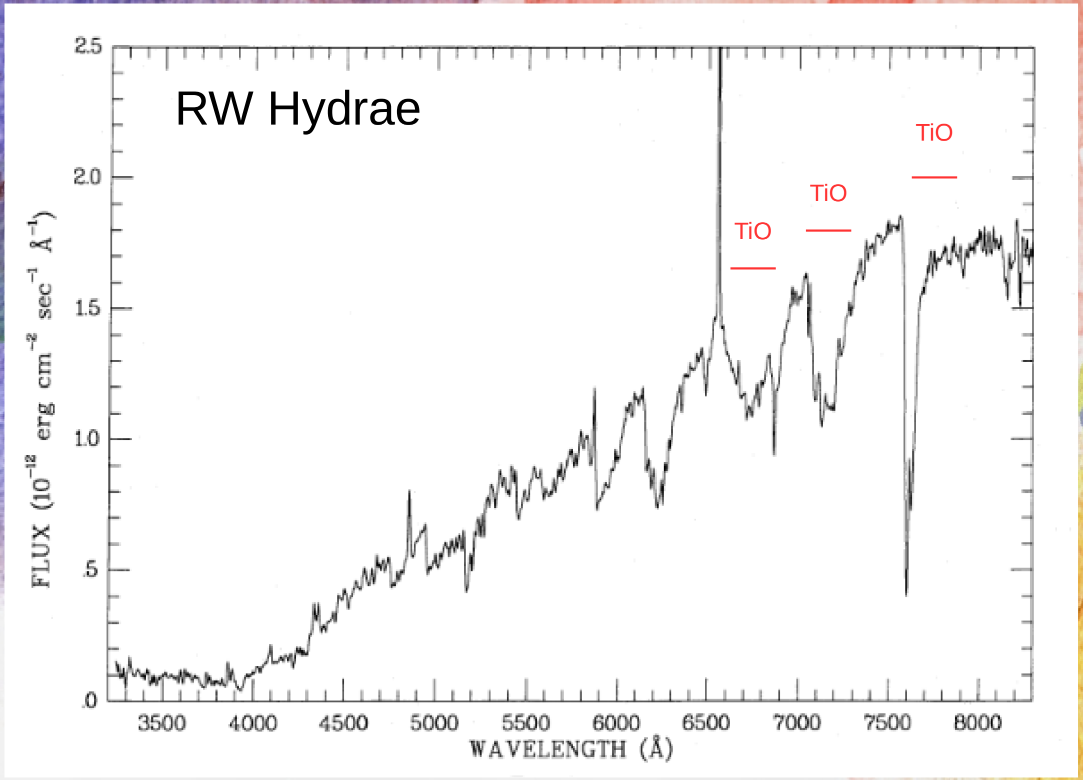
32 years of optical spectroscopy for the symbiotic binary PU Vul

Virginia Cúneo

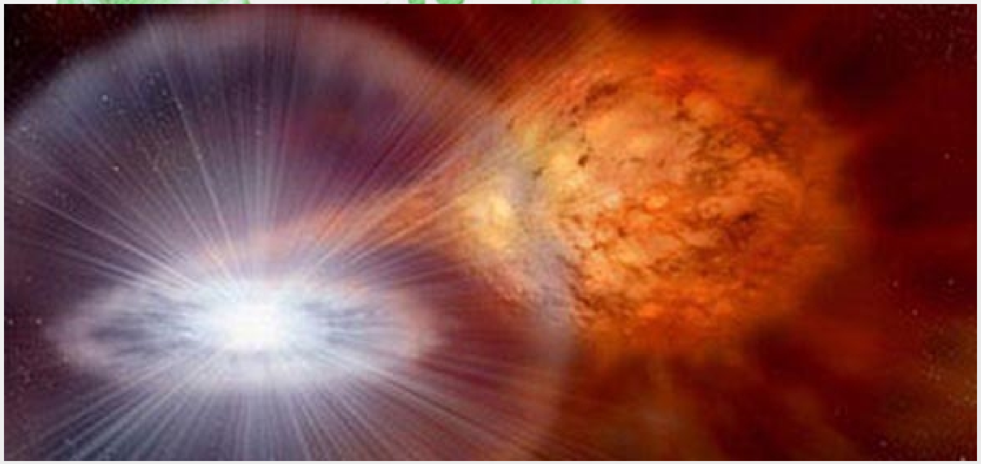
Dr. Mercedes Gómez
Dr. Scott Kenyon

Symbiotic Stars

- Merrill & Humason, 1932
- Giant 3 M-type stars with He II (λ4686) line in strong emission
- Long period “Peculiar variables”
- Nova-like eruption with ~3 mag amplitude



Kenyon & Fernandez-Castro (1987)

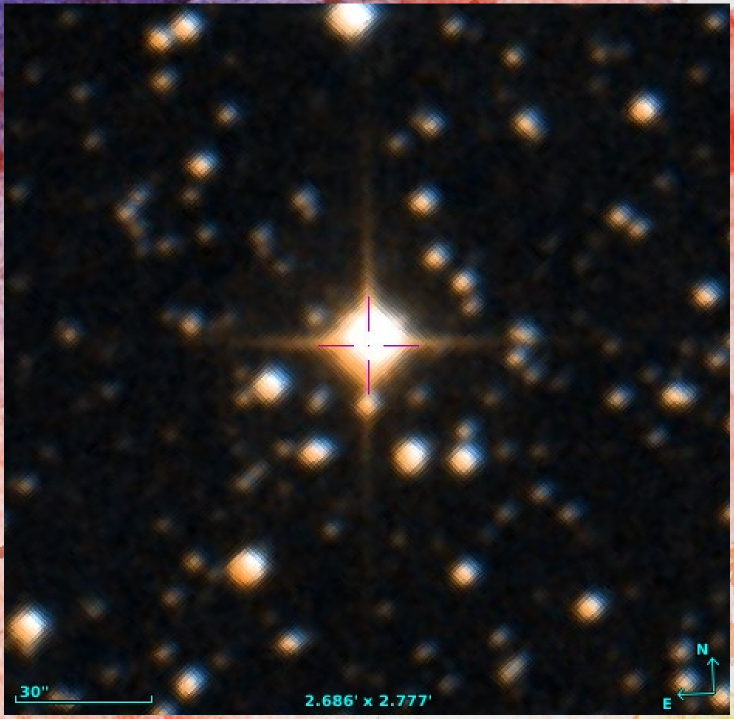


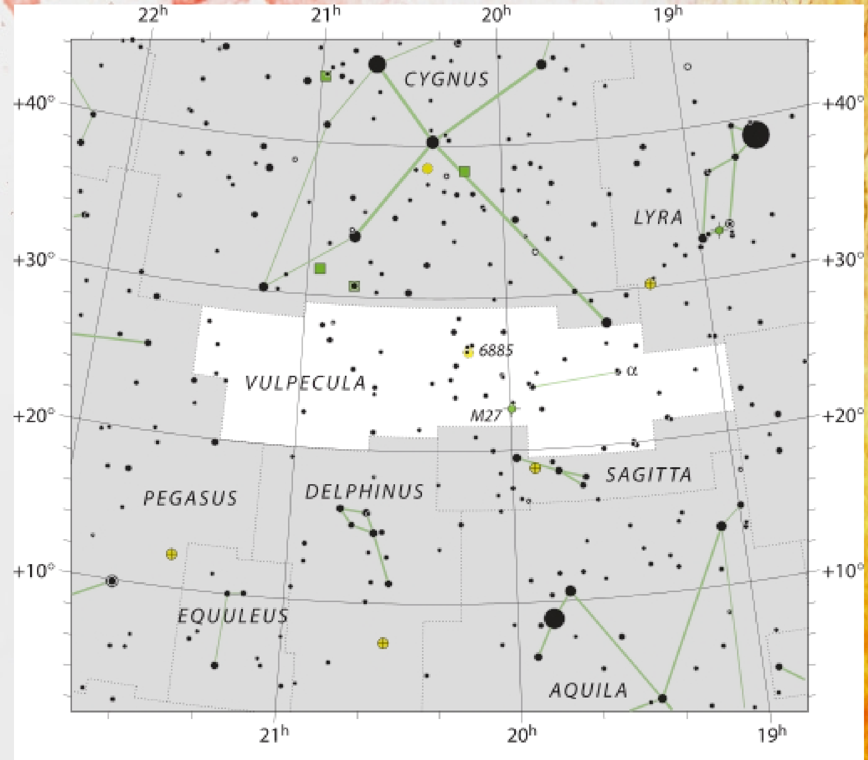
Symbiotic novae

- Closed system
- Thermonuclear bursts that can last several years
- Mira-type companion
- Long periods

PU Vulpecula

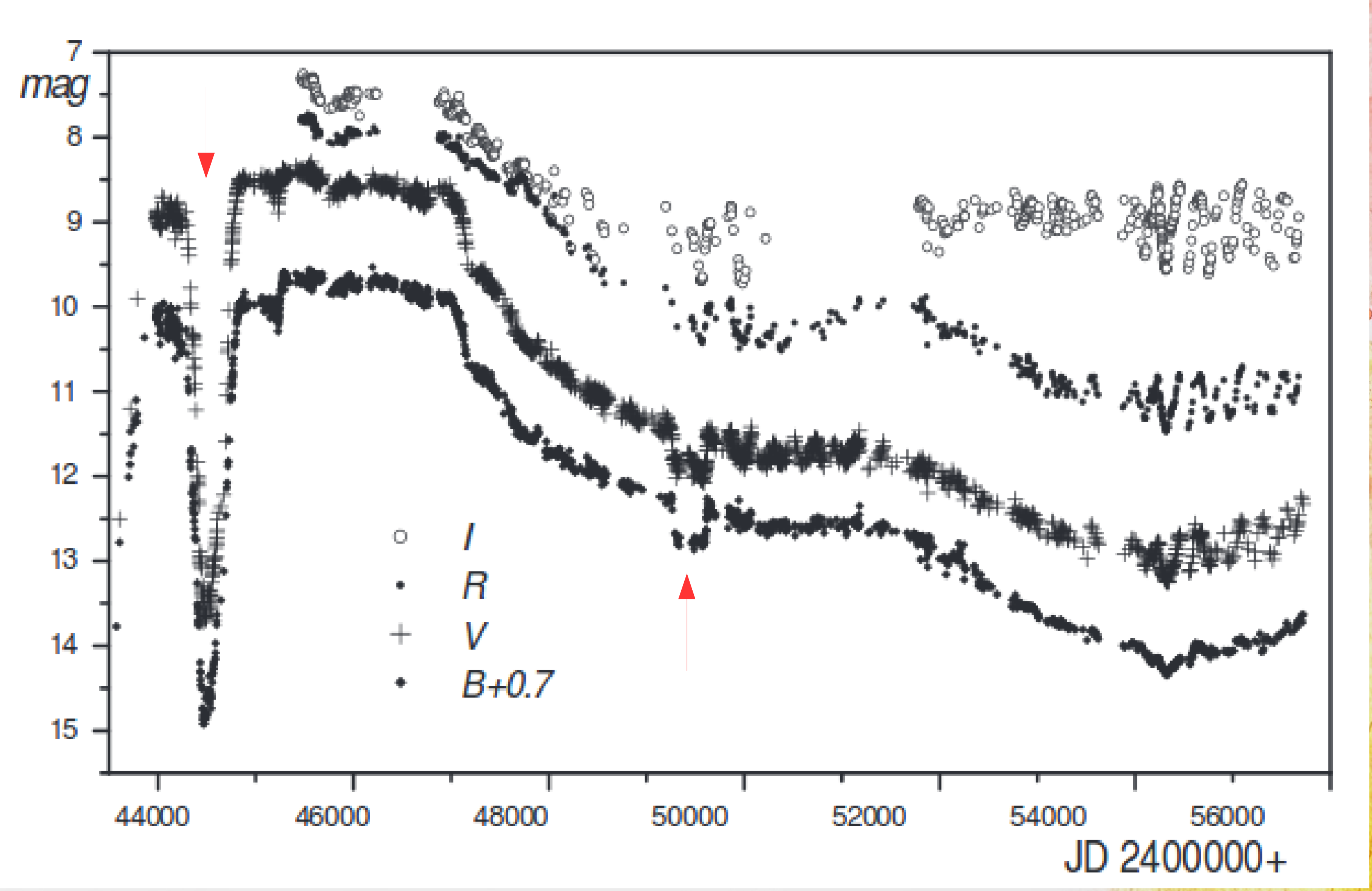
- Kuwano (Kozai et al., 1979) and Honda (Argyle et al., 1979)
- α = 20 21 13.317
- δ = +21 34 18.72
- M6 red giant
- White dwarf
- P=13.4 years





Light curve from 1978 to 2011

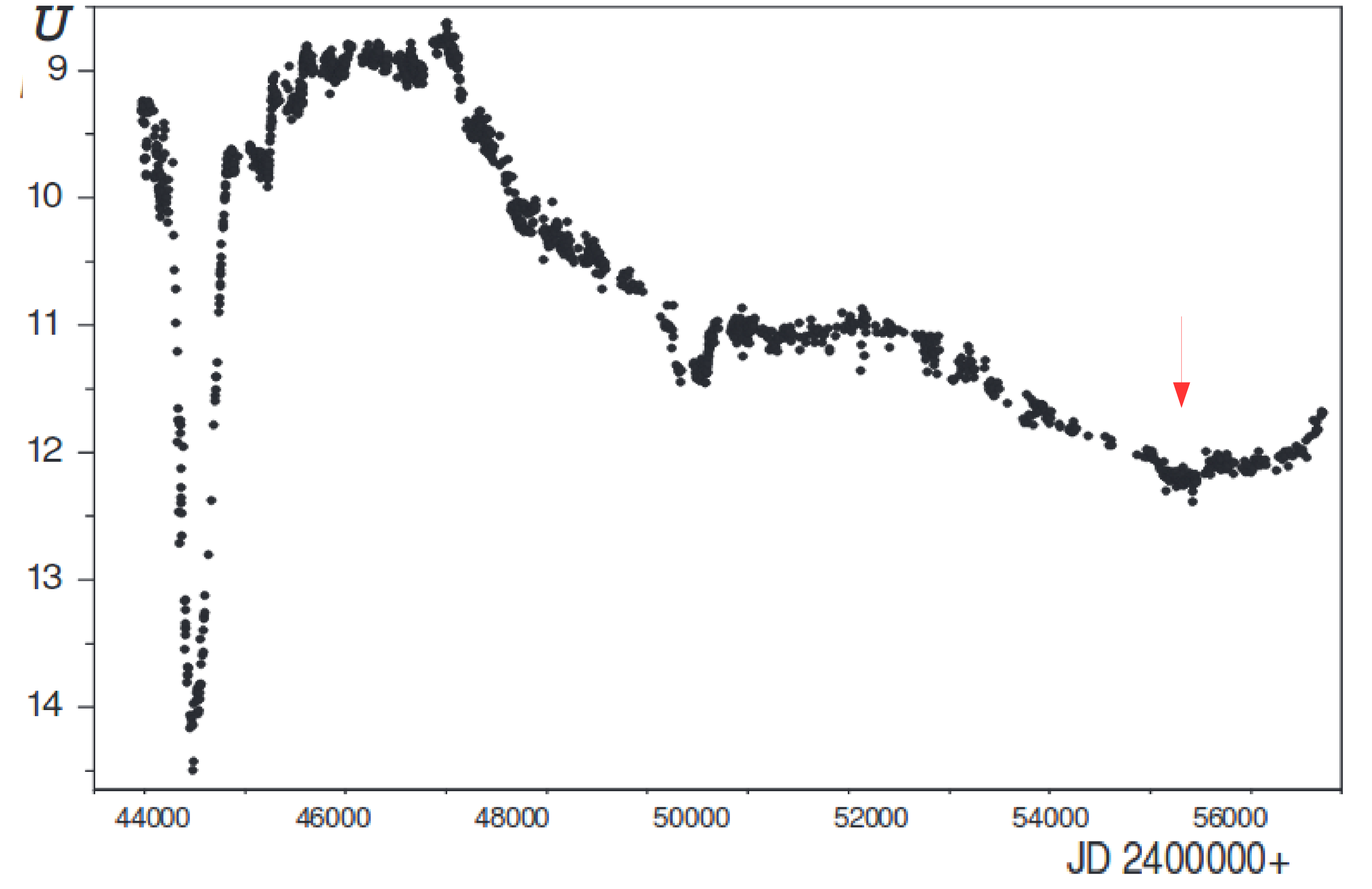
Eclipse duration ~ 300 days
$P_{puls.}$ = ~ 218 days



Shugarov, Chochol & Kolotilov (2012)

Light curve from 1978 to 2011

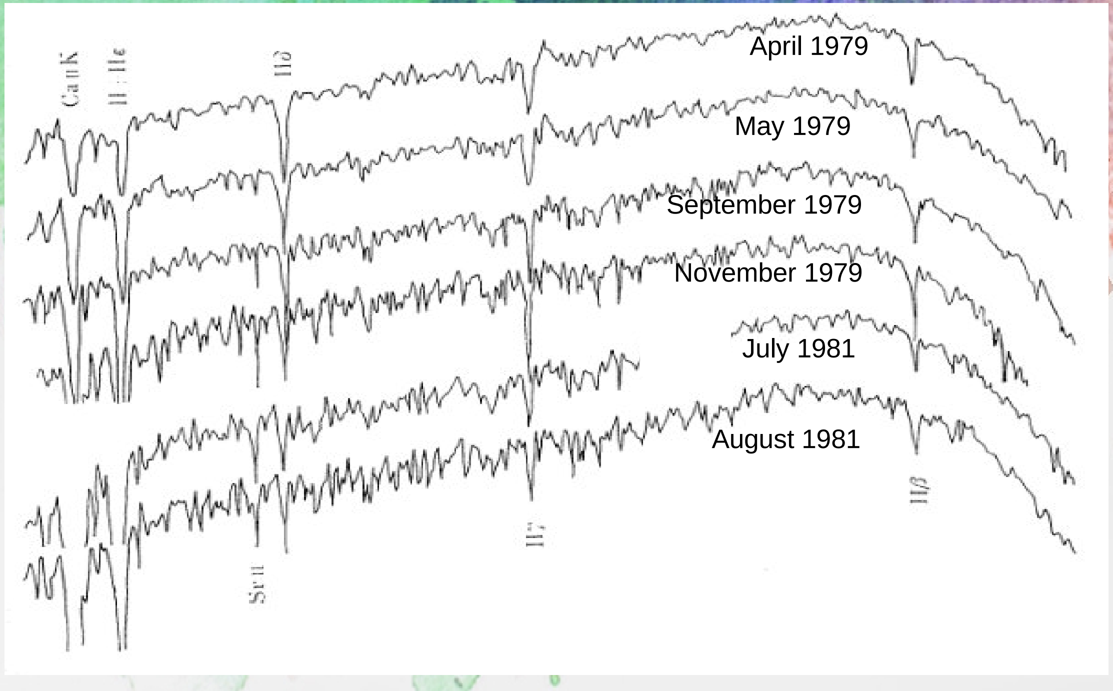
Eclipse duration ~ 300 days
$P_{puls.}$ = ~ 218 days

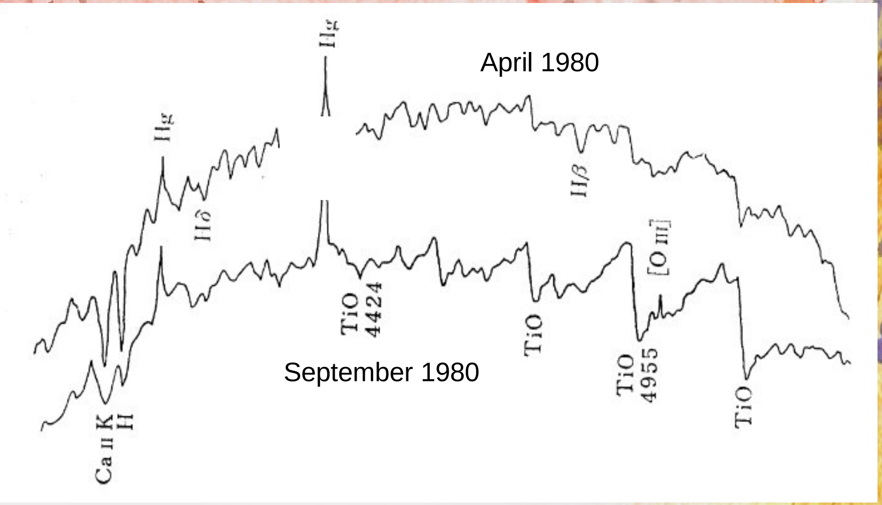


Shugarov, Chochol & Kolotilov (2012)

Spectroscopic variation

- Red giant phase (1979 - 1981)

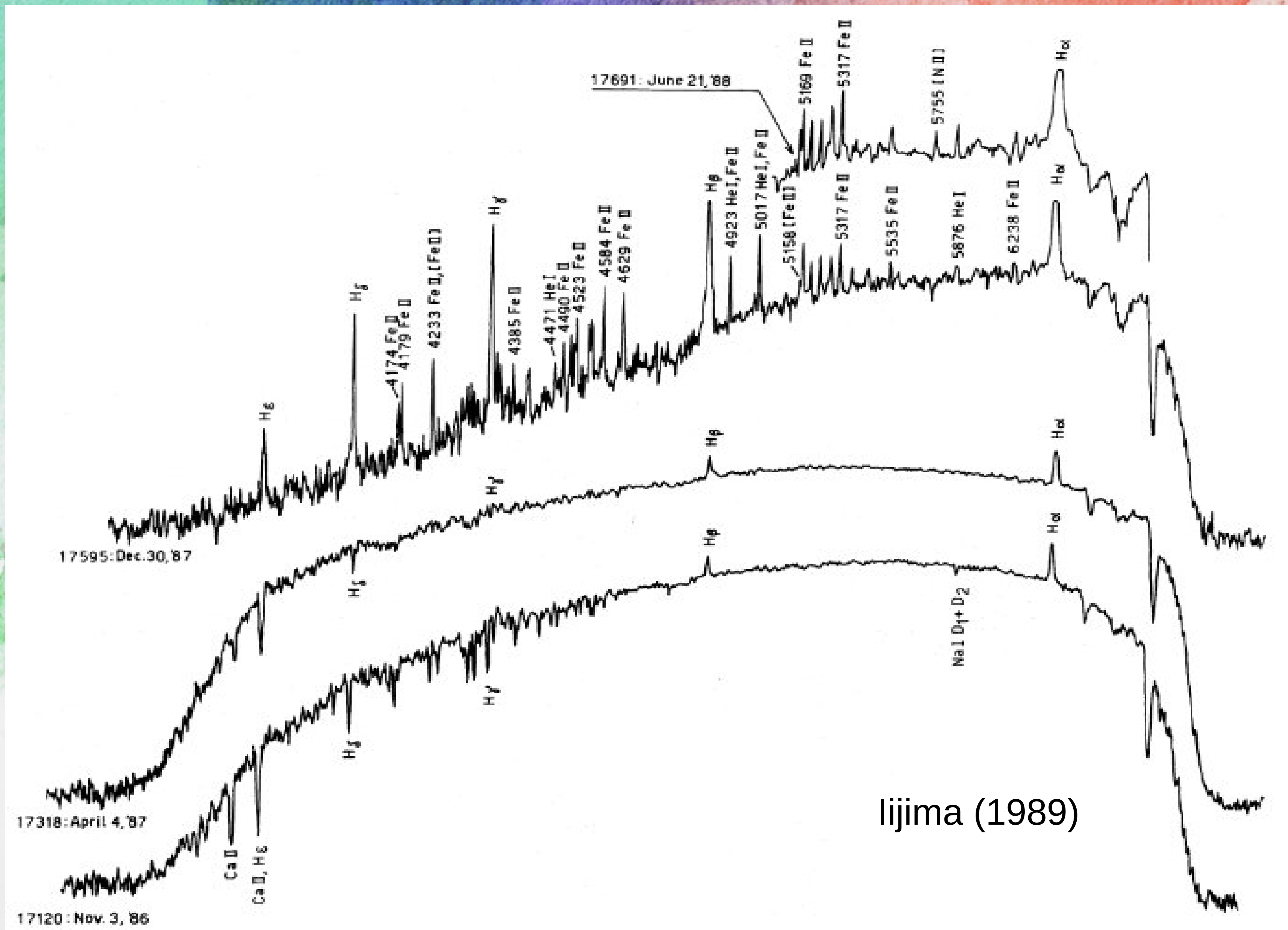




Yamashita et al. (1982)

Spectroscopic variation

- Nebular phase (1982 - 1987)

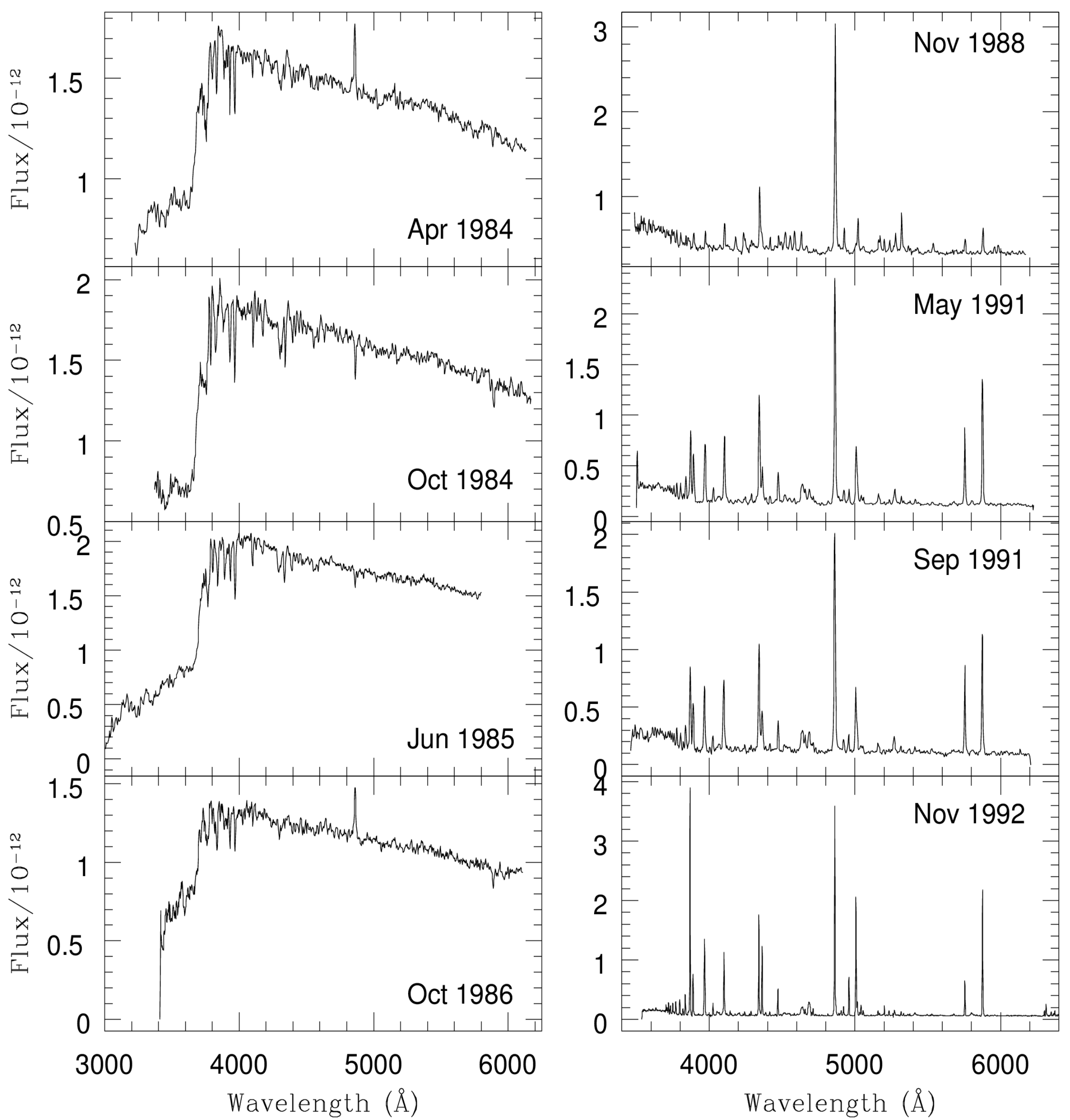


Observations

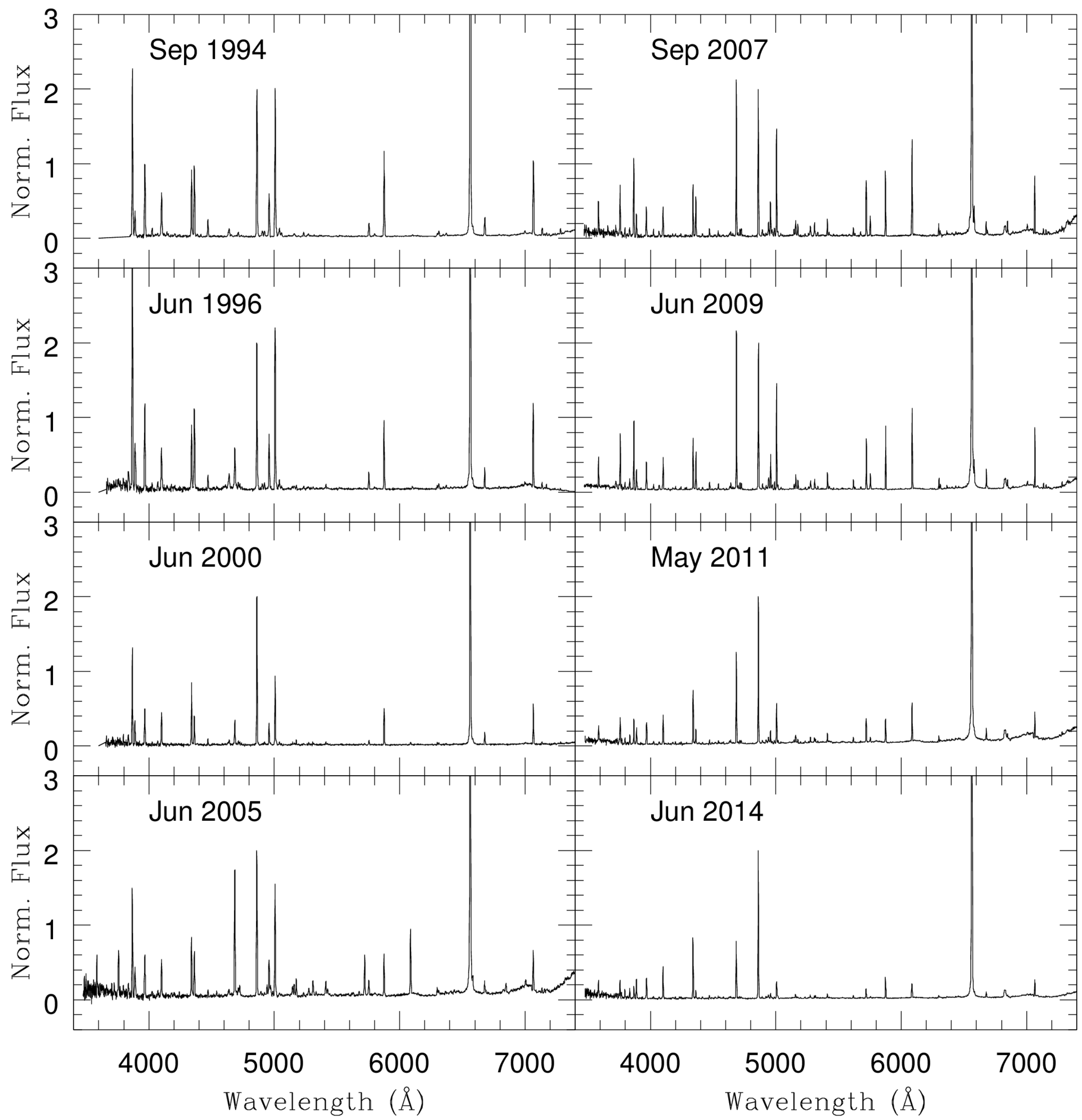
- 1984-1992
- 21 spectra, 3500-8400 Å
- Intensified Reticon Scanner (IRS)
- CCD GoldCam
- White spectrograph, 0.9m telescope on KPNO, Tucson, USA
- 2-3 Å/pixel resolution
- Exposure times: 240-1200 sec.
- S/N ~ 15-20 at 5500 Å

- 1994-2016
- 458 spectra, 3800-7500 Å
- FAST spectrograph, Tillinghast telescope on Fred L. Whipple observatory, Mount Hopkins, Arizona, USA
- CCD: 512 x 2688 pixel
- 300 g/mm grating, blazed at 4750 Å
- 3 arcsec slit
- 6 Å/pixel resolution
- Exposure times: 1-300 sec.
- S/N ≥ 15 for ~100 sec of exposure

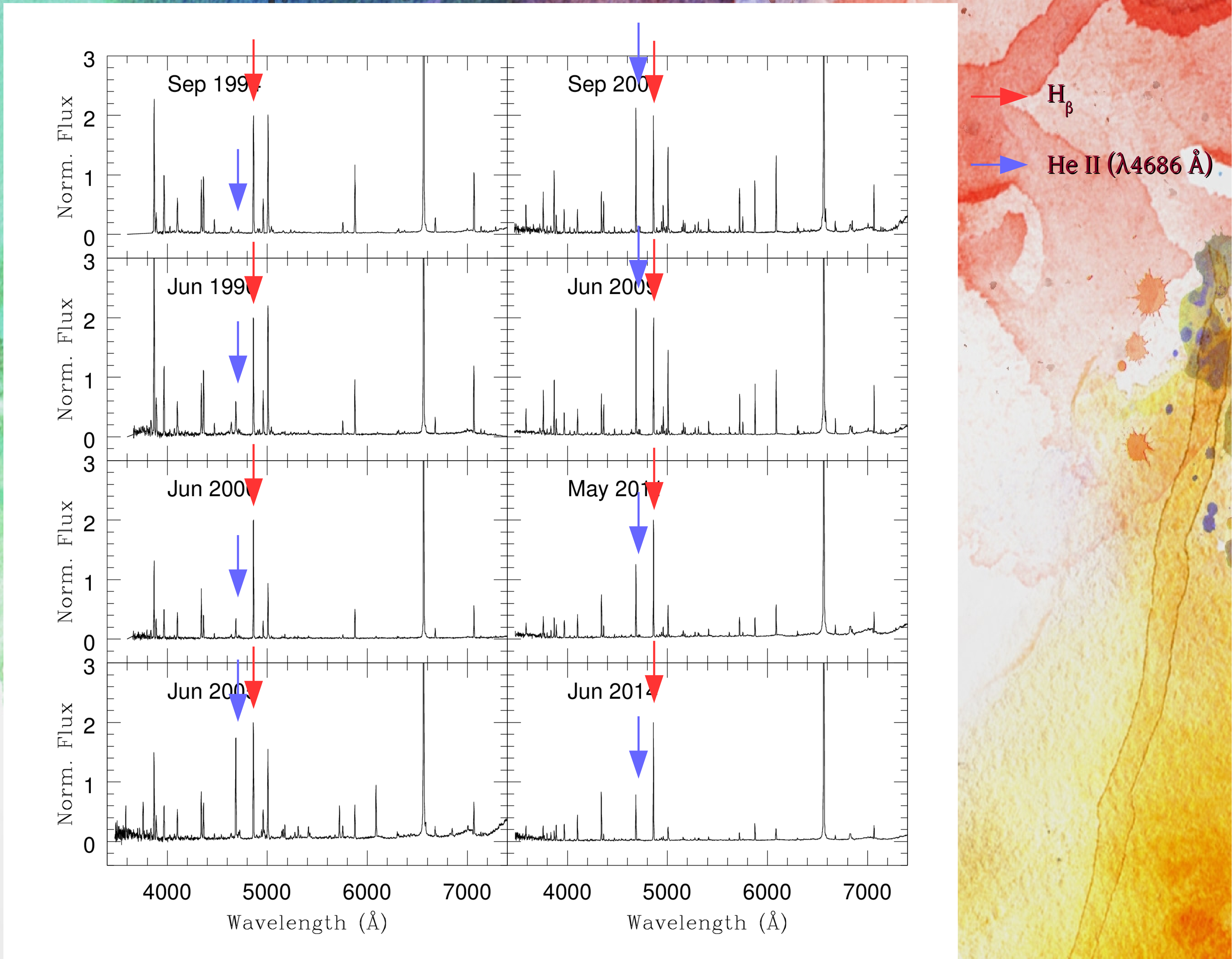
Observations: 1984 - 1992



Observations: 1994 - 2016



Observations: 1994 - 2016



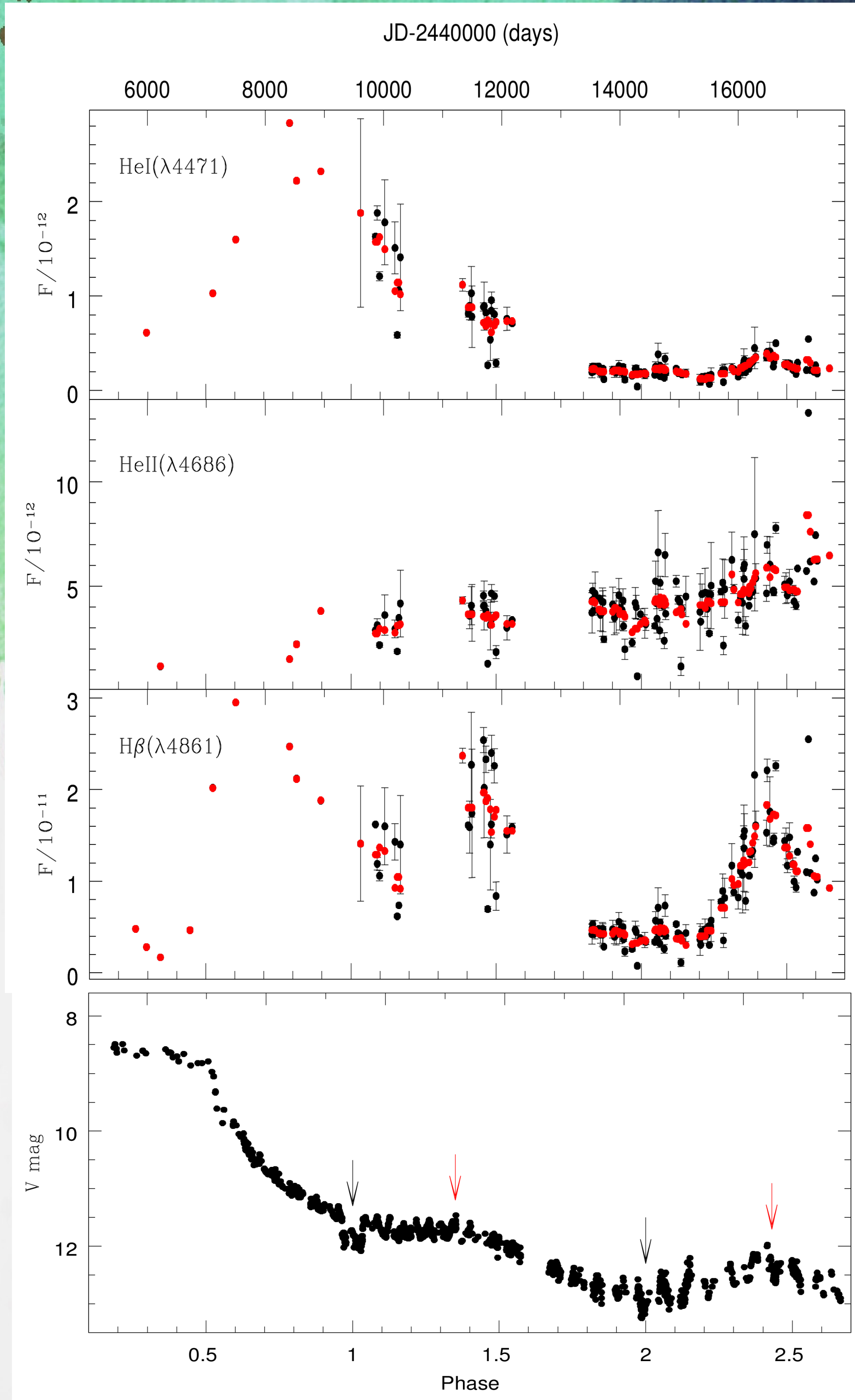
Line intensities

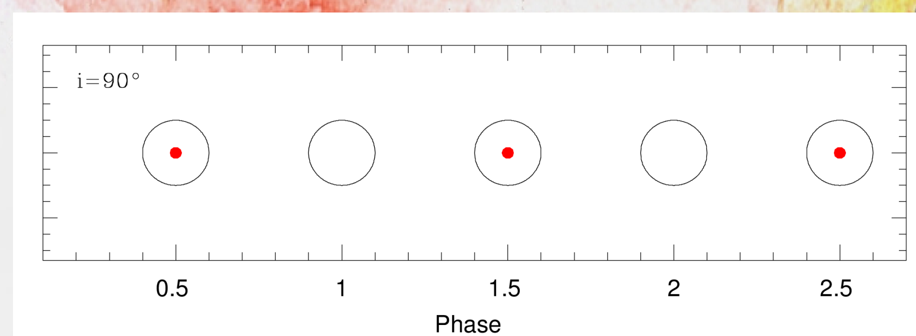
JD_0 = 2444532 days

P = 4915 days

Maximum: phase ~1.3-1.4 (JD~2451200)

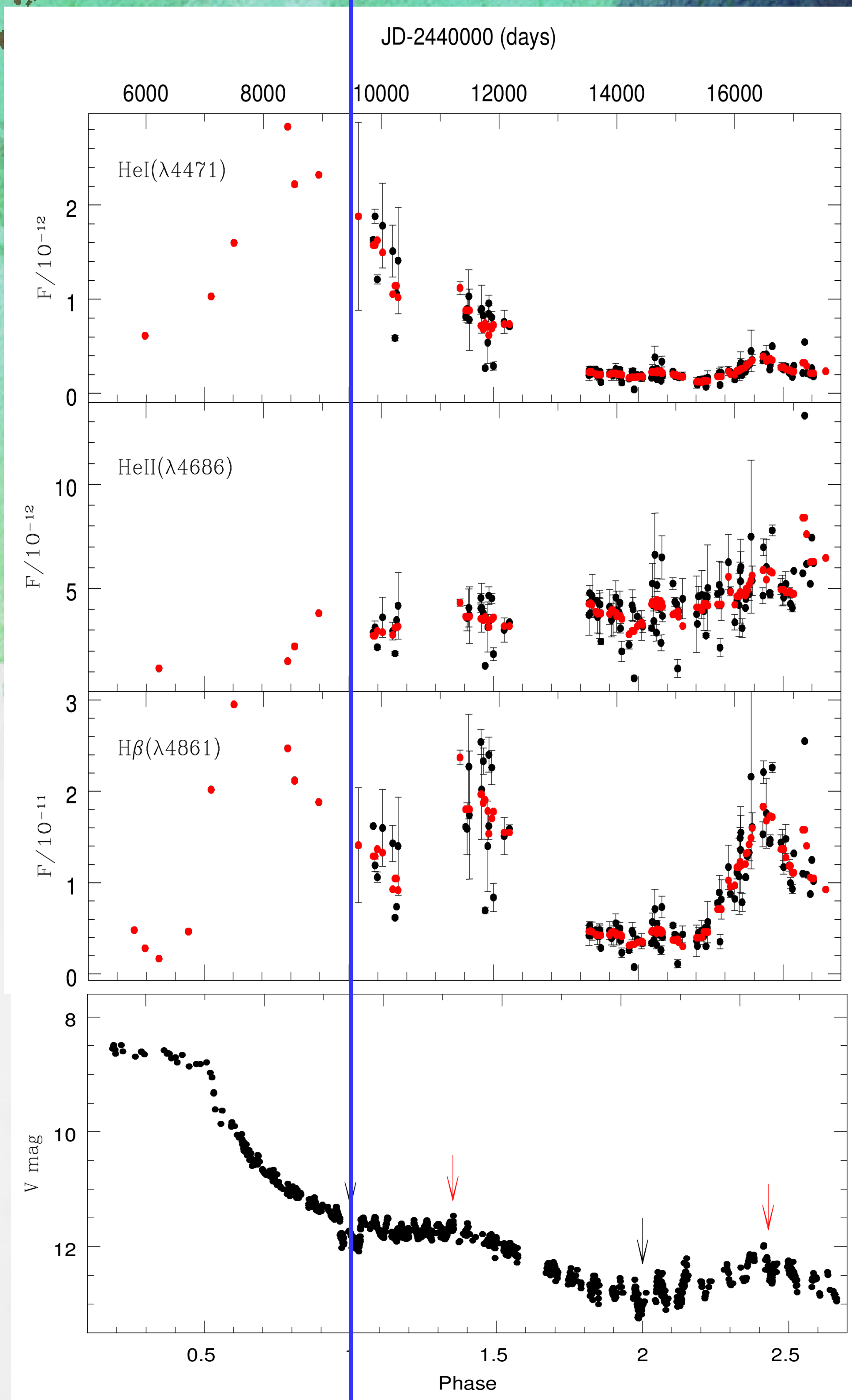
phase ~ 2.4-2.45 (JD~2456500)





AAVSO, ASAS, Yoon & Honeycutt (2000), Shugarov et al. (2012), Kolotilov et al. (1995), Klein et al. (1994), Kanamitsu et al. (1991)

Line intensities

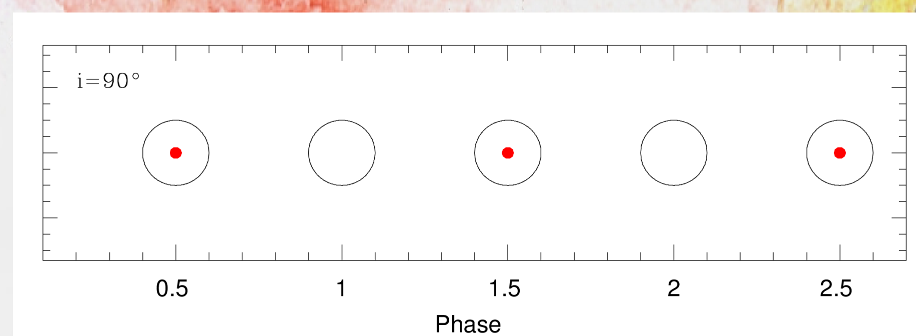


JD_0 = 2444532 days

P = 4915 days

Maximum: phase ~1.3-1.4 (JD~2451200)

phase ~ 2.4-2.45 (JD~2456500)

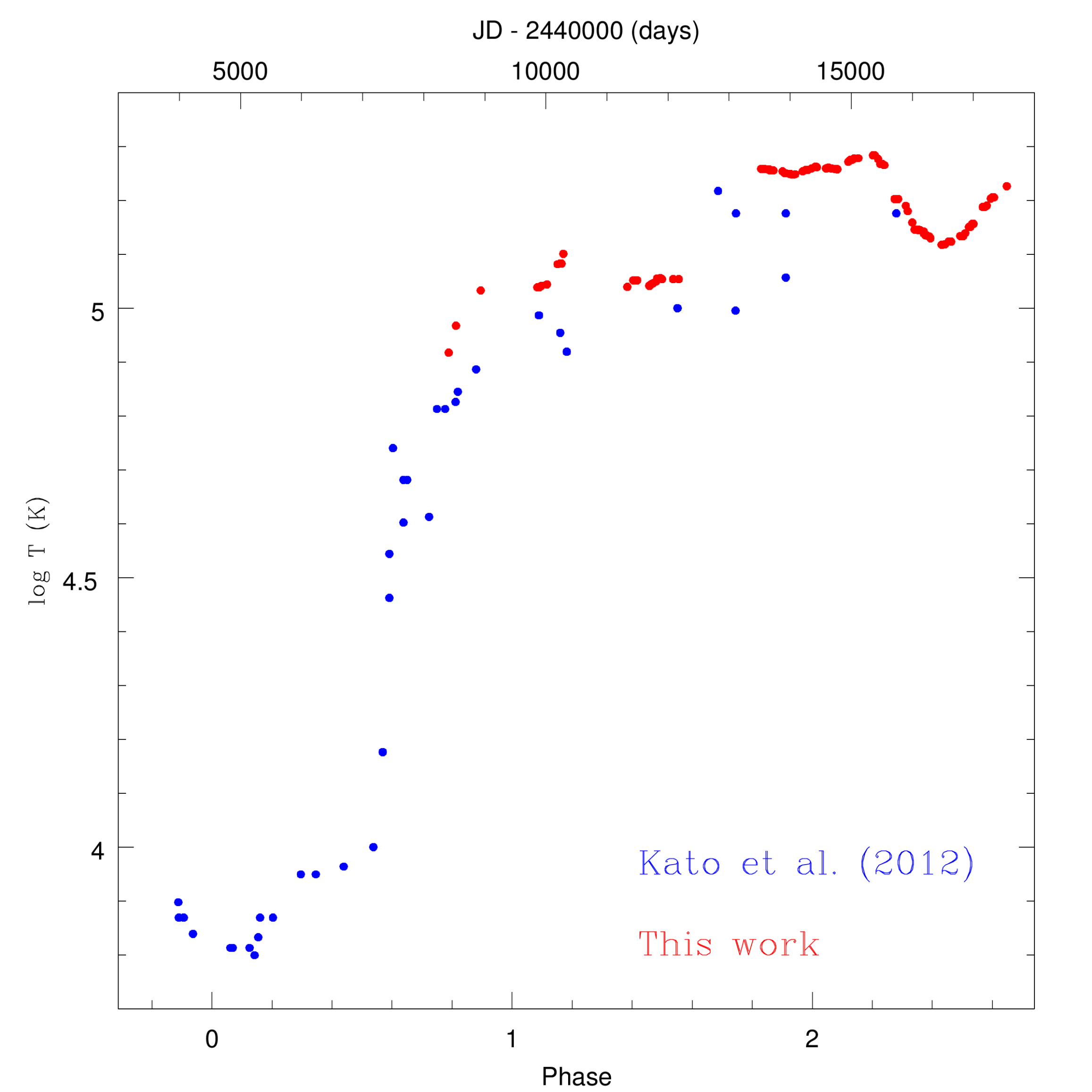


AAVSO, ASAS, Yoon & Honeycutt (2000), Shugarov et al. (2012), Kolotilov et al. (1995), Klein et al. (1994), Kanamitsu et al. (1991)

Hot component temperatures

$$T_h \times 10^{-4} = 19.38\left(\frac{2.2F_{4686}}{4.16F_{H_\beta} + 9.94F_{4471}}\right)^{1/2} + 5.13$$

Iijima (1981)



Hot component luminosities

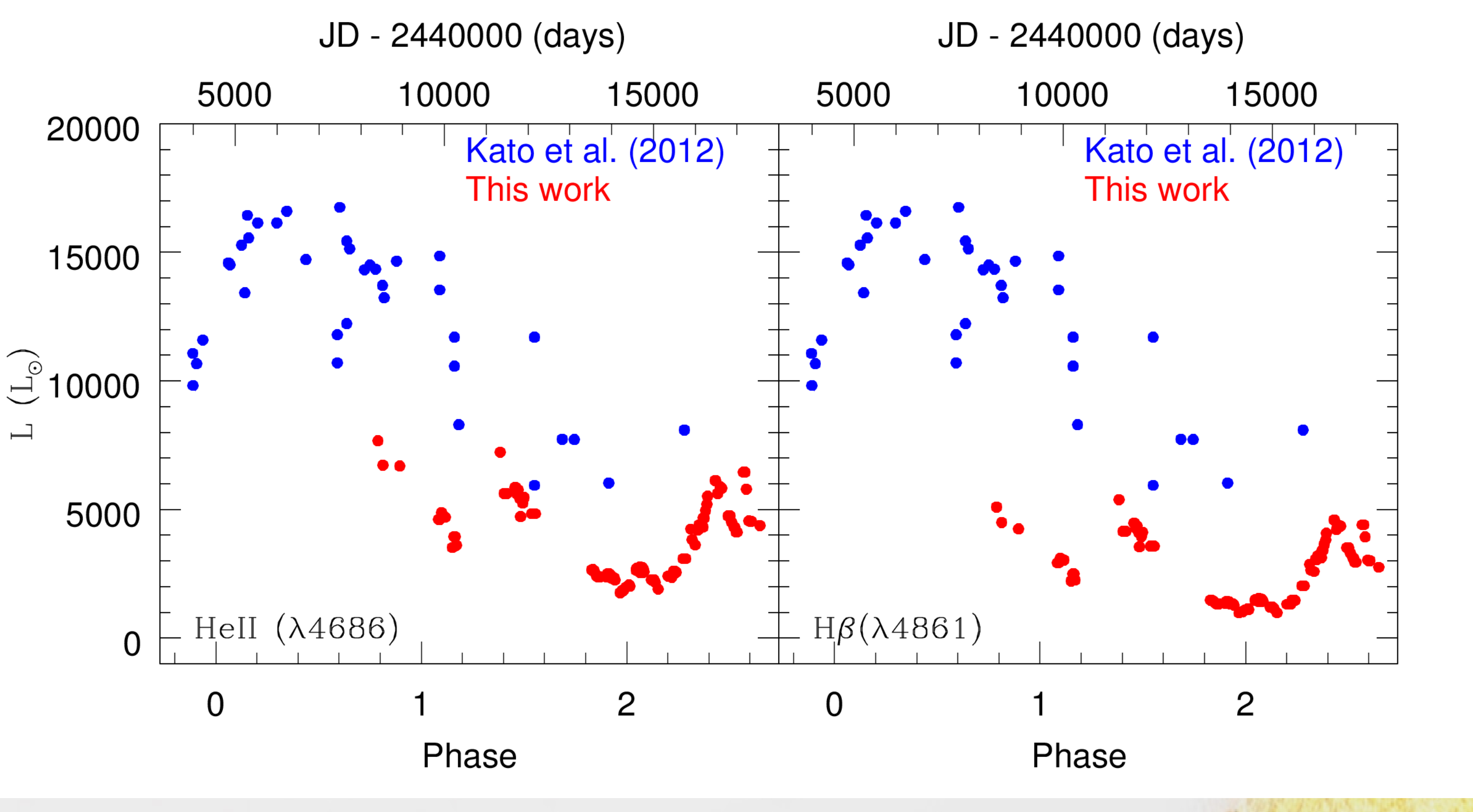
$$L_g(H_\beta) = n_p n_e V K_\beta.$$

K_β = emission coefficient

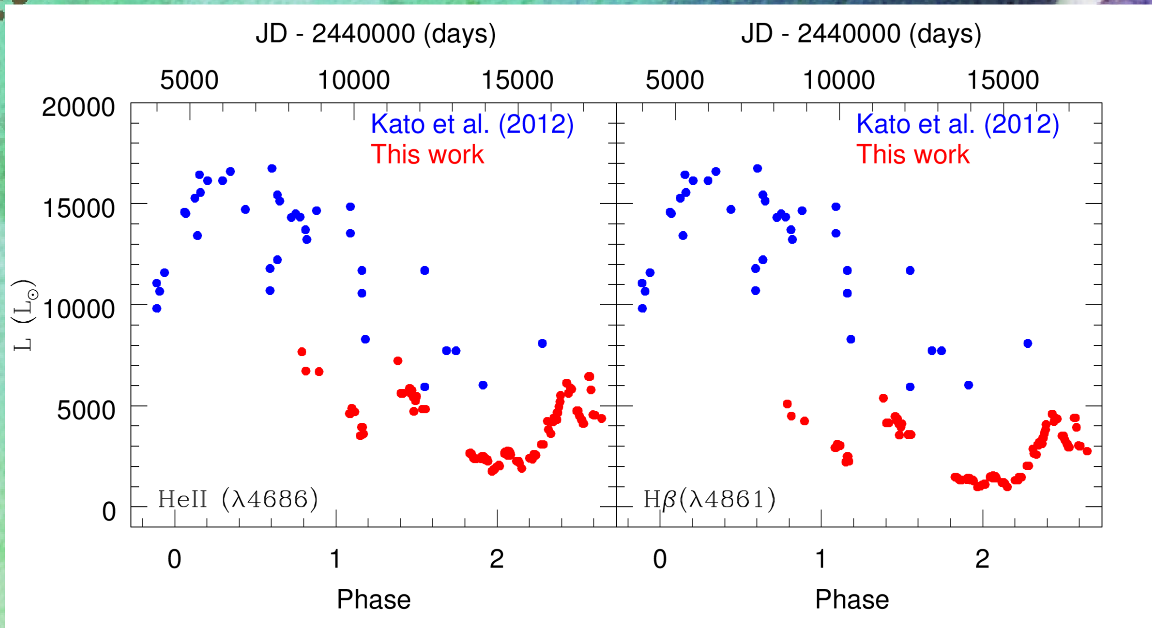
$n_p n_e V$ = emission measure

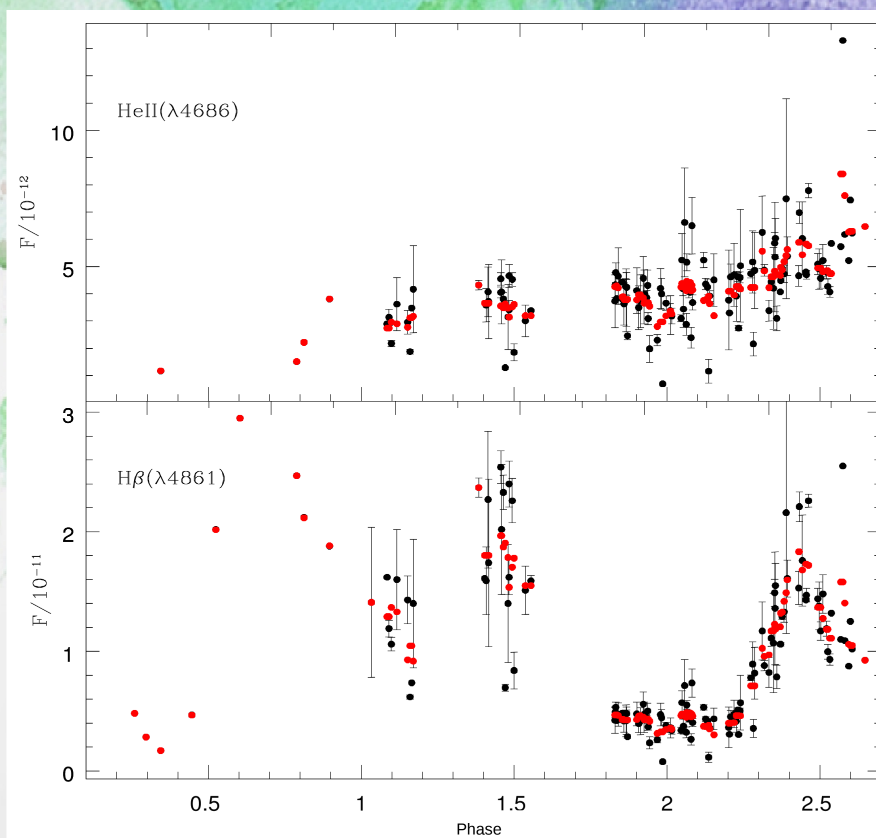
$$L_s(H_\beta) = \frac{2.5 \times 10^7 \left(\frac{d}{kpc}\right)^2 TF(H_\beta)}{f_H}$$

where n_p is proton density,
n_e is electron density and V
is the emission region volume.



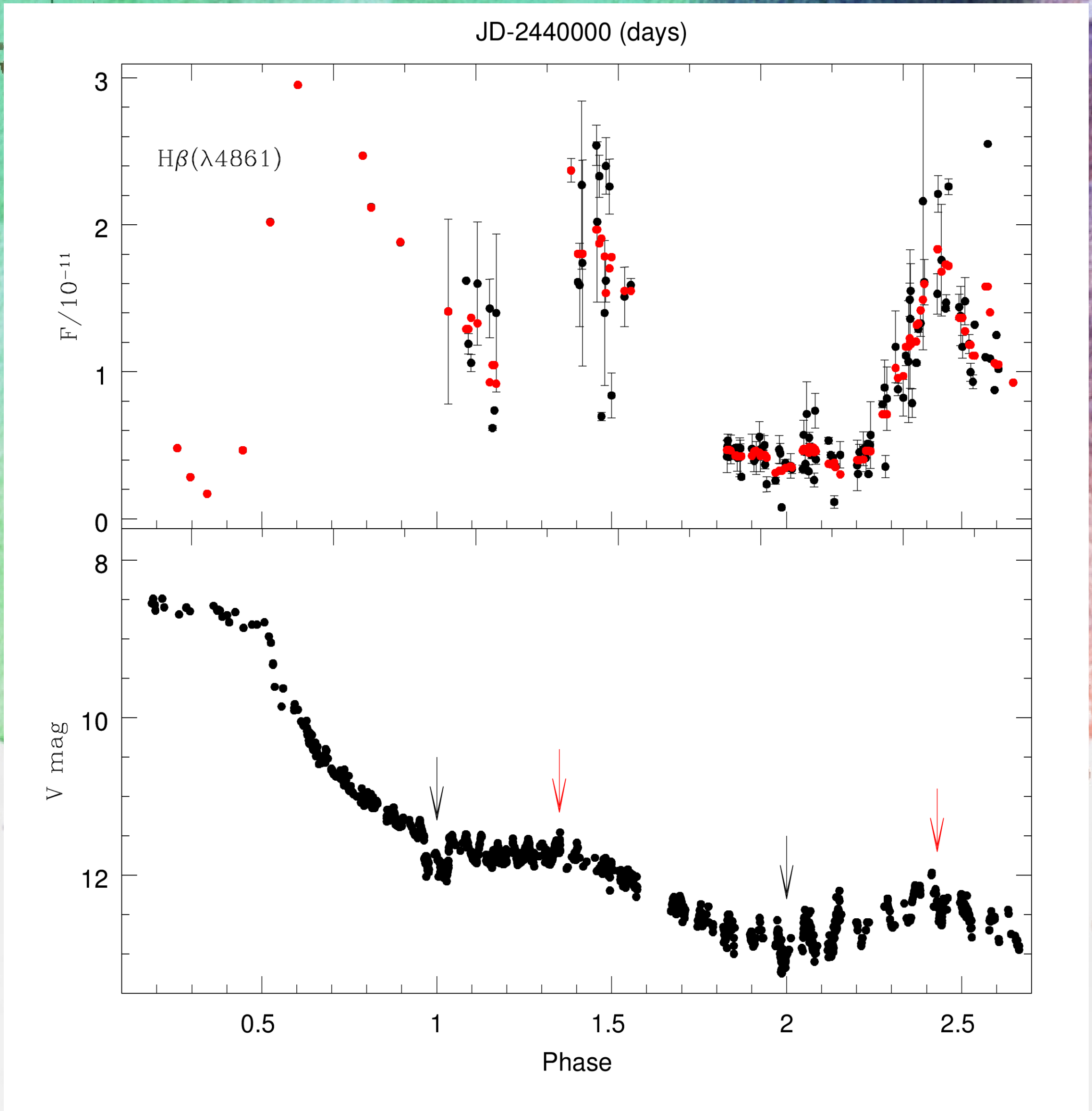
Luminosities and fluxes

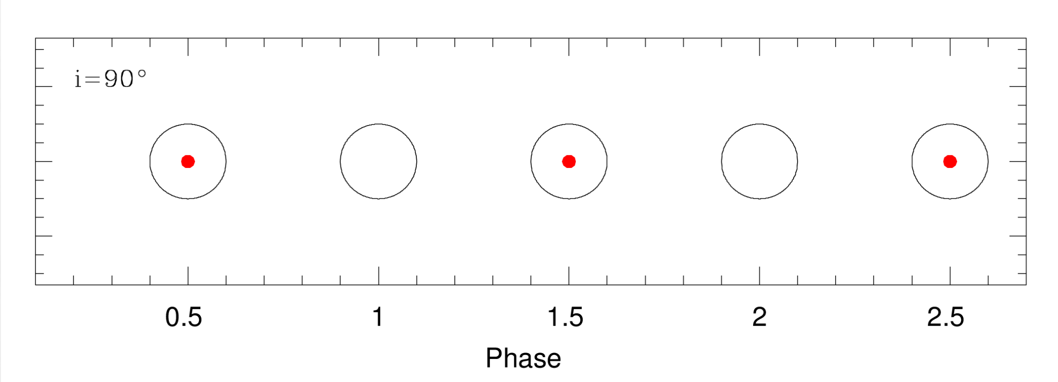




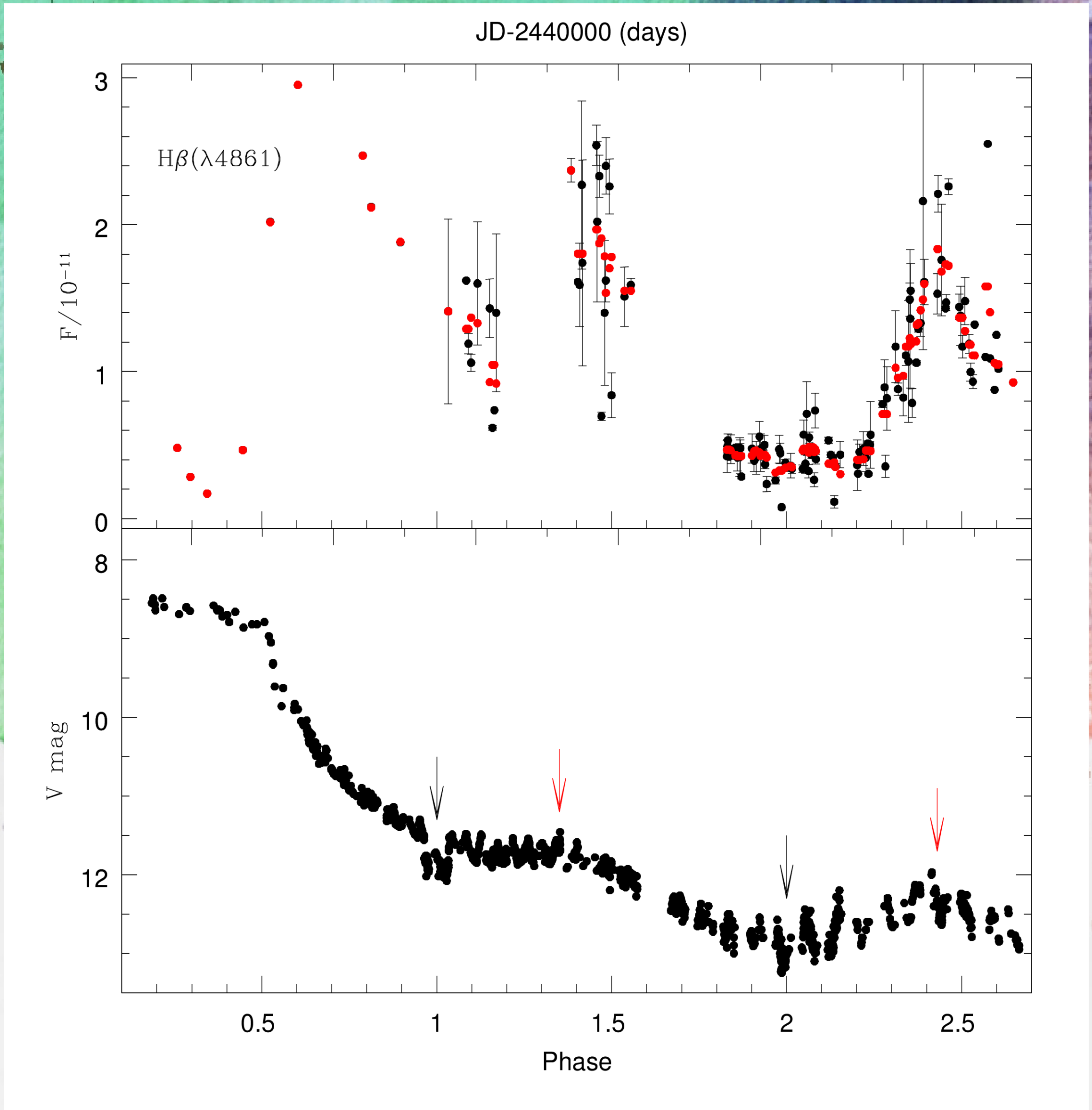
Nebula geometry

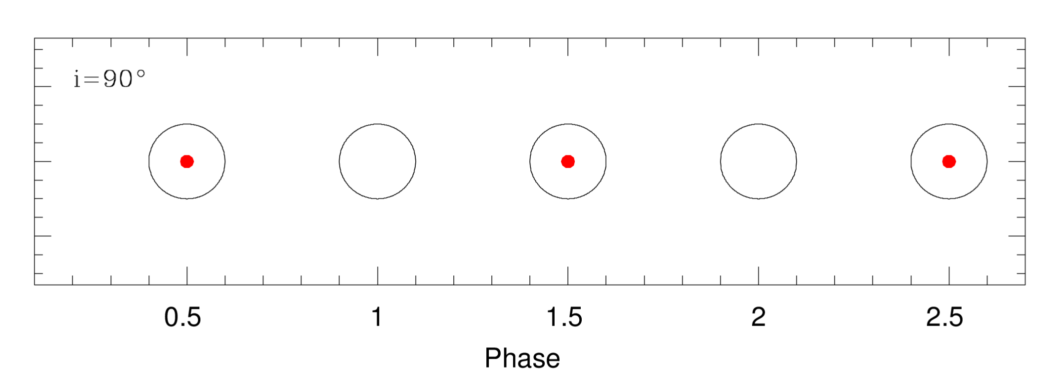
Darkening due to an expansion of the nebula

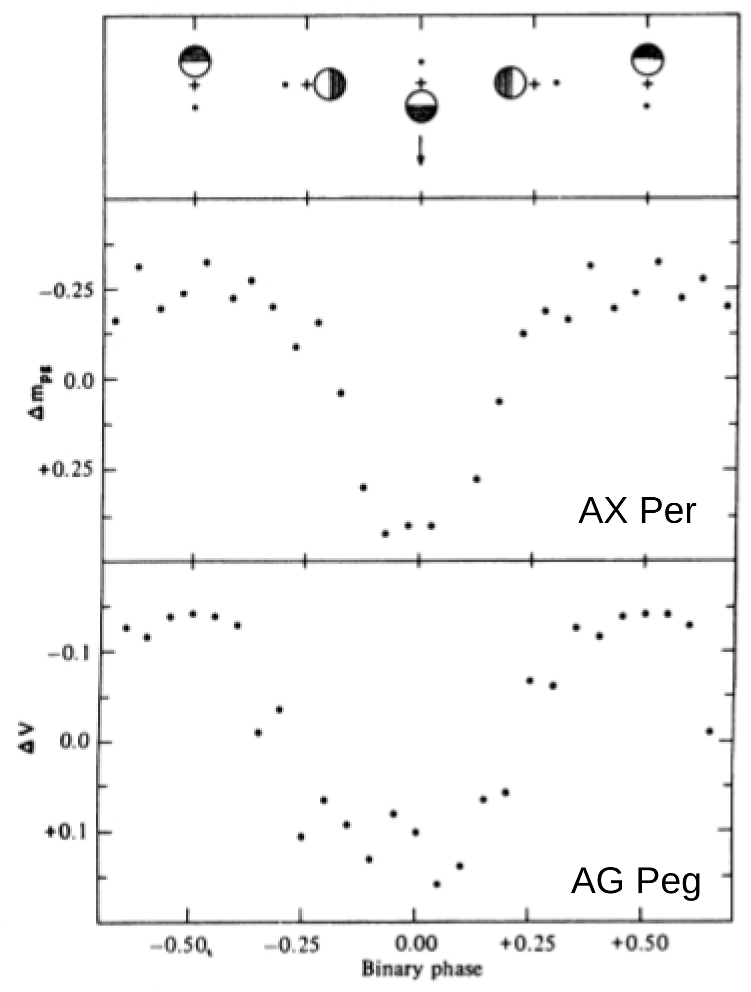




Illumination effect
Proga et al. (1996,1998)







Kenyon (1986)

Main results

- We measured line fluxes for He I (λ4471), He II (λ4686) and Hβ, and we determined they are being mainly produced in a region close to the white dwarf. However, there is weak emission associated to the region surrounding the red giant.

- We determined the hot component luminosities and compared them to line fluxes. We found the same behaviour in both curves indicating that the system is more luminous when fluxes are higher.

- Finally, to explain the flux and light curve shapes, we proposed a scenario where the nebula is expanding and there is an illumination effect increasing the system's brightness.

Thank you!!!