Pushing the limits of binary evolution models with PSR J1012+5307

Abstract: PSR J1012+5307 is a millisecond pulsar (MSP) in a 14.5-h orbit with an extremely light helium-core white dwarf companion (ELM WD). We perform an optical spectroscopic campaign to characterise the companion star dynamics, yielding a mass ratio of q= 10.44+-0.11. We attempt to infer the white dwarf mass from observational constraints using new binary evolution models for extremely low-mass white dwarfs, but find that they cannot reproduce all observed parameters simultaneously. This highlights our limited understanding of extremely low-mass white dwarf evolution that results from binary interaction. After inspection of different scenarios, we propose a conservative white dwarf mass estimate of M_{WD}= 0.165+-0.015 M_{sun}, which enables us to infer a pulsar mass of M_{NS}= 1.72+-0.16 M_{sun}.

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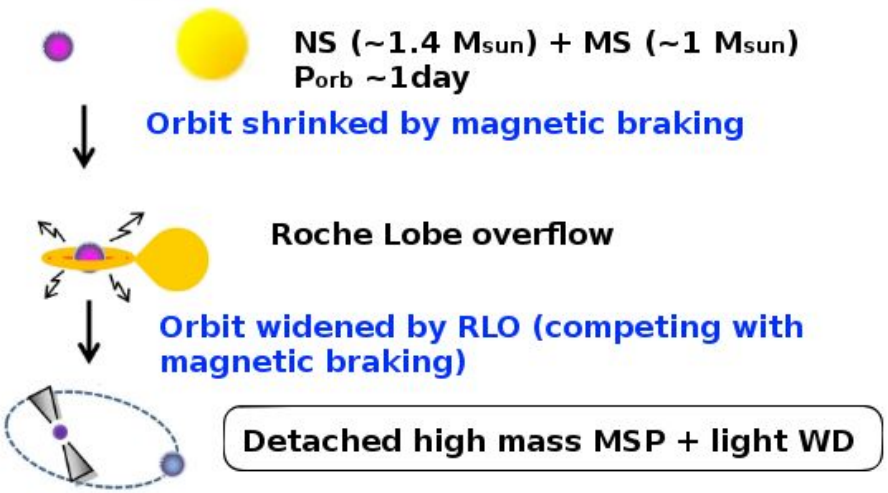
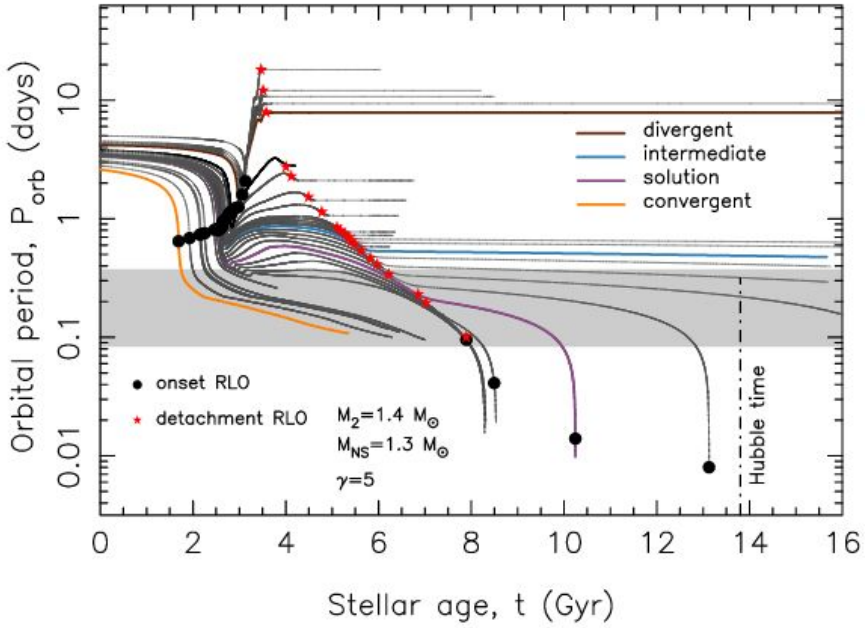
Context

Building a MSP + ELM WD binary:



Orbit keeps shrinking by GW radiation. RLO might resume (ultracompact X-ray binary).

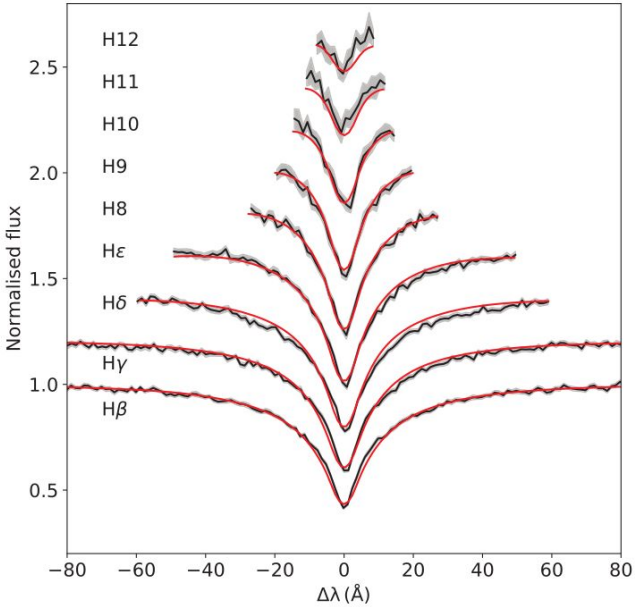
Credit: modified figure from Freire et al. (2014)

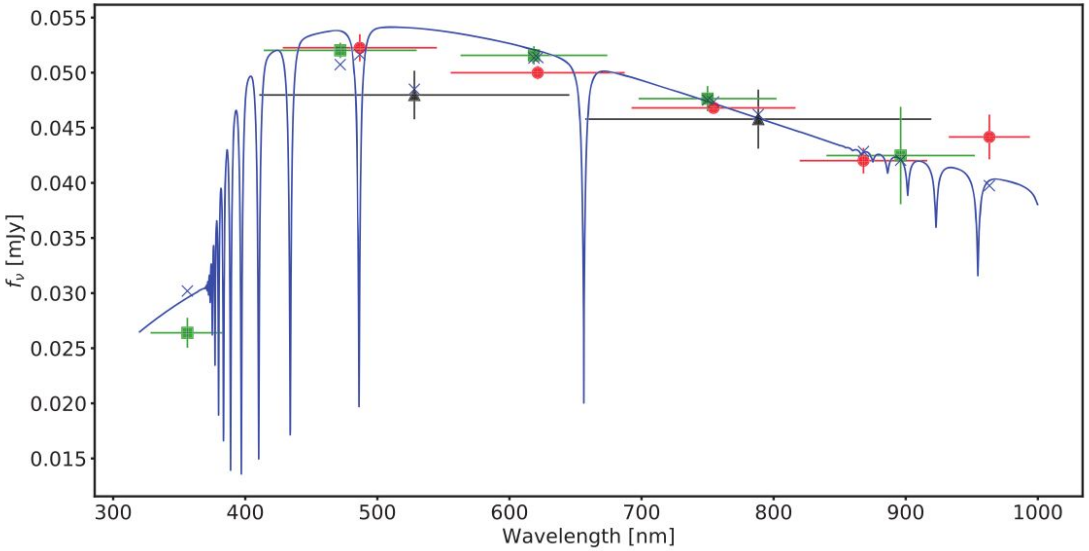


Credit: Istrate et al. (2014)

Observations/methodology

- Observational constraints from optical spectroscopy and SED fitting:



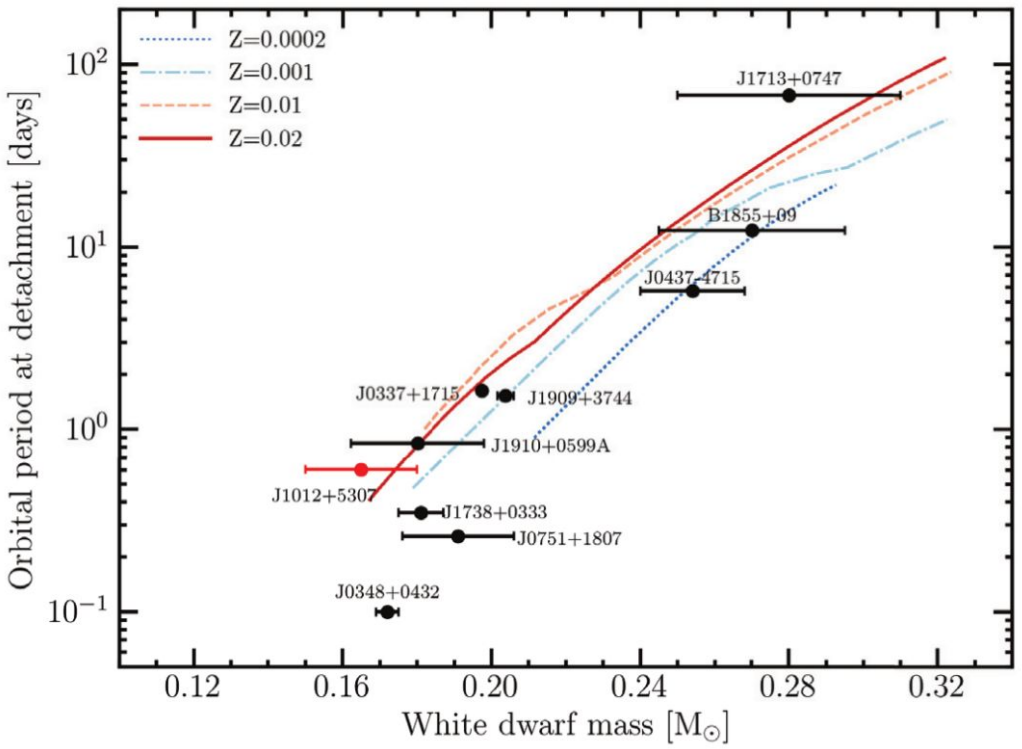


- Combination with radio-derived parameters (parallax, pulsar radial velocity...)

Results

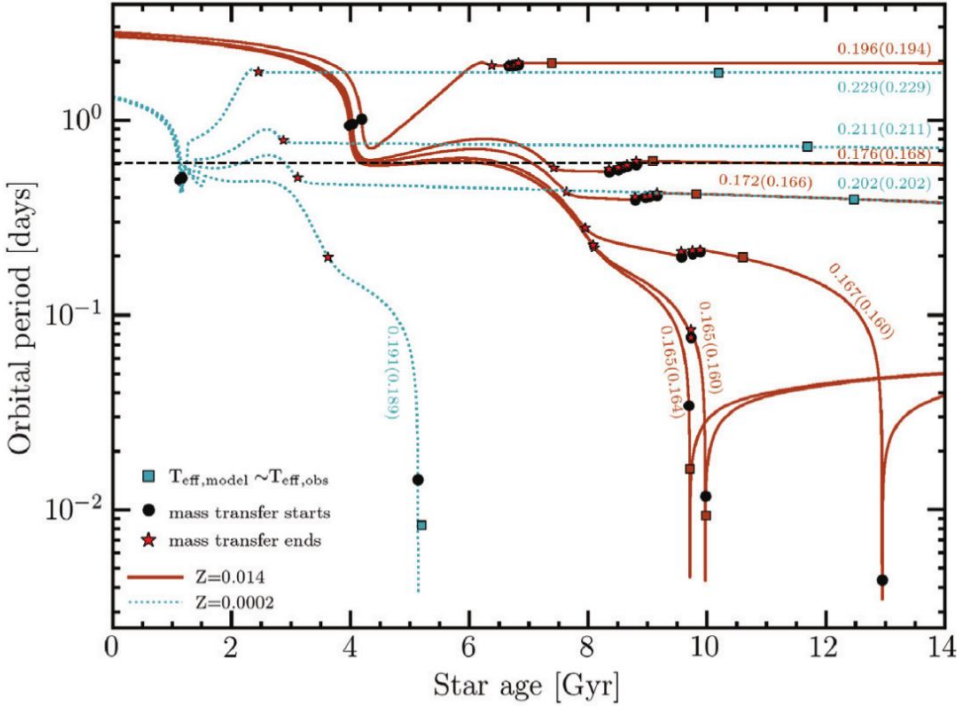
- Parameter measurements derived:
  - T_{eff} = 8360 +- 30 K
  - log g = 6.26 +- 0.04
  - R_{WD} = 0.047+- 0.003 R_{sun}
  - q = 10.44 +- 0.11

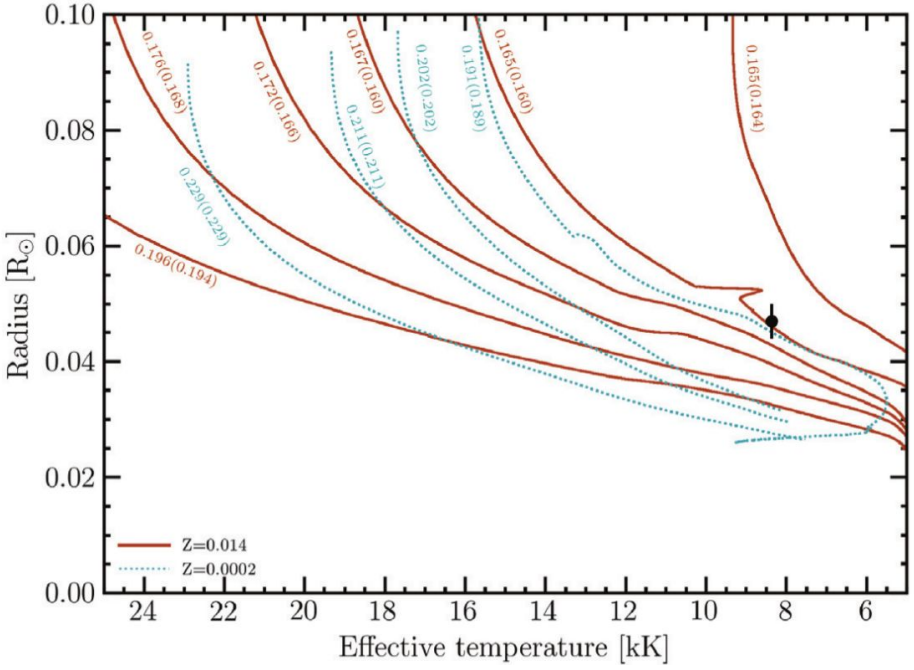
- Methods to derive M_{WD}:
  - Mass-radius relationship
  - Evolutionary models
    (inspect different initial conditions, mass loss, metallicity, ...)
  - Period-mass relationship



Results

- Evolutionary models cannot fit simultaneously Porb, Teff and RWD





For detailed description see Mata Sánchez et al. (2020)

Impact and prospect for the future

- J1012 conservative results for masses and inclination:
  - M_{WD} = 0.165 +- 0.015 M_{sun}
  - M_{NS} = 1.72 +- 0.16 M_{sun}
  - i = 50 +- 2 deg

- We are currently limited by our understanding of the binary evolution models
- Determination of ages/masses particularly affected.
- Revision of binary evolutionary models:
  - Effect of hydrogen flashes
  - Magnetic braking law