Structure and Evolution of Stars

Lecture 24: Extreme and some Fun Stars

- Most Distant "Star" yet seen

- Light Echos and Revealing the History of Mass Loss

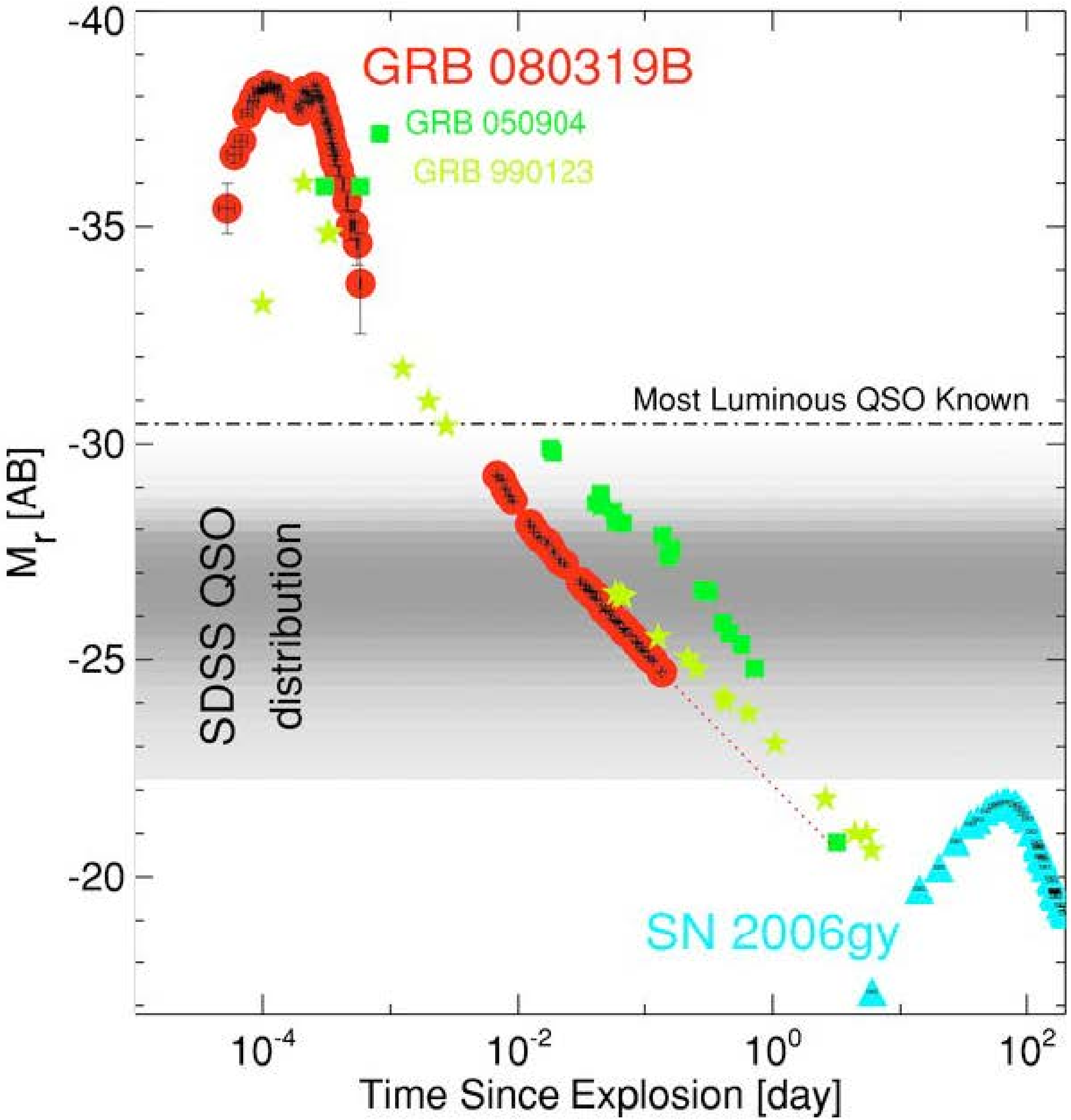
- *Star of the Week* #7: WD1145+017 – a white dwarf whose brightness was monitored to high accuracy over ~3 months by the *Kepler* planet-transit hunting satellite

● GRB090423 - Most distant "star" seen to date. Link of gamma-ray bursts (GRBs) to optical transients that are interpreted as "hypernovae" – SN-class Type Ic

Long period before the GRB-SN connection established

GRBs seen to high redshifts and apparently possess extraordinary luminosities

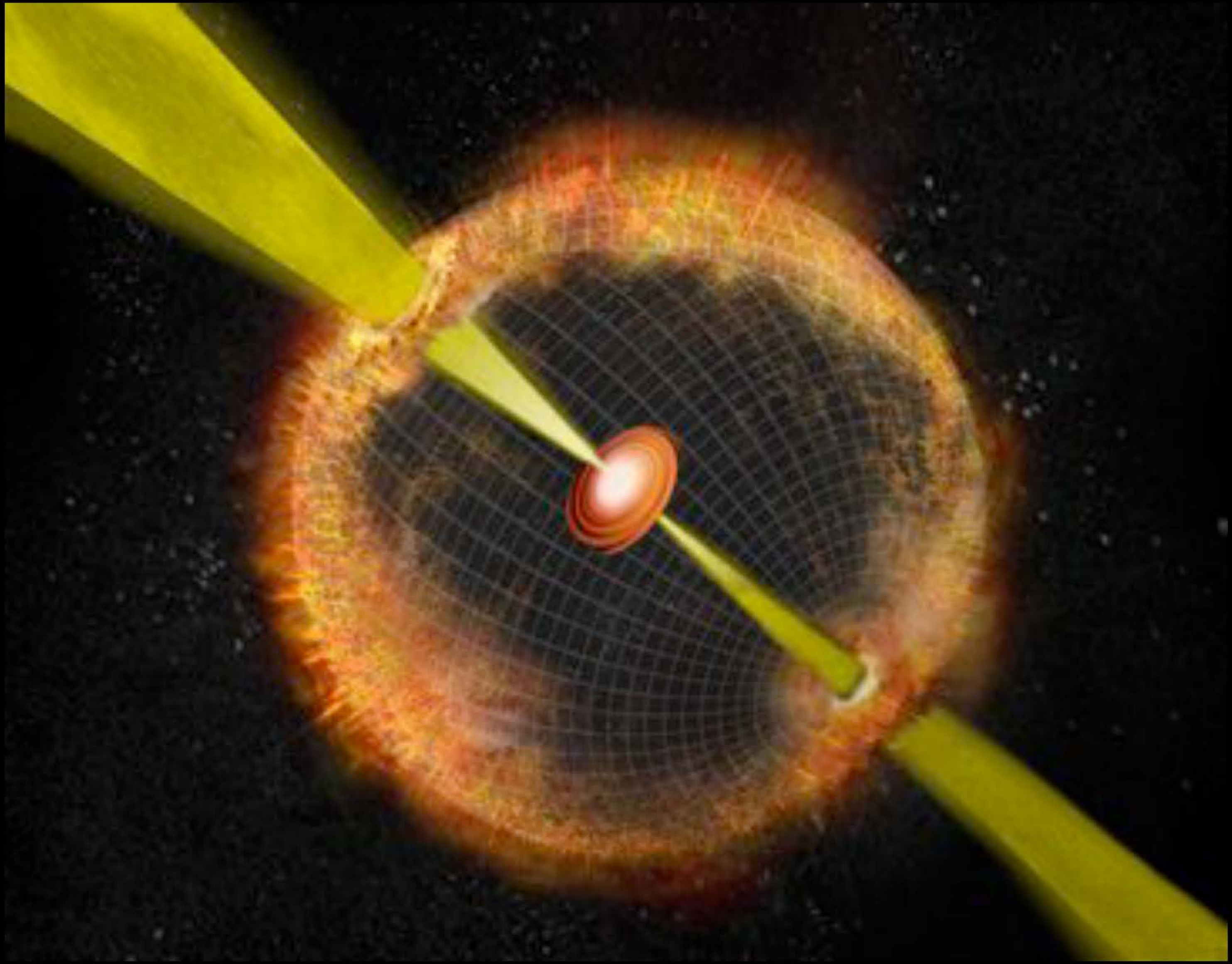
What is usually assumed when calculating a luminosity from a flux?

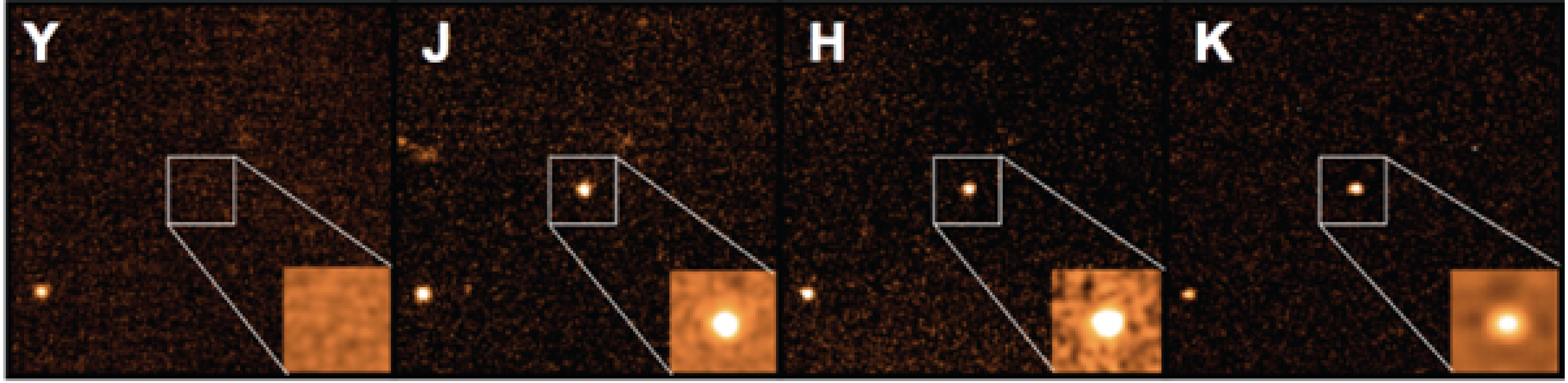


Bloom et al. 2009

● GRB model – involves highly collimated outburst from core-collapse of massive star

Angular momentum clearly important





● Detection of GRB, then rapid imaging of position followed by call to very large optical telescope to acquire spectrum – interesting collaboration (need a mobile phone!)

Near-infrared (YJH) images from the 3.8m UKIRT telescope within 1.5 hours, K-band image from Gemini telescope within 30 minutes of the GRB detection

If the intergalactic-medium contains neutral hydrogen, what happens to a photon with energy sufficient to ionise hydrogen? Need 13.6eV, wavelength <912 Angstroms

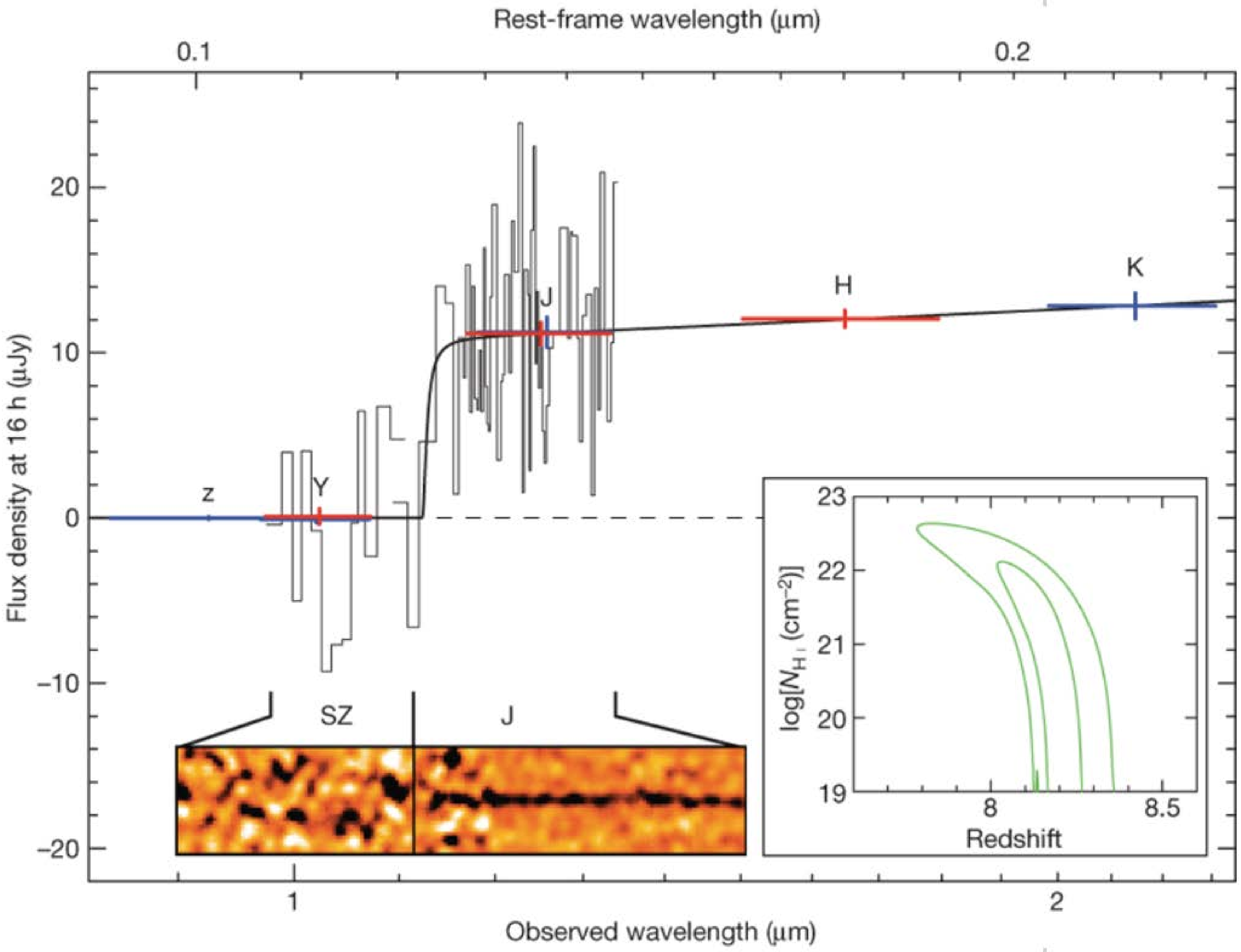
Y-band sensitive to ~10500 Angstroms. Why is the image montage above potentially interesting?

ESO 8.4m VLT spectrum within 17.5 hours after GRB090423

Dramatic “break” at 11300 Angstroms

Neutral hydrogen in host galaxy and IGM absorption responsible for complete absence of flux below 11300 Angstroms

Redshift z=8.2 (cf. most distant quasar z=7.084)

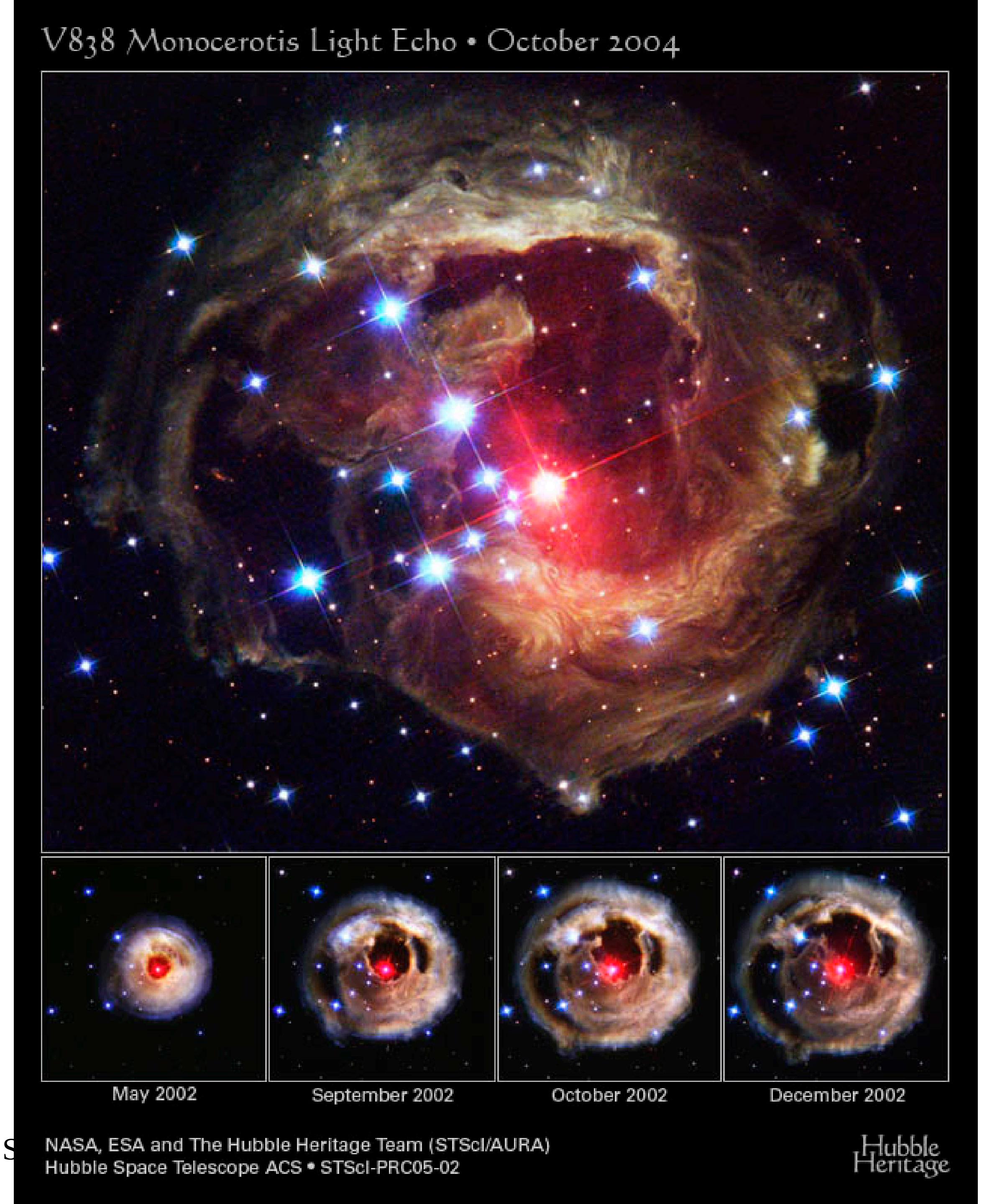


Tanvir etal. 2009 Nature 461 1254 – “small” collaboration, 63 authors

• Probing mass loss history with light Echos:

Probe environment of stars undergoing sudden increase in brightness using light-travel time differences – SN1987A most famous example

V838 Monoceros – outburst seen in 2002. AGB star at ~6kpc – detailed picture of previous mass-loss history



● V838 Mon – experienced a sudden 9 magnitude brightening in 2002

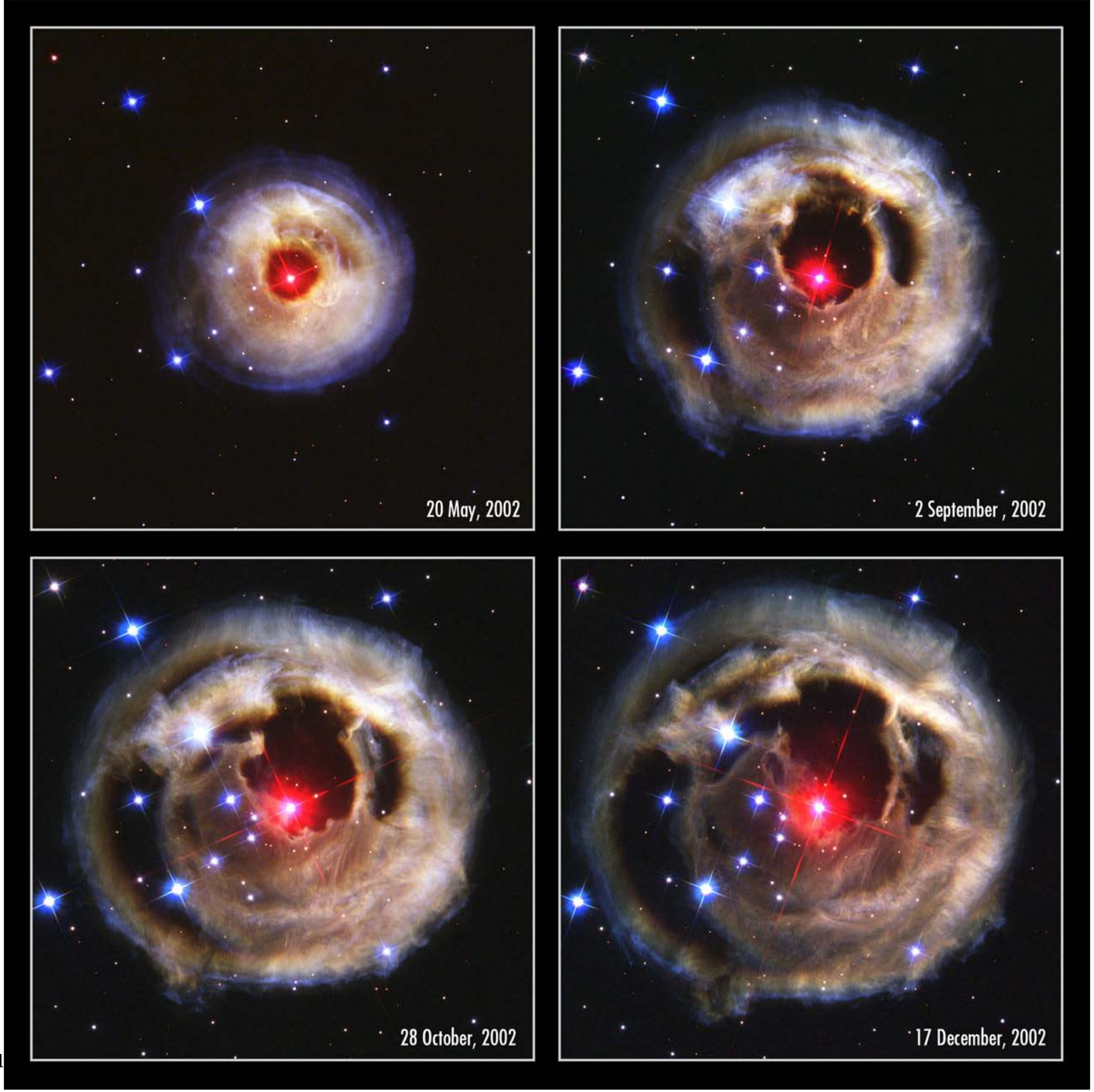
Has a B3V binary companion at relatively large separation

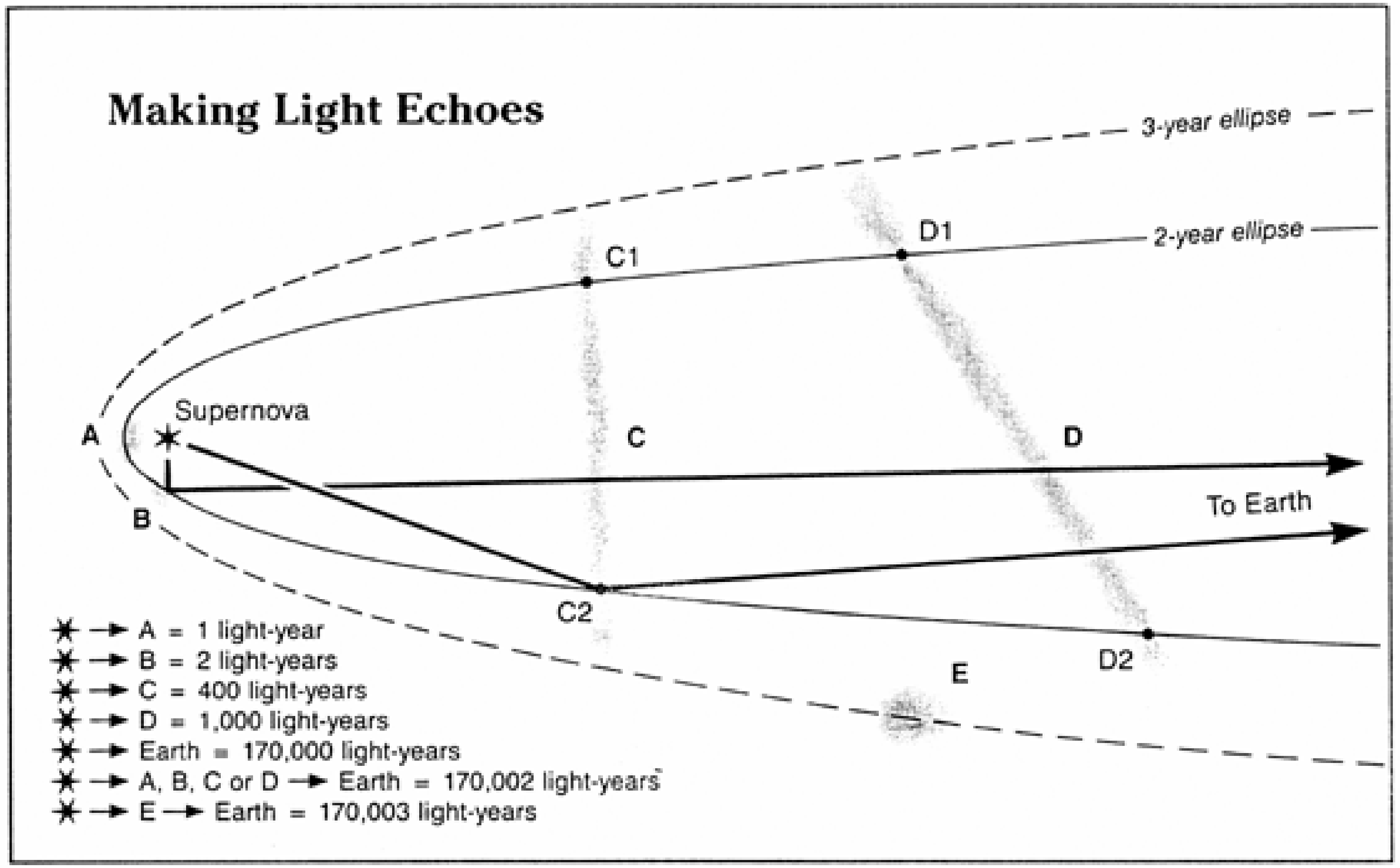
Favoured model involves a merger of two stars in order to work energetically

V838 Mon is now seen as an L-type supergiant (OBAFGKML classes) with a surface temperature of ≈2200K

To the right of the Hayashi-locus on the HR-diagram. Are you worried [Paul has been talking nonsense]?

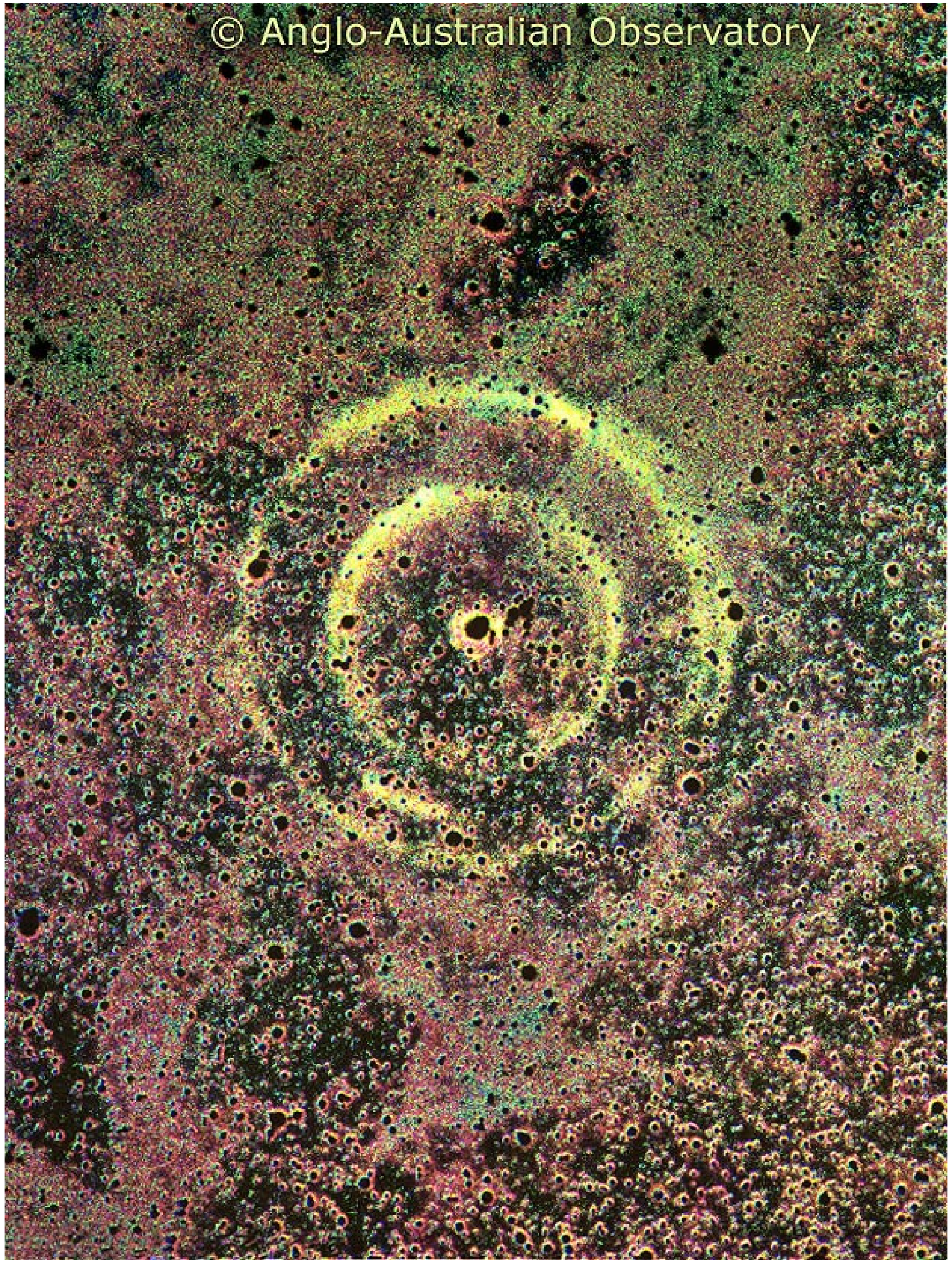
Stru



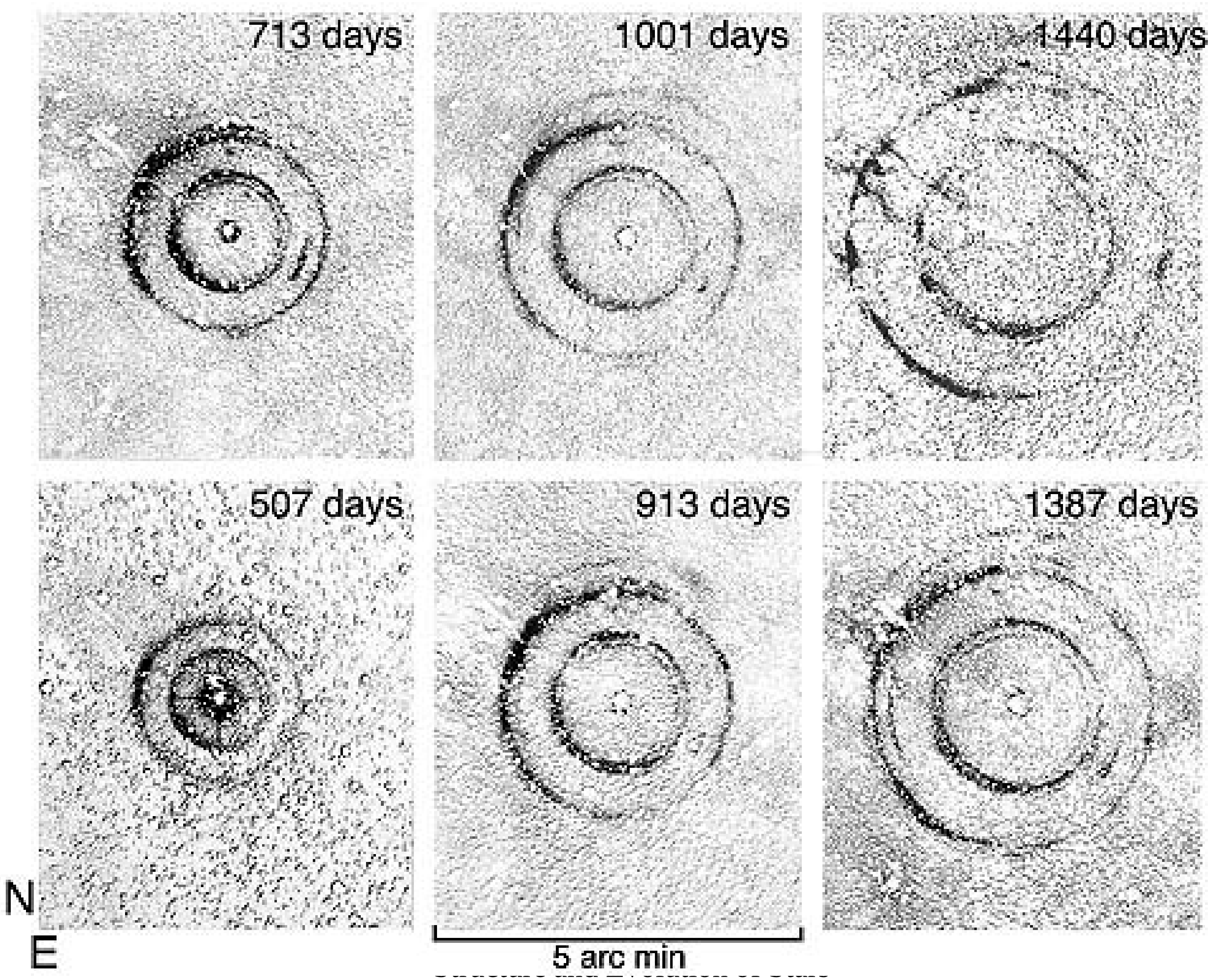


How light echoes are formed. The gray areas are clouds of dust. As discussed more fully on page 25, echoes can come not only from material behind the supernova (*A*), but also from dust at the same distance (*B*) and even closer to us than the explosion (*C*, *D*, and *E*). Wherever these interstellar clouds intersect the inner, solid ellipse we will see a light echo two years after the supernova's maximum light. After three years the echo ellipse has expanded to the dashed line and the echoes have moved outwards, revealing dust cloud *E*. For clarity the clouds of reflective particles have been drawn much closer to the supernova than they are in reality, and the ellipses and relative location of the supernova are not to scale. The ellipses are actually extremely narrow.

SN1987A
Light Echos



SN1987A Light Echo Evolution

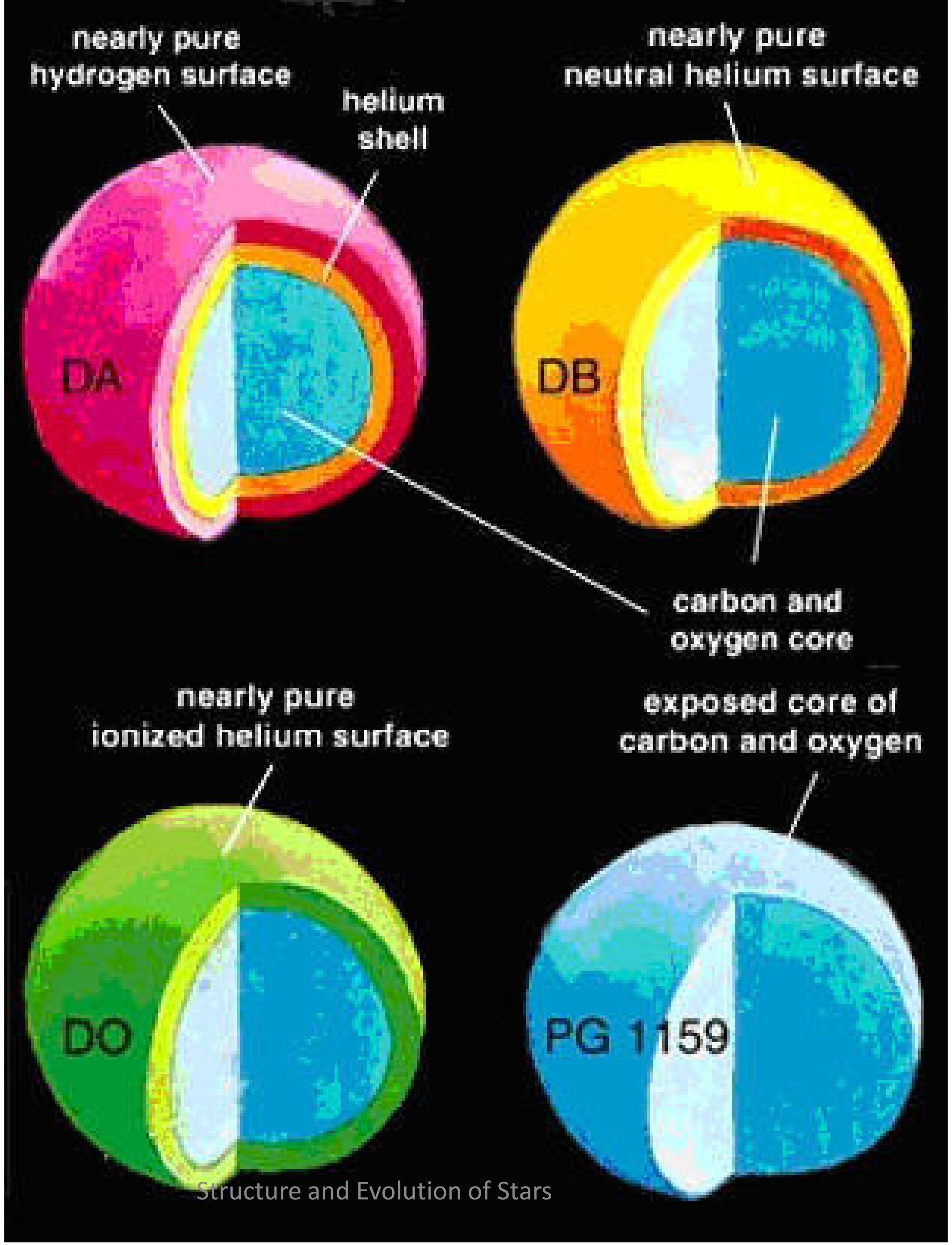


White Dwarf Spectral Classification

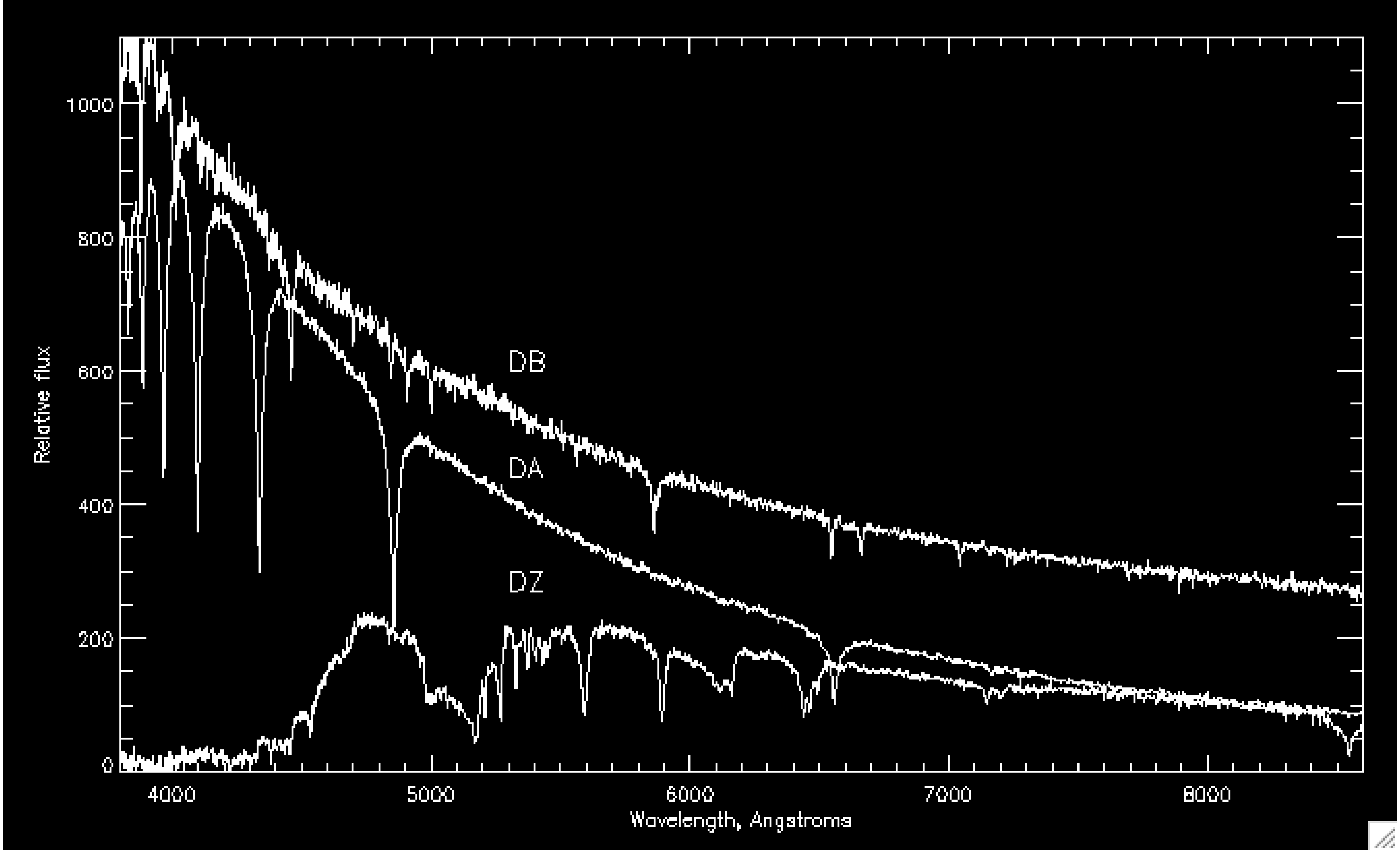
- White dwarf spectroscopic classification – involves a little more knowledge than was true when spectral classification and supernovae classification schemes originated
- The white dwarfs are isothermal, uniform–density, degenerate systems, composed of either C+O or He, the latter from stars that did not experience AGB-evolution (Star of the Week #5)
- The degenerate systems have a thin, non-degenerate, atmosphere – used such a model to calculate how white-dwarfs cool in Lecture 19. Really is pretty thin - ~5-10km and can consist of hydrogen, helium or a mix of both
- Using "D" for degenerate and the established temperature-related OBA classes for normal stars, we have:
    - DA – hydrogen dominated atmospheres
    - DB – neutral helium-dominated atmospheres
    - DO – ionized helium-dominated atmospheres [much higher T]
    - DZ – things we didn't really understand with strong "metal" signatures

● Schematic illustration of white-dwarf types

Does not include the He-core white-dwarfs, discovery of which is quite recent but have same scheme, where atmosphere can be H, He or even completely stripped



David Darling

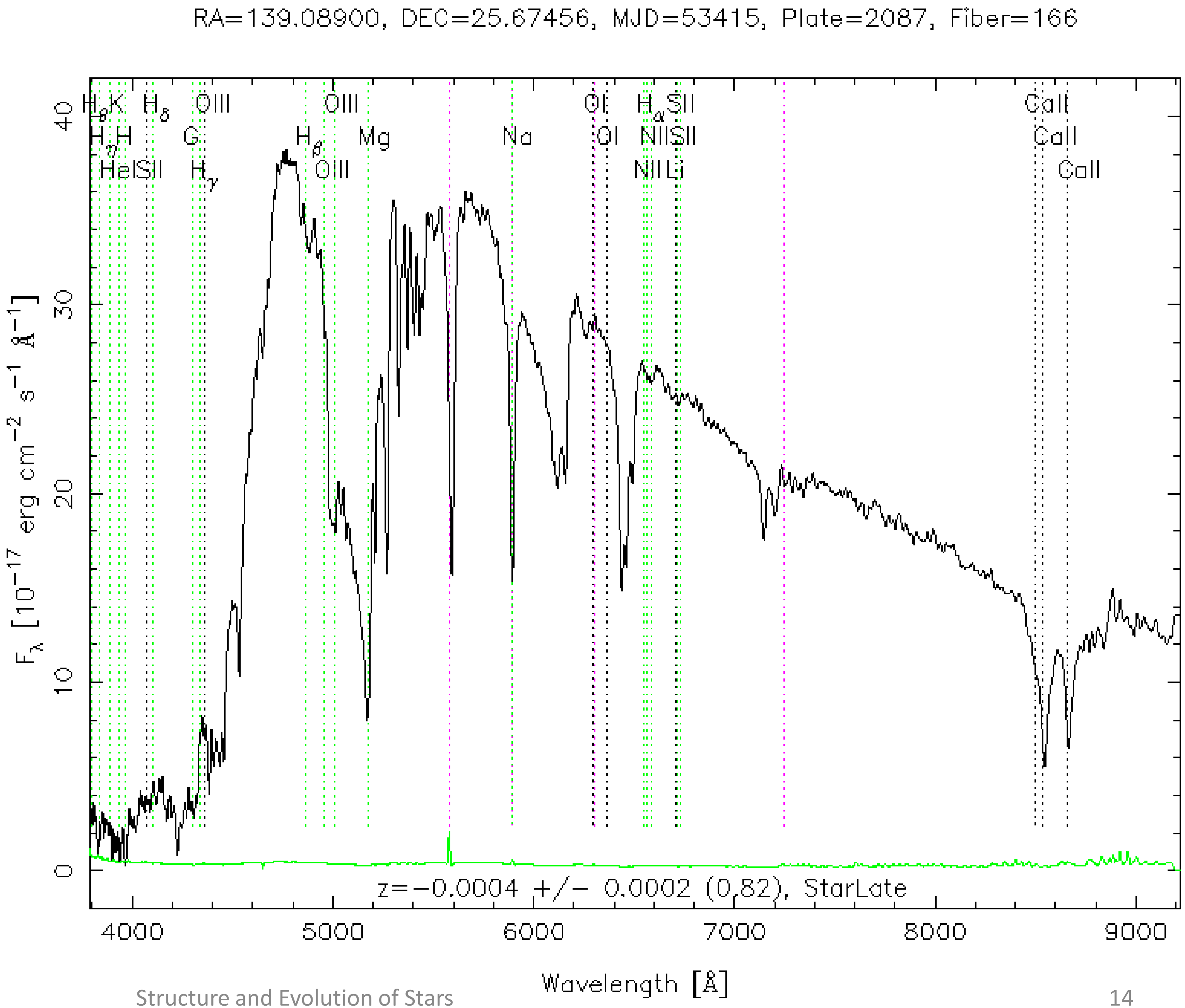


Actual white dwarf spectra from the Sloan Digital Sky Survey (SDSS)

• Last slide - note extremely broad absorption lines -50-100 Angstroms -compared to few Angstroms for the Sun. High surface gravity, high density leads to extreme pressure broadening

Where do the metals visible in the DZ spectra, like that shown here, come from?

What is likely to happen to high mass ions?



- Some 25-50% of white dwarfs show evidence for metals in their atmospheres (if you look carefully)

- Census of species seen in atmospheres – which are fairly well understood – suggests origin of the the contaminating material much like Solar System rocky bodies (inner planets, asteroids,…)

- For given mass and orbital properties of a planet, why are white dwarfs of interest compared to searches around normal main-sequence stars?

- Star of the week #7: WD1145+017 “A disintegrating minor planet transiting a white dwarf” – Vanderburg et al. 2015, Nature, 526, 546, Zhou et al. 2016, MNRAS, 463, 4432 [September]

● Photospheric temperature 15,900K.

Age (from cooling) 175±75 Myr

Evidence for warm dusty debris disk from infrared photometry, T=1,150K

Metals would settle away from surface in ~1Myr

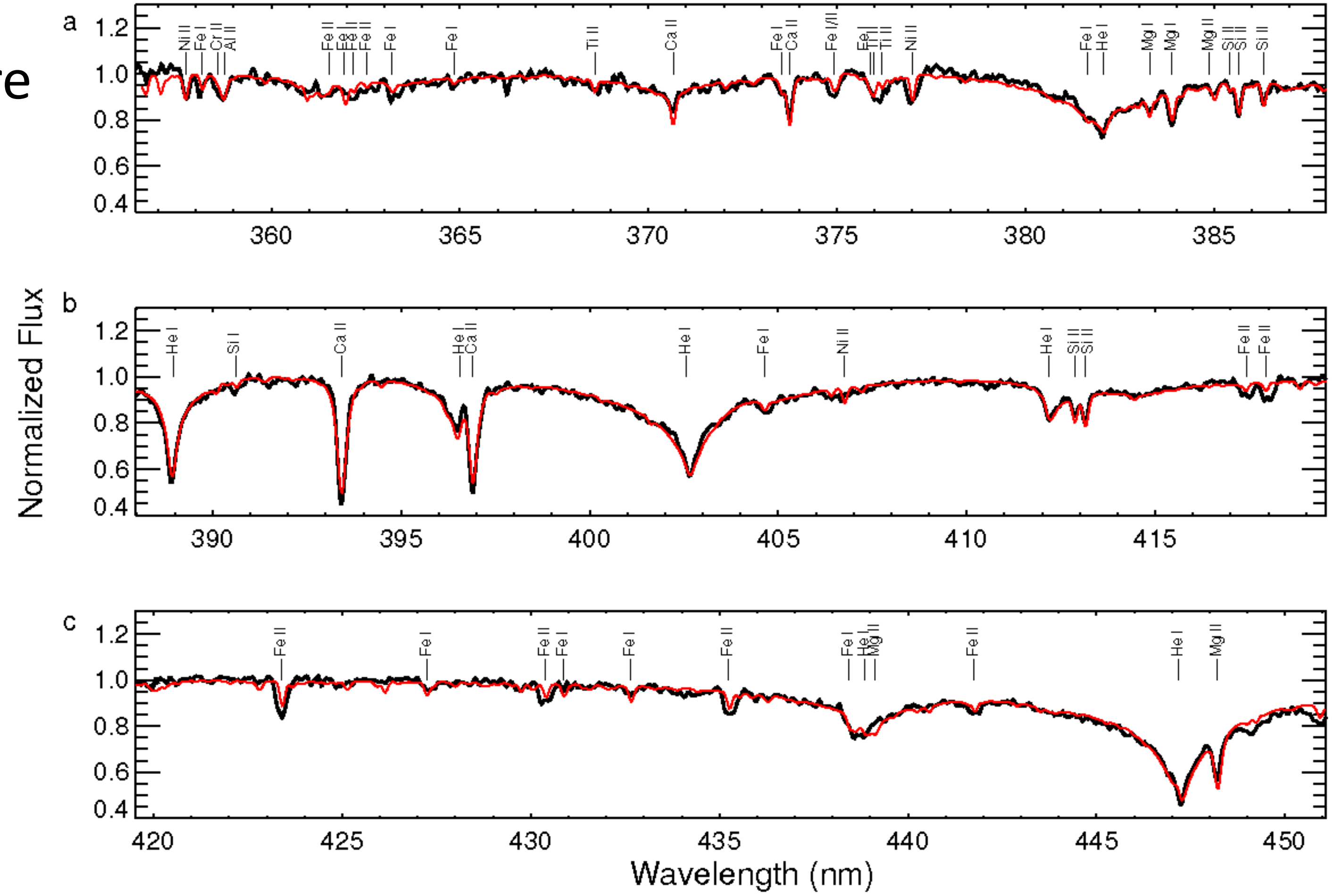


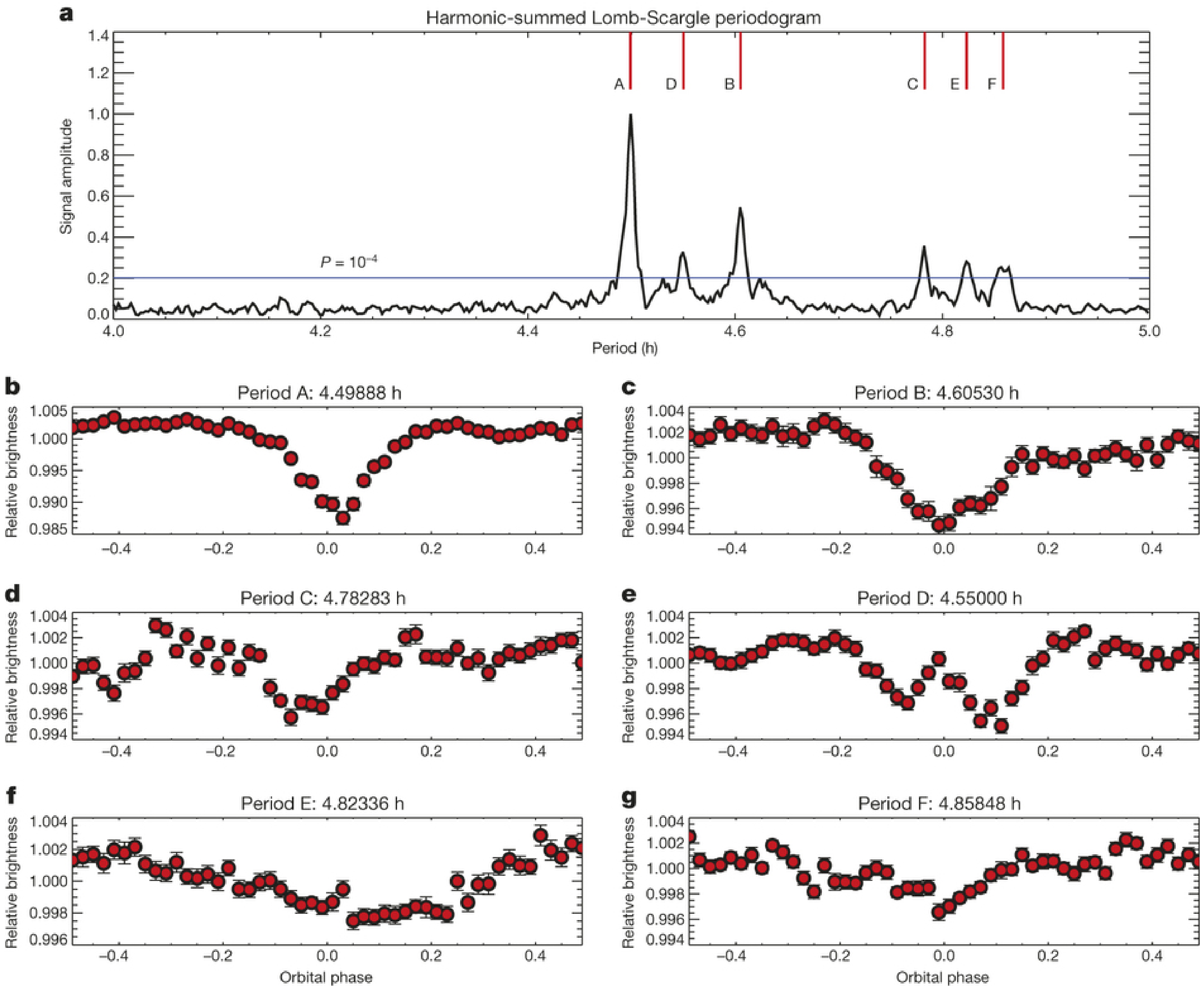
Figure S3: Spectrum of WD 1145+017 and best-fit model. We obtained five 300 second exposures of WD 1145+017 with the MMT Blue Channel spectrograph, summed them together, continuum normalised, and smoothed over a resolution element to produce this figure. We overplot a model spectrum in red, which we fit to the data to measure elemental abundances. The spectrum shows absorption features corresponding to magnesium, aluminium, silicon, calcium, iron, and nickel, which we label. We also see some evidence for titanium and chromium lines.

● 80 days of continuous photometry with 30 minute exposures.

Run a fourier analysis looking for periodicities in the data train.

Much more effective than ground-based monitoring with nasty “window” visibility artefacts.

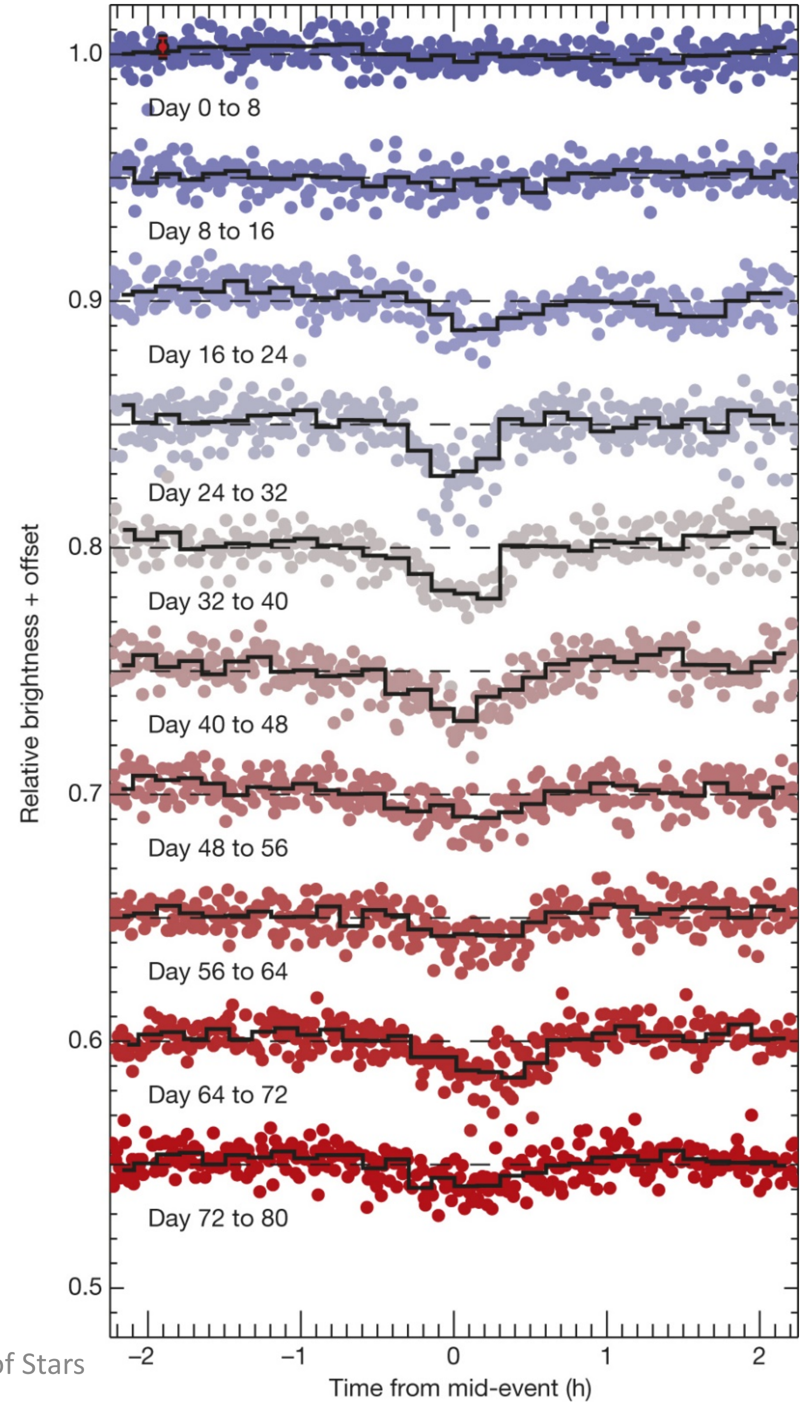
Six periods, all with periods 4.5-4.9 hours



● Evolution of the transit light curve with the 4.5 hour period

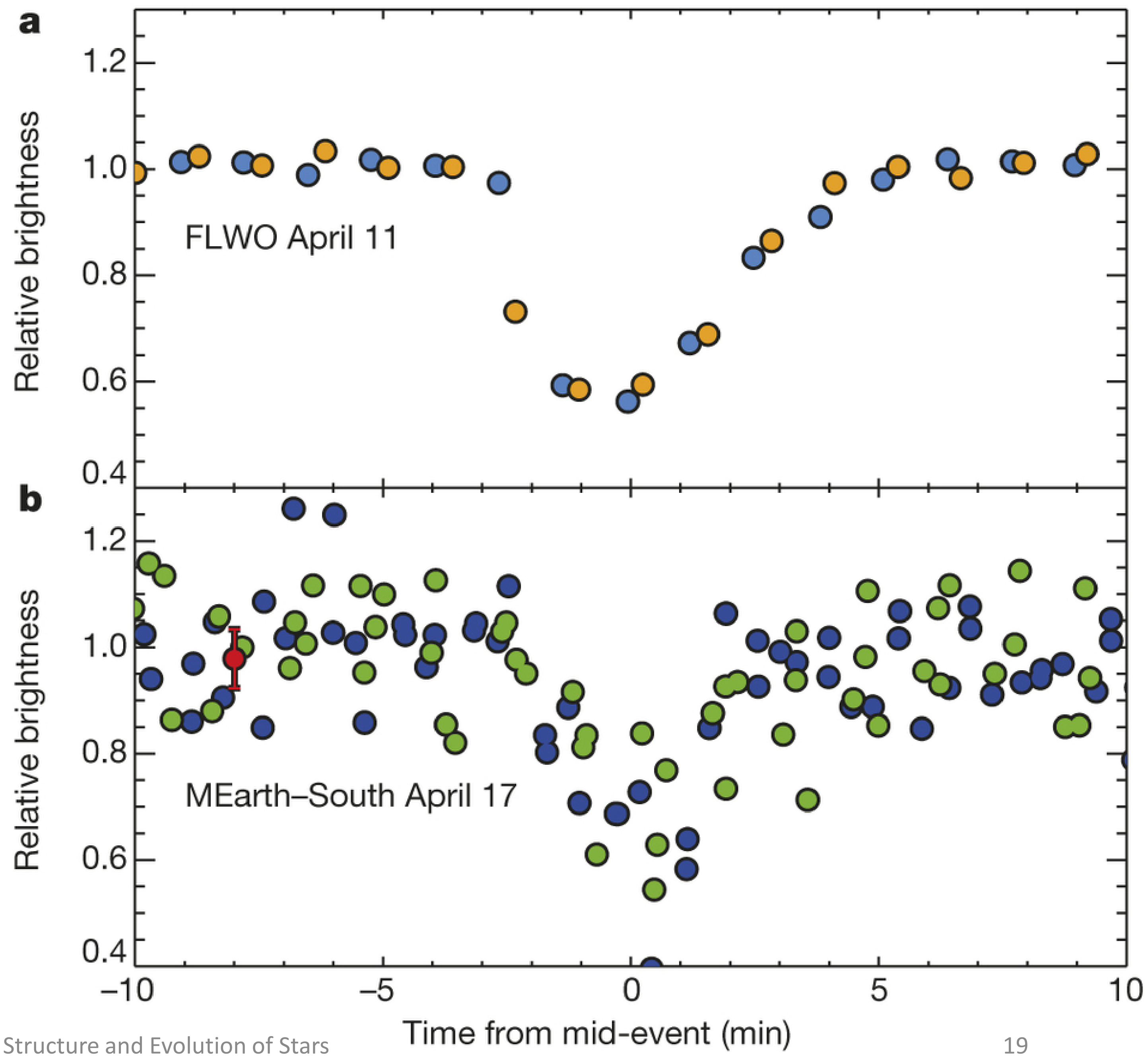
Data plotted in 10-day intervals with solid lines indicating the mean light-curves. Points are the individual 30-minute exposures

Essentially the same period but transit shape asymmetric and changes with time



● Ground-based observations of the white-dwarf at times of predicted 4.5 hour period transits. Each colour is a different transit.

Observations in lower-panel have low signal-to-noise ratio but clear from both sets of observations that transits continue to occur.



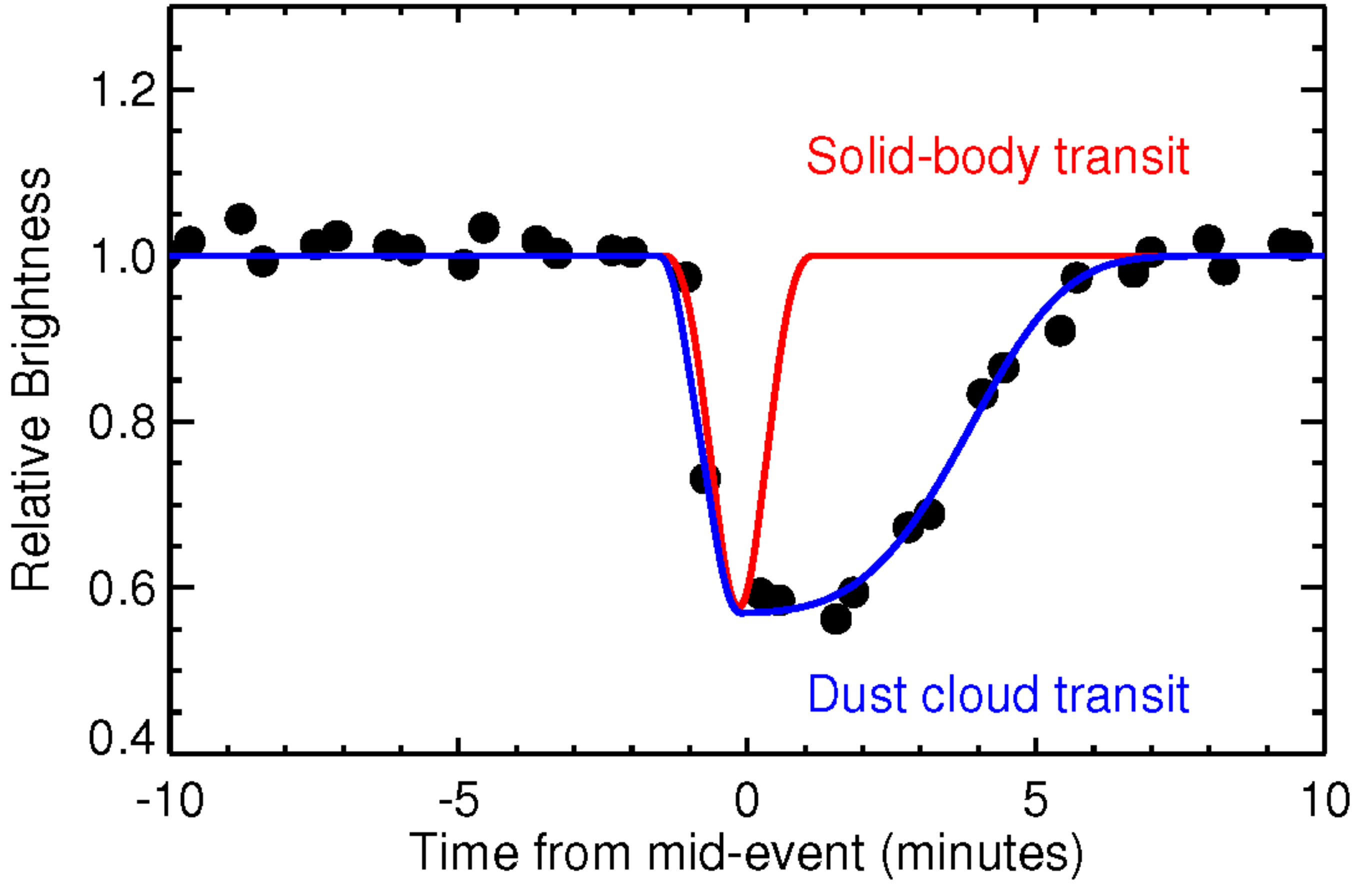
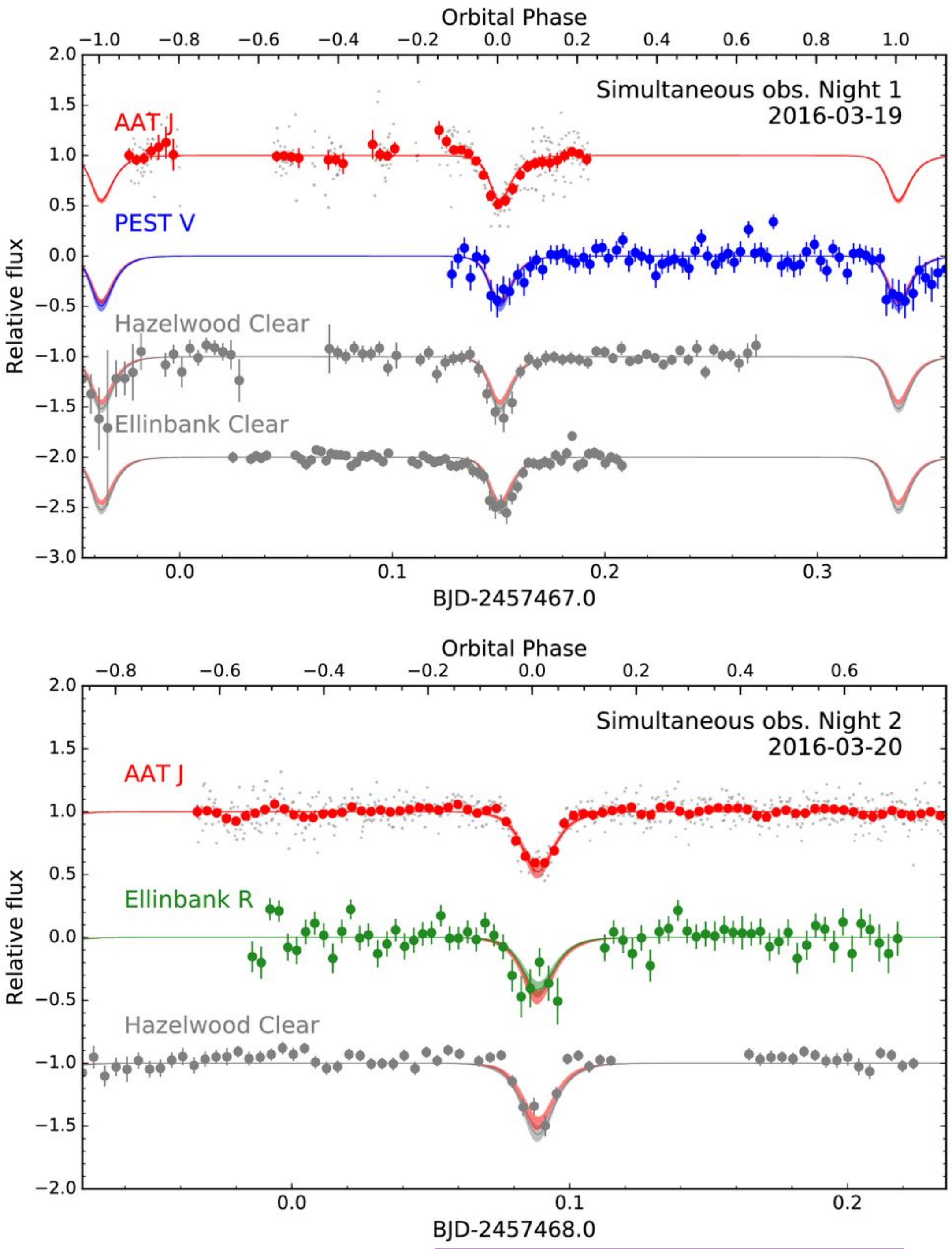


Figure S5: FLWO transits compared with a solid body transit model and a dusty tail transit model. The solid body model (shown in red) is calculated for a sub-Earth sized planet transiting a white dwarf with our stellar parameters in a 4.5 hour orbit, and has a much shorter duration than we see. The dust transit model (blue) simulates a dusty tail crossing over the star with optical depth $\tau \propto \exp(-ax^4)$, where a is a free parameter. The typical measurement uncertainties are smaller than the size of the symbols.

The light curves of WD 1145+017 from 2016 March 19 (top panel) and 2016 March 20 (bottom panel), simultaneously observed by the AAT in the infrared J band, and by three small telescopes in the optical.

G. Zhou et al. MNRAS 2016;463:4422-4432



What do the observations tell us about the obscuring material?