Formation of double white dwarfs from thermally unstable progenitor systems

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- Subject of the interest: Pre-cataclysmic systems with “massive” donors
- Model: WD, AM, MT
- Mass transfer sequences
- Semi-analytic approach
- Zoo of outcomes: channels

Physics

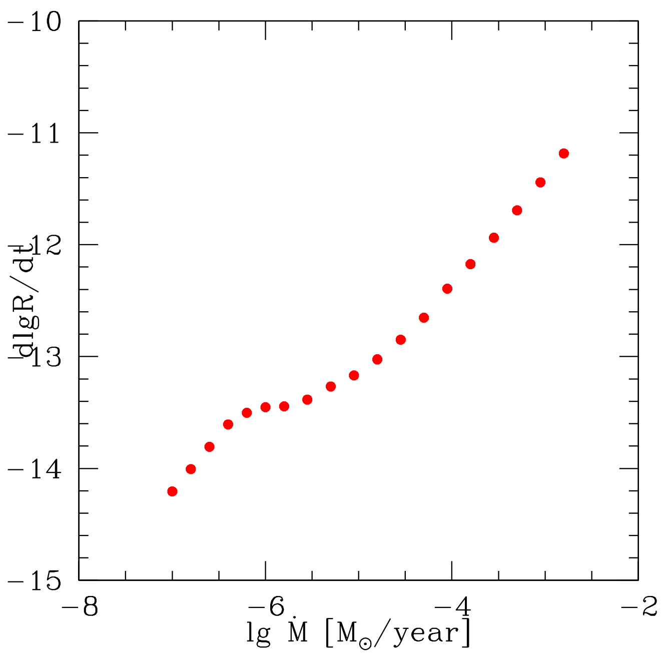
WD evolution: (Hachisu, Kato and Nomoto, 1999)

- $\dot{M}_{\rm tr} \geq \dot{M}_{\rm cr} \approx 0.75 \times 10^{-6}\,(M_{\rm wd} - 0.4)\; M_{\odot}{\rm yr}^{-1}$: *superwind* $\rightarrow$ WD does not become a Red Giant : no CE formation
- Consider mass accumulation on the WD during the stable and unstable hydrogen burning; strong nova explosion
- Keep track of the accumulation of helium in the He shell : always unstable. Sub Chandrasekhar mass Type Ia SN? *Very narrow range of $\dot{M}$* allows accumulation of He without burning
- AIC: O+Ne+Mg WD, $\dot{M} > 10^{-8} M_{\odot}{\rm y}^{-1} \rightarrow$ NS formation through the electron capture for WD$\geq 1.1 M_{\odot}$ (Nomoto & Kondo 1991).

AM evolution:

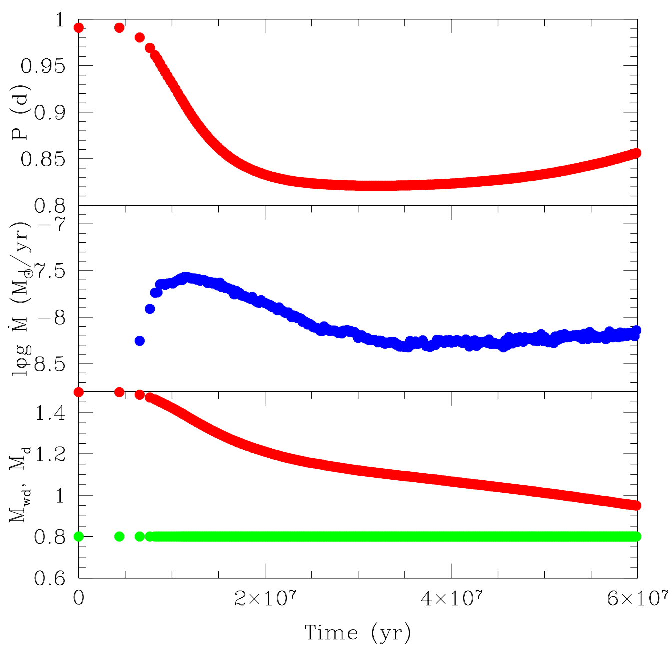
- Mass loss, mass transfer, gravitational radiation, magnetic braking.

Mass Transfer Rates

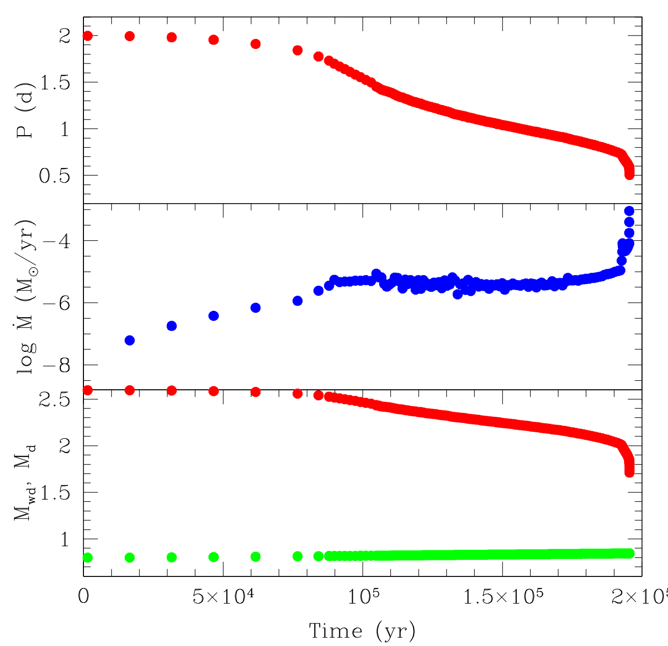


- Ideology: to find the response of the star due to the mass transfer as the function of the mass transfer rate and the time-step $\Delta R_{\rm star} = \Delta R_{\rm star}(\Delta M)$
- "+": keeps the star within its Roche lobe for each time-step self-consistently with the same precision as the radius of the star can be found.
- "-": the response function has to be updated very regularly; mass loss rate can be found only within the error bar associated with the error bar for the star radius: the noise increases with the decrease of the time-step.

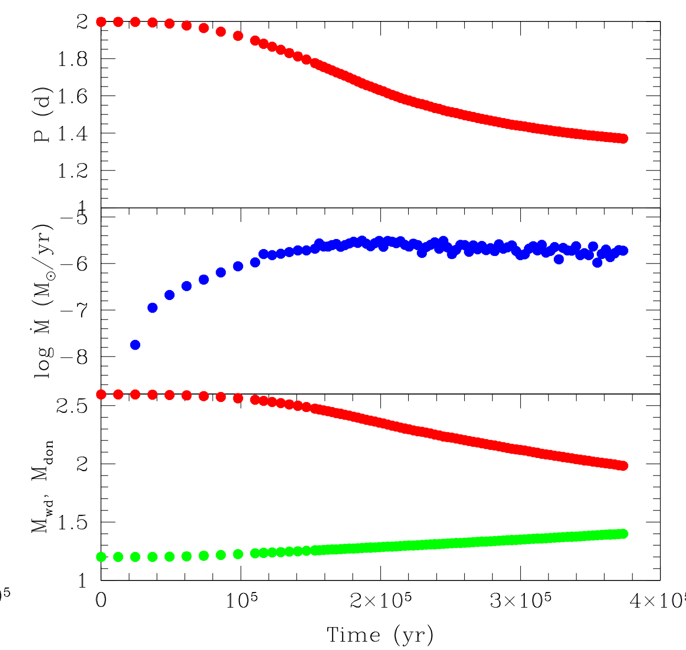
Mass Transfer Sequences



double white dwarf
$M_{\rm he} \approx 0.25 M_\odot$

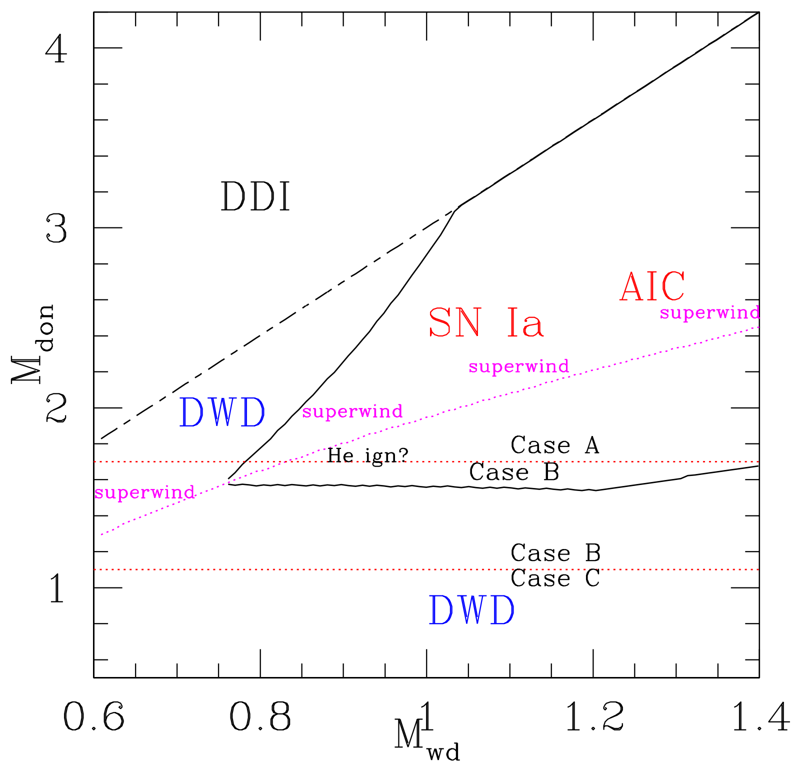


merger (DDI)



SN Ia/AIC

Semi-analytic picture (P=1 day)

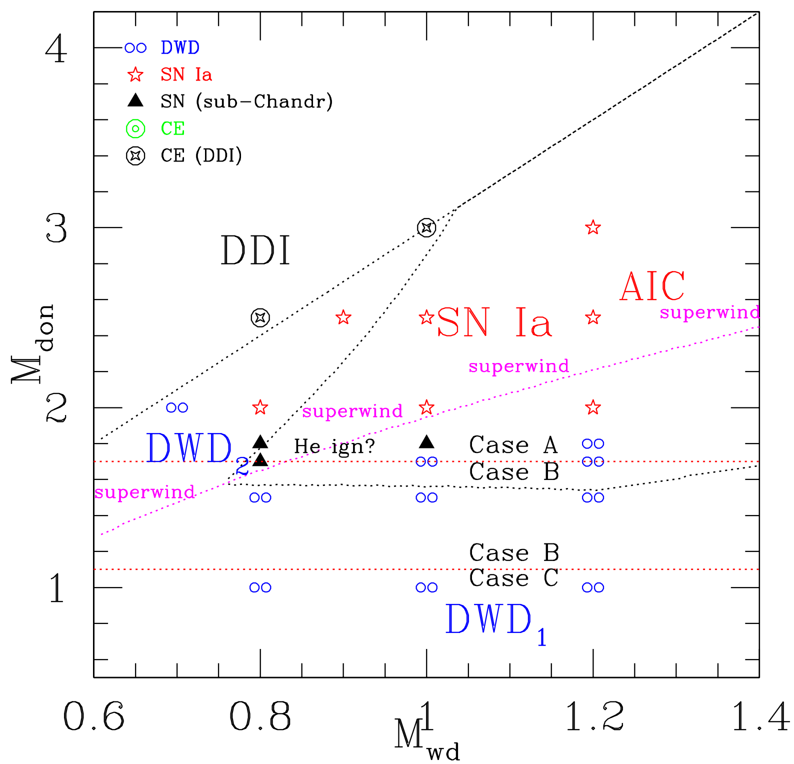


<u>Assumed:</u>

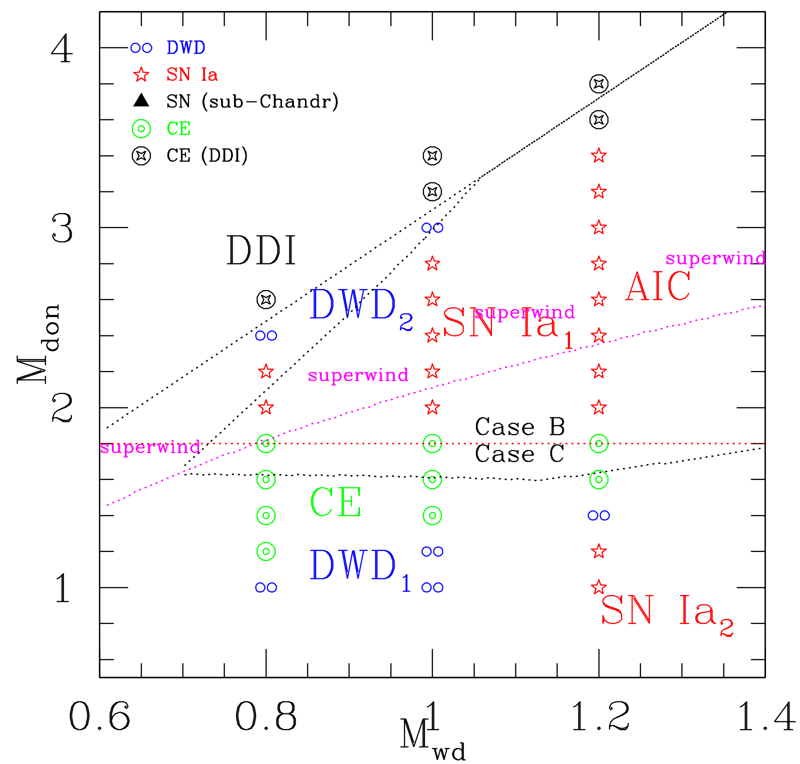
- Mass loss on the thermal time-scale
- Accumulation of the mass on the WD as described

<u>Results:</u>

- Two different ways of DWD formation: rapid and slow MT rate
- Accumulation of He in the shell: possible only when MT is low and occurs on the long time-scale: only bottom of SN Ia region, for case A systems?



P=1day



P=2days

- SN Ia_1 : $M_d \geq 1.2 M_\odot$, $P \approx 0.5 P_0$; SN Ia_2 : $M_d \approx 0.7 M_\odot$, $P \approx 3d$
- CE: $M_{he} \approx 0.2 M_\odot$, $P \approx 1 - 2h$
- Sub-Ch SN: $M_d \approx 0.5 - 1.5 M_\odot$, $P \approx 0.8d$
- AIC: $M_d \geq 1.2 M_\odot \ \rightarrow \ M_{he} \approx 0.3 M_\odot$, $P \approx 0.5 P_0$
- DWD_1: $M_d \approx 0.6 - 1.0 M_\odot \ \rightarrow \ M_{he} \approx 0.2 M_\odot$, $P \approx 1 - 2d$
- DWD_2: $M_d \approx 0.25 - 0.6 M_\odot \ \rightarrow \ M_{he} \approx 0.25 M_\odot$, $P \approx 0.5 - 4d$

Results

- Type Ia SN progenitors: 2 regions with 2 different periods at the moment of SN
- Sub Chandrasekhar mass Type 1a SN pregenitors: only for the MT case A
- AIC: channel to form low mass X-ray binaries and NS-He WD systems with the period less than day
- Formation of CVs with the period about day and more
- Short period ($P \approx 2$h) are formed due to the MT case C leading to the CE for $M_{\rm don} < 2M_\odot$