Optical spectroscopy and X-ray observations of the D-type symbiotic star EF Aql

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Symbiotic stars

S-type - normal red giant
D-type - Mira variable
D'-type - F or G giant

The history of EF Aql

Reinmuth (1925) - variable star

Konigstuhl Observatory

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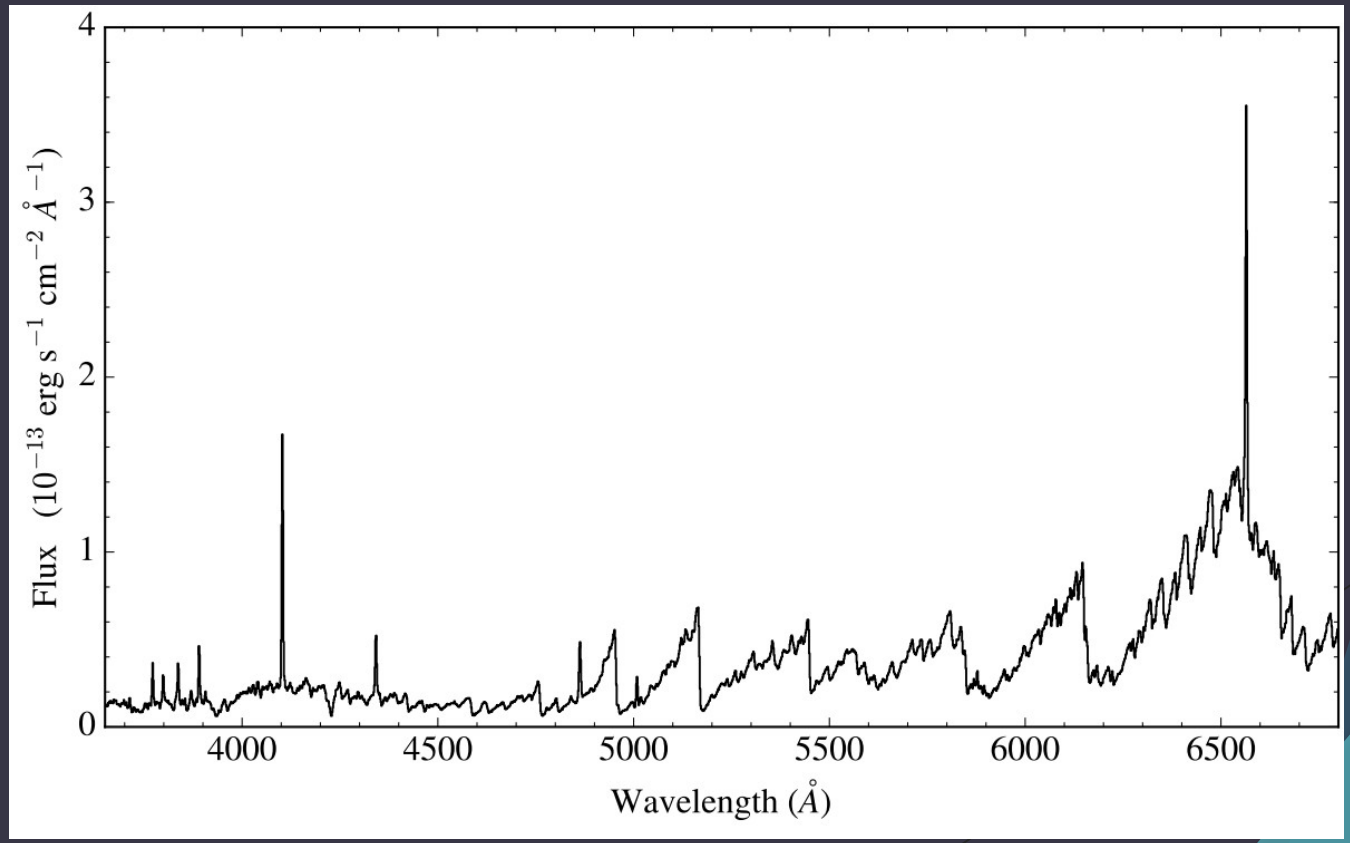
Margon et al. (2016) - bright UV flux, prominent Balmer emission lines and [O III] λ5007 emission



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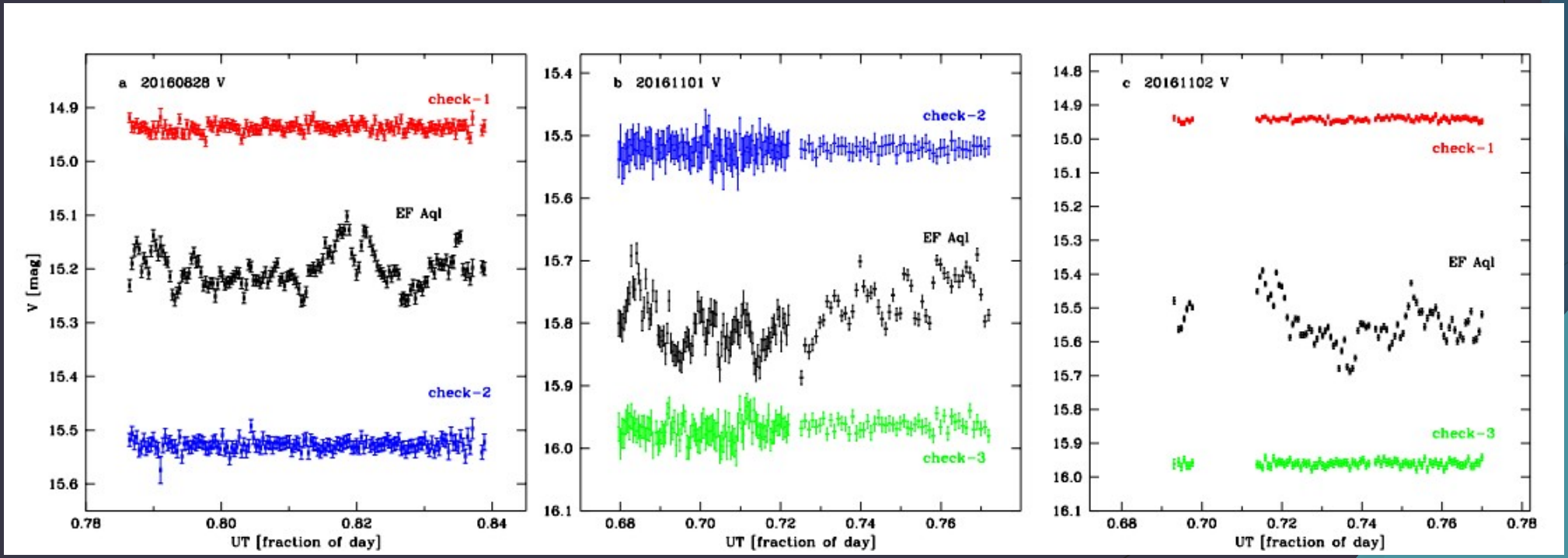
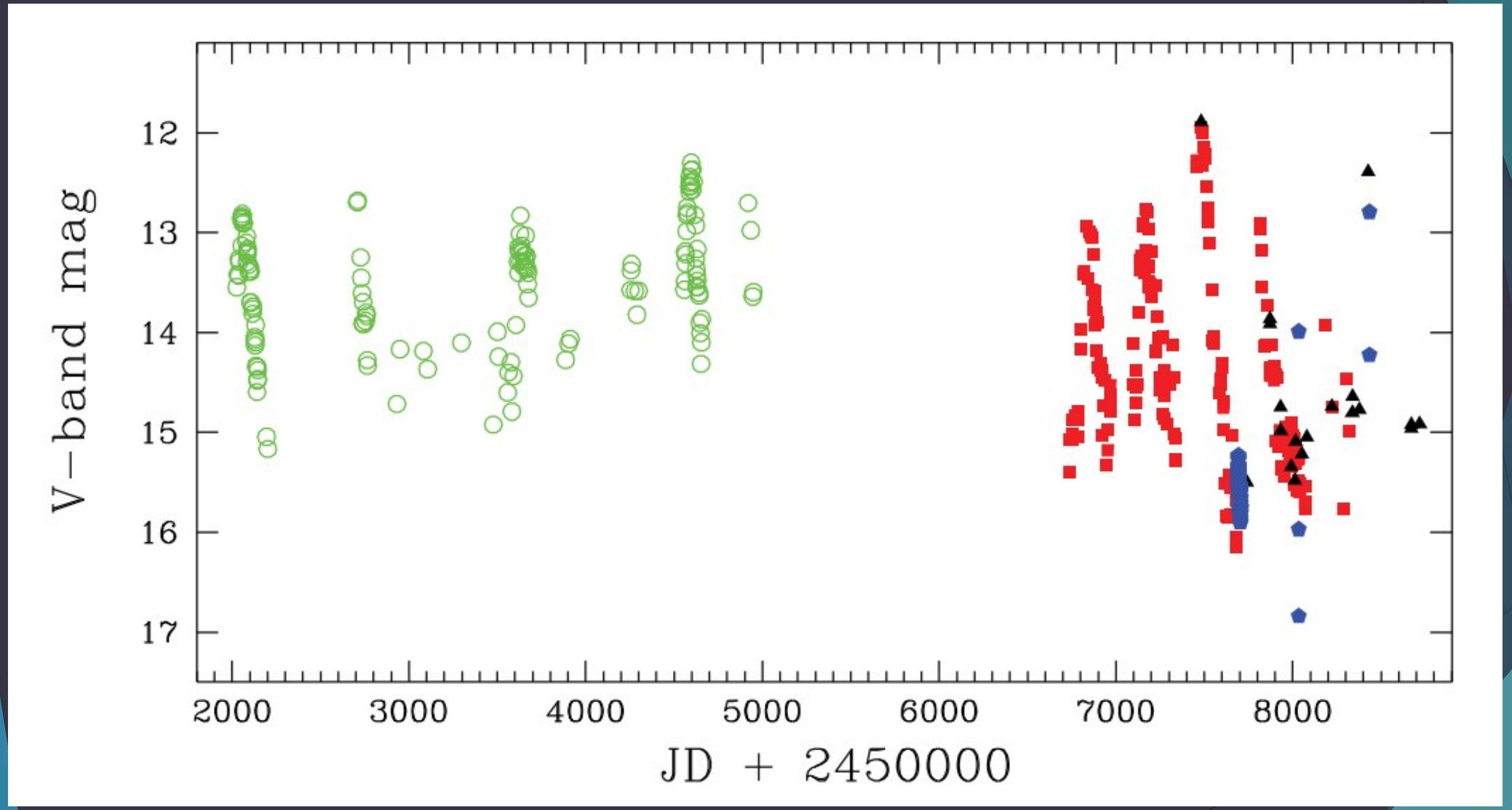
Zamanov et al. (2017) – optical flickering

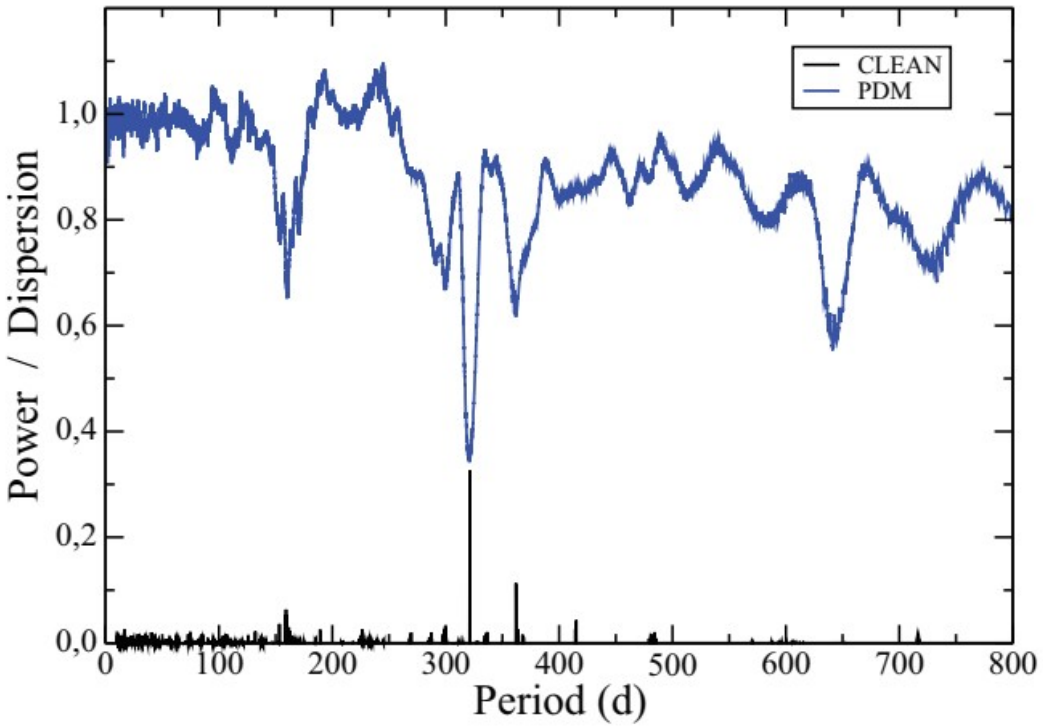


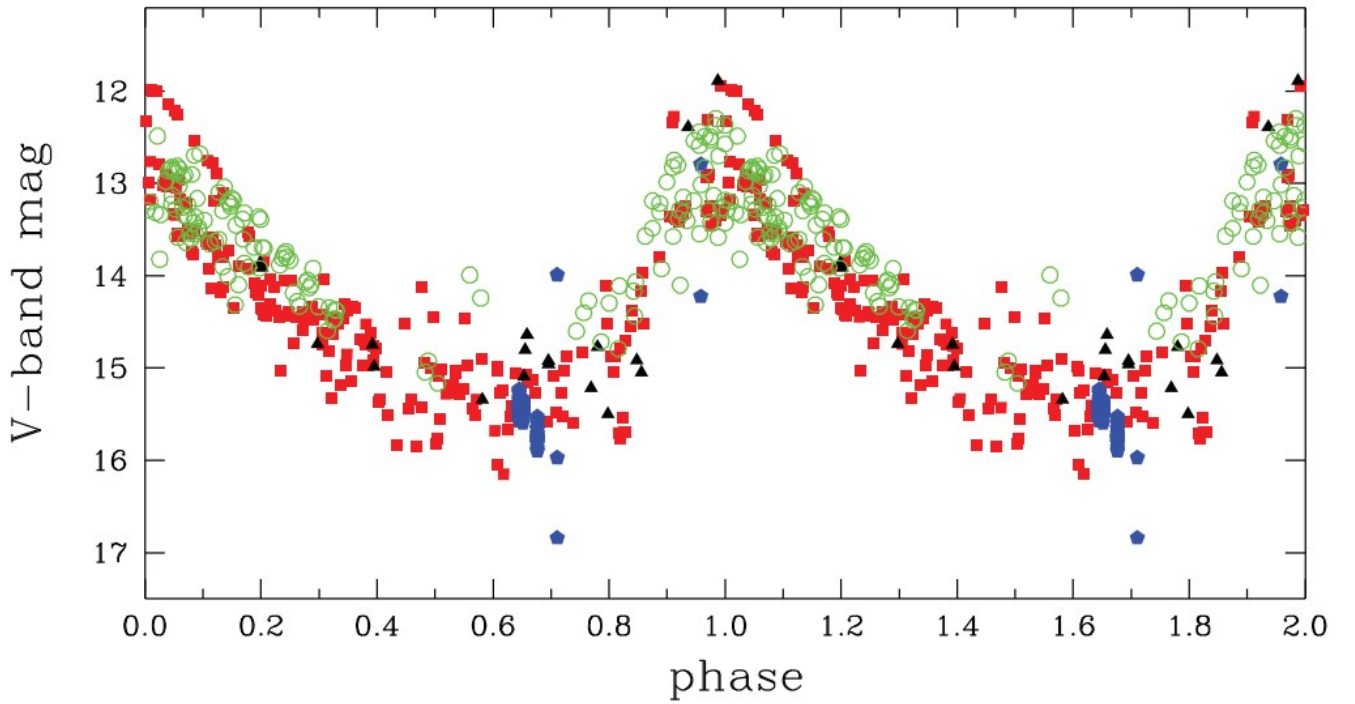
Optical photometry of EF Aql



ASAS
ASAS-SN
AAVSO
Rozhen NAO

Photometry of EF Aql: period of pulsations

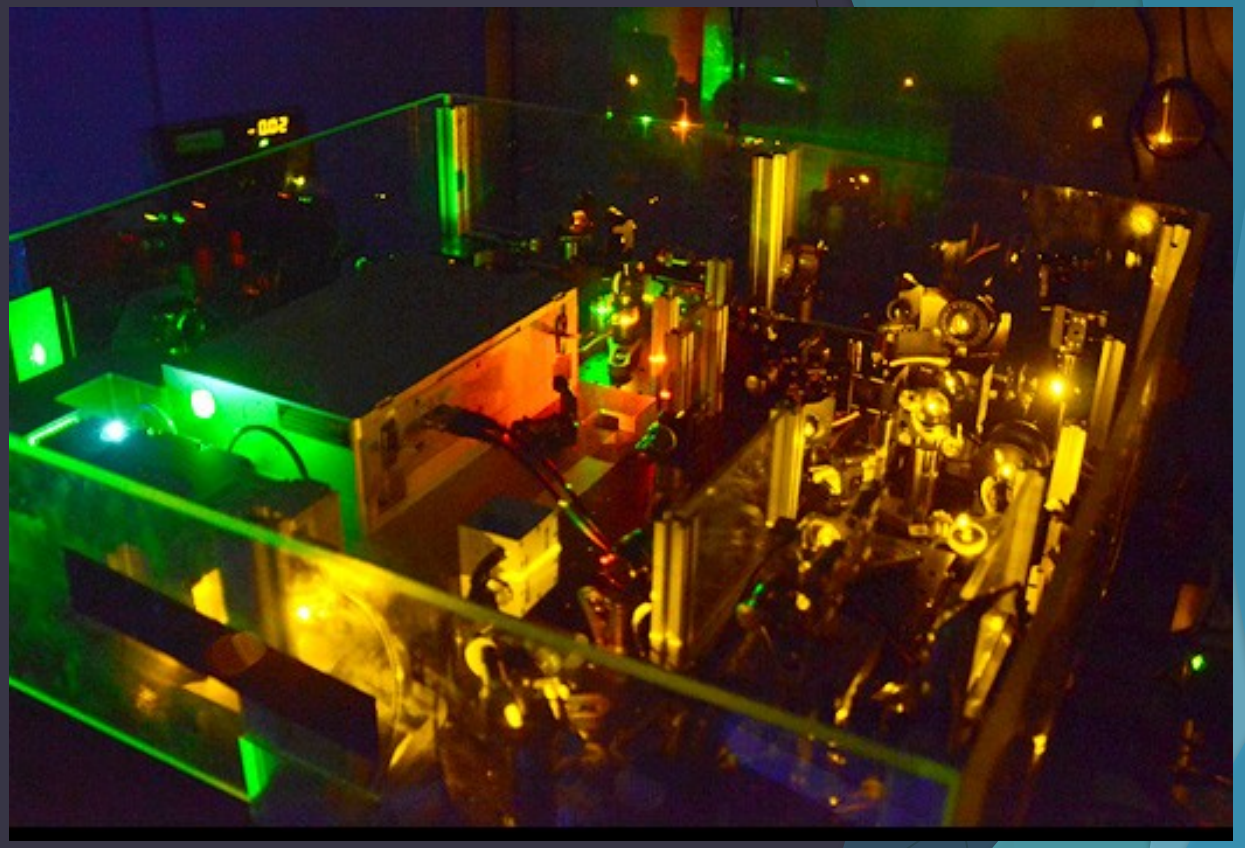




Improved period - 320.4 d

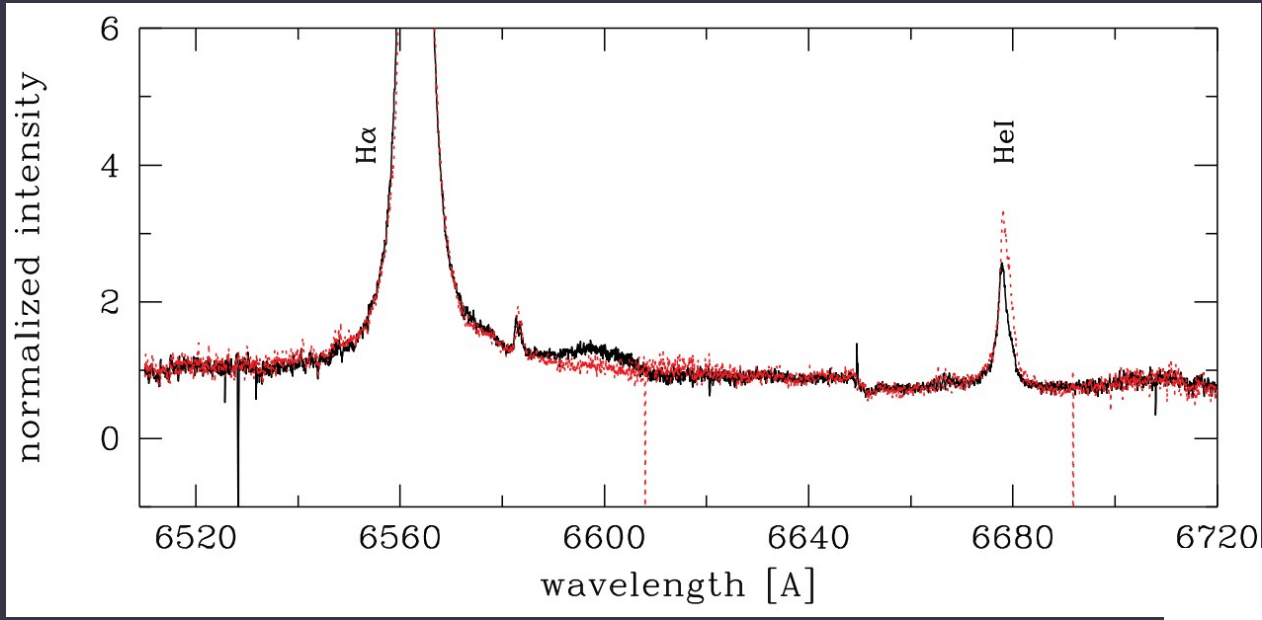
The period of pulsations and the amplitude are typical for Mira-type variables (Whitelock et al. 2003)

Optical spectroscopy of EF Aql: SALT + HRS



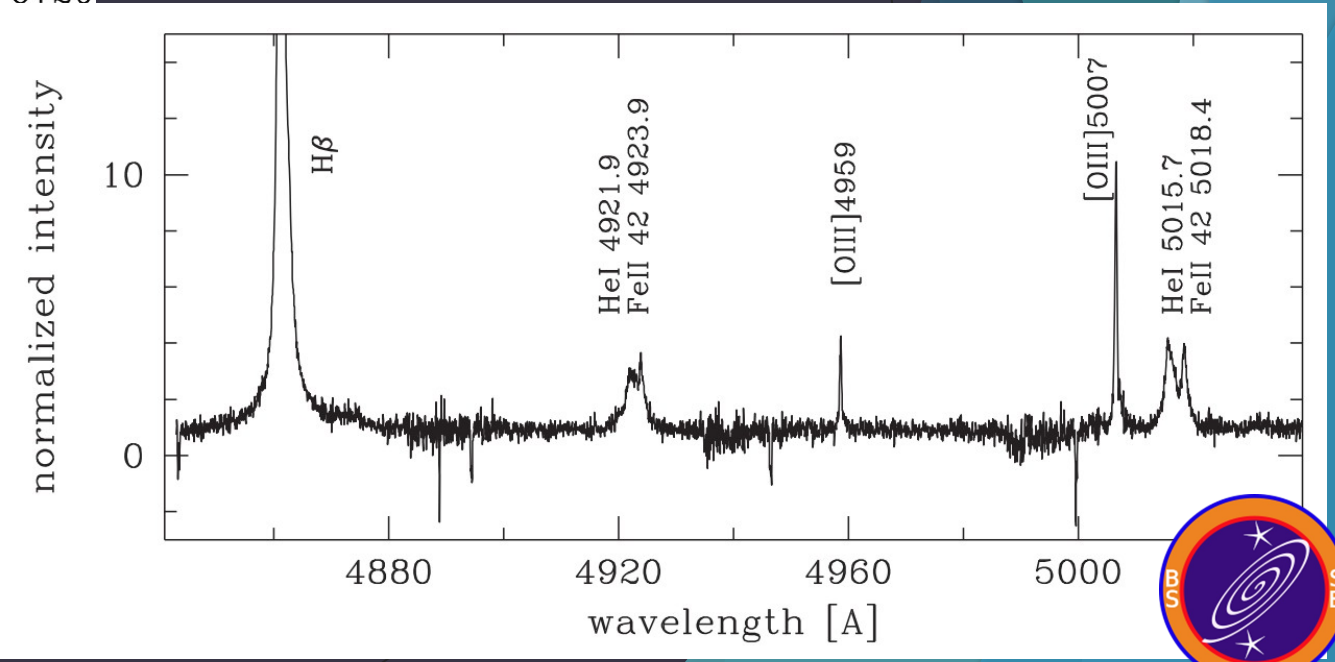
2019 June 7, July 9 and July 14: R ~ 40 000 and wavelength coverage 4000 - 8800 Å

Optical spectroscopy of EF Aql



Possible ionization-potential-dependent stratification?

The [O III] λ5007 emission line is similar to that in PNe.



Distance and interstellar reddening

Using $K = 4.78 \pm 0.58$ (2MASS; DENIS)
and $M_K = -7.69$ (from Whitelock et al. 2008 using P = 320.4 d)

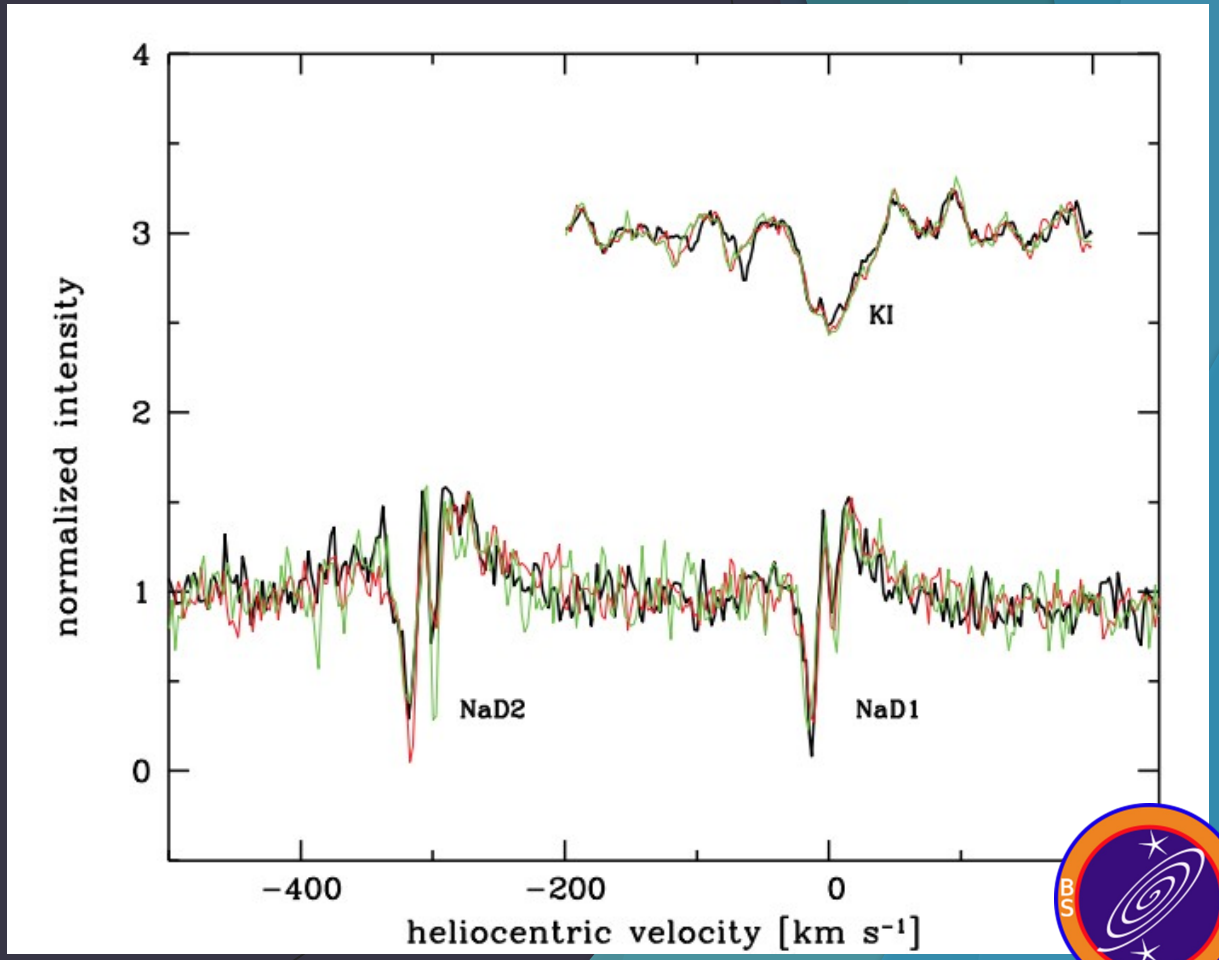
→ d = 3.1 kpc

Interstellar + circumstellar extinction:
$(J - K)_0 = 0.71 \log P - 0.39$ (Whitelock et al. 2000)
J - K = 1.71 (2MASS; DENIS)

→ E (J - K) = 0.32 ± 0.10

EW(Na D1) = 0.31 - 0.45 Å

→ E (B - V) = 0.12 - 0.25



Temperature and luminosity of the WD

The minimum temperature is set by the maximum ionization potential observed in the spectrum that in EF Aql is 35.12 eV corresponding to the [O III] lines. This gives a temperature $T_{WD} \geq 35\,000$ K.
The lack of any traces of He II lines and the presence of strong He I lines means that $T_{WD} \leq 60\,000$ K.

The ratio F(He I 5876)/F(H_β) indicates $T_{WD} \sim 55\,000$ K.

Using d = 3.1 kpc → $L_{WD} \sim 5.3\ L_\odot$

T_{WD} in symbiotic systems - 35 000 - 500 000 K
L_{WD} in symbiotic systems - 0.3 - 37 000 $L_\odot$

→ The WD in EF Aql is with low luminosity

Mass-loss rate

Whitelock et al. (1994): a correlation between the mass-loss rate and the K – [12] colour:

Larger K – [12] means thicker shell
K – [12] = 2.89 (2MASS; IRAS)

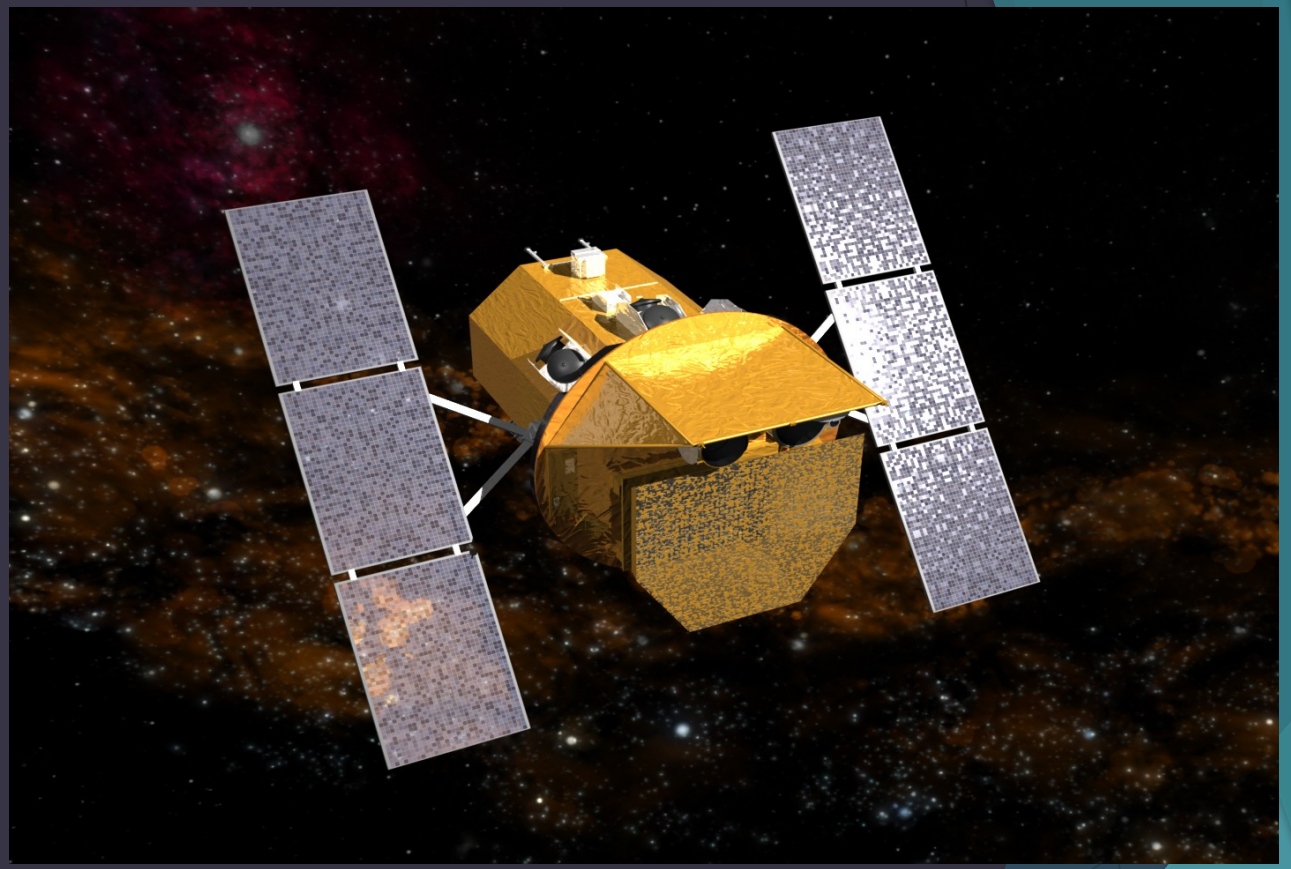
→ mass-loss rate ~ $2.5\ 10^{-7}\ M_{\odot}\ yr^{-1}$

Single O-rich Miras – 10^{-7} - $10^{-5}\ M_{\odot}\ yr^{-1}$
Miras in Symbiotic systems - ~ $3.2\ 10^{-6}\ M_{\odot}\ yr^{-1}$

→ supports the idea for a low-luminosity system

X-ray and UV observations of EF Aql

2019 Sep 12
ToO mode
First ever pointed X-ray observations
XRT - photon-counting mode
UVOT - imaging mode using
UVM2 filter centered at 2200 Å
Total exposure of 3.8 ks



No detection of EF Aql in X-rays
Assuming temperature of the plasma 10 KeV, upper limit of the flux is 10^{-12} erg cm^{-2} s^{-1}

→ faintest δ-type symbiotic star detected so far

EF Aql was detected with UVOT - UVM2 mag is 14.05
Got 0.2 UVM2 mag fainter during the observations - maybe caused by a flickering from the accretion disc

Conclusions:

- T_{WD} ~ 55 000 K and L_{WD} ~ 5.3 $L_{\odot}$
- Possible ionization-potential-dependent stratification
- Improved period of pulsations 320.4 ± 0.3 d
- No detection in X-rays, faintest δ-type symbiotic star detected so far
- UVM2 = 14.05 mag
- d ~ 3.1 kpc
- Mass-loss rate ~ 2.5 10^{-7} $M_{\odot}$ yr^{-1}

The optical and X-ray observations point that EF Aql is an accretion-powered symbiotic star without shell burning!!!