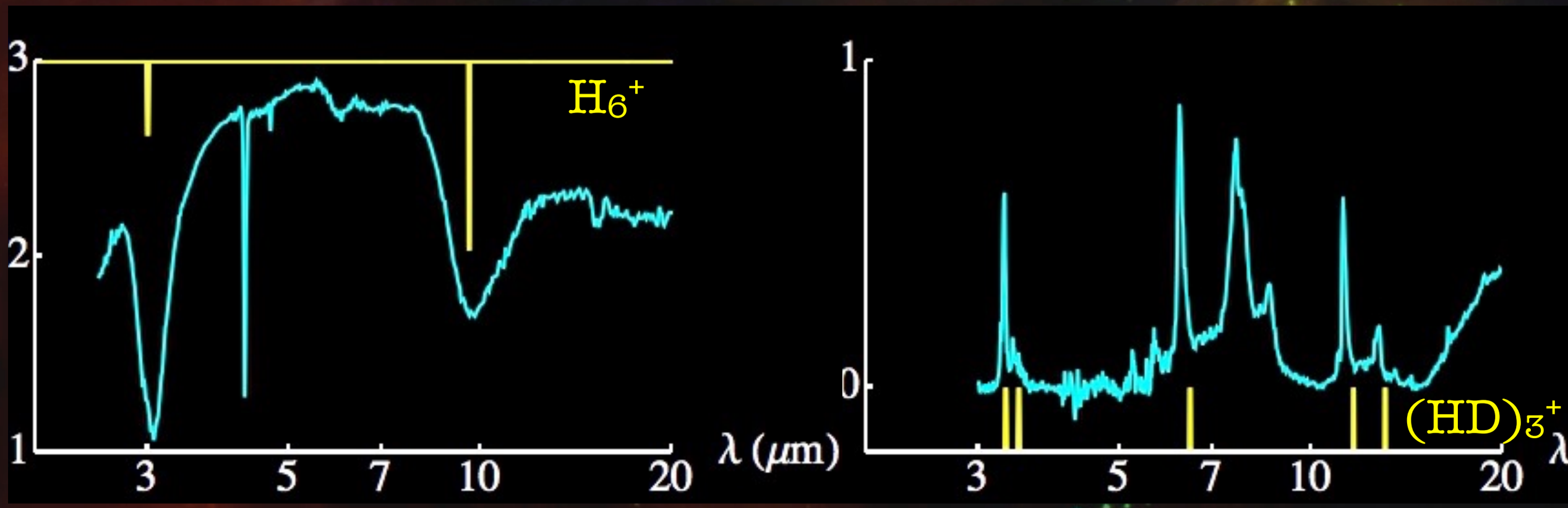
Hydrogen snow clouds and the B[e] phenomenon

Mark Walker
(Manly Astrophysics)

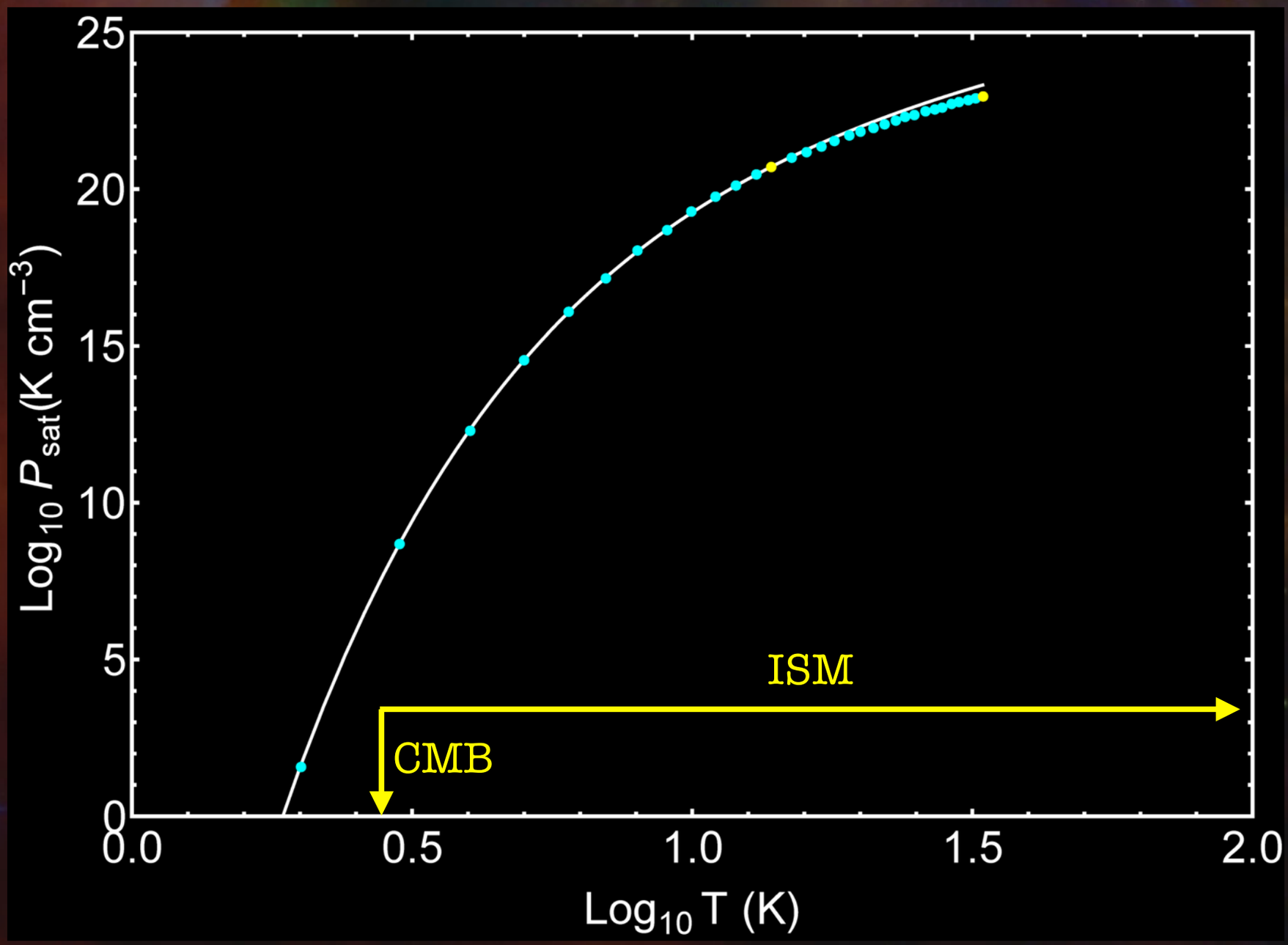
H_2 snowflakes : interstellar dust?

- Pure solid H_2 is volatile - cannot survive in ISM
  - Charged grains much more durable (MW 2013)
- Pure solid H_2 is highly transparent in optical/IR
  - Dominant spectral features from impurities
- Ionisation chemistry differs from gas phase
  - "New" molecule : H_6^+ (Lin, Gilbert & MW 2011)



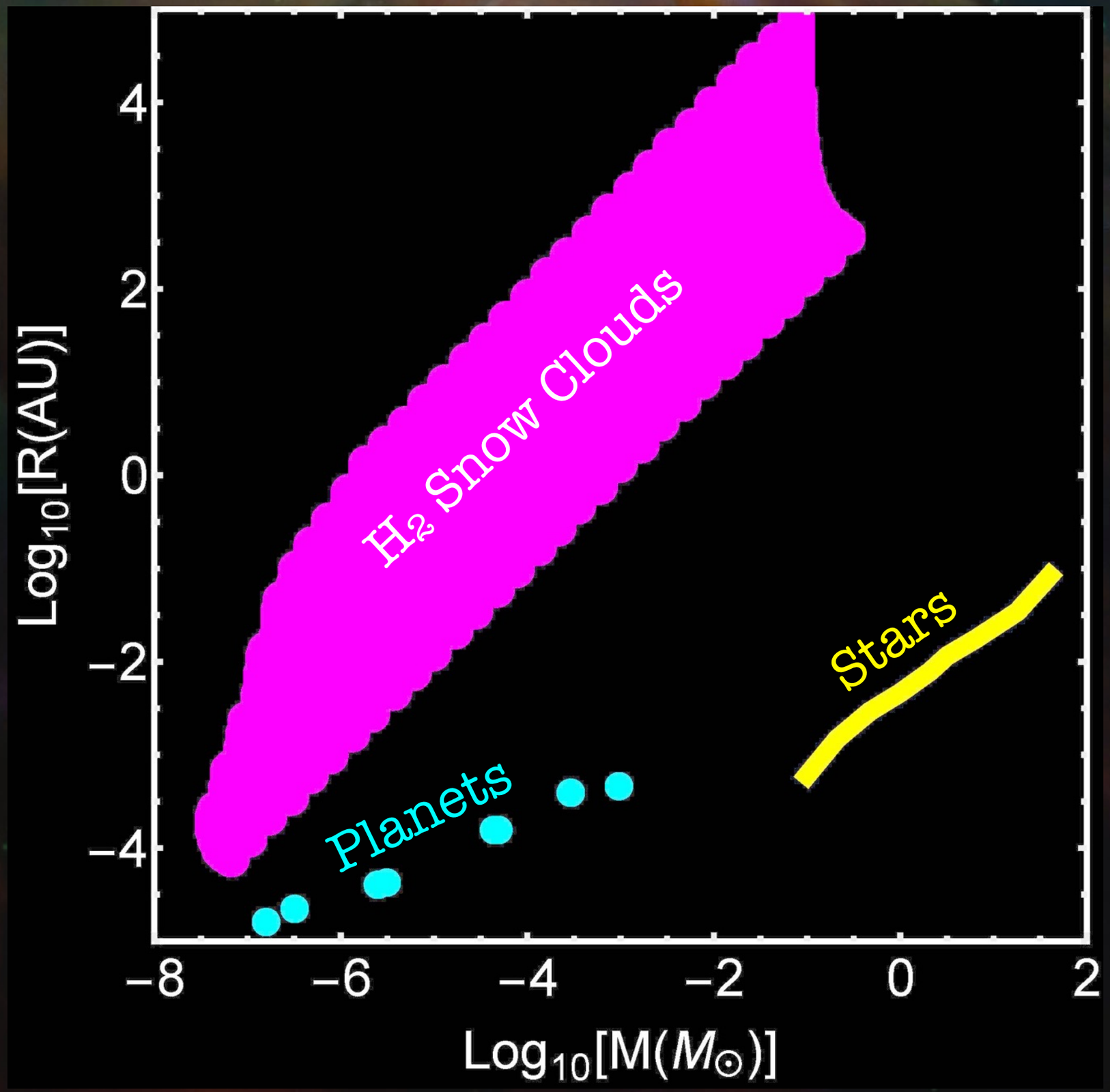
Making H_2 snow requires cold, dense gas

- $P = P_{sat} \gg P_{ism}$: self-gravitating (Pfenniger & Combes 1994)



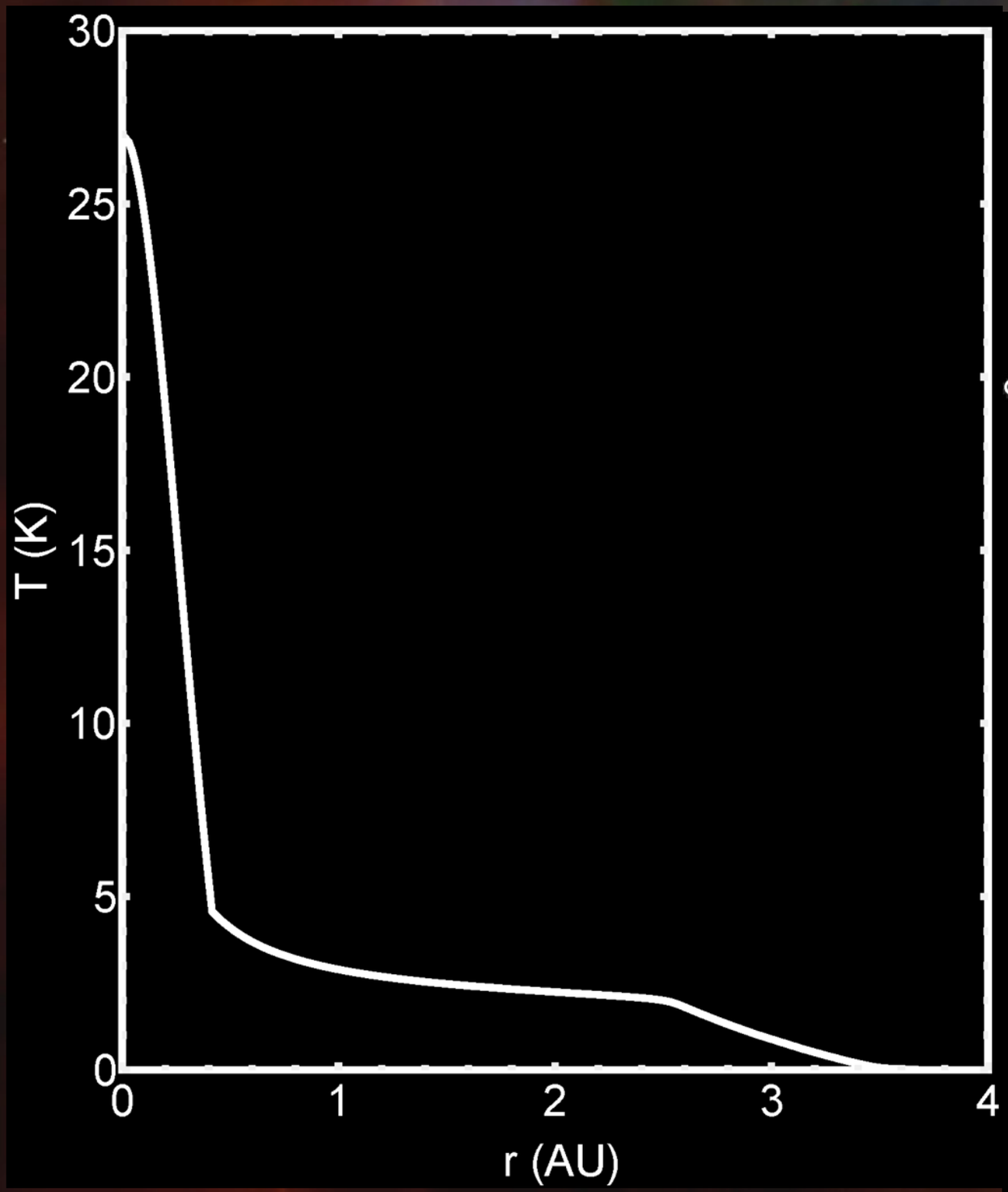
Snow clouds : low masses & large radii

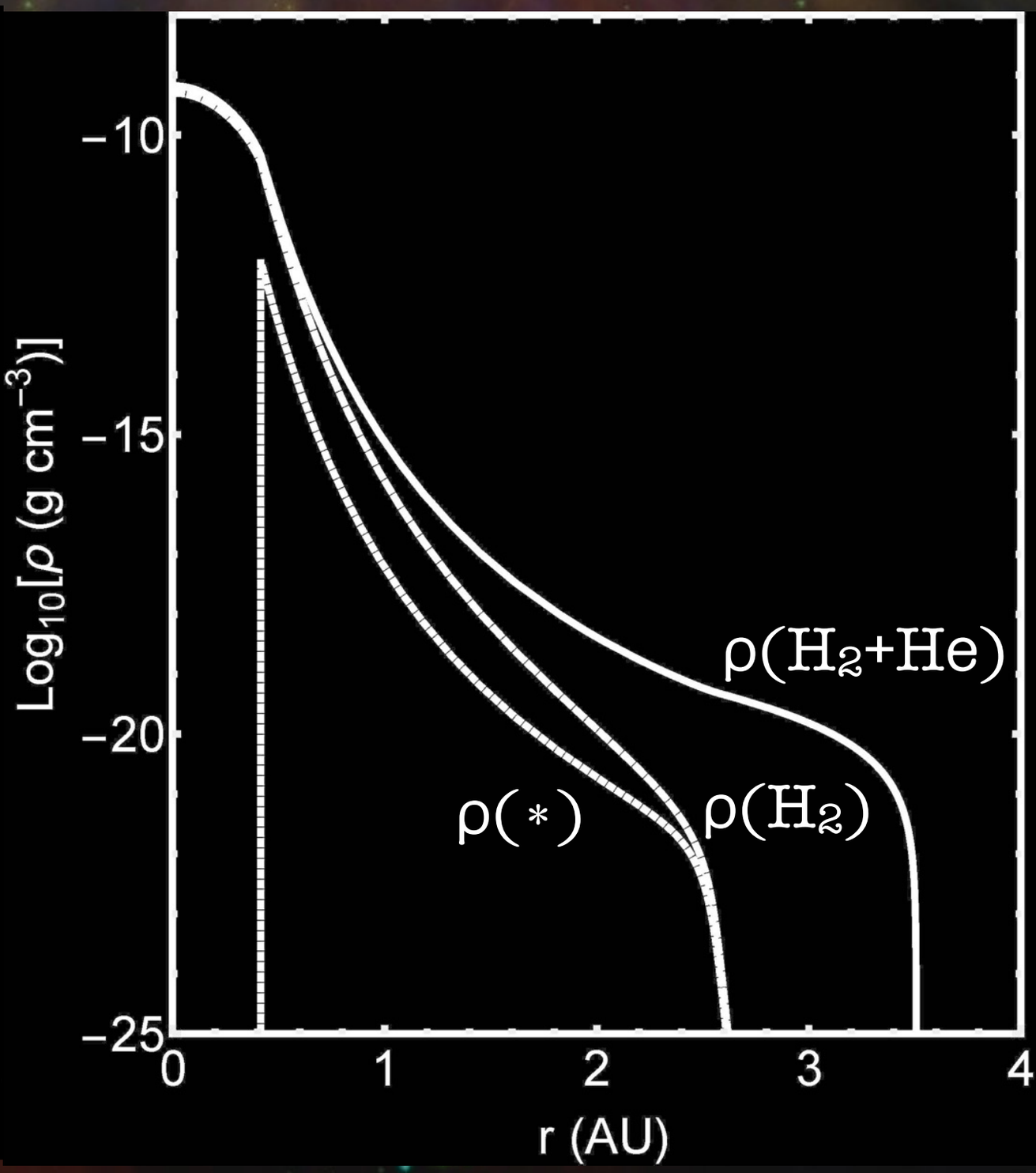
Spherical
Self-gravitating
Hydrostatic equilibria
75% H_2, 25% He
No Metals
Minimal snow content
(MW & Wardle 2016)



High density, robust structures

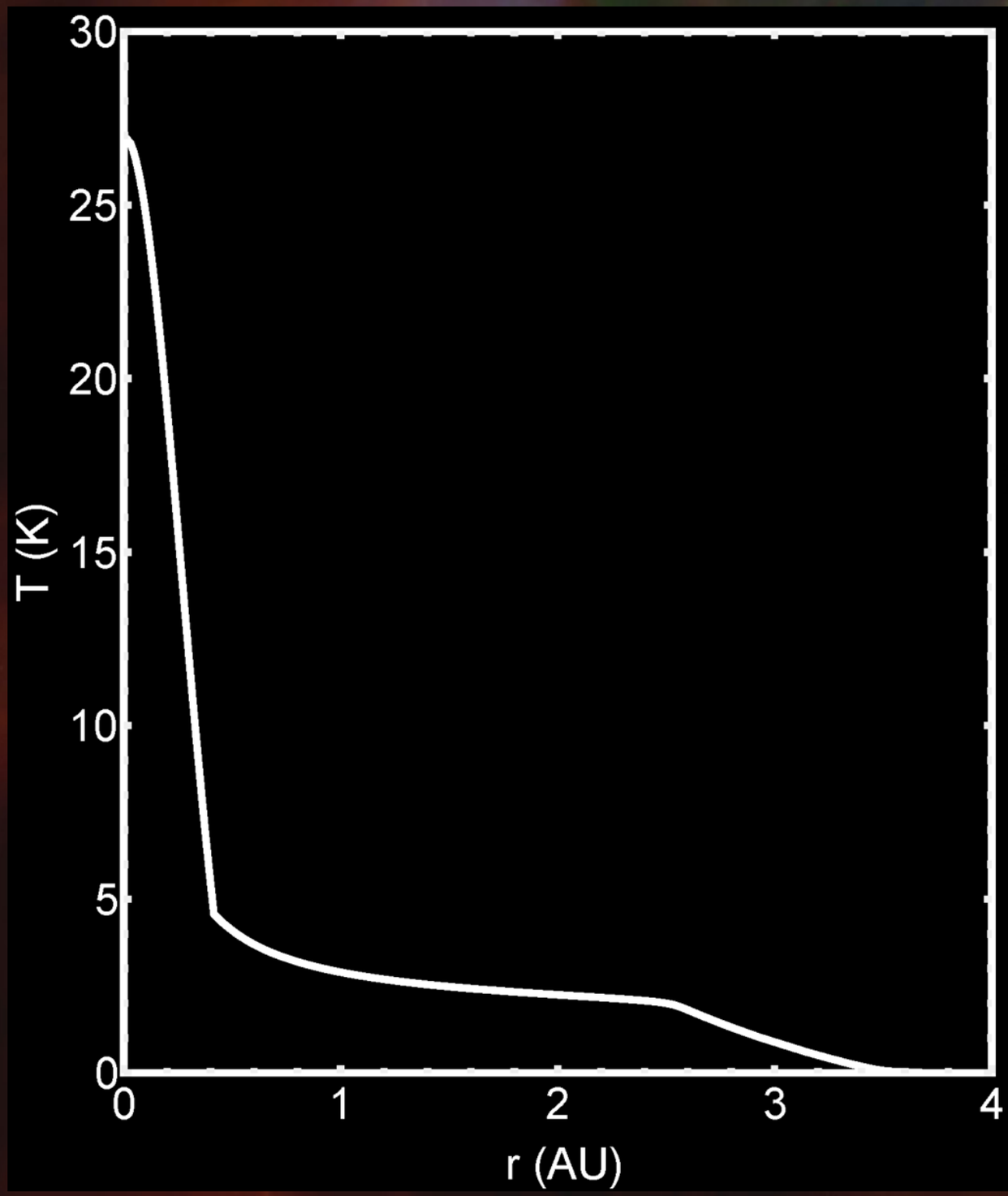
Example with $M = 10^{-4} M_{\odot}$

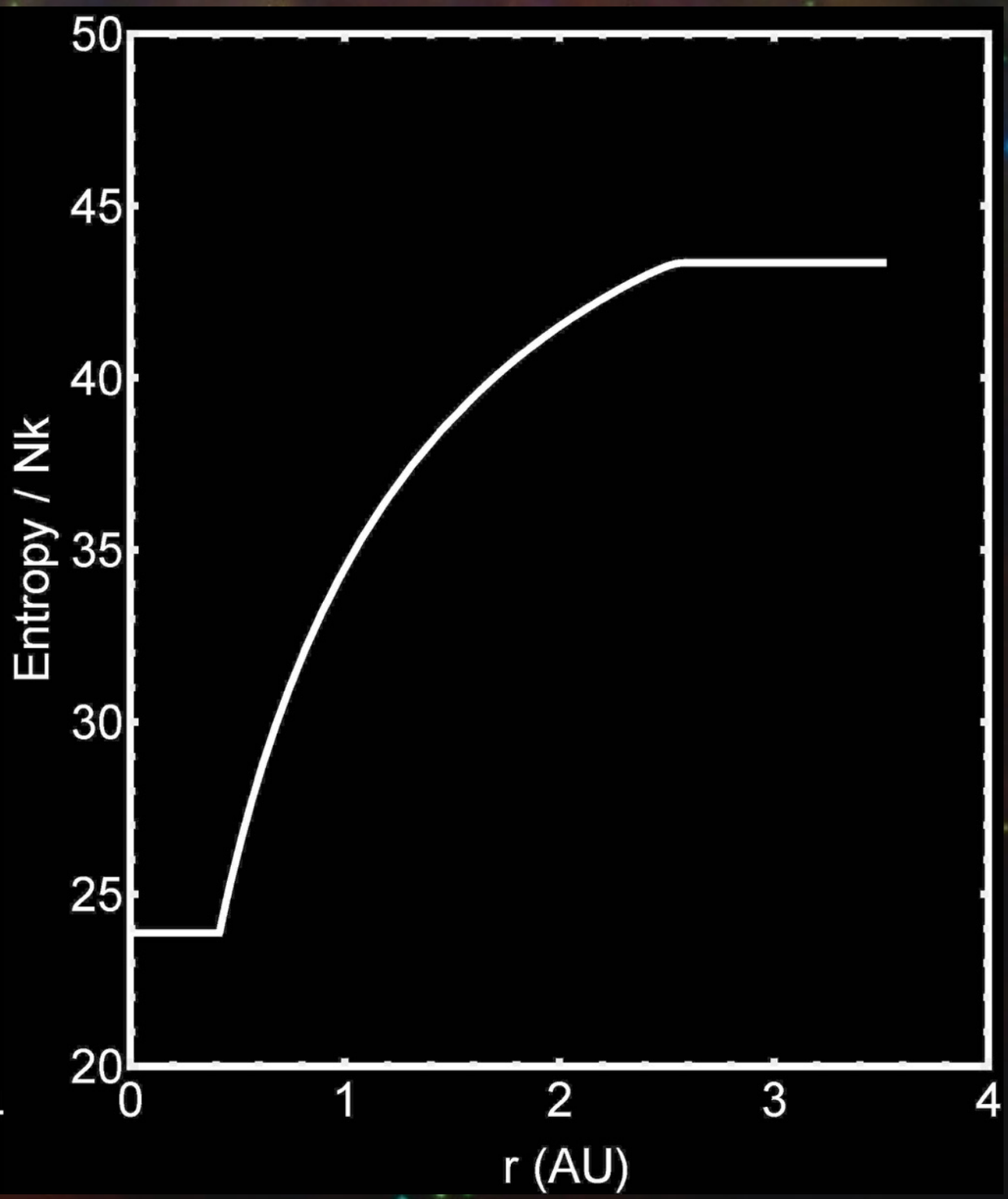




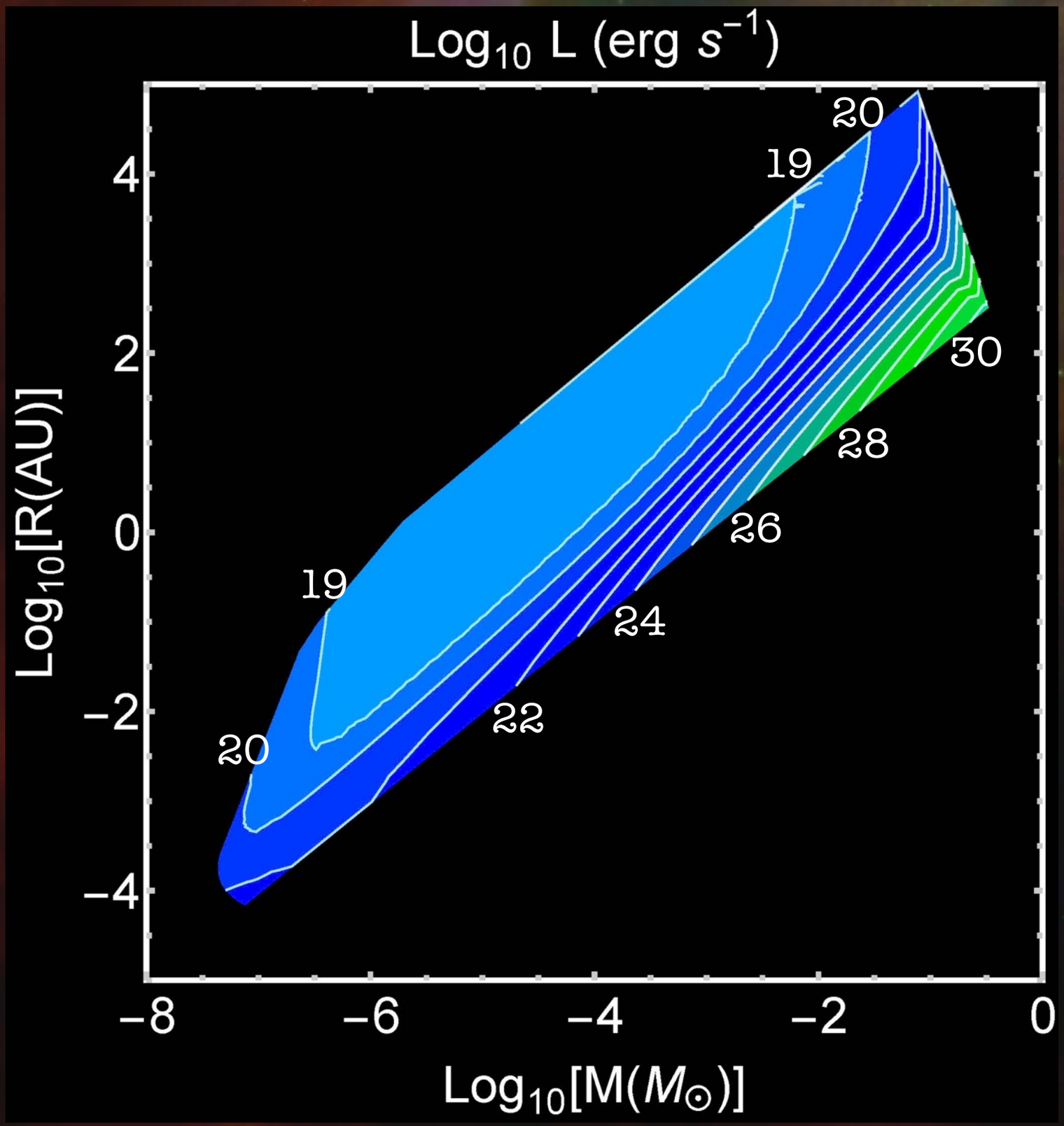
Convection transports heat inwards

Buoyant instability, but entropy increases outwards



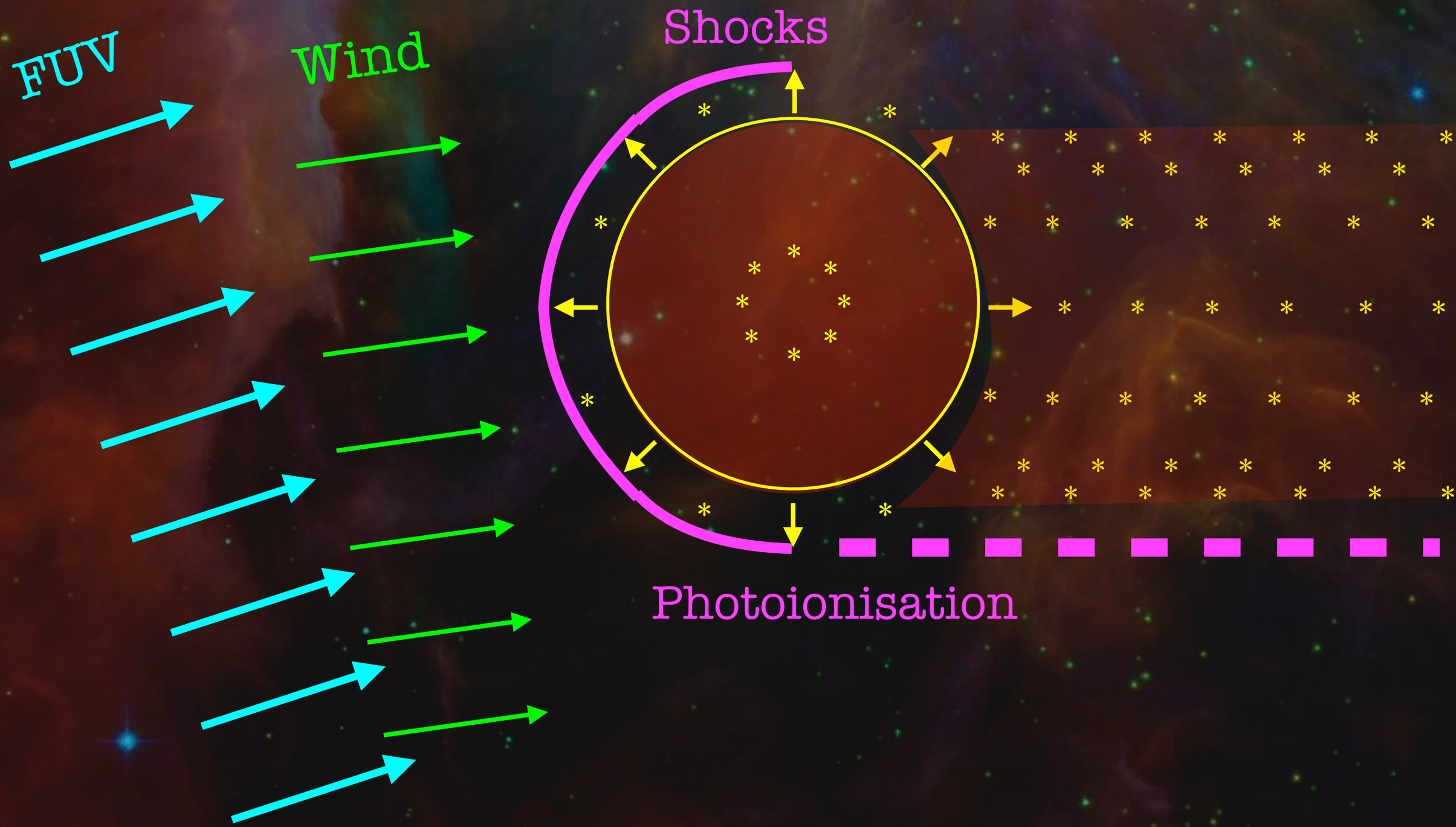


Snow clouds are very dim



- Baryonic Dark Matter
  - Maybe lots of them
- Vigorous heating is disruptive
- Translucent in optical
- But FUV is absorbed
  - Rapid destruction near hot stars

Snow cloud near a (hot) star



Manly Astrophysics

Cometary globules in the Helix Nebula

Matsuura^{++} 2009
H_2 2.2 μm

O'Dell + Handron
1996 [O III]

Circumstellar manifestations : 1. High eccentricity orbit

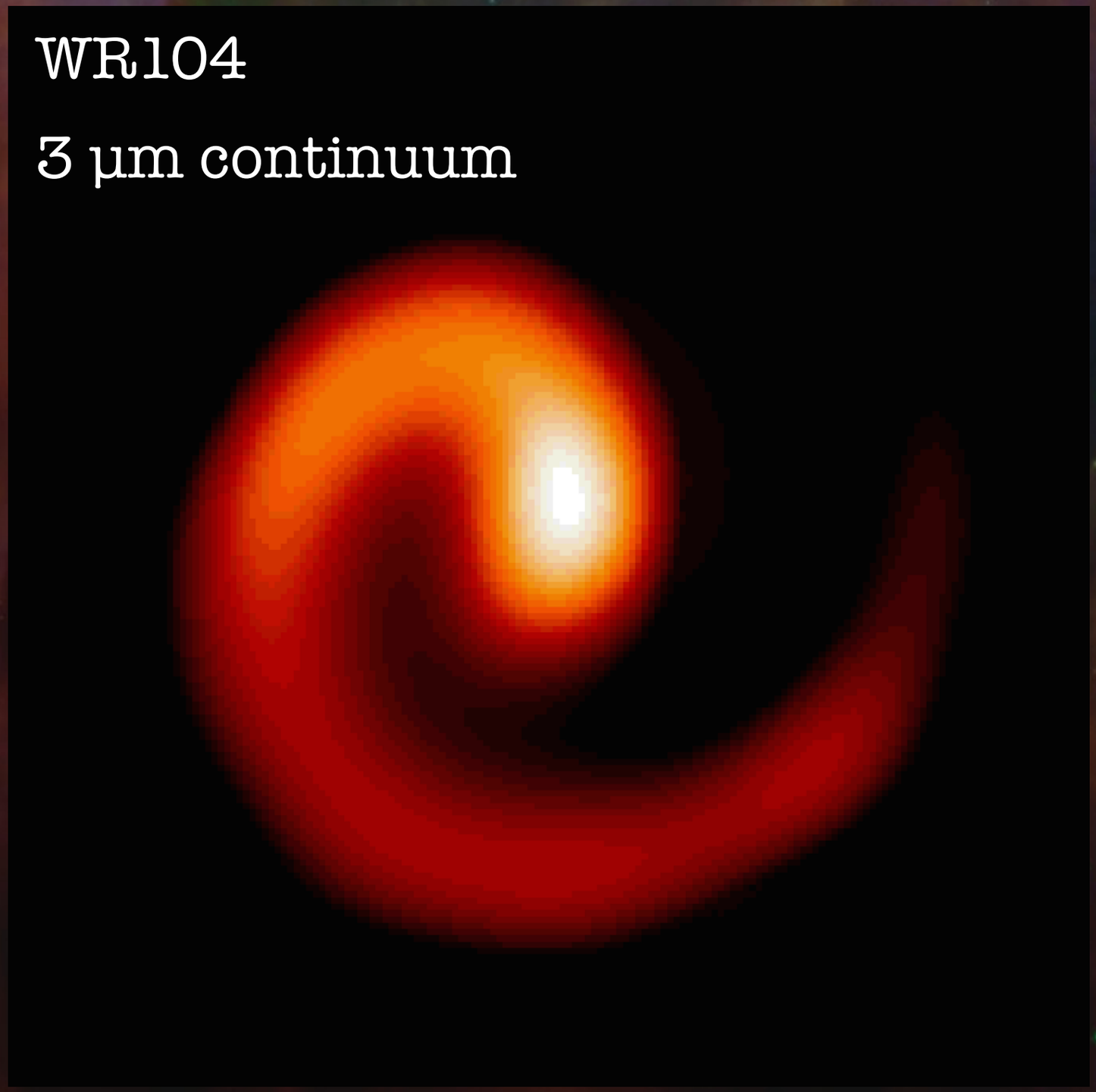
- High mass-loss rate near periastron
  - Regular outburst behaviour
- Huge tides : rapid circularisation of orbit
- Hydrodynamics of tail influenced by gravity, stellar wind, and radiation pressure (on dust)

Circumstellar manifestations : 2. Low eccentricity orbit

- Cometary spiral
- Steady mass-loss
- Aspect-dependent periodic variations in :
  - Photometry
  - Emission-line velocity profiles
    (cf. V/R variations in Be star emission lines)

Dusty “pinwheels” in Wolf-Rayet systems

Tuthill[++] 2008



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Summary

- Snow clouds form a distinct new class of astronomical object
  - Planetary masses, but large radii
  - Very dim (baryonic dark matter) : maybe lots of them
  - Mechanically robust, but thermally fragile
- Intense FUV → thermal disruption via dusty wind
  - Emission lines from photoionisation and shocks
- Cloud mass-loss + orbital motion → cometary morphology
  - High eccentricity orbits → transient tails
  - Low eccentricity orbits → steady, revolving spirals
- Generic to all spectral types & evolutionary states
  - Maybe relevant to various “stellar” peculiarities
  - Most obvious near hot, luminous stars → Be and B[e] ?