

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

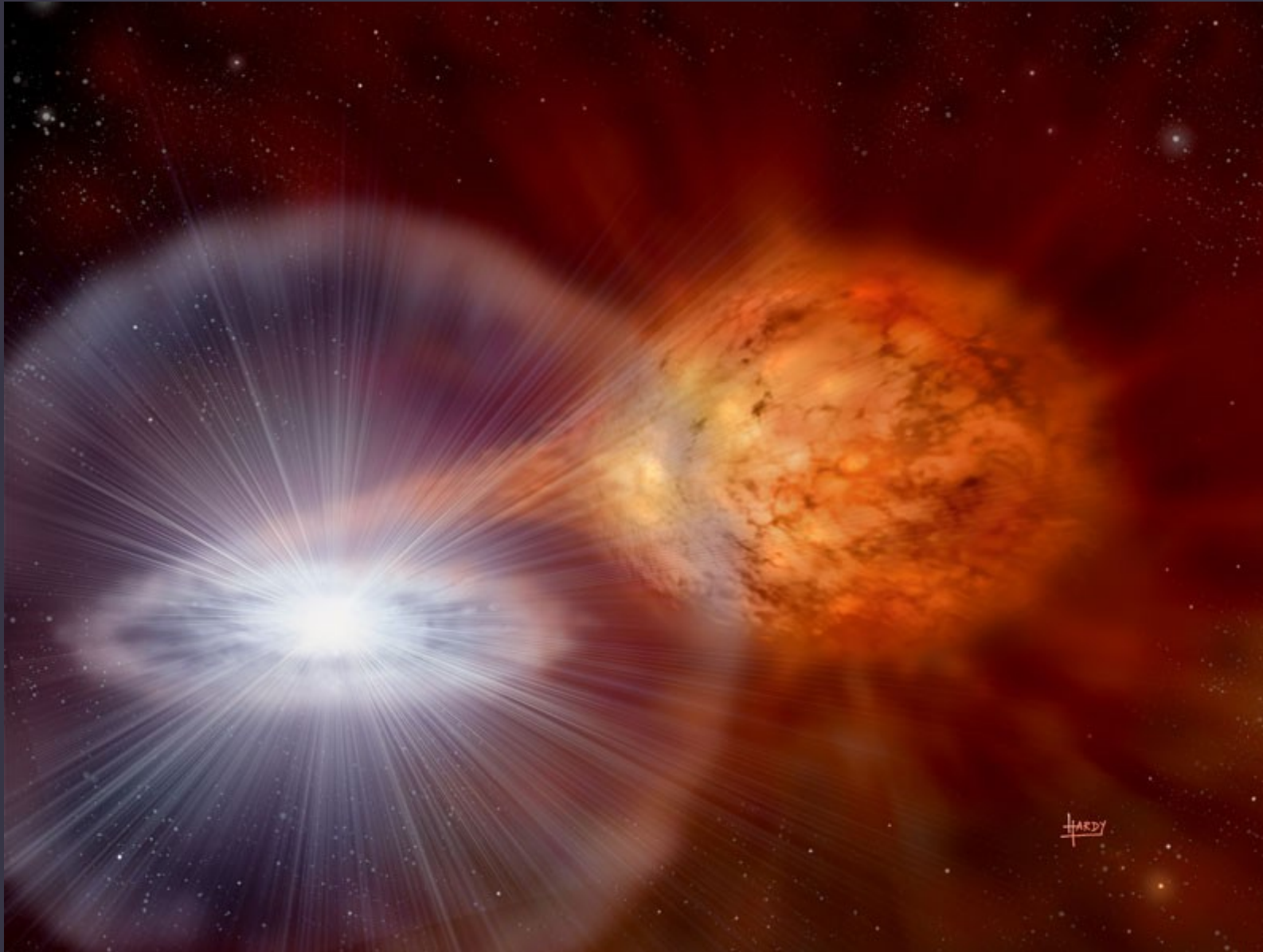


K. A. Stoyanov¹

in collaboration with K. Itkiewicz², G. J. M. Luna^{3,4,5}, J. Mikołajewska², K. Mukai^{6,7},
J. Martí⁸, G. Latev¹, S. Boeva¹, R. K. Zamanov¹



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



Königstuhl Observatory



The history of EF Aql

Reinmuth (1925) - variable star

Le Bertre et al. (2003) - O-rich Mira-type variable



The history of EF Aql

Reinmuth (1925) - variable star

Le Bertre et al. (2003) - O-rich Mira-type variable

Richwine et al. (2005) - $P = 329.4$ d



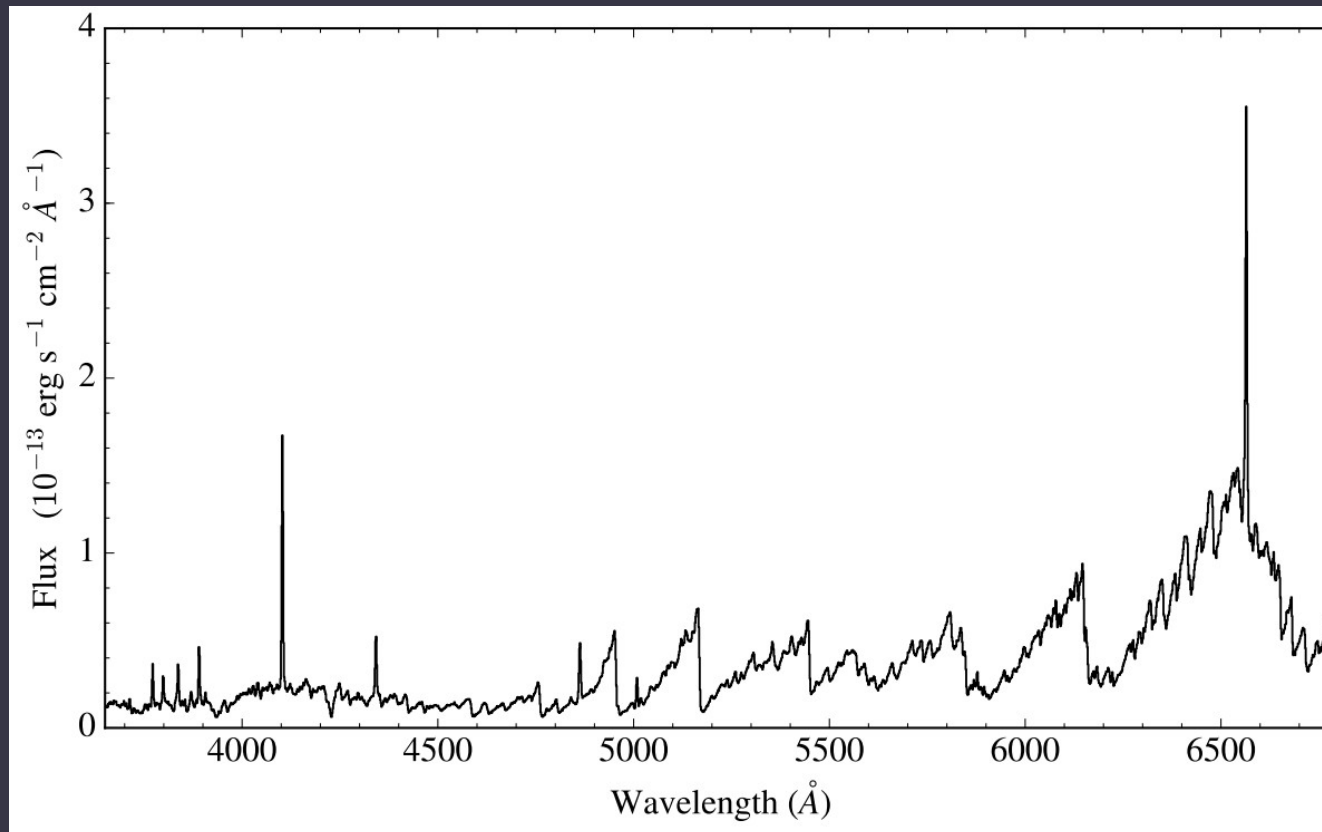
The history of EF Aql

Reinmuth (1925) - variable star

Le Bertre et al. (2003) - O-rich Mira-type variable

Richwine et al. (2005) - $P = 329.4$ d

Margon et al. (2016) - bright UV flux, prominent Balmer emission lines and [O III] $\lambda 5007$ emission



The history of EF Aql

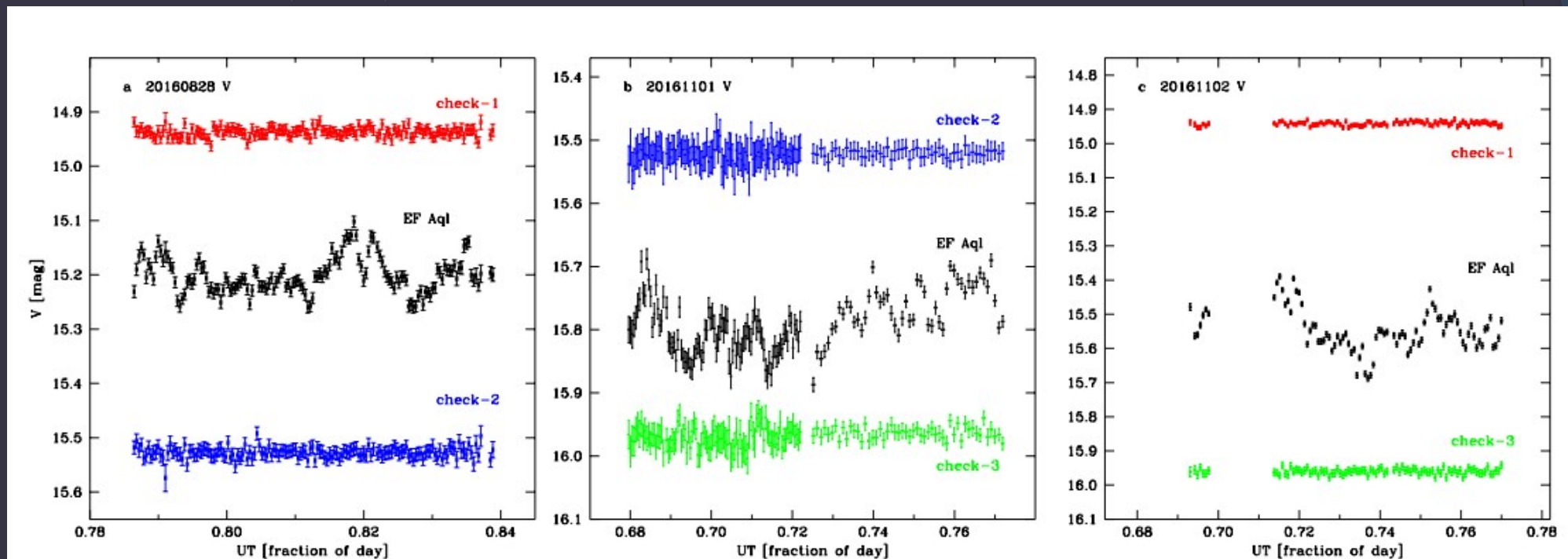
Reinmuth (1925) - variable star

Le Bertre et al. (2003) - O-rich Mira-type variable

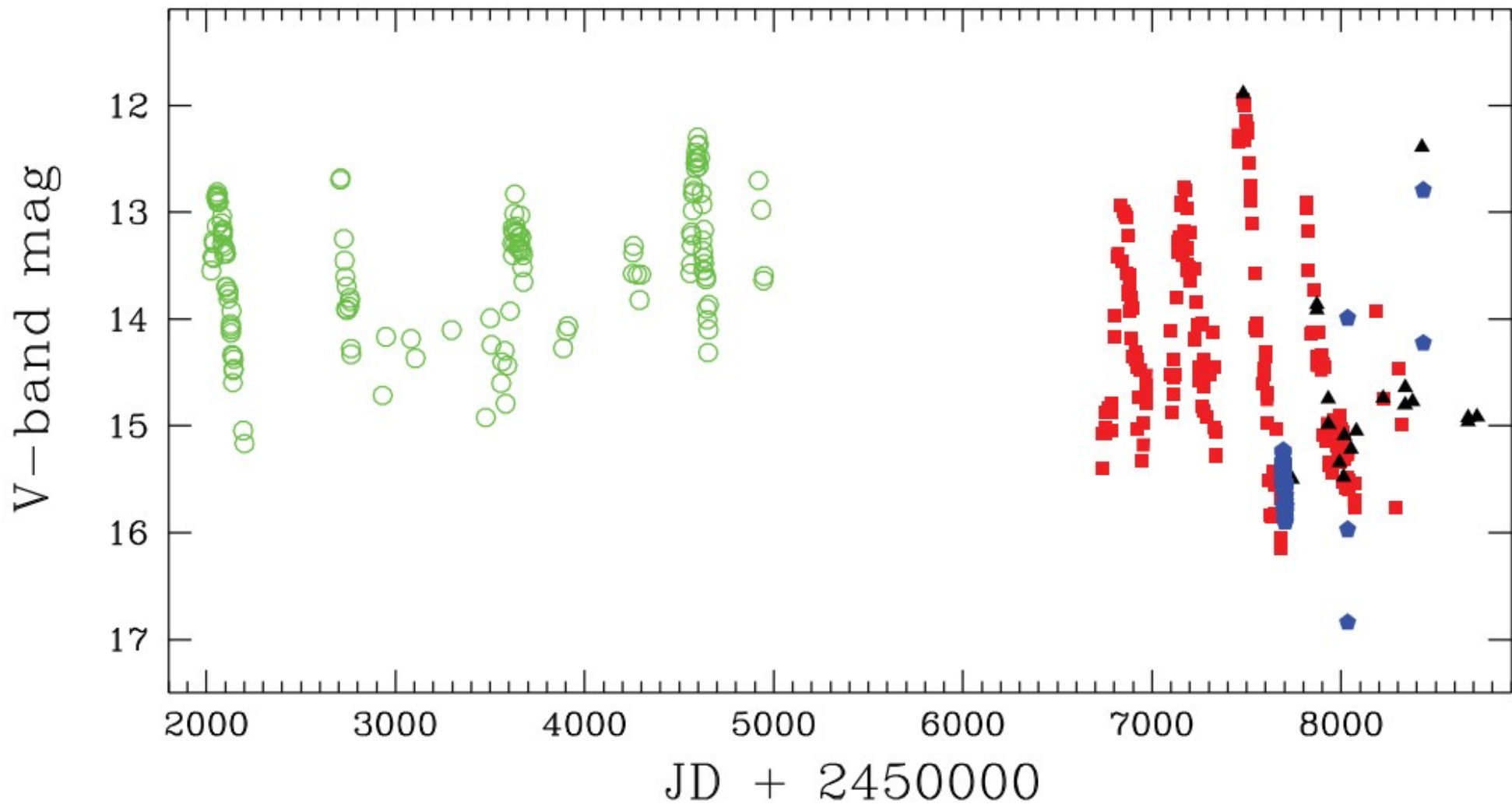
Richwine et al. (2005) - $P = 329.4$ d

Margon et al. (2016) - bright UV flux, prominent Balmer emission lines and [O III] $\lambda 5007$ emission

Zamanov et al. (2017) - optical flickering



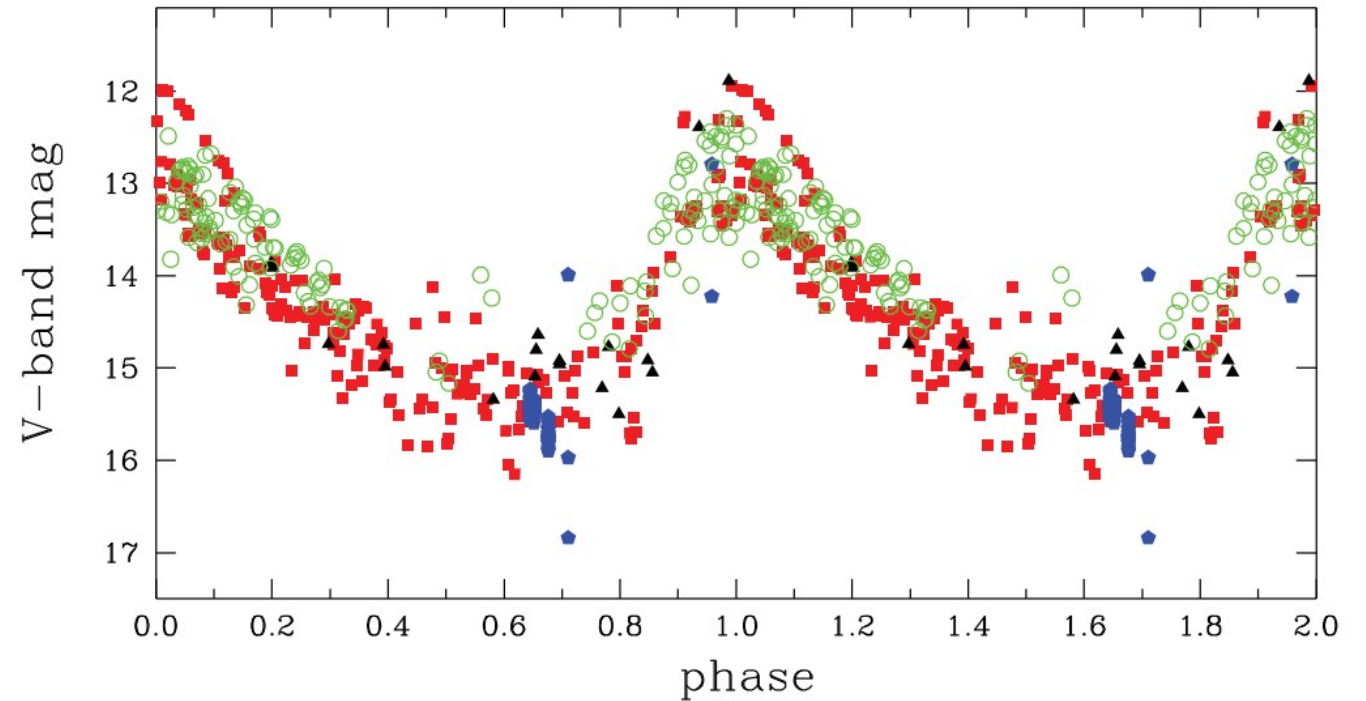
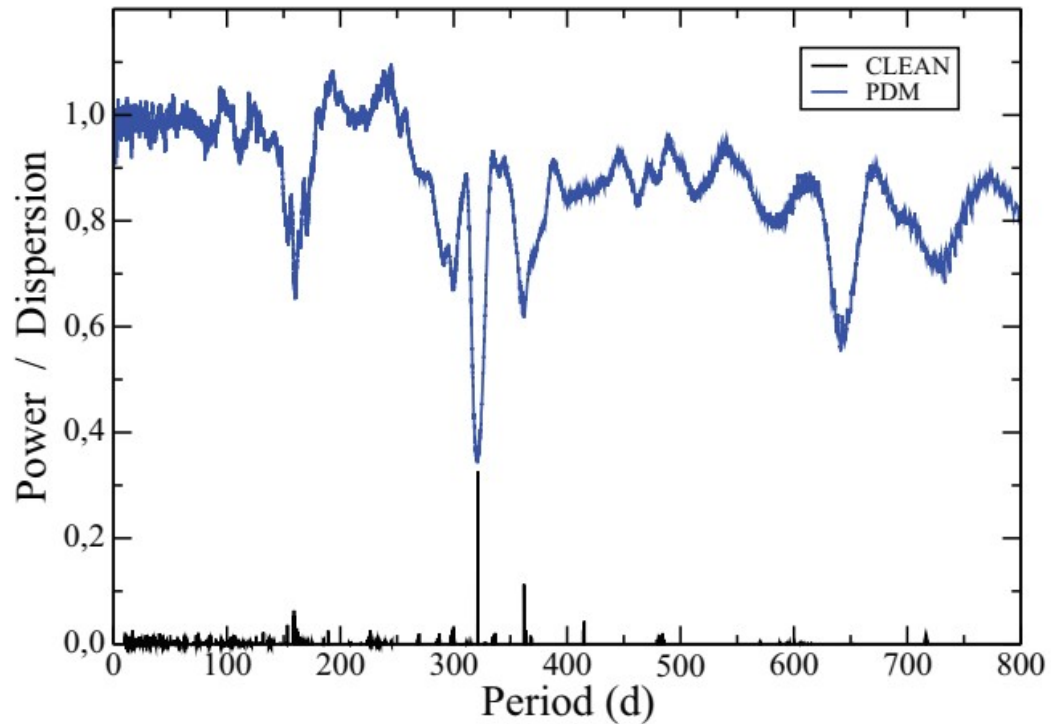
Optical photometry of EF Aql



ASAS
ASAS-SN
AAVSO
Rozhen NAO



Photometry of EF Aql: period of pulsations

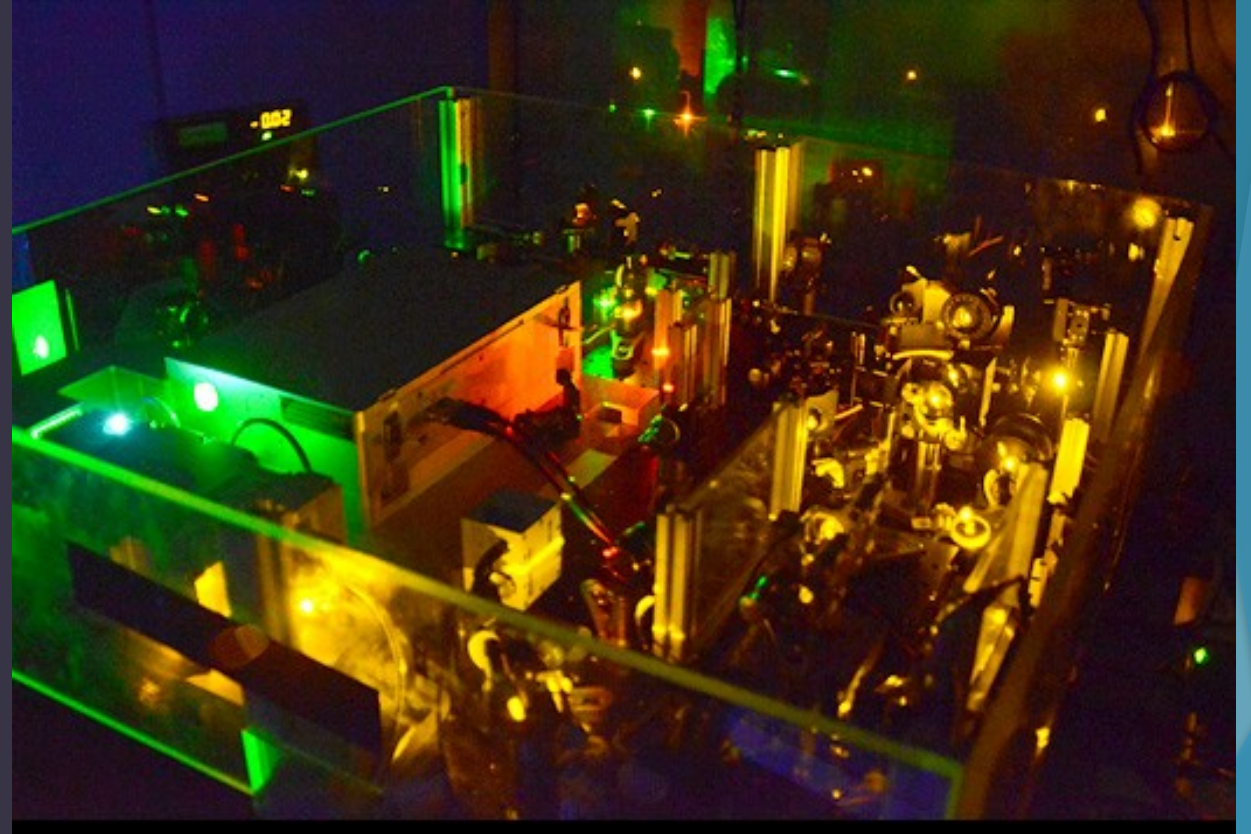


Improved period - **320.4 d**

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



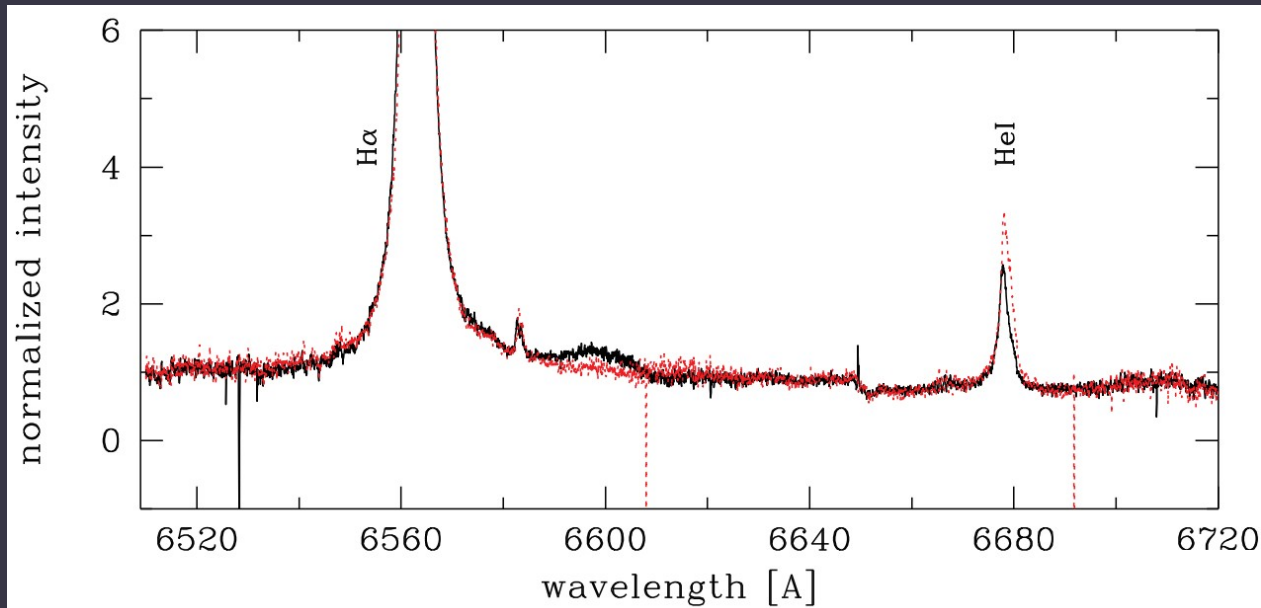
Optical spectroscopy of EF Aql: SALT + HRS



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

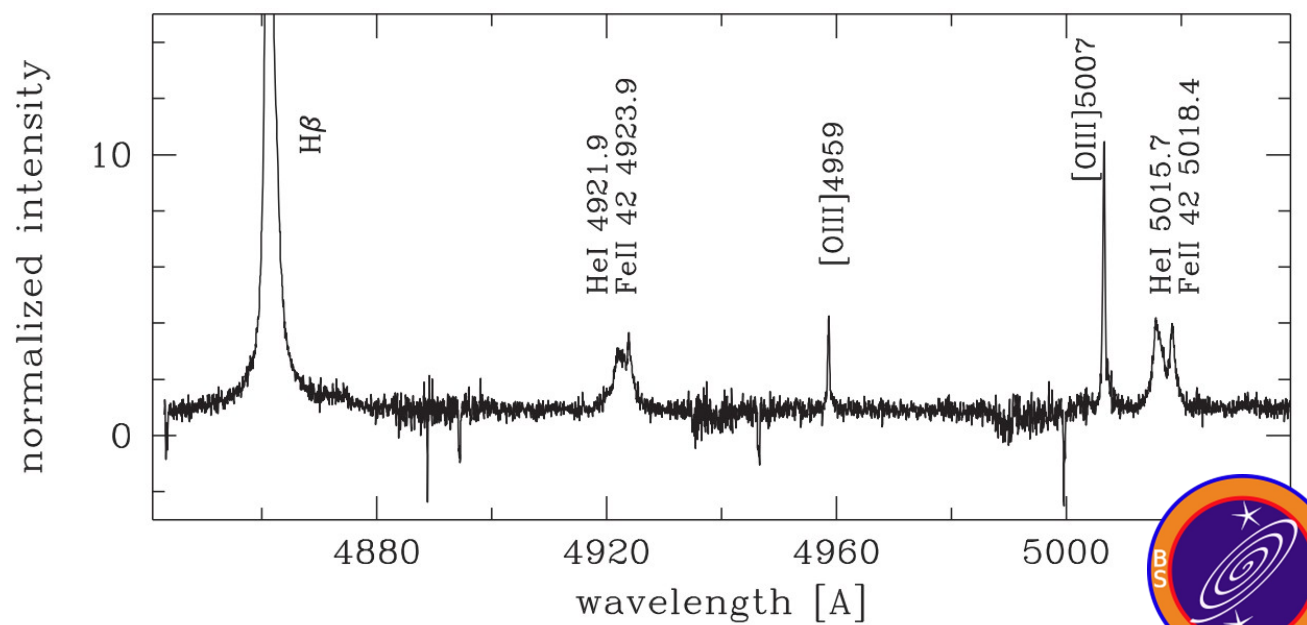


Optical spectroscopy of EF Aql



Possible ionization-potential-dependent stratification?

The [O III] λ 5007 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)

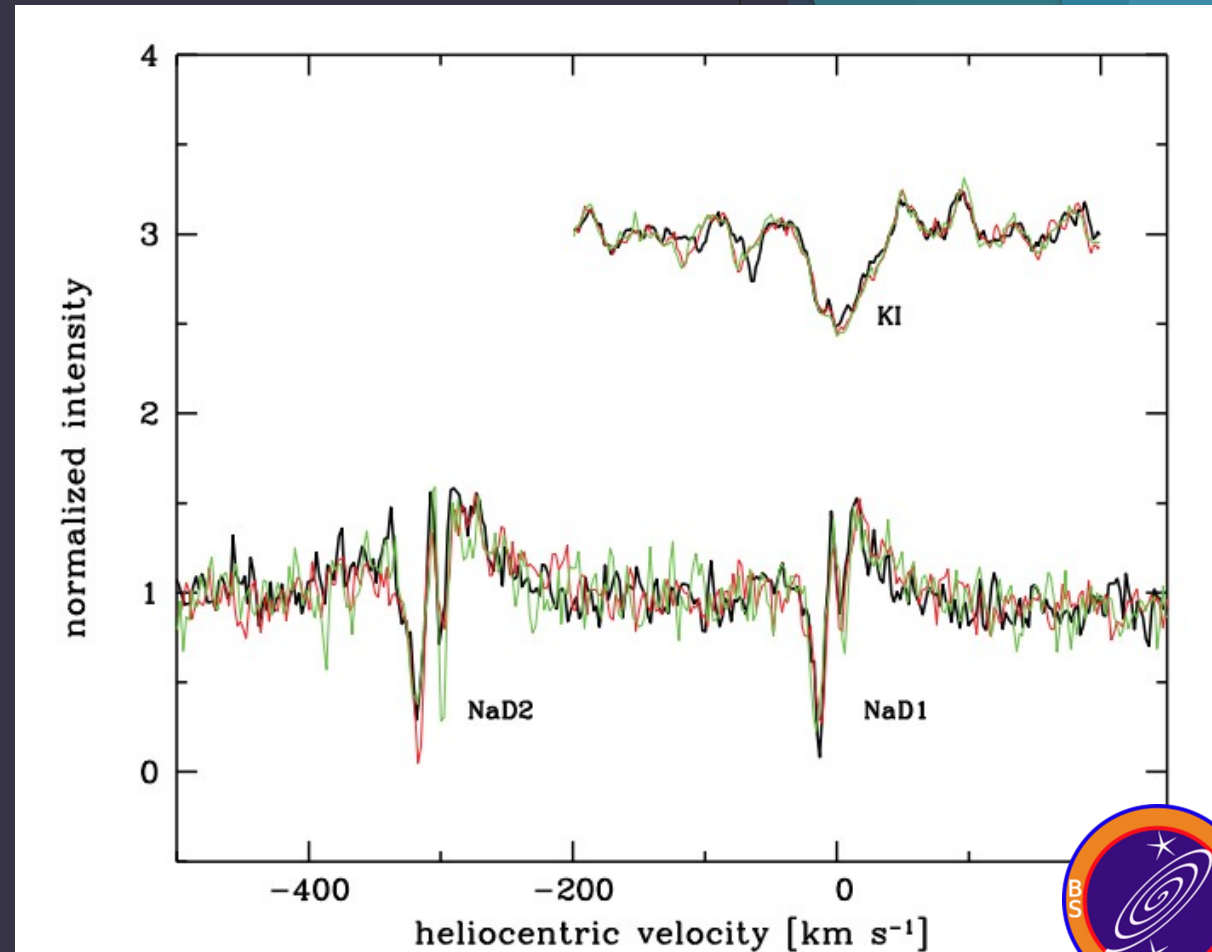
➡ $d = 3.1$ kpc

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

➡ $E(J - K) = 0.32 \pm 0.10$

$EW(\text{Na D1}) = 0.31 - 0.45 \text{ \AA}$

➡ $E(B - V) = 0.12 - 0.25$



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

$$T_{\text{WD}} \geq 35\,000\text{ K.}$$

The lack of any traces of He II lines and the presence of strong He I lines means that $T_{\text{WD}} \leq 60\,000\text{ K.}$

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

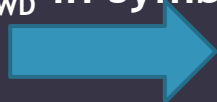
Using $d = 3.1\text{ kpc}$



$$L_{\text{WD}} \sim 5.3 L_{\odot}$$

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 $\sim 2.5 \cdot 10^{-7} M_{\odot} \text{ yr}^{-1}$

Single O-rich Miras - $10^{-7} - 10^{-5} M_{\odot} \text{ yr}^{-1}$

Miras in Symbiotic systems - $\sim 3.2 \cdot 10^{-6} M_{\odot} \text{ yr}^{-1}$

→ 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

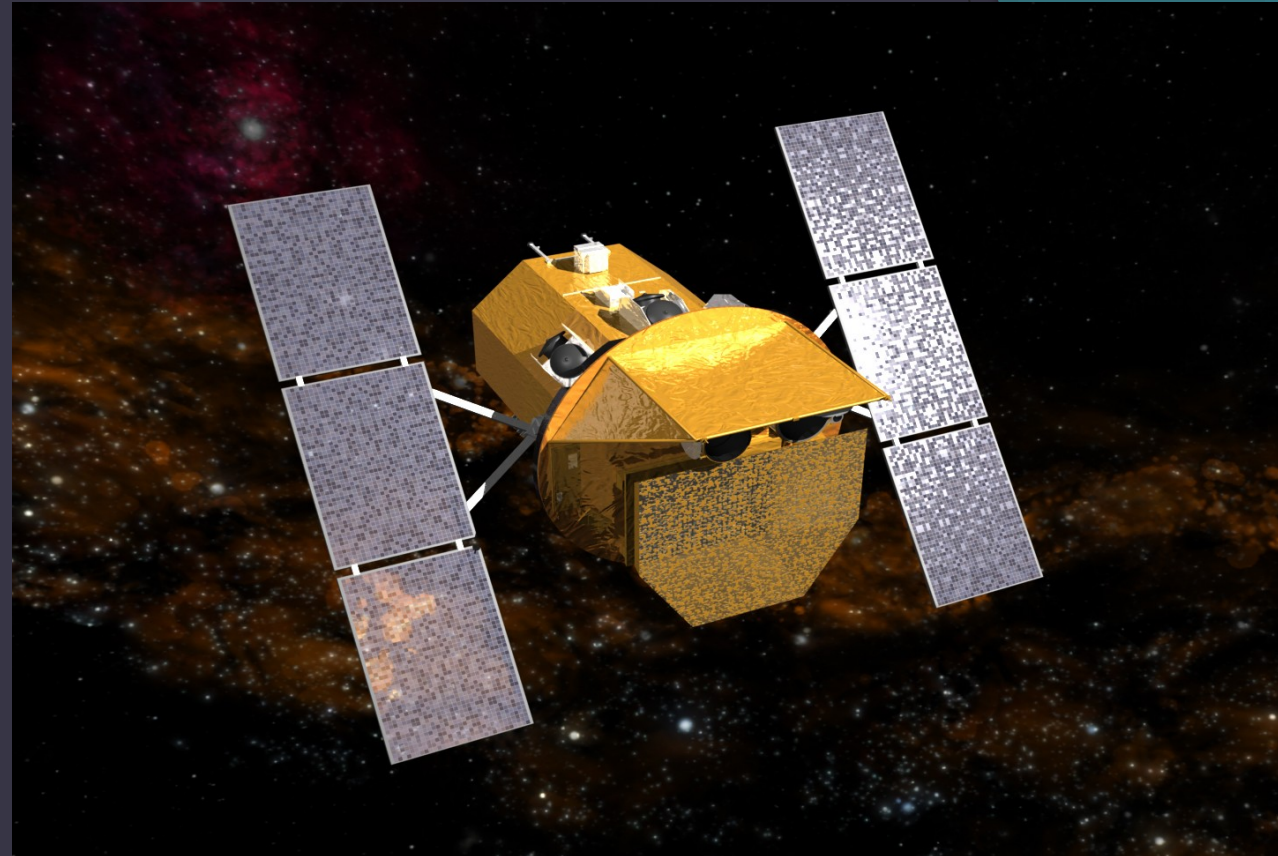
UVM2 filter centered at 2200 Å

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 $\text{cm}^{-2} \text{s}^{-1}$

→ 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:

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

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

