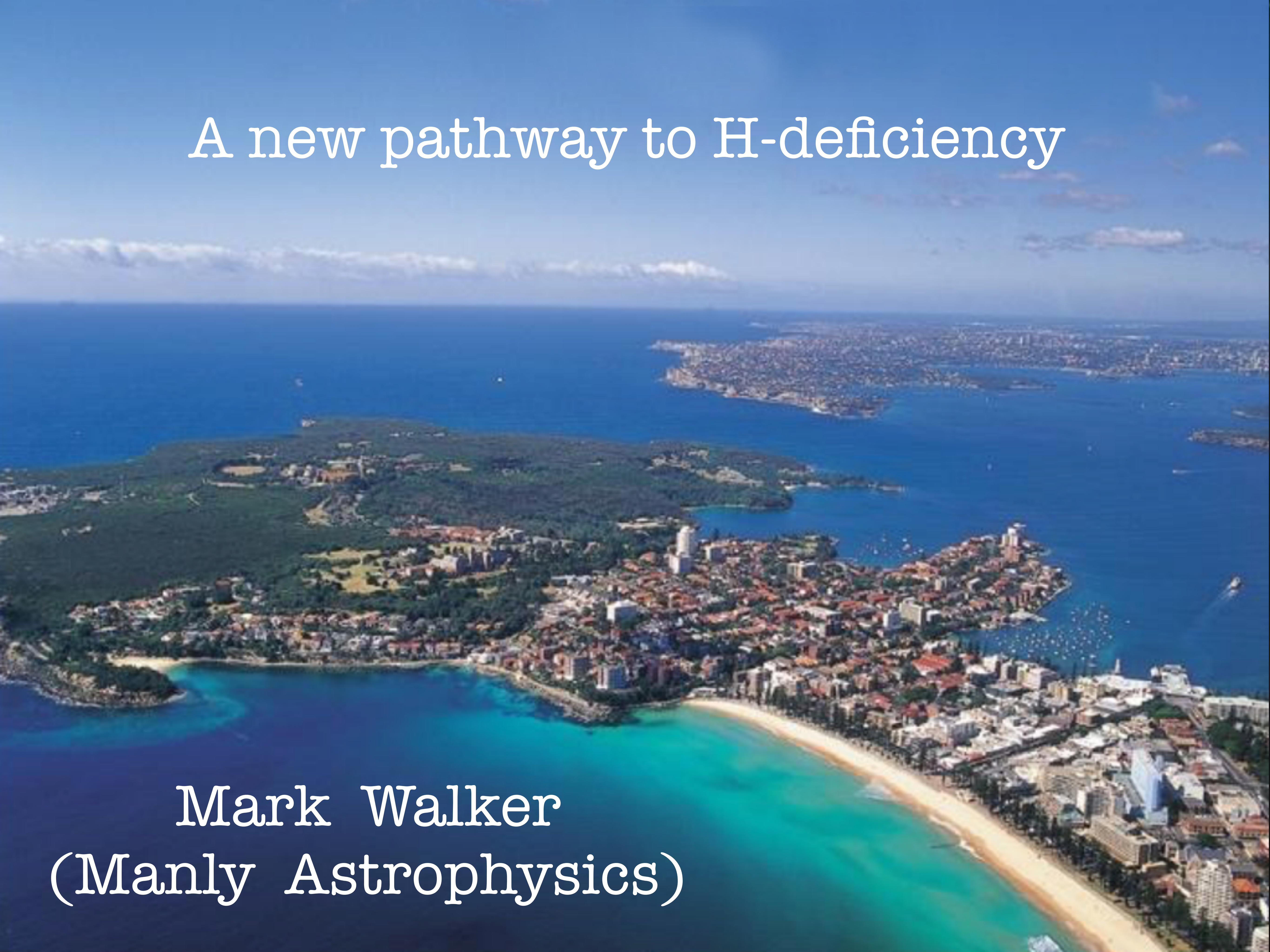


A new pathway to H-deficiency

Mark Walker
(Manly Astrophysics)

Conventionally:

- HDEF explained in terms of stellar evolution
- Get rid of H by burning it

This talk:

- HDEF explained by reference to circumstellar clouds
  - Cold, dense, self-gravitating, molecular gas
- Get rid of H by condensing gaseous H_2 into snowflakes

Outline:

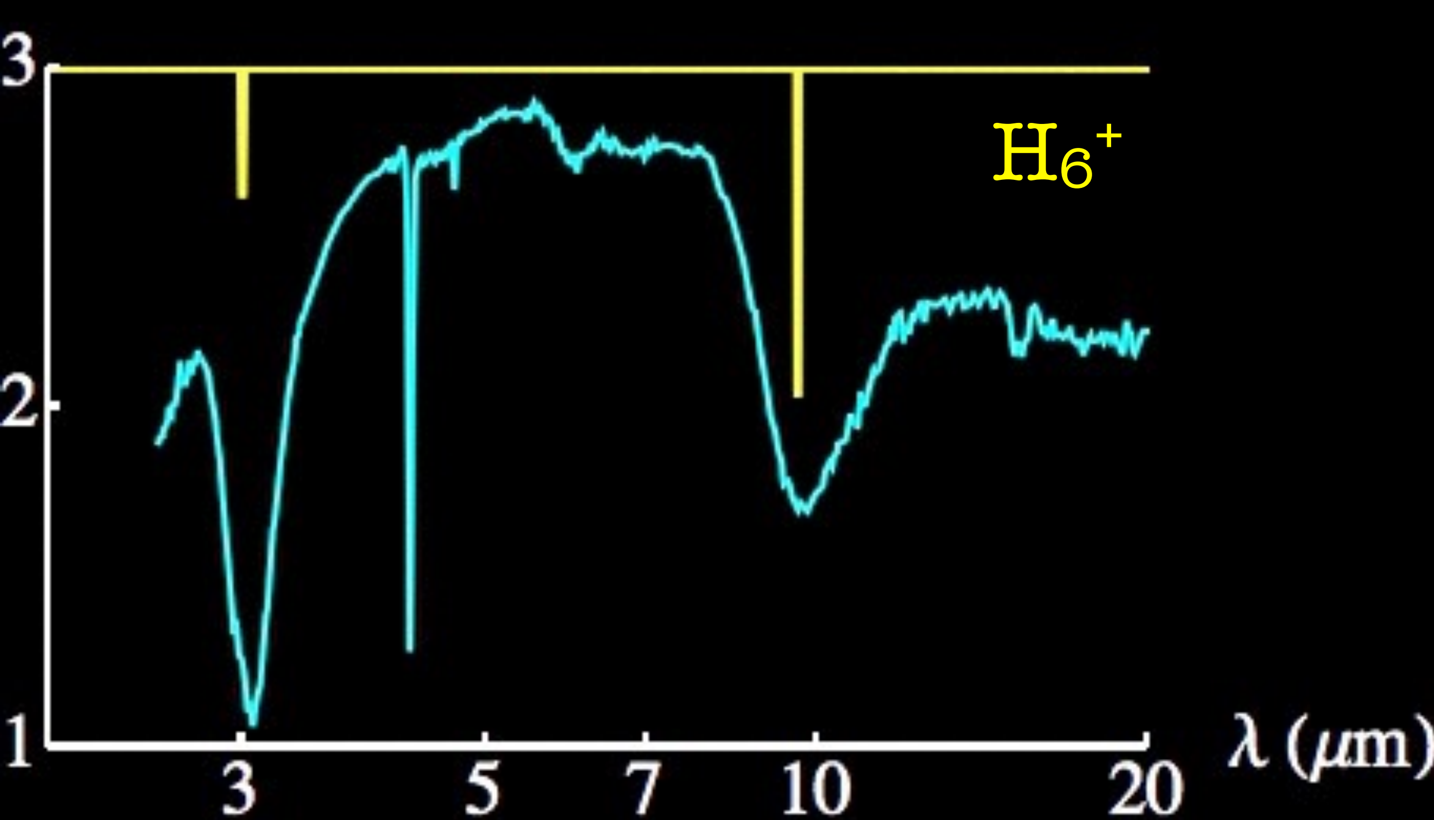
- Motivations for H_2 snow clouds & snowflakes
- Sketch of snow cloud properties
- Star-cloud interactions
- Interpretation of two HDEF phenomena

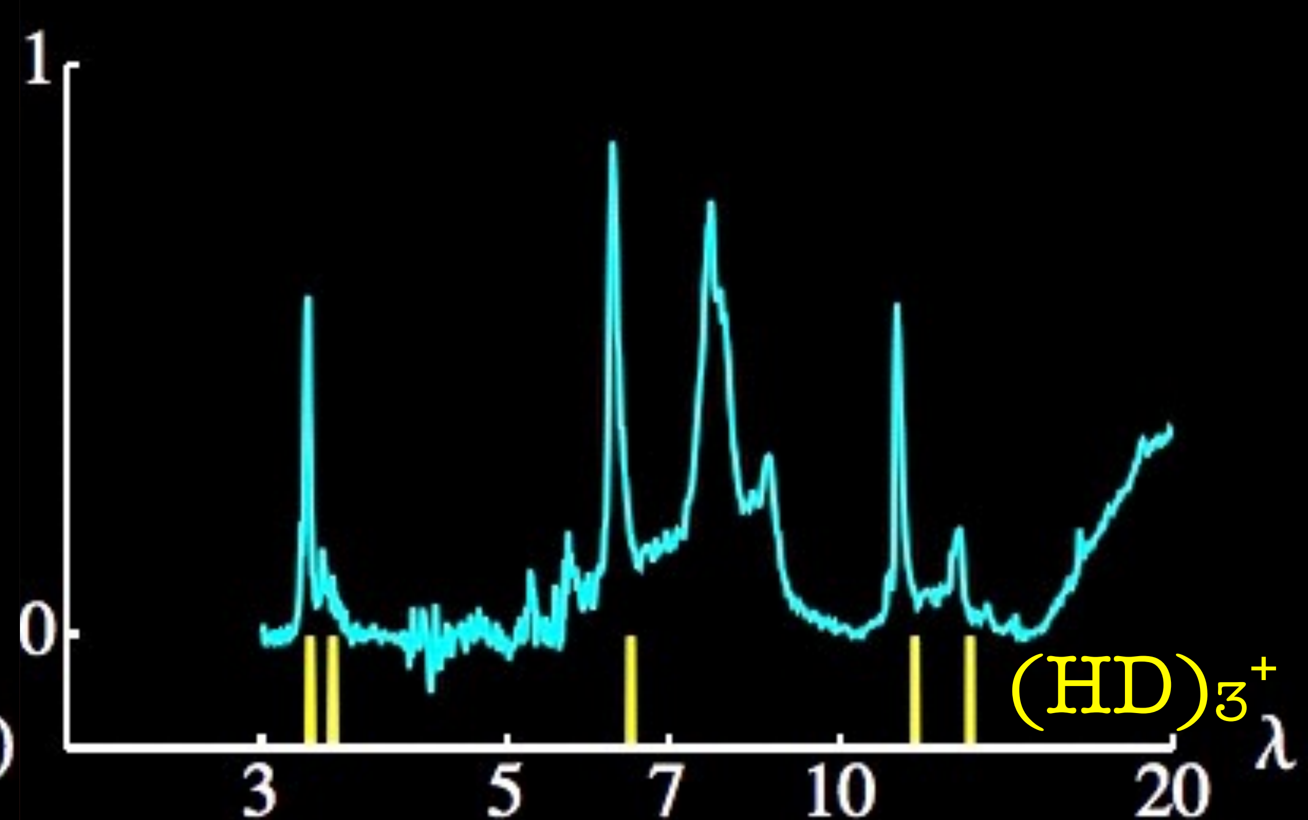
Snow Clouds

- Cold, dense molecular gas is very hard to detect.
  Maybe a lot of mass in this form (Pfenniger & Combes 1994)
- Radio scintillation data suggest lots of unseen circumstellar gas clouds (MW et al 2017)

Snowflakes

- Charged snowflakes are durable in diffuse ISM (MW 2013)
- Ionisation chemistry differs from gas phase H_2
  - "New" molecule : H_6^+ (Lin, Gilbert & MW 2011)

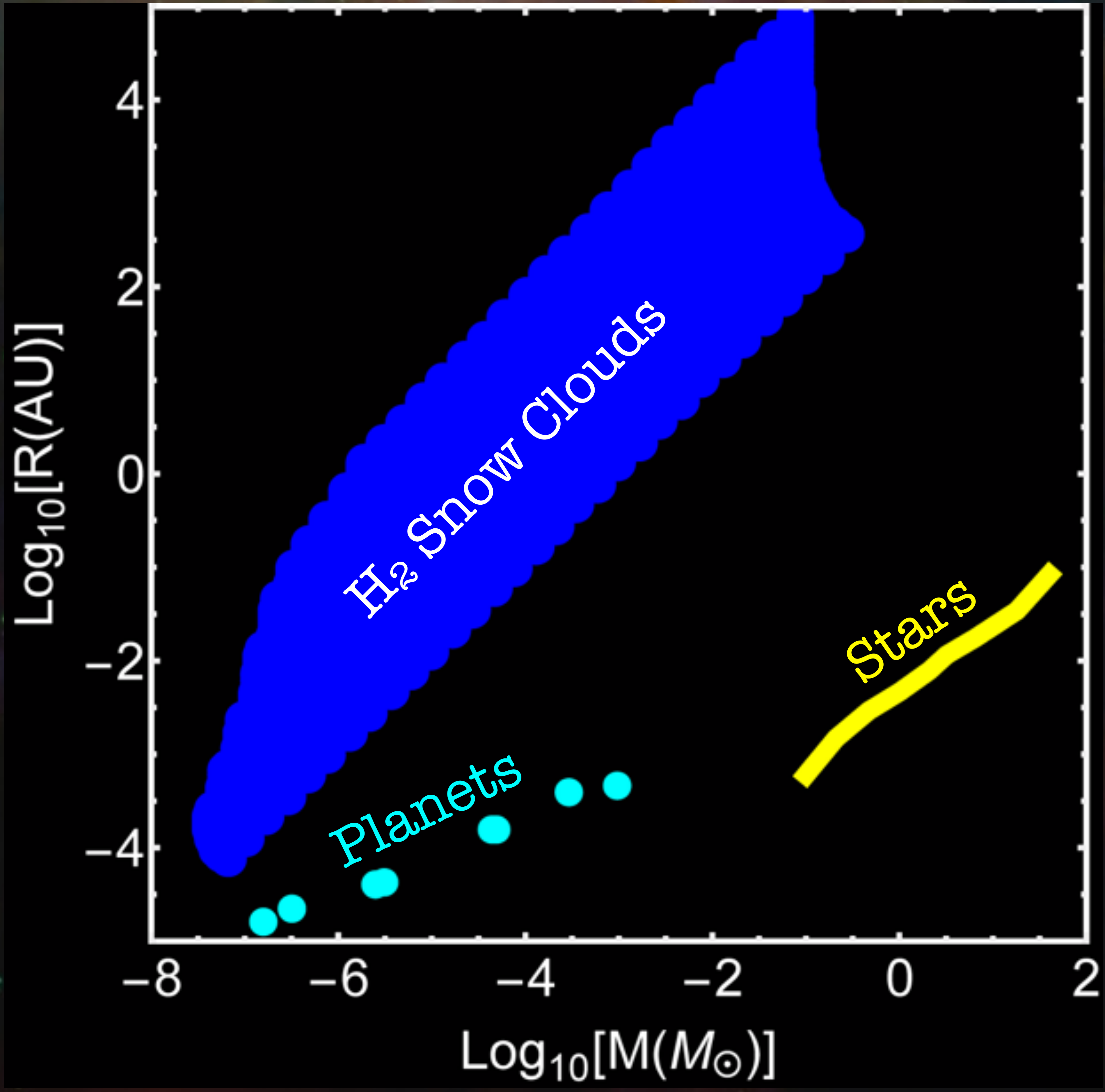




Hydrostatic models of H_2 snow clouds

<u>Assumptions:</u>
Spherical
Self-gravitating
Fully convective
75% H_2, 25% He
No Metals
Minimal snow content

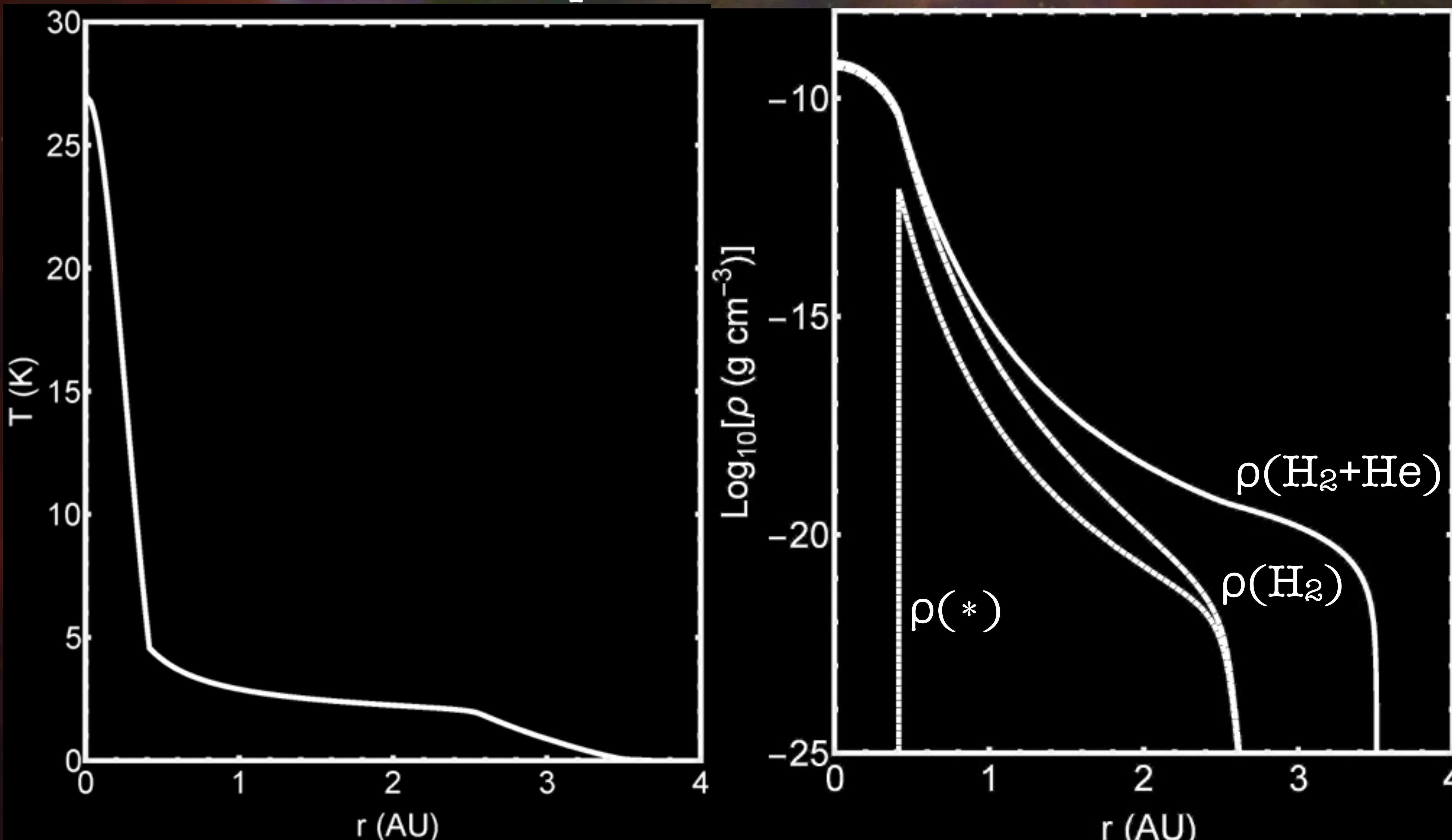
<u>Key Characteristics:</u>
Low masses
Low densities
Low luminosities



(MW & M.Wardle 2018 ... hopefully)

High density, robust structures

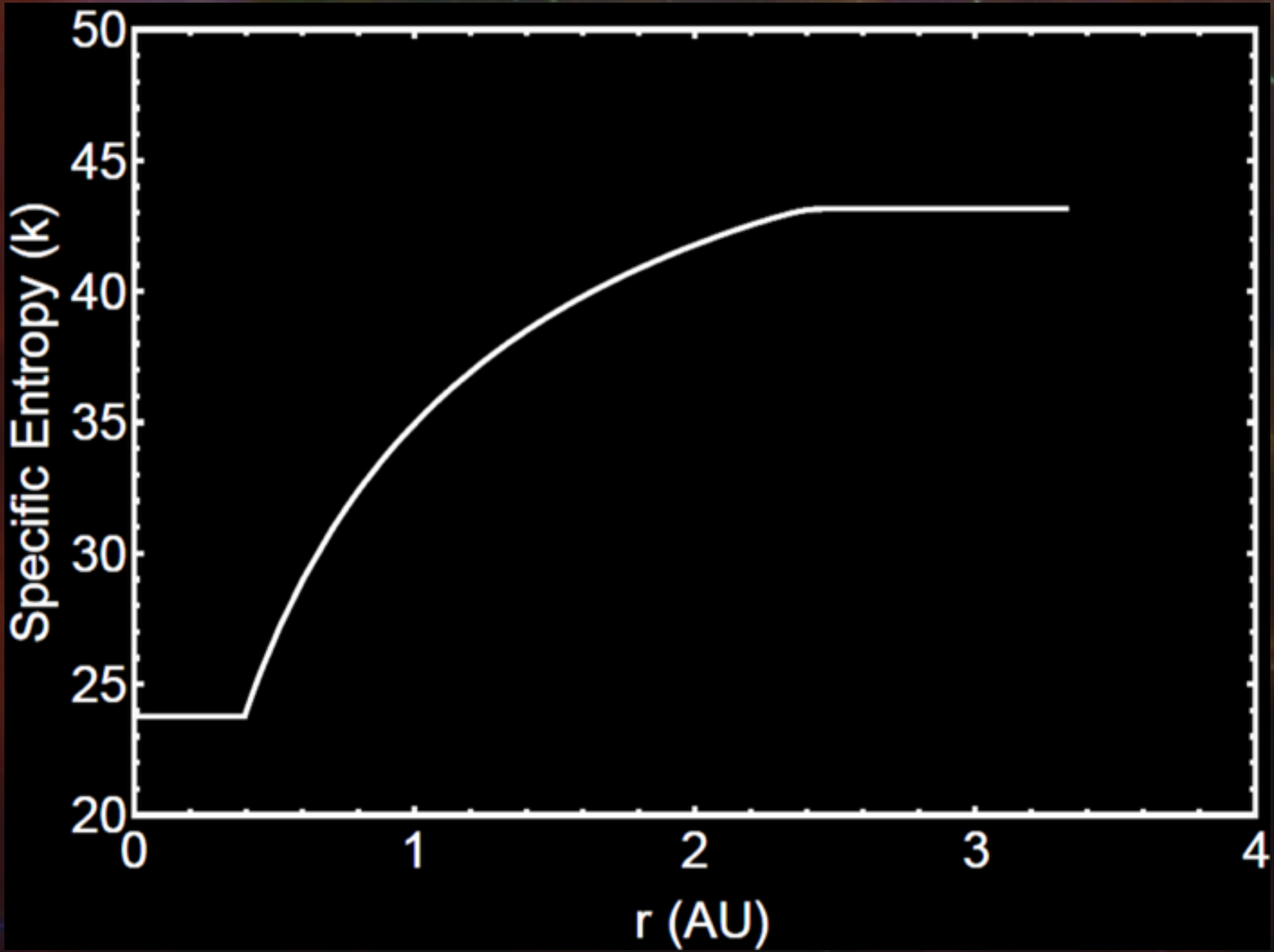
Example with $M = 10^{-4} M_{\odot}$



Manly Astrophysics

Convection transports heat inwards

Buoyant instability, but entropy increases outwards



Star-cloud interactions: 1. Radiation

- Radiation pressure strips snowflakes from cloud
  - Cloud gradually becomes H-deficient
- Radiation absorbed inside the cloud
  - Heat input causes expansion and cooling
  - More snowflakes produced (and stripped)
- Hot stars more effective at heating
  - Far-UV component absorbed by snowflakes

Star-cloud interactions: 2. Collisions

- Strong shocks. High temperatures. Destruction of cloud. Luminous transient. Emission lines.
- Dwarfs: no significant penetration of star by cloud
  - Stellar surface enriched in both H and He
- Giants: cloud core might penetrate stellar envelope
  - Stellar surface enriched in He

Star-cloud interactions: 3. Tides

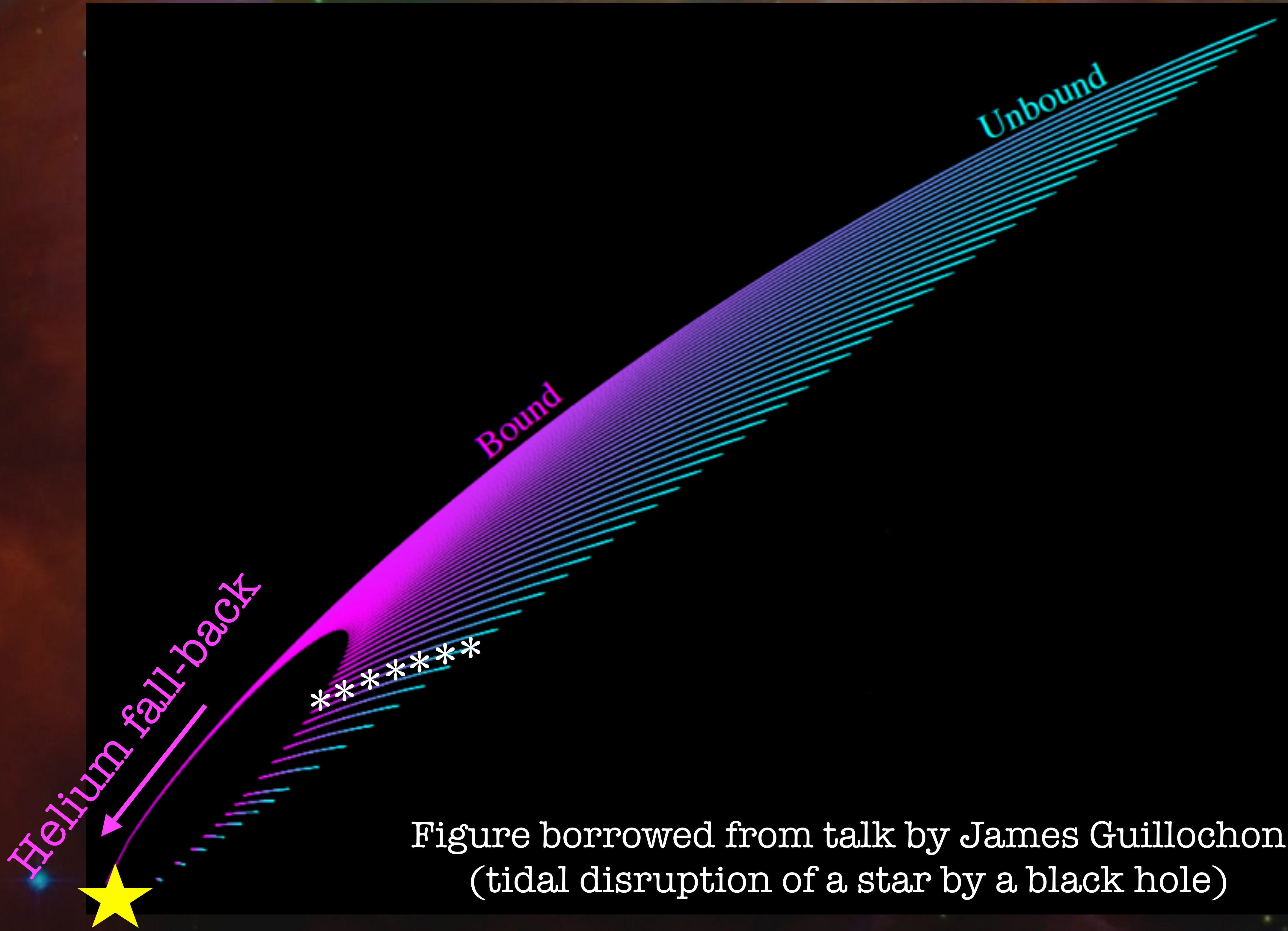
Circular orbits:

- Roche lobe overflow
  - Heat input by star drives expansion of cloud
- Disk accretion onto star
  - Some accretion power
- Disk is pure He
  - Stellar surface becomes H-deficient

Highly eccentric orbits:

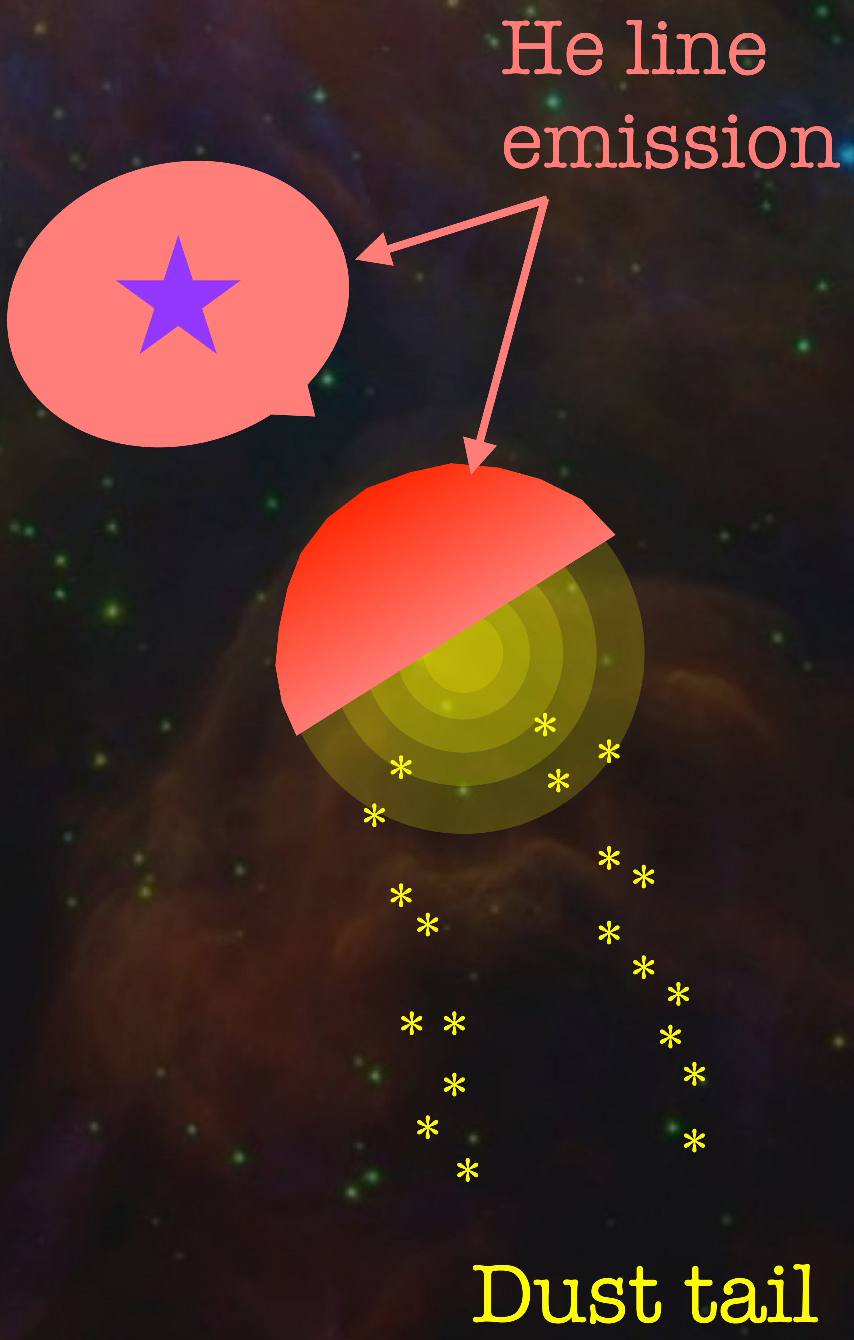
- Tidal disruption of cloud
  - Adiabatic expansion. Most H_2 turns to snow
  - Spray of He & snowflakes
- Snowflakes driven out by radiation pressure
- Half of He may fall back
  - Stellar Surface becomes H-deficient

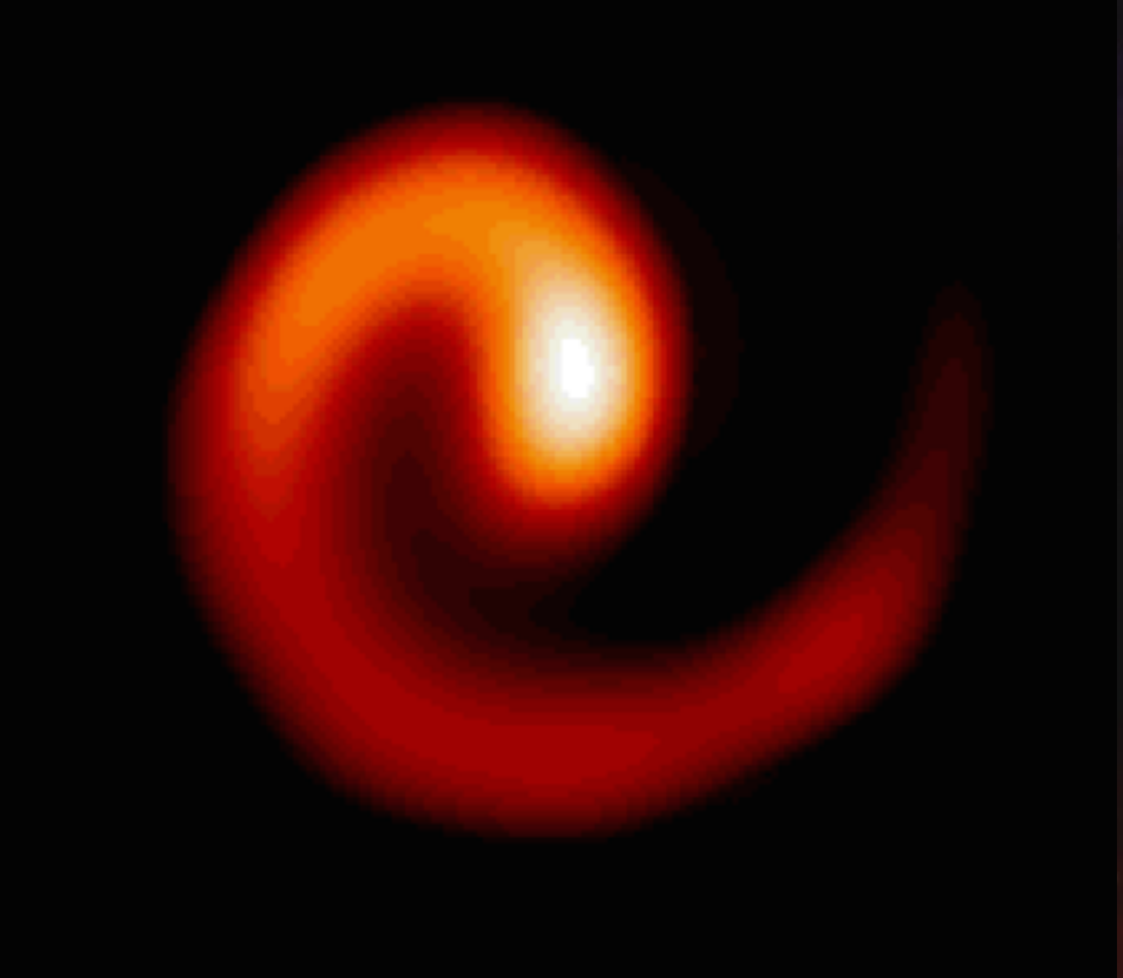
Tidal disruption of clouds: R Cor Bor stars?



Circular orbit around hot star: Wolf-Rayets?

- $E > 24$ eV : $He \rightarrow He^{+}$
  - He emission lines
- $E > 10$ eV : $H_2 \rightarrow H_2^{*}$
  - Absorbed by snow





WR104 : Tuthill++ 2008

Summary

- Snow clouds are a new class of astronomical object
  - They have HDEF surfaces, because of H_2 precipitation
- Circumstellar snow clouds can yield HDEF stellar surfaces
  - By Roche Lobe overflow onto star
  - By tidal disruption of clouds, and fall-back of Helium
- Snow clouds might provide alternative explanations for HDEF systems where there is dust production
  - Wolf-Rayet phenomenon
  - R Cor Bor phenomenon