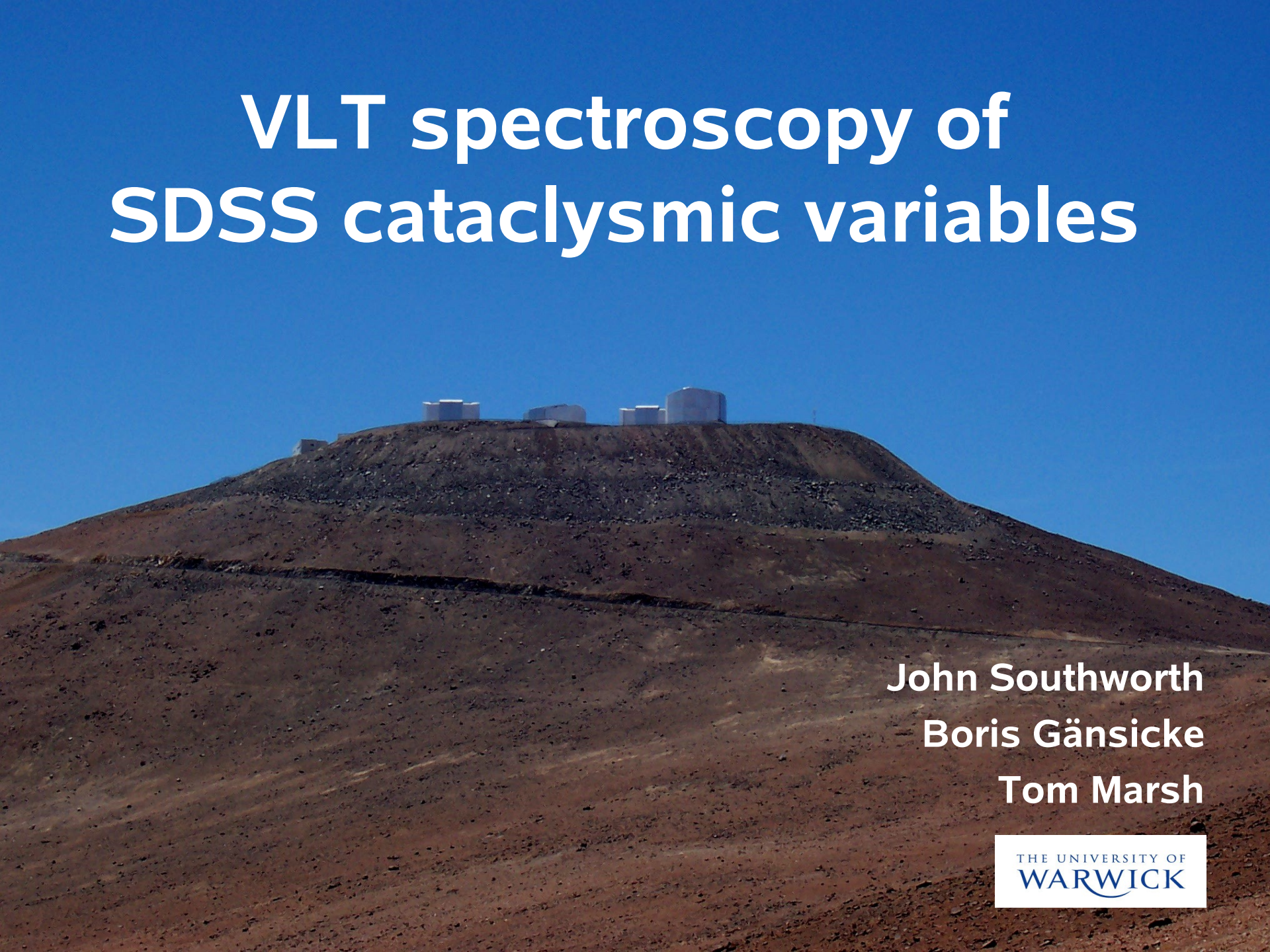
# VLT spectroscopy of SDSS cataclysmic variables



John Southworth
Boris Gänsicke
Tom Marsh

THE UNIVERSITY OF WARWICK

# How do CVs occur?

- Common envelope evolution
  - Close binary containing white dwarf and M dwarf
- Angular momentum loss by magnetic braking
  - P = 3 hours: donor shrinks so mass transfer ceases

# How do CVs occur?

- Common envelope evolution
  - Close binary containing white dwarf and M dwarf
- Angular momentum loss by magnetic braking
  - P = 3 hours: donor shrinks so mass transfer ceases
- Angular momentum loss by gravitational radiation
  - P = 2 hours: mass donor fills Roche Lobe again
  - Mass transfer restarts, period decreases

# How do CVs occur?

- Common envelope evolution
  - Close binary containing white dwarf and M dwarf
- Angular momentum loss by magnetic braking
  - P = 3 hours: donor shrinks so mass transfer ceases
- Angular momentum loss by gravitational radiation
  - P = 2 hours: mass donor fills Roche Lobe again
  - Mass transfer restarts, period decreases
- Minimum period of 80 minutes
  - M dwarf becomes degenerate
  - Period increases
- Old CVs: faint due to low mass transfer

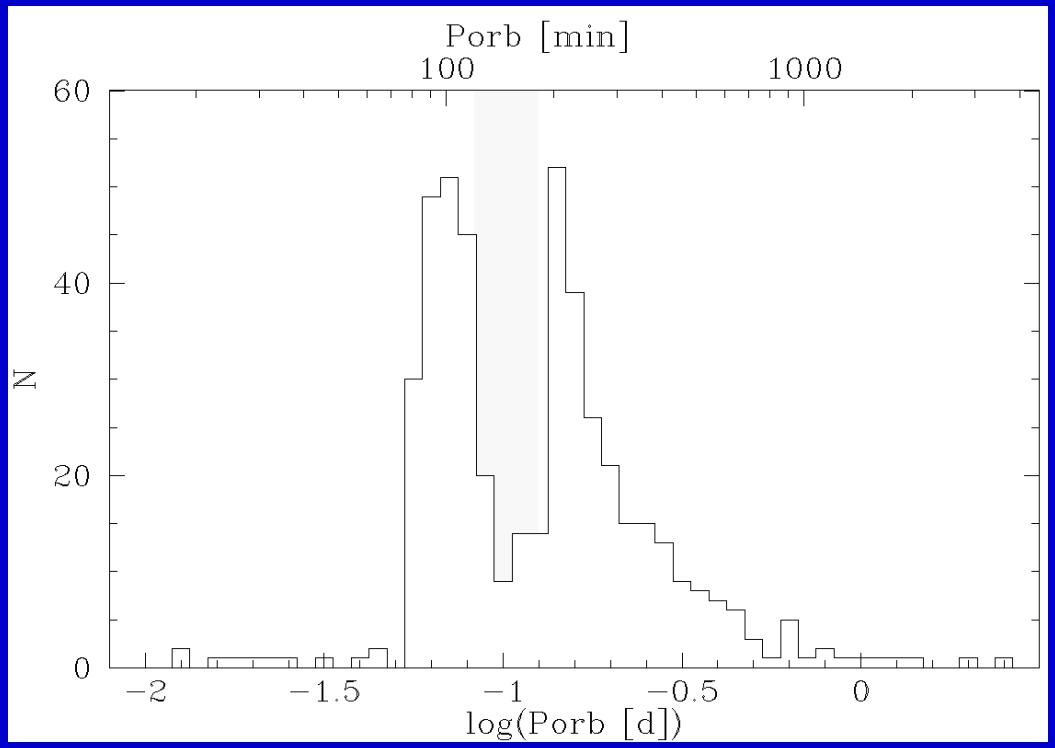
# Binary evolution theory

- Population synthesis models:
  - Standard angular momentum loss
  - Minimum period reached = 65 minutes
  - 99% of CVs should have periods below 2 hours
  - 70% of CVs should have brown dwarf donors

# Binary evolution theory

- Population synthesis models:
  - Standard angular momentum loss
  - Minimum period reached = 65 minutes
  - 99% of CVs should have periods below 2 hours
  - 70% of CVs should have brown dwarf donors

- Observations:
  - Minimum period = 80 minutes
  - Equal numbers of CVs above and below gap
  - No CV with confirmed brown dwarf donor



# SDSS CVs:
## a more homogeneous sample

- CVs traditionally discovered by:
  - Nova outbursts
  - X-ray emission
  - Photometric surveys for blue objects
- SDSS CVs discovered by:
  - *u'g'r'i'z'* colours different to normal MS stars
  - Balmer and helium spectral line emission
  - Faintest magnitude ~20:  almost volume limited

# SDSS CVs:
## a more homogeneous sample

- CVs traditionally discovered by:
  - Nova outbursts
  - X-ray emission
  - Photometric surveys for blue objects
- SDSS CVs discovered by:
  - *u'g'r'i'z'* colours different to normal MS stars
  - Balmer and helium spectral line emission
  - Faintest magnitude ~20:  almost volume limited

- **SDSS may have found the faint short-period CVs which theory says should exist**

# VLT spectroscopy of faint SDSS CVs

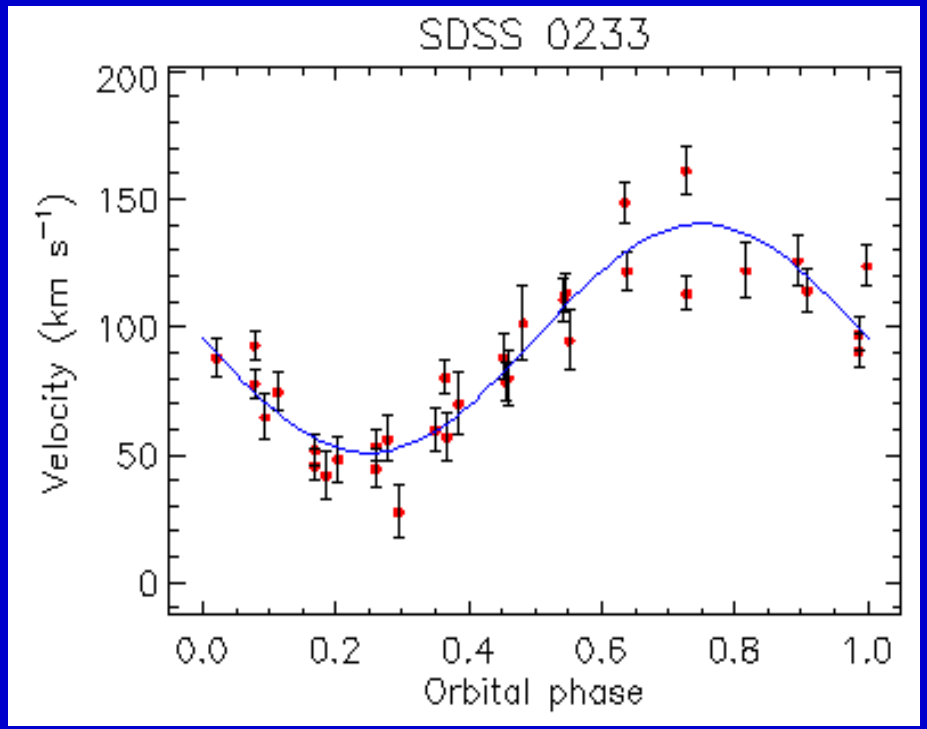
- UT2 + FORS2 grism spectrograph
- H$\alpha$ observations at 1.2 Å/px
- H$\beta$ observations at 1.5 Å/px

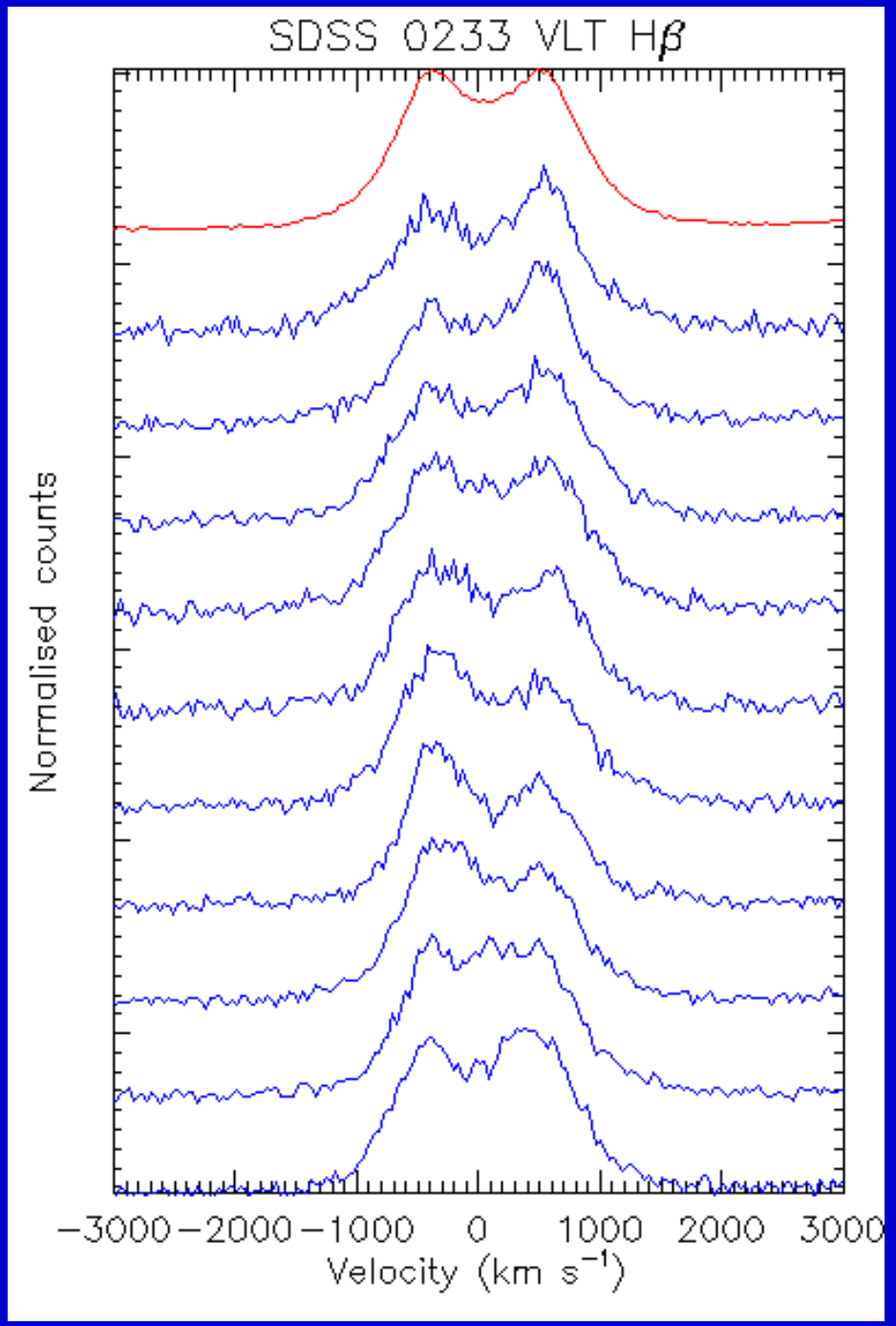
# VLT spectroscopy of faint SDSS CVs

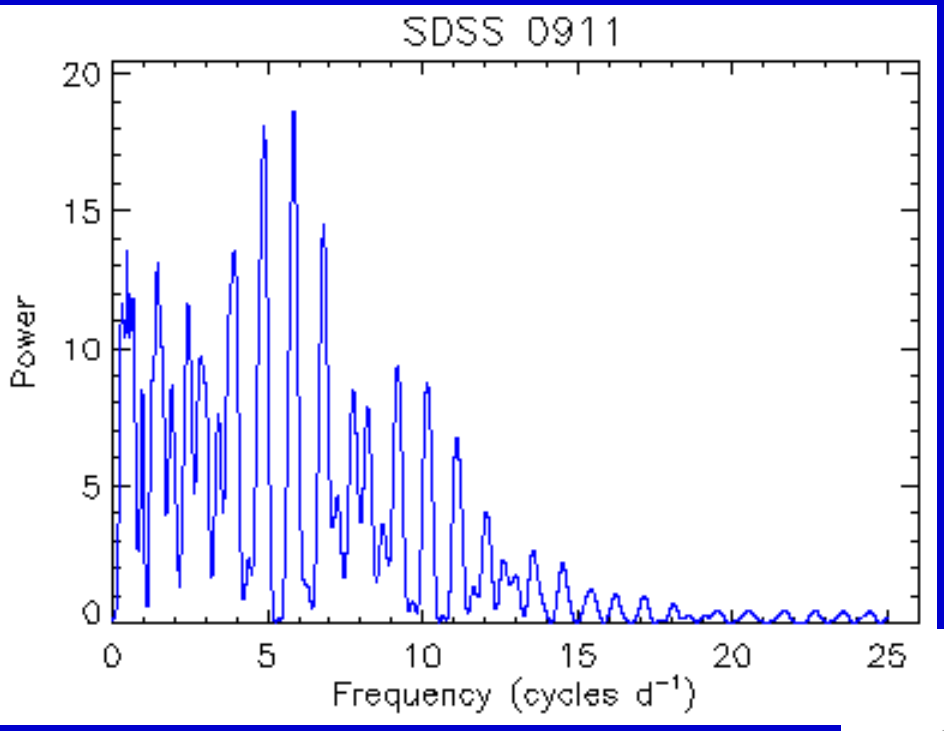
- Radial velocities measured using double Gaussians
- Period search: Scargle periodograms
- Spectroscopic orbits fitted: SBOP

# SDSS 0233

- Double-peaked emission lines
- Orbital period:
  96.08 ± 0.09 minutes

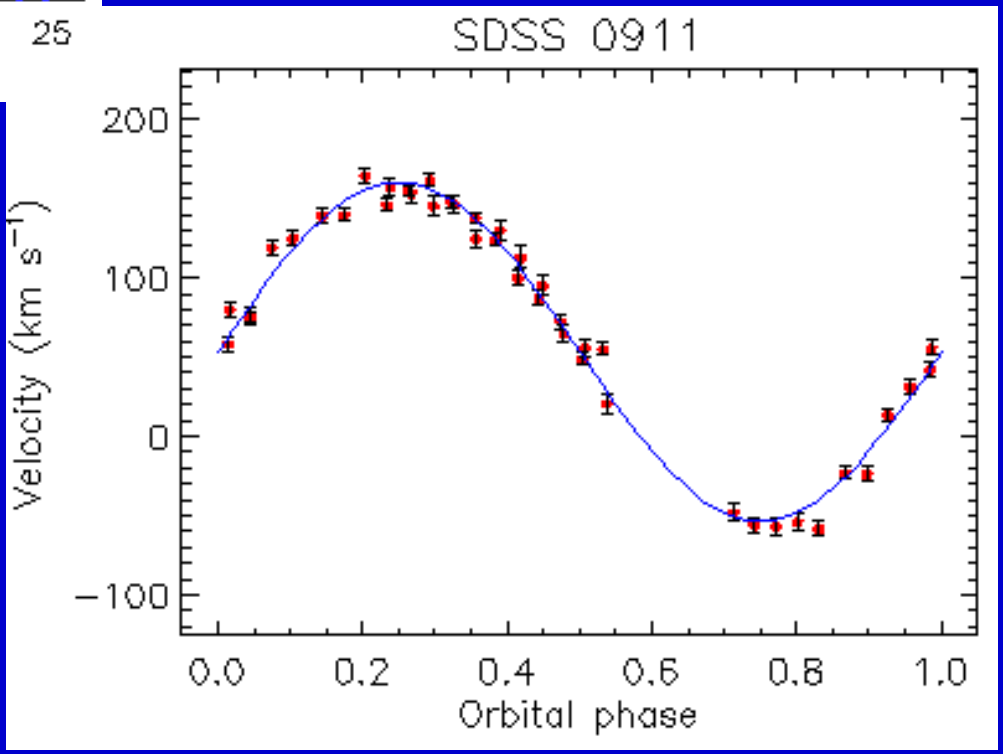


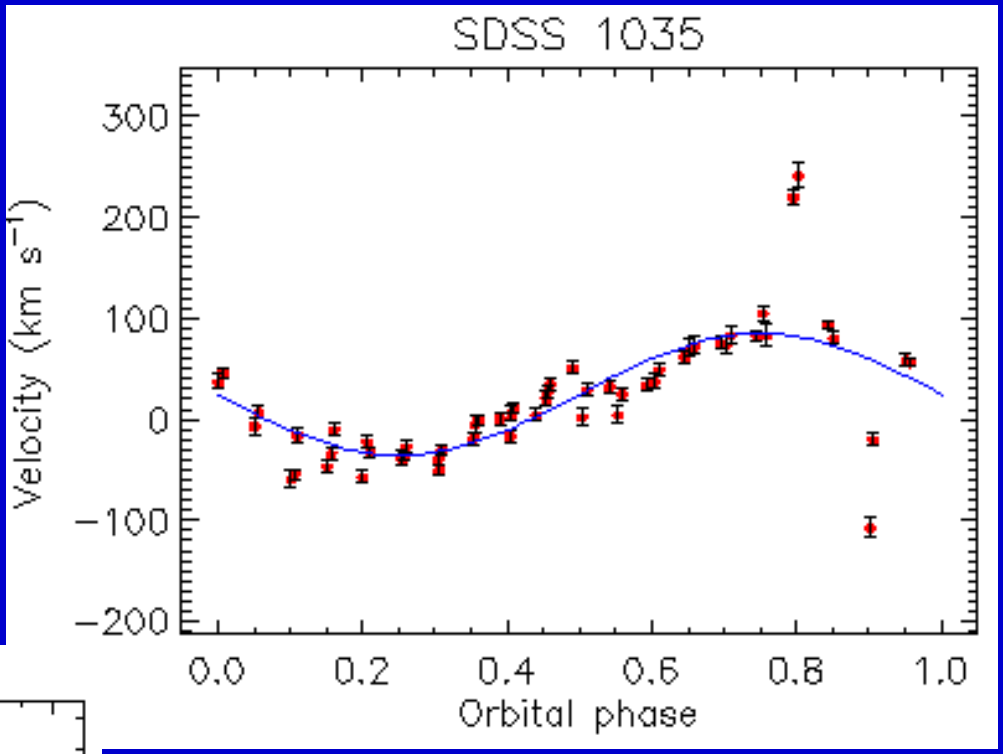


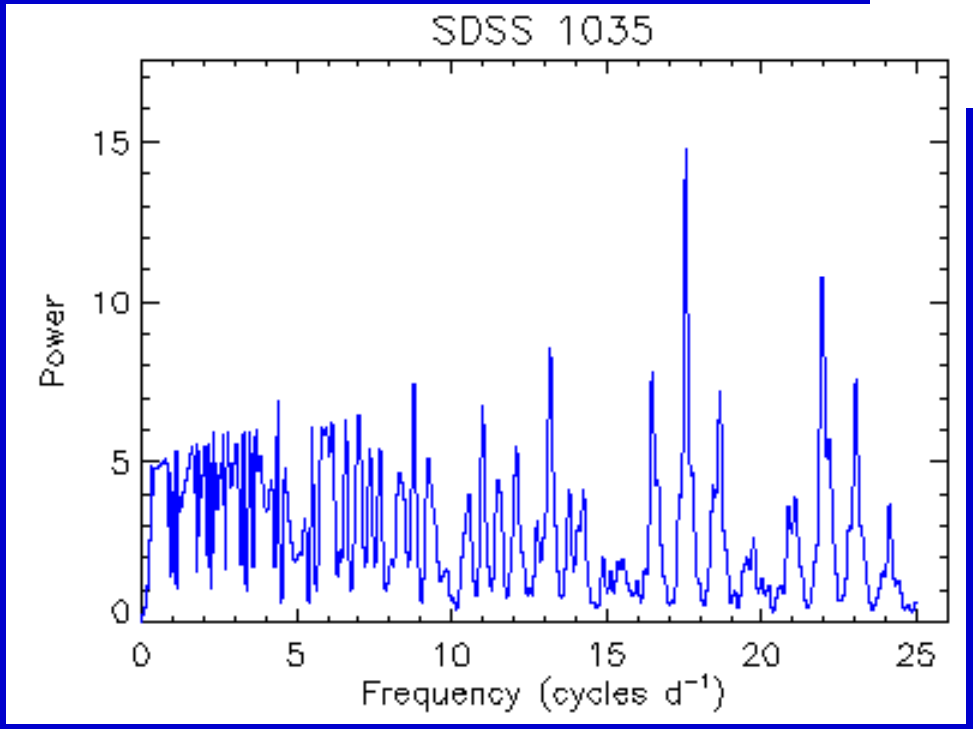

# SDSS 0911

- Two possible periods: 5 and 6 hours
  - 6hr period gives sinusoidal radial velocities
- Orbital period: 295.74 ± 0.22 minutes



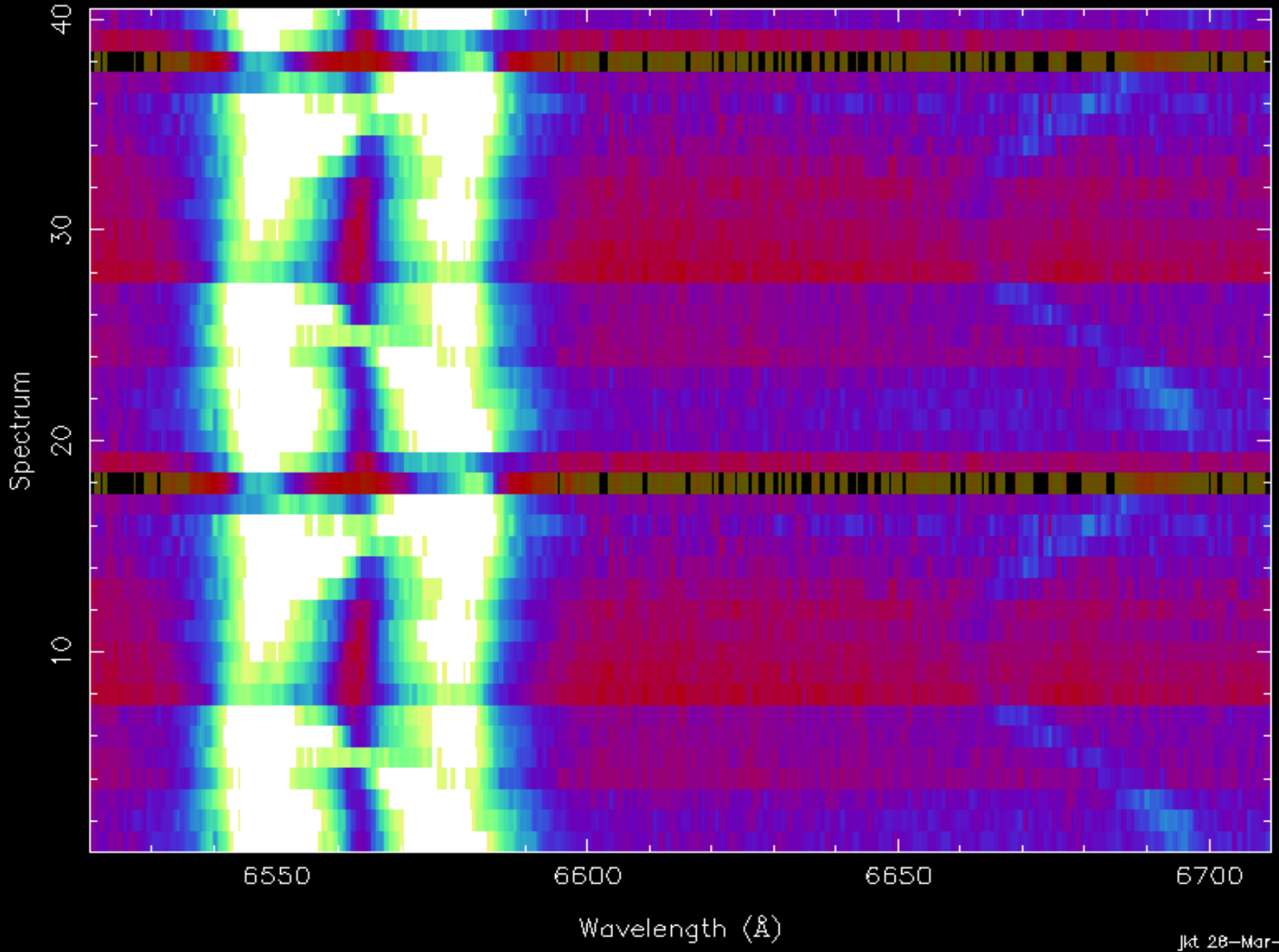
# SDSS 1035: eclipsing

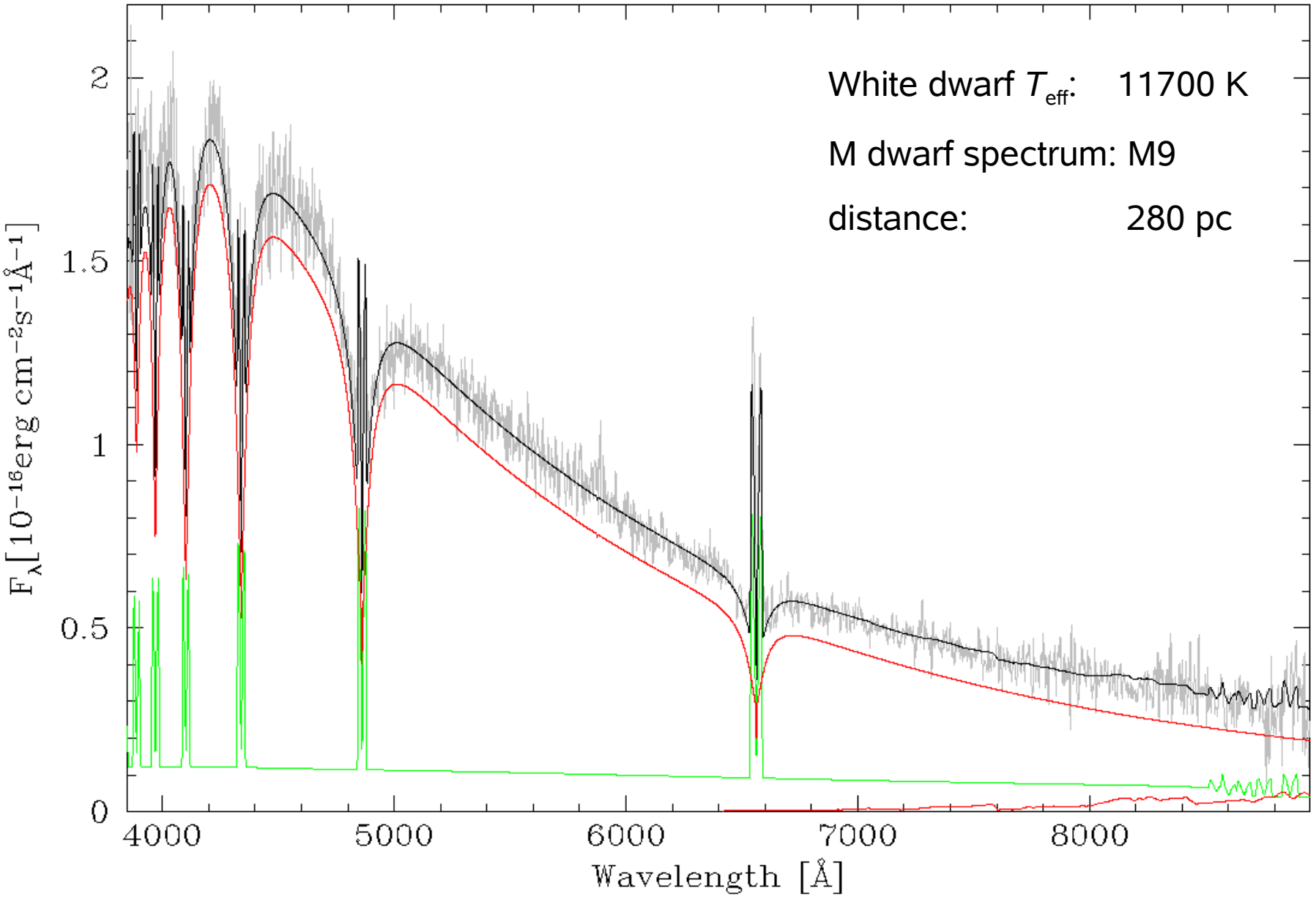



- Orbital period: 82.10 ± 0.09 minutes
- Radial velocities perturbed by eclipses

# SDSS 1035 eclipses

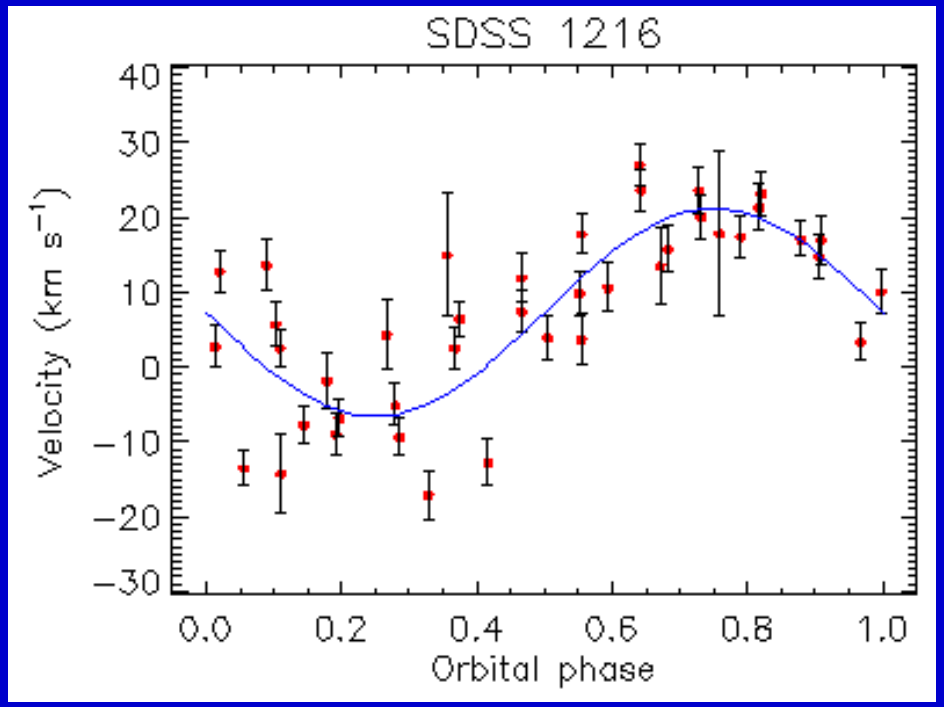


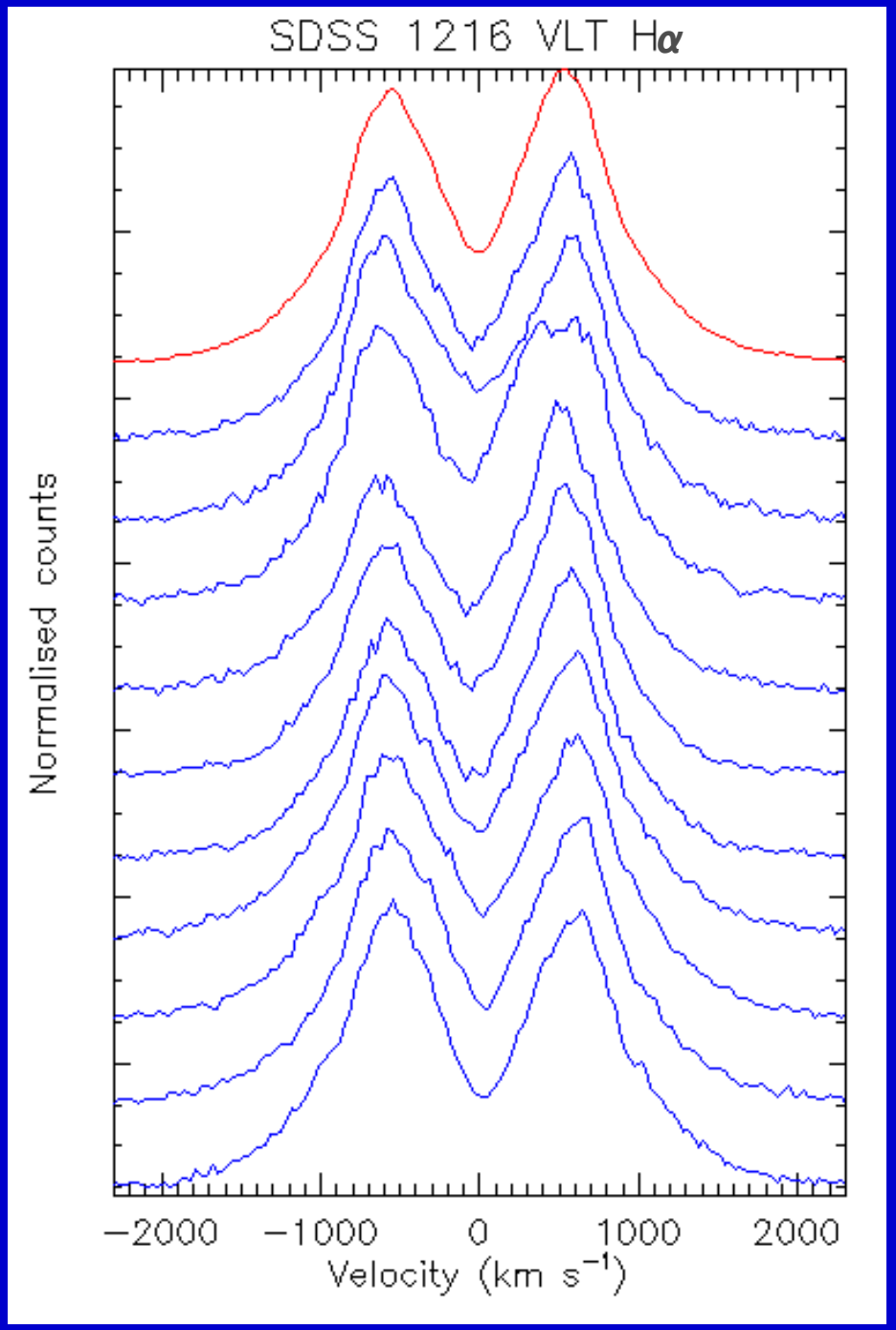

White dwarf $T_{eff}$: 11700 K
M dwarf spectrum: M9
distance: 280 pc
$F_\lambda [10^{-16} erg\ cm^{-2} s^{-1} Å^{-1}]$
0
0.5
1
1.5
2
4000
5000
6000
7000
8000
Wavelength [Å]

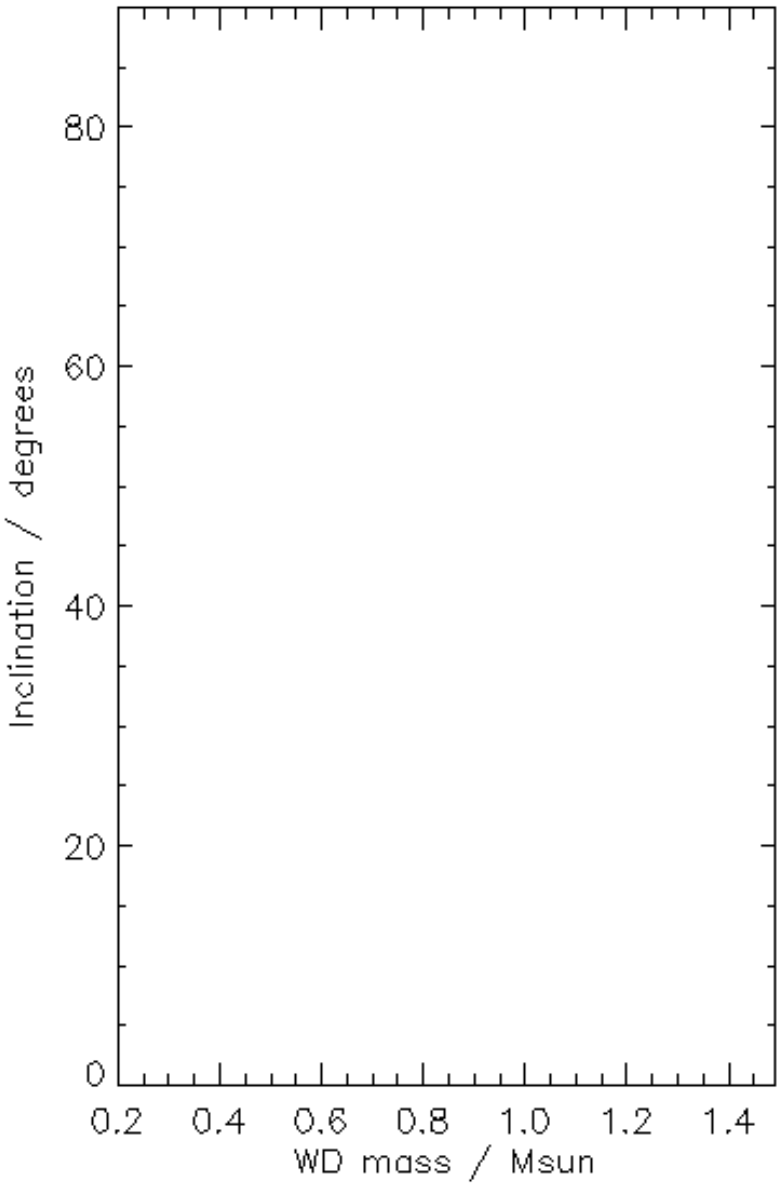
SDSS 1035

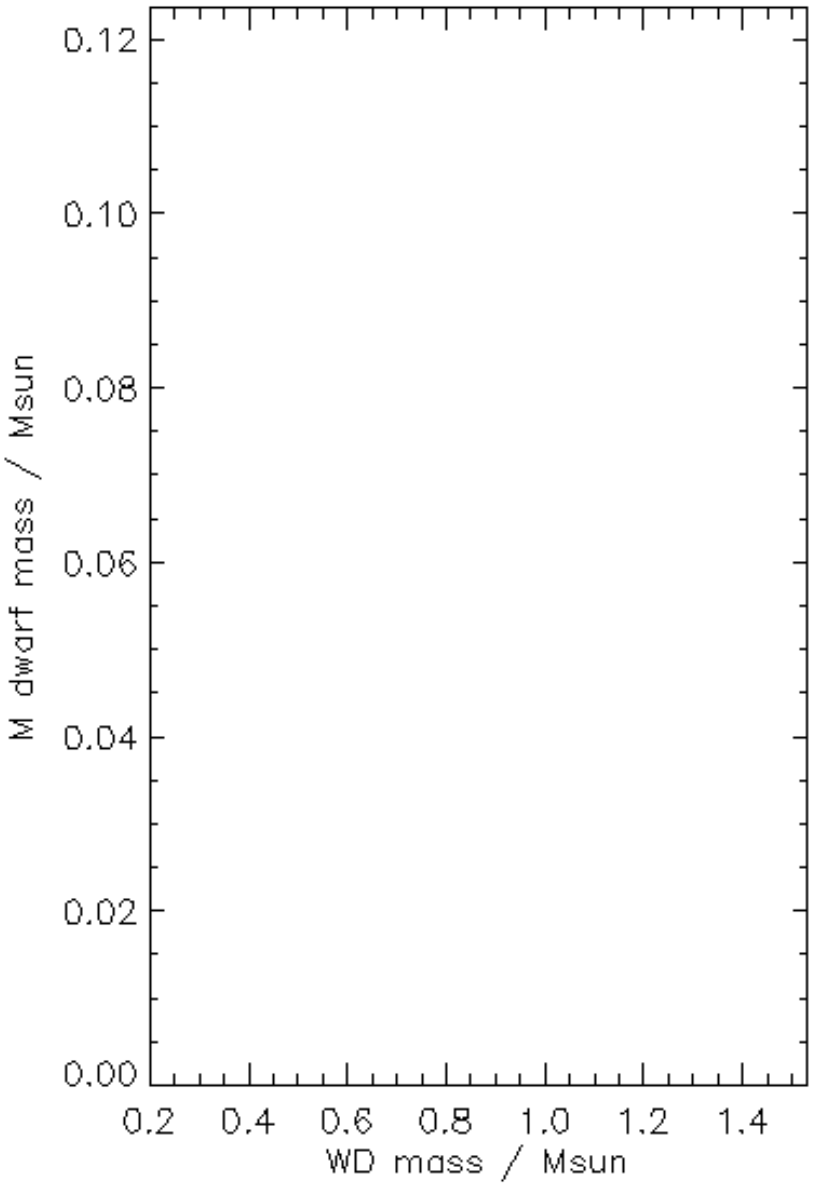
# SDSS 1216: low-mass donor

- Orbital period:
  98.82 ± 0.16 minutes
- Velocity semiamplitude:
  13.8 ± 1.6 km/s

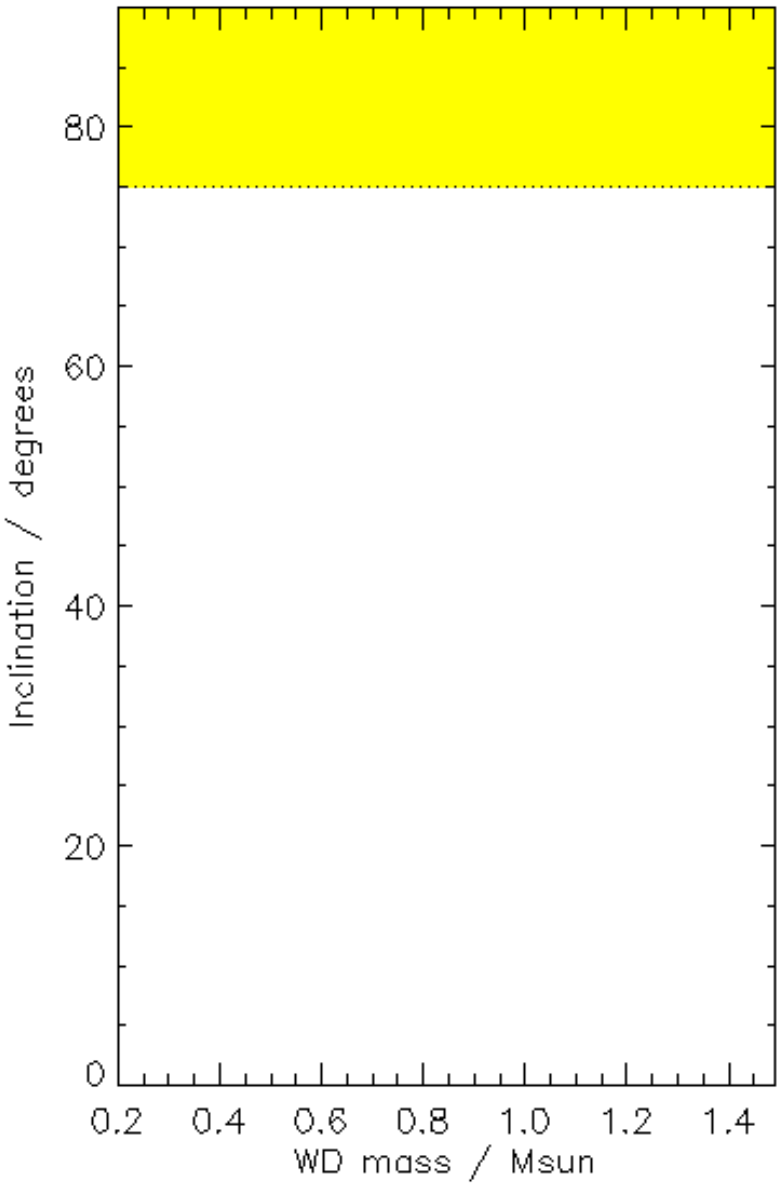


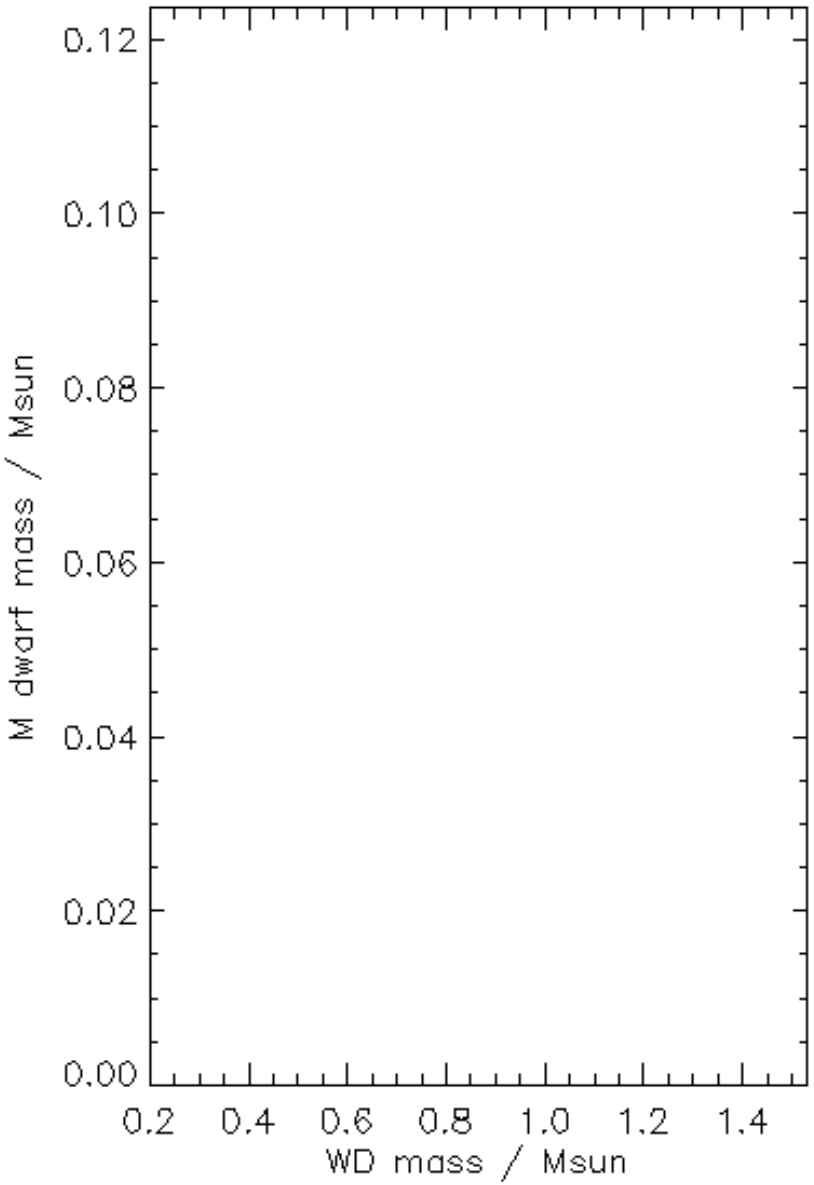




Inclination / degrees
0
20
40
60
80
0.2
0.4
0.6
0.8
1.0
1.2
1.4
WD mass / Msun

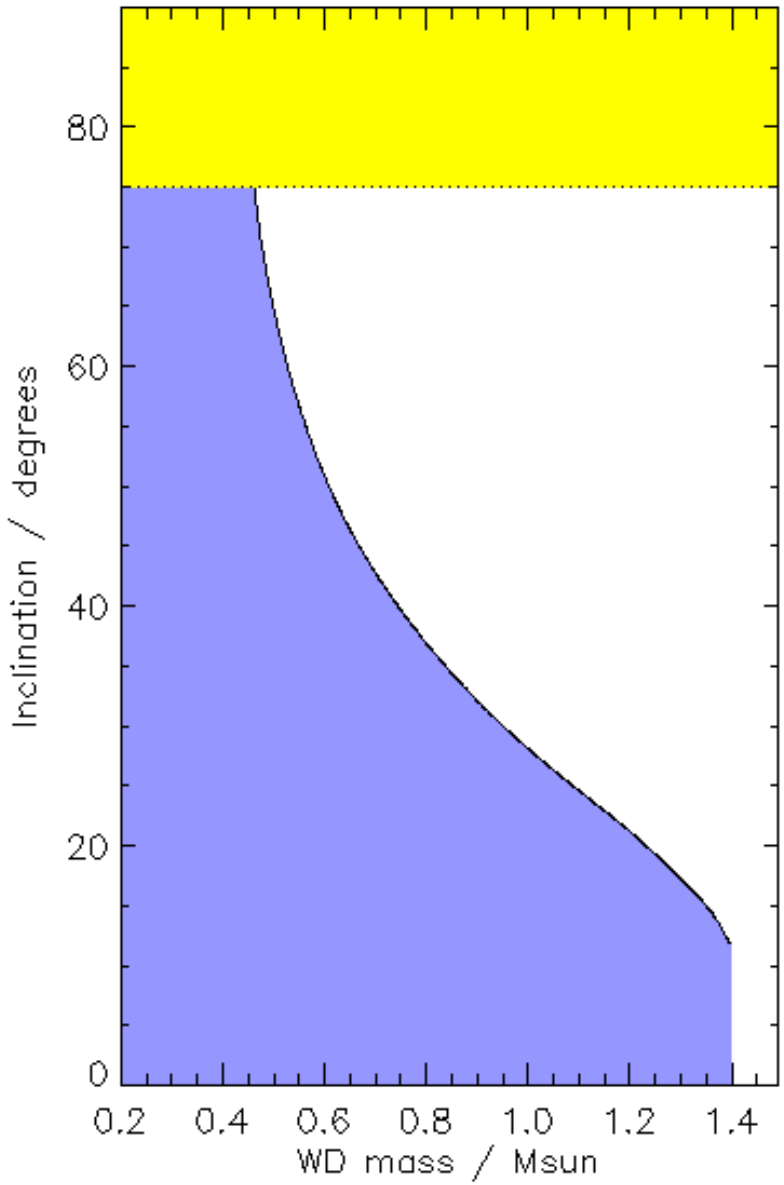

M dwarf mass / Msun
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.2
0.4
0.6
0.8
1.0
1.2
1.4
WD mass / Msun

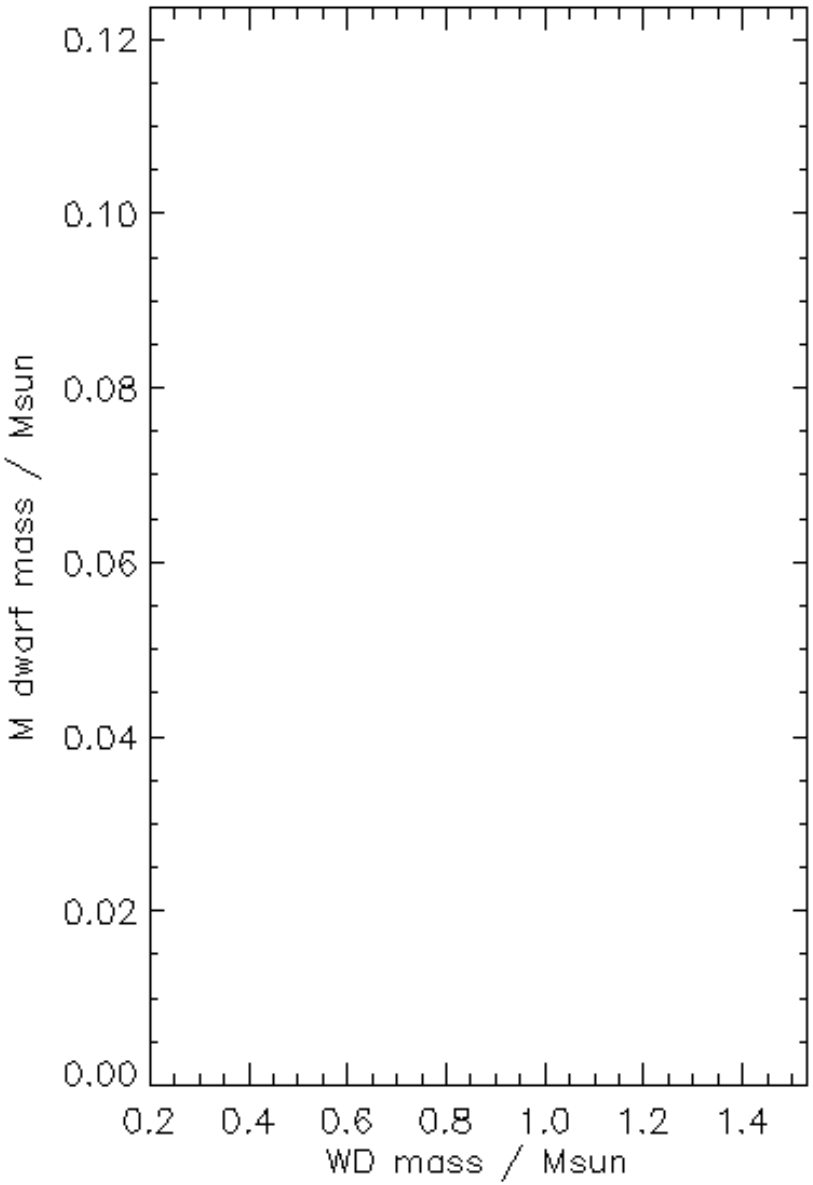
# SDSS 1216



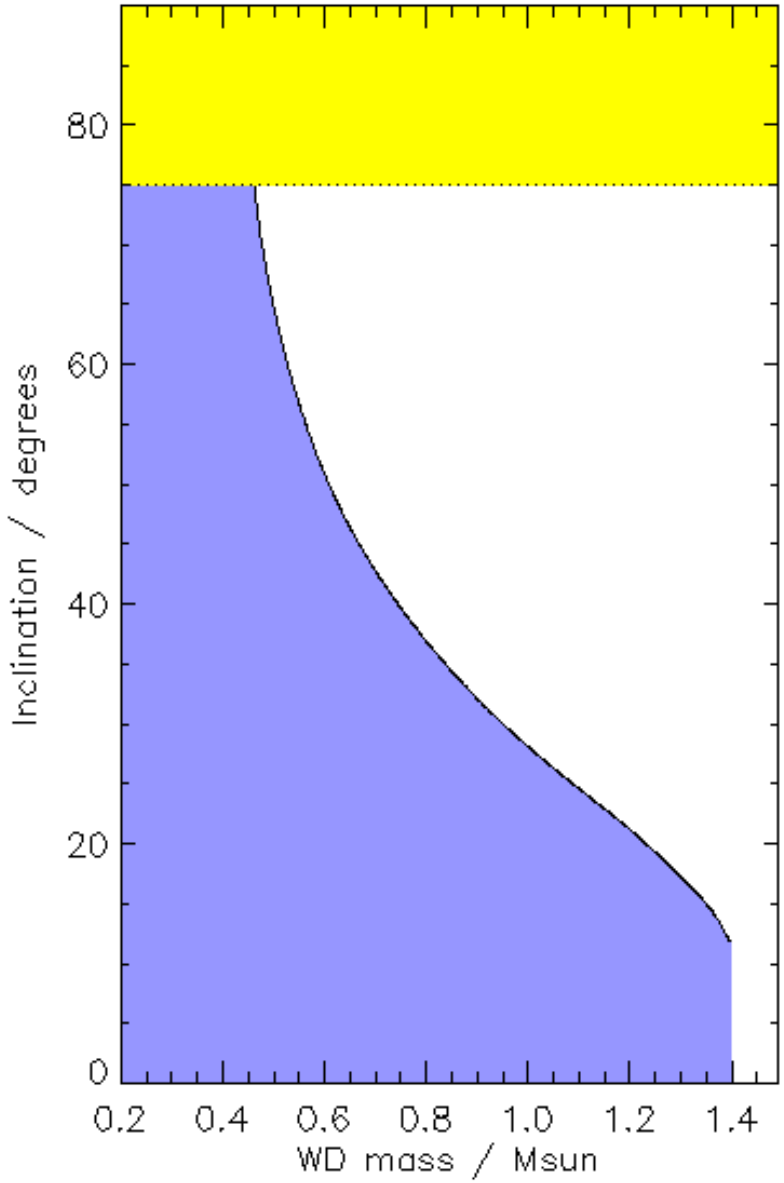



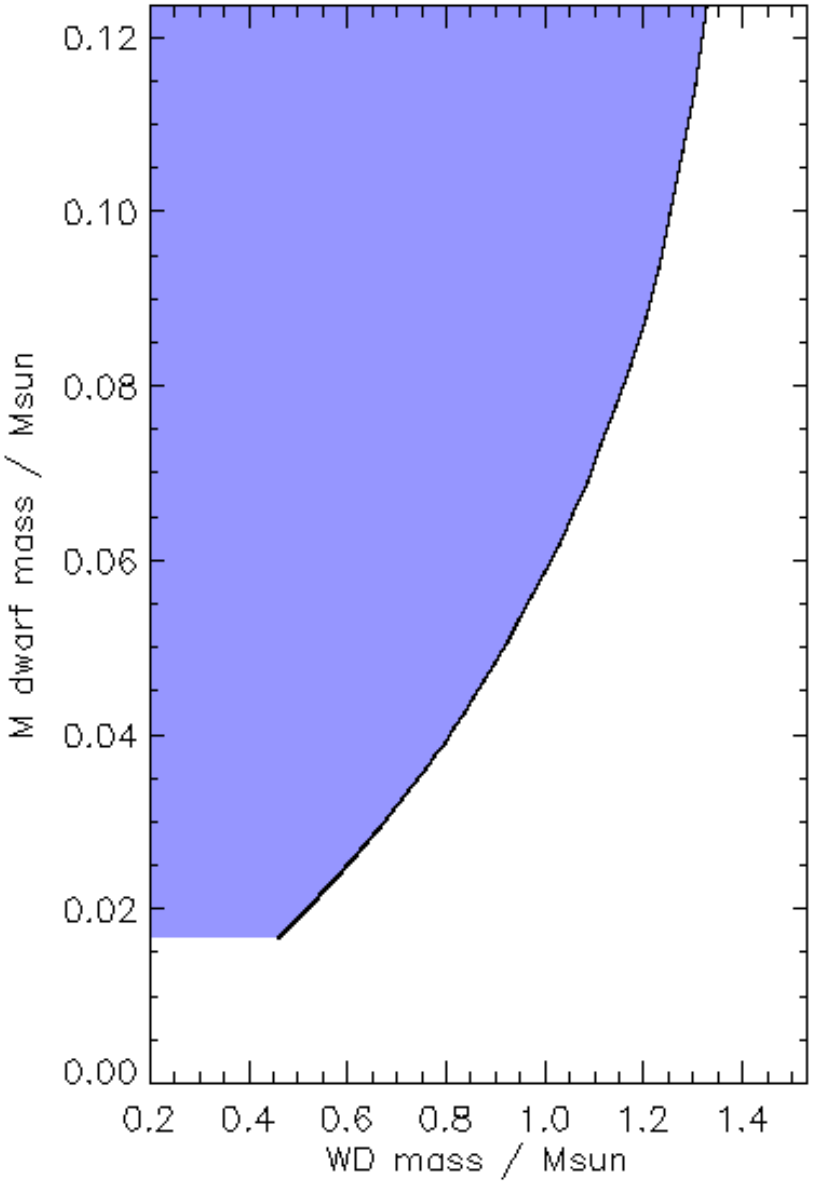

No eclipses seen in the spectra: $i < 75^{o}$



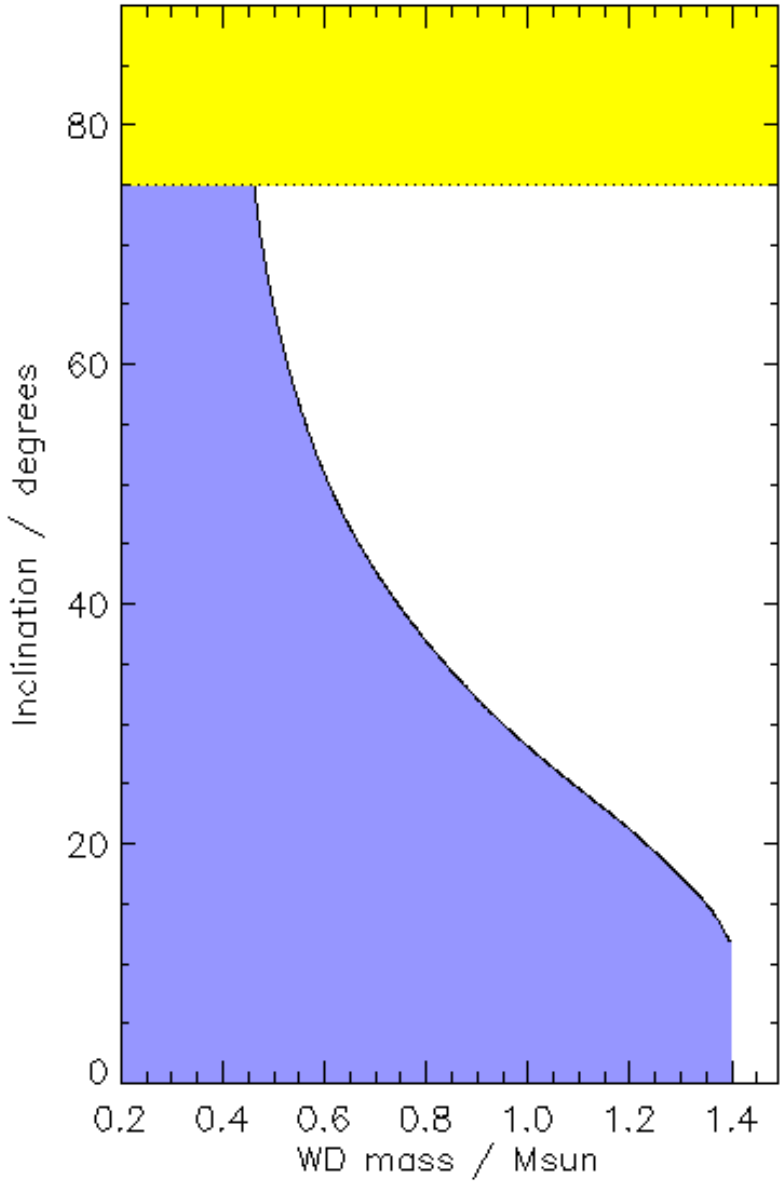



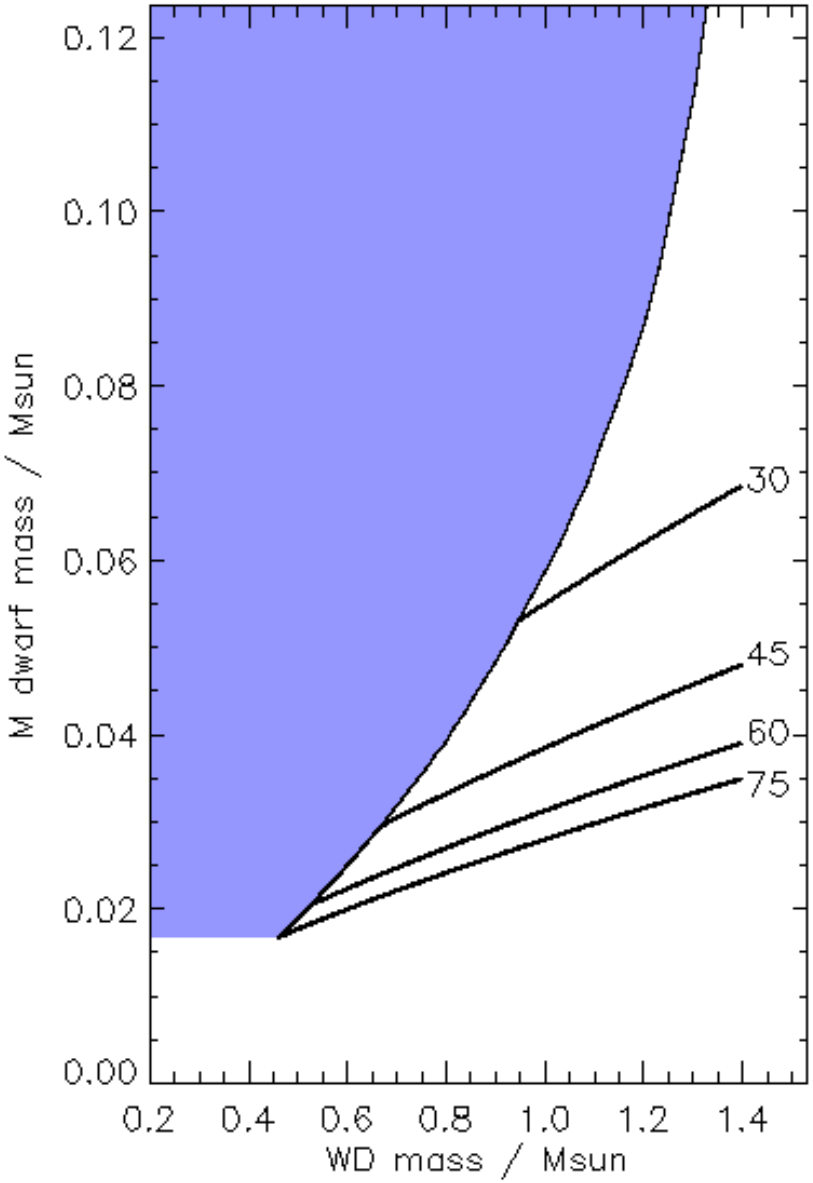

Maximum velocity in emission line: 2290 ± 230 km/s



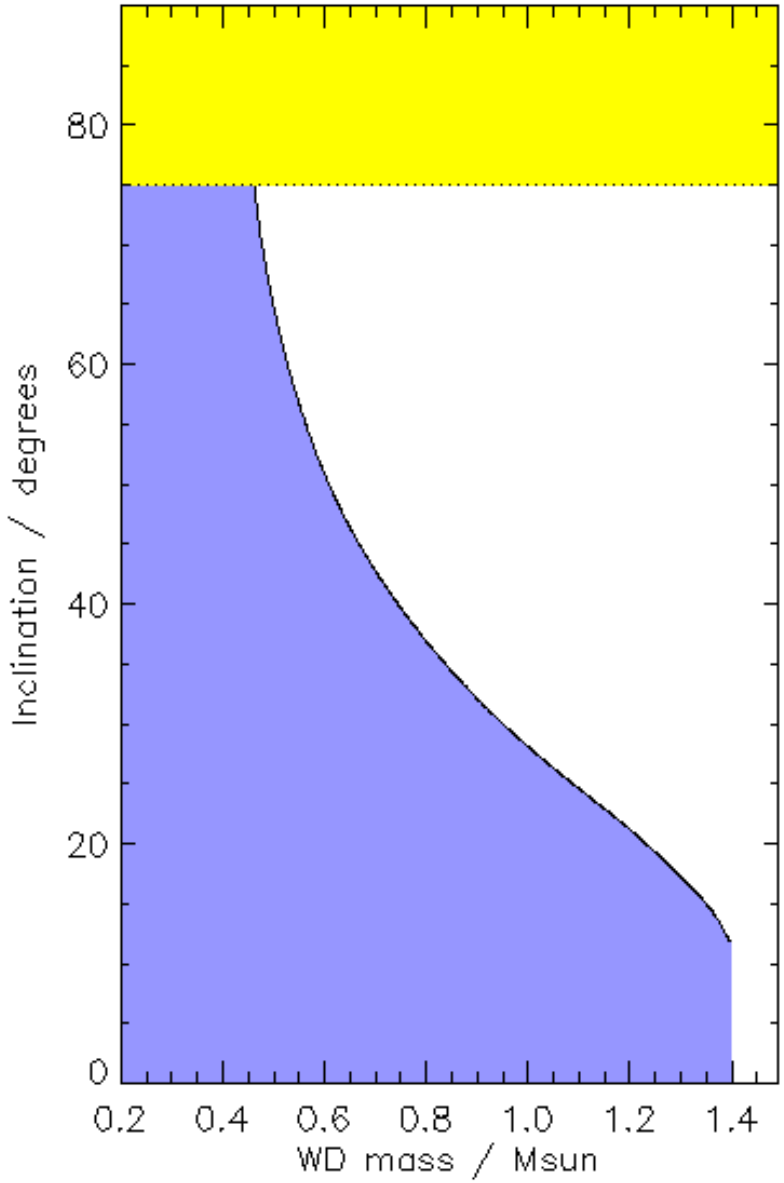



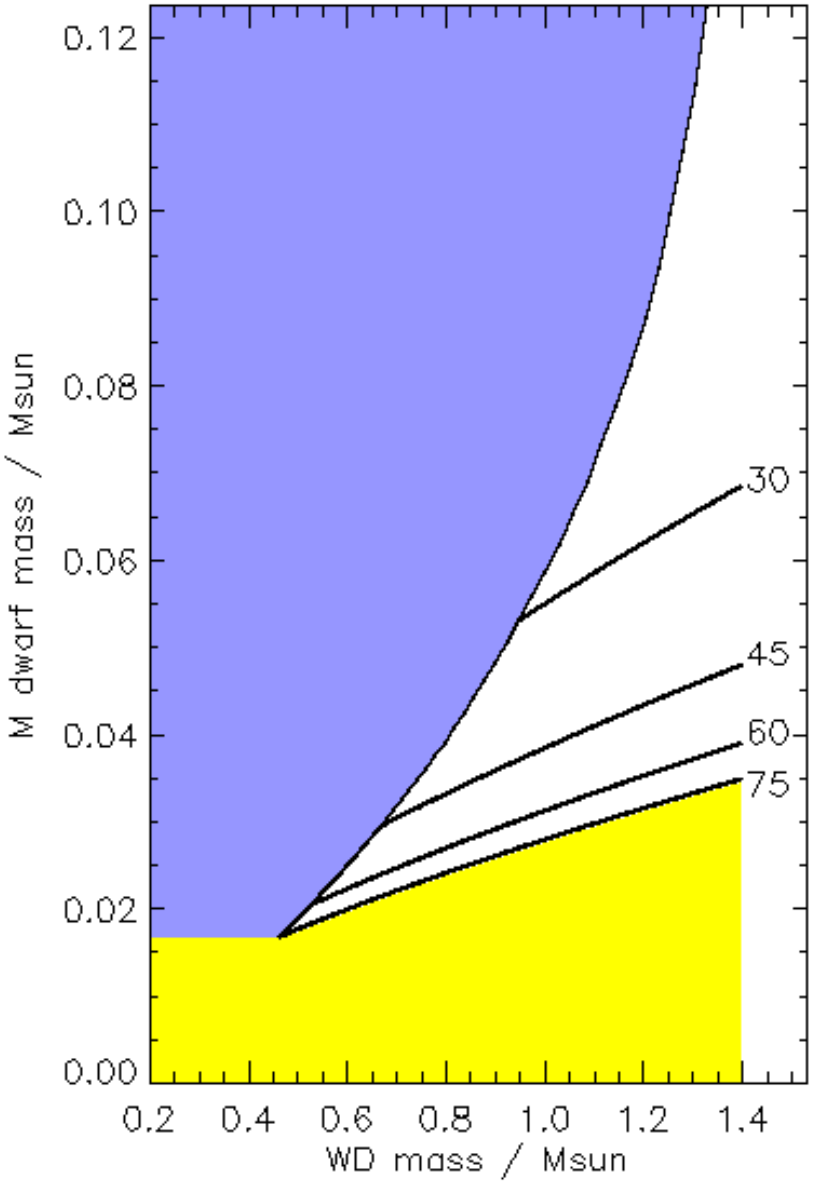

Maximum velocity constraint




Mass function: $f(M) = (1.8 \pm 0.6) \times 10^{-5}\ M$




No eclipses seen in the spectra: $i < 75^{o}$

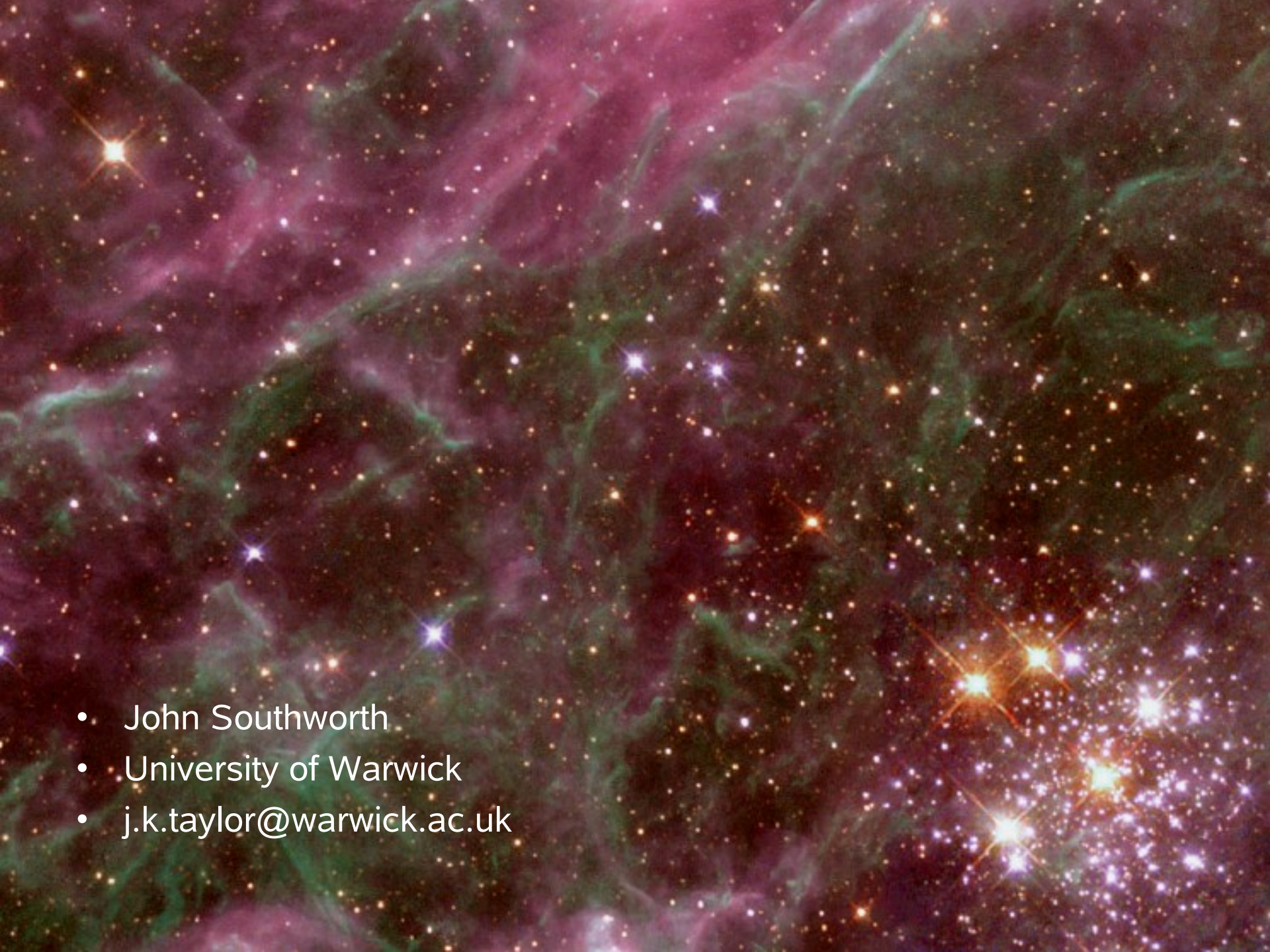
# Conclusions

- SDSS 0233: 96 minute period
- SDSS 0911: 296 minute period
- SDSS 1035: 82 minute period, eclipsing
- SDSS 1216: 99 minute period, low-mass donor star

# Conclusions

- SDSS 0233: 96 minute period
- SDSS 0911: 296 minute period
- SDSS 1035: 82 minute period, eclipsing
- SDSS 1216: 99 minute period, low-mass donor star

- CVs discovered by the SDSS are a more homogeneous sample
  - Less strongly biased towards high mass transfer rates
  - Finding more short-period CVs
  - Binary evolution models may be better than we think




- John Southworth
- University of Warwick
- j.k.taylor@warwick.ac.uk