Milliarcsecond imaging of clumpy dust clouds in the red giant L_2 Pup with Very Large Telescope Interferometer

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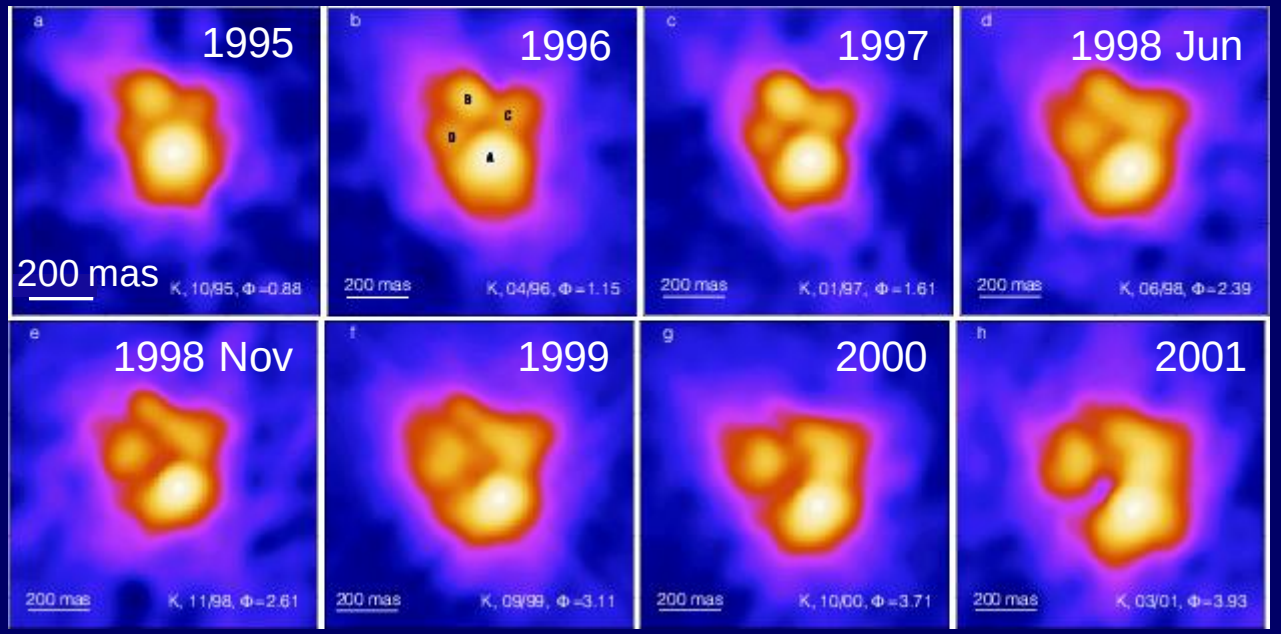
Dust formation in cool evolved stars

✓ Dust formation not understood well

- Where and what kind of dust forms and grow
- Not clear whether dust is the cause or result of the mass loss
- Dust formation may be intrinsically clumpy

IRC+10216 (2.2 μm)
1995--2001

Weigelt et al. (2002)



Dust formation in the M6.5 giant L_2 Pup

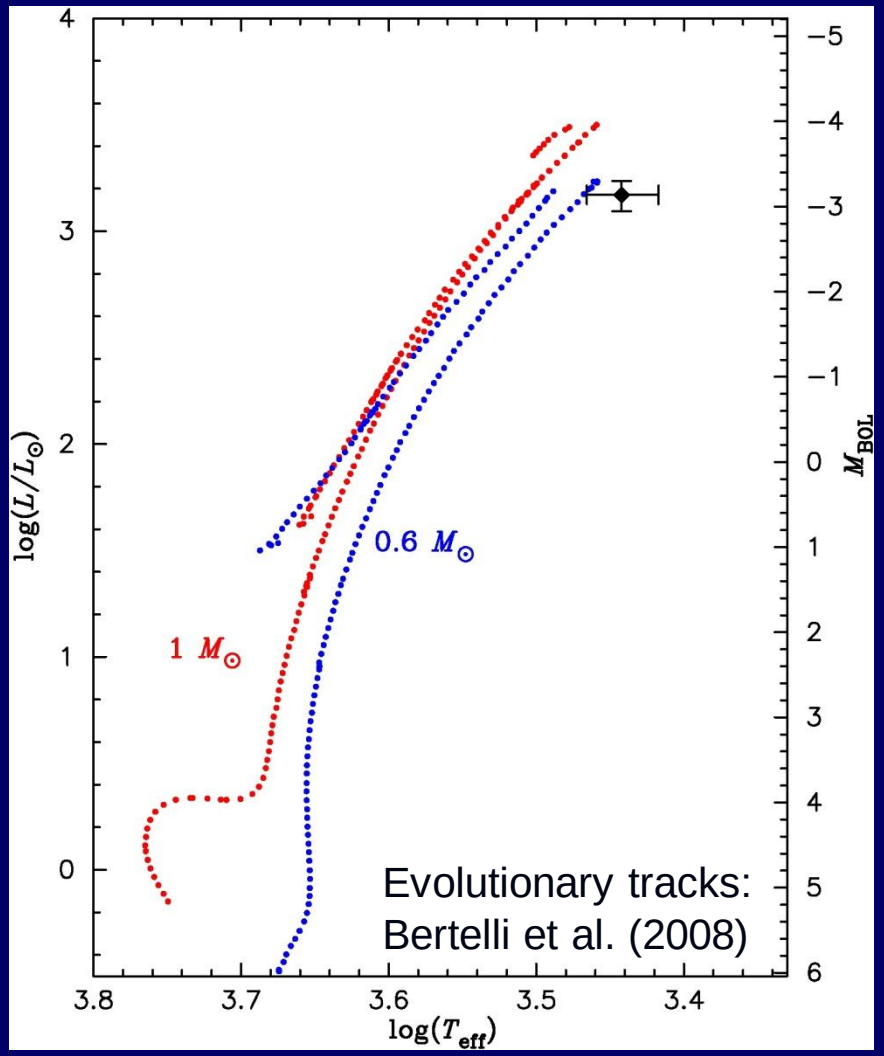
- ✓ Nearby (64 pc), semiregular M giant

  *T*eff = 2800 K, *L* = 1500 $L_\odot$
  (Ohnaka 2014)

- ✓ Very slow wind (~3 km/s)
  Mass-loss rate ~ 3 x 10^{-7} $M_\odot$/yr
  (Jura et al. 2002; Winters et al. 2002)

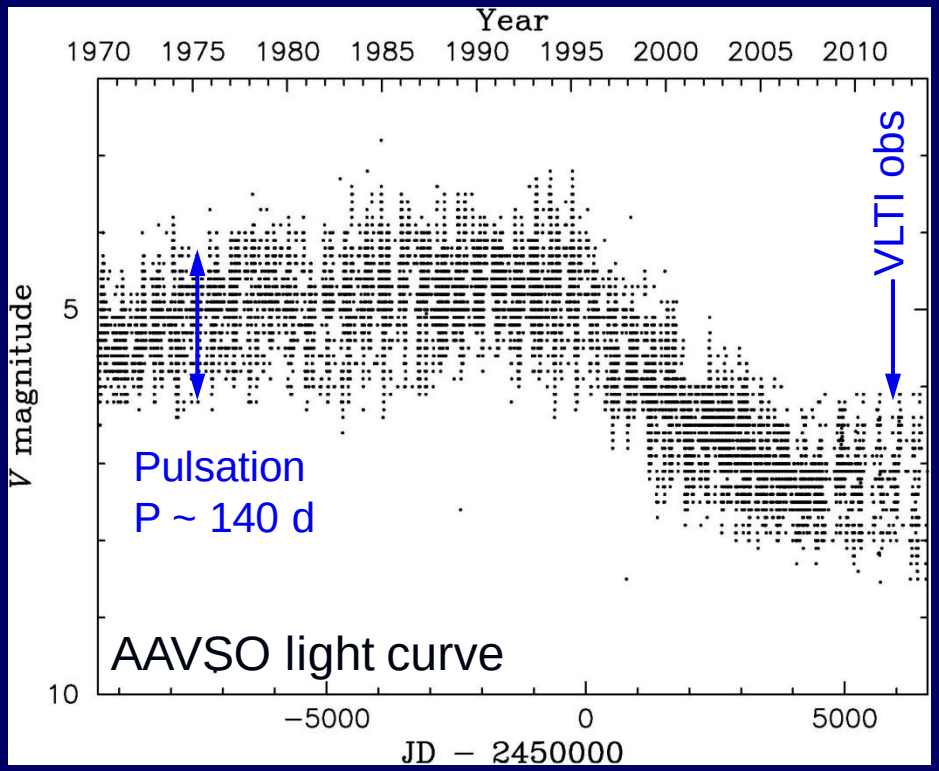
- ✓ Time variation in polarization
  (Magalhaes et al. 1986)
  → Grain growth and dissipation
  Asymmetric dust cloud

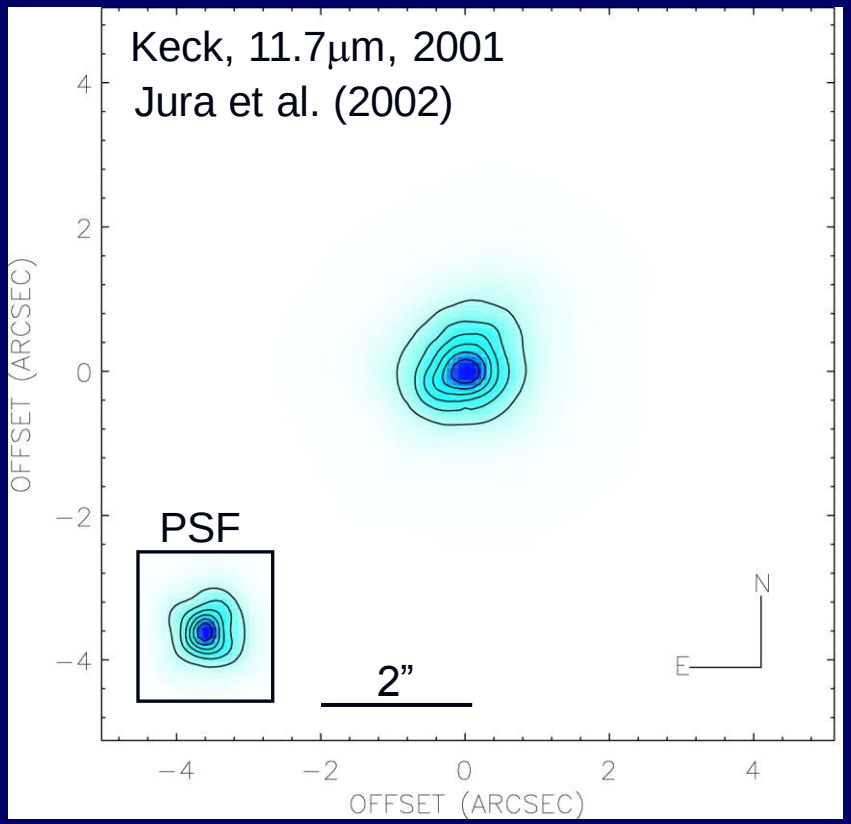
- ✓ Evidence of asymmetric brightness profile (Ireland et al. 2004)



Dust formation in the M6.5 giant L_2 Pup

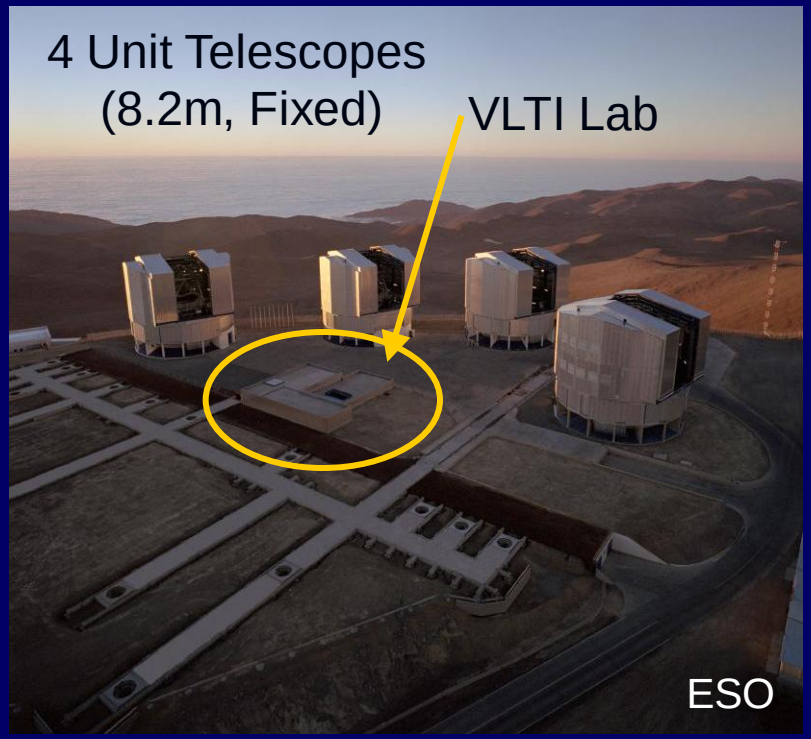
- ✓ Dimming event started in 1995 (Bedding et al. 2002): $\Delta V \sim 2.5$ mag
  → Episodic dust formation
- ✓ Elongated circumstellar envelope (Jura et al. 2002)
- ✓ Where and how dust forms?
  Angular diameter = 20–24 mas → High angular resolution needed





Very Large Telescope Interferometer (VLTI)

Chile, Cerro Paranal



4 Auxiliary Telescopes
(1.8m, Movable)

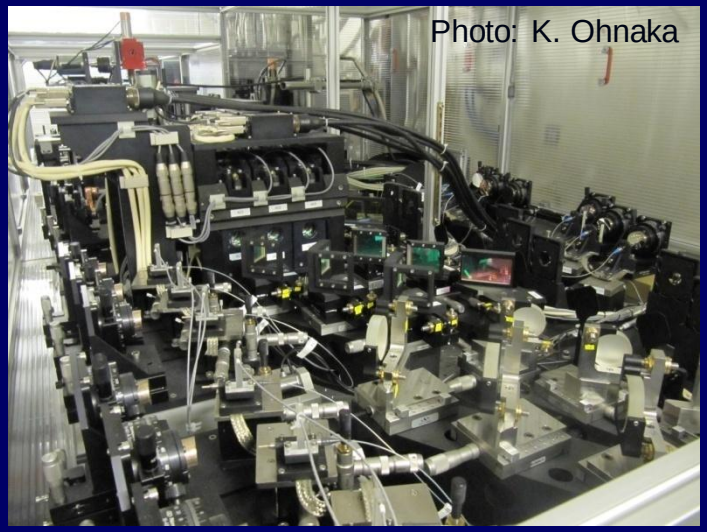
Change the array configuration depending on object's size/shape & Science cases

AMBER: near-IR interferometric instrument

Operating at 1.3 – 2.4μm

Angular resolution = 1 mas (2 μm)

Spectral resolution = 35, 1500, 12000



✓ Aperture-synthesis imaging is possible if enough *uv* points are sampled.

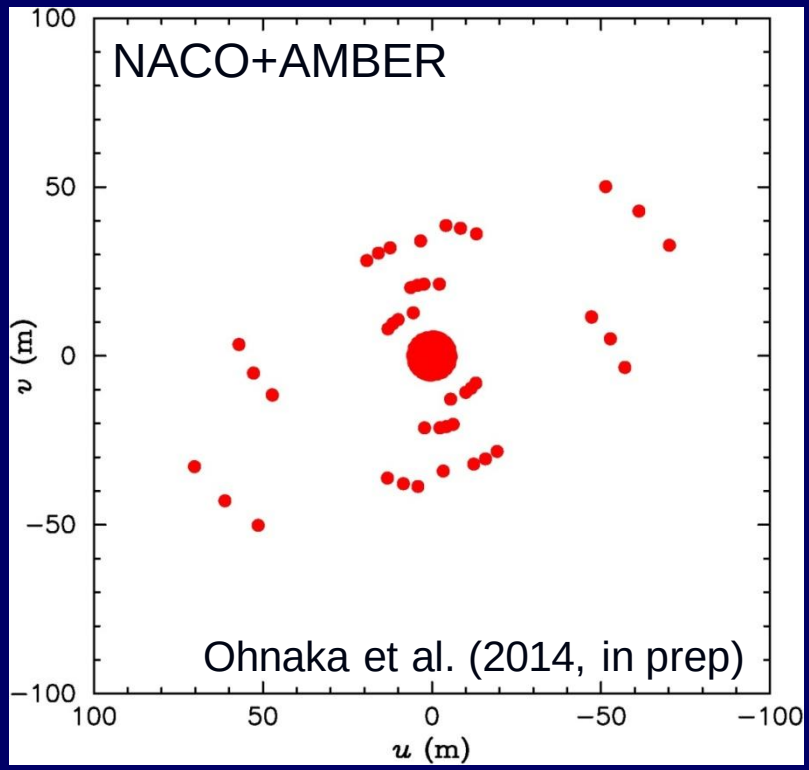
AMBER + NACO observations of L_2 Pup

✓ VLTI/AMBER 2.2 – 2.35μm
Baseline = 15 – 80 m

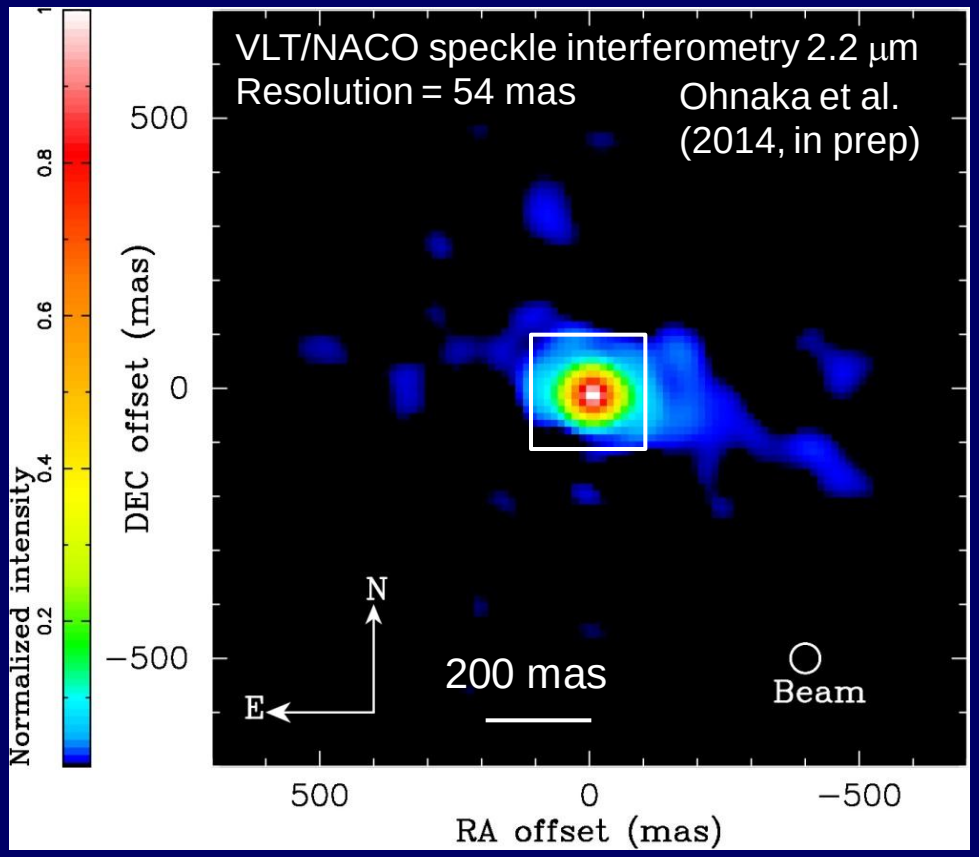
✓ VLT/NACO
Single-dish speckle interferomery

1. Diffraction-limited (54 mas) image

2. Combined image reconstruction with speckle interferometry (0 – 8m) + AMBER (15 – 80m)

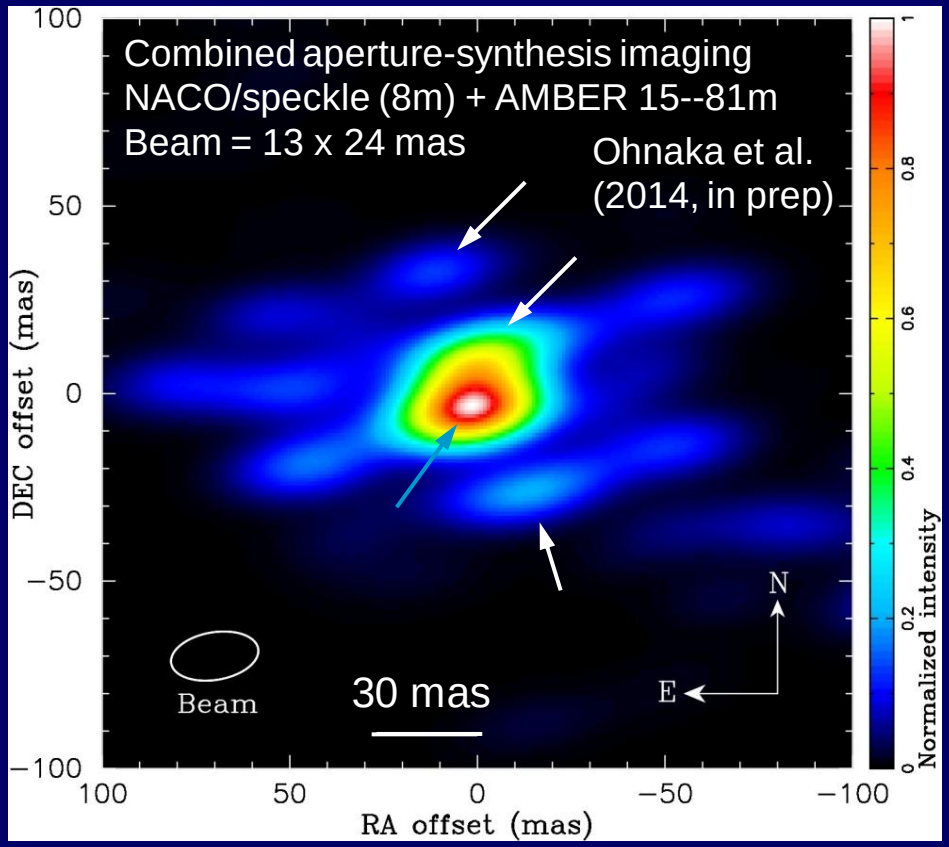


Clumpy dust envelope of the M7 giant L_2 Pup



- ✓ Dust envelope elongated in E-W direction: ~300 x 150 mas
- ✓ Not aligned with the mid-IR image (taken in 2001)
  → Time variation in 10 years or mid-IR & near-IR emission originates in different regions

Clumpy dust envelope of the M7 giant L_2 Pup



- ✓ **Clumpy dust clouds imaged for the first time**
  Off the star at 20 – 30 mas = ~2–3 stellar radii
  Over the stellar surface
  (Structure in E-W direction not resolved well)

Discussion & Outlook

✓ Dust formation at as close as 2 stellar radii
→ Temperature ~ 1700 K
→ Al_2O_3?

✓ Grains of 0.3μm size detected at ~2 stellar radii in 3 Mira stars (Norris et al. 2012)
→ L_2 Pup as well?
→ Mass loss may be driven by scattering on dust grains as proposed by Höfner (2008)

✓ Proper motion of the dust clouds
V_{exp} = 3 km/s → 0.8 stellar radii / yr = 9 mas/yr
→ Can be resolved well with VLTI/AMBER
= Witness the initiation of the mass outflow

Thank you for your attention!

Acknowledgements:
ESO VLTI team

Photo: K. Ohnaka