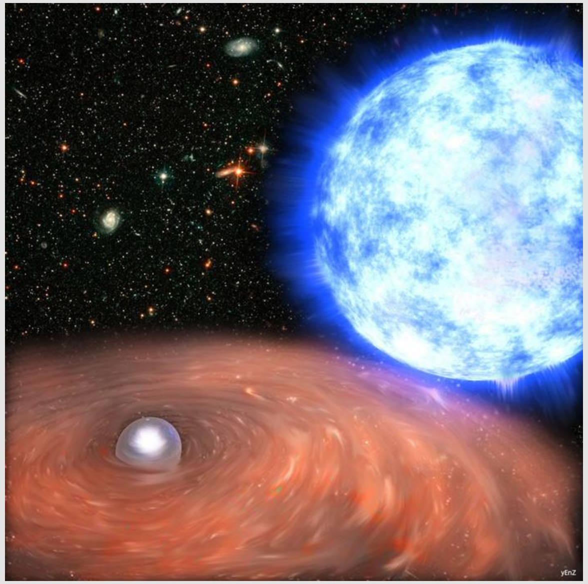
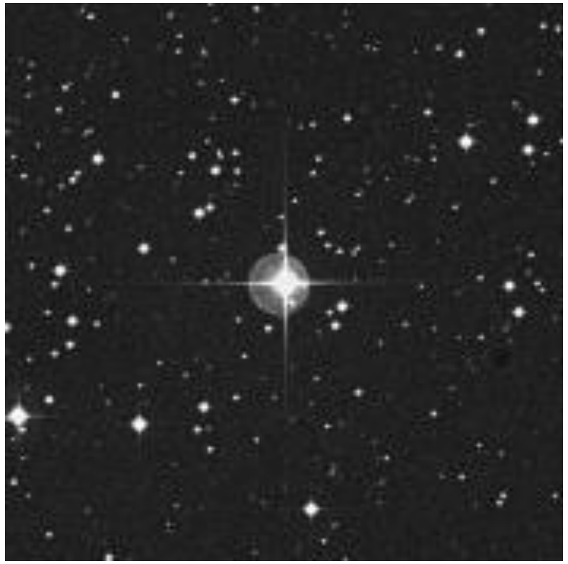
HD 49798:
First contracting WD

S.Popov, S. Mereghetti, S. Blinnikov, A. Kuranov, L. Yungelson



HD 49798

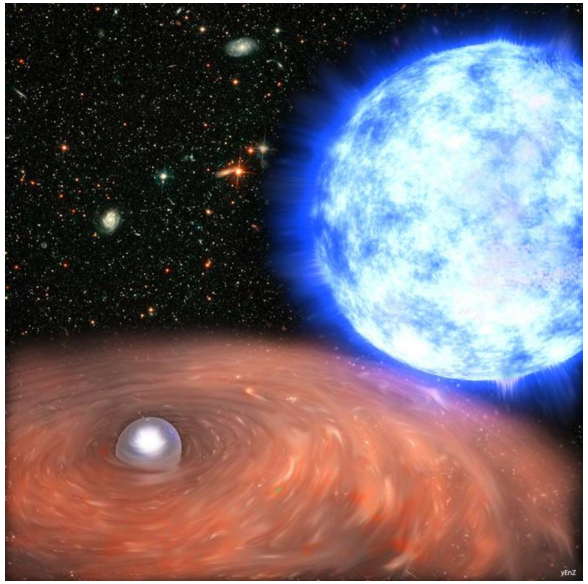


alpha(2000) = 06h 48m 04.64s , delta(2000) = -44d 18' 59.3"
V = 8.30, B-V = -0.29, Spectral type: O6
constellation Puppis
about 650 parsecs from Earth

HD 49798 was discovered in 1964
a rare hydrogen-deficient O class subdwarf

$$\dot{M}_{\mathrm{W}} = 3 \times 10^{-9}\ \mathrm{M}_{\odot}\ \mathrm{yr}^{-1}$$

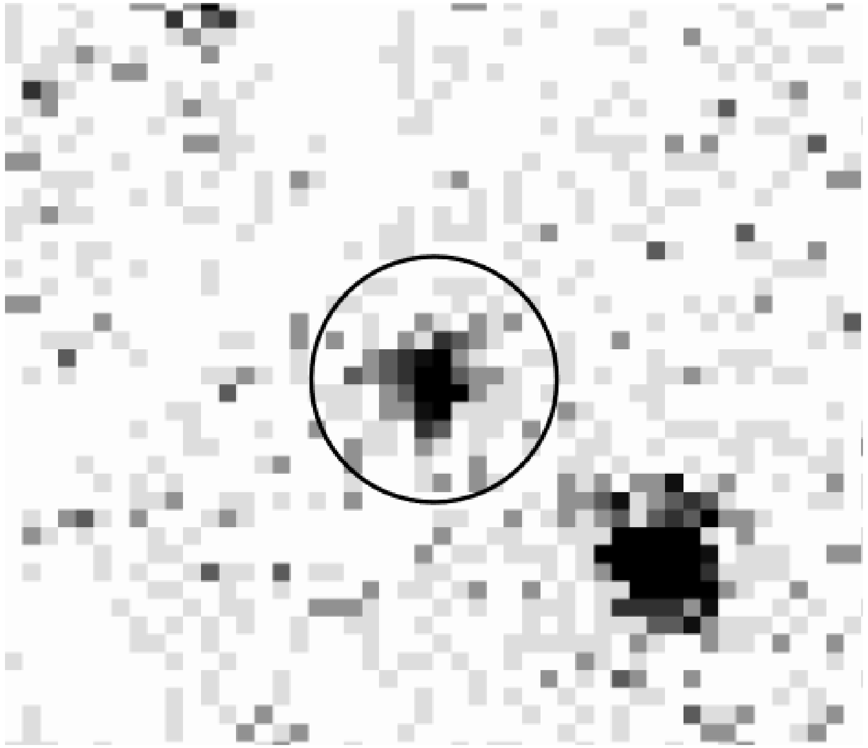
X-ray source RX J0648.0-4418
Porb=1.55 days
Pspin=13.2 s
Mx=1.28+/-0.05 Msolar

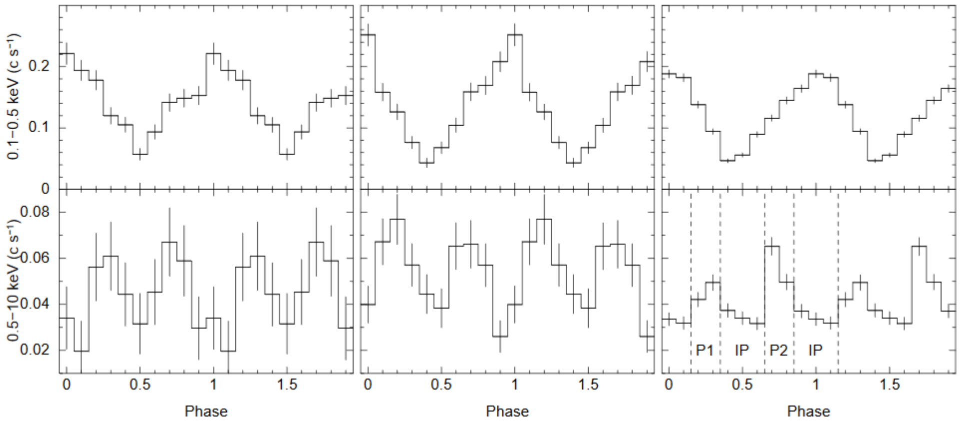


System parameters

Parameter	Value	Units
Right Ascension	$6^h\ 48^m\ 4.7^s$	J2000
Declination	$-44°\ 18'\ 58.4''$	J2000
Orbital period	1.547666(2)	d
$A_X \sin i$	9.79(19)	light-s
T^*	43961.243(15)	MJD
ν_0	0.0758480846(1)	Hz
$\dot{\nu}$	$1.24(2) \times 10^{-17}$	Hz s^{-1}
P_0	13.18424856(2)	s
$\dot{P}$	$-2.15(5) \times 10^{-15}$	s s^{-1}
T_0	48937. 7681361	MJD
M_X	1.28(5)	$M_\odot$
M_C	1.50(5)	$M_\odot$

Mereghetti et al. (2016) 1603.01505

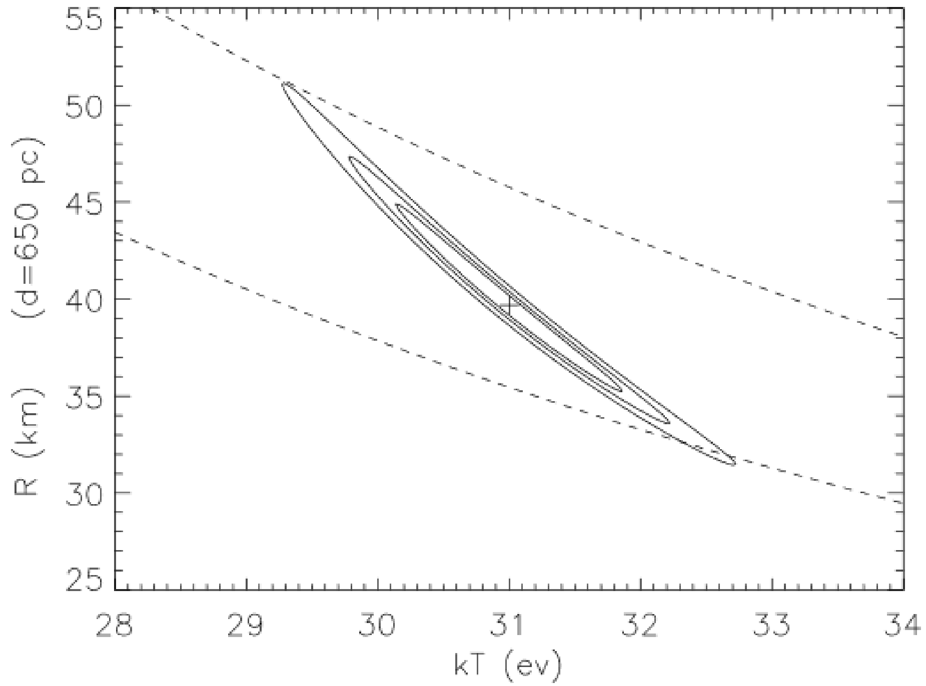




Mereghetti et al. (2011) 1105.6227

Problems with interpretation: a WD or a NS?

Mereghetti et al. (2016) 1603.01505



Before Pdot measurements
all systems parameters
have been well explained
in the model of accreting WD.

Pdot measurements pointed
to a NS instead of a WD,
because with the observed
accretion luminosity
it is difficult to explain
such significant Pdot of a WD.

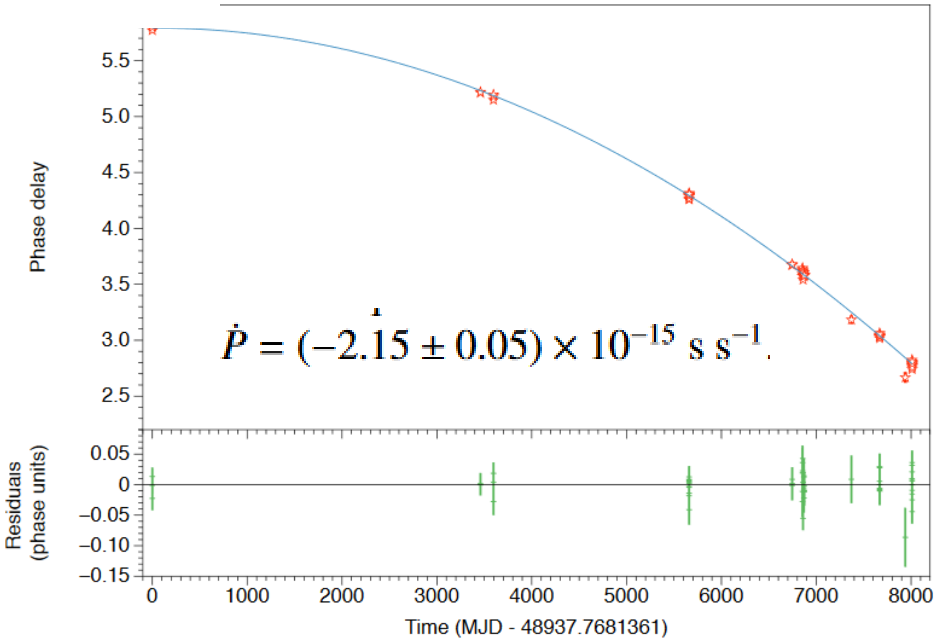
$$j = \frac{2\pi \dot{\nu} I G M}{L_X R},$$

$$j_{WD} = 2.2 \times 10^{19} \left(\frac{L_X}{2 \times 10^{32} \text{ erg s}^{-1}} \right)^{-1} \text{ cm}^2 \text{ s}^{-1},$$

$$j_{NS} = 5.5 \times 10^{16} \left(\frac{L_X}{2 \times 10^{32} \text{ erg s}^{-1}} \right)^{-1} \text{ cm}^2 \text{ s}^{-1}.$$

$\dot{M} > 2 \times 10^{16}$ g s^{-1}, in the case of a WD,

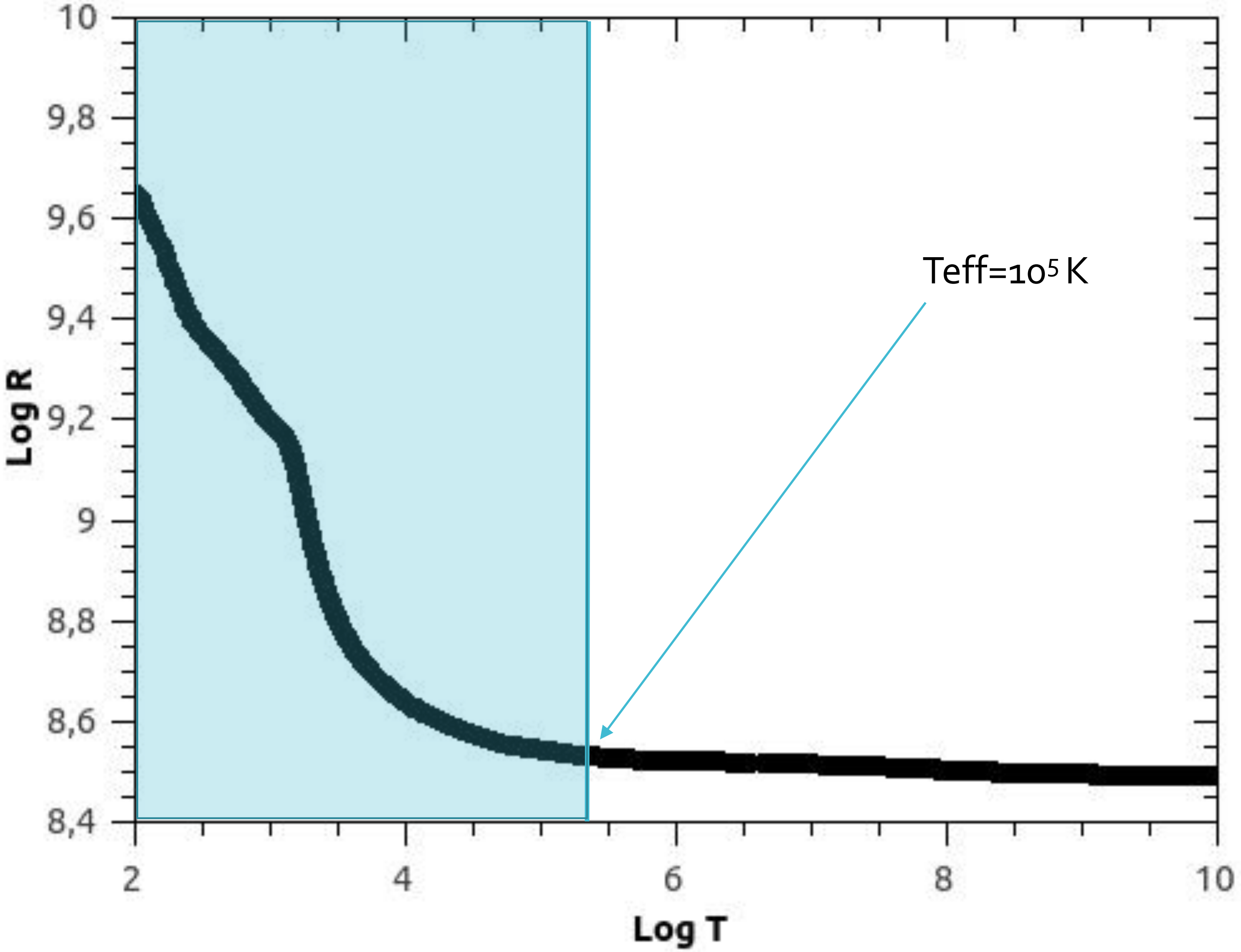
$\dot{M} > 2 \times 10^{11}$ g s^{-1}, in the case of a NS.



Contracting White Dwarf!!!!

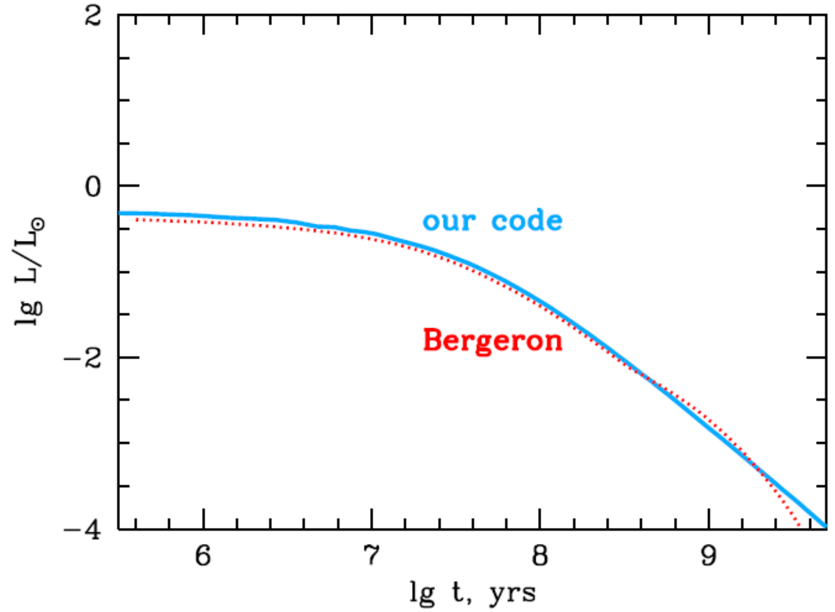
A new idea

Contraction of a white dwarf



M=1.28 Msolar

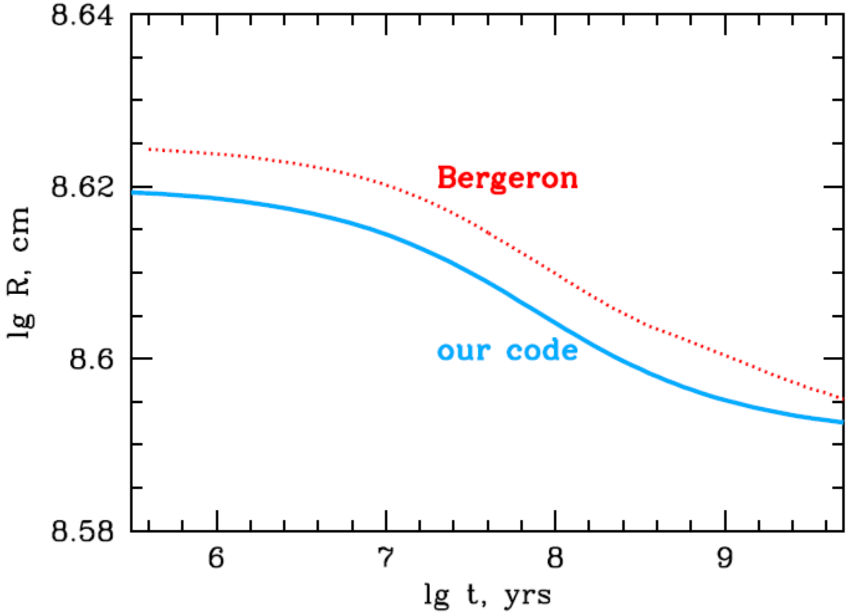
Comparison with the code of white dwarf evolution by Bergeron et al.

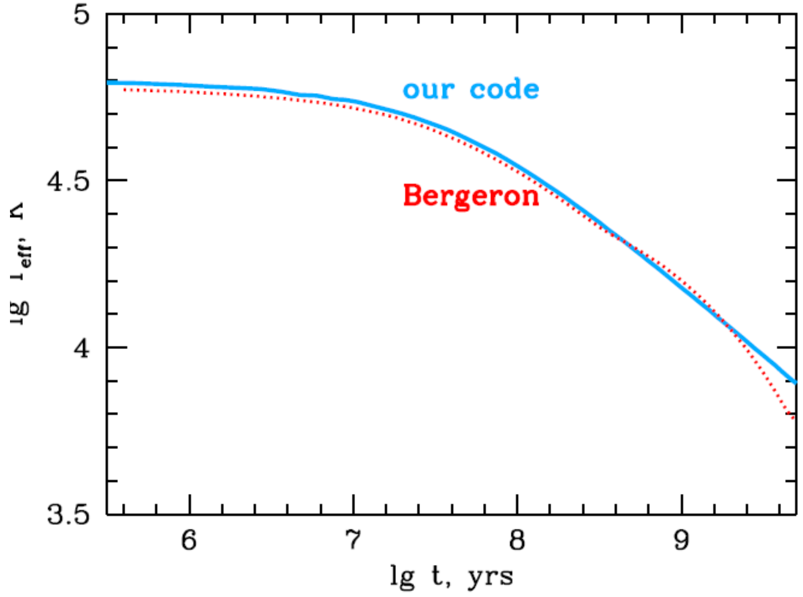


The code by Blinnikov and Dunina-Barkovskaya (1994).

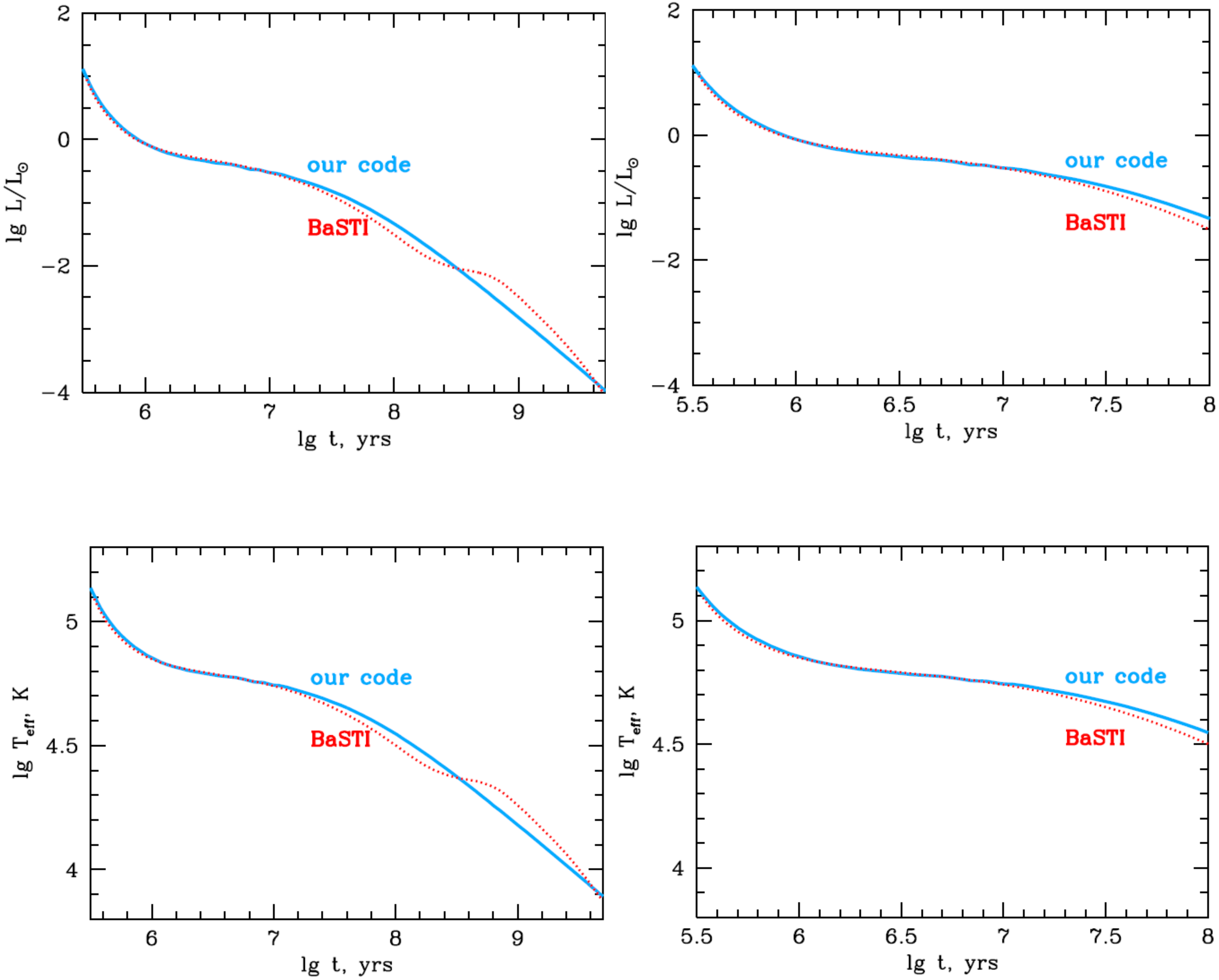
We compared it with recent codes for WD evolution.

Correspondence is very good.

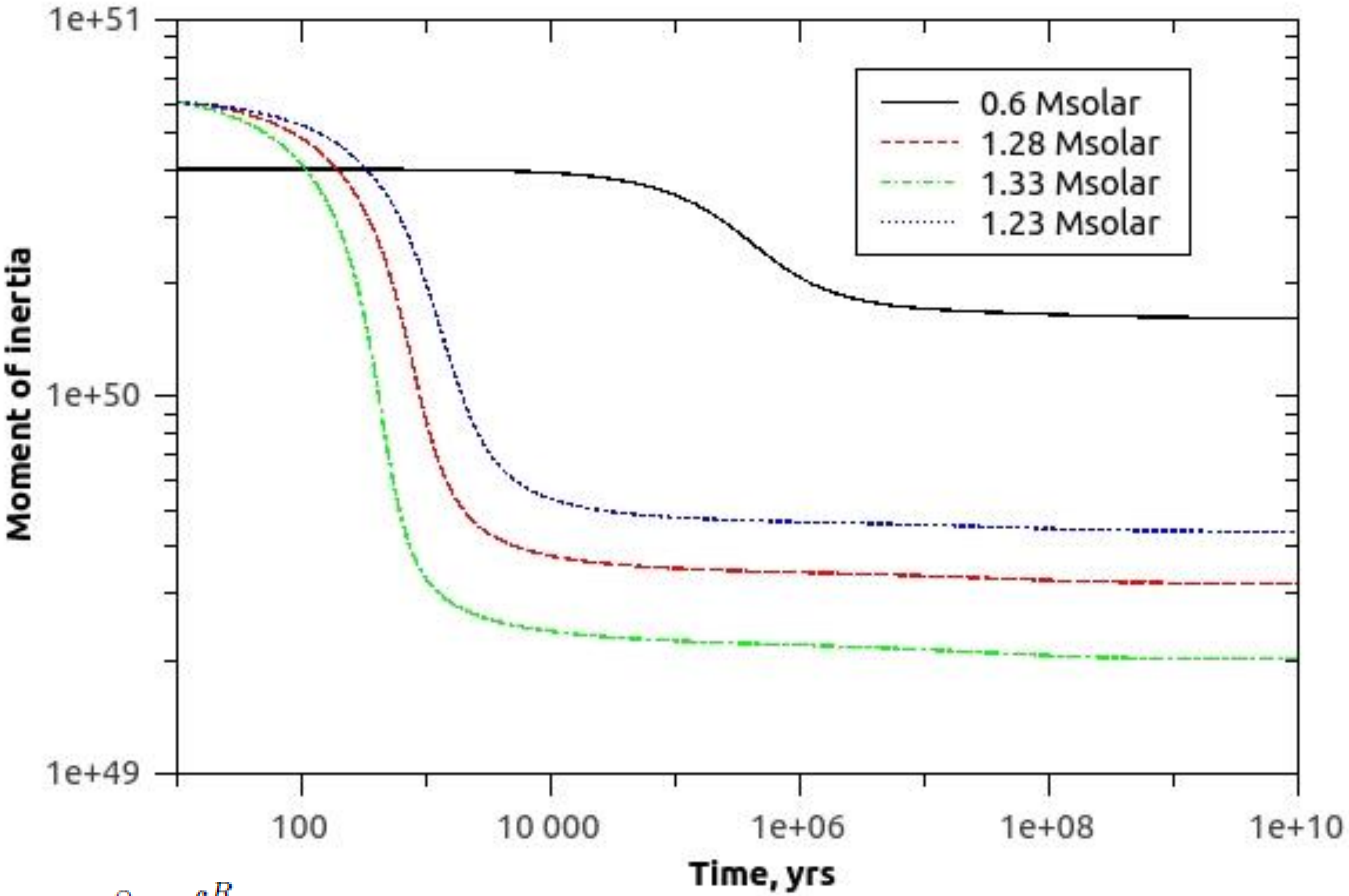




Comparison with BaSTI

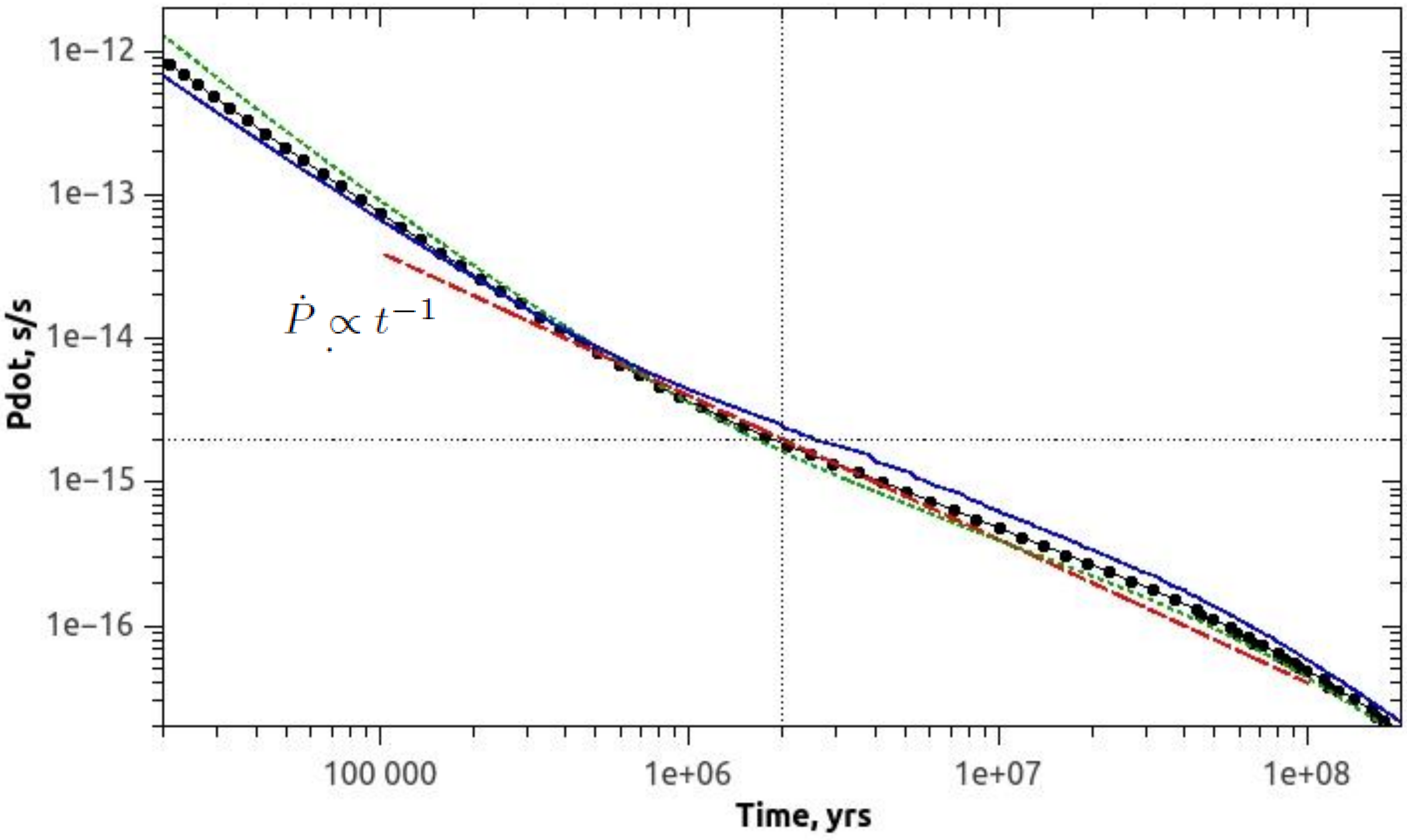


Evolution of the moment of inertia



$$I = \frac{8\pi}{3}\int_0^R \rho r^4 dr,$$

Period variation: theory and observations



$$I_1/I_2 = P_1/P_2 \qquad \dot{P} = \Delta P/\Delta t = \frac{P}{\Delta t}\left(\frac{I_1}{I_2} - 1\right)$$

Contraction vs. accretion

Let us compare torque due to accretion onto a WD with the spin-up due to contraction.

Let the accretion disc be terminated at the corotation radius:

$$R_{\rm co} = (GMP^2/4\pi^2)^{1/3}$$

Then we have

$$2\pi I\dot{\nu} = \dot{M}(GMR_{\rm co})^{1/2}$$

With accretion rate

$$\dot{M} = L(GM/R)^{-1} = 1.8\times 10^{14} L_{32}\ {\rm g\ s^{-1}}$$

we obtain

$$\dot{\nu} = 1.1\times 10^{-19} L_{32} I_{50}^{-1} (R/3000\,{\rm km})^{-1}\ {\rm Hz\ s^{-1}}$$

i.e.

$$\dot{P} = 2\times 10^{-17} L_{32}\ {\rm s\ s^{-1}}$$

WD properties

To fit all data the WD might have:

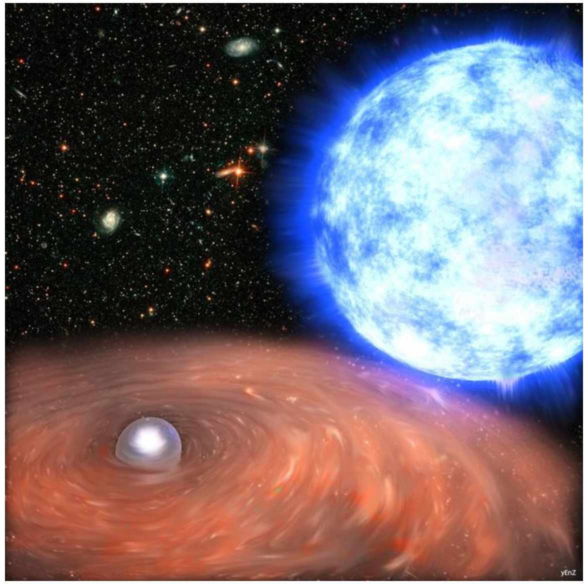
M=1.28 Msolar

Age ~ 2 Myrs (1<Age<5 Myrs)

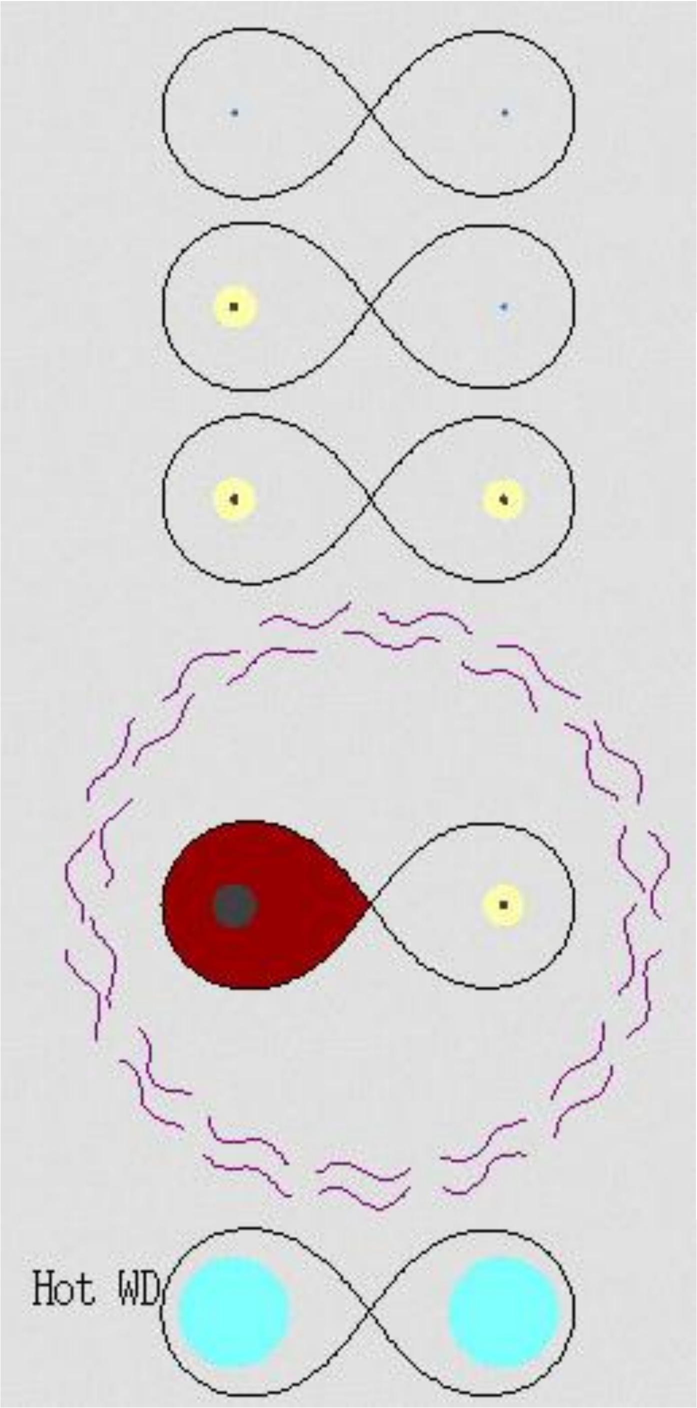
This corresponds to

- radius 3340 km
- temperature 75 000K

Luminosity of the sdO star is much larger ~10^4 Lsolar.



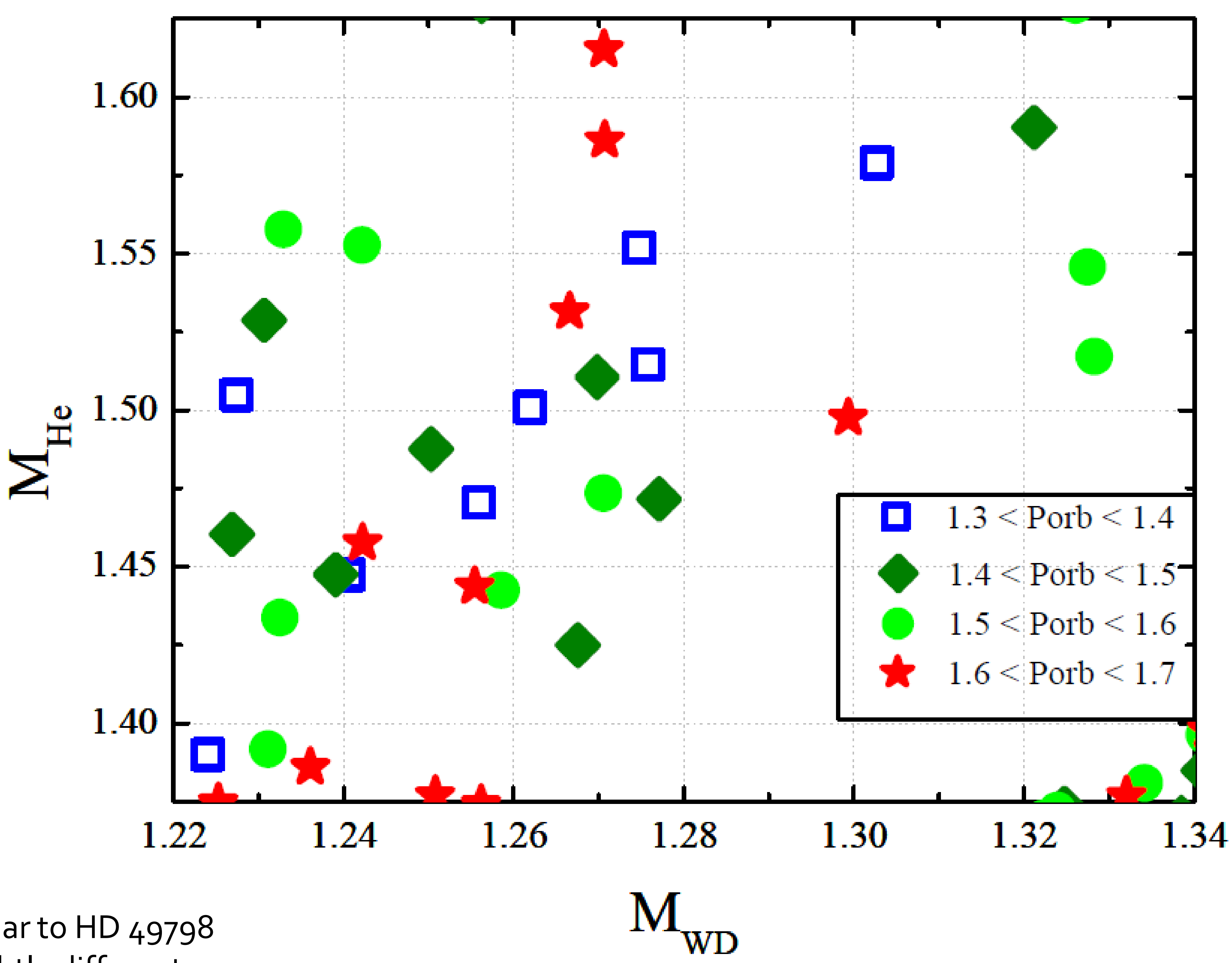
Binary and its evolution



Time (Myr)	M_1 ($M_\odot$)	M_2 ($M_\odot$)	Period (days)	Stage
0.0	7.0	6.75	4550.3	ZAMS
48.8	7.06	6.75	4550.3	RG+MS
49.0	7.05	6.75	4551.6	CHB+MS
53.0	6.89	6.75	4621.7	CHB+RG
53.1	6.89	6.75	4623.4	CHB+CHB
55.0	6.84	6.69	4691.9	EAGB+CHB
55.3	6.8	6.69	4657.4	TPAGB+CHB
55.7	5.96	6.84	4101.8	CE
55.7	1.28	1.47	1.48	ONe WD+He$\star$
64.1	1.28	1.43	1.52	ONe WD+HeG
64.8	1.28	1.42	1.53	CE
64.8	1.28	0.83	0.15	ONe+CO WDs
467.5	1.28	0.83	0.0004	Merger

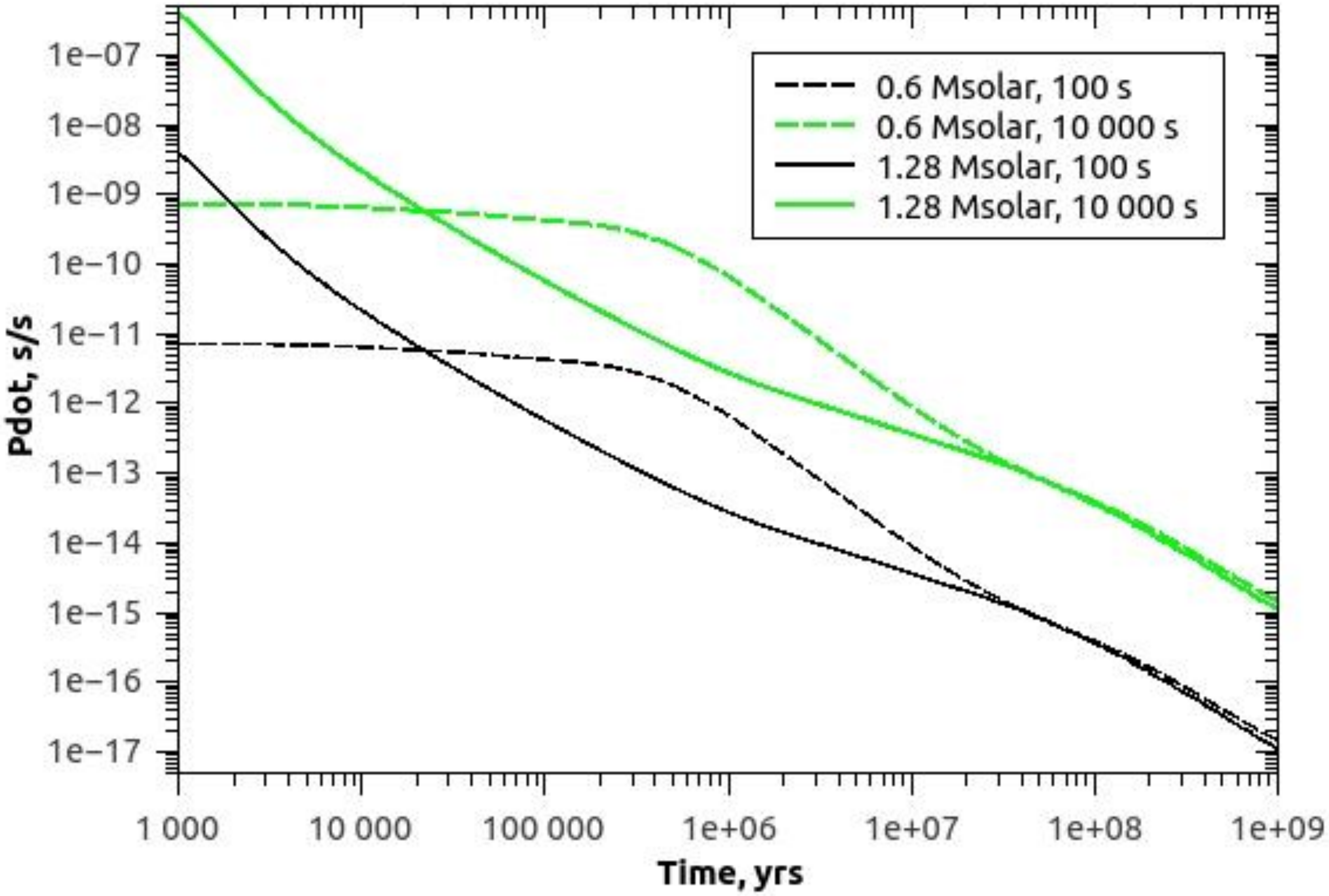
He-star is formed after the WD

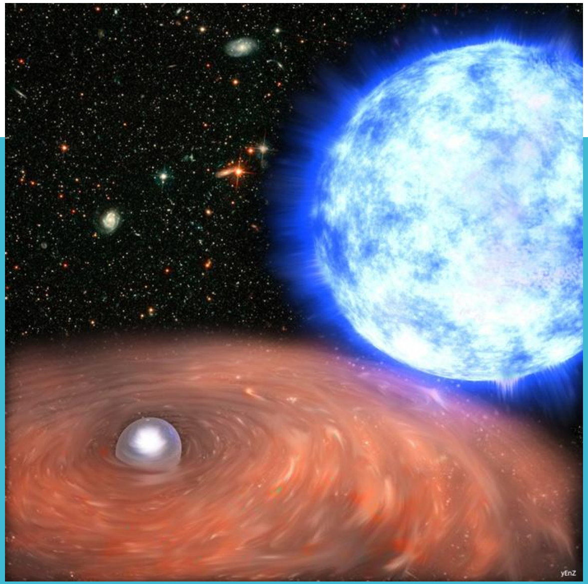
Binary statistics



~25 systems in the Galaxy very similar to HD 49798
and hundreds of systems with slightly different masses.

Pdot for different parameters of WDs





Conclusions

We conclude that all properties of the binary system HD 49798
can be explained in the model
where the accreting compact object
is a young WD with an age ~2 Myrs.

Observed luminosity is due to accretion
but observed Pdot is due to WD contraction.

The system is rare but not unique.
We expect that tens or even hundreds of such binaries
are there in the Galaxy.

Discovery of similar system
might help to probe interesting early stages of WD evolution.