Symbiotic stars, weird novae, and related embarrassing binaries
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Evolution of the mass accretion rate in symbiotic stars- MWC 560, Rs Oph and T Cr B

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Goals

- To follow the time evolution of the mass accretion rate for symbiotic stars along with other parameters like effective temperature, radius and luminosity, calculated from multicolor photometry.
- To estimate the total amount of mass accretion between the last two nova eruptions of RS Oph using public data from AAVSO
- To make more precise calculations for mass accretion using our own photometric observational data for T CrB

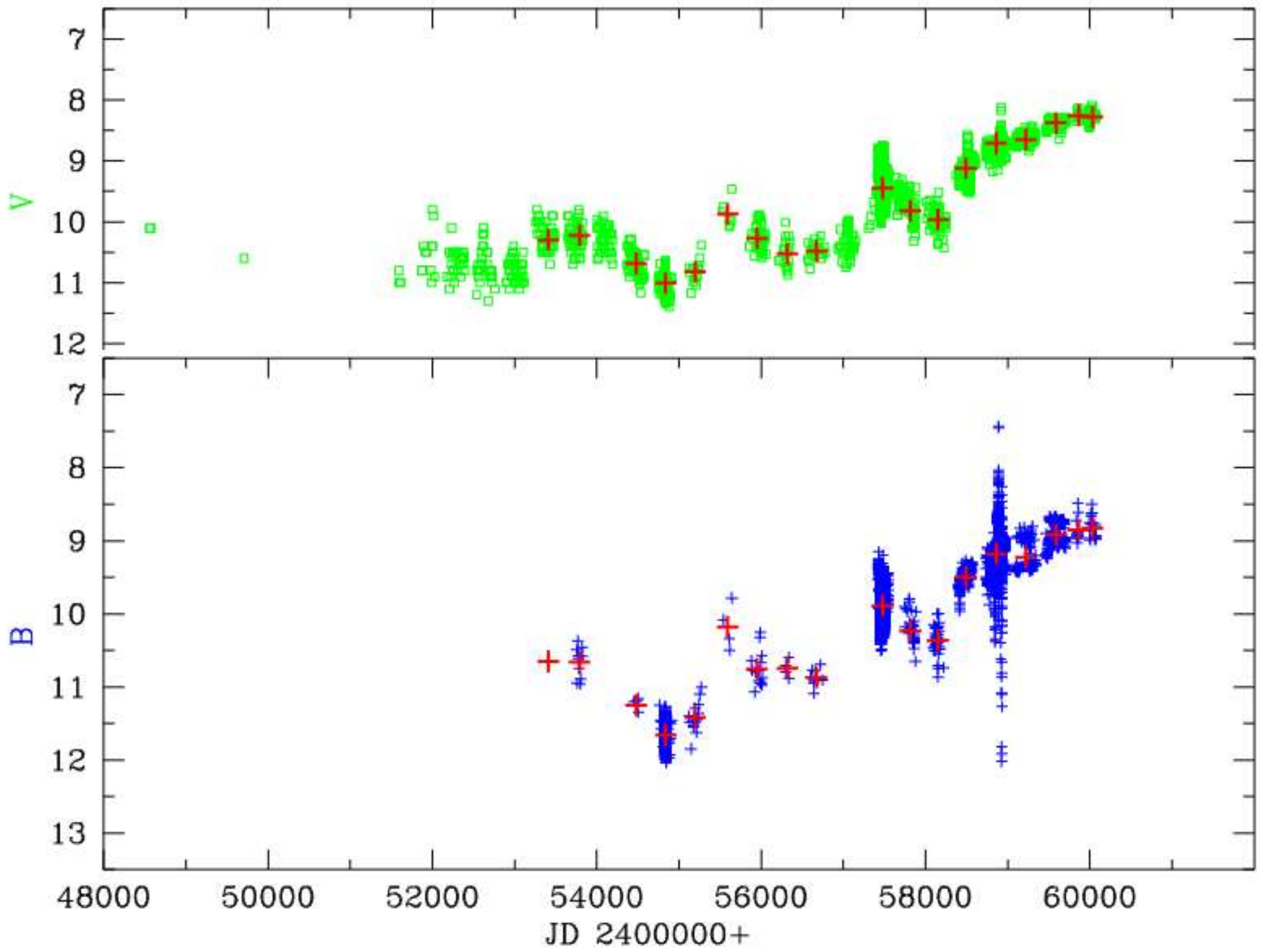
MWC560

- MWC560 (V694 Mon) – identified as an emission line object by Merrill & Burwell (1943)
- Spectroscopic observations from 1984 show extraordinary symbiotic star with absorption – 3000 km/s at Hβ and other Balmer lines (Bond et al. 1984)
- Later spectroscopy from early 1990 at the NAO Rozhen Observatory demonstrate outflow velocities 6000 – 7000 km/s and Tomov et al. (1990a) proposed absorption is caused by a jet along the line of site
- The outflow could be a highly collimated baryon-loaded jet (Schmid et al. 2001) or wind from the polar regions (Lucy, Knigge & Sokoloski 2018)

- Considered to be a non-relativistic analog of the quasars:

1. Collimated outflow (jets)
2. The optical emission lines (Balmer lines and FeII lines) are similar to those of the low-redshift quasars (Zamanov & Marziani 2002)
3. The absorption lines are similar to the lines of the broad absorption lines quasars (Lucy et al. 2018)

B and V photometric data from AAVSO



Procedure

1. Obtaining B and V – magnitudes of the hot component by subtracting the contribution of the giant:
For B filter – λ_{eff}= 4371.07 Å zero magnitude star 6.13 $\times 10^{-9}$ erg cm^{-2} s^{-1} $Å^{-1}$, and for Generic Bessell.
For V filter – λ_{eff}= 5477.70 Å , zero magnitude star 3.63 $\times$ 10^{-9} erg cm^{-2} s^{-1} $Å^{-1}$.
2. Correction for the interstellar extinction and obtaining B_0 and V_0 achieving $(B\text{-}V)_0$
3. Using $(B - V)_0$ and the calibration for black body (Table 18 in Strayzis 1992), we calculate the effective temperature of the hot component, T_{eff} .
4. Using distance d [pc], the dereddened magnitudes B_0 and V_0, and the calculated T_{eff} we estimate the effective radius R_{eff} of the hot component.
5. To derive the optical luminosity of the hot component we use the standard formula:

$$\boldsymbol{L = 4\pi R_{eff}^2 \sigma\, T_{eff}^4}$$

6. Calculating the accretion rate using:

$$\boldsymbol{L = \frac{1}{2} G \frac{M_{wd} \dot{M}_a}{R_{wd}}}$$

Parameters

- For the red giant :

m_V = 12.25 and ***m_B = 13.94*** (Zamanov et al. 2020)

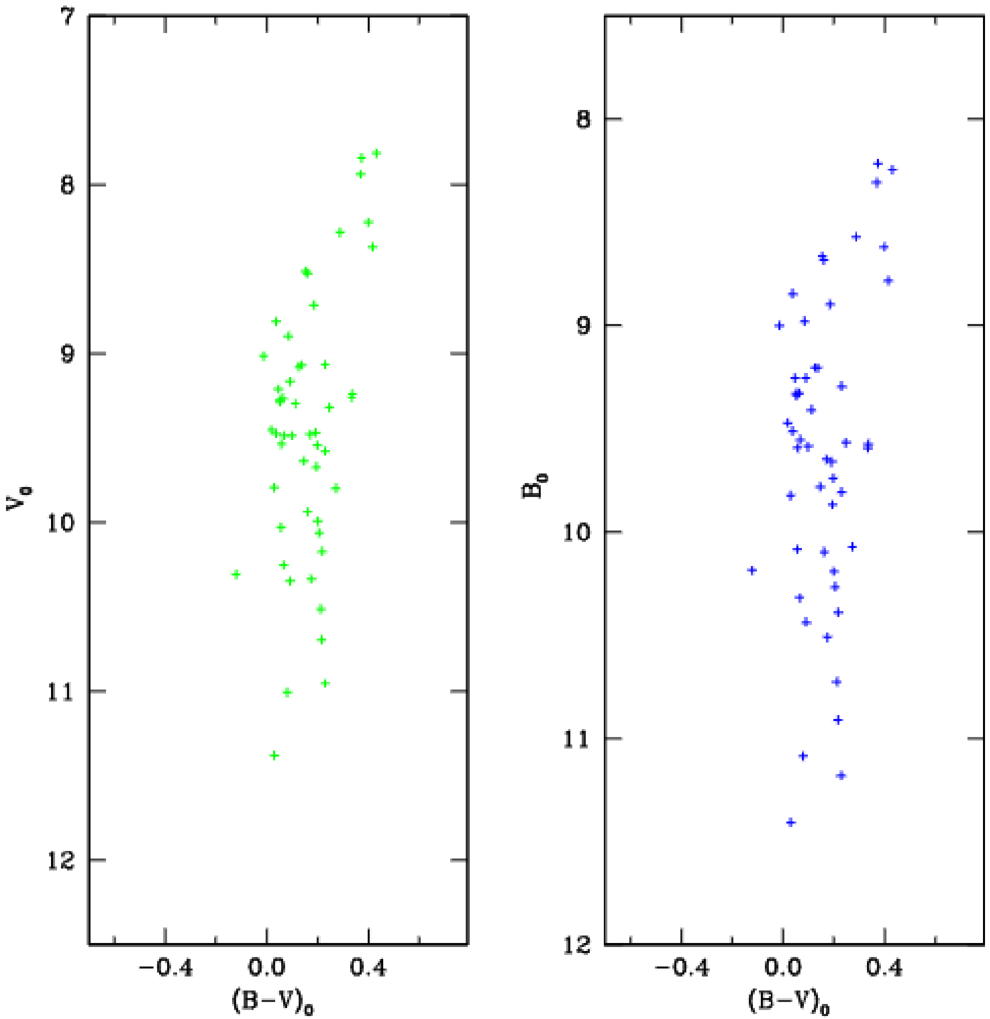
- Interstellar extinction ***E(B-V)=0.15 mag*** (from the 2200 ˚A feature, Schmid et al. 2001)
- We estimate extinction in B and V bands - ***A_B = 0.620*** and ***A_V = 0.468*** following the mean extinction law (Eq.1, Eq.3a, Eq.3b in Cardelli, Clayton, & Mathis 1989)
- Distance we get from Bailer-Jones (2021) for the Gaia EDR3 data (Gaia Collaboration et al. 2018)

d = 2217 pc

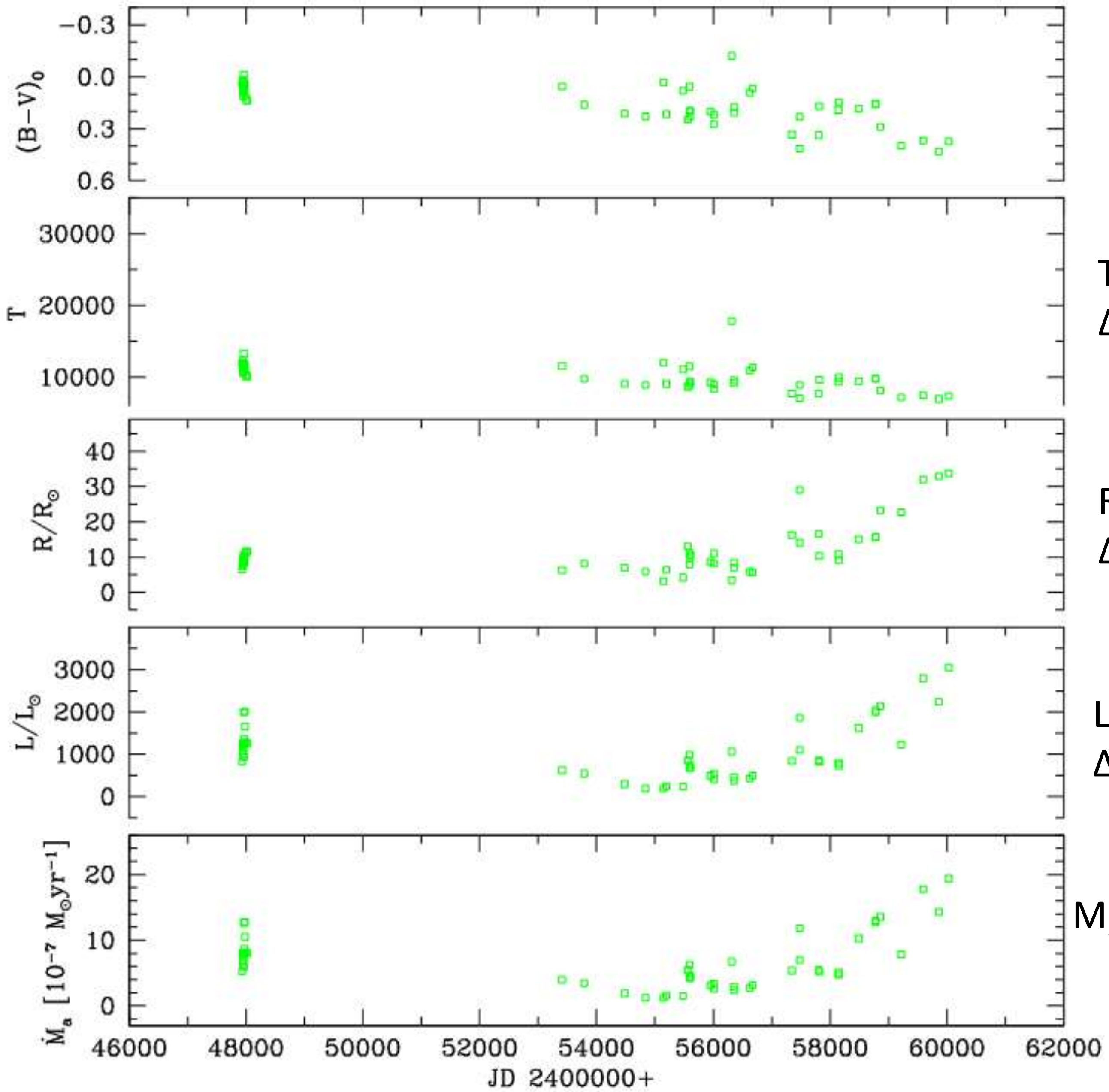
M_{wd}=0.9$M_\odot$ (Zamanov et al. 2011)

R_{wd}=6221km (Zamanov et al. 2011)

Dereddened color-magnitude diagram for the hot component of MWC560



Results MWC560



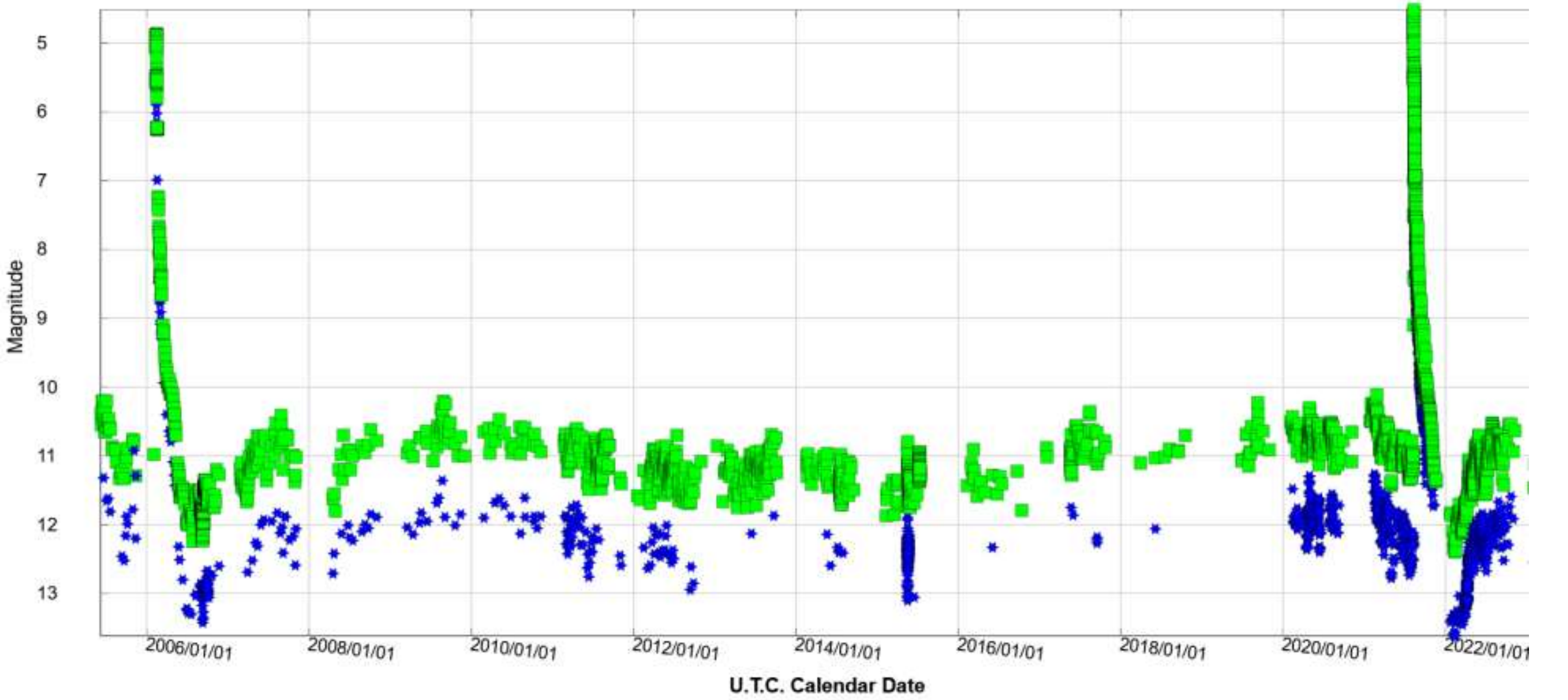
T_{eff} in the range of 7000 – 13000 K, ΔT=± 600K

R_{eff} in the range of 3 – 33 $R_{\odot}$, ΔR=±6-8%

L in the range of 800 – 3000 $L_{\odot}$, ΔL=±4%

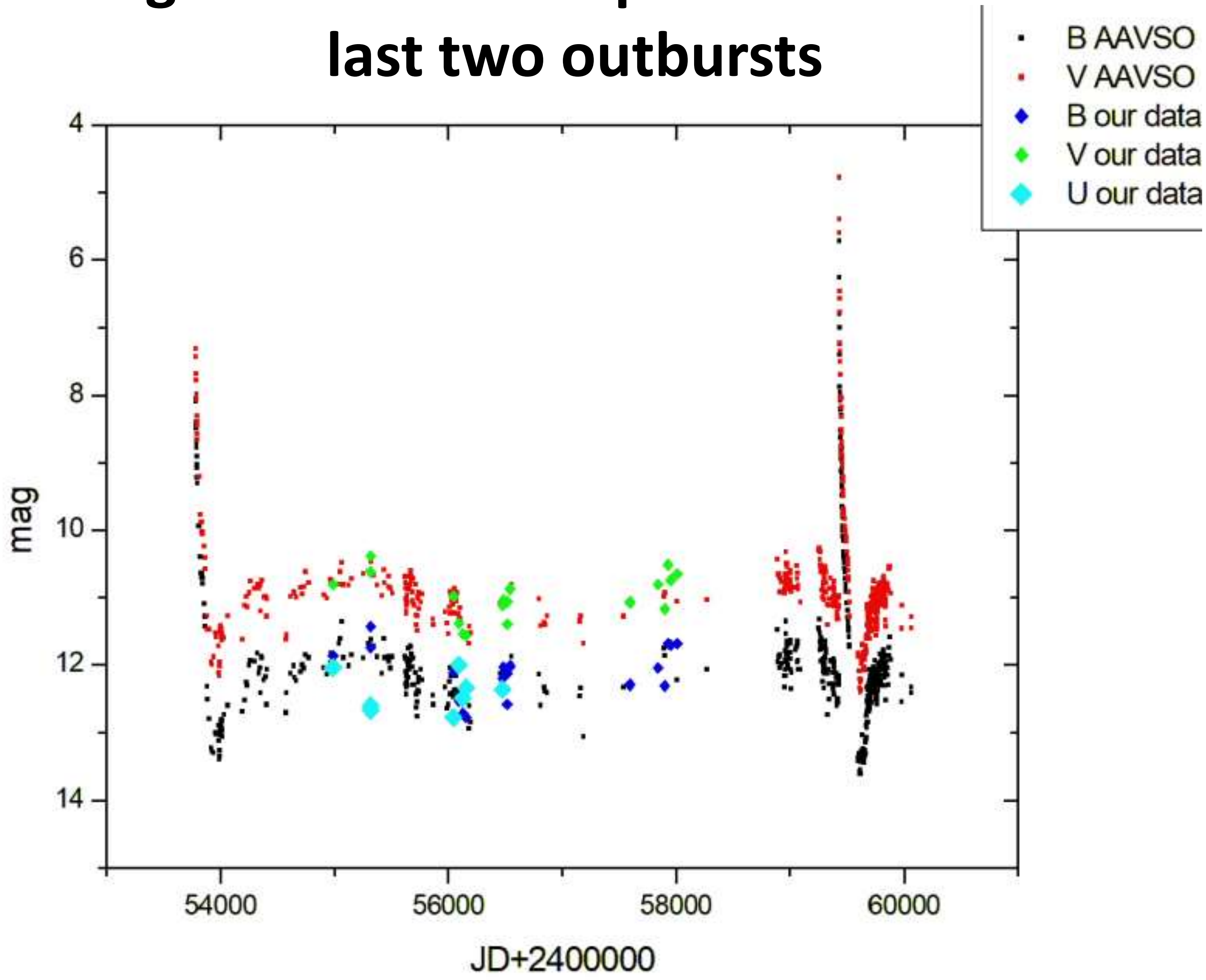
M_a in the range of 5 – 20 [$10^{-7} M_{\odot} yr^{-1}$]

RS Oph

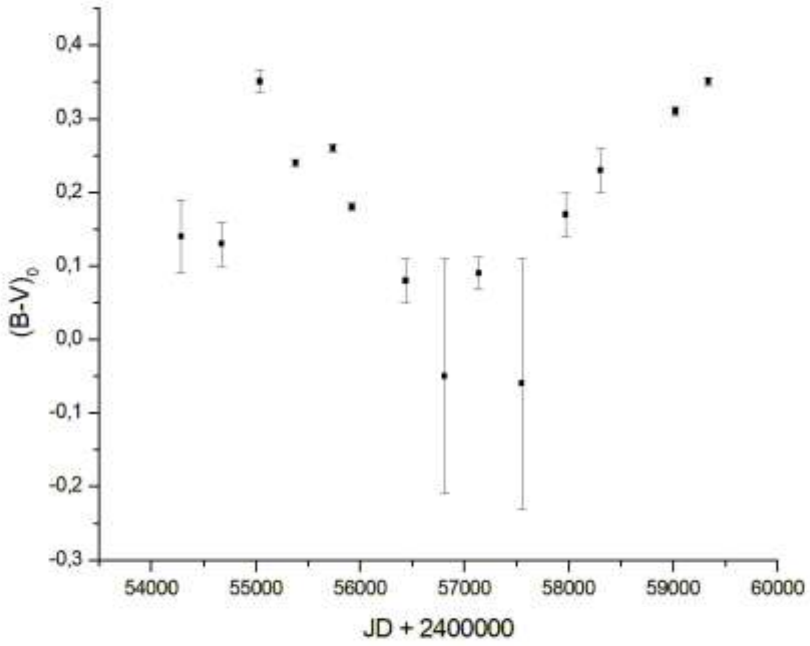


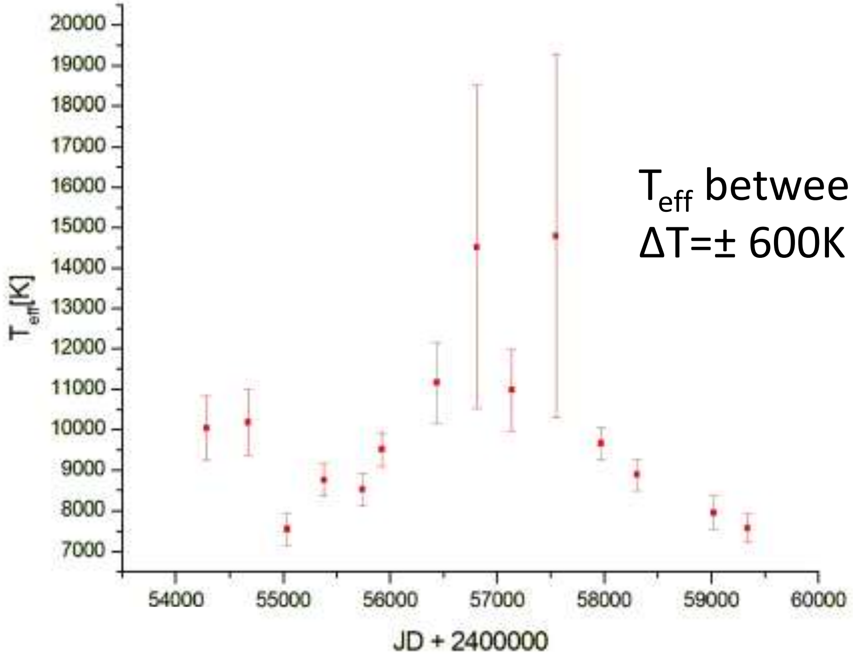
d=2.6kpc (GAIA)
E(B-V)=0.69 ± 0.07 mag
A_B = 2.832 and ***A_V = 2.139***
m_V = 12.46 and ***m_B = 14.55***
M_{wd}=1.35* ± 0.01*$M_\odot$ (super soft x-ray flux Kayo et al. 2008)
R_{wd}=2296km (using the mass radius relation given by Eggleton's formula Verbunt & Rappaport 1988)

Light curve of RS Oph between the last two outbursts

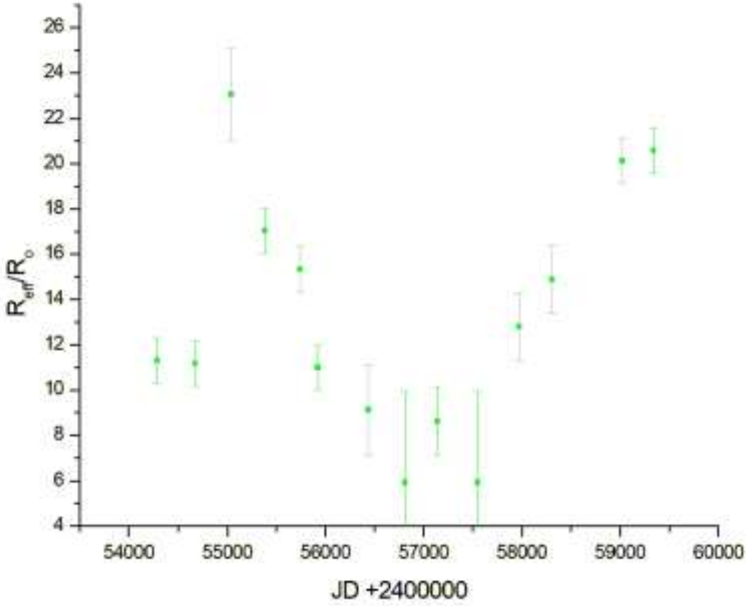


Results RS Oph



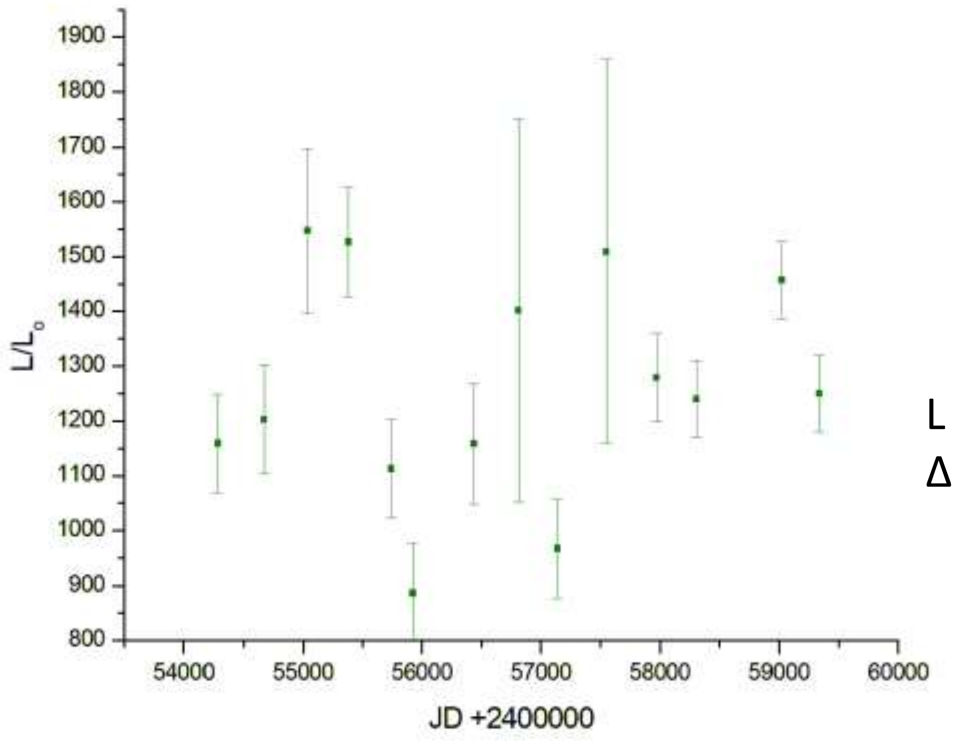


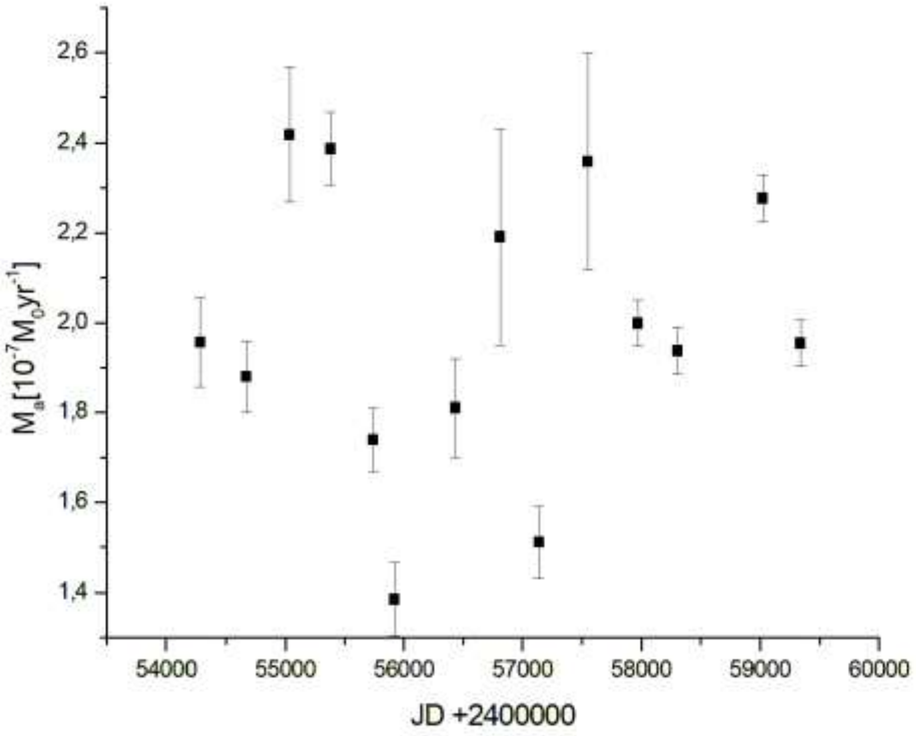
T_{eff} between 7000 – 11000K,
$\Delta T = \pm$ 600K



R_{eff} between 8-23$R_\odot$,
$\Delta R = \pm 8$-10%

Results RS Oph





L between 800 – 1500$L_{\odot}$, ΔL=±8%

M_a between 1.4 – 2.5 [$10^{-7} M_{\odot} yr^{-1}$]

Critical pressure

Strength of the nova outburst is determined by the pressure achieved at the core-envelope interface $\boldsymbol{P_{ce}}$. Which is given by the formula:

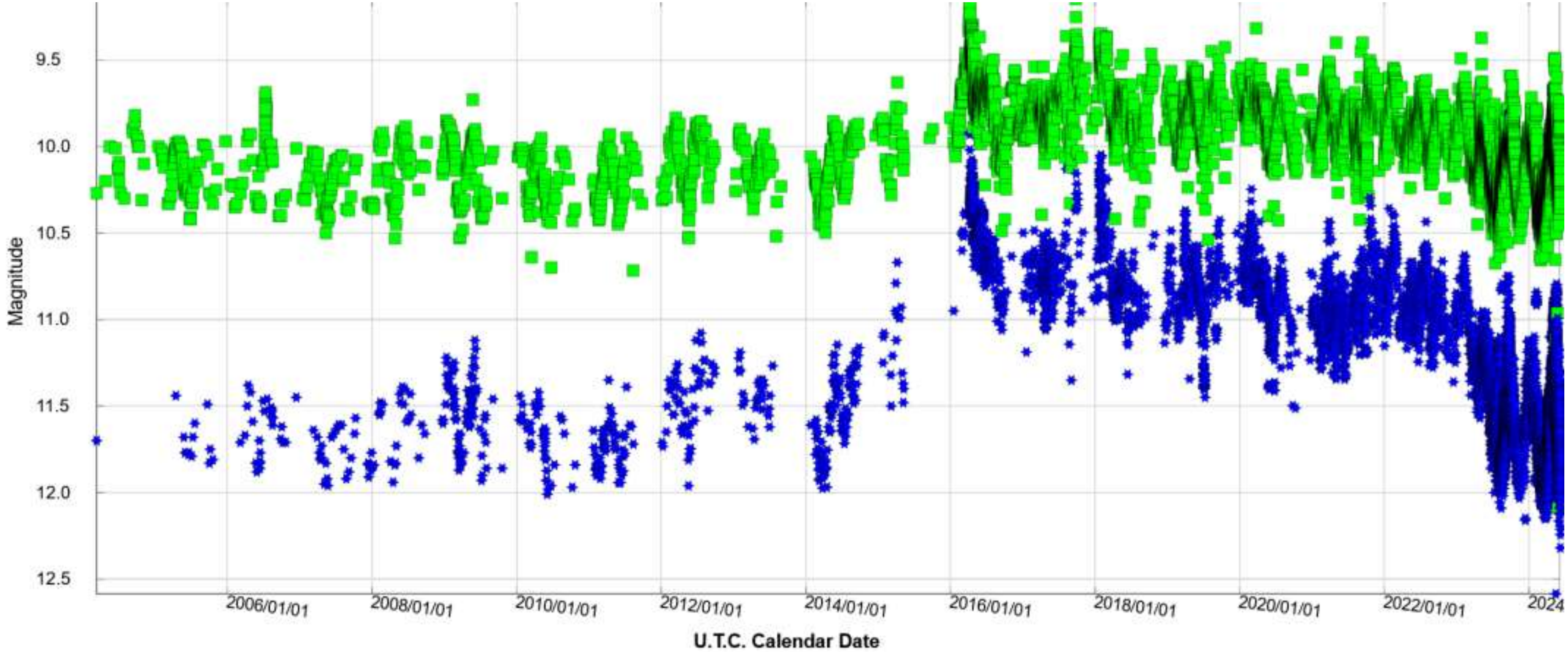
$$P_{ce} = \frac{GM_{wd}}{4\pi R_{wd}^4}\Delta M_a$$

$P_{ce} \sim 10^{19} - 10^{20} dyn\ cm^{-2}$ (Fujimoto 1982, MacDonald 1983)

Between the last two outbursts RS Oph accumulated $\Delta M_a = 3.01 \times 10^{-6} M_\odot$

This give is critical pressure $P_{ce} = 3.06 \times 10^{19} dyn\ cm^{-2}$

T Cr B



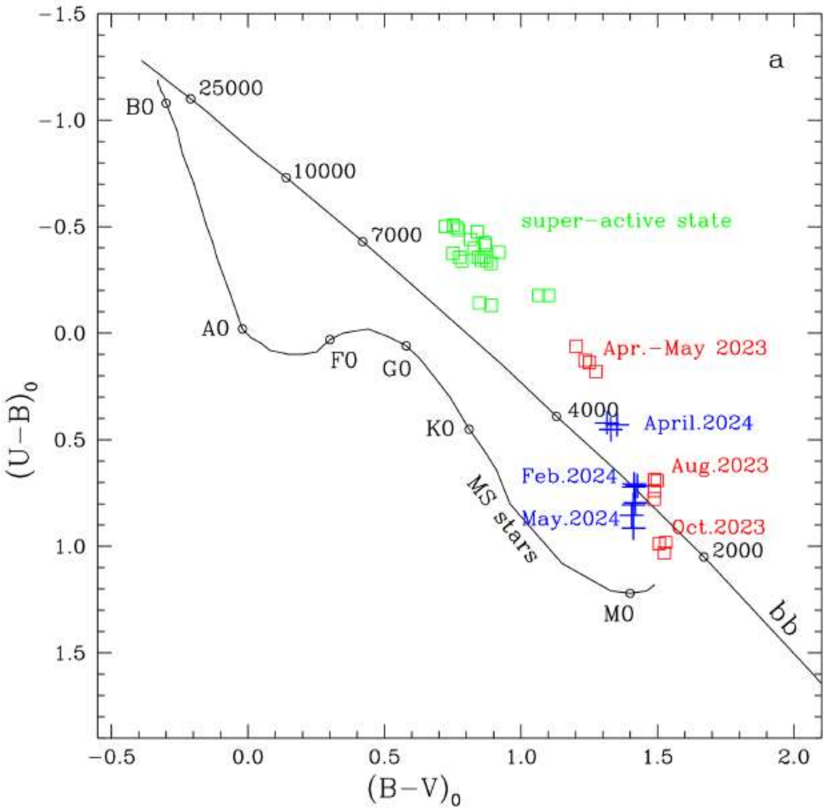
d=914pc (Schaefer 2022)
E(B-V)=0.07mag (Nikolov 2022)
m_V = 12.46 and ***m_B = 14.55***
M_{wd}=1.37 **± 0.13*$M_{\odot}$*** (Stanishev et al. 2004)
R_{wd}=2018km (using the mass radius relation given by Eggleton’s formula, Verbunt & Rappaport 1988)

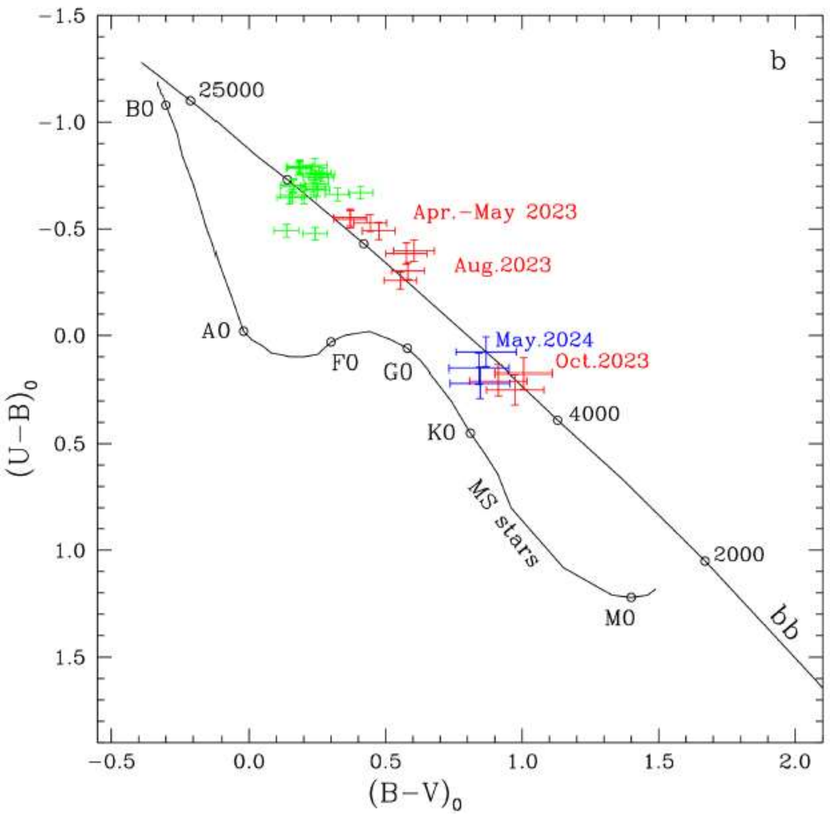
Using our data for the calculations

date	JD	orb.phase	hot comp. U_0	hot comp. $(U-B)_0$	hot comp. $(B-V)_0$	T_{eff} [K]	R_{eff} [$R_\odot$]	L_{opt} [$L_\odot$]	$\dot{M}_a$ [$10^{-8} M_\odot$ yr^{-1}]
2016-02-07	57425.584	0.768	9.946	-0.800	0.240	10012	2.44	53.8	1.90
2016-04-01	57479.584	0.005	9.462	-0.647	0.201	9131	3.70	85.4	3.02
2016-04-03	57481.576	0.014	9.137	-0.740	0.263	9322	4.11	114.5	4.05
2017-02-23	57807.593	0.447	10.083	-0.491	0.137	8762	3.05	49.1	1.74
2017-02-24	57808.569	0.451	10.083	-0.477	0.242	8044	3.73	52.3	1.85
2017-03-28	57841.460	0.595	9.941	-0.697	0.161	9675	2.63	54.2	1.92
2017-03-28	57841.499	0.596	9.900	-0.704	0.162	9710	2.66	56.2	1.99
2017-04-26	57870.479	0.723	9.981	-0.711	0.245	9232	2.85	52.8	1.87
2017-04-27	57870.542	0.723	9.900	-0.743	0.245	9462	2.80	56.5	2.00
2018-01-24	58142.635	0.919	9.451	-0.793	0.185	10292	2.91	85.0	3.01
2018-01-24	58142.663	0.919	9.492	-0.787	0.187	10224	2.89	81.8	2.89
2018-01-24	58142.684	0.919	9.531	-0.782	0.181	10217	2.84	78.9	2.79
2018-04-14	58223.499	0.274	10.084	-0.759	0.240	9639	2.48	47.5	1.68
2018-04-15	58223.555	0.274	10.050	-0.762	0.255	9572	2.55	49.1	1.74
2018-07-06	58306.354	0.638	9.834	-0.656	0.158	9452	2.90	60.0	2.12
2018-07-06	58306.388	0.638	9.890	-0.646	0.148	9456	2.82	57.0	2.02
2020-04-16	58955.520	0.491	10.337	-0.661	0.324	8494	2.91	39.6	1.40
2020-04-16	58955.585	0.491	10.355	-0.669	0.408	8191	3.15	40.1	1.42
2021-01-20	59234.645	0.717	10.206	-0.682	0.250	9030	2.69	43.2	1.53
2021-01-20	59234.667	0.718	10.133	-0.700	0.234	9236	2.65	45.9	1.62
2021-01-20	59234.695	0.718	10.173	-0.688	0.235	9159	2.65	44.3	1.57
2022-07-23	59784.277	0.133	9.984	-0.754	0.268	9418	2.72	52.3	1.85
2023-04-28	60063.347	0.359	11.201	-0.490	0.475	7059	3.14	22.0	0.78
2023-04-28	60063.454	0.359	11.067	-0.527	0.444	7298	3.05	23.7	0.84
2023-05-24	60089.347	0.473	11.078	-0.553	0.370	7682	2.65	21.9	0.78
2023-05-24	60089.402	0.473	11.180	-0.545	0.371	7647	2.56	20.1	0.71
2023-08-11	60168.393	0.821	12.533	-0.384	0.576	6385	2.28	7.8	0.28
2023-08-11	60168.395	0.821	12.556	-0.397	0.604	6354	2.29	7.7	0.27
2023-08-25	60182.292	0.882	12.526	-0.258	0.554	6103	2.64	8.7	0.31
2023-08-25	60182.361	0.882	12.466	-0.303	0.582	6143	2.66	9.0	0.32
2023-10-14	60232.218	0.101	12.661	0.206	0.913	4500	[a]		
2023-10-19	60237.197	0.123	12.727	0.174	1.005	4400	[a]		
2023-10-20	60238.201	0.127	12.819	0.248	0.974	4400	[a]		

[a] the uncertainties are large due to the low brightness.

T Cr B results





During the super-active state (green squares) between April 2016 and July 2022 we see:

L between 40-100 $L_\odot$

T between 8000 – 12000K

M_a between 1,4 – 4.0 [$10^{-8} M_\odot yr^{-1}$]

Total mass accretion accumulated during the super-active state:

$$M_a \sim 2 \times 10^{-7} M_\odot$$

According to Jose et al. 2020; Shara et al. 2018, for TNR is needed $5 \times 10^{-7} - 1.6 \times 10^{-6}\ M_\odot$

Thank you for the attention!