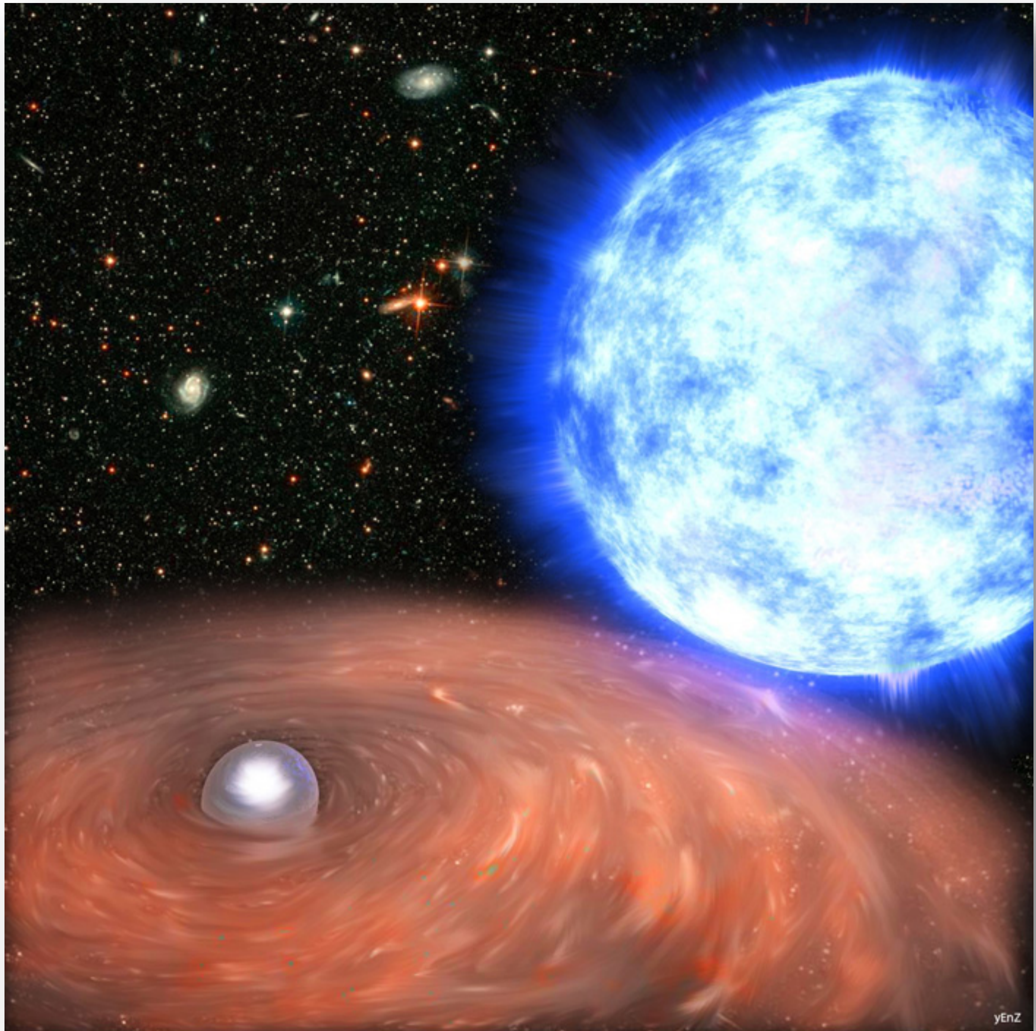
La cura dimagrante della Nana Cicciona



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Astrosiesta
11 gennaio 2018

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1970: HD 49798 is a spectroscopic binary
…but its companion is invisible in optical/UV

Thackeray 1970
Kudritzky et al. 1978
Hamann et al. 1981
Bruhweiler et al. 1981
Stickland & Lloyd 1984

HD 49798

The brightest
hot subdwarf (sdO)
B=8 mag

single-lined
spectroscopic binary
(P_{ORB} = 1.55 days)

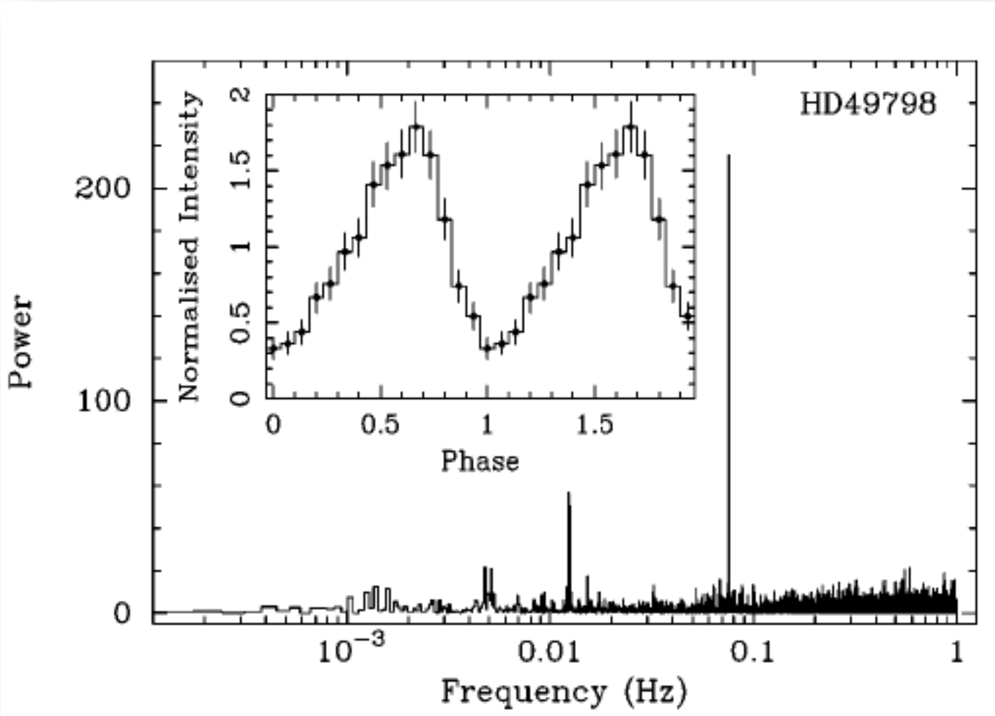
+

?

Companion
invisible in
optical / UV data

1997: discovery of very soft, pulsed X-ray emission with ROSAT

Israel et al. 1997, ApJ



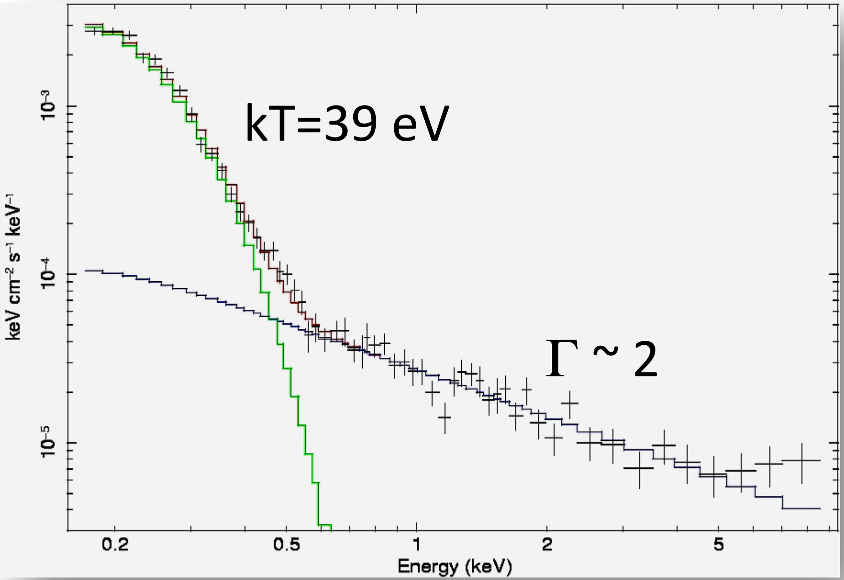
P=13.2 s → the companion is a **Neutron Star** or a **White Dwarf**

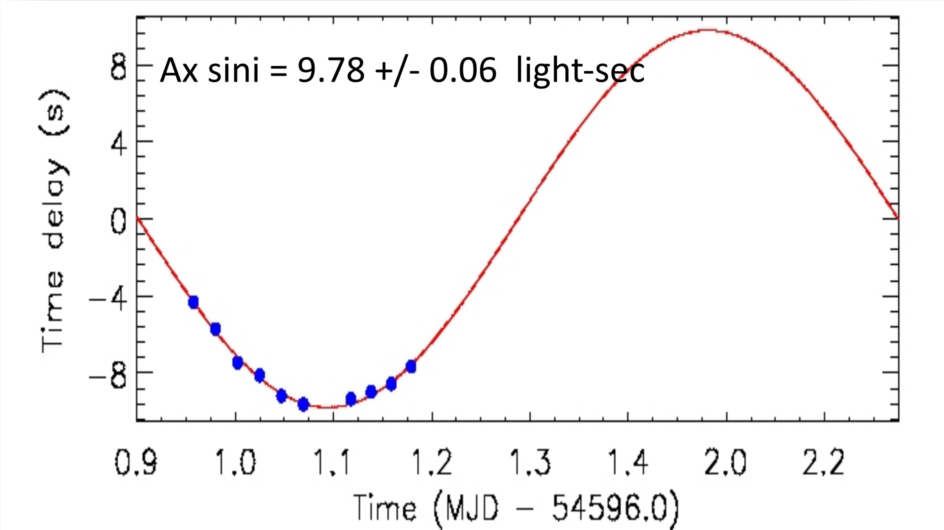
Poorly constrained X-ray spectrum → large uncertainty on X-ray luminosity

10^{32} - $>10^{38}$ erg/s

2008: Long observation with XMM-Newton good spectrum and dynamical measure of the masses

Mereghetti et al. 2009, Science





Blackbody + Power law

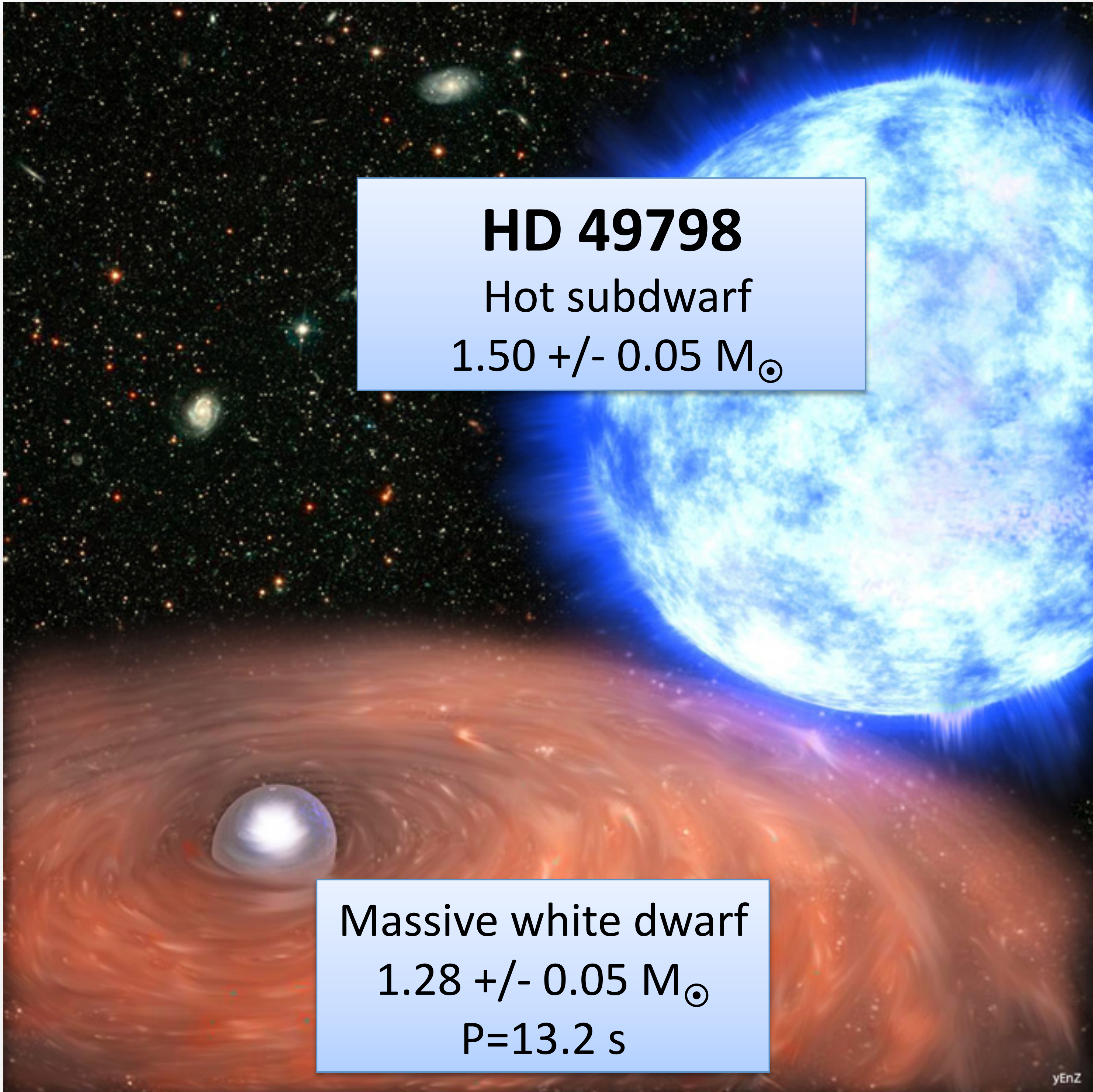
$L_{bol} \sim 2\ 10^{32}$ erg/s

too small for a NS accreting in the sdO wind !

The companion is a massive White Dwarf

Unique X-ray binary

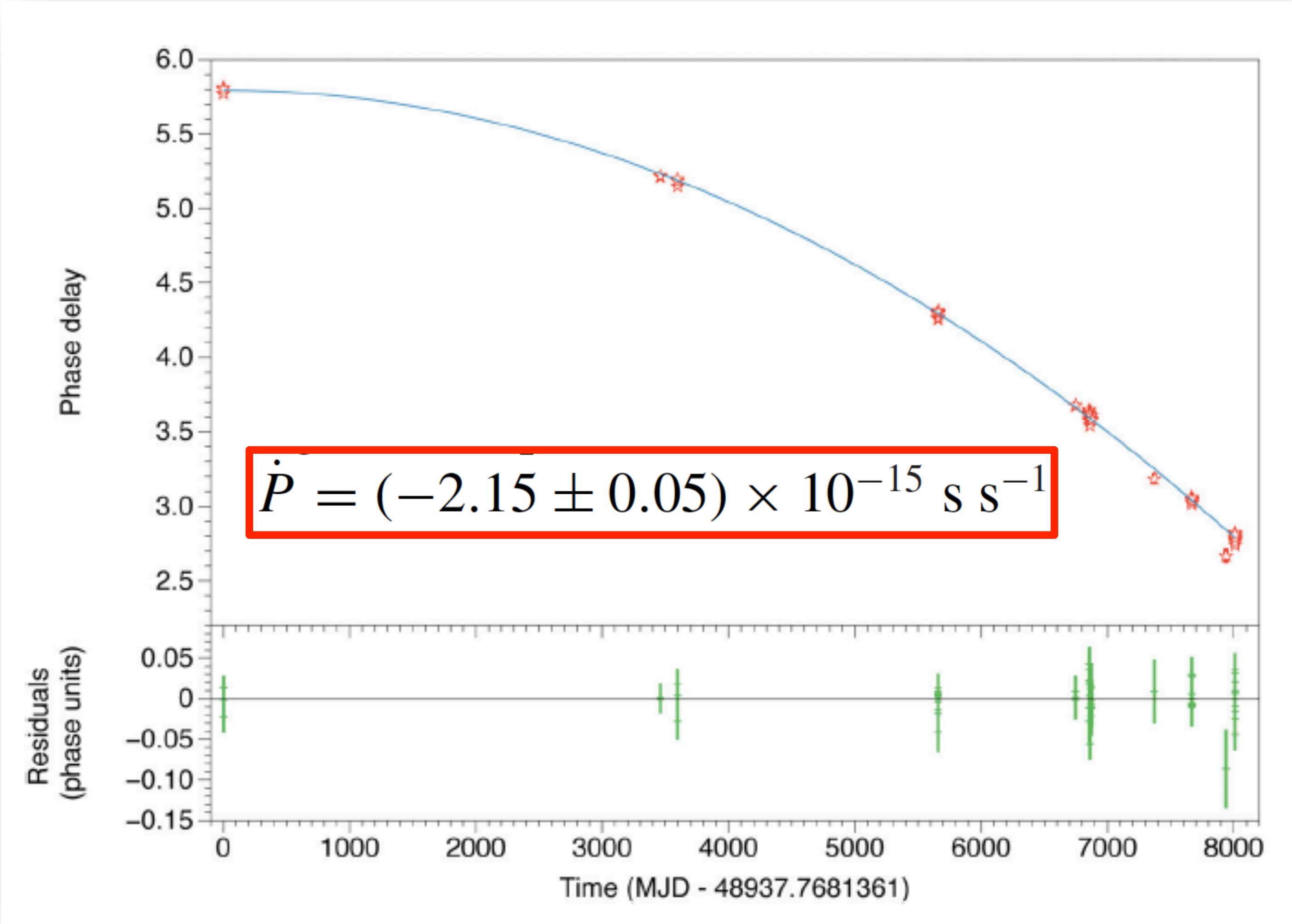
Possible progenitor of type Ia SN or ms PSR



2016: discovery of spin-up

Mereghetti et al. 2016, MNRAS

Phase connection over ~20 yrs - (ROSAT / XMM-Newton / Swift)



Problems with interpretation: a WD or a NS ?

Before Pdot measurements all systems parameters were well explained with an accreting WD.

But the high spin-up rate favors a NS, because, with the observed accretion luminosity, it is difficult to explain such significant Pdot of a WD.

Specific angular momentum accreted by the compact companion:

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

⇒

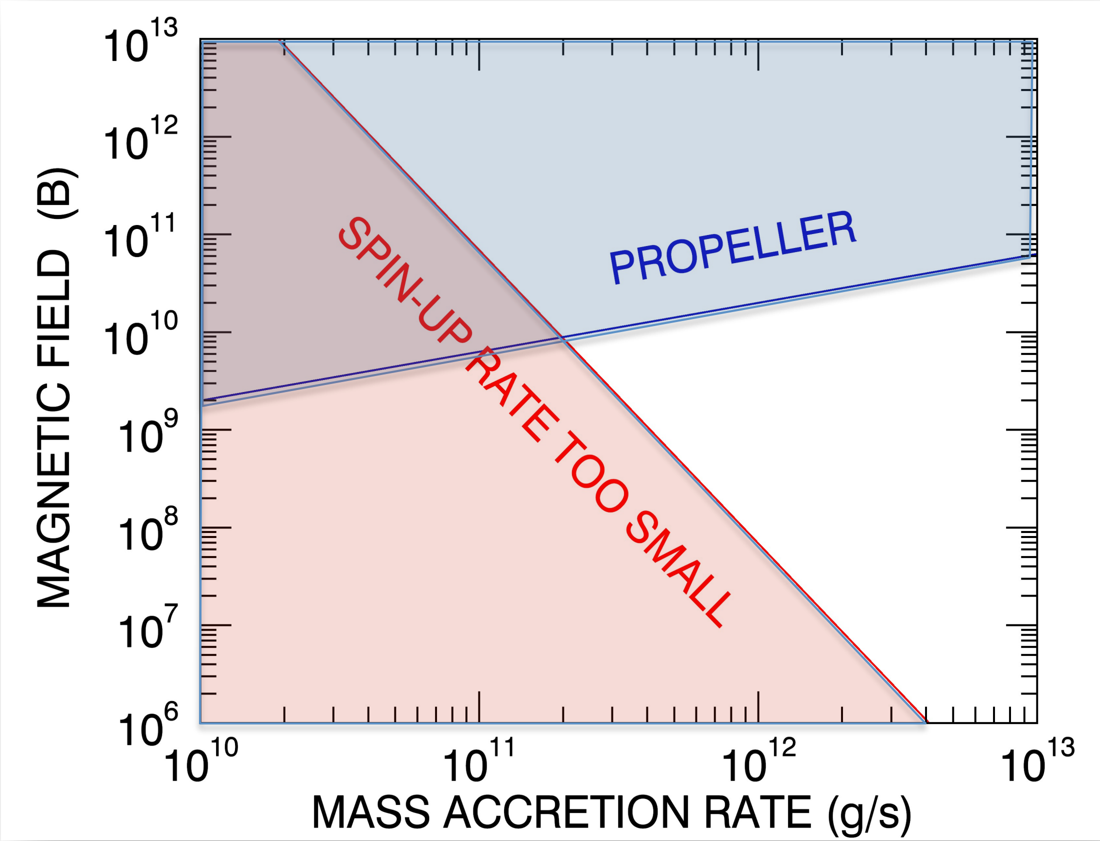
$$j_{\rm WD} = 2.2 \times 10^{19} \left(\frac{L_X}{2 \times 10^{32}\ {\rm erg\ s^{-1}}}\right)^{-1} {\rm cm^2\ s^{-1}}$$

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

It is too large in case of a WD

Problems with interpretation: a WD or a NS ?

Also with a NS there are problems:



$\dot{M} > 2 \times 10^{11}$ g s^{-1}

$\Rightarrow$ 2×10^{7} G $< B_{NS} < 3 \times 10^{10}$ G (very low)

$\Rightarrow$ stability of the spin-up rate for a time period longer than 20 yr

$\Rightarrow$ $R_{\rm BB} \sim 40$ (d/650 pc) km $> R_{\rm NS}$

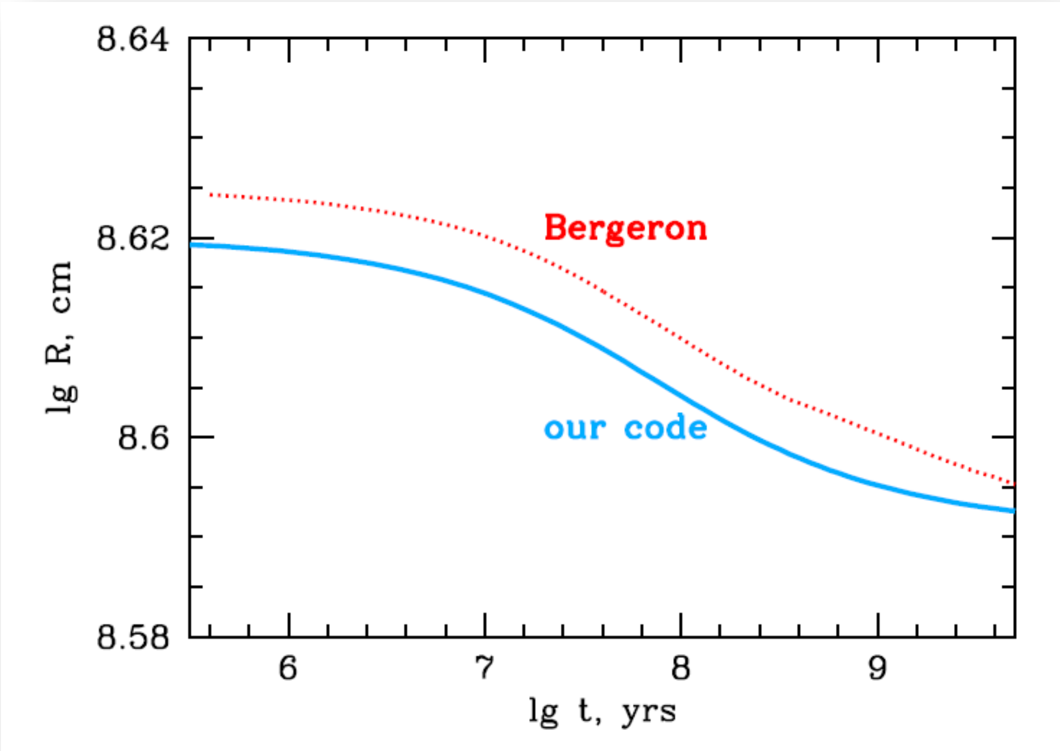
A new idea: a contracting white dwarf

Popov, SM, et al. 2017, MNRAS

WD evolutionary code

Blinnikov & Dunina-Barkovskaya 1994

Theoretical WD contraction

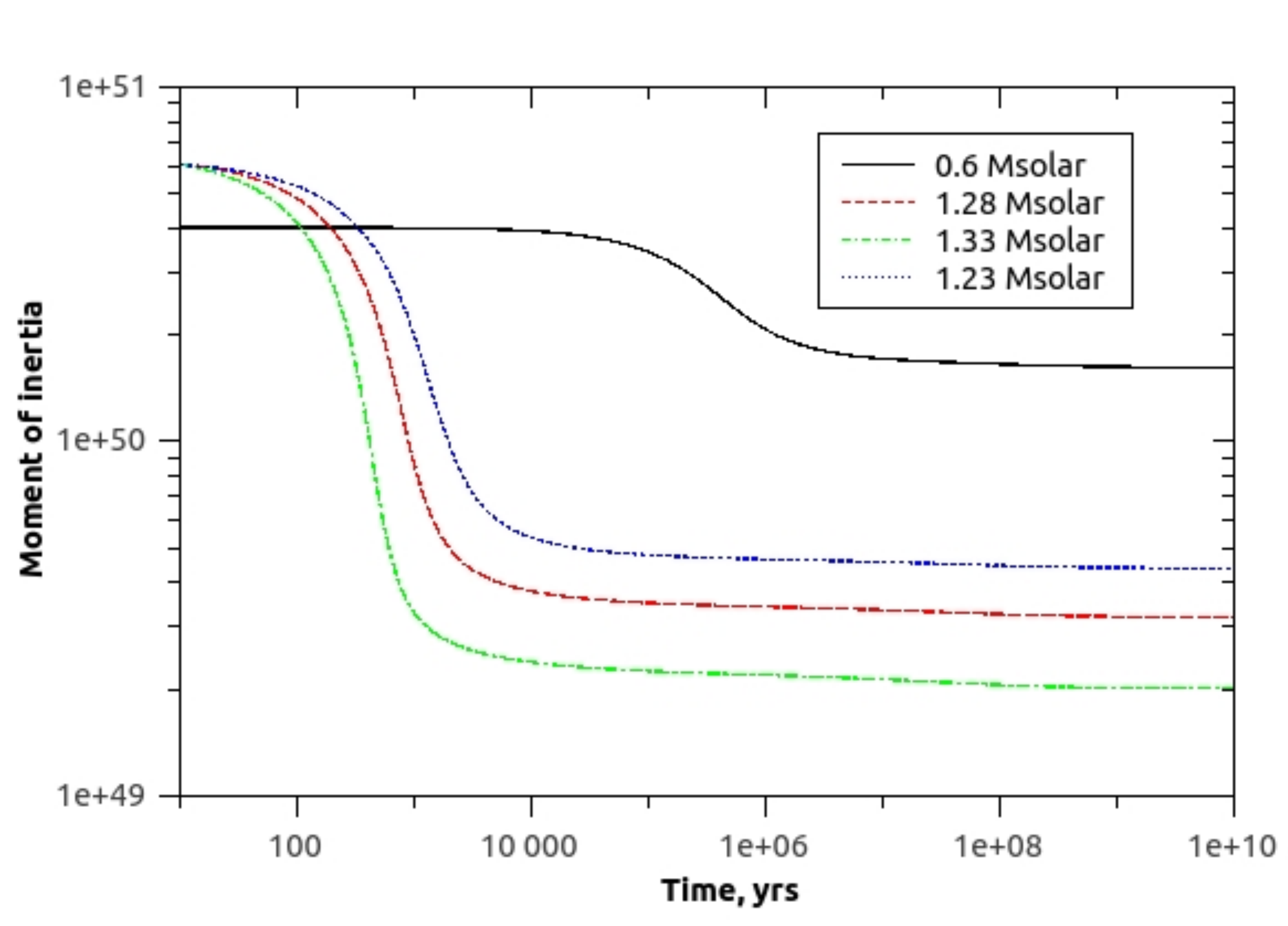


Includes
- equation of state
-Electrons heat conductivity
-Rate of neutrino losses
-Coulomb screening in thermonuclear reactions

Resulting cooling curves reproduce well the observed luminosity function and mass distribution of WDs

Agrees with other recent computations

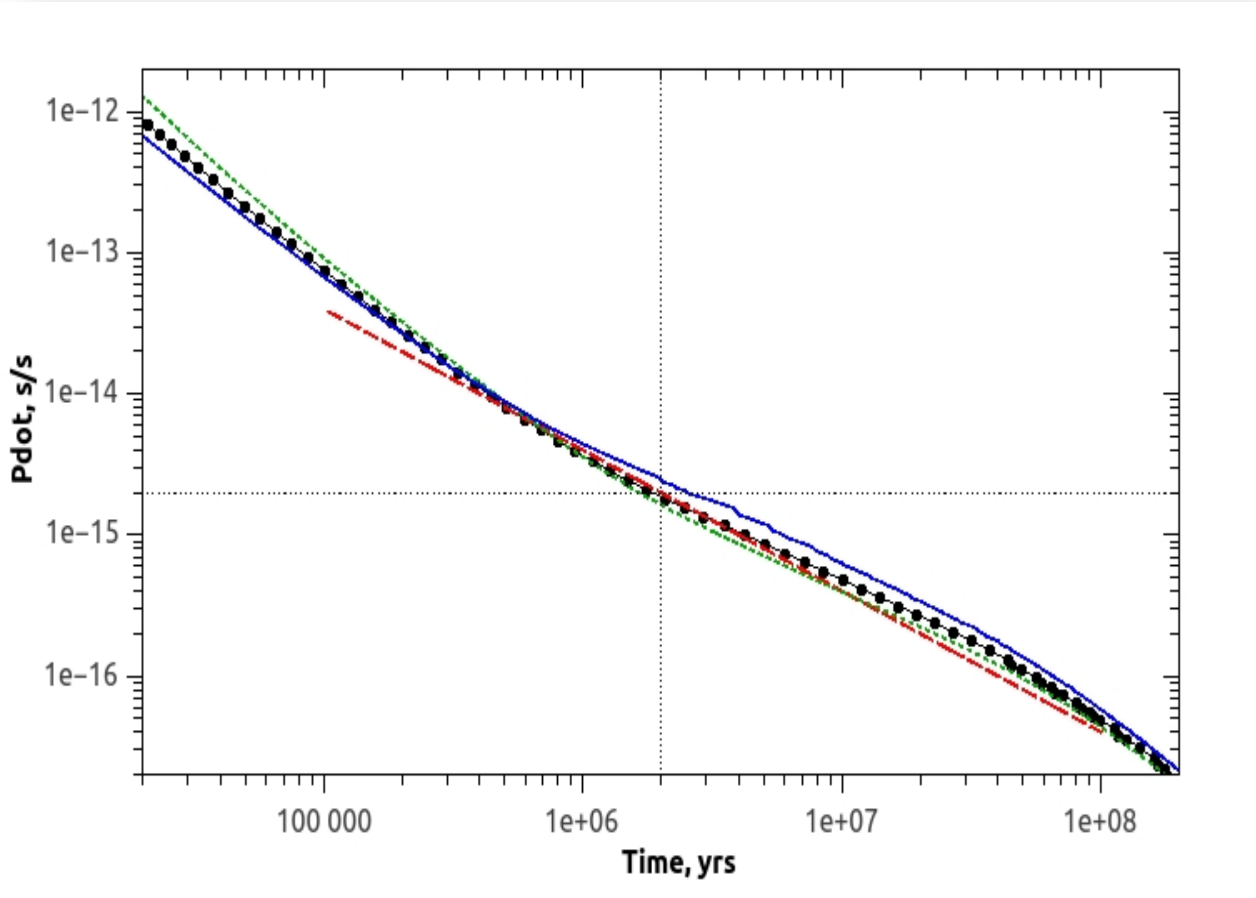
Moment of inertia as a function of WD age



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

Evolution of spin-up rate

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



The observed spin-up rate is that expected for a WD of ~2 million years

WD age of few Myr consistent with evolutionary scenario for the formation of systems like HD 49798, starting from intermediate mass binaries and involving common envelope phases

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

Conclusion

Accretion torques cannot produce the spin-up rate of the HD 49798 companion if it is a WD

(… and very difficult also if it is a NS)

But the contraction rate (~ 1 cm/yr) of a young (few Myr) WD can easily explain the rapid spin-up rate (70 ns/yr)

If this is the correct explanation, this would be the **first observational evidence of the contraction of a young WD** (predicted by theory but never observed before)