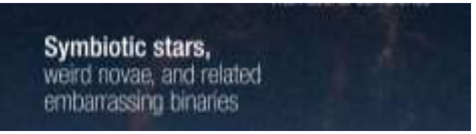

ARIEL UNIVERSITY

ERUPTIVE NOVAE IN SYMBIOTIC SYSTEMS

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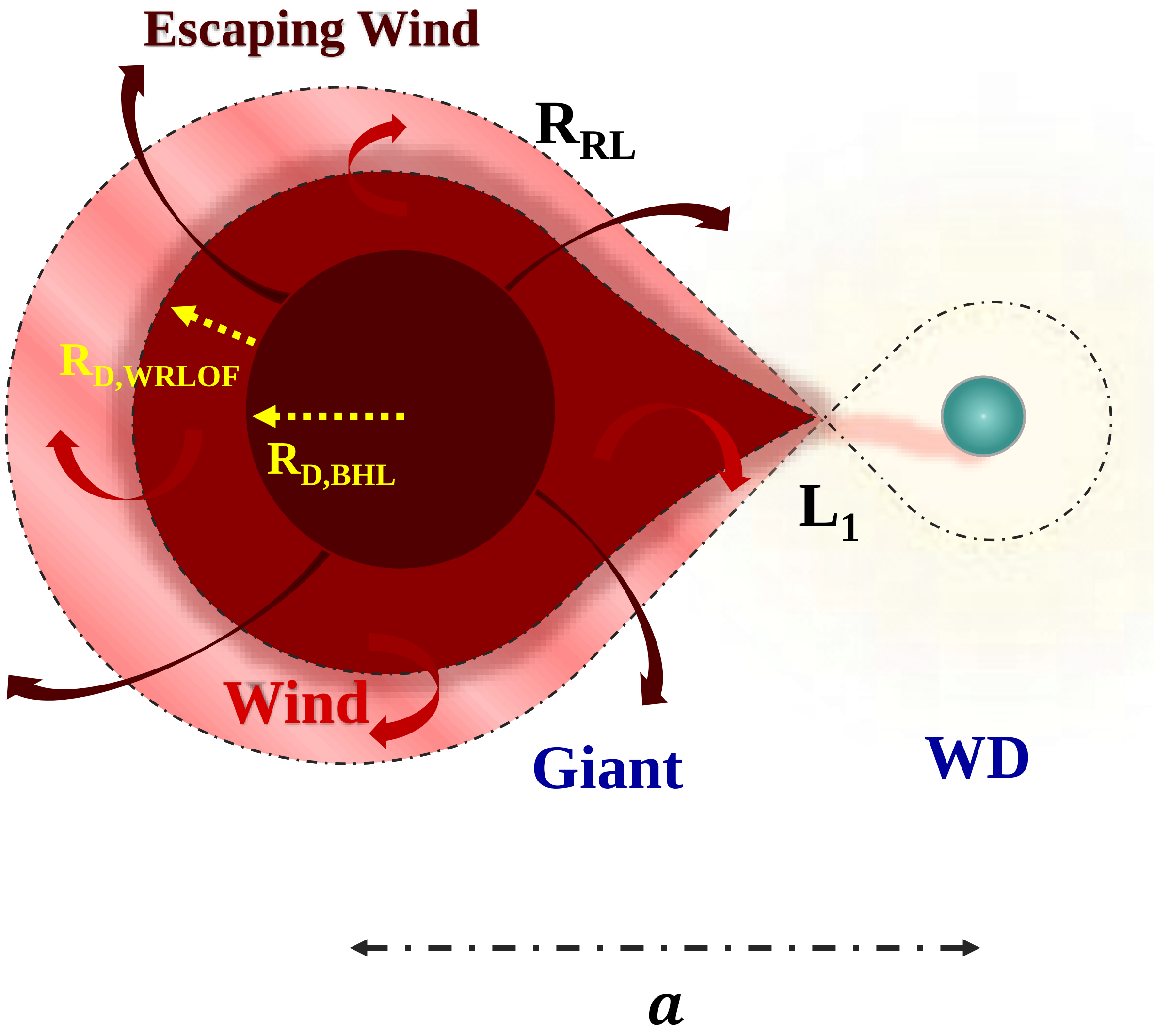
Mass Transfer Mechanisms In Symbiotic Systems

- **Roche-lobe overflow (RLOF)**
  $R_D \approx R_{RL}$

- **Wind Roche-lobe overflow (WRLOF)**
  $R_D < R_{RL}$; $v_{wind} < v_{esc}$

- **Bondi-Hoyle-Lyttleton (BHL) Accretion**
  $R_D \ll R_{RL}$; $v_{wind} > v_{esc}$

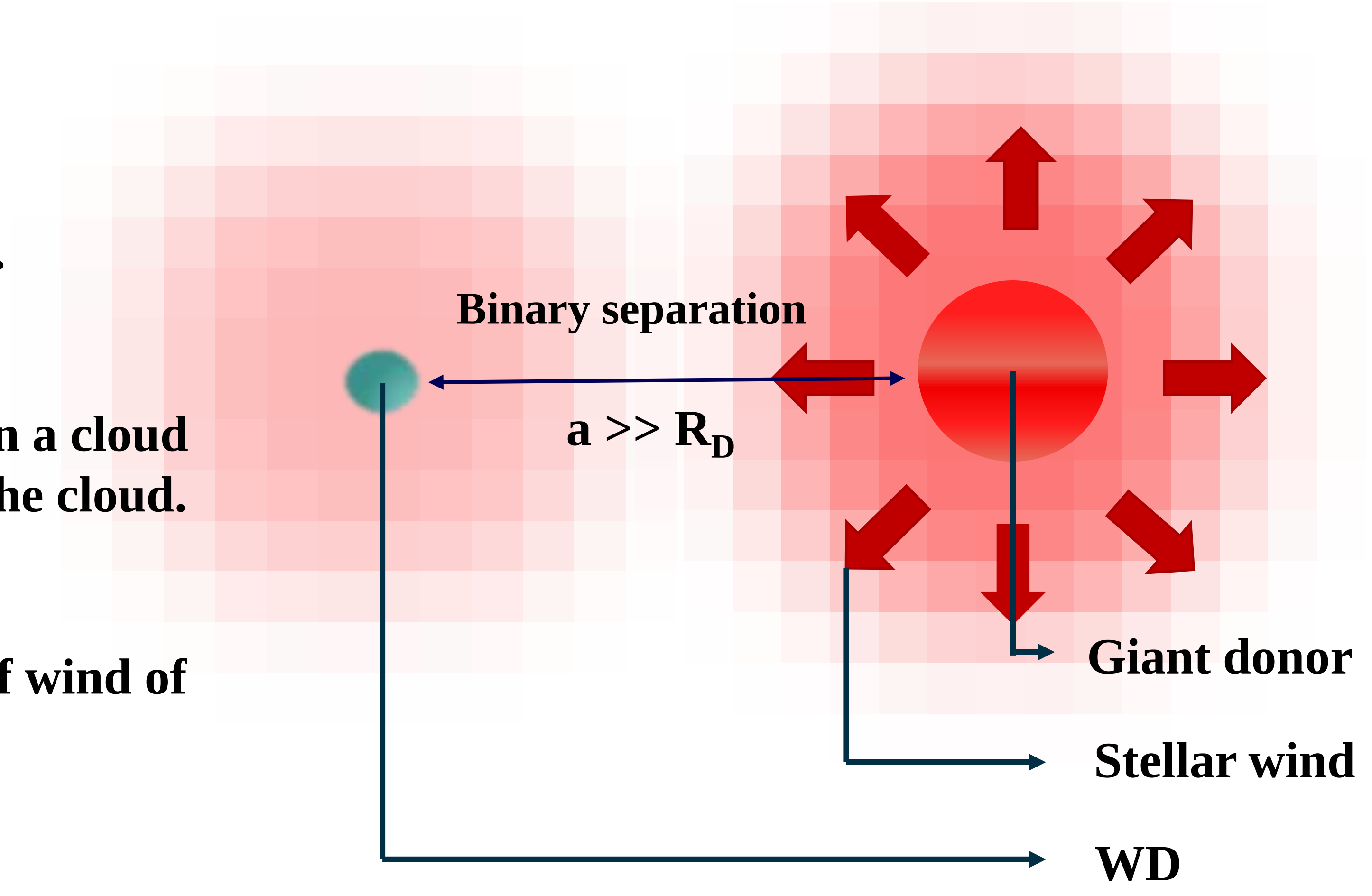


Bondi-Hoyle-Lyttleton Accretion

- Symbiotic system (WD+ giant).

- A point star or object moving in a cloud of gas --- accrete matter from the cloud.

- WD accretes matter --- cloud of wind of the giant.



- Wind escapes iso-tropically --- a fraction is captured by the WD --- the rest is lost from the system.

- Accretion rate is calculated as:

$$r_a = \frac{2GM_{WD}}{v_w^2}$$

$$\dot{M} = 2\pi\rho_w r_a v_w^2 \frac{GM_{WD}}{\left(v_w^2 + v_s^2\right)^{\frac{3}{2}}}$$

$$\rho_w = \frac{\dot{M}_w}{4\pi a^2 v_w}$$

- r_a : accretion radius.
- v_w : wind velocity.
- v_s : speed of sound in the cloud of gas.
- ρ_w : density of donor’s wind.
- $\dot{M}_w$: wind rate.
- a : binary separation.

Bondi H., Hoyle F., 1944, MNRAS, 104, 273.

Methodology For Simulation

Self-consistent binary evolution code

- **Binary systems (WD + RD).**
- **Roche lobe geometry conditions.**
- **Feedback dominated accretion rate calculations.**
- **AML due to GR and MB.**

Hillman Y., Shara M. M., Prialnik D., Kovetz A., 2020, Nature Astronomy, 4, 886
Hillman Y., 2021, MNRAS, 505, 3260

Modified binary evolution code

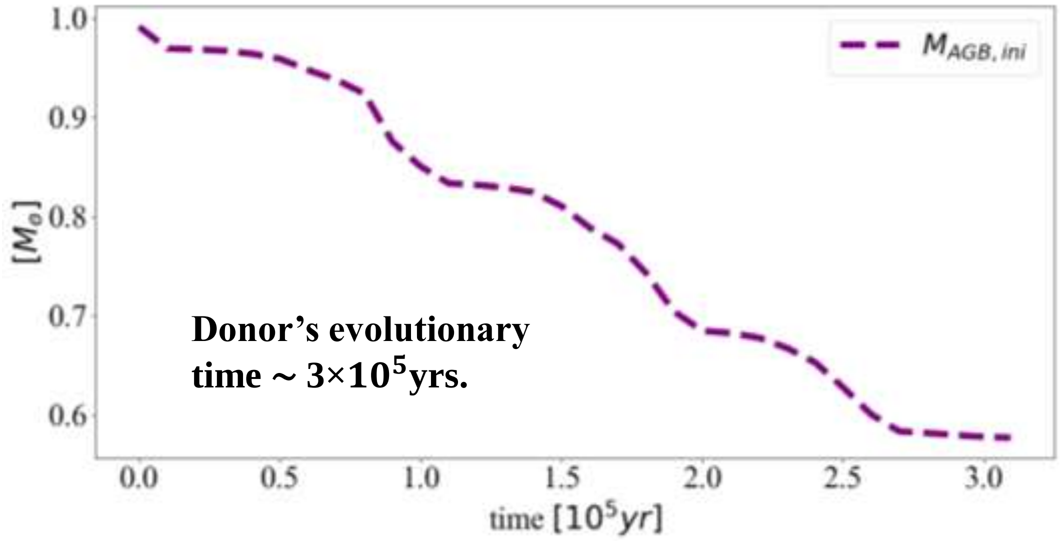
- **Wind of giant --- widely separated system --- accretes on WD.**
- **AML due to GR, MB and drag.**

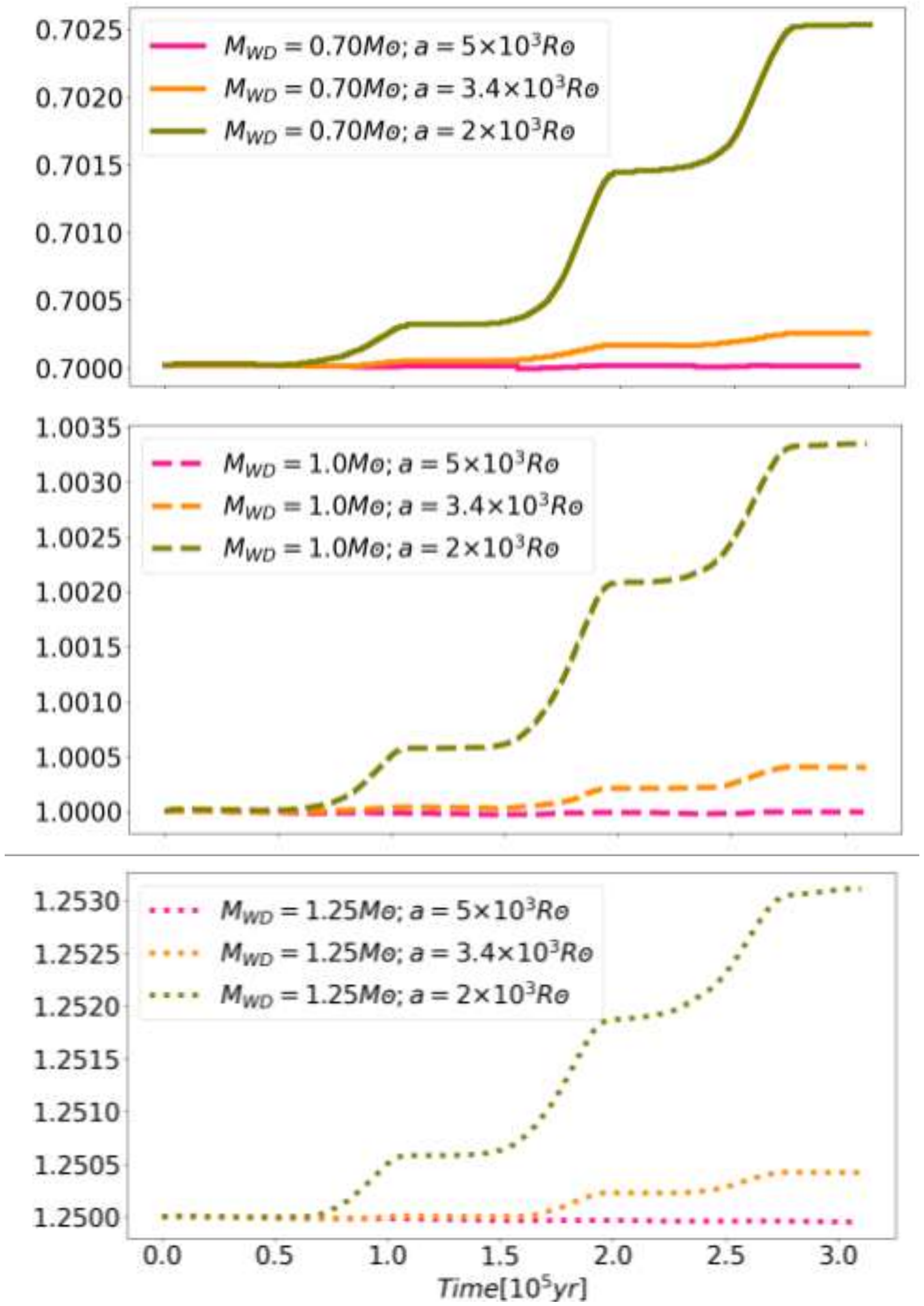
Hillman Y., Kashi A., 2021, MNRAS, 501, 201

Table Of Data

M_{WD} $[M_\odot]$	a_{init} $[10^3 R_\odot]$	No of Cycles	δ $[M_\odot]$
1.25	2.0	8092	$+3.1\times 10^{-3}$
	3.4	2203	$+4.2\times 10^{-4}$
	5.0	904	-4.8×10^{-5}
1.0	2.0	1006	$+3.3\times 10^{-3}$
	3.4	261	$+3.9\times 10^{-4}$
	5.0	105	-7.6×10^{-6}
0.7	2.0	122	$+2.5\times 10^{-3}$
	3.4	30	$+2.3\times 10^{-4}$
	5.0	14	-5.1×10^{-6}

MASS EVOLUTION OF AGB AND WD

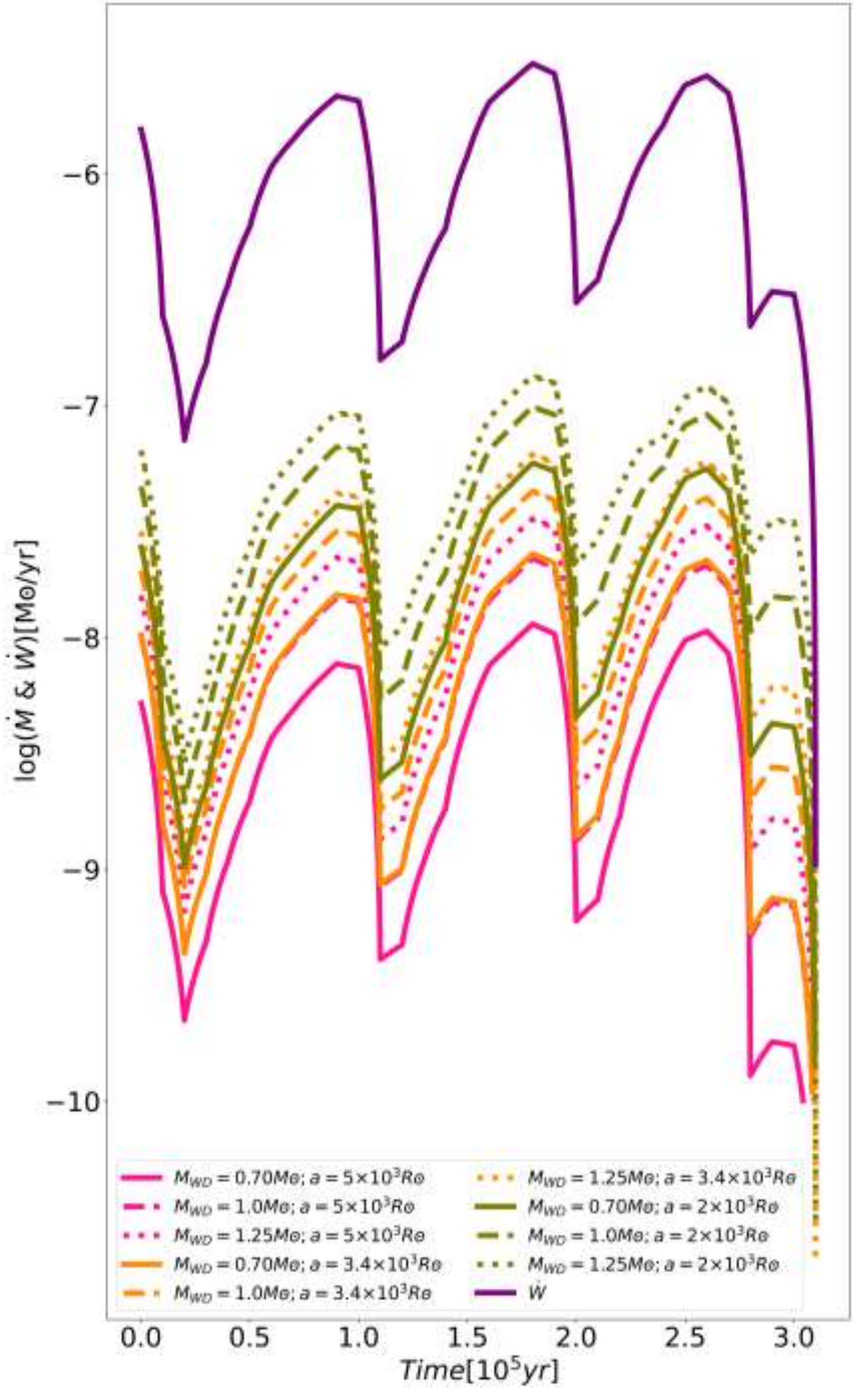




- **Farthest separation --- WD mass decrease.**
- **Smaller separation --- higher average accretion rate --- more efficient mass retention.**
- **Recurrence period shorter --- more eruptions.**

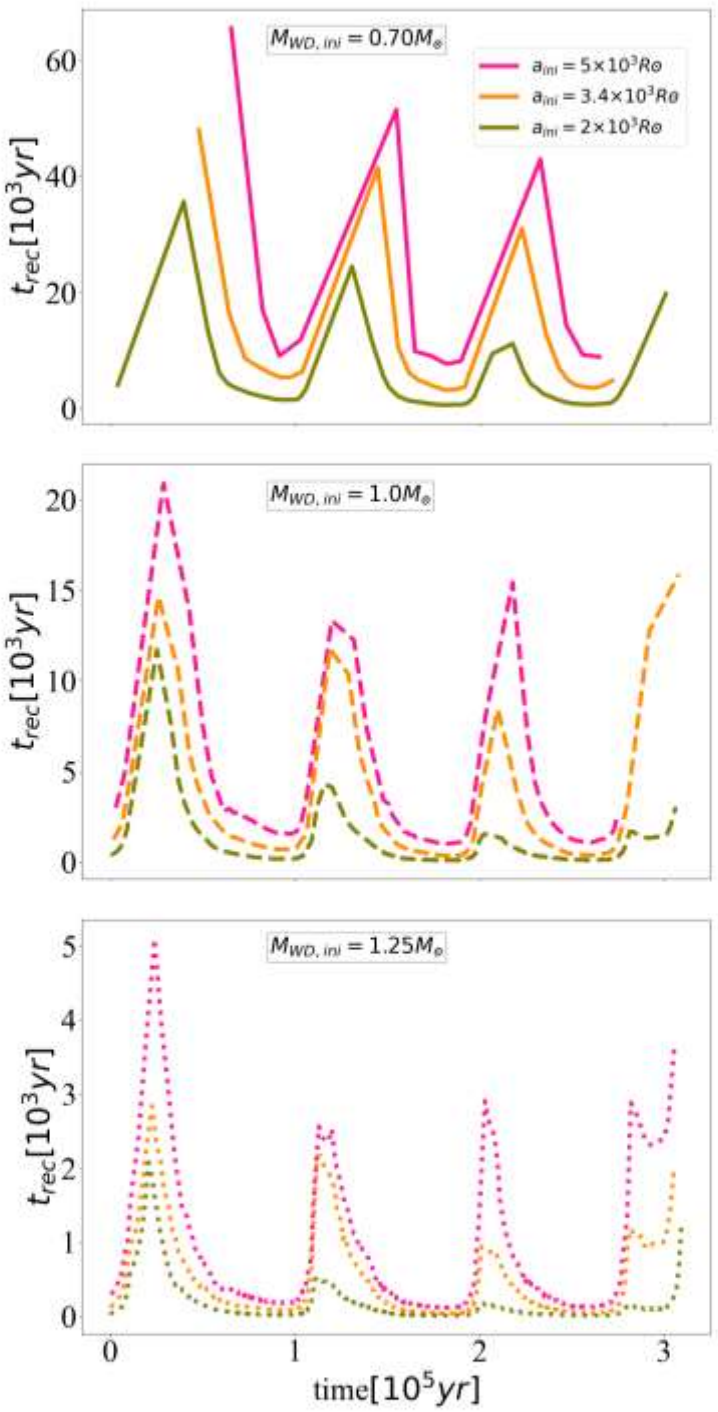
Accretion Rate And Wind Rate

- $\dot{M}$ has high and low epochs during its evolution.
- Follows wind rate.
- Correlation between the accretion rate, WD mass and the separation:
  Massive WD --- High $\dot{M}$
  Smaller separation --- High $\dot{M}$.
- $\dot{M} \; \alpha \; \frac{M_{WD}^2}{a^2}$

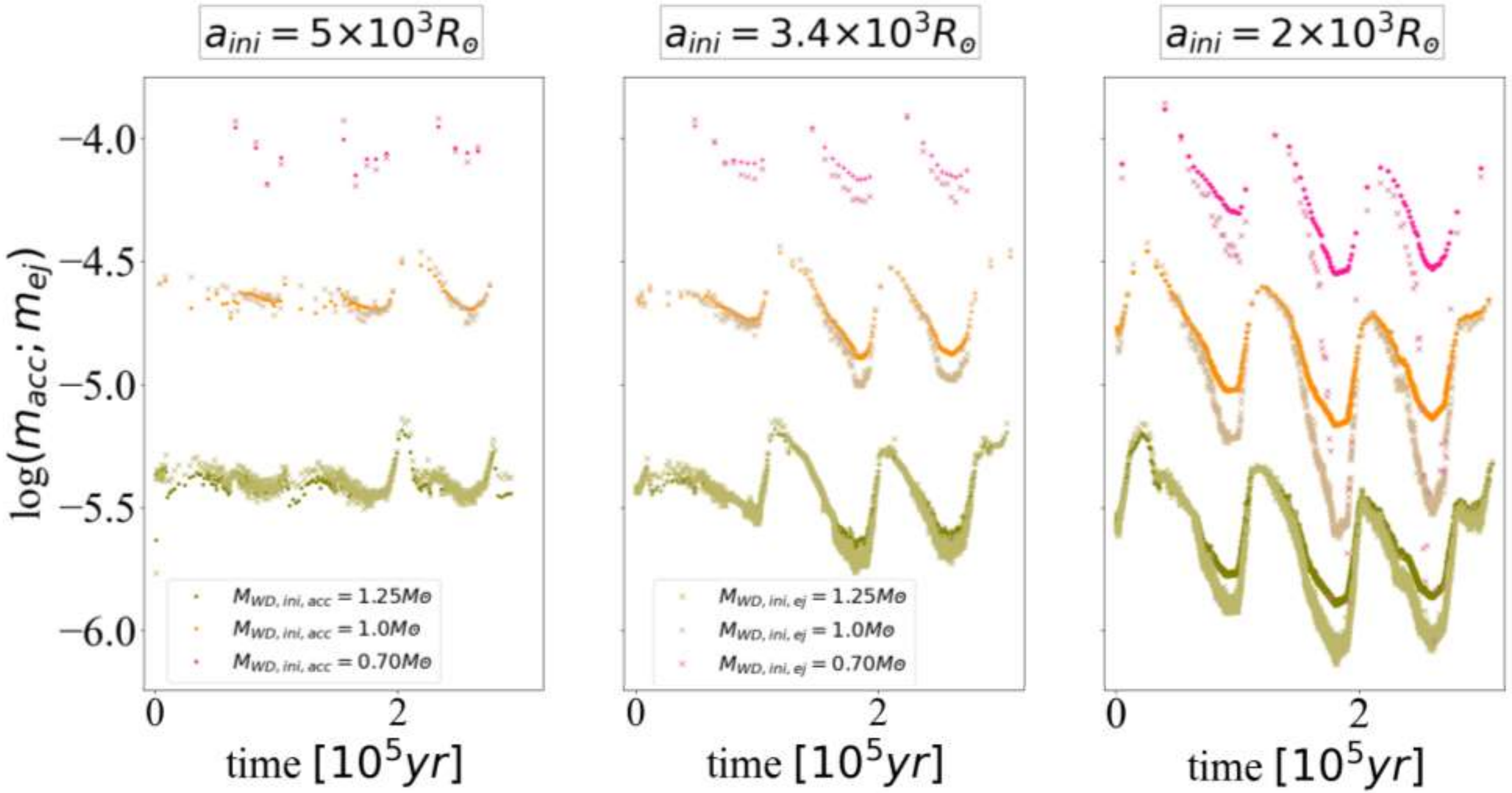


Recurrence Time (t_{rec})

- t_{rec} --- anti-correlation with accretion and wind rates.
- Higher accretion rates --- critical mass for a TNR faster --- reduce the recurrence period.
- t_{rec} --- tens to ten thousands of years.
- Given separation --- t_{rec} --- shorter for more massive WDs.
- t_{rec} , mass of WD, wind rate --- influences periodicity of eruptions and enrichment levels.



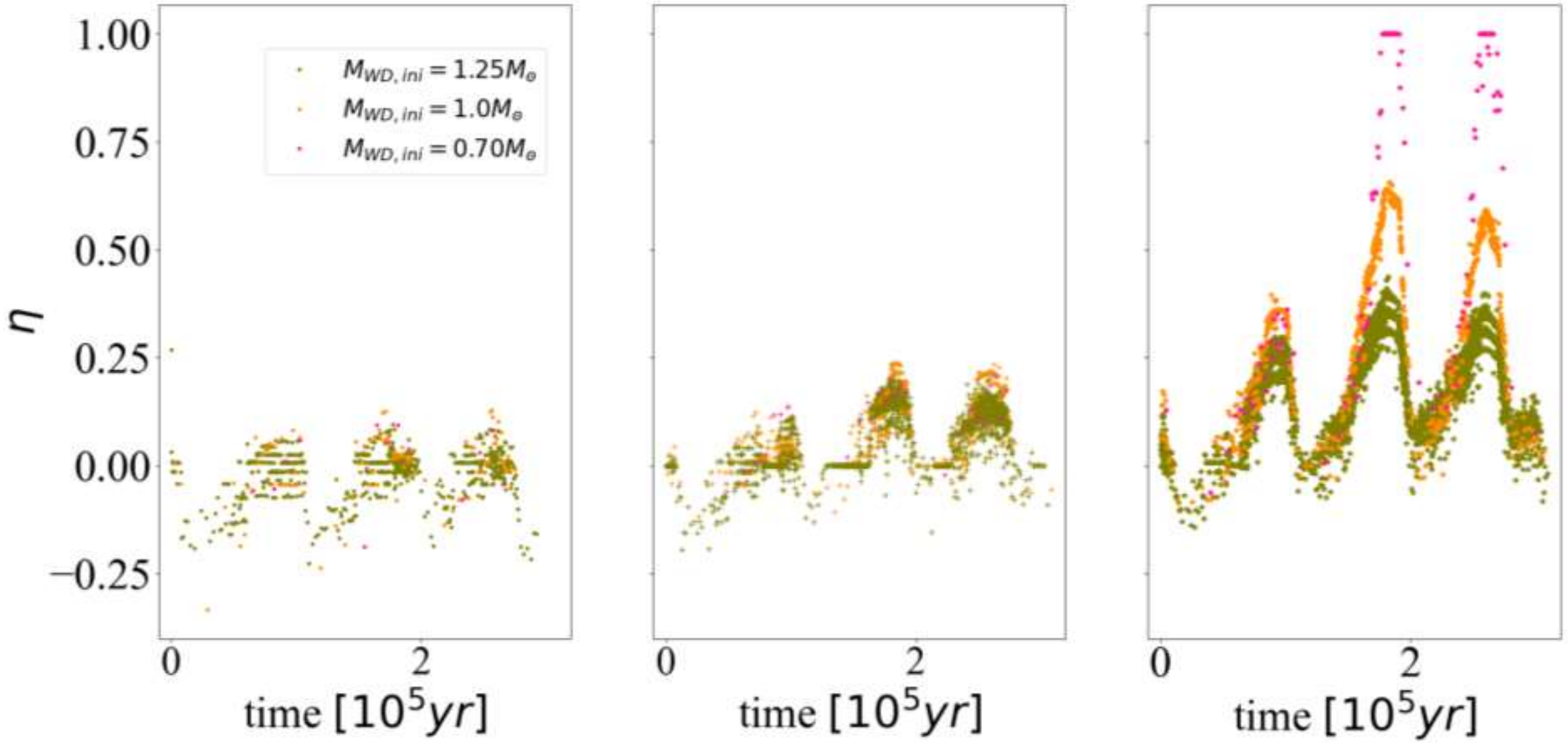
Accreted and ejected mass



- **m_{acc} --- higher for less massive WDs.**
- **m_{ej} --- greater for wider separations.**
- **Anti-correlation between separation and accretion rates.**

η (Mass retention efficiency)

$a_{ini} = 5 \times 10^3 R_\odot$ | $a_{ini} = 3.4 \times 10^3 R_\odot$ | $a_{ini} = 2 \times 10^3 R_\odot$

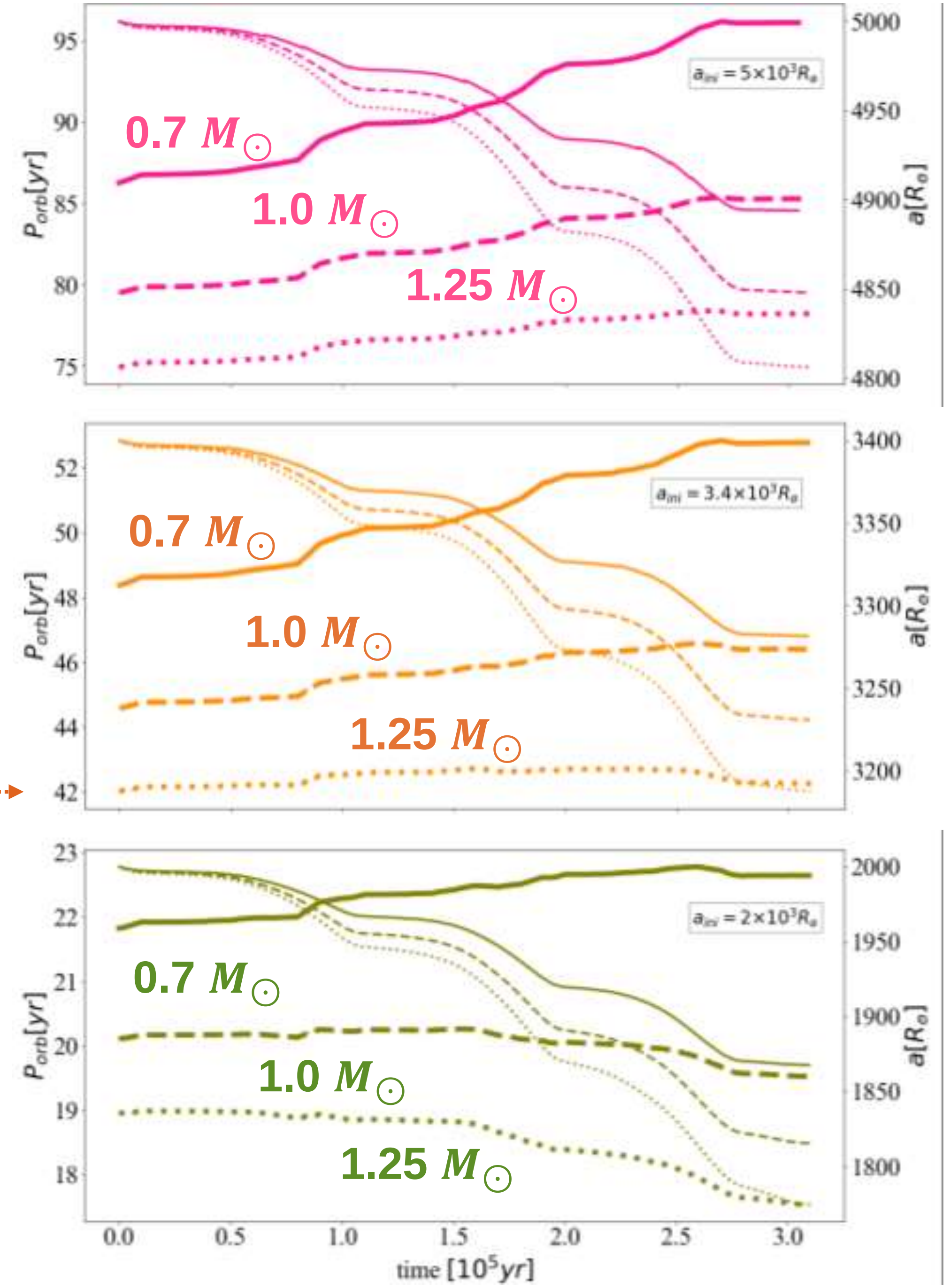


- $\eta = \dfrac{m_{acc} - m_{ej}}{m_{acc}}$
- **η --- decreases with increasing separation.**
- **The maximum value --- $\eta = 1$ --- non-ejective cycles.**

Evolution Of P_{orb} And Separation

- **Monotonic decrease --- of separation with time.**
- $P_{orb} = \left[\frac{4\pi^2}{G(M_D+M_{WD})} \times a^3\right]^{1/2}$
- **Period increase --- even if separation decreases.**
- **If mass change is faster than separation change.**

V407 Cyg is a symbiotic systems, comprising a ~1.2 $M_\odot$ WD accreting from a ~1.0 $M_\odot$ donor, with an orbital period of ~43 years.



Conclusions

- **In symbiotic systems, separation decreases rapidly due to significant drag effects.**
- **Orbital period in symbiotic systems can change abruptly based on the wind rate of the AGB donor.**
- **Decreasing separation leads to a decrease in orbital period, while a more substantial decrease in mass leads to an increase in orbital period.**
- **Smaller separations and more massive WDs result in higher accretion rates, facilitating recurrent novae (RNs) and WD growth.**
- **Models with a positive change in WD mass could be considered potential progenitors of Type Ia supernovae (SNIa), if the donor star could provide sufficient mass.**
- **Parameter combinations allowing WD mass gain hint at the potential for more massive WDs to become SNIa progenitors over time.**

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Eruptive novae in symbiotic systems

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THANK YOU

QUESTIONS ?

Comparison of ejective and Non-ejective cycle

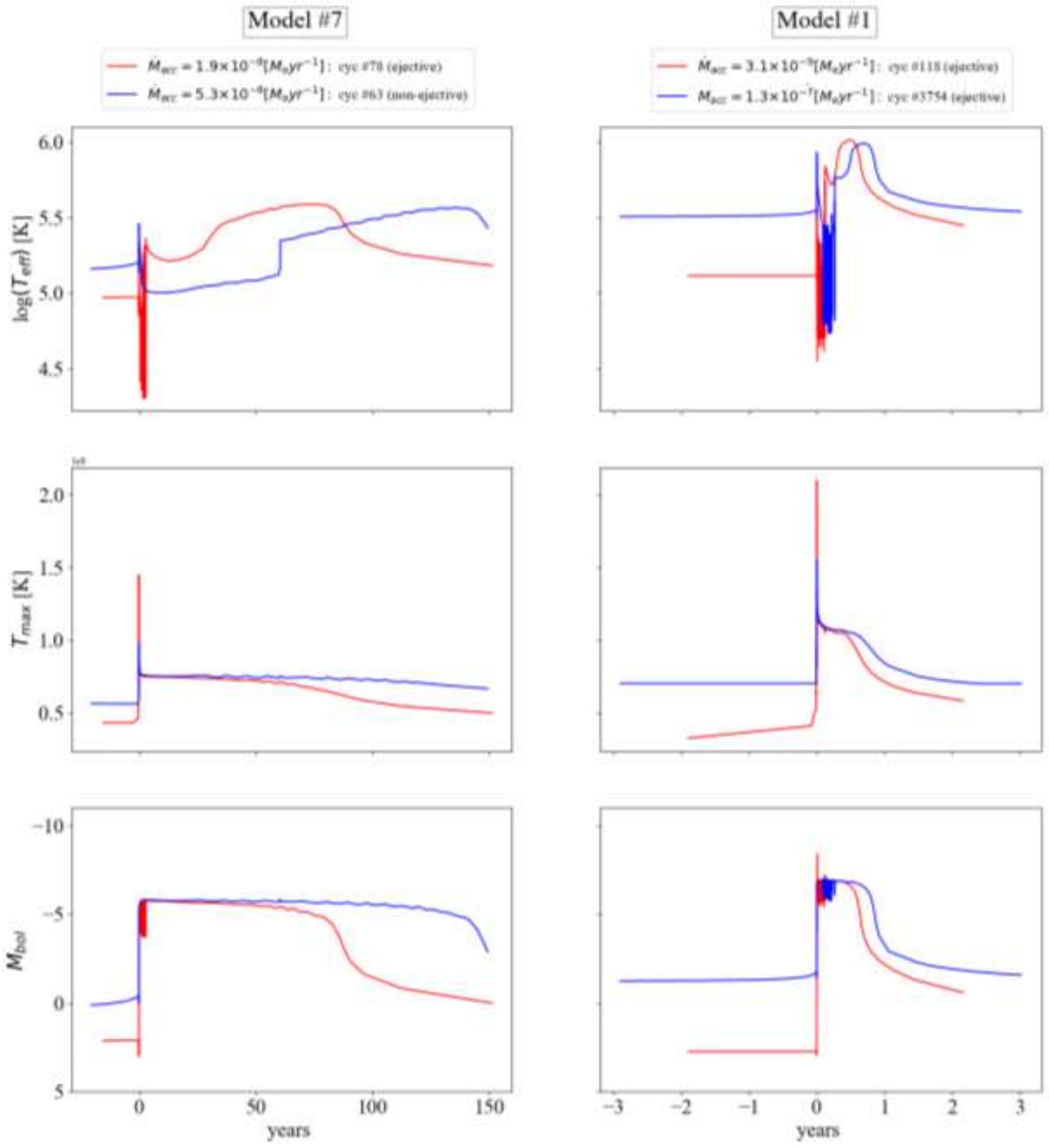
- **Model 7 – no mass ejection during eruptions.**

- **TNR occurs on surface of WD with no or very little mass ejection.**

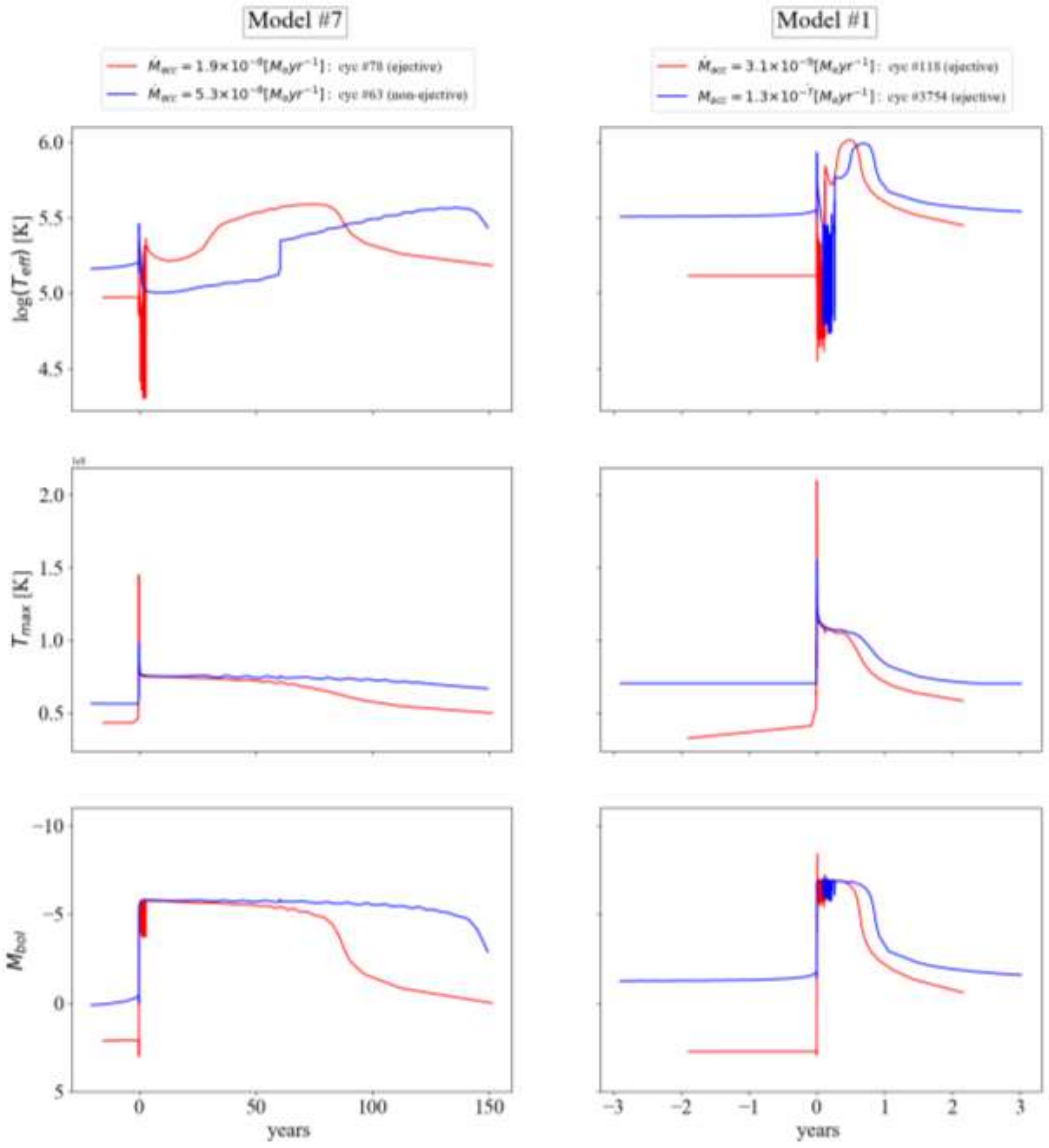
- **The effective temperature decreases for high TNR (ejective cycles) due to the expansion of the outer layers of the WD.**

- **T_{max} is higher for ejective cycles because there is substantial burning, whereas there is very little burning in non-ejective cycles.**

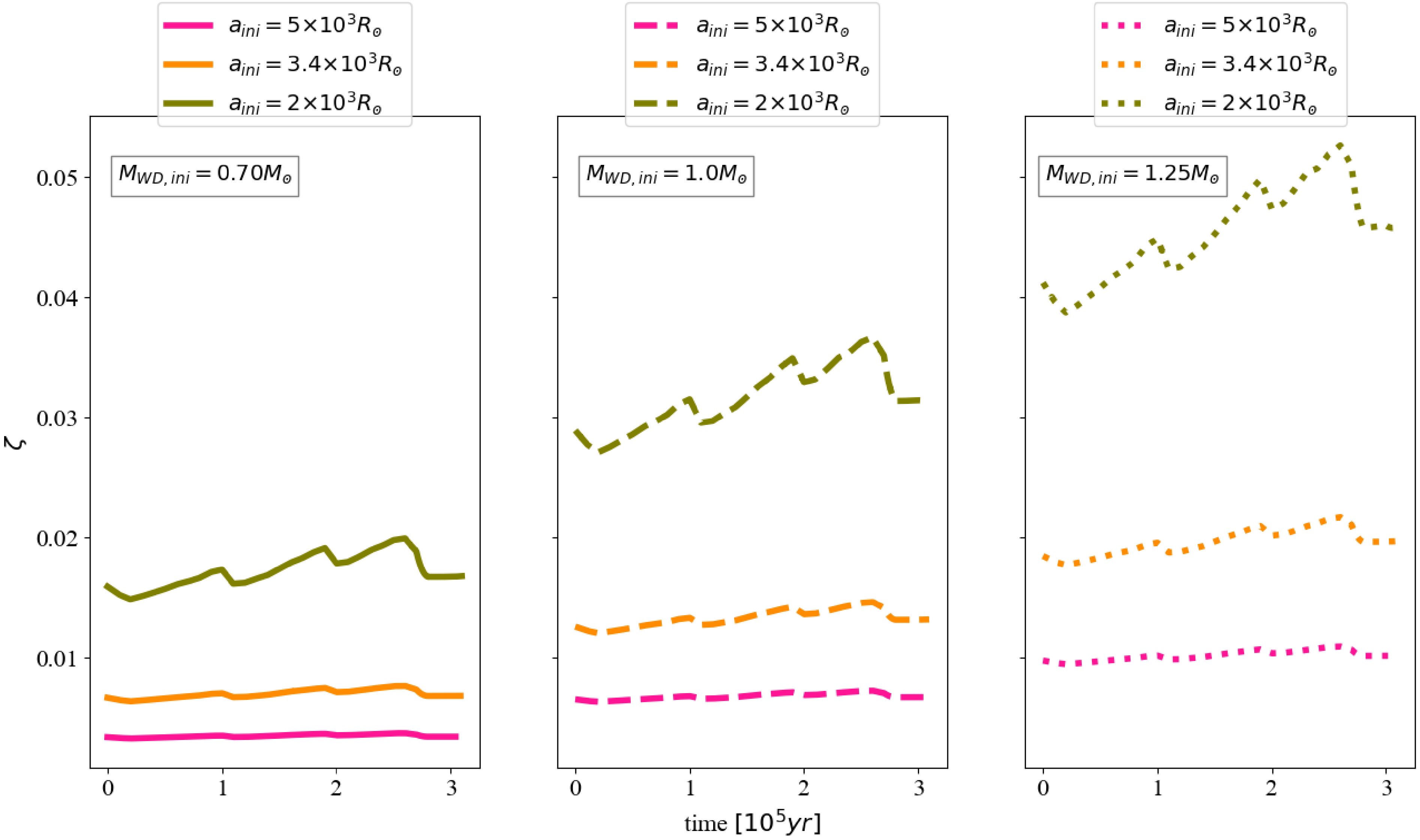
- **Same m_{bol} for both cycles with different amplitude.**



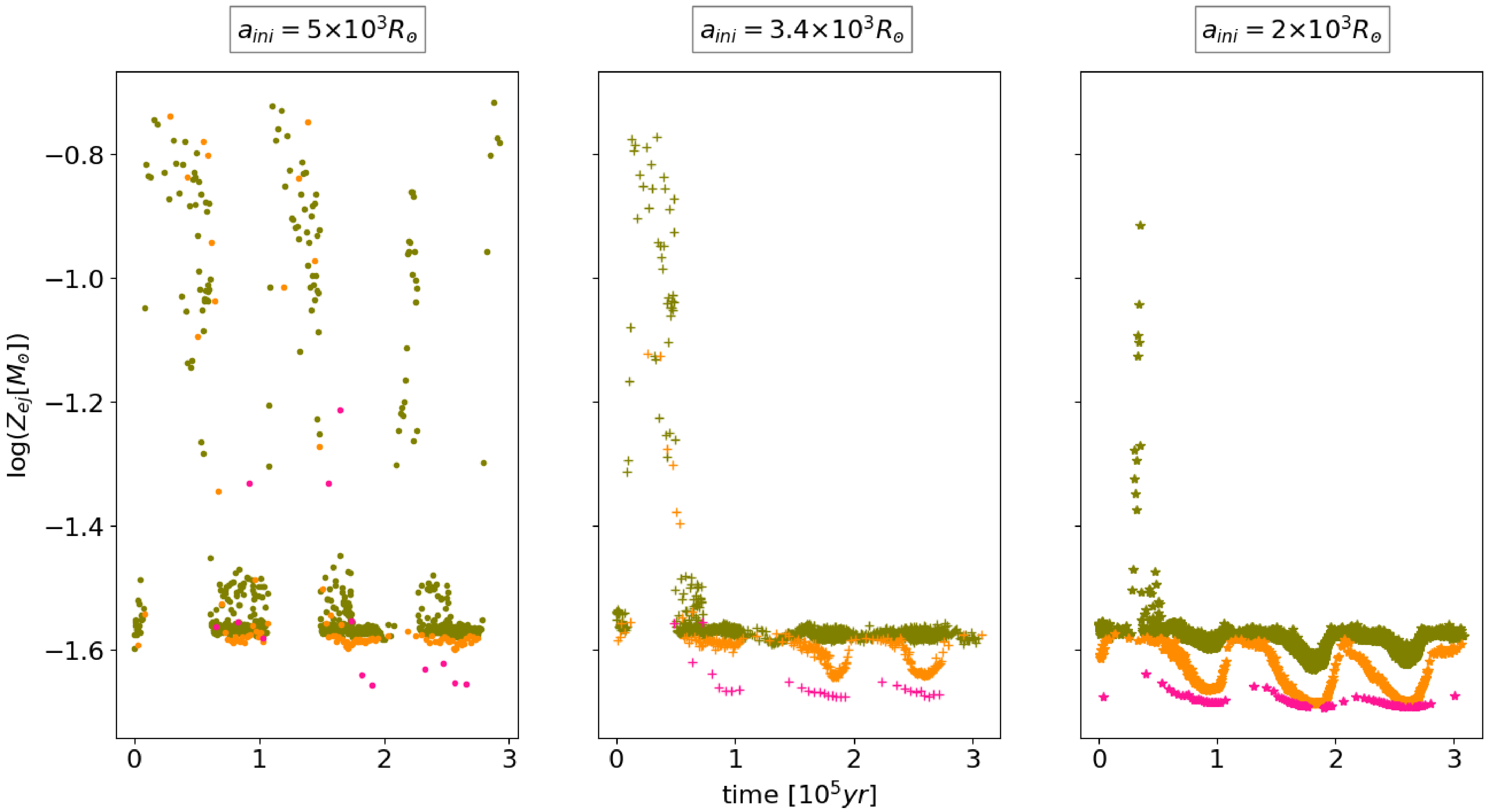
- **Non-ejective cycles occurs for high accretion rate.**
- **Accretion occurs rapidly so that there is little time for diffusion causing TNR to occurs very close to surface.**
- **Such TNR will be very weak with insufficient energy to bring ejecta to escape velocity.**



Accretion Efficiency



Ejecta Abundance



Evolves a star from its pre-main sequence

Through all stellar evolution process

Giant

WD

Until it contract and cool to become a WD

Kovetz A., Yaron O., Prialnik D., 2009, MNRAS, 395, 1857

Hydrostatic stellar evolution code

+

Nova evolution code

WD

Simulate consecutive nova eruptions for a given initial WD mass and constant accretion rate

Prialnik D., Kovetz A., 1995, Astrophysical Journal, 445, 789

Binary evolution code

AML of the system

- Magnetic Braking (MB) caused by materials that are captured by magnetic field of donor carries away angular momentum. Change in angular momentum due to MB ($\dot{J}_{MB}$) can be calculated as:

$$\dot{J}_{MB} = -1.06 \times 10^{20} M_D R_D^4 P_{orb}^{-3}$$

Paxton B., et al., 2015, Astrophysical Journal, 220, 15.

- Gravitational Radiation (GR) caused by massive objects moving, changing the gravitational field carries away angular momentum. Change in angular momentum due to GR ($\dot{J}_{GR}$) can be calculated as:

$$\dot{J}_{GR} = -\frac{32}{5c^5}\left(\frac{2\pi G}{P_{orb}}\right)^{\frac{7}{3}} \frac{(M_{WD} M_D)^2}{(M_{WD} + M_D)^{\frac{2}{3}}}$$

Addison E., 2014, PhD thesis, Utah State University

- Symbiotic system experience an additional angular momentum loss due to drag as it moves through the wind coming from the donor. Change in angular momentum due to drag (D_w) can be calculated as:

$$D_w = \pi \rho_w r_a^2 v_w^2$$

Alexander M. E., Chau W. Y., Henriksen R. N., 1976, Astrophysical Journal, 204, 879.

V 1016 Cyg

- Mira component - 0.81$\pm$ 0.20 $M_\odot$
- WD – 1.1 $M_\odot$
- Recurrence period – 15.1 $\pm$ 0.2 yr (1949, 1964, 1980, 1994)

RS Oph

- RG- $0.68 - 0.80\ M_\odot$
- WD – 1.2 – 1.4 $M_\odot$
- Recurrence period – 21 yr (1898, 1933, 1958, 1985, 2006,2021)

V 407 Cyg

- Mira - $1.0 M_\odot$
- WD – 1.2 $M_\odot$
- Orbital period – 43 yr