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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Zamanov et al. (2017) - optical flickering
Optical photometry of EF Aql
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 $4000 - 8800\,\text{Å}$
Optical spectroscopy of EF Aql

The [O III] $\lambda 5007$ emission line is similar to that in PNe.

Possible ionization-potential-dependent stratification?
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)

\[E(J - K) = 0.32 \pm 0.10\]

\[\text{EW(Na D1)} = 0.31 - 0.45 \text{ Å}\]

\[E(B - V) = 0.12 - 0.25\]
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 $T_{\text{WD}} \geq 35000 \text{ K}$.

The lack of any traces of He II lines and the presence of strong He I lines means that $T_{\text{WD}} \leq 60000 \text{ K}$.

The ratio $F(\text{He I} 5876)/F(H\beta)$ indicates $T_{\text{WD}} \sim 55000 \text{ K}$.

Using $d = 3.1 \text{ kpc}$

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

$T_{\text{WD}}$ in symbiotic systems - 35000 - 500000 K

$L_{\text{WD}}$ in symbiotic systems - 0.3 - 37000 $\text{ L}_\odot$

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 \( \sim 2.5 \times 10^{-7} \, M_\odot \, yr^{-1} \)

Single O-rich Miras - \( 10^{-7} - 10^{-5} \, M_\odot \, yr^{-1} \)
Miras in Symbiotic systems - \( \sim 3.2 \times 10^{-6} \, M_\odot \, yr^{-1} \)

supports the idea for a low-luminosity system
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:

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

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