Detection and characterization of very young planets

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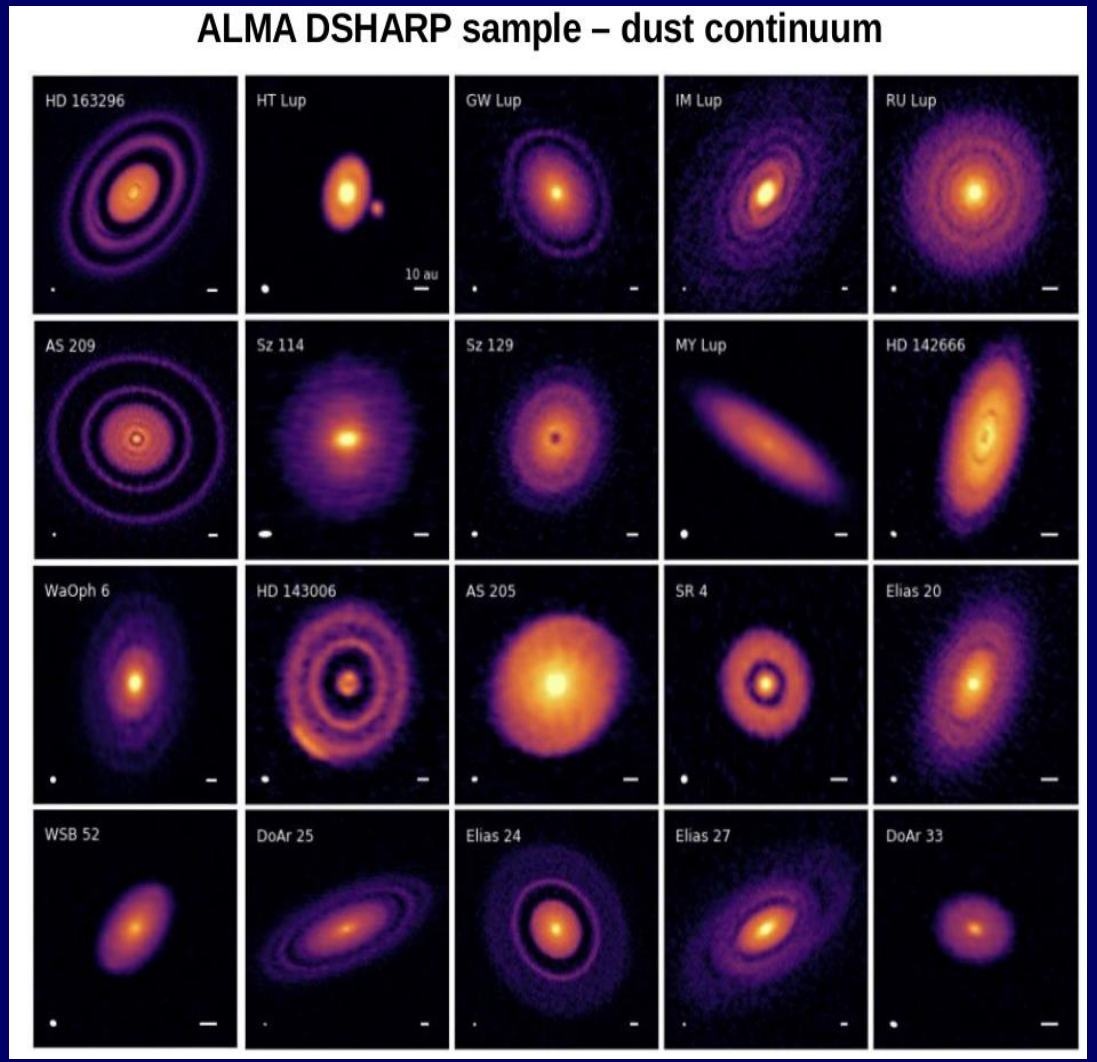
- ALMA data revealed a number of structures in disk around even very young stars



Andrews+ 2018

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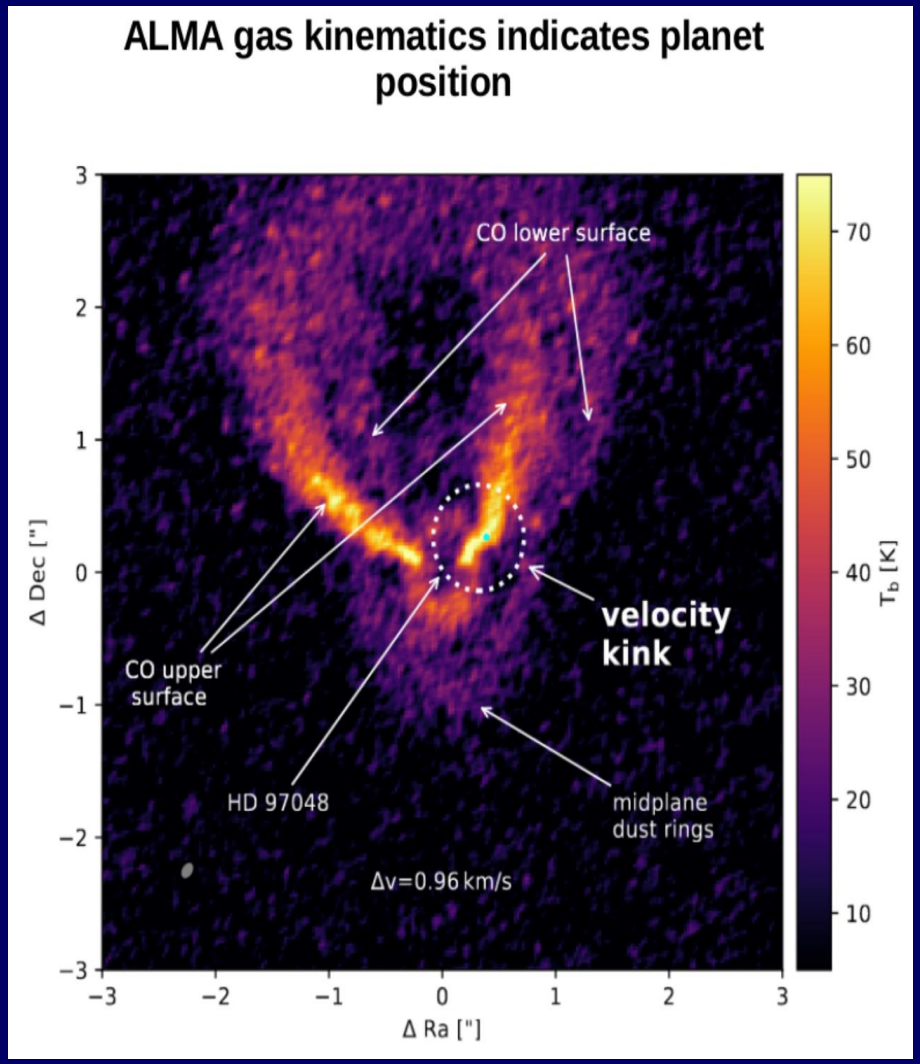
- This suggests that planets form very early within disks
- But where are these planets?
- Only indirect (and possibly ambiguous) evidence from ALMA data



Pinte et al. 2019

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- We need direct observations of extremely young, still forming planets
- This requires high contrast imaging in the NIR
- But how a very young planets should look like?

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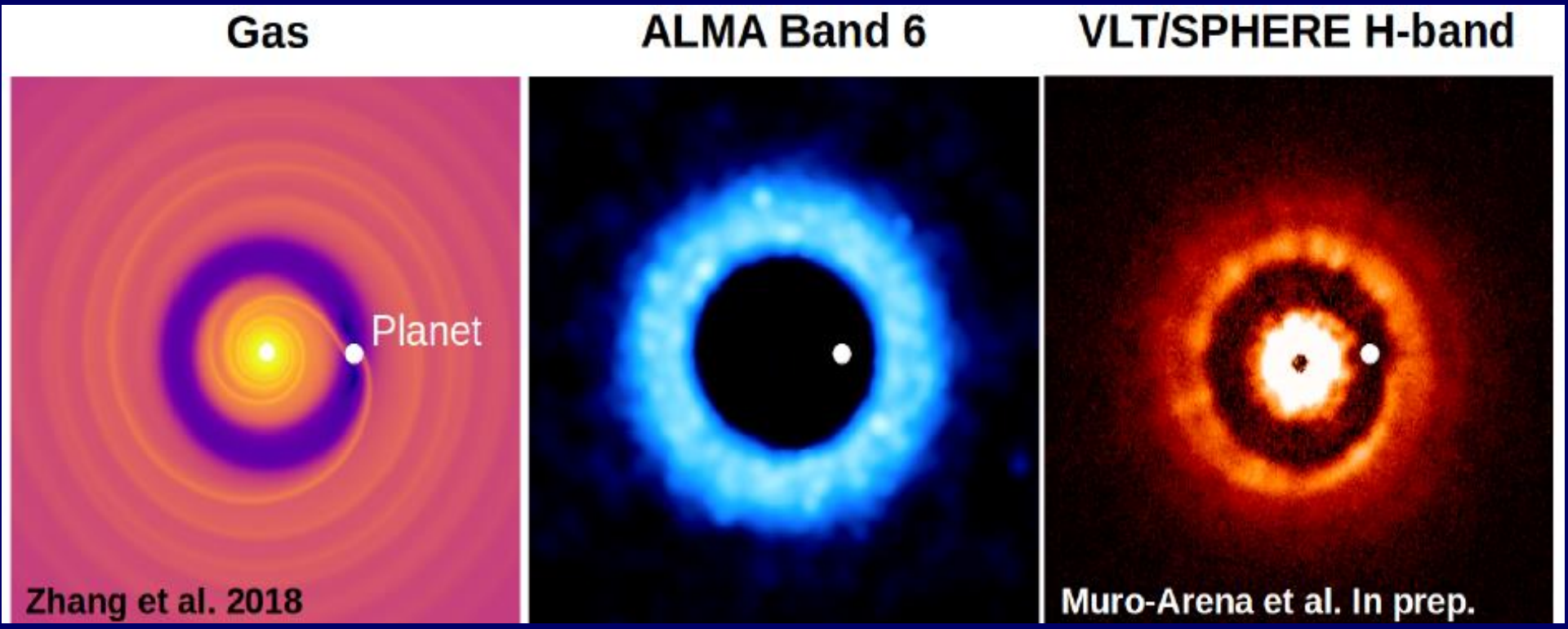
What we expect?



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HD169142

- HD169142 is a ~1.7 Mo star:
  - Age 5-11 Myr (Blondel+ 06; Manoj+ 07)
  - Almost face-on gas-rich disk (i=13: Raman+07); NaCo+ALMA
  - Parallax 8.77 mas (GAIA DR2)
  - Two candidate planets proposed (Biller+, Reggiani+)
- Previous studies in SPHERE GTO:
  - Ligi+: Rejection of planets, two blobs moving on Keplerian orbits
  - Pohl+: Disks clearly detected in pol. light; blobs are likely made of dust bc detected also by simulating ADI on pol images

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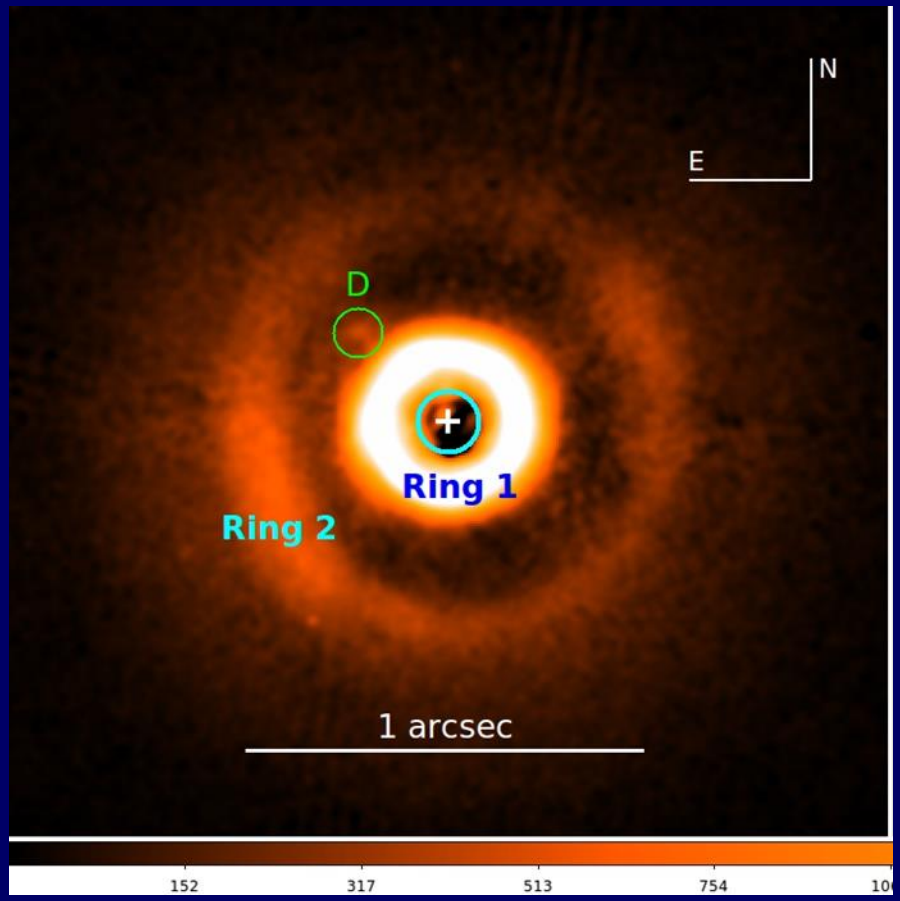
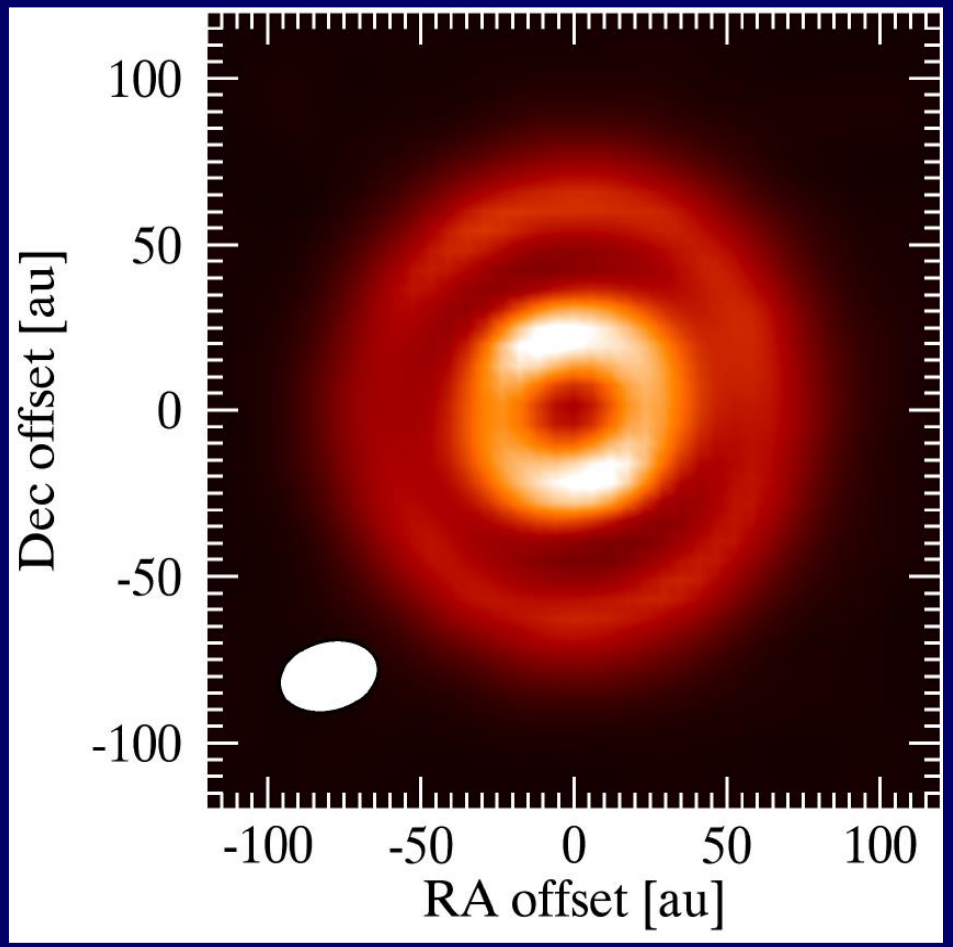
Disk images



SPHERE H-band PDI (Pohl+ 2017)



ALMA 1.3 mm dust (Fedele+ 2017)

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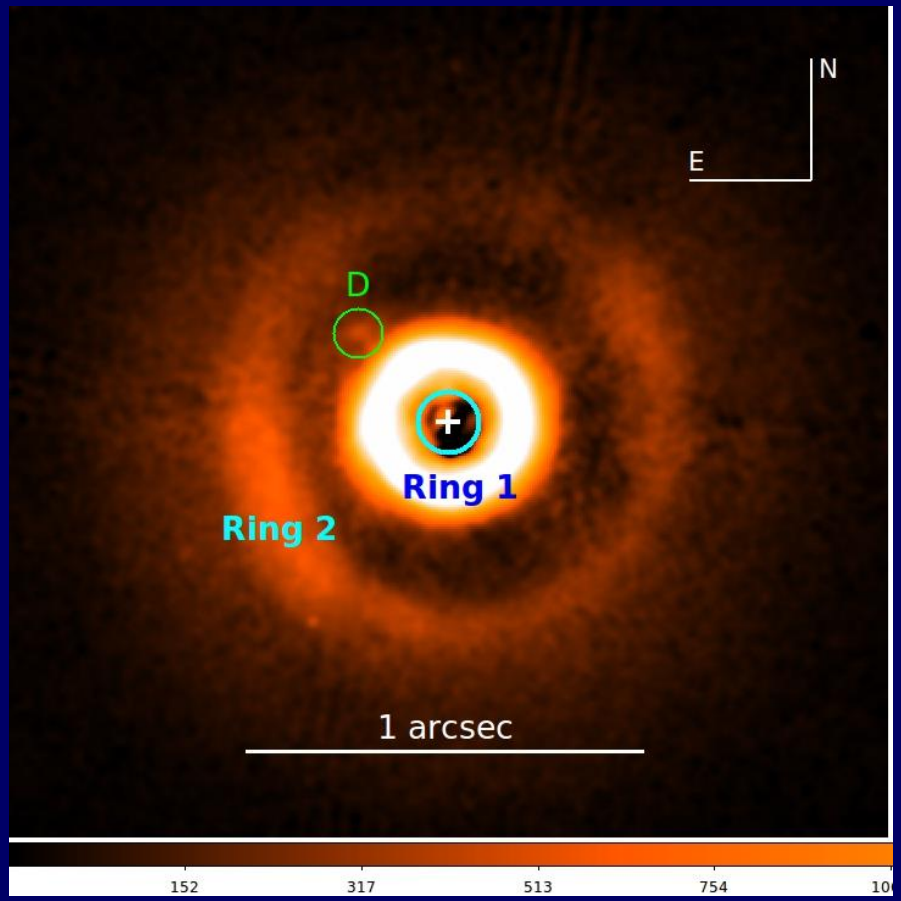
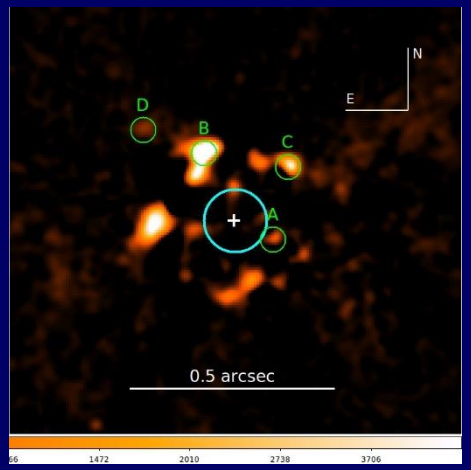
Qphi image





SPHERE H-band PDI (Pohl+ 2017)

Differential imaging enhancing features

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Blob D might be around a planet

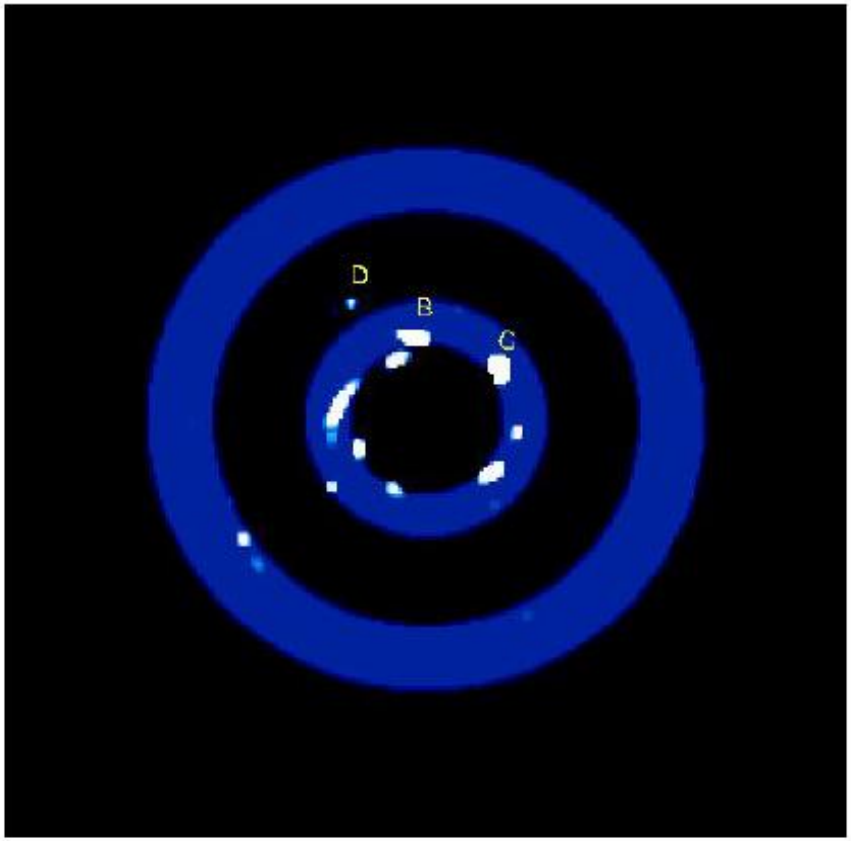

Fig. 3. Same as the lower panel of Fig 2, but with the two disk rings shadowed (ring edges are according to Fedele et al. 2017). Blobs B, C and D are labeled

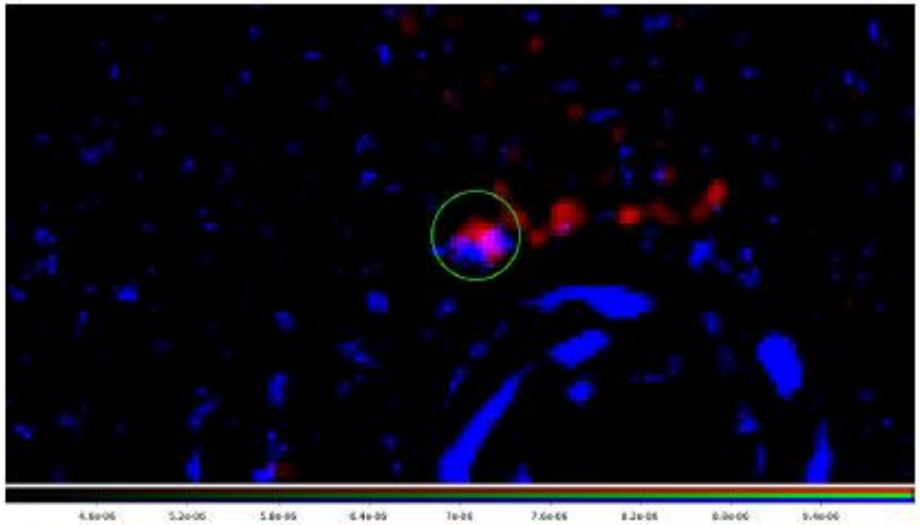

Fig. 4. Zoom of a two colour image of the region around blob D. This image was constructed using the K2 observation of JD=2458288.19 (red) and the weighted sum of all the IFS images (collapsed against wavelength) and rotated for a Keplerian motion assuming that the star has a mass of 1.7 $M_{\odot}$ (blue). This last image is for the same epoch of the K2 observation. For clarity, the region within 0.28 arcsec from the star (that is within the outer edge of Ring 1) was masked in the K2 band image. The green circle is centered on the position of the blob measured on the K2 image. Note the different aspect and small offset between the position of the blob in the K2 image with respect to that at shorter wavelength

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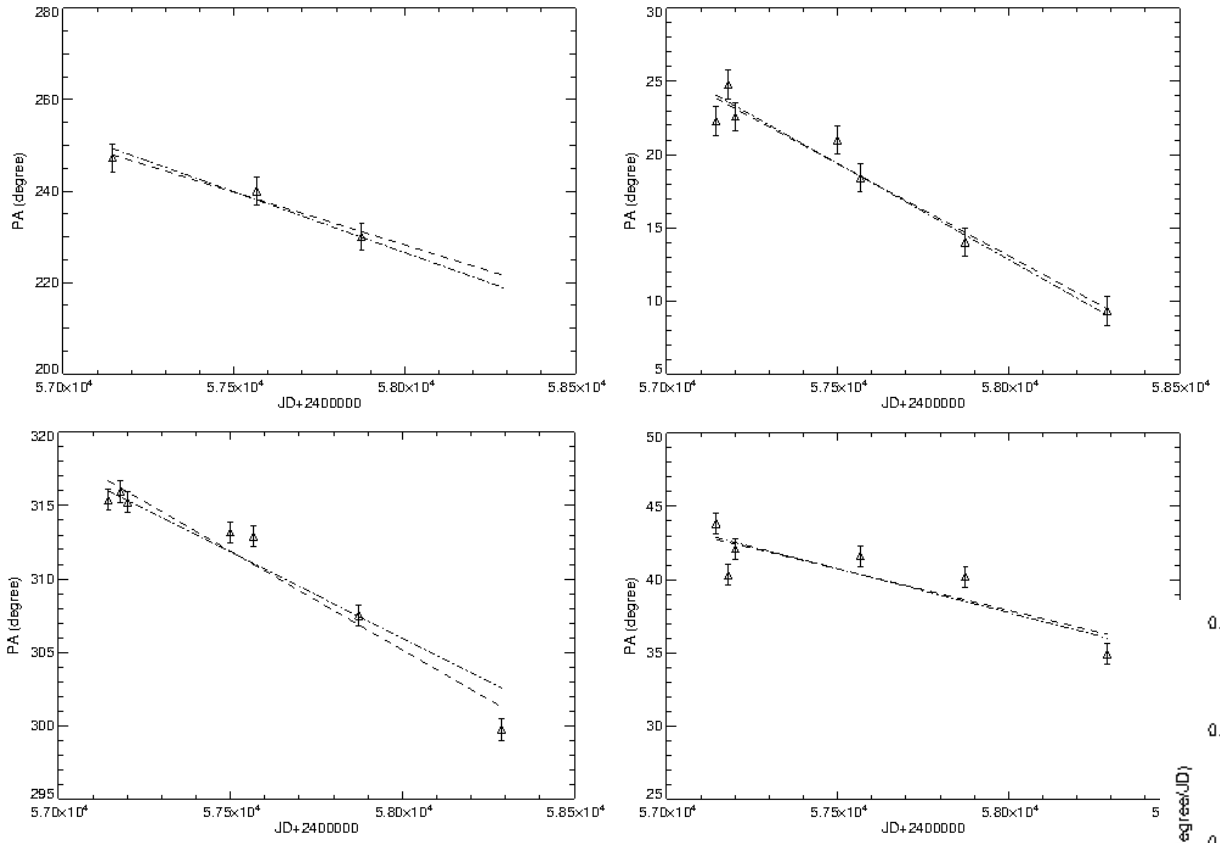
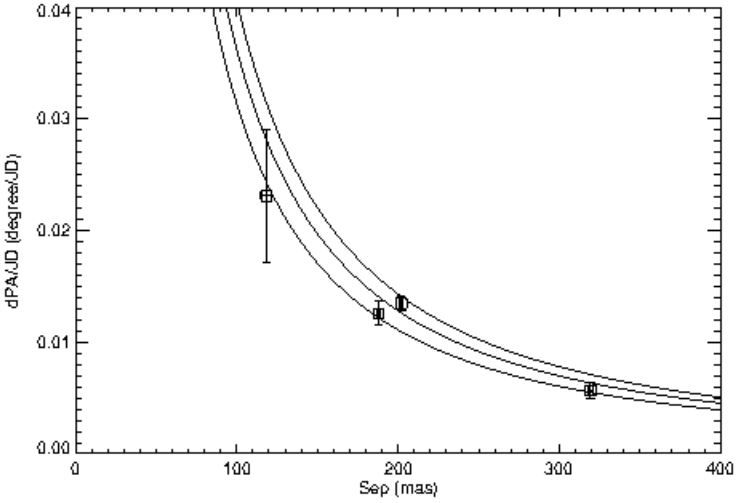
Blob rotation



All blobs rotate following keplerian motion



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Blobs spectra

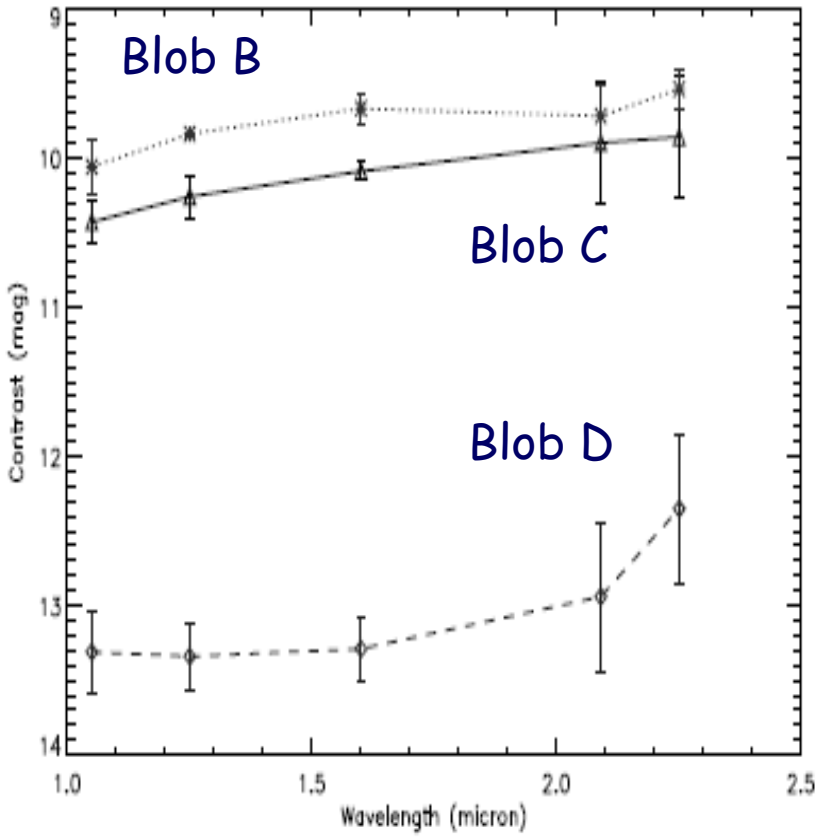

Fig. 6. Contrast of blobs as a function of wavelength. Blob B: Asterisks and dotted line; Blob C: triangles and solid line; Blob D: diamonds and dashed line

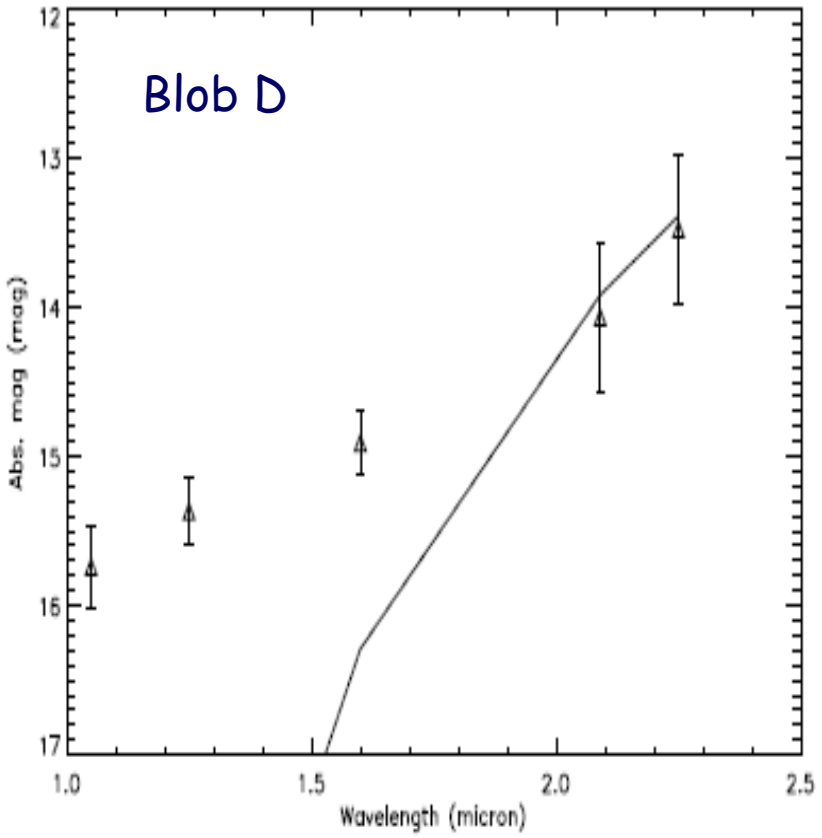

Fig. 7. Absolute magnitude of blob D in various bands (diamonds). The solid line is the prediction for a 3 M_J, 5 Myrs old planet using dusty isochrones by Allard et al. (2001)

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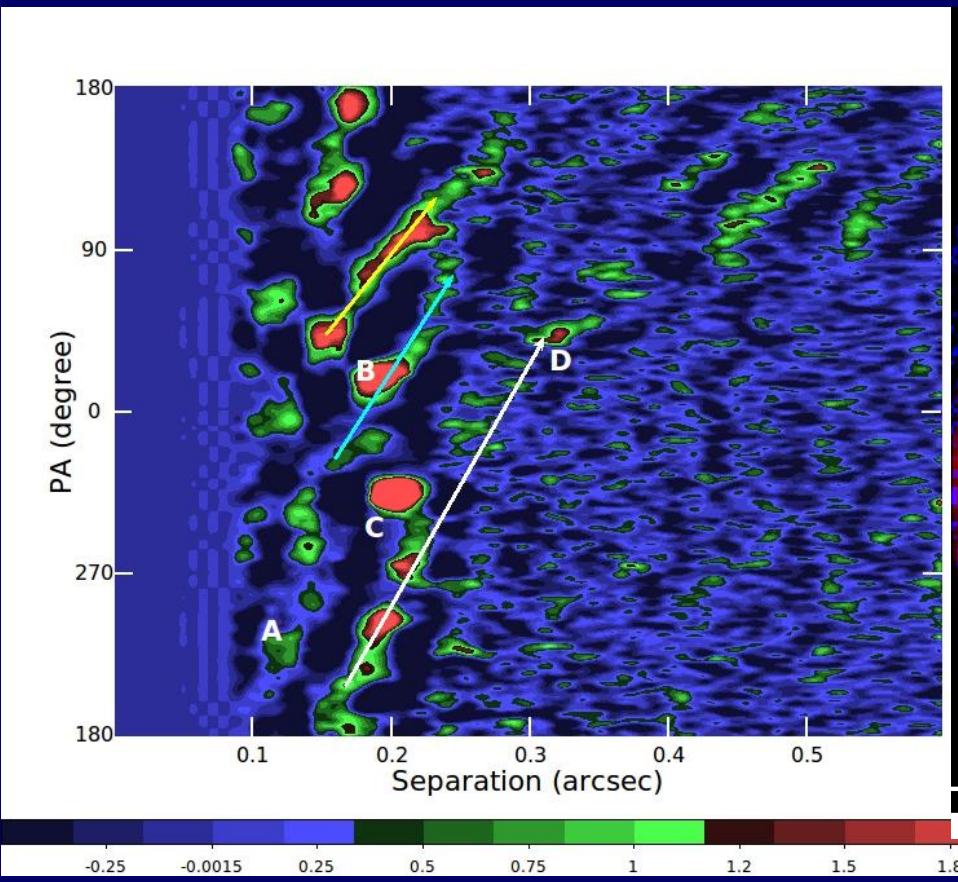
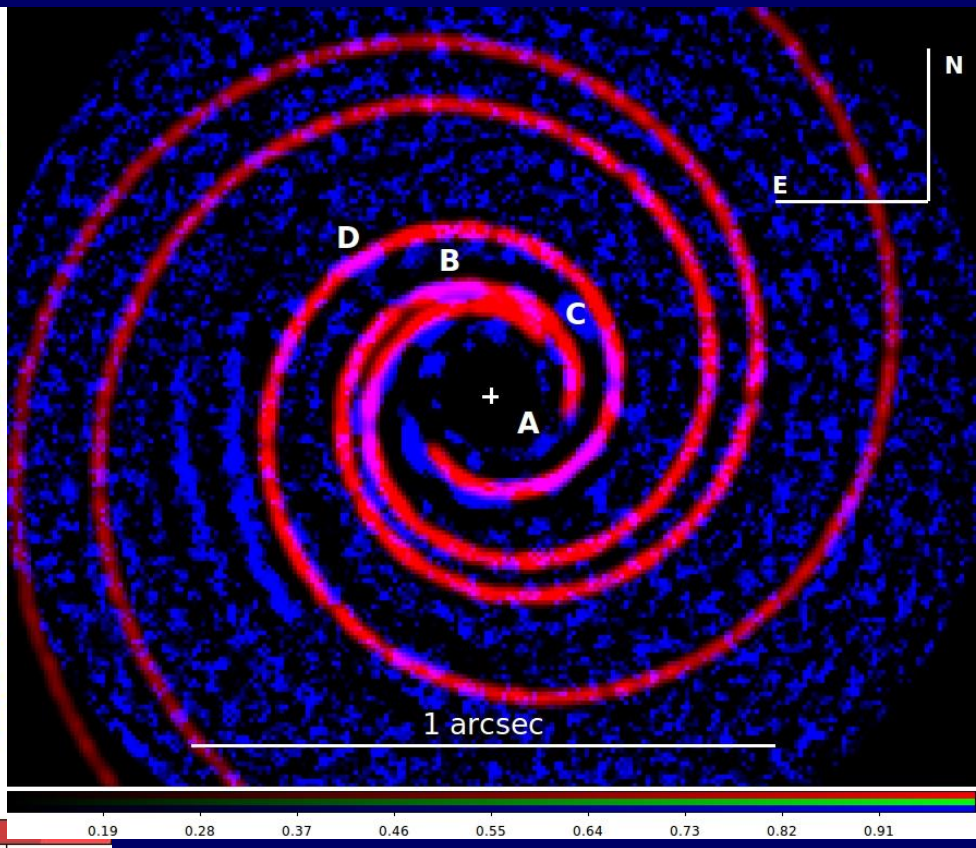
Three spiral arms

Polar coordinates





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Planet b (?) mass determinations

- Photometry (depends on models and age): ~3 M_J
- Hill radius: 16.5±5 mas @ 326 mas → 0.25-1.6 M_J
- Spiral arm separation (Fung & Dong 15): 127.2 degree → 5.1±1.1 M_J
- Pitch angle (Zhu+ 15): 17.5 degree @ 183 mas = 0.55 r_p → q=0.006 → 6 M_J
- Disk gap (depends on disk thickness and viscosity):
  - Kanagawa+ 16: 0.75 M_J
  - Dong & Fung 17: 0.56 M_J

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What are blobs B & C?

- Blobs are near the 1:2 resonance of the proposed planet (around blob D)
- They may be vortices (discussed in Ligi+)
- Alternatively, they may be clouds of debris generated by the collision of asteroids

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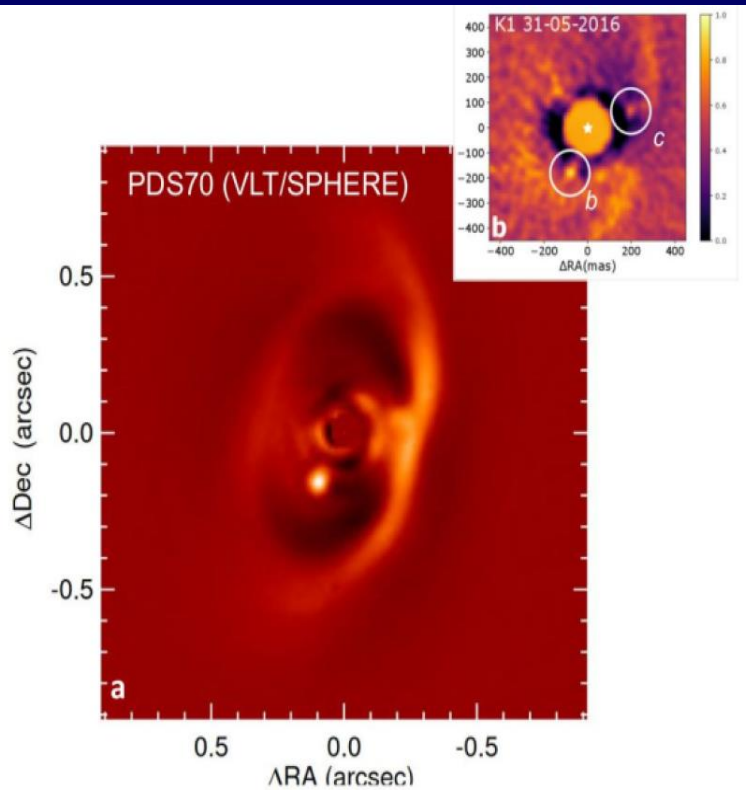
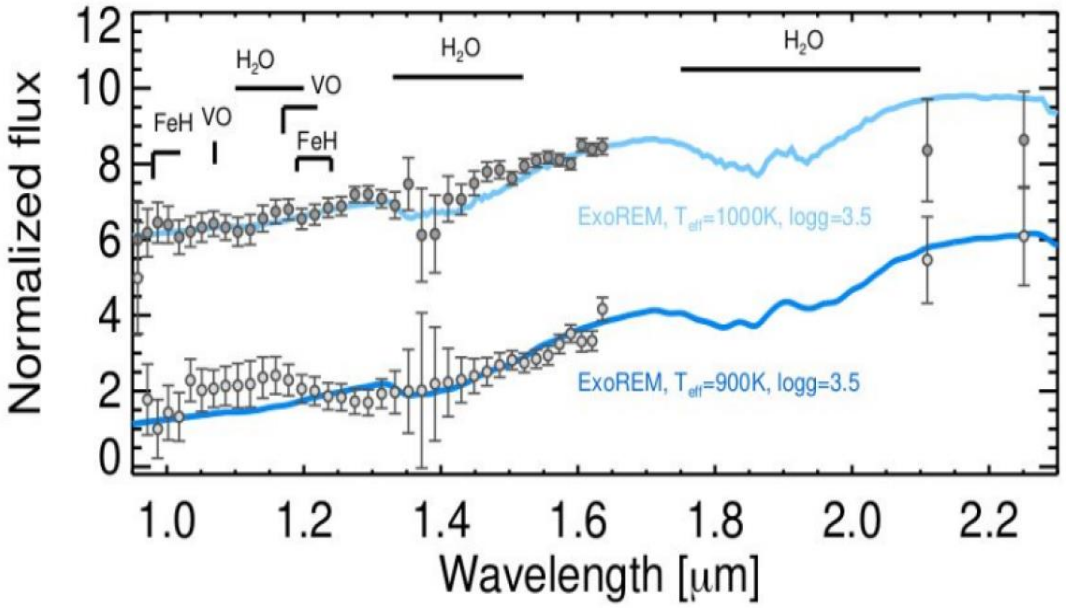
PDS-70

A system with a planet embedded in a gas-rich protoplanetary disk around a 6 Myr old solar type star (~0.7 Mo)





Keppler + 2018

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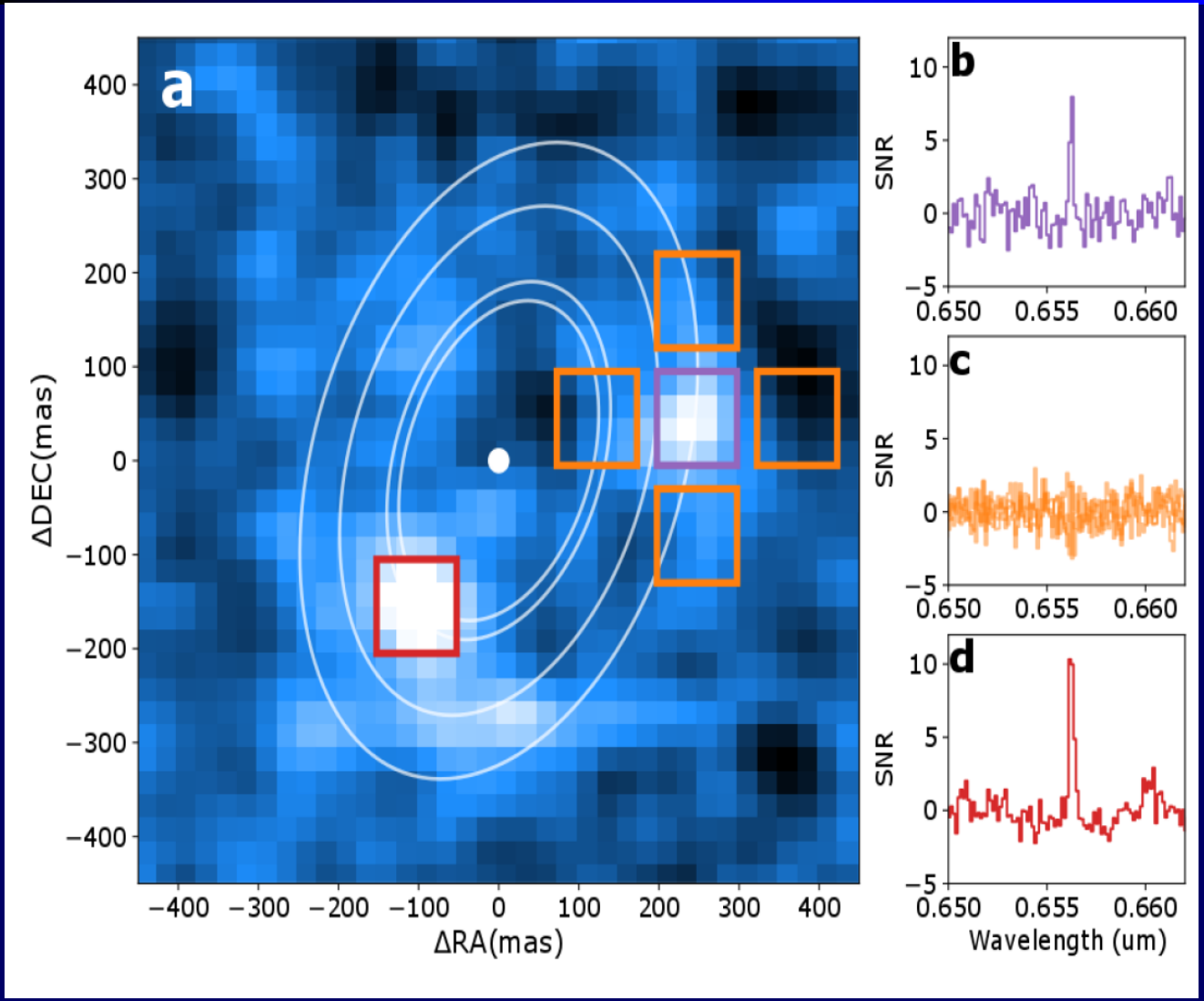
Haffert et al 2019:
Two accreting planets detected from Ha emission with MUSE



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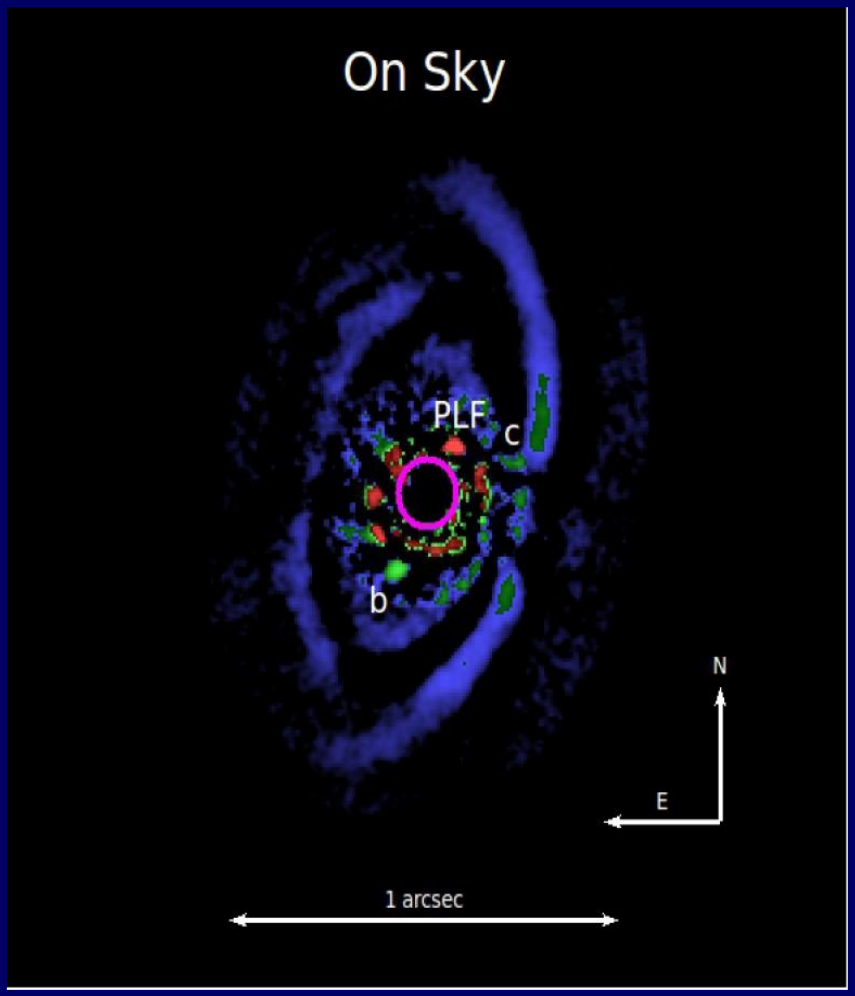
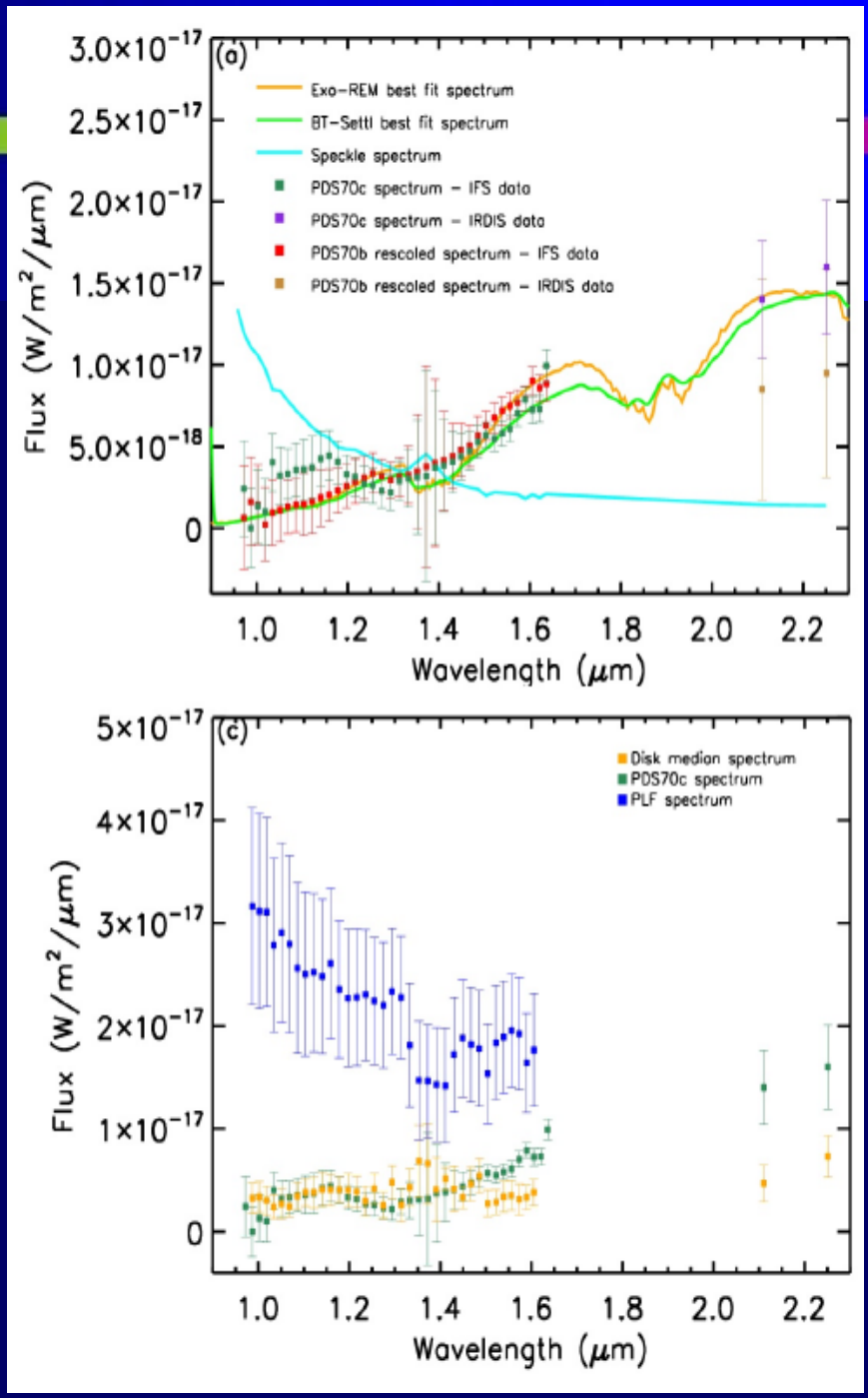
Cc around PDS-70





Mesa+ 2019: Two, perhaps three planets

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Conclusions

- Detection of still forming planet is crucial to understand the mechanisms of planet formation
- Very young planets are very red and dusty, are likely still accreting, and may be surrounded by a circumplanetary disk that reflects star light
- Confusion with disk features is a major issue, mainly so if the system is not seen face-on
- We need:
  - High contrast
  - Very high resolution
  - Wide spectral coverage, possibly using IFS
  - Combine with info from poarimetry and ALMA