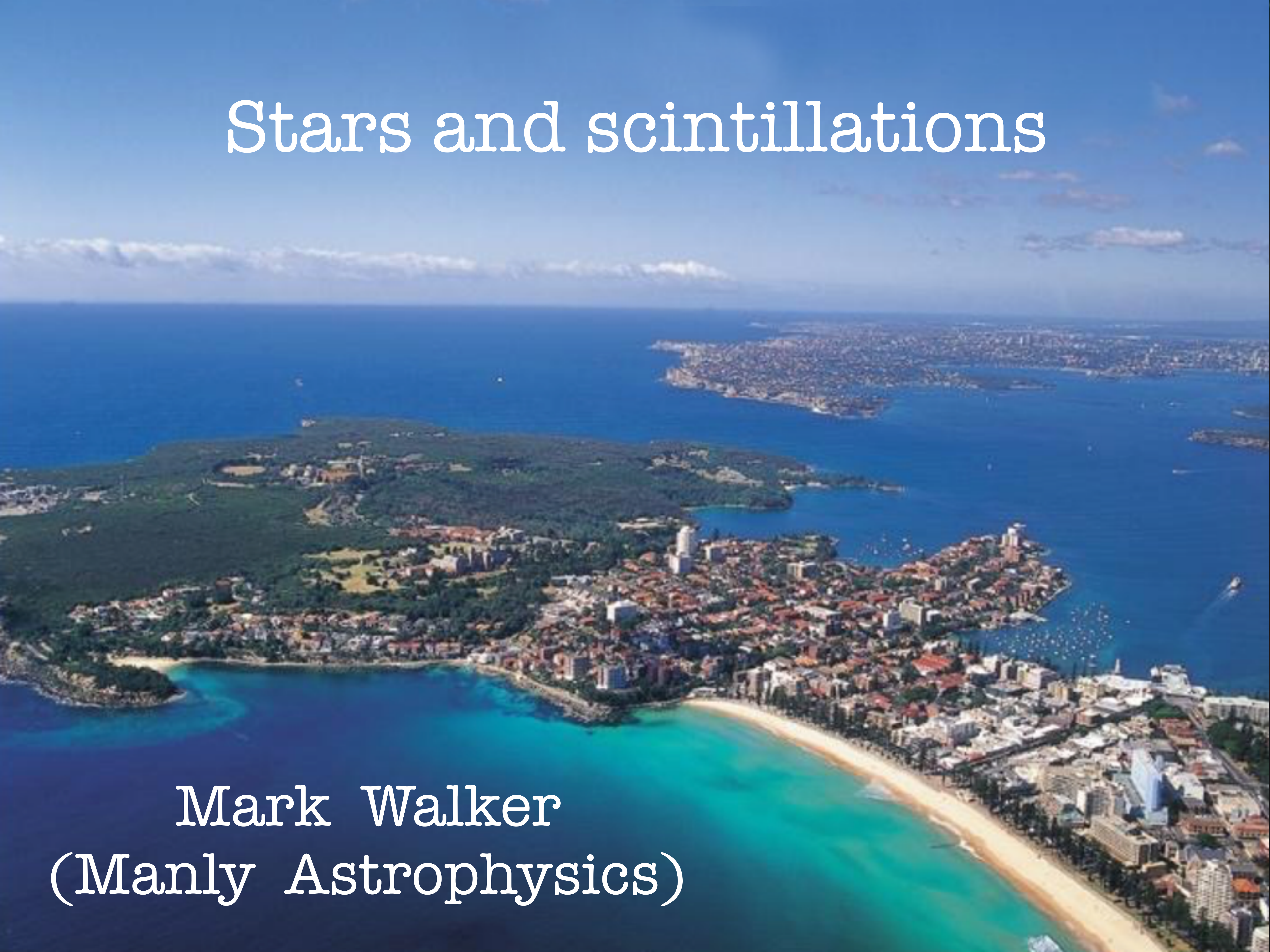
Stars and scintillations



Mark Walker
(Manly Astrophysics)

Overview

- Why is radio-wave propagation interesting?
- The ATESE project: who and what
- Discovery of Intra-Day Variability in PKS1322-110
  - Right next to Spica!
- Annual cycles in PKS1257-326 and J1819+3845
  - Association between IDV and local, hot stars
- News! Annual cycles in PKS1322-110 and J0437-4715
- Inferences about the circumstellar medium
  - Most stars are like the Helix
- Connections to other areas of astrophysics

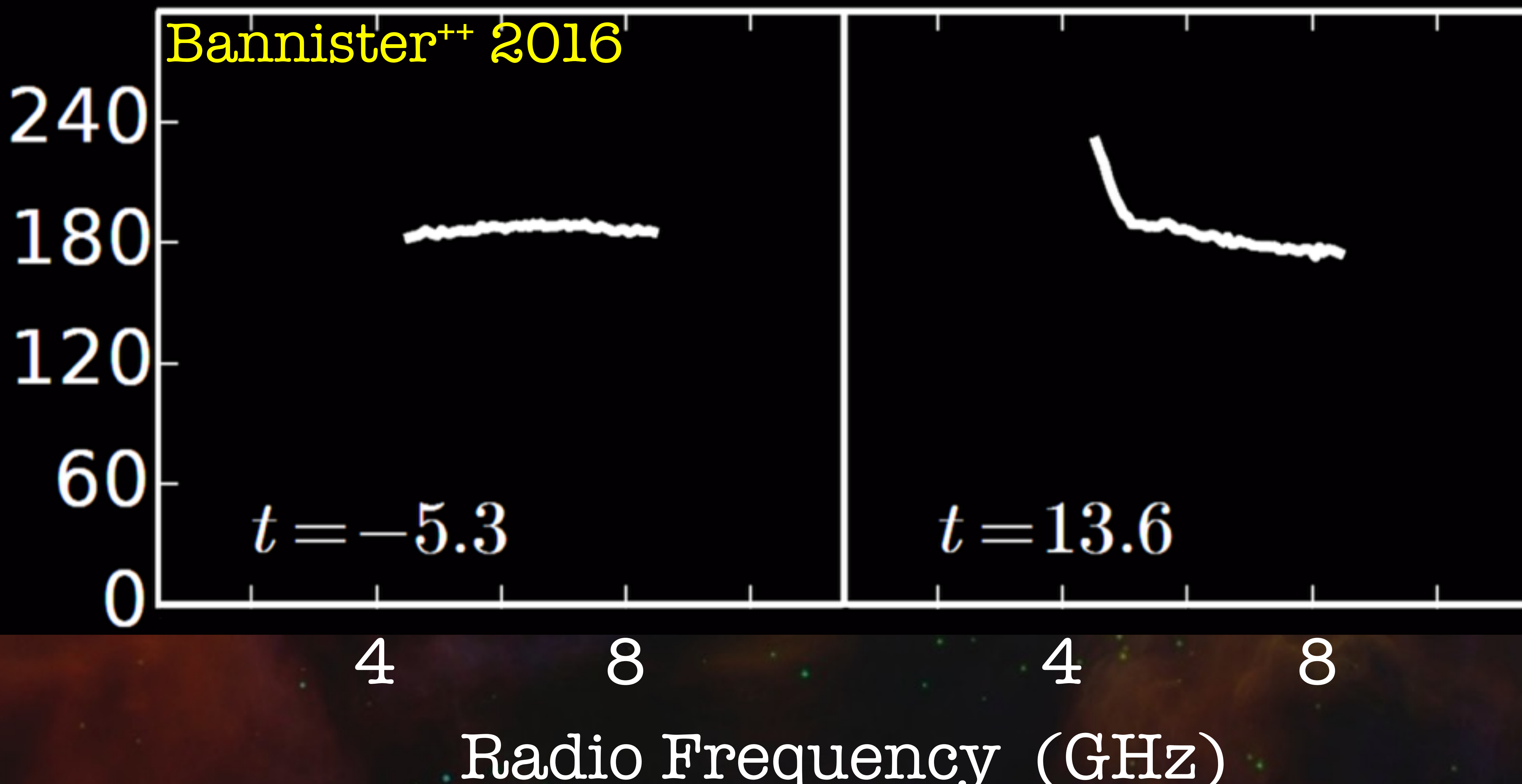
Why radio source scintillation is interesting

- A powerful "microscope" for the ionised ISM
  - "Resolution" ~ 10^{11} cm (Fresnel scale)
  - "Sensitivity" ~ 10^{11} cm^{-2} (Unit phase change)
- Usually see low-level flux variations of radio quasars
  - Distributed turbulence throughout Galactic ISM (?)
- Sometimes see large, rapid flux variations
  - Extreme Scattering Events (ESEs) - plasma lensing
  - Intra-Day Variability (IDV) - scattering by plasma microstructure (highly anisotropic)
  - ESEs/IDV suggest numerous small regions ($10^{1\pm1}$ AU) that are over-pressured ($n_e \sim 10^{2\pm1}$ cm^{-3})

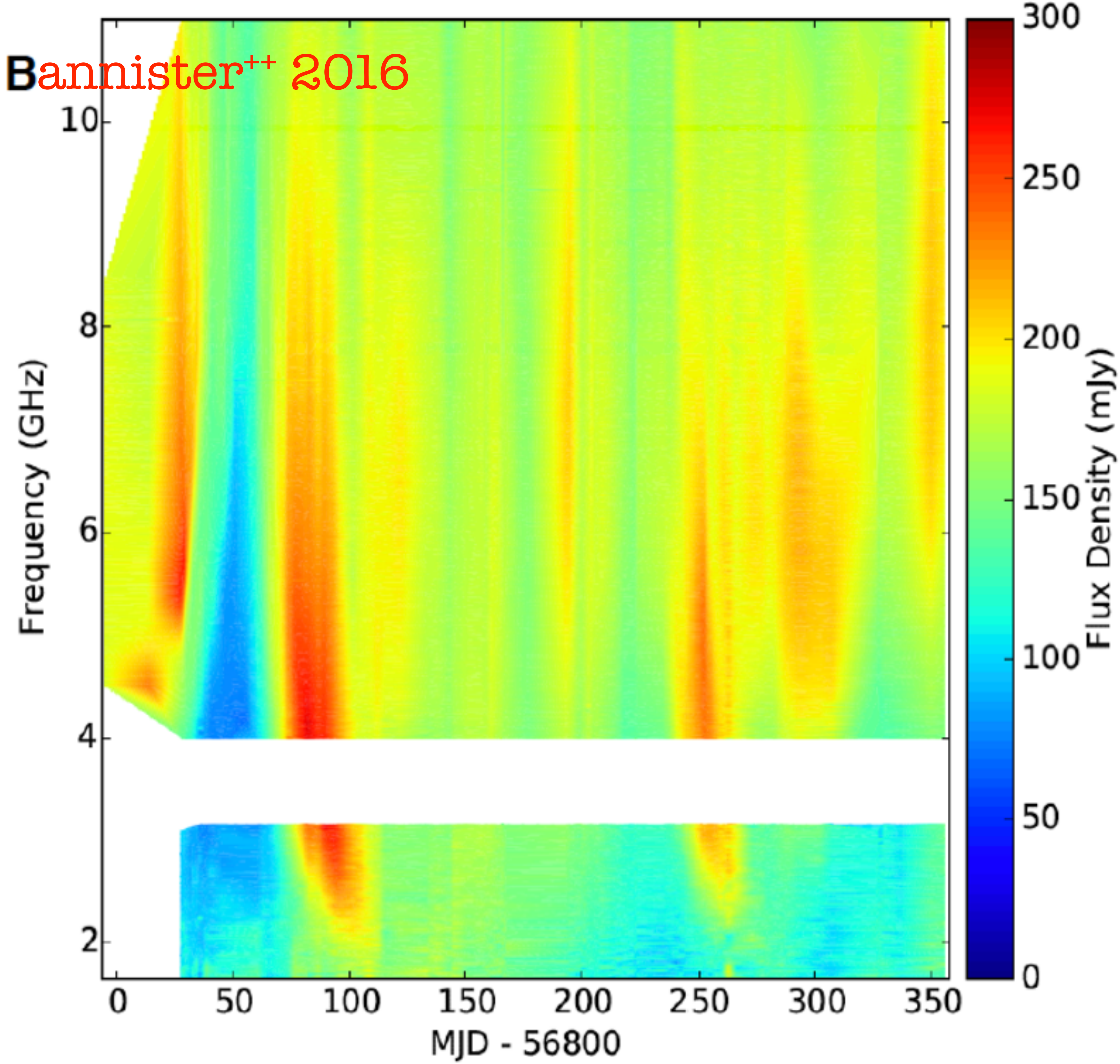
ATESE: ATCA survey for Extreme Scattering Events

- Keith Bannister (PI), Jamie Stevens, Simon Johnston, Hayley Bignall, Cormac Reynolds (CSIRO) - radio obs. Artem Tuntsov & MW (Manly) - theory
    - + Vikram Ravi (Caltech) - optical follow-up
- Ran from April 2014 to October 2017
    - (Same team now studying fast scintillators)
- Monthly observations of 10^3 compact radio quasars
    - Wide-band spectra (4 - 8 GHz)
- Intensive follow-up of interesting sources
    - Mainly triggering on weird spectra

First Event: PKS1939-315

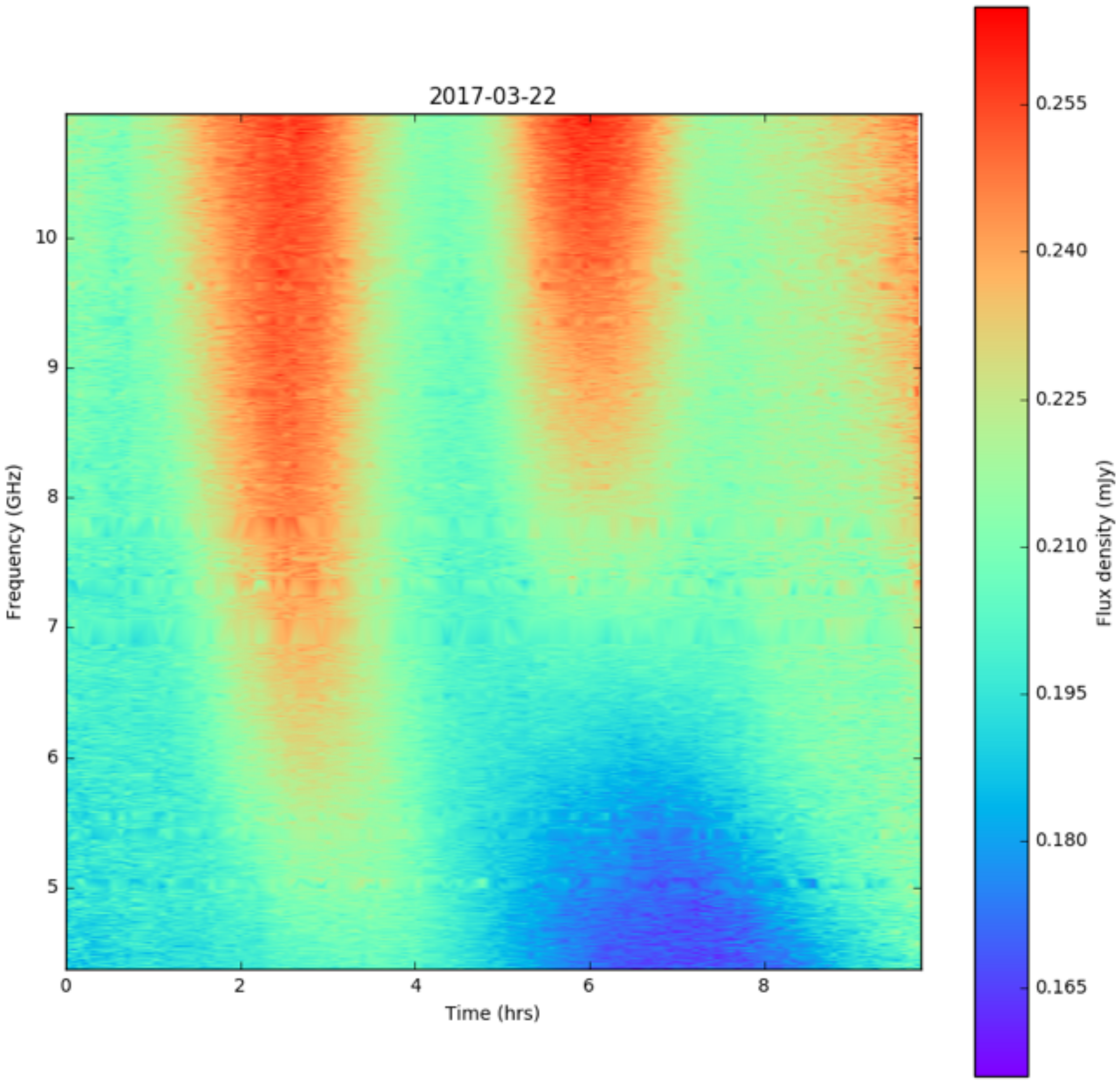


Manly Astrophysics



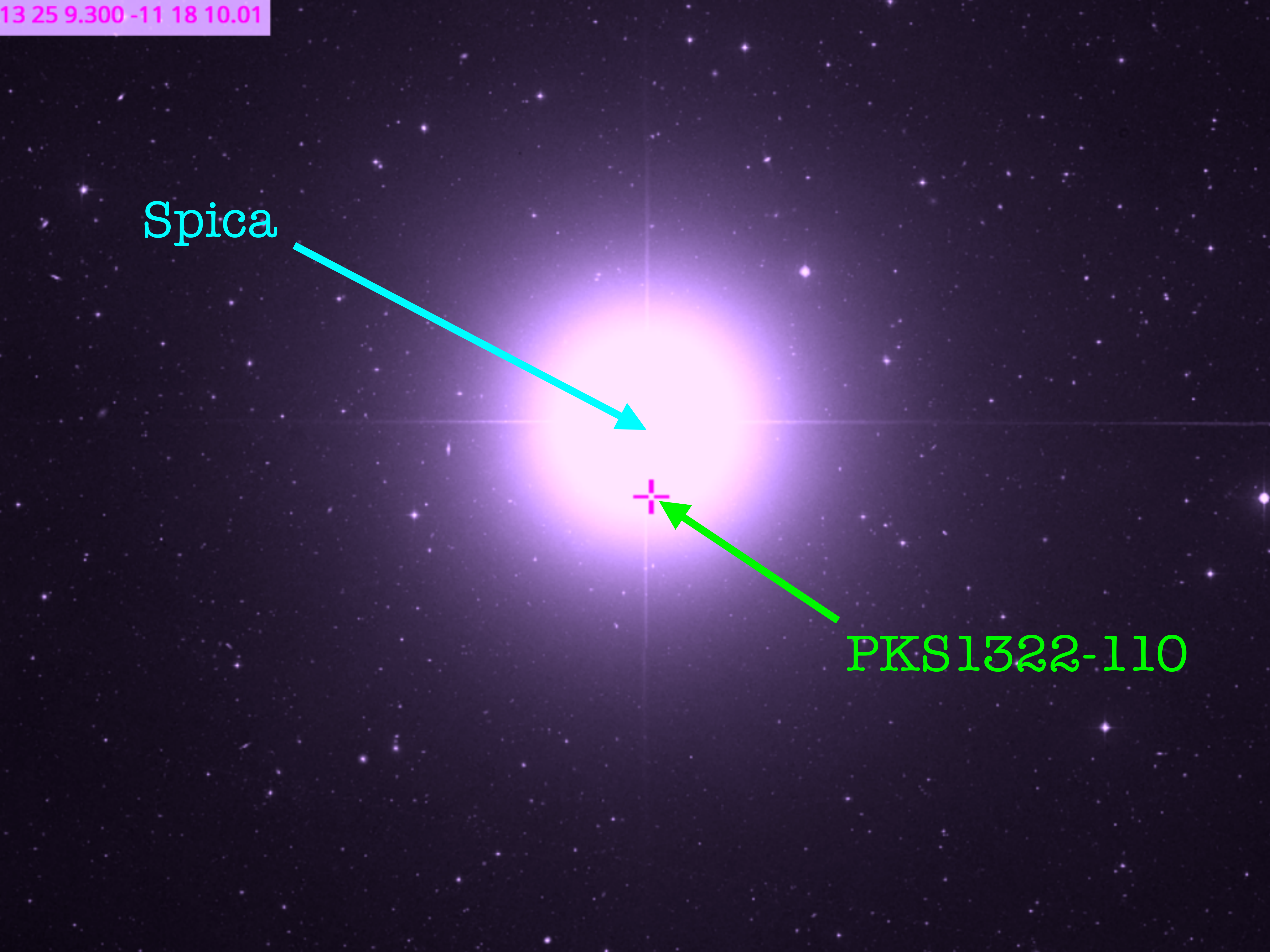
Bannister++ 2016
Frequency (GHz)
10
8
6
4
2
0
50
100
150
200
250
300
350
MJD - 56800
Flux Density (mJy)
300
250
200
150
100
50
0

PKS 1322-110 : a new IDV



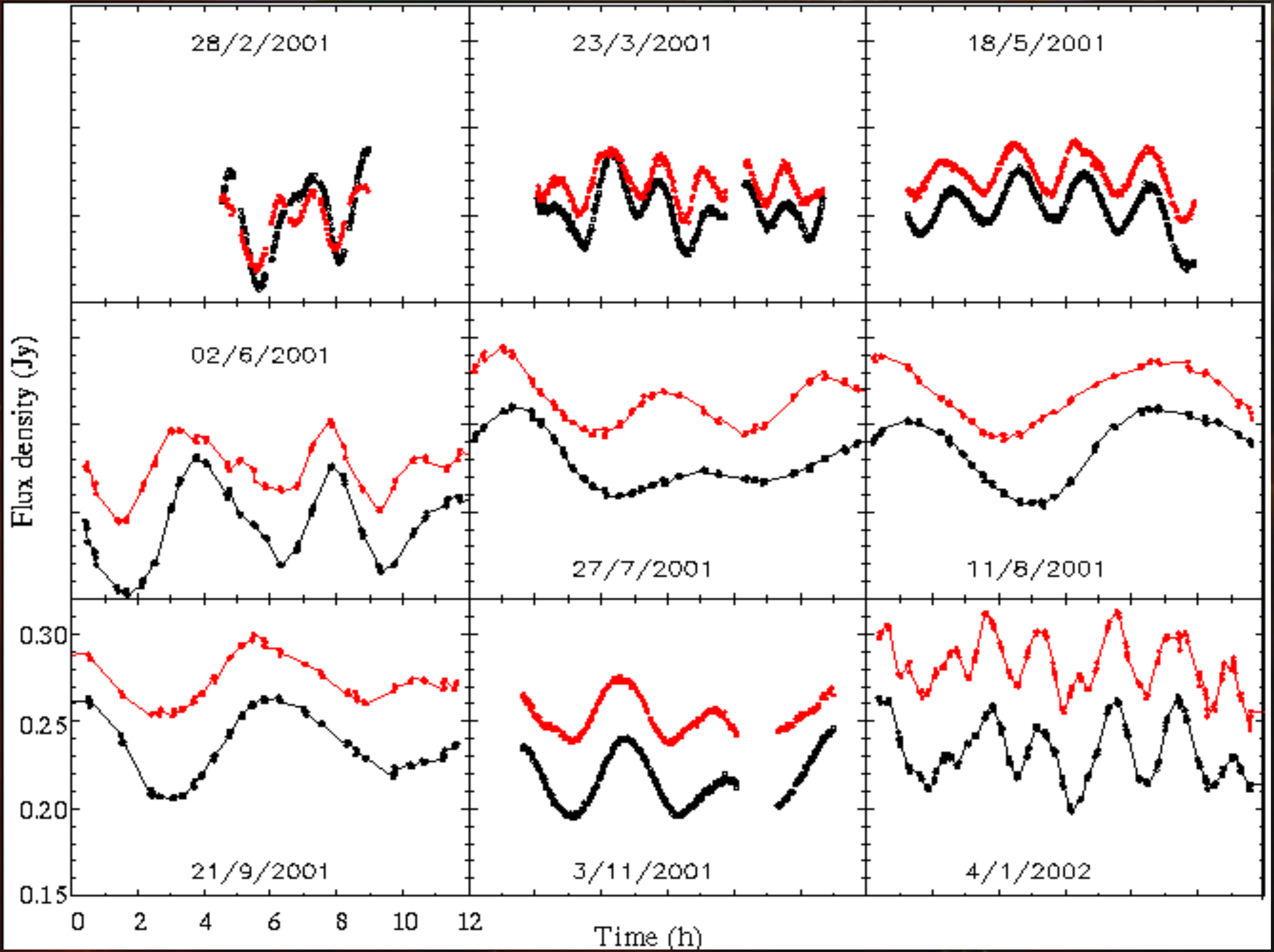
ATESE Team (2018)

Manly Astrophysics


13 25 9.300 -11 18 10.01
Spica
PKS1322-110

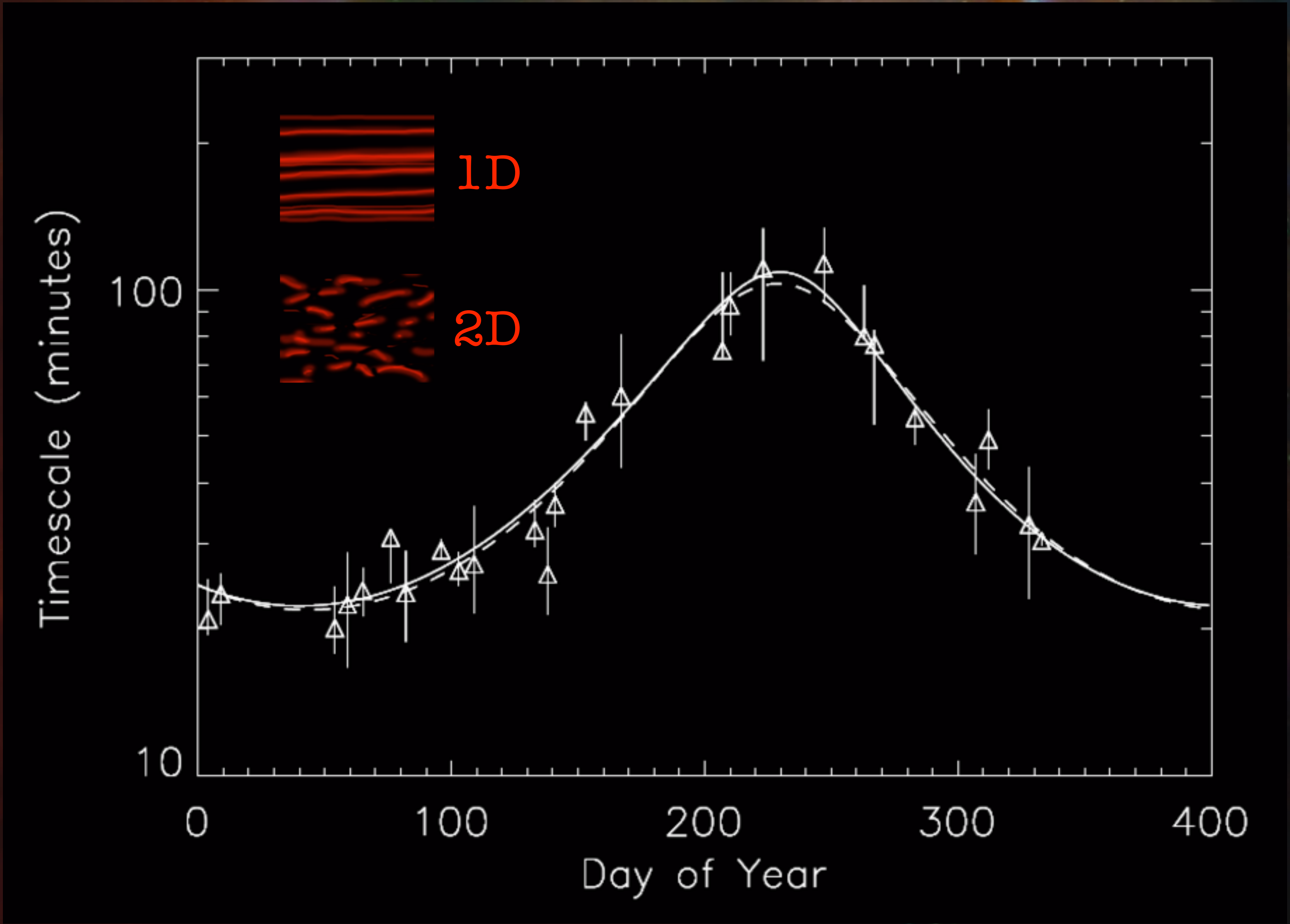
PKS1257-326 (Hayley's source)

Bignall++ 2003



PKS1257-326 (Hayley's source)

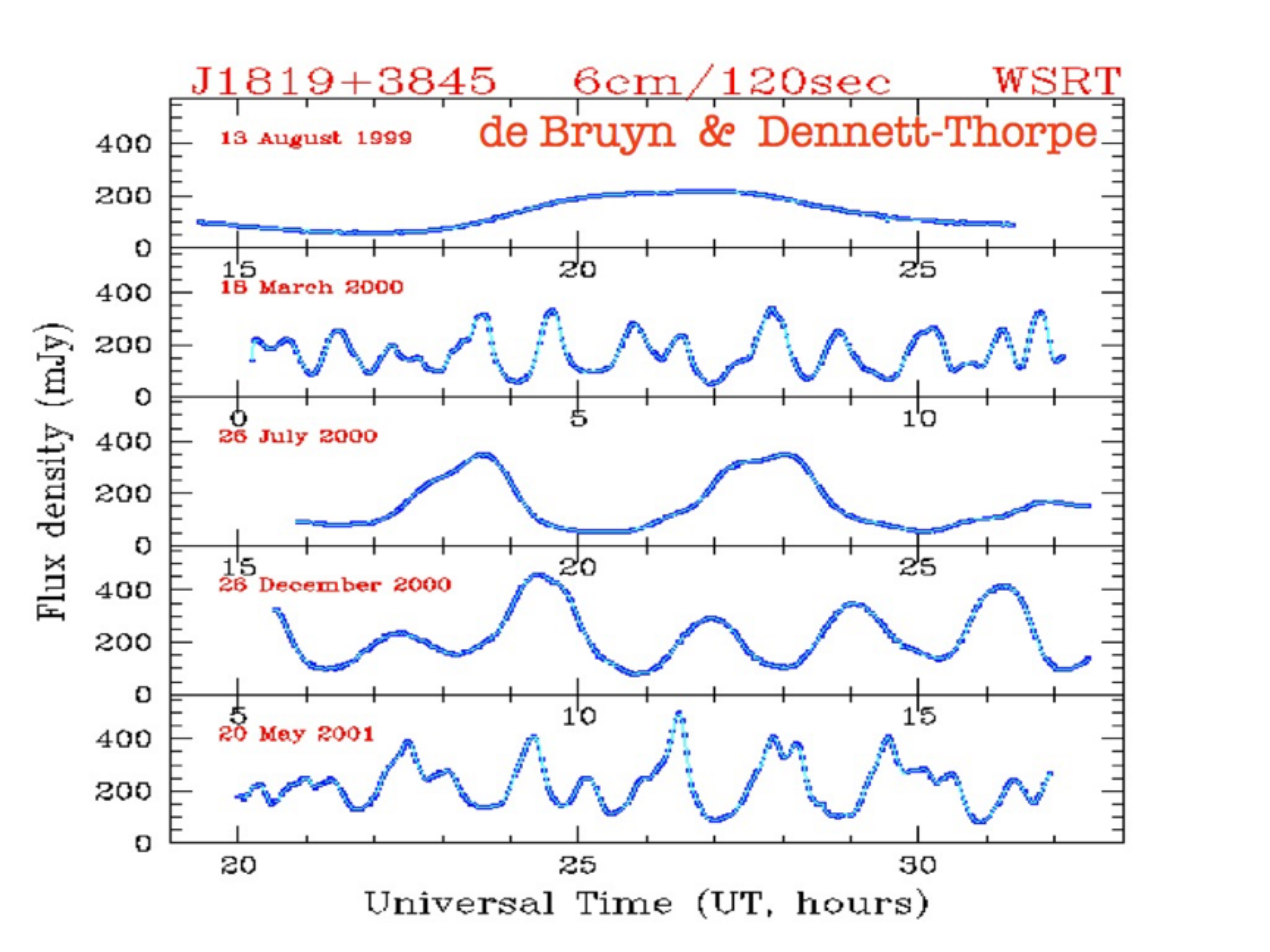
Bignall[++] 2003



Manly Astrophysics

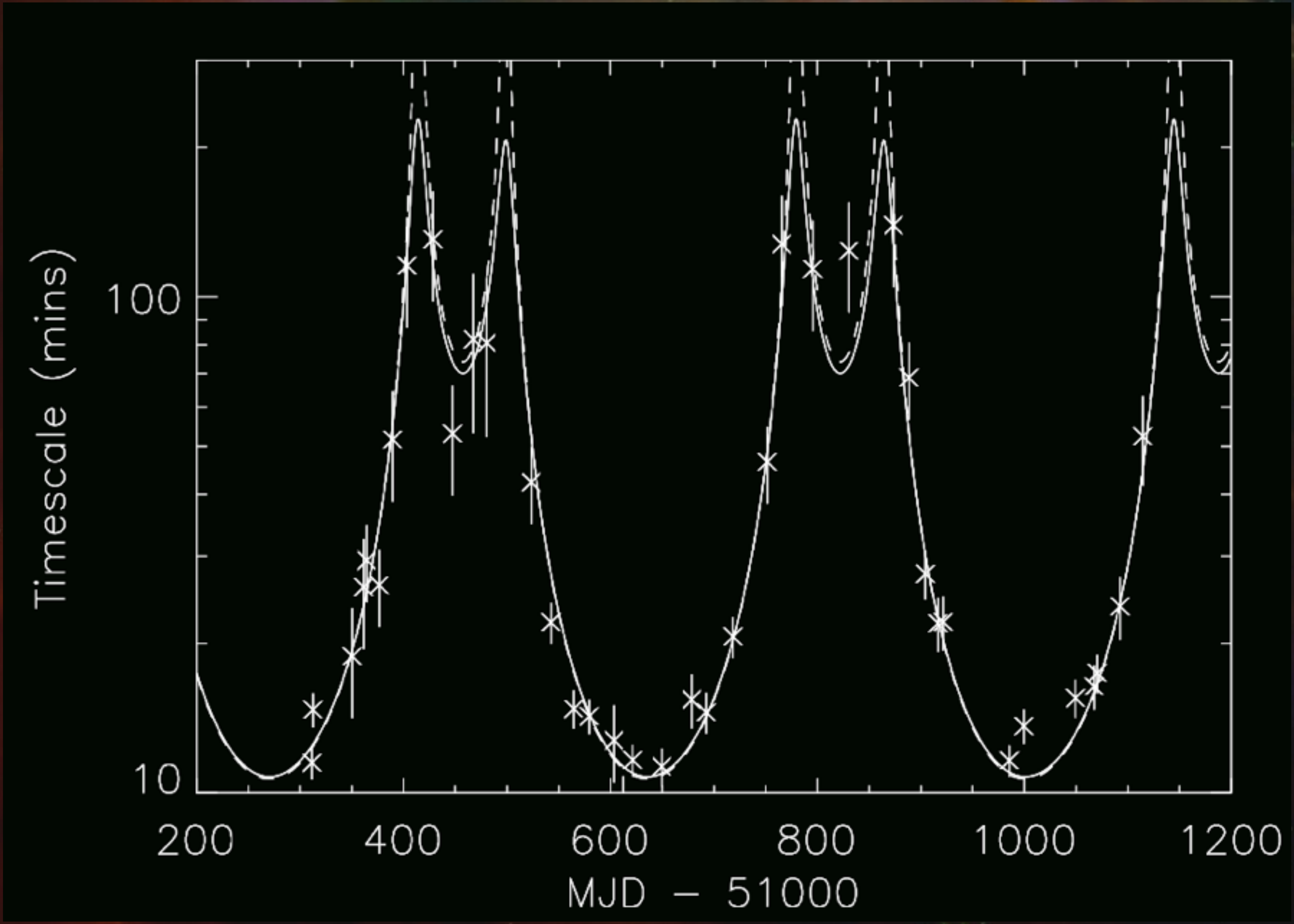
J1819+3845 (Jane's source)

Dennett-Thorpe and de Bruyn 2003



J1819+3845 (Jane's source)

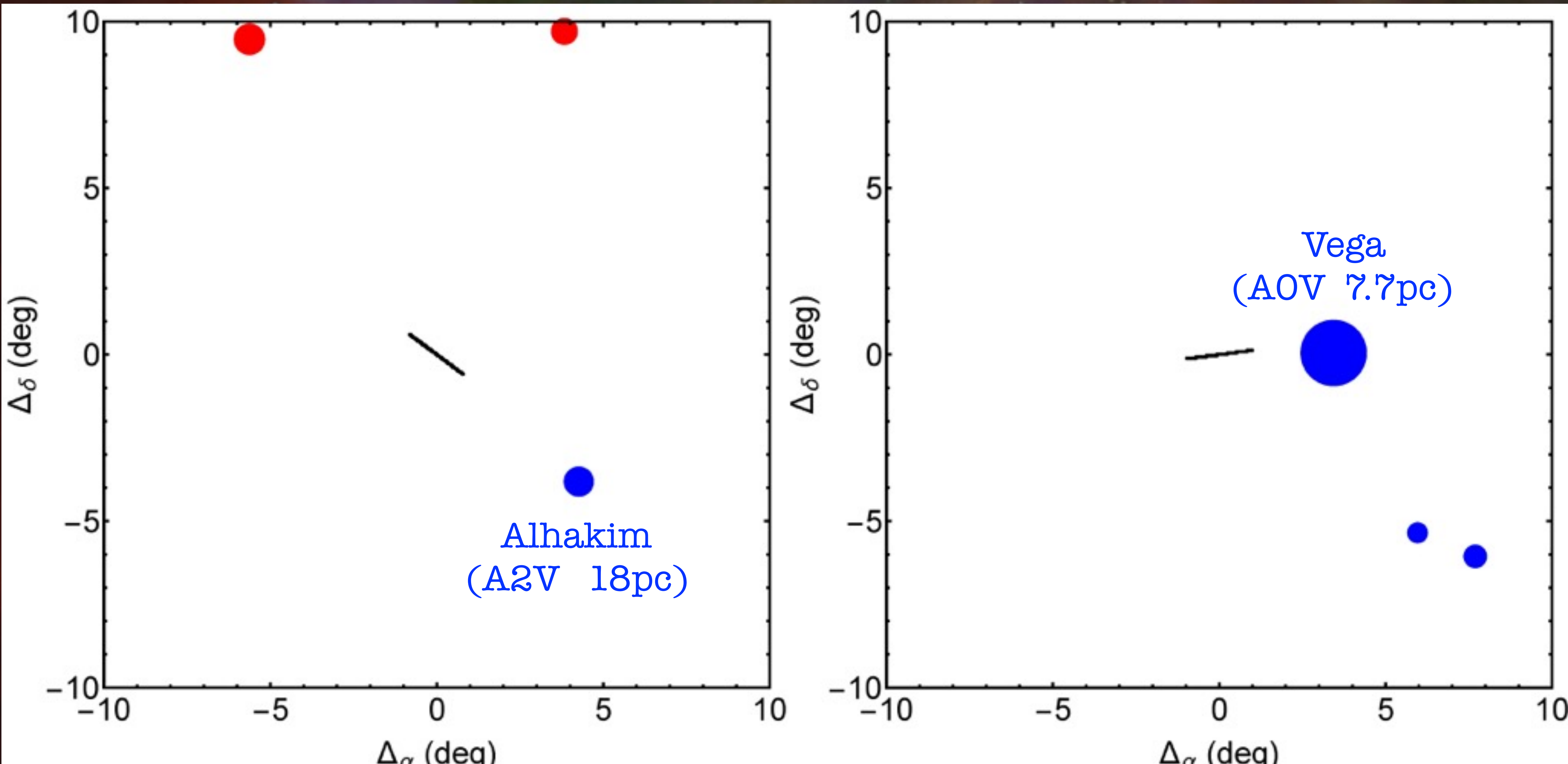
Walker, de Bruyn & Bignall 2009



Manly Astrophysics

Bright stars in the foreground

PKS1257-326 J1819+3845



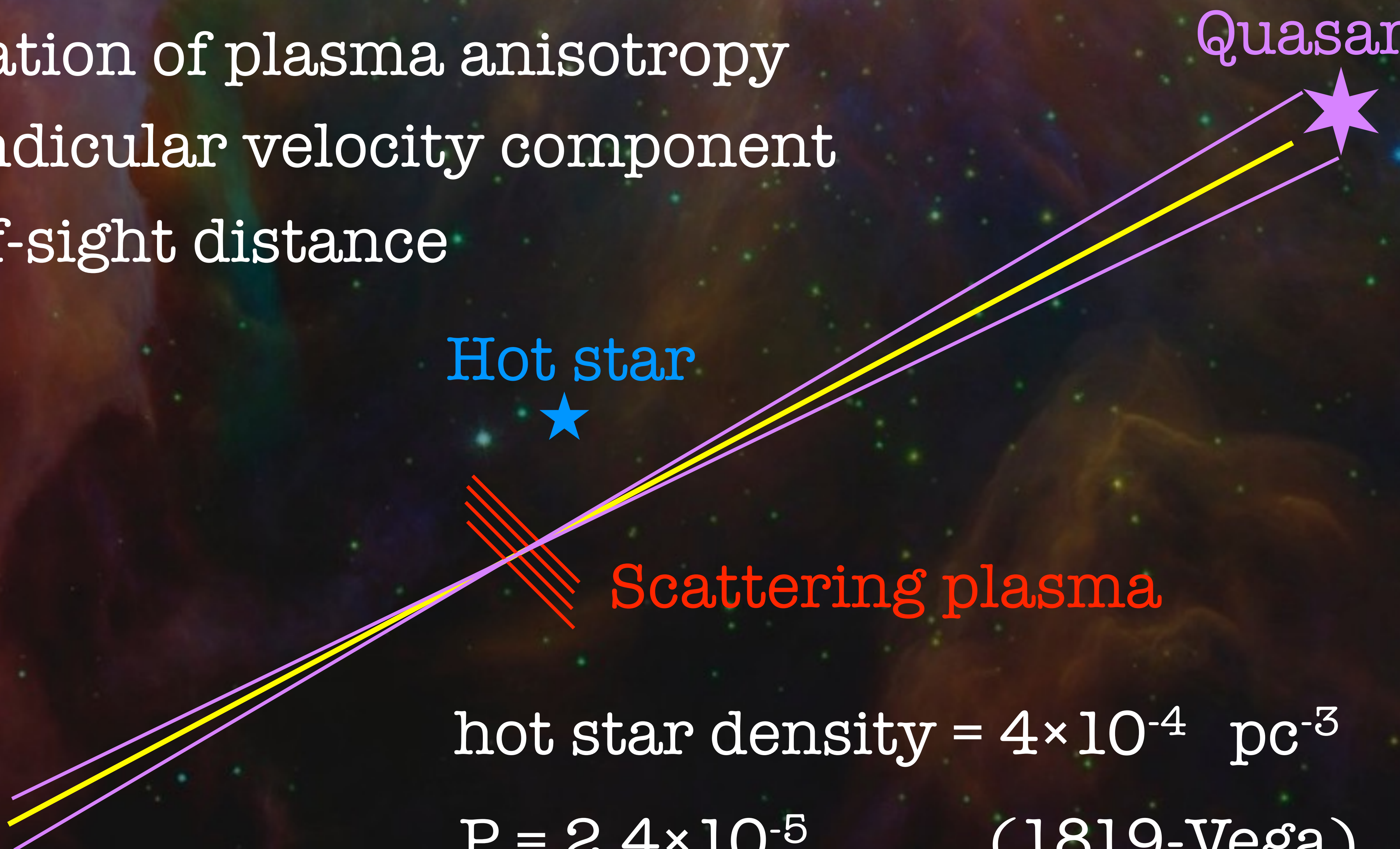
Model: radial filaments, comoving with star

Walker[++] 2017

Lucky coincidences?

Fitting to annual cycle gives:

1. Orientation of plasma anisotropy
2. Perpendicular velocity component
3. Line-of-sight distance



hot star density = 4×10^{-4} pc^{-3}

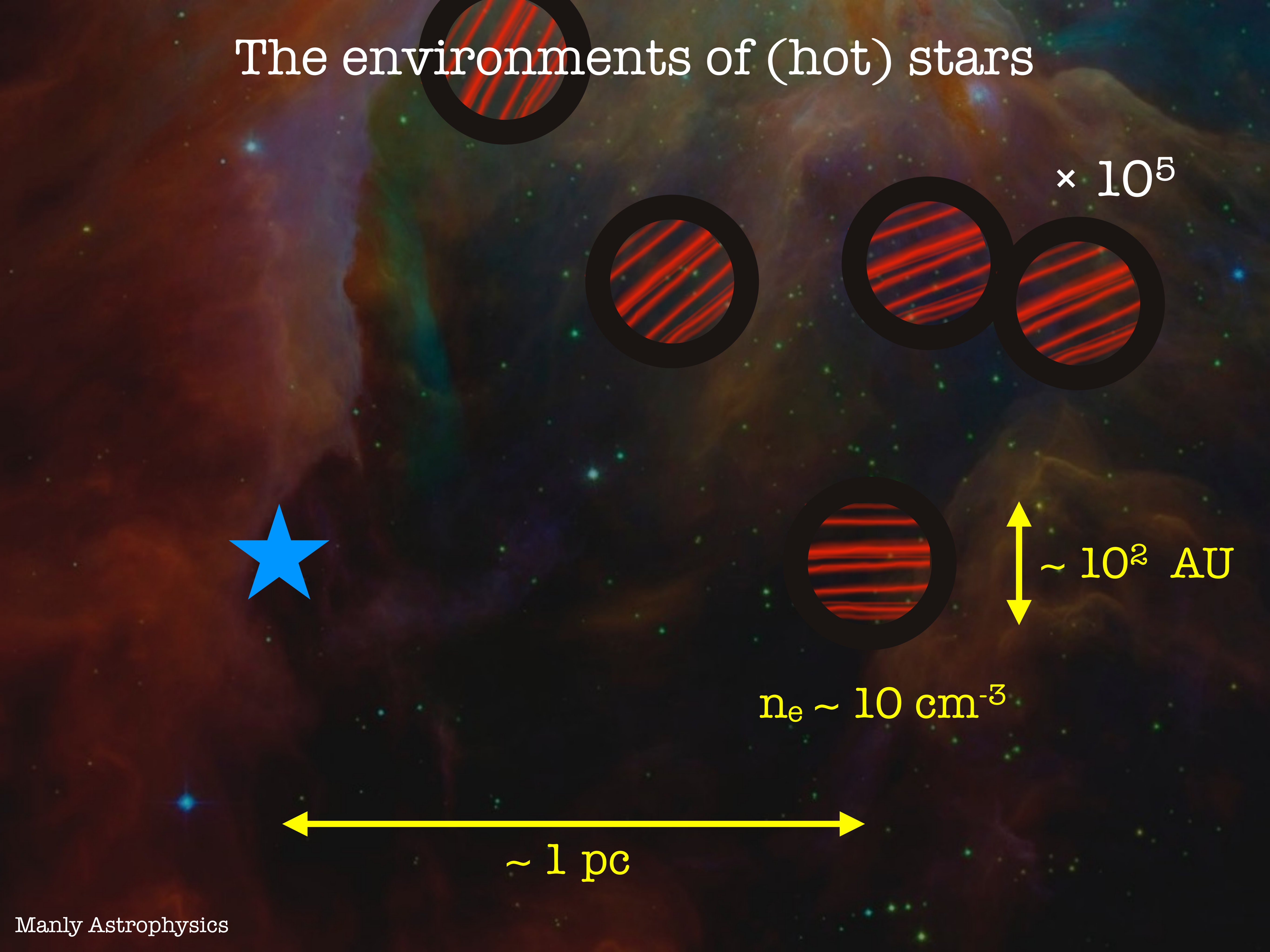
$P = 2.4 \times 10^{-5}$ (1819-Vega)

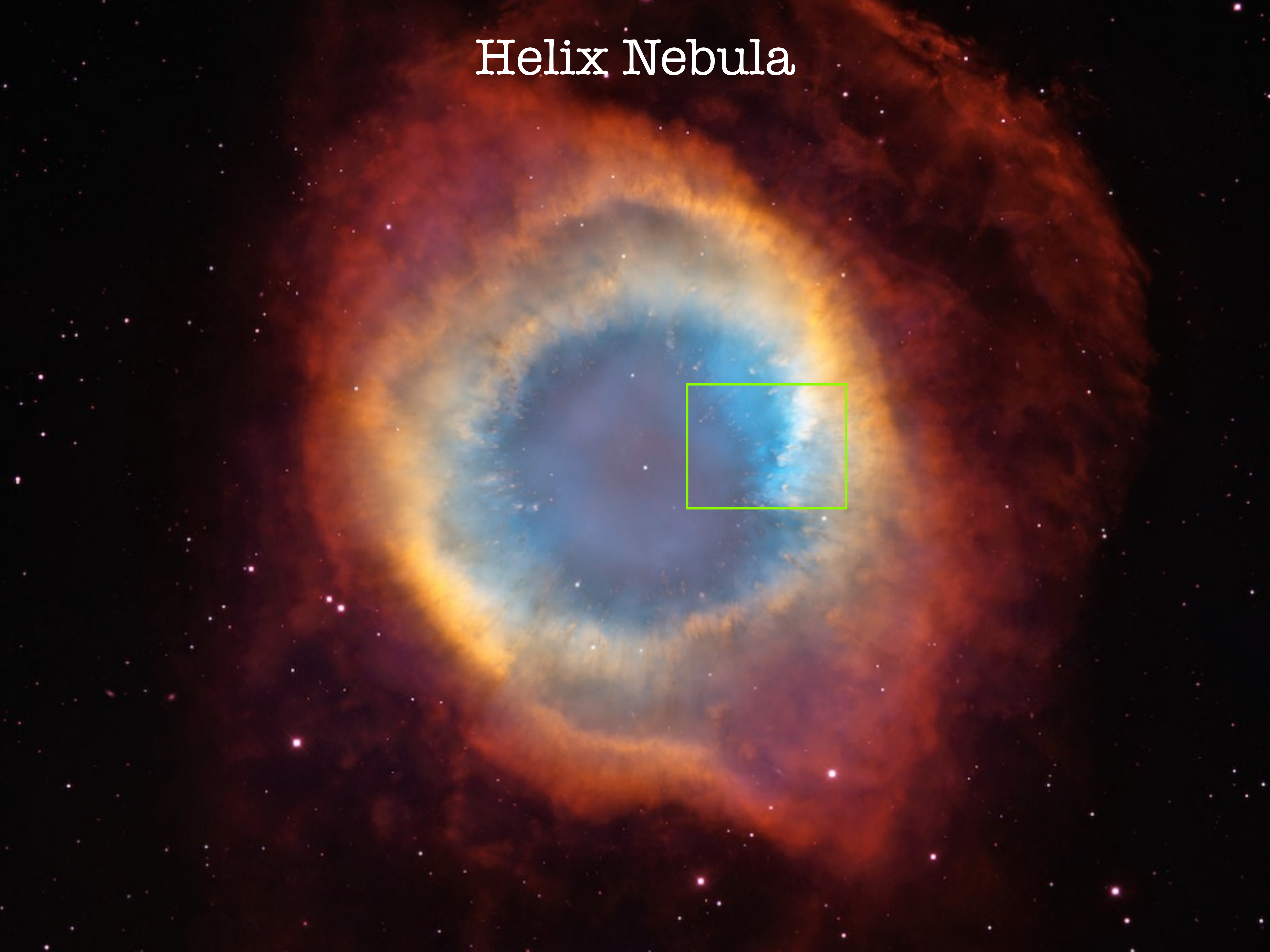
$P = 1.7 \times 10^{-4}$ (1257-Alhakim)

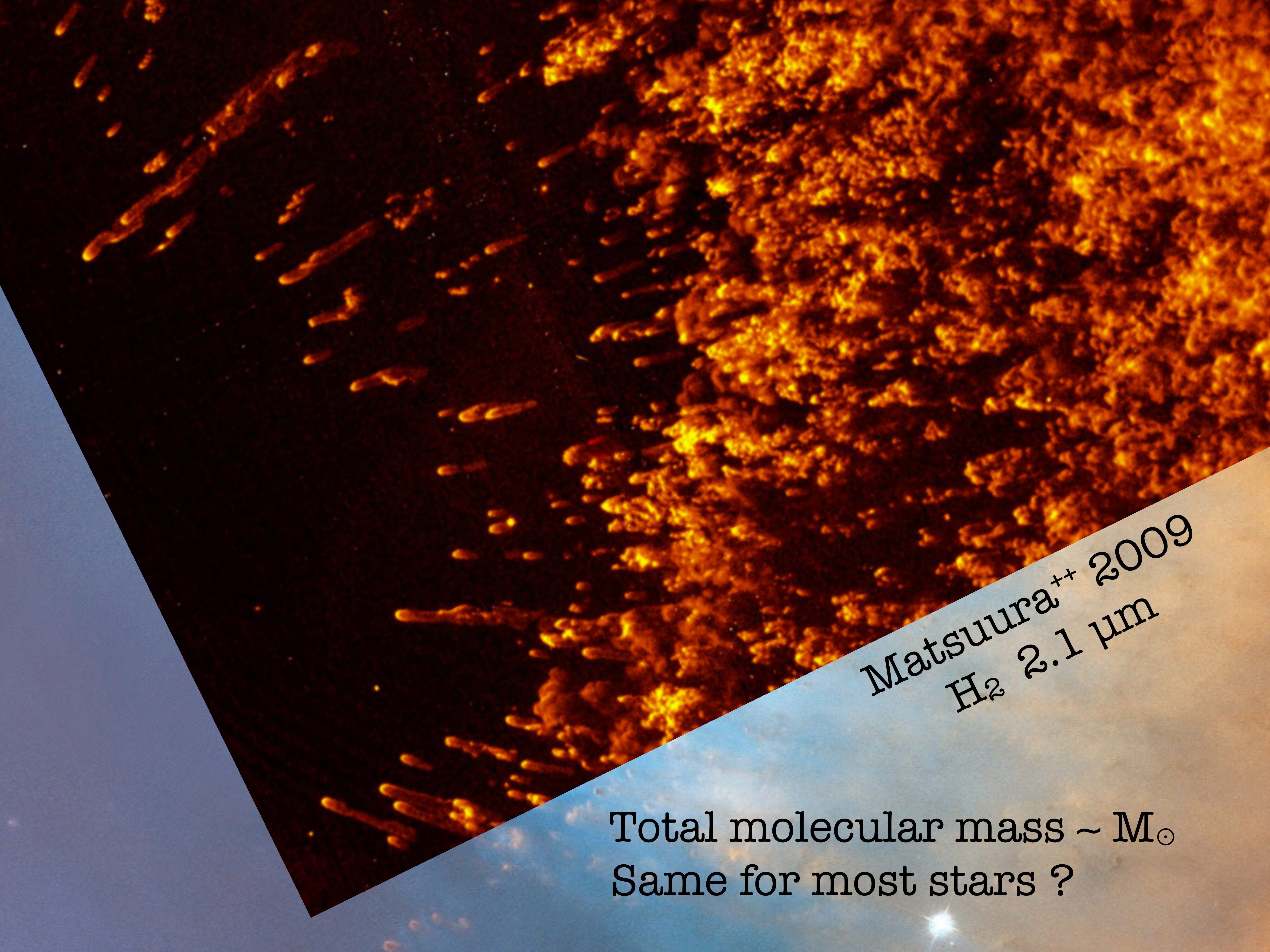
Manly Astrophysics

Walker^{++} 2017

The environments of (hot) stars

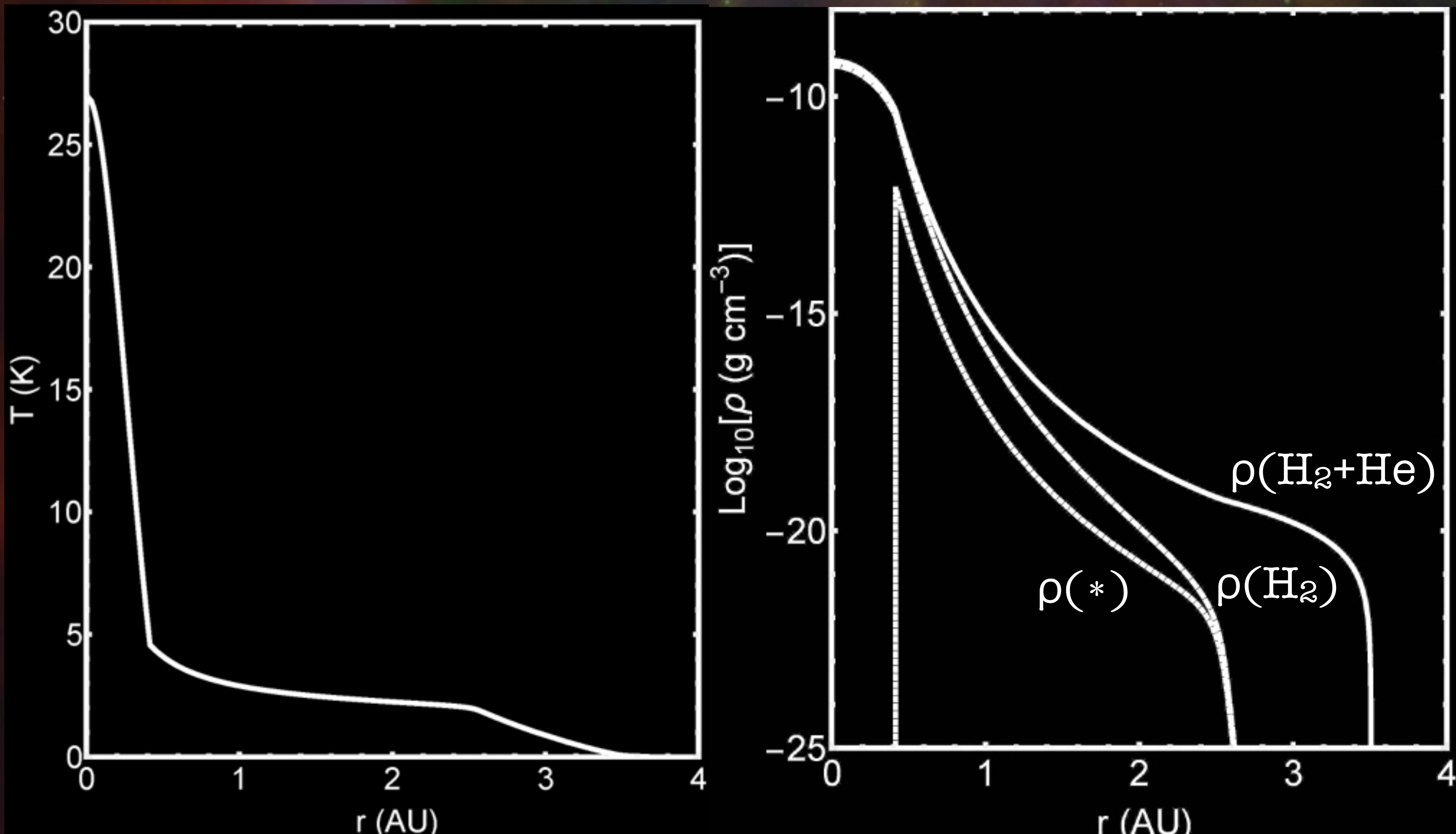



Helix Nebula

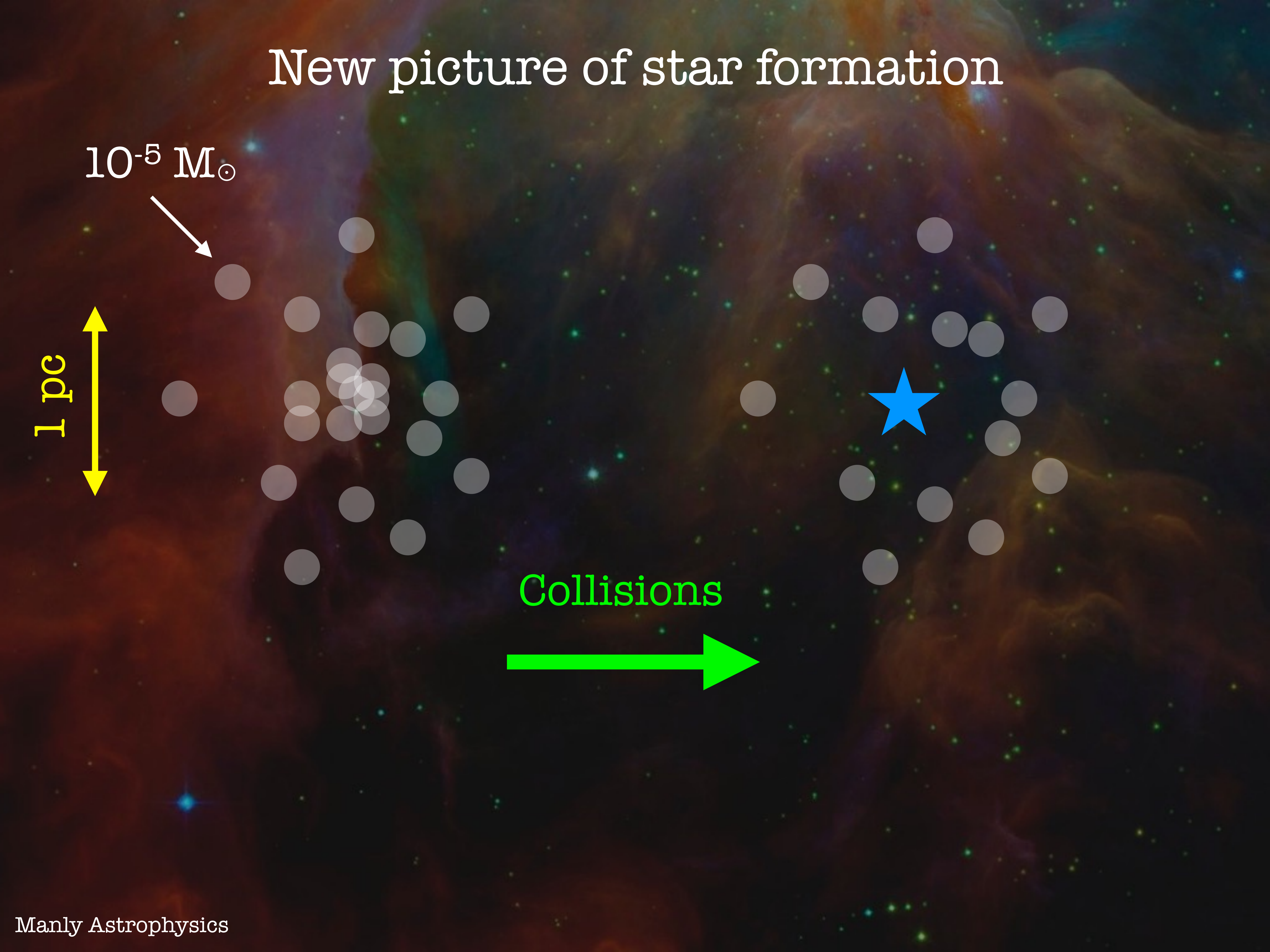

Matsuura++ 2009
H_2 2.1 μm
Total molecular mass ~ $M_\odot$
Same for most stars ?

These are likely H_2 snow clouds

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



Walker & Wardle 2018


New picture of star formation
10-5 M☉
1 pc
Collisions
Manly Astrophysics

~~New~~ Old picture of ~~star~~ galaxy formation

Yields a simple model for M_{vis}(Velocity)

Manly Astrophysics

Walker 1999

Star-Cloud Interactions

1. Irradiation

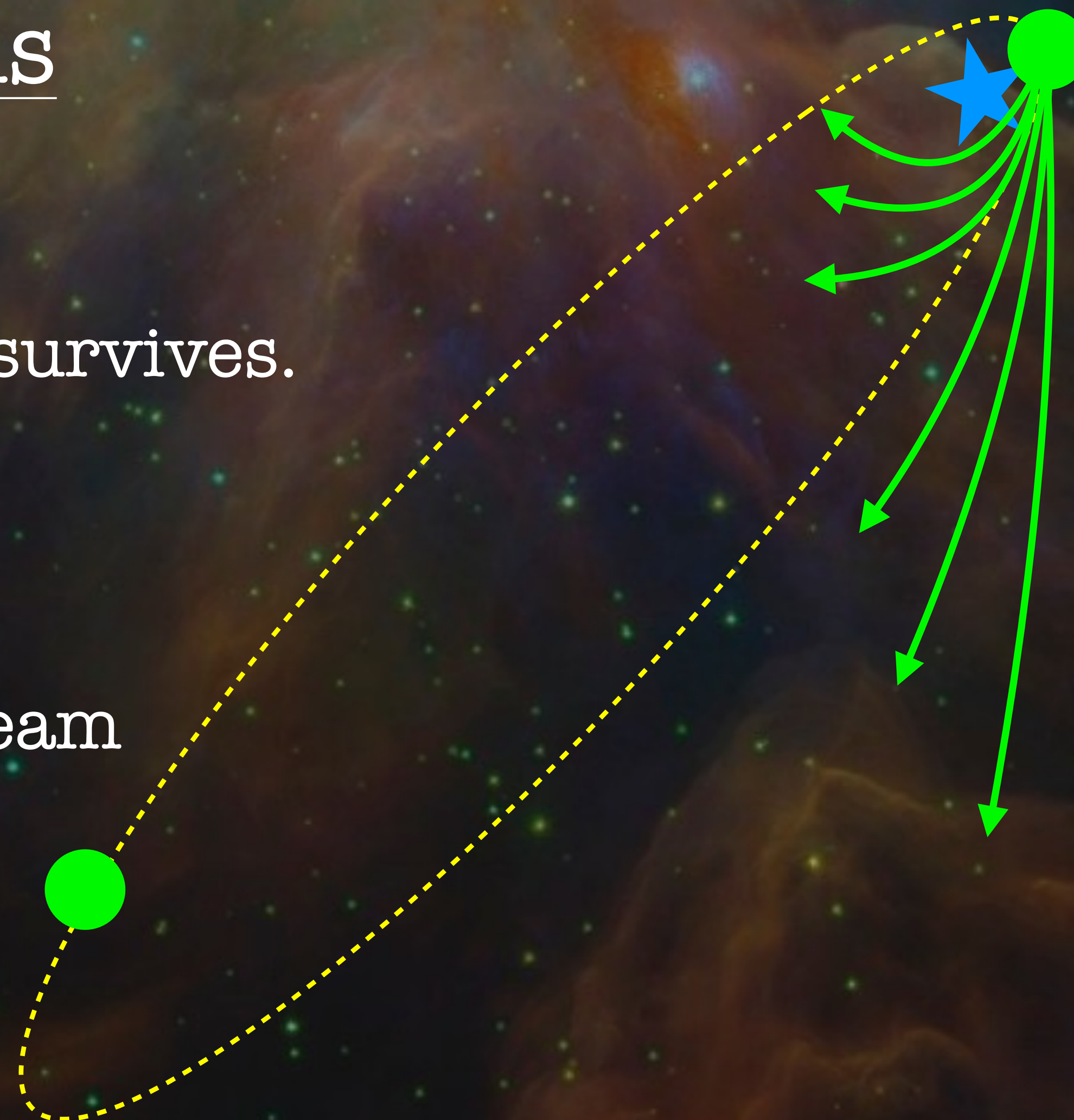
Thermal disruption (heating > cooling).
Cometary tail of gas and H_2 dust.

Possible manifestations?
PNe cometary knots.
SNe dust production events.
B[e] stars.
Wolf-Rayet "pinwheels".

Tuthill++ 2008

O'Dell & Handron 1996

Star-Cloud Interactions
2. Tidal Stripping



Envelope easily stripped, core survives.
Periodic events.
Episodic accretion onto star
 - shocks, line emission.

Some tidal debris escapes - stream
 of cold gas and H_2 dust.
Obscuration events;
blue-shifted absorption lines.

Possible manifestations?
Be stars
R Cor Bor stars

Summary

- Radio-wave scattering is mainly due to radial, circumstellar plasma filaments
  - Now testing this model with QSOs and pulsars
- Six points of similarity to the plasma structures in the Helix Nebula
  - Instigating deep searches for molecular counterparts
- Likely connections to a wide range of astrophysics
  - Interstellar dust (H_2 snowflakes)
  - Star and planet formation
  - Many "stellar" phenomena
    - Wolf Rayet, Be stars, R Cor Bor, etc
  - Galaxy formation and evolution; early universe etc