The evolution of low mass, close binary systems and the formation of “Black Widow” systems

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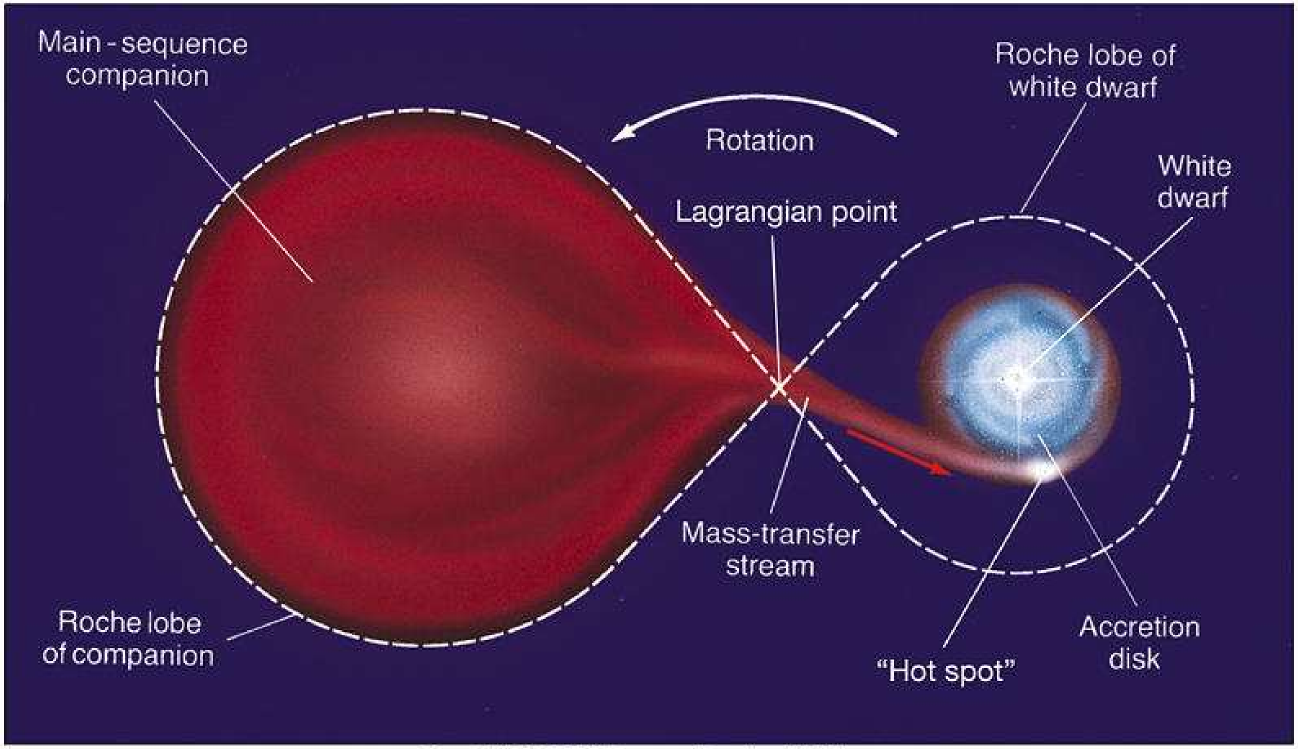
Roche Lobe Overflow



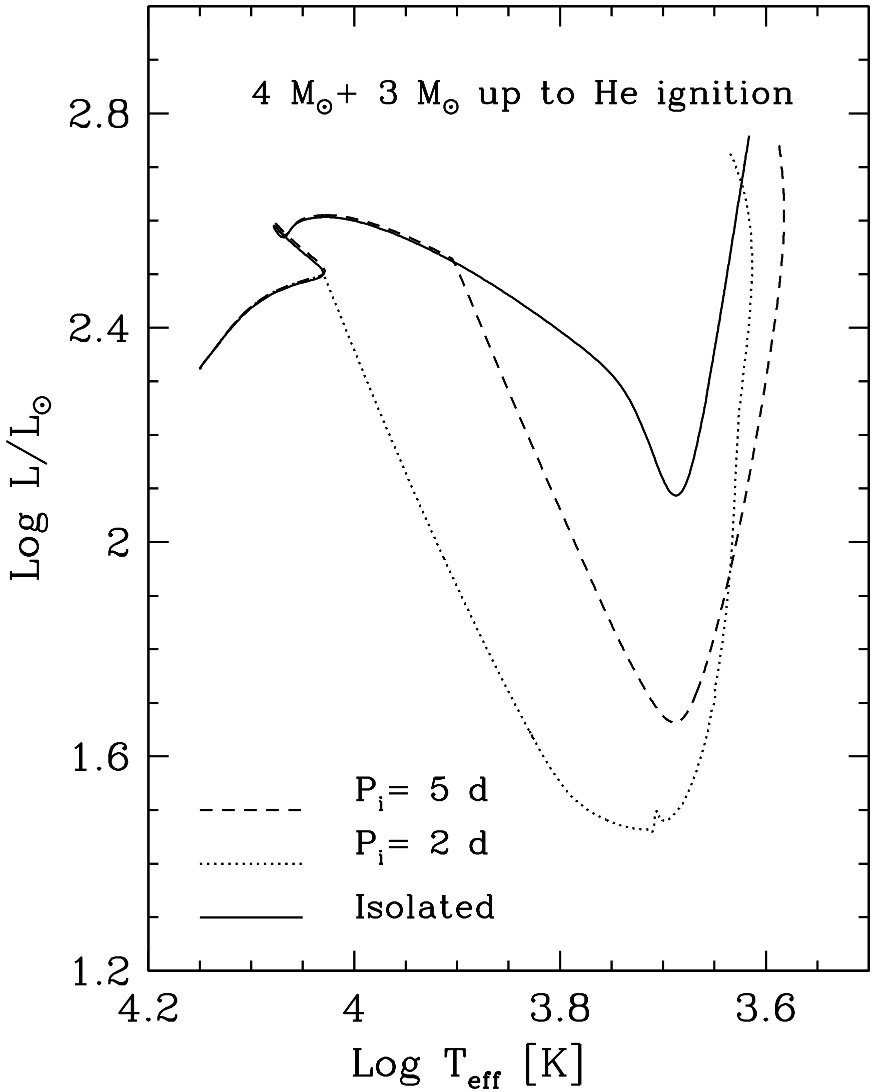
Roche Lobe Overflow

- At detached conditions: Standard Stellar Evolution
- When the donor star fills its Roche Lobe hydrostatic equilibrium is not possible at L_1: Binary Stellar Evolution
- A mass transfer episode starts
- The orbit of the stars begins to evolve
- The mass lost by the primary (donor) may be accreted by the companion
- Angular momentum exchange processes should be treated with care.

Our Binary Stellar Evolution Code

- We consider detailed and updated standard physical ingredients as those employed in isolated stellar evolution
- We generalized the Henyey method to solve for the donor structure, the mass transfer and the orbital semiaxis in a fully implicit, self consistent way.
- We consider that a fraction of mass can be lost from the system carrying away some angular momentum
- Other sinks: Gravitational Radiation
- Other sinks: Magnetic Braking

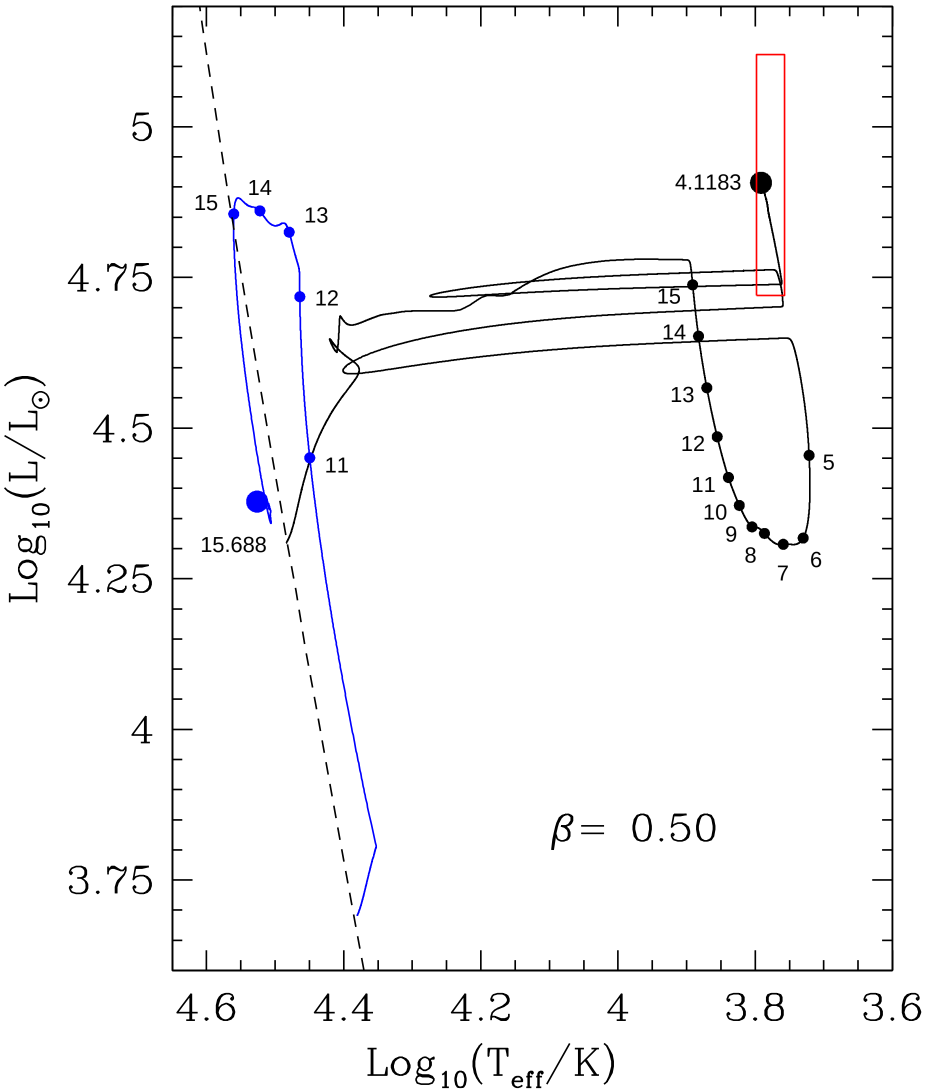
Typical Results



Applications

- Applied to the formation of binary He WD + pulsar systems (e.g., De Vito, Benvenuto, 2012, MNRAS, 421, 2206)
- Recently we have applied it to the study of the progenitor of Supernova SN2011dh (Benvenuto, Bersten, Nomoto, 2013, ApJ, 762, 74)
- and to the formation of “Black Widow” systems (Benvenuto, De Vito, Horvath, 2012, ApJ, 753, L33)

The case of SN2011dh



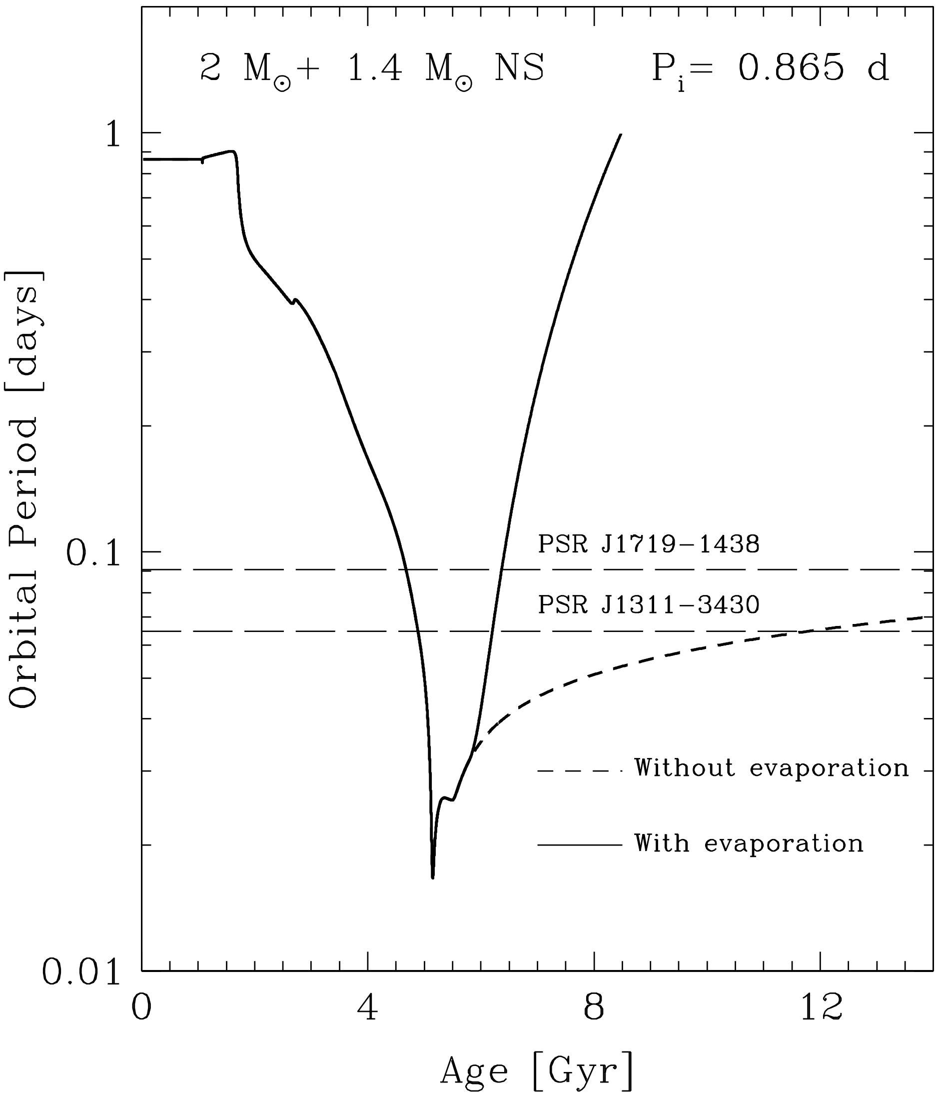
Let us apply our code

to the case of

“Black Widow”

binary millisecond pulsars

Typical Results for Low Initial Periods



Evaporation is due to the pulsar irradiation on the very low mass companion

Mass loss due to evaporation

drastically affects the orbital period

evolution of the binary

allowing to reach much larger periods !

The first “Black Widow”: PSR 1957+20

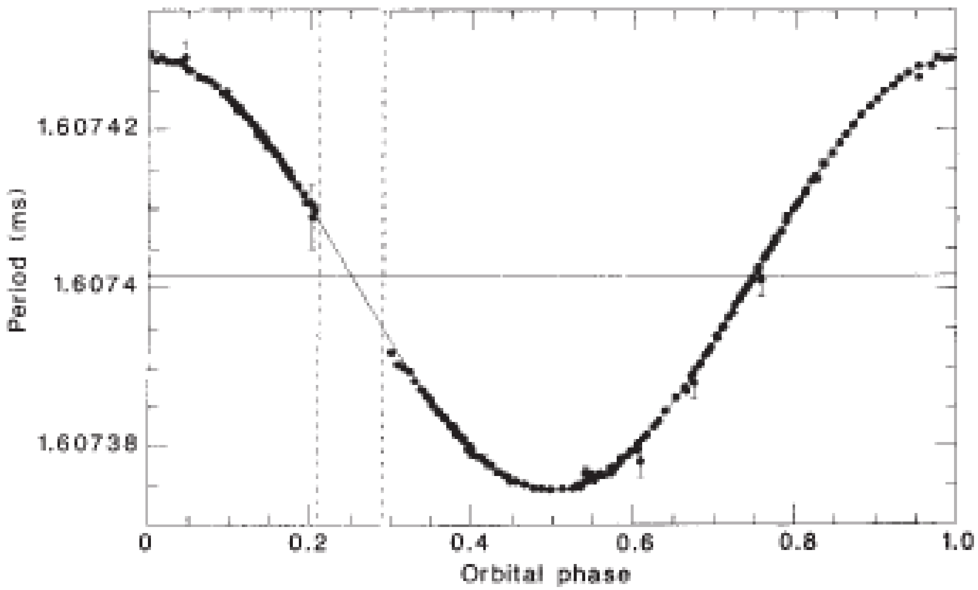


Fig. 2 Orbital velocity curve of PSR1957+20. The pulsar is eclipsed by its companion between phases 0.21–0.29. Points with visible error bars were taken using the pulsar survey system; all other points were obtained with the data acquisition system designed for timing millisecond pulsars.

The first “Black Widow”: PSR 1957+20

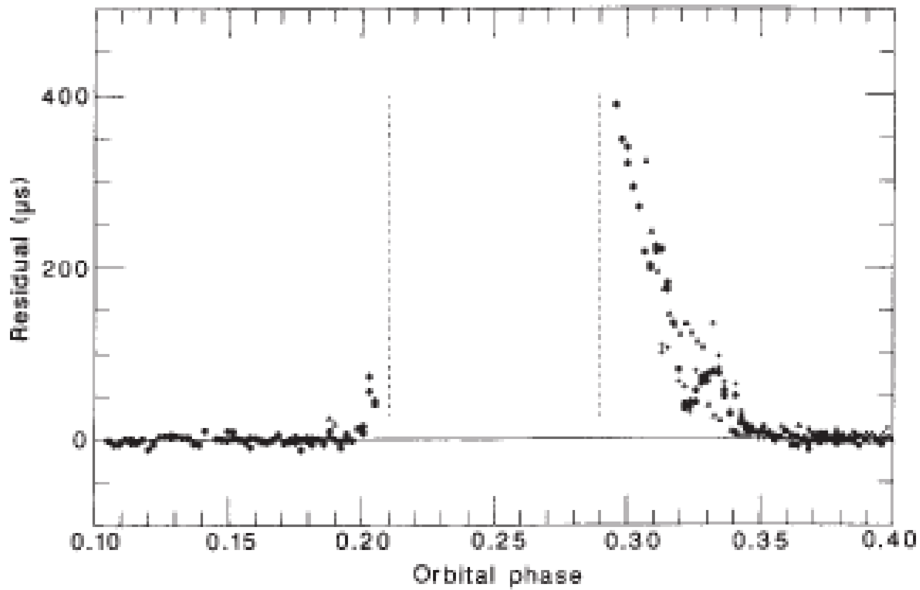


Fig. 3 Excess group delays in the pulsar signal at 430 MHz relative to a model based on our best-fit parameters, plotted as a function of orbital phase near the centre of eclipse. Different symbols correspond to different observing days.

The first “Black Widow”: PSR 1957+20

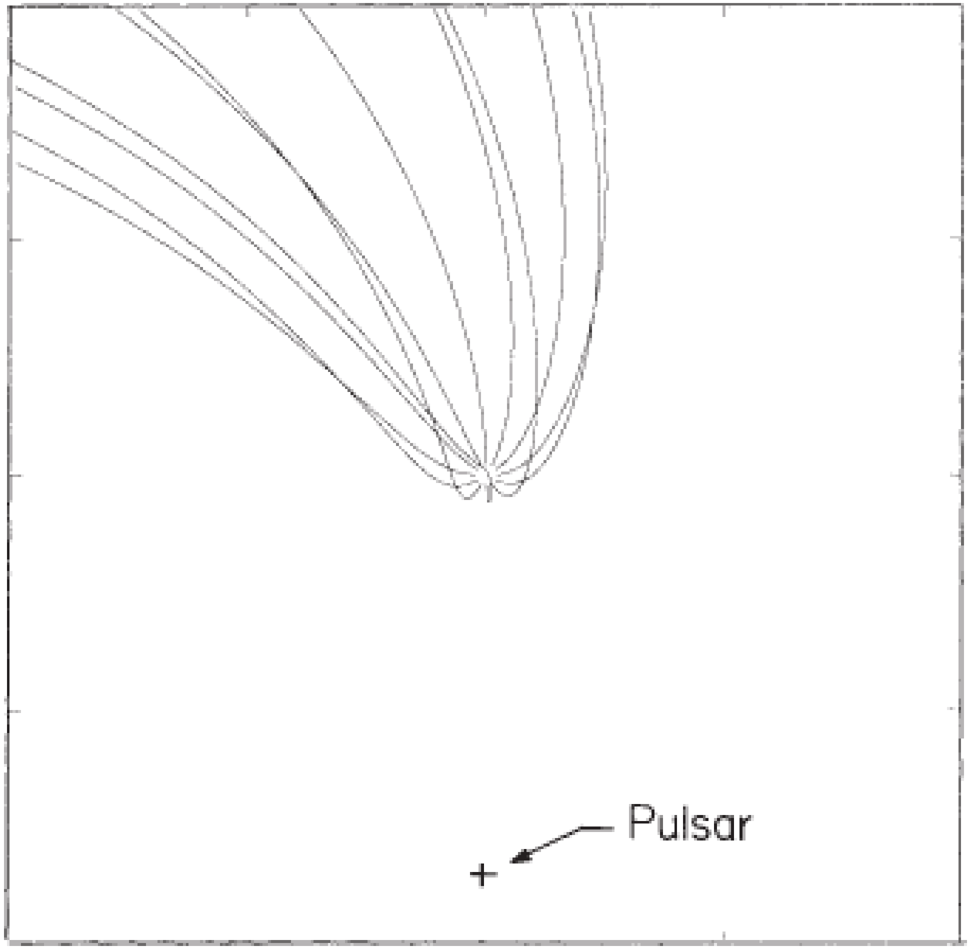
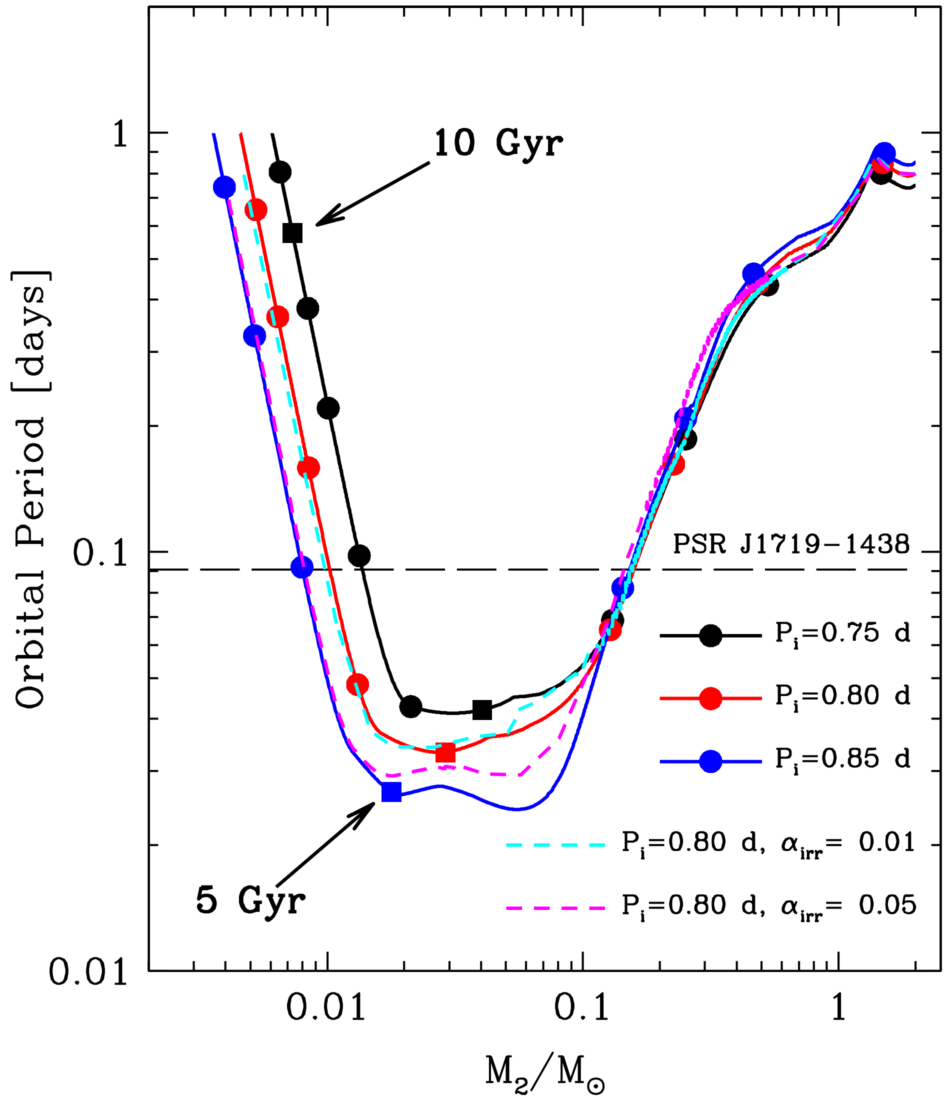
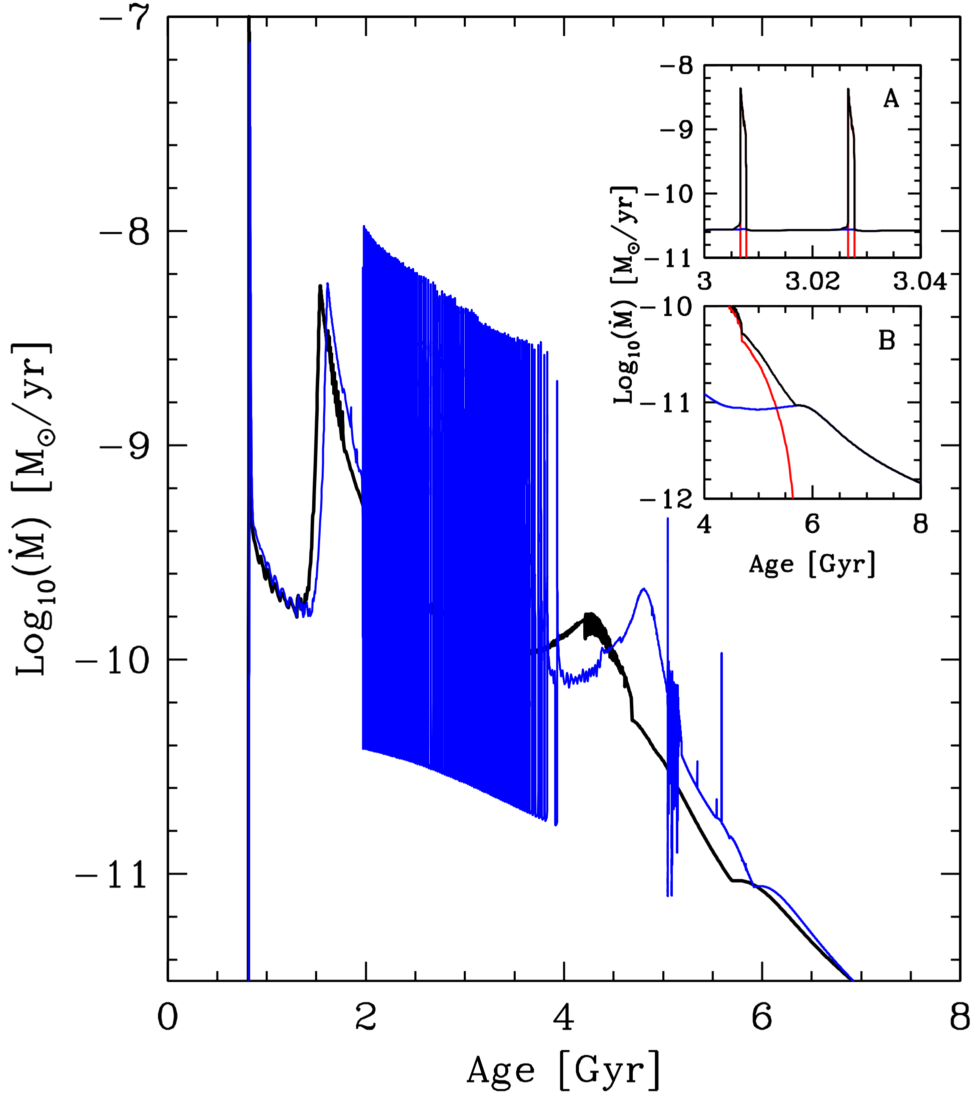


Fig. 1. Simulated cometary wind. Individual particle trajectories are shown in the co-rotating frame, assuming an outflow of 600 km s^{-1} and an outward pulsar-wind acceleration of 12 times the pulsar gravitational attraction (required to give a reasonable scale). Orbital motion is clockwise. Such a system can give a sharp entry eclipse and a sharp refraction exit eclipse, but the exit eclipse would be geometrically unrelated in phase with the entry eclipse, and for refraction to be important the exit eclipse would also have a very large associated time decay. Eclipses are instead observed to be quite symmetric, with only a small time delay.

The case of PSR J1719-1438



The case of PSR J1719-1438



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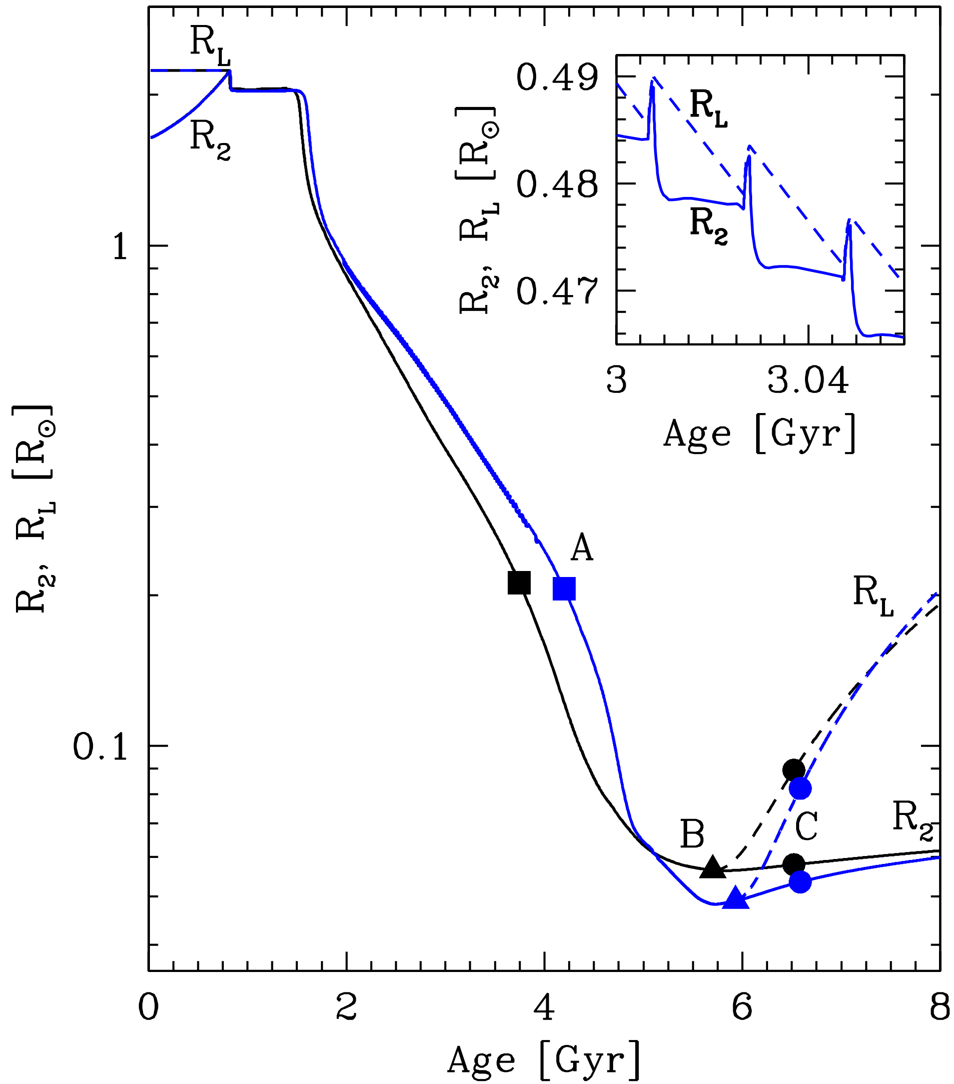
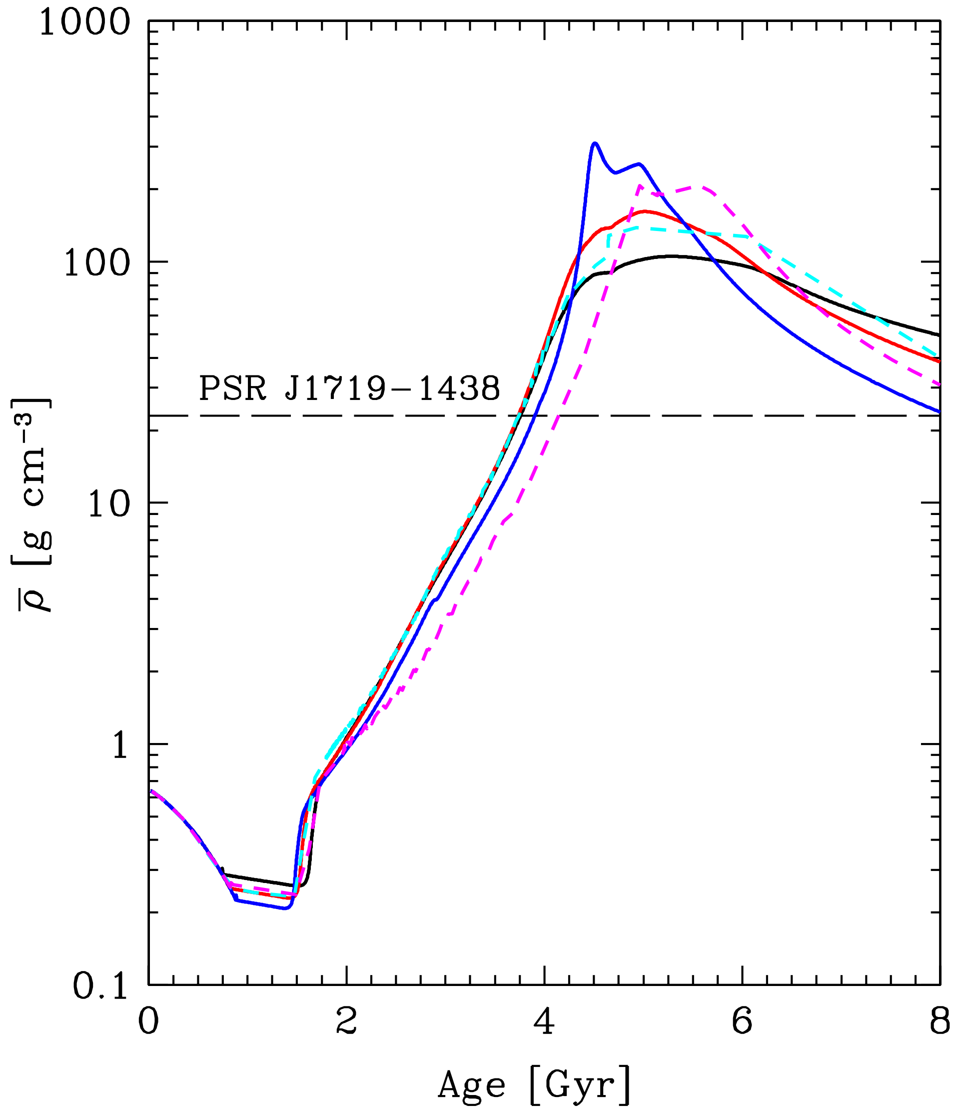
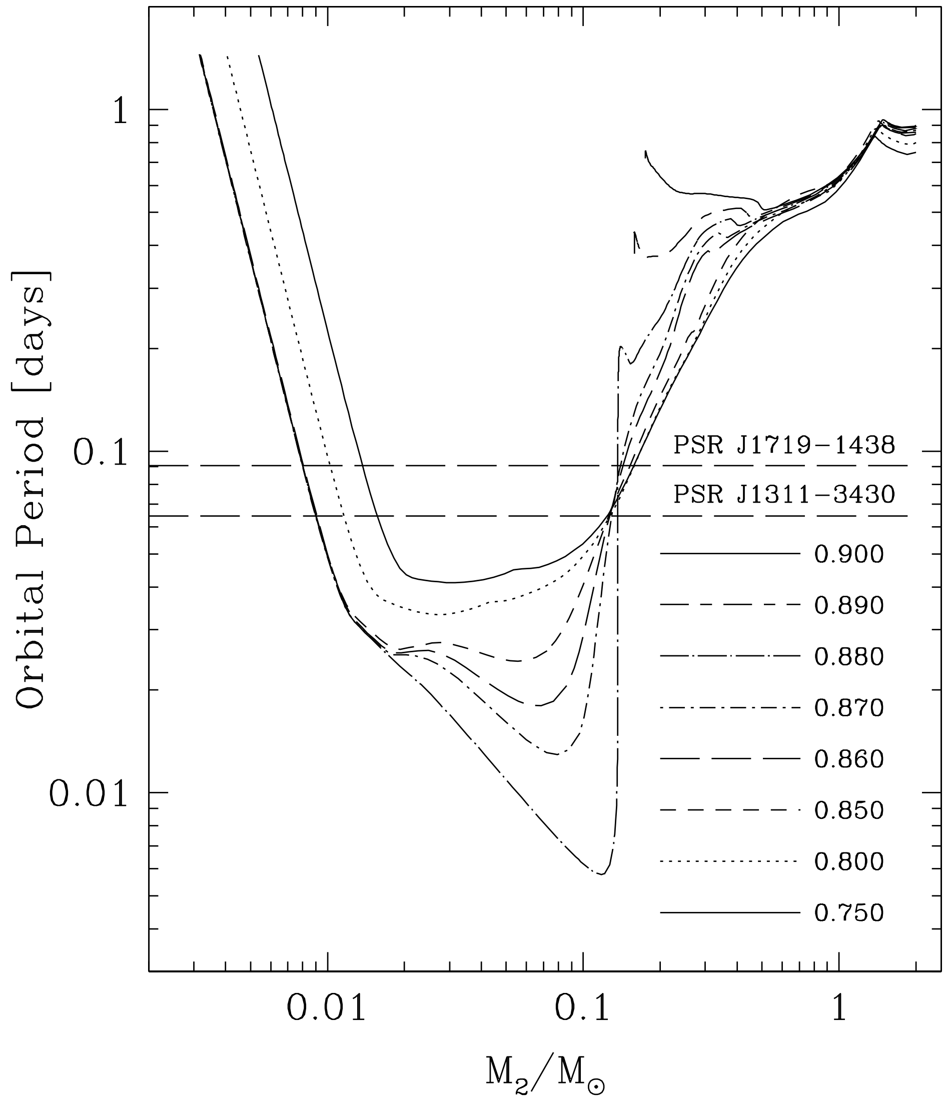


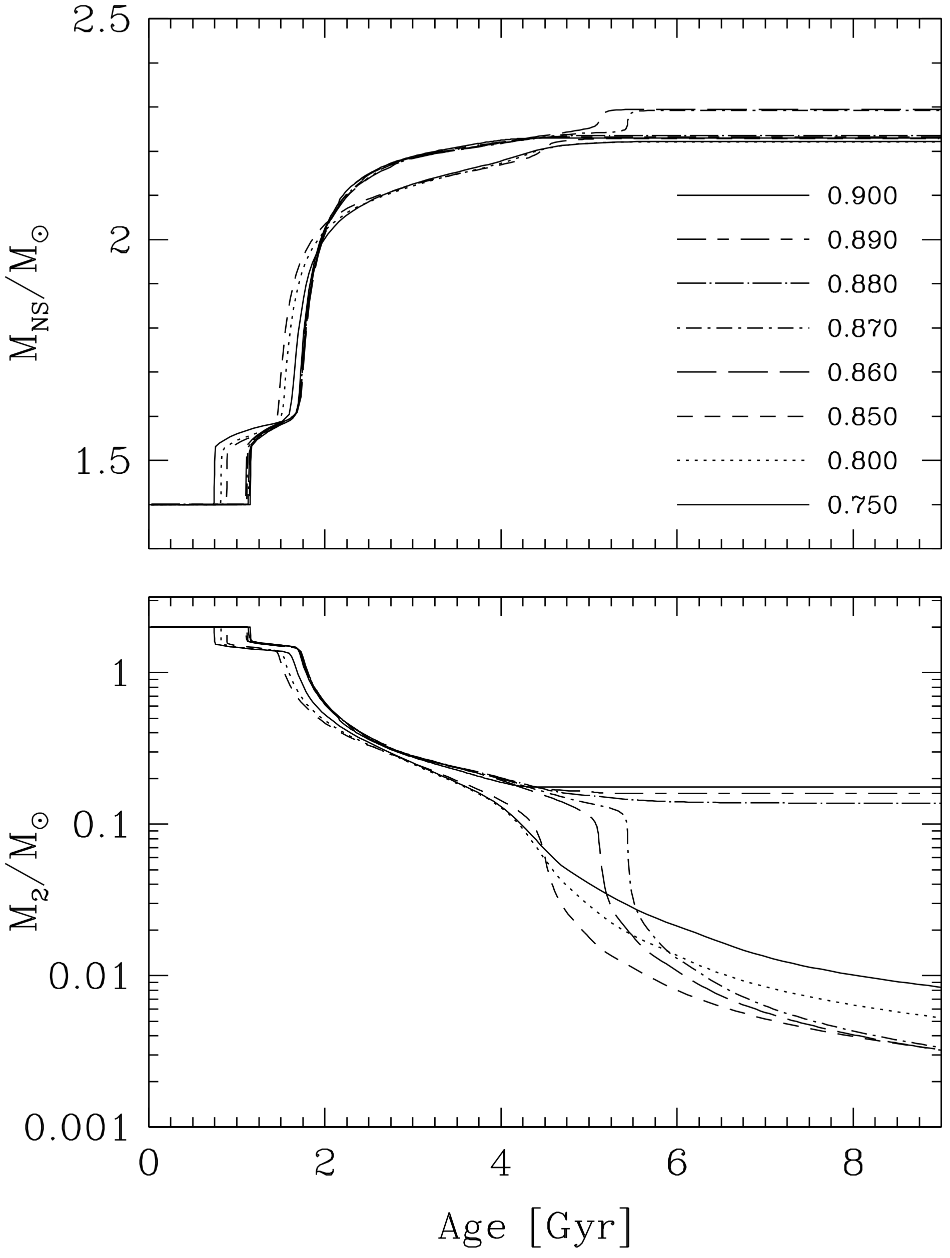
The case of PSR J1719-1438



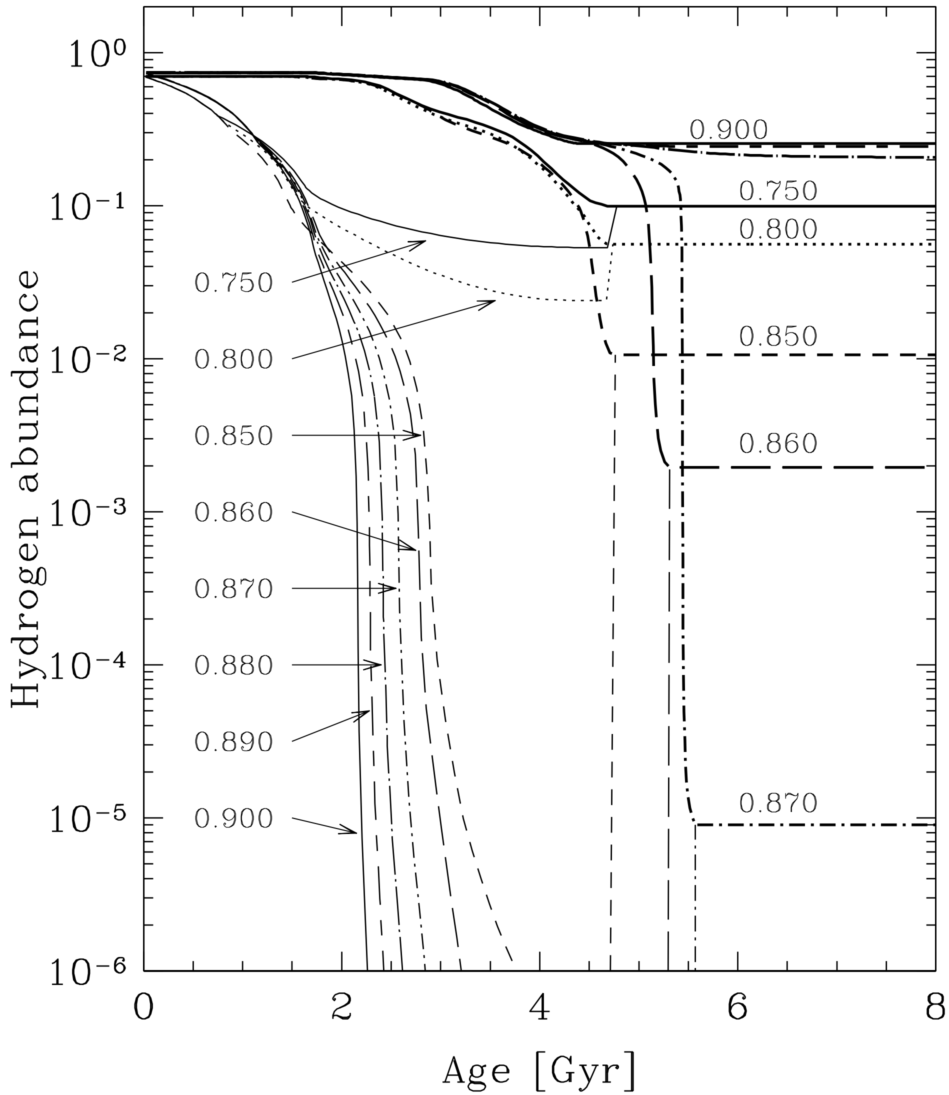
The case of PSR J1311-3430



The case of PSR J1311-3430



The case of PSR J1311-3430



Conclusions

- We have applied our stellar evolution code to the study the evolution of low mass systems with short initial orbital periods.
- These systems naturally lead to the formation of black widow systems.
- Considering evaporation of the low mass companion it is possible to reach the *large* orbital periods observed; otherwise not.
- Irradiation feedback lead to the occurrence of discontinuous RLOF episodes due to the blocking effect of the incoming radiation. These RLOF episodes affect the initial stages of evolution but not the final evolution of the system.

Conclusions

- It is possible to account for the observed masses and the orbital period simultaneously.
- These systems lead to the formation of very massive neutron stars.
- About 5% of the black widow companions have already lost all their hydrogen.
- A lot of work remains to be done on this topic.

Thanks for your attention !

and

Thanks to Ken Nomoto and the IPMU for supporting me, making it possible my visit here.