 2017

V1247 Ori: Sparse Aperture Masking

2012-01-09
K-band

2012-12-18
K-band

2013-10-20
K-band



We see systematic PA change during the 21 months covered by our data

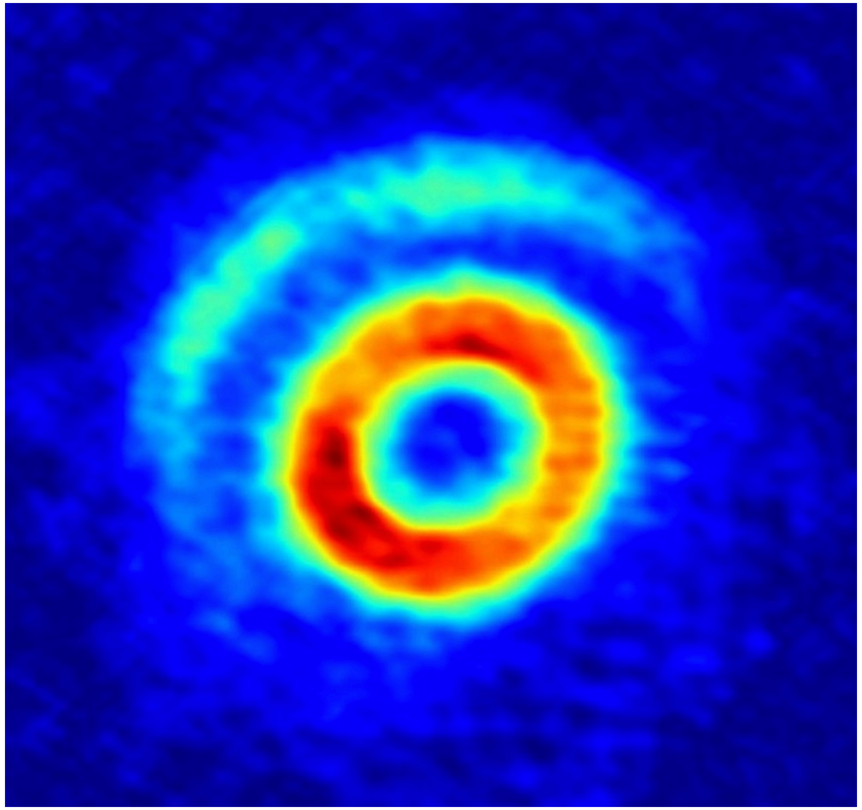
Signal can be fitted with companion at ≅ 0.04”

However, PA change of ≅ 90° is too fast to be compatible with companion @ 0.04”

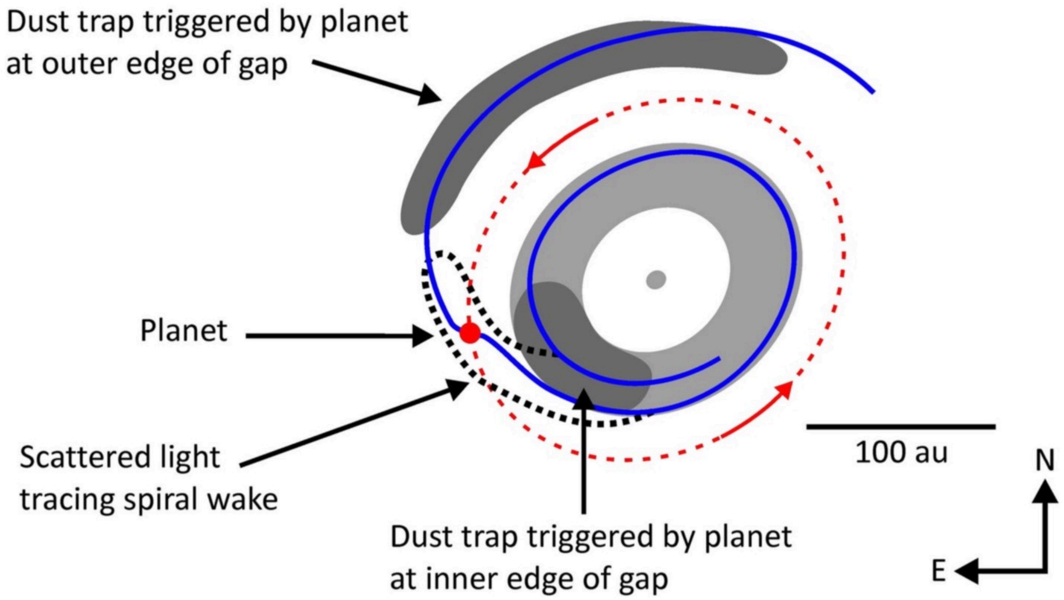
When taking the extended disk emission into account, we can fit the data with a companion at 0.02” (6 au)

Willson et al. submitted

V1247 Ori: Summary



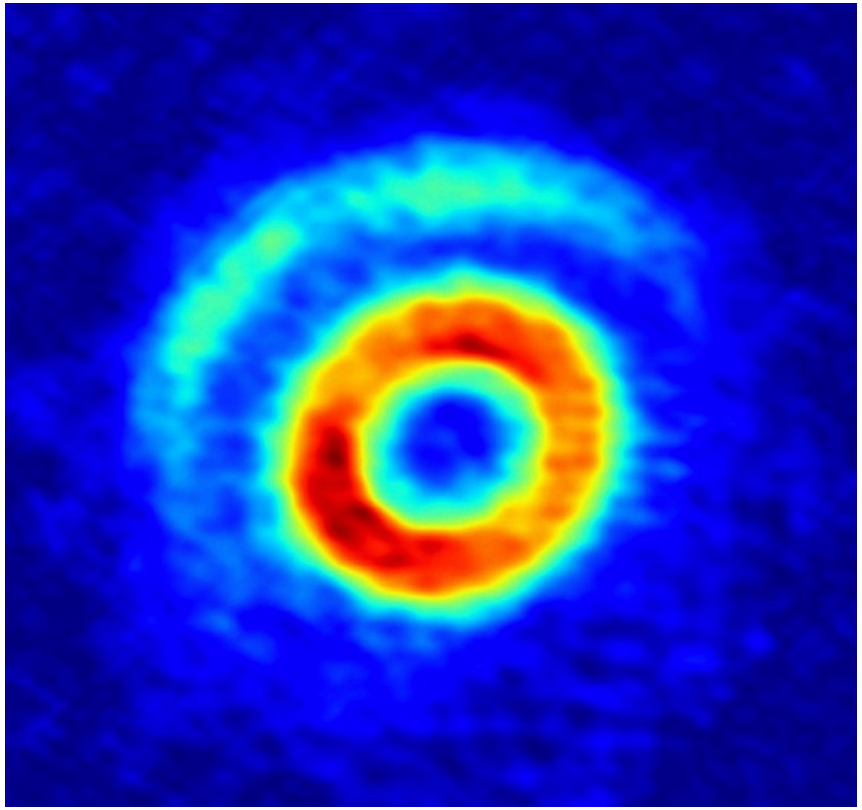
- ALMA image shows 2 potential dust traps, at inner + outer edge of density gap
- Spiral arm in scattered light might trace yet unseen planet
- Moving structure in inner disk, possibly companion @ 6 au



References:

- S. Kraus, A. Kreplin, M. Fukugawa, T. Muto, M. Sitko, A. Young, M. Bate, C. Grady, T. Harries, J. Monnier, M. Willson, J. Wisniewski 2017, ApJ 848, L11
- Willson et al., A&A, submitted

Thanks for your attention!



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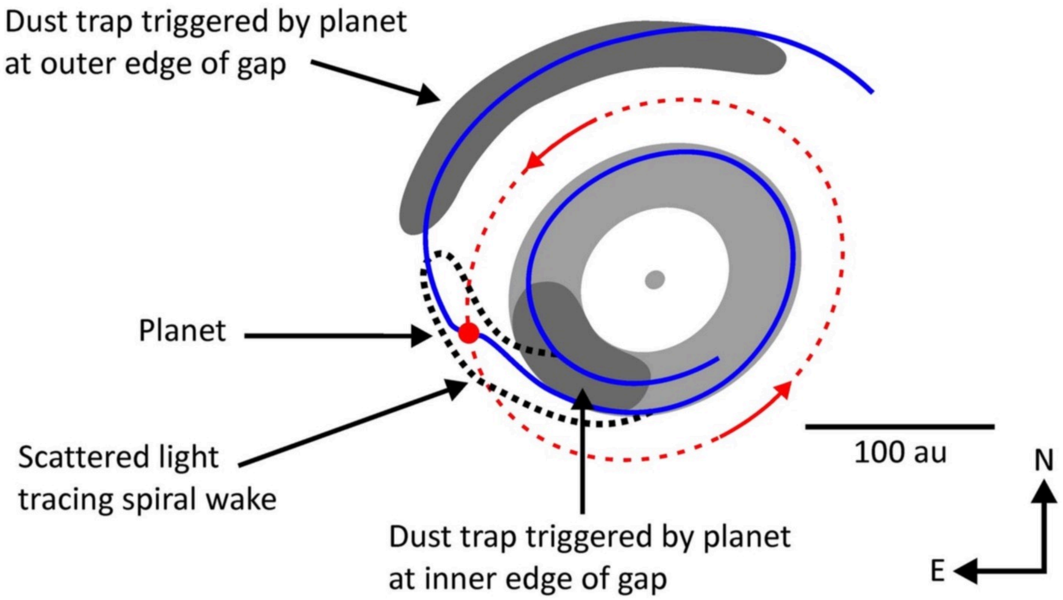

References:

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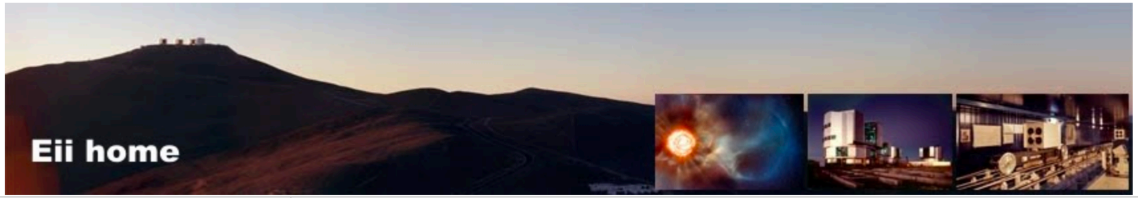
VLTI Expertise Centres

- JMMC, Porto, Exeter, Heidelberg, Nice, Liege
- Provide support on:
  - Proposal preparation
  - Observation preparation
  - Data reduction
- Contact address for all “future” VLTI users
- Travel funds to visit VLTI expertise centres (Fizeau exchange programme)
- Organisation of schools, trainings and workshops, VLTI community days



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VLTI Expertise Centres Network

A structured development of optical interferometry requires leaping towards a European network of VLTI Expertise Centres. These centres will be the backbone of dissemination activities to new VLTI users, by organising observing preparation and data reduction schools, by co-organising with ESO the VLTI community days, and being the end-points of the Fizeau staff exchange programme.

The leap aims at bringing the impact and return of the programme in spreading know-how in Europe to a new level. It follows at a smaller scale the successful experience of the ALMA Regional Centres, where researchers travel to the expertise centres to reduce their data. The centres will be the visible first contact point for astronomers interested in using VLTI.

The planned network of VLTI Expertise Centres includes the three partners from the OPTICON H2020 networking activity:

- Jean-Marie Mariotti Centre - Service aux Utilisateurs du VLTI, France,
- Portuguese VLTI Expertise Centre, Portugal,
- University of Exeter, United Kingdom,

as well as the three interferometry JRA (WP8) lead partners:

- Max Planck Institute for Astronomy, Germany,
- Observatoire de la Cote d'Azur, France,
- Université de Liége, Belgium.

http://www.european-interferometry.eu/

Subpages (1): JMMC - Service aux Utilisateurs du VLTI

Comments