

A unified model for the evolution of cataclysmic variables (CVs) and AM Canum Venaticorum (AM CVn) stars

Sarkar and Tout (2022) ; Sarkar, Ge, and Tout (in prep.)

Arnab Sarkar

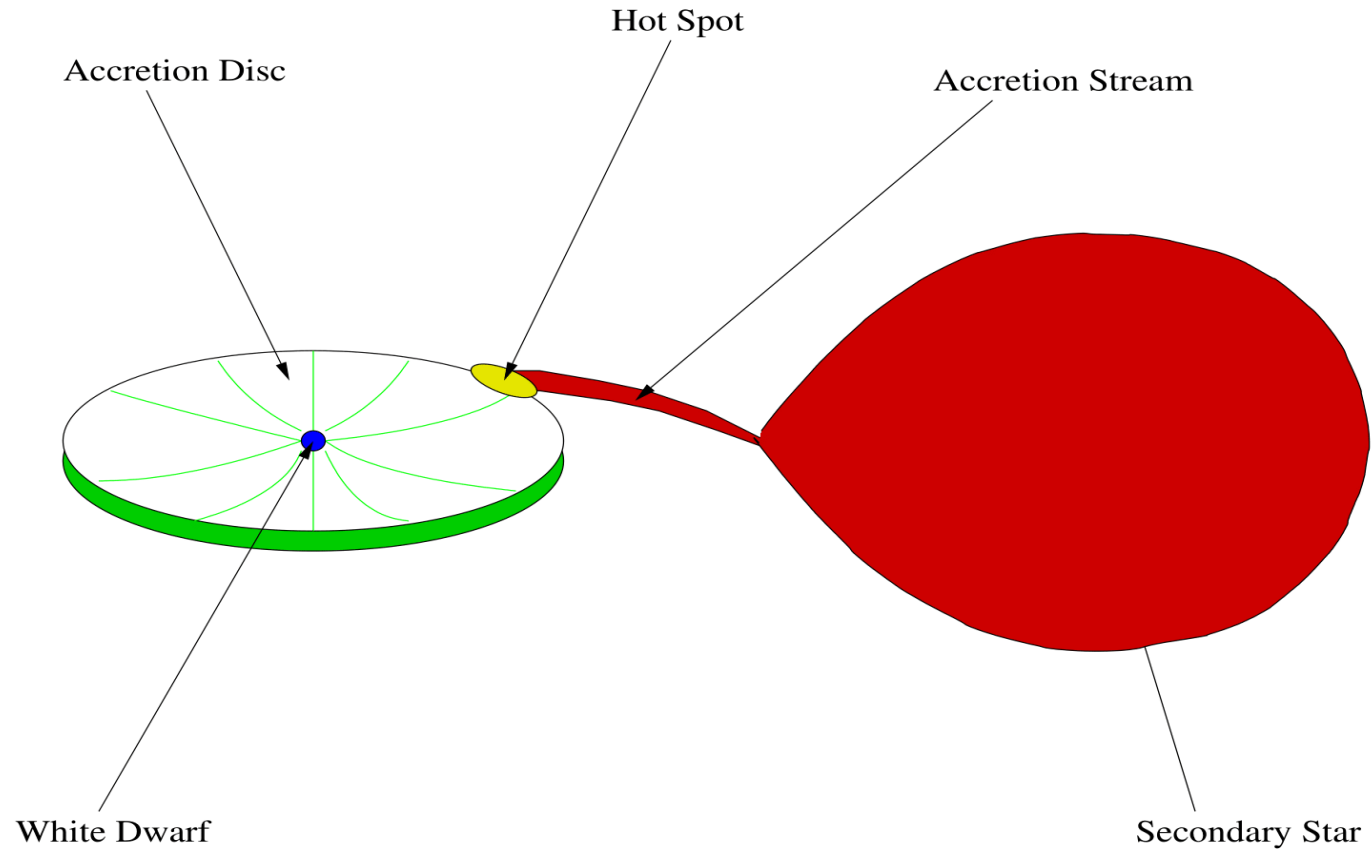
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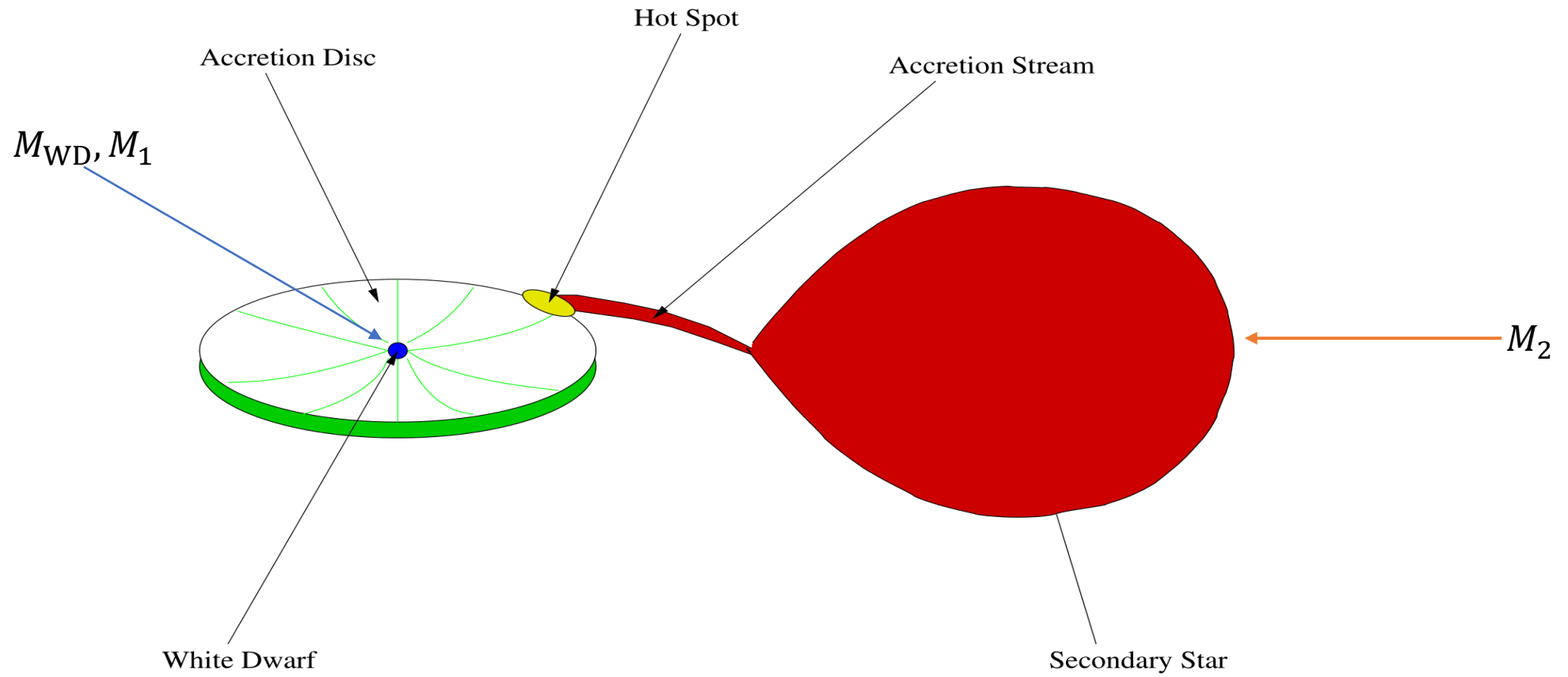


What are CVs (and AM CVns)?



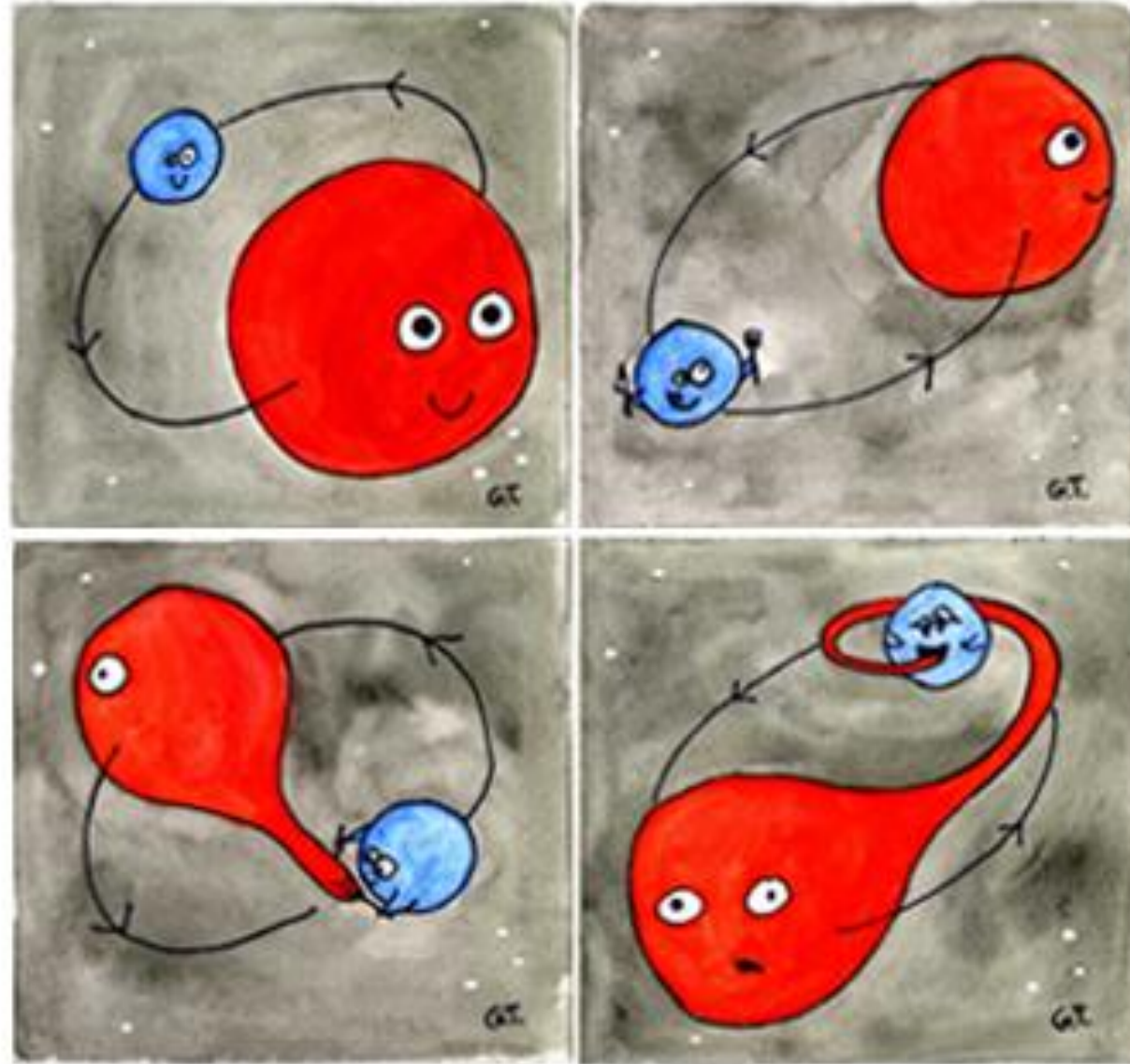
Cataclysmic Variable Star

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Cataclysmic Variable Star

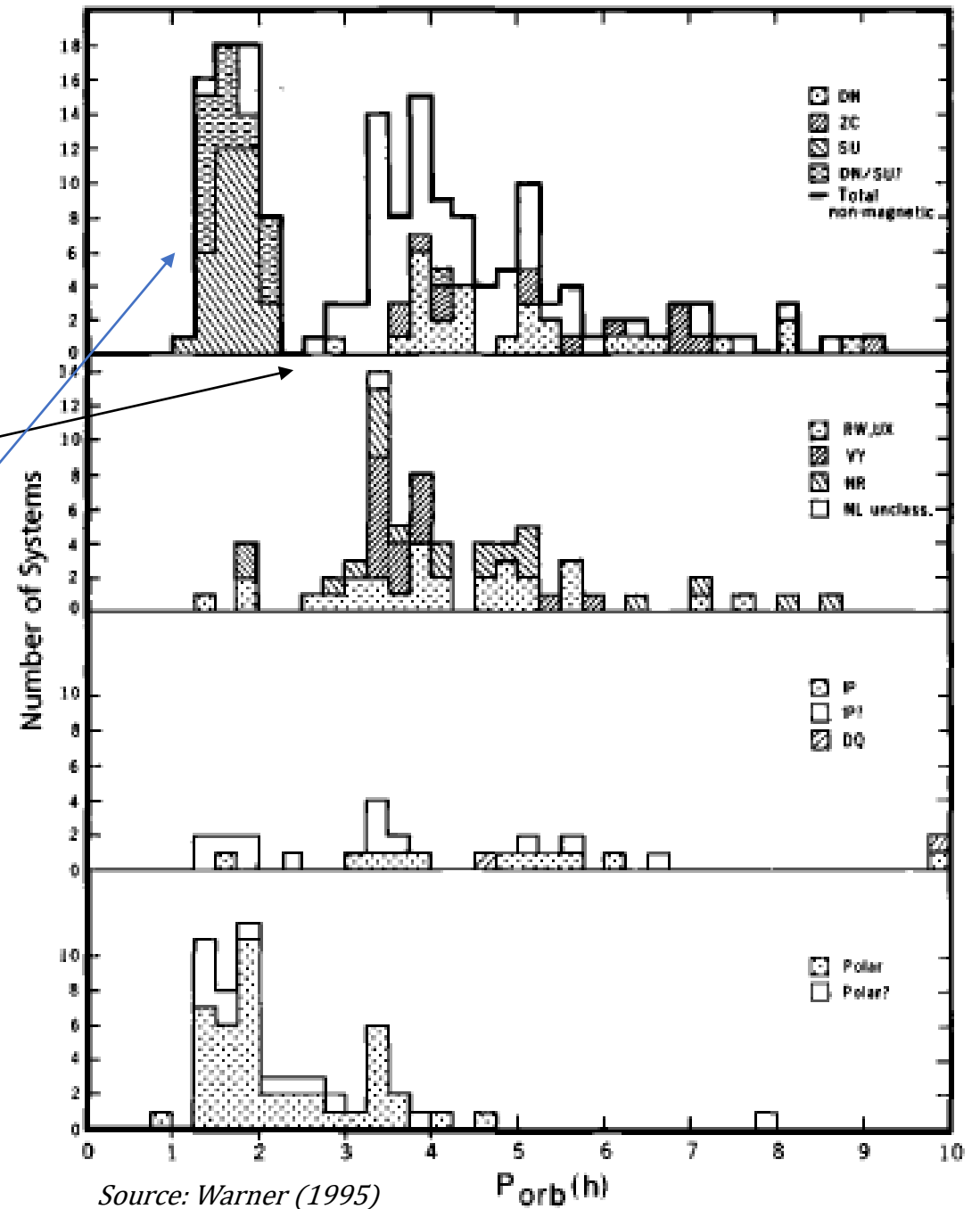
How do CVs evolve?



Source: Gaia in the UK

Prominent features

1. Dearth of observed CVs
 $2 \leq P_{\text{orb}}/\text{hr} \leq 3$,
called the Period Gap.
2. Observed peak
 $80 \leq P_{\text{orb}}/\text{min} \leq 86$,
called the
Period Minimum Spike.



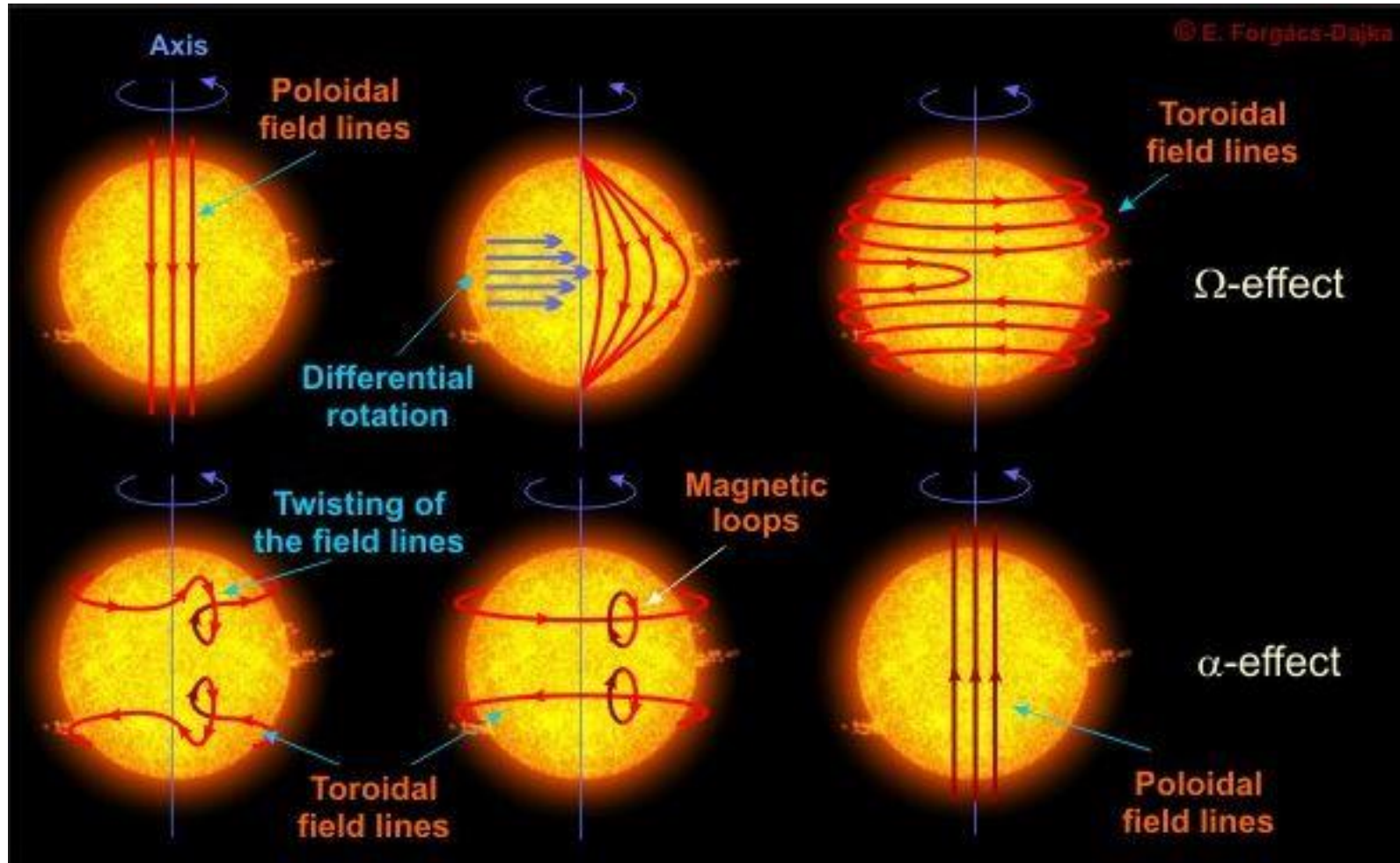
- CV evolution is driven by Angular Momentum Loss (AML) from the system.
 - AML mechanism of gravitational waves (**known**)
 - AML mechanism of magnetic braking (**unknown**)
- Interplay between mass-loss timescale (MLT), thermal timescale (THT) and degeneracy.
 - When $MLT \gg THT$: orbit shrinks
 - When $MLT \approx THT$: orbit expands

Thus the occurrence of a period minimum.

Our aim is to model the evolution of CVs with a physically motivated AML mechanism!

An $\alpha - \Omega$ dynamo mechanism in the donor may be able to explain this!

What is an $\alpha - \Omega$ dynamo?



Source: *The Credible Hulk*

The Double Dynamo (DD) model:

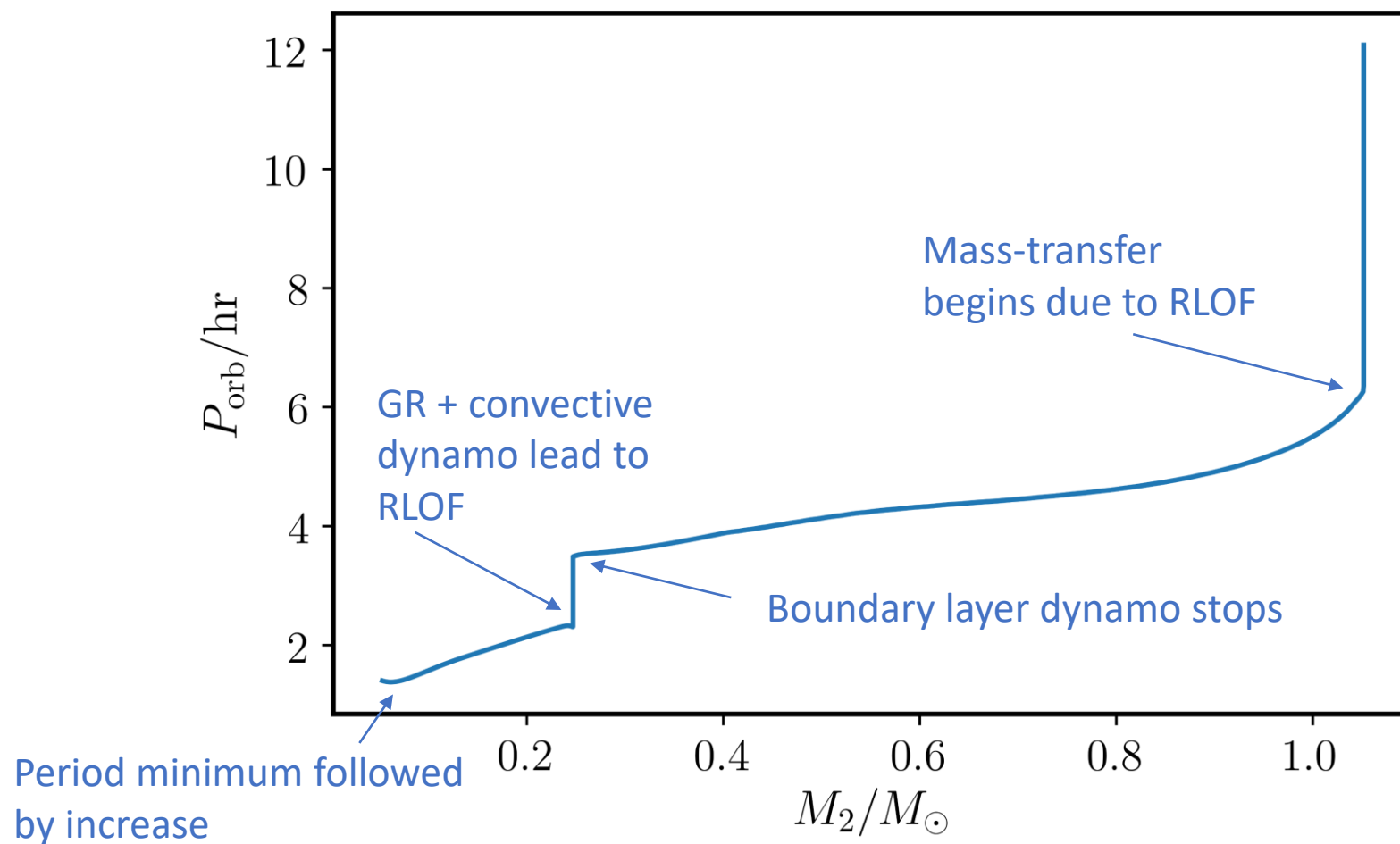
- Two $\alpha - \Omega$ dynamos in the donor ($M_2 \leq 1.4M_\odot$).
 - One in the convective envelope.
 - The other at the boundary between the radiative core and the convective envelope.
- The dynamos lead to magnetic winds which carry away angular momentum (magnetic braking).
- The boundary layer dynamo ceases to operate when the donor becomes fully convective.
- Makes the donor shrink back into its Roche lobe and causes the cessation of mass-transfer.
- Mass-transfer commences again as AML due to GR and the convective dynamo causes the donor to fill its Roche lobe.

Under the following assumptions:

- Tidal locking between spin of the convective layer of the donor and orbit.
- Radiative core is not linked to the convective envelope and has negligible spin.
- AML is due to the poloidal component of the magnetic field.
- Mass-transfer is fully non-conservative.

Full evolution with the DD model

Source: Sarkar and Tout (2022)

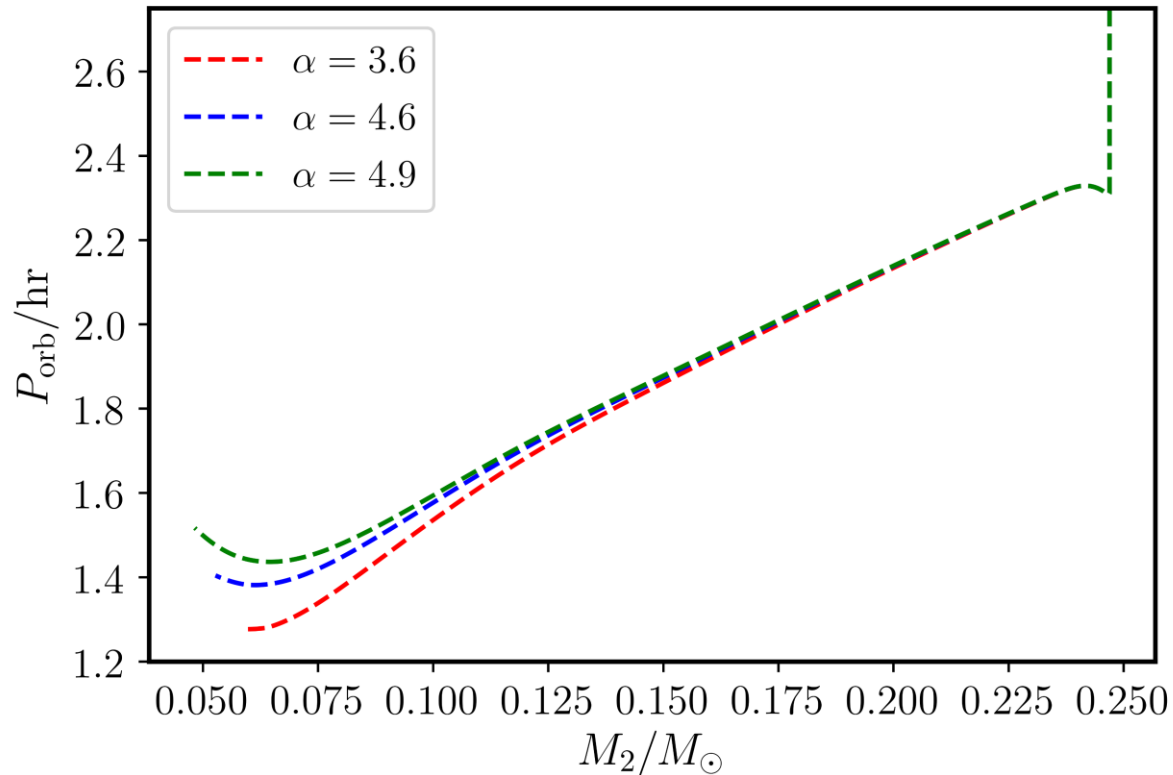


Extra AML below the period gap

- Discrepancy between theoretical and observed period minimum.
- Complete cessation of magnetic field in fully convective stars is implausible.
- An extra AML mechanism at play below the period gap.

An enhancement of the convective dynamo in the DD model can explain this!

Source: Sarkar and Tout (2022)



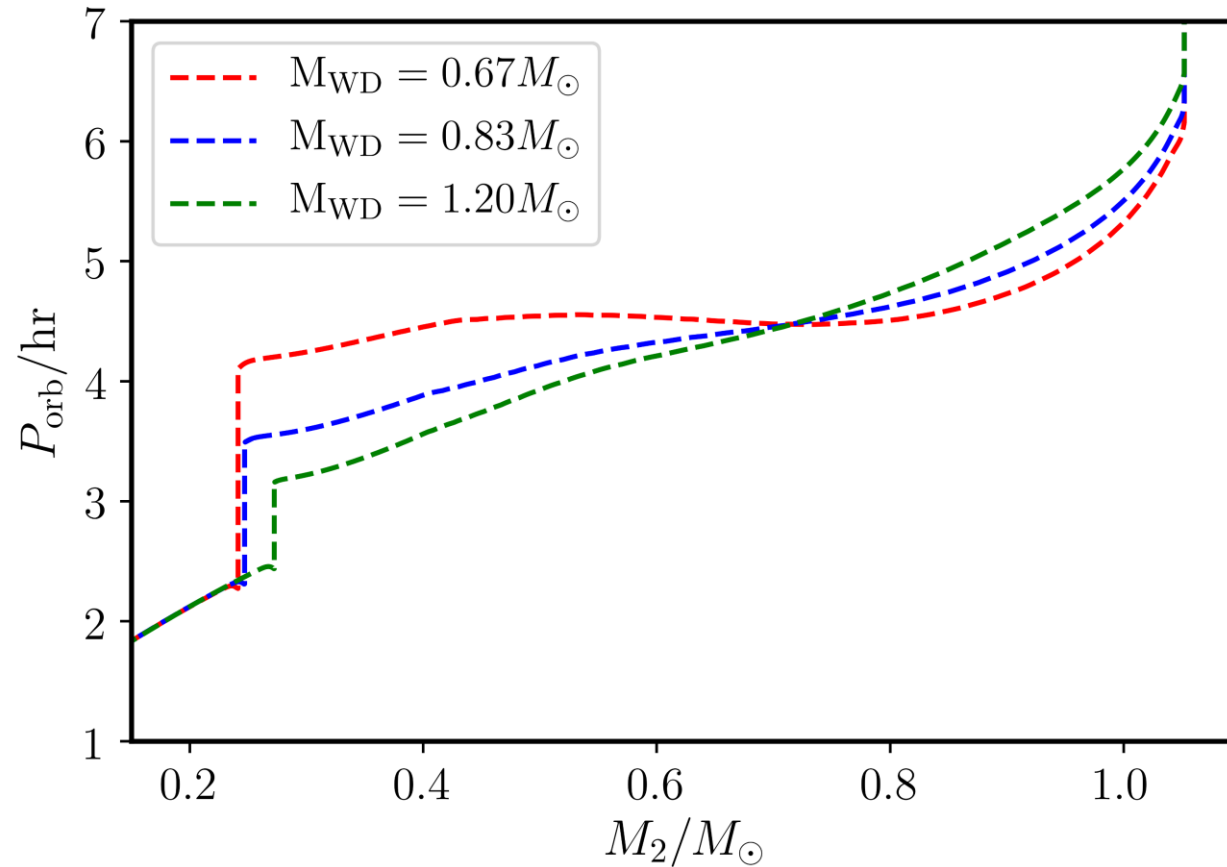
Enhancement of the AML of the convective dynamo below the period gap of the form

$$\frac{\dot{J}}{J} \propto \left(\frac{M_{\text{conv}}}{M_2} \right)^\alpha$$

where M_{conv} is the mass of the donor when it becomes fully convective

But wait! Trajectories are dependent on the WD (accretor) mass.

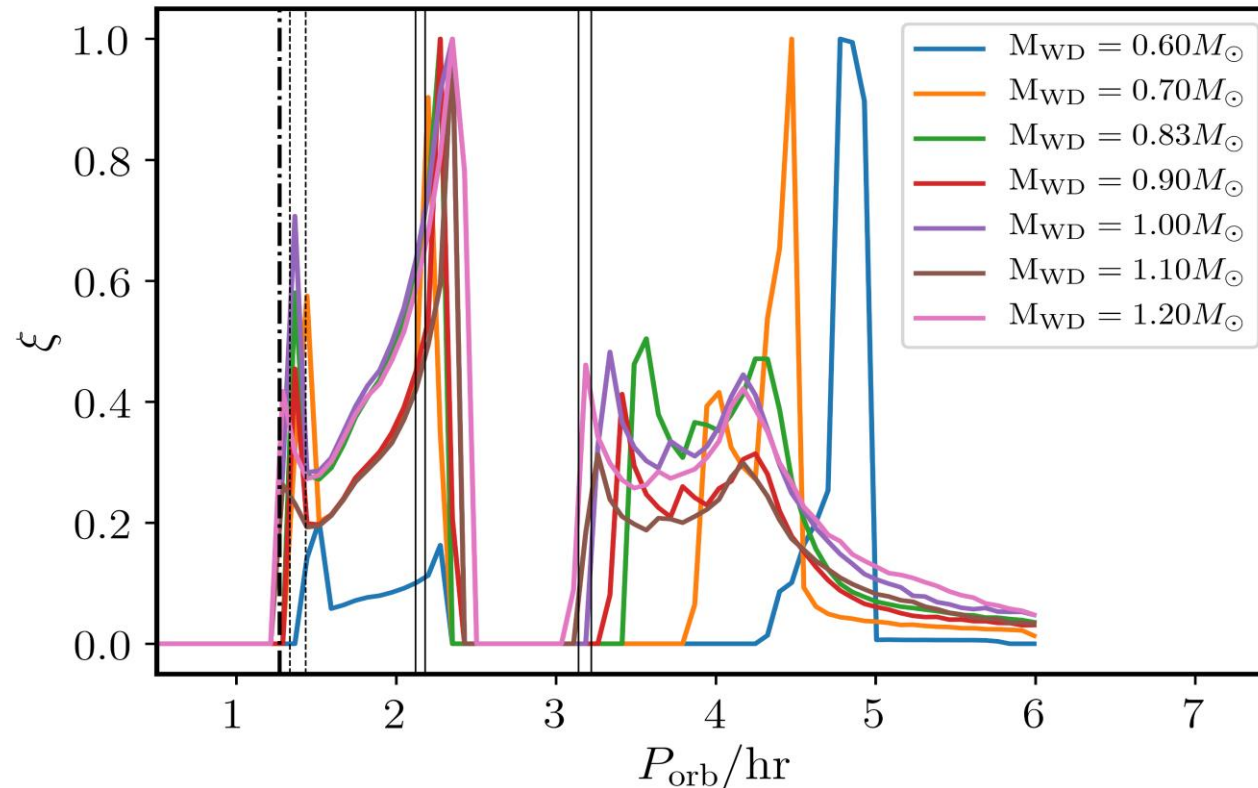
Source: Sarkar and Tout (2022)



Probability distribution

- Divide the orbital period parameter space into bins.
- Assign to each bin a weight based on the time spent in it as a mass-transferring CV.

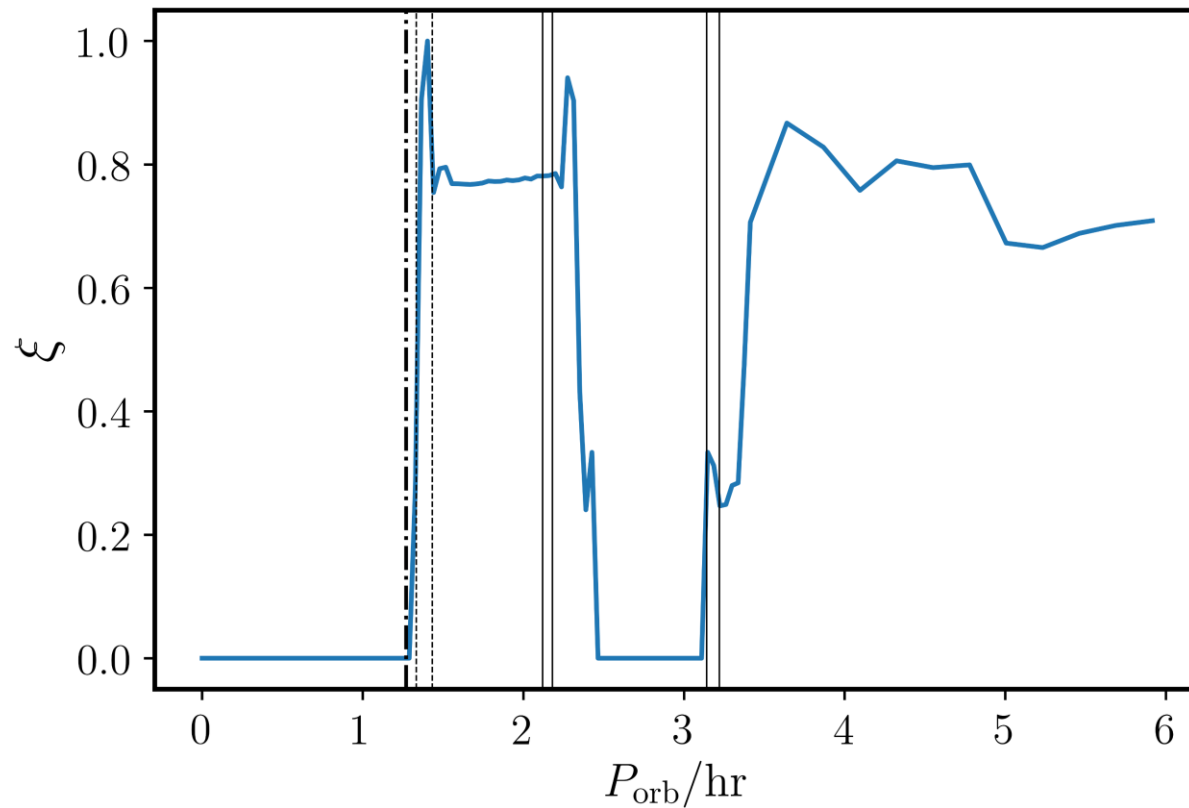
Source: Sarkar and Tout (2022)



Scaled distribution

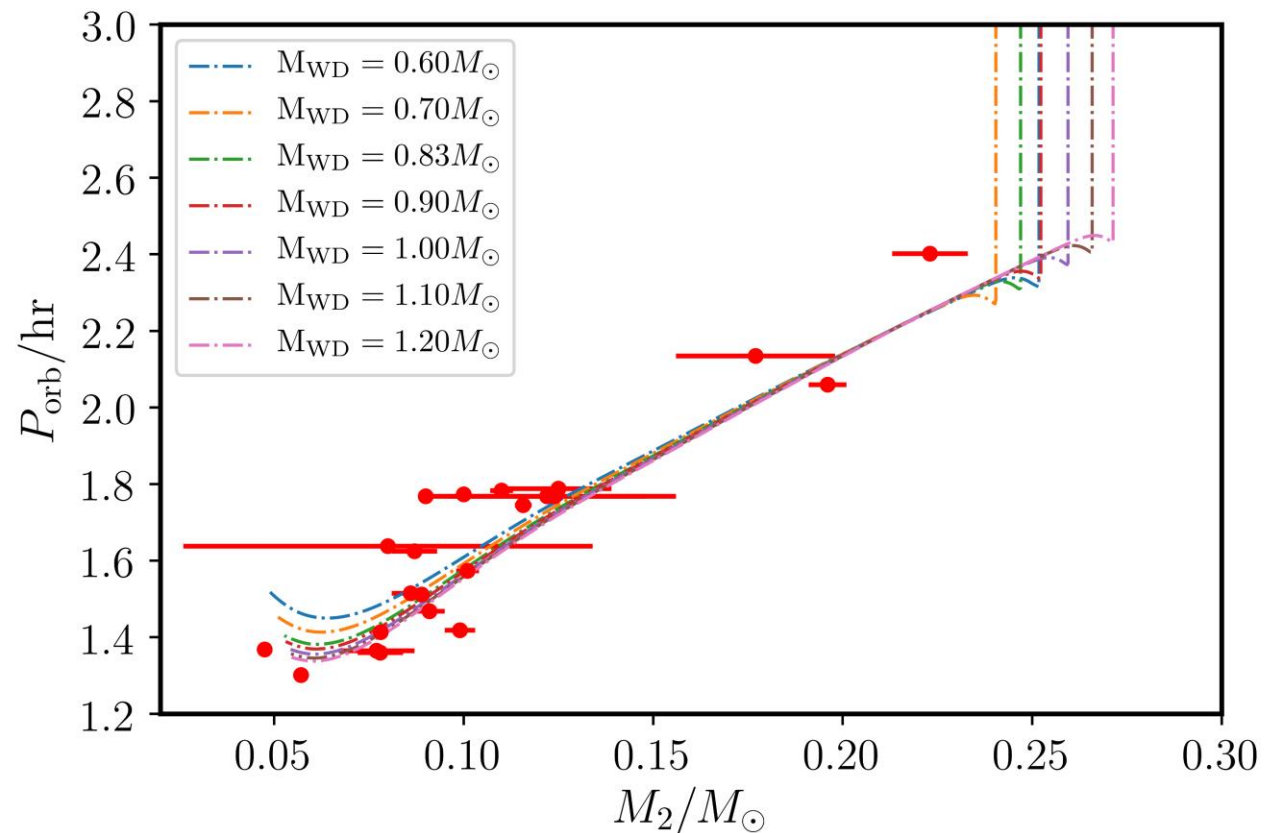
- Scale the previous plot to take into account WD mass distribution in CVs.

Source: Sarkar and Tout (2022)

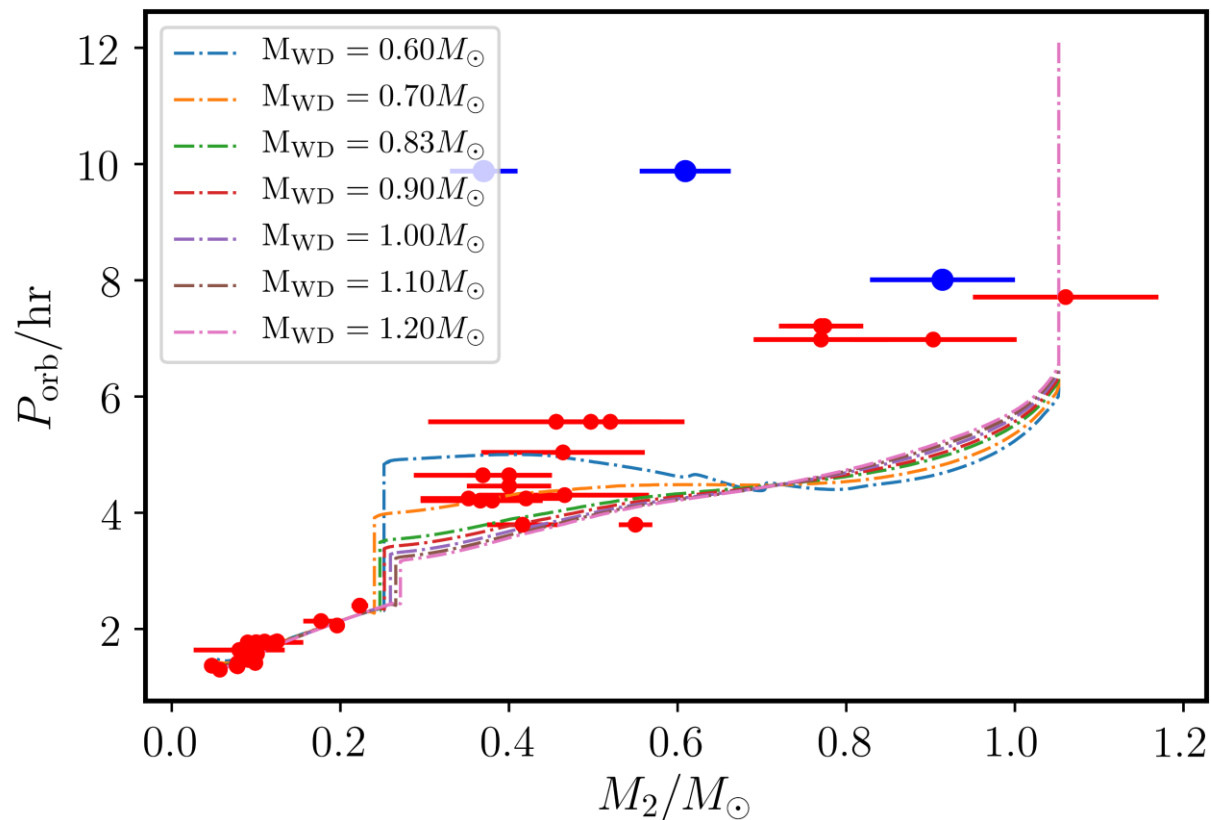


Comparison with observations

Source: Sarkar and Tout (2022)



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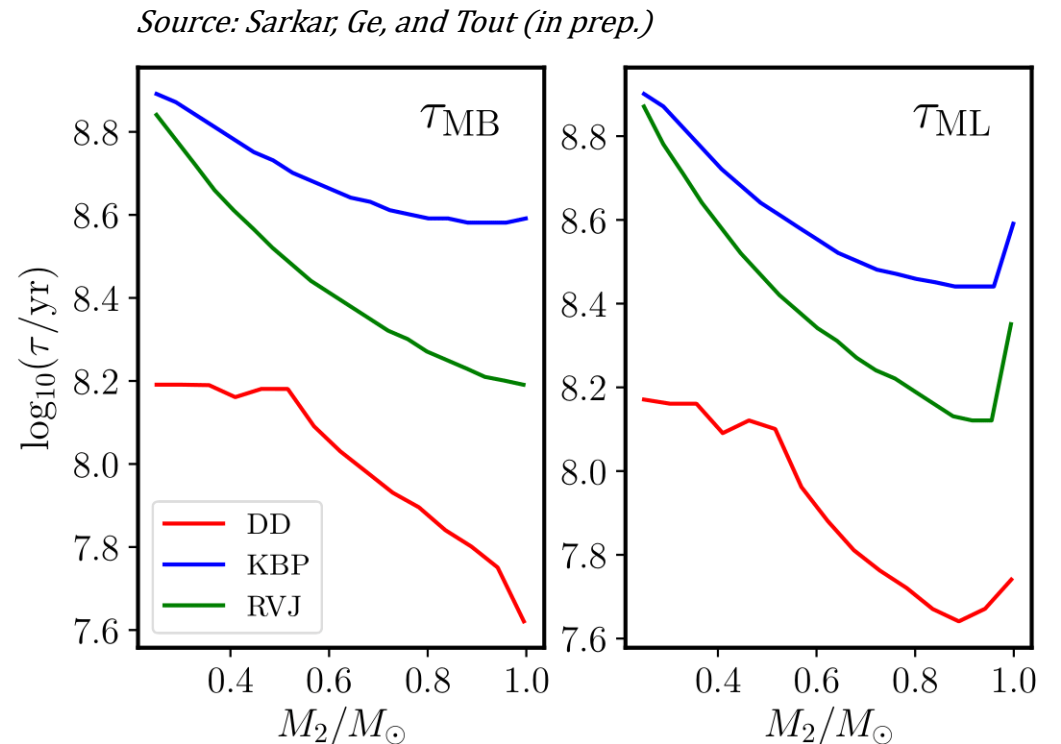
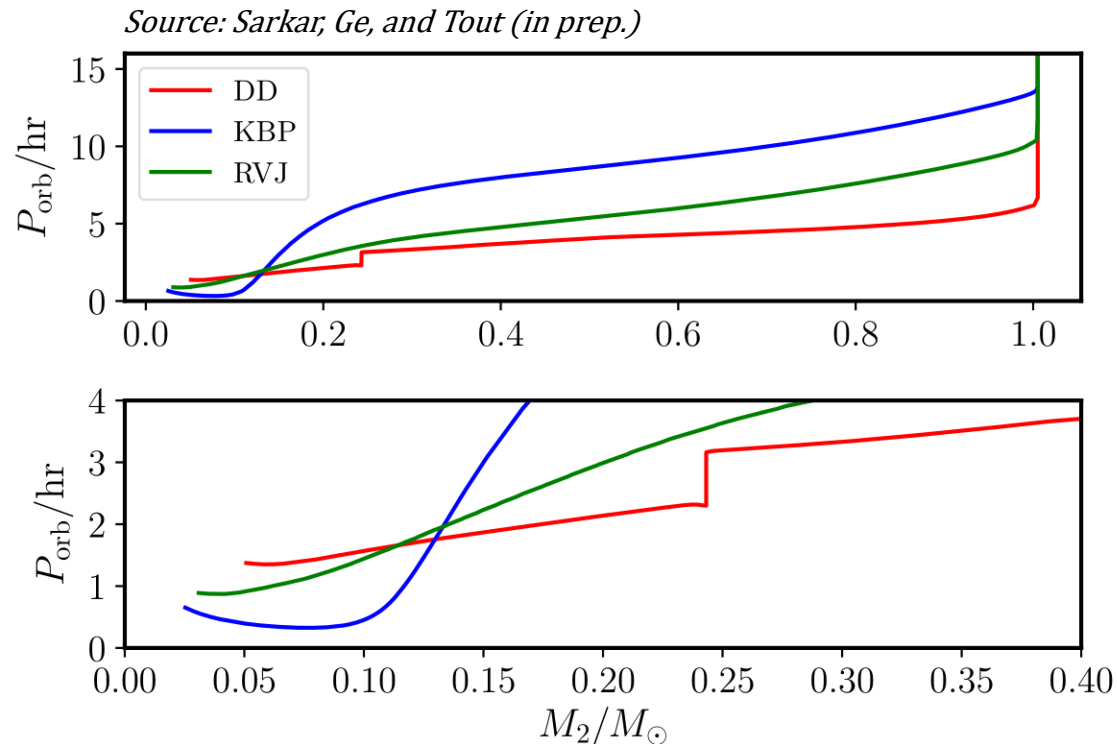


Red: non-magnetic CVs Blue: Intermediate polars

Conclusion

The DD model produces the period gap and the period minimum spike in CV distribution.

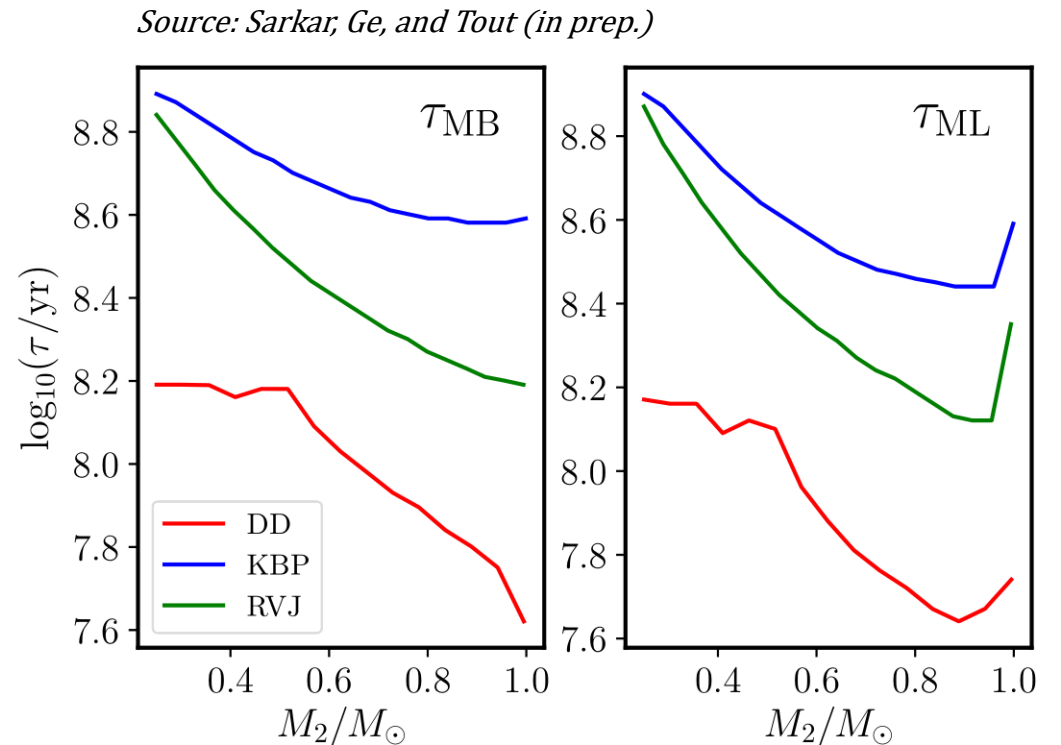
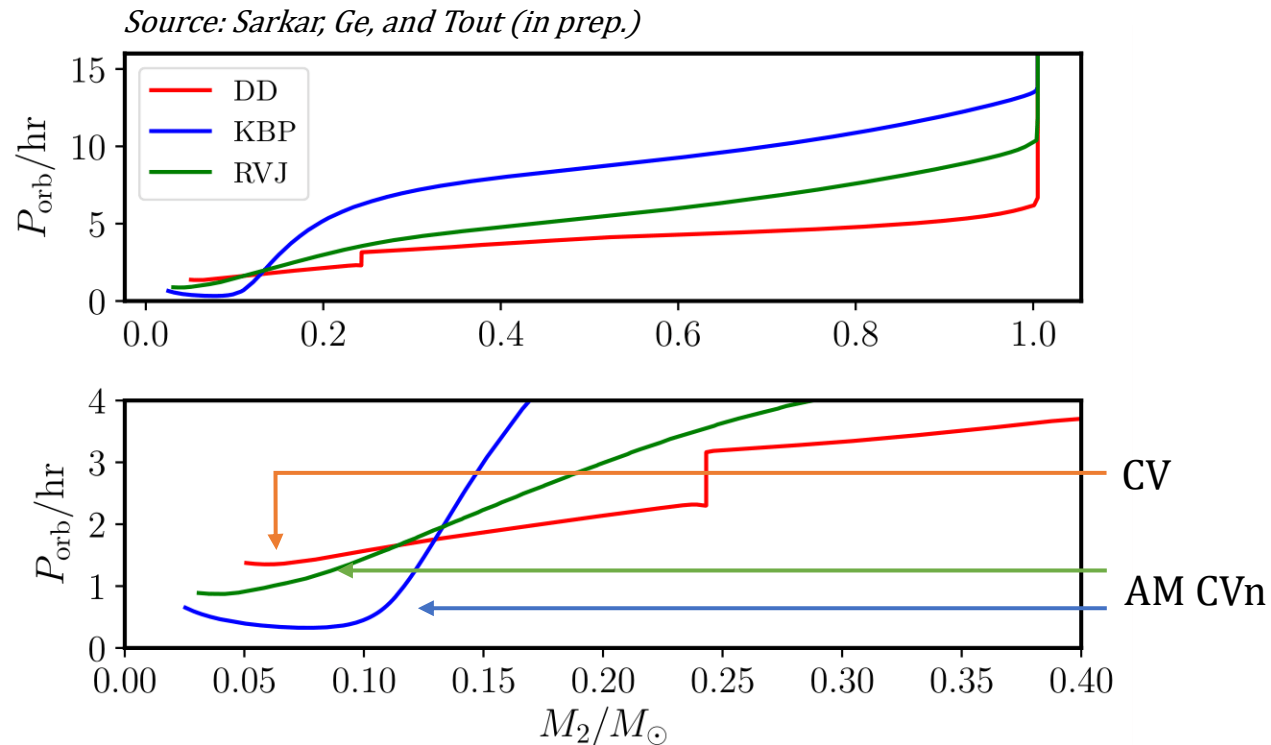
As a consequence of the DD model, angular momentum of the system is lost faster above the period gap.



Conclusion

The DD model produces the period gap and the period minimum spike in CV distribution.

As a consequence of the DD model, angular momentum of the system is lost faster above the period gap.



Future work with the DD model

- Analysis of unusual CVs and AM CVn systems
- Magnetic braking in AM Her stars
- Spin-down of low-mass single stars