Ultra-compact binaries in the Galaxy

Gijs Nelemans

Institute of Astronomy, Cambridge

Outline

- Formation and evolution of ultra-compact binaries
- The formation of Ne rich donors in ultra-compact X-ray binaries
- A model for the Galactic population
- Comparison with observations: selection effects
- Gravitational waves from ultra-compact binaries

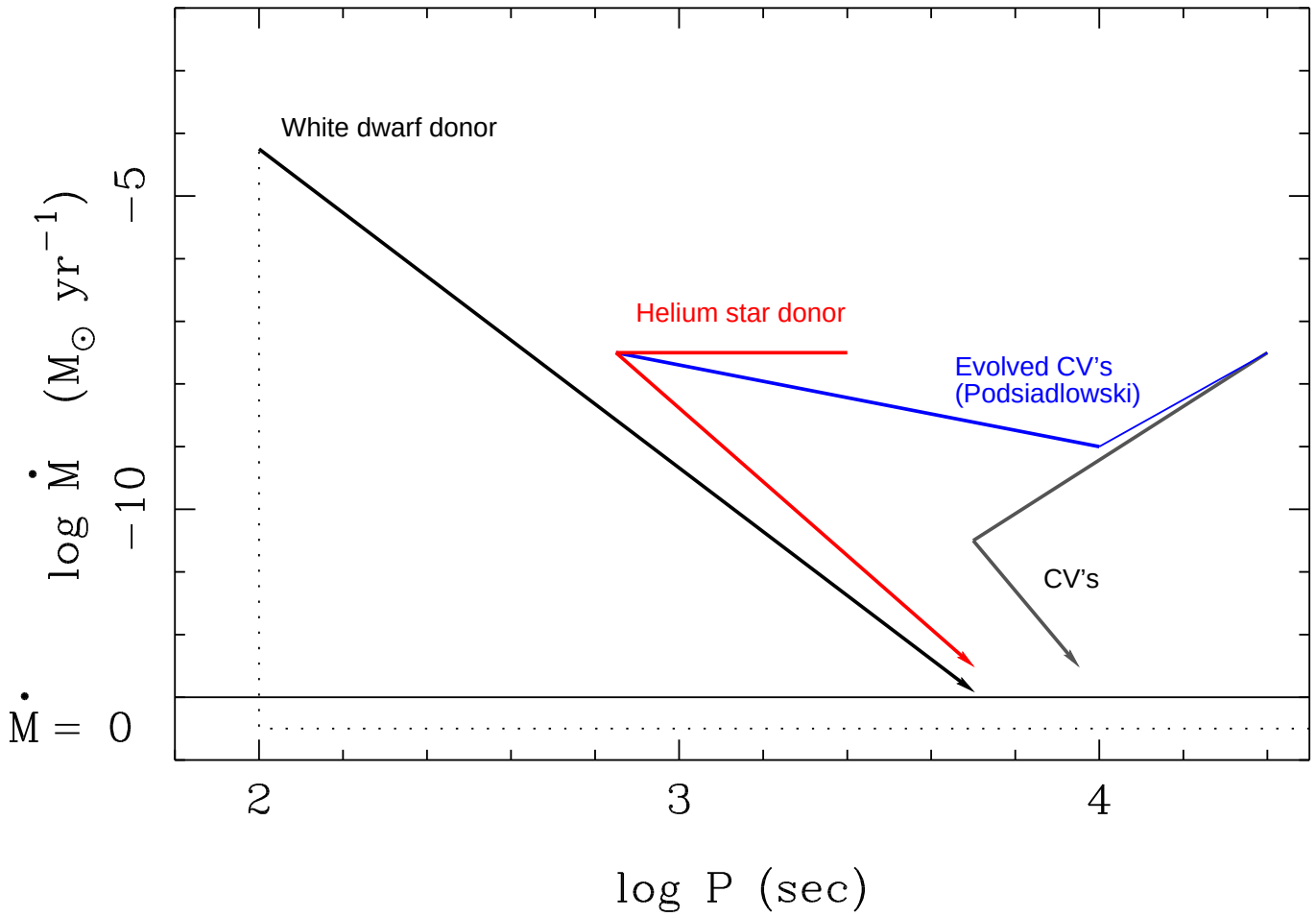
Formation and evolution of ultra-compact binaries

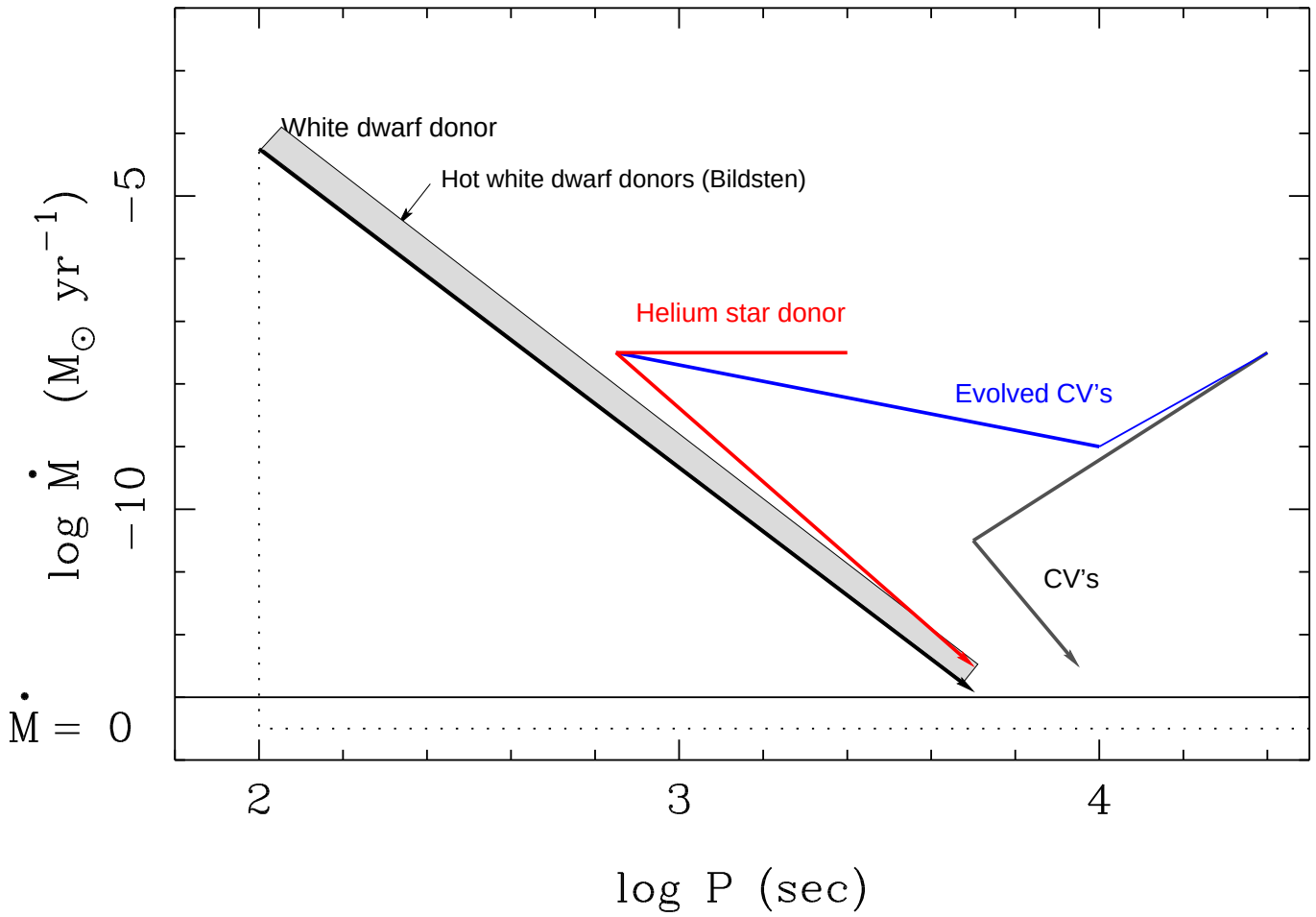
- Ultra-compact binaries: $P < 1$ hr.
- Two types
  - With white dwarf donors: AM CVn systems
  - With neutron star (black hole) donors: ultra-compact X-ray binaries
- Three main formation scenario's
  - White dwarf donor + compact object

    Paczyński 1967, Joss et al 1978
  - Helium star + compact object

    Savonije et al. 1986, Iben & Tutukov 1991
  - From CV's with evolved donors

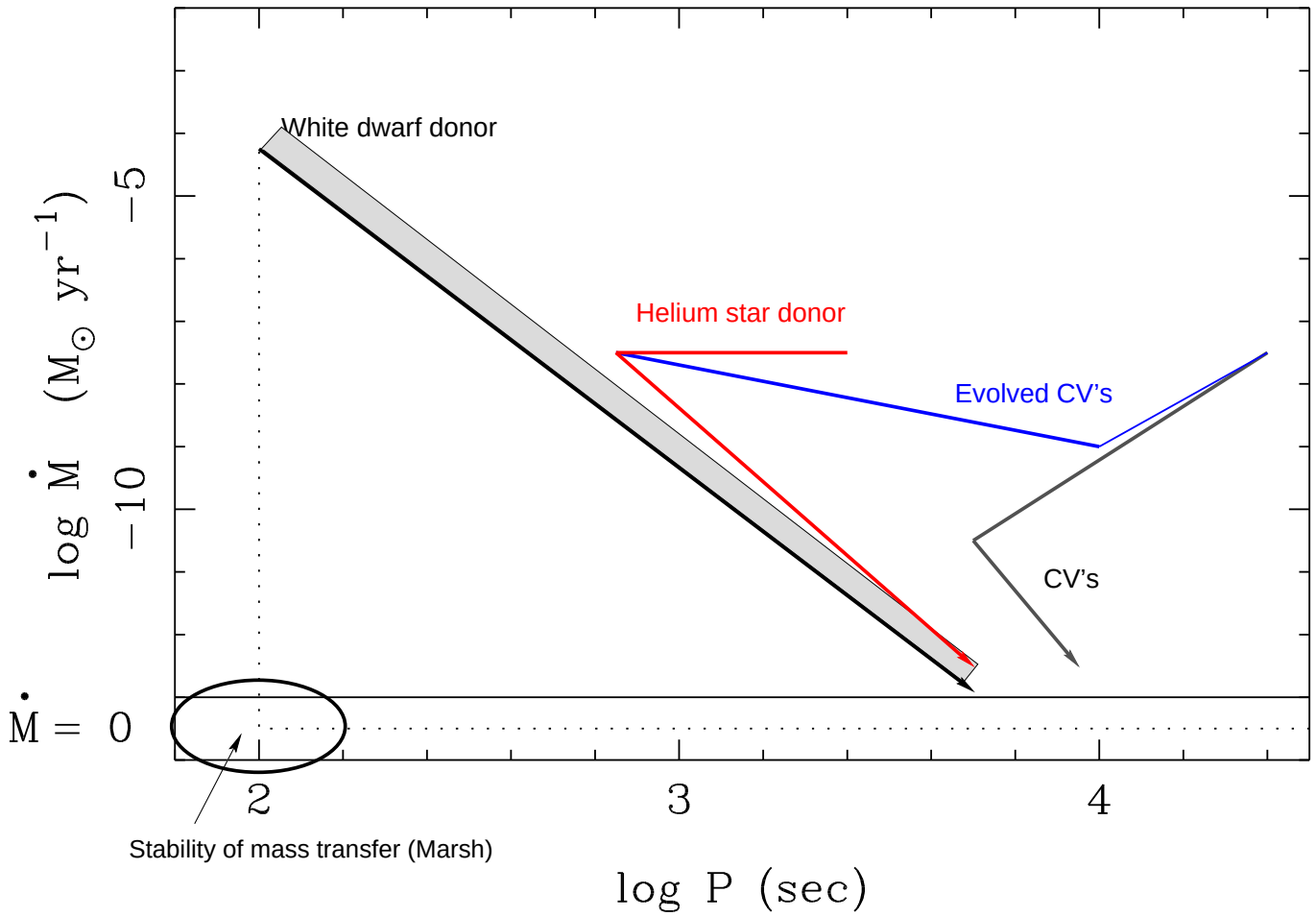
    Tutukov et al 1987, Podsiadlowski et al 2002


White dwarf donor
Helium star donor
Evolved CV's
(Podsiadlowski)
CV's
log Ṁ (M⊙ yr⁻¹)
−5
−10
Ṁ = 0
2
3
4
log P (sec)



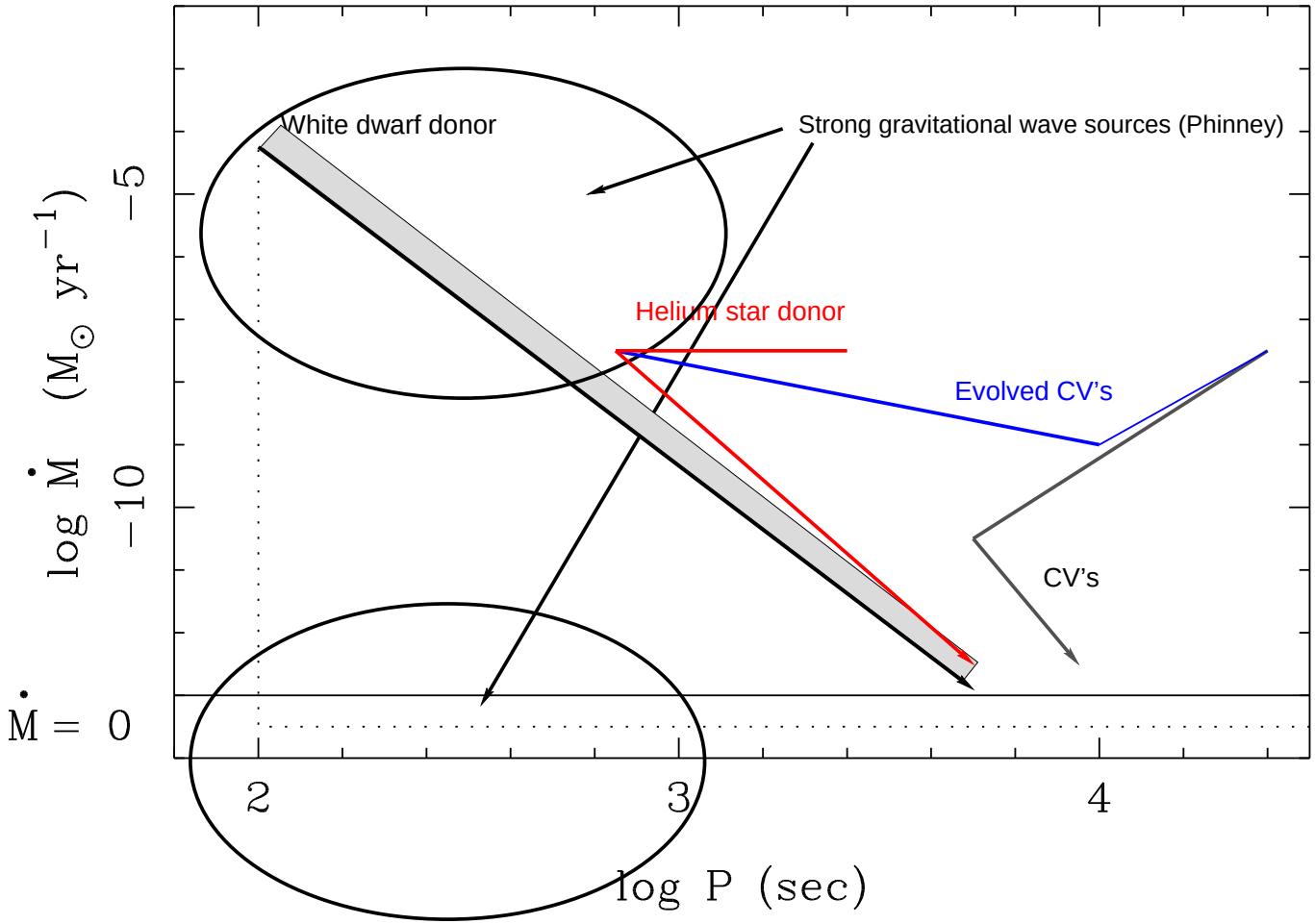
Hot white dwarf donors

Bildsten, 2002, ApJ, 577, 27

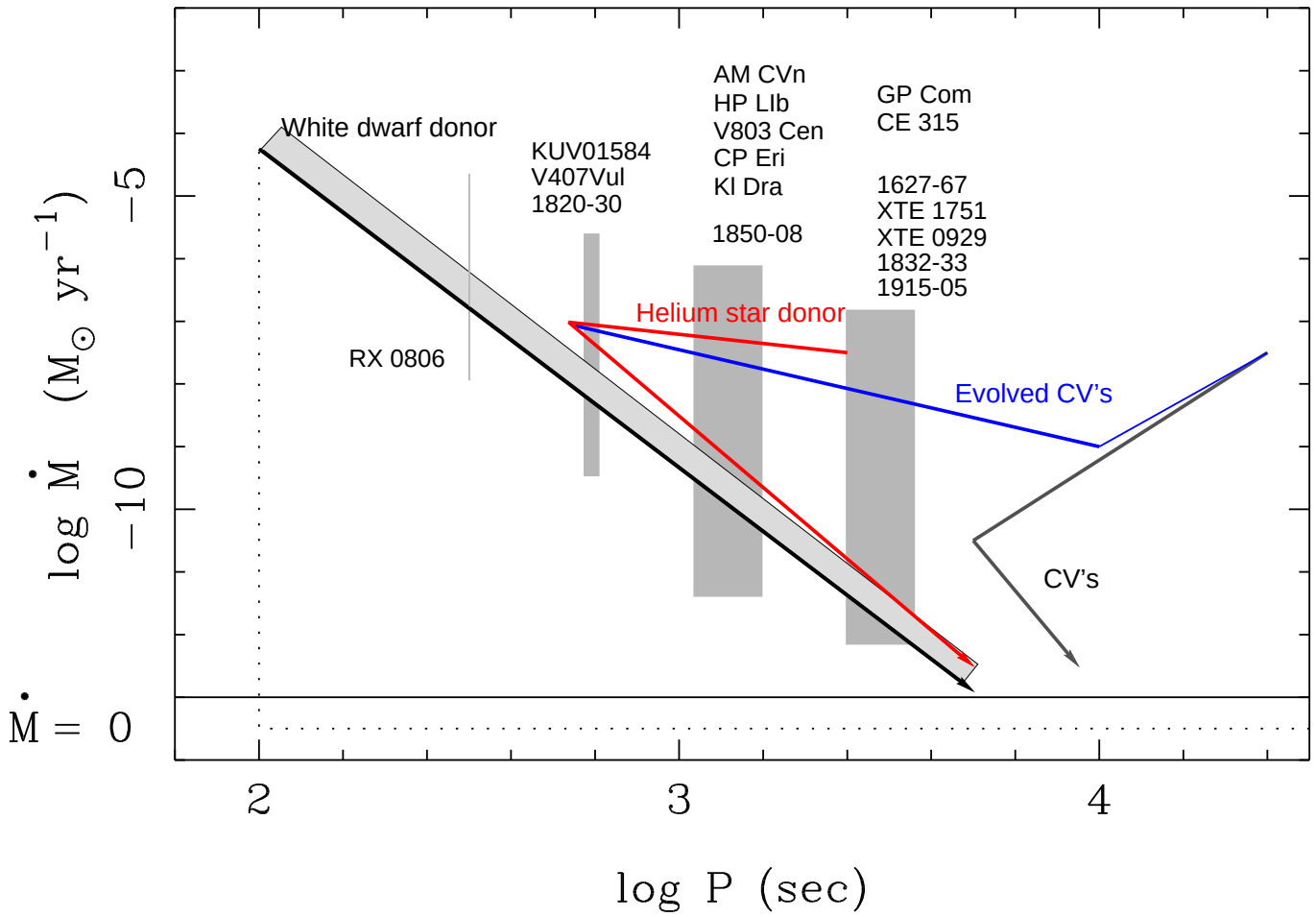


Stability of mass transfer

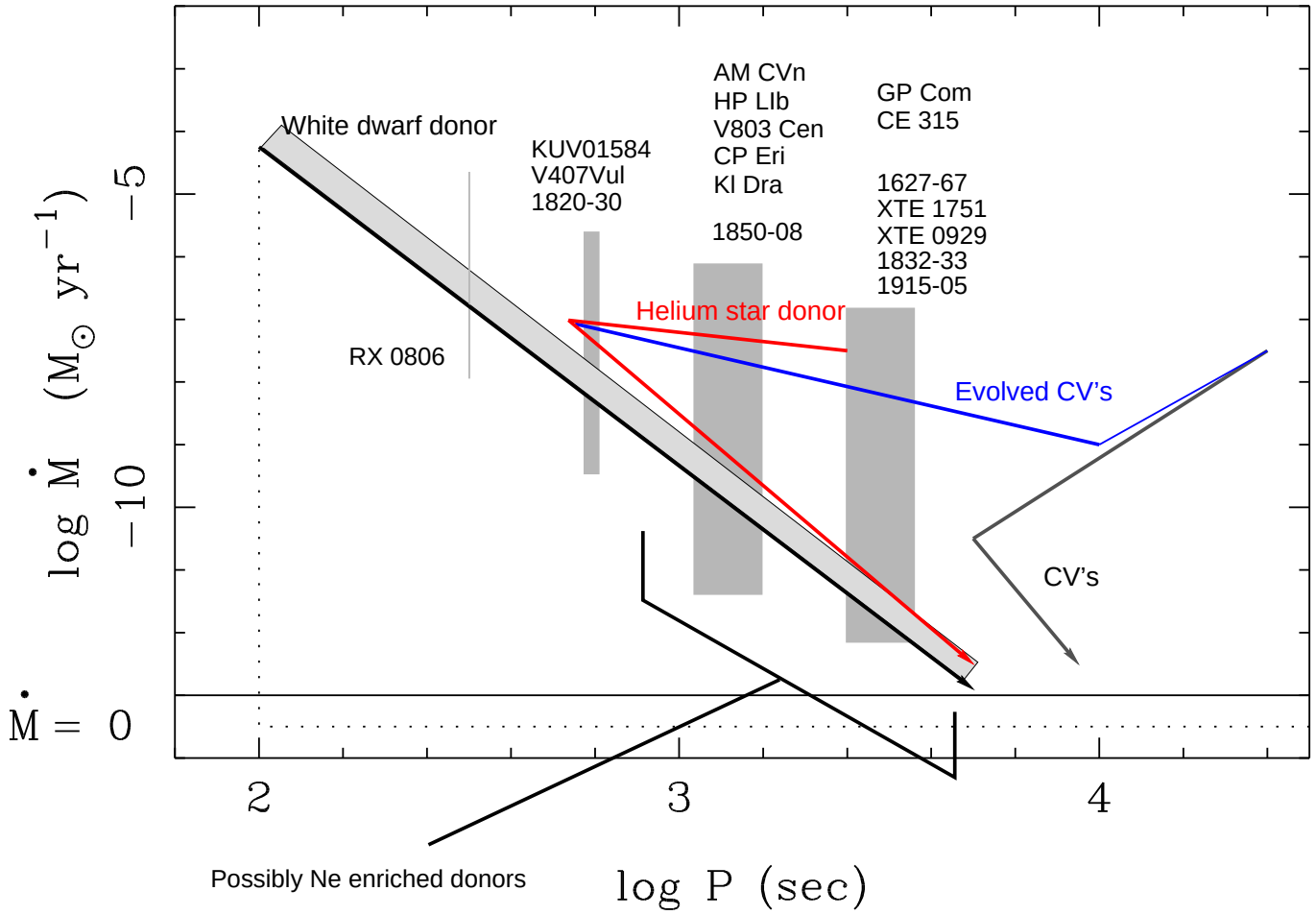
Nelemans et al., 2001, A&A, 368, 939, Marsh, Nelemans, Steeghs 2003, submitted



Gravitational waves



Observed systems



Gravitational settling might give Ne rich donors

Yungelson, Nelemans & van den Heuvel, 2002, A&A, 388, 456

A model for the Galactic population

- Simplified binary evolution

  Portegies Zwart & Verbunt, 1996, A&A, 309, 179, Nelemans et al. 2001, A&A, 365, 491

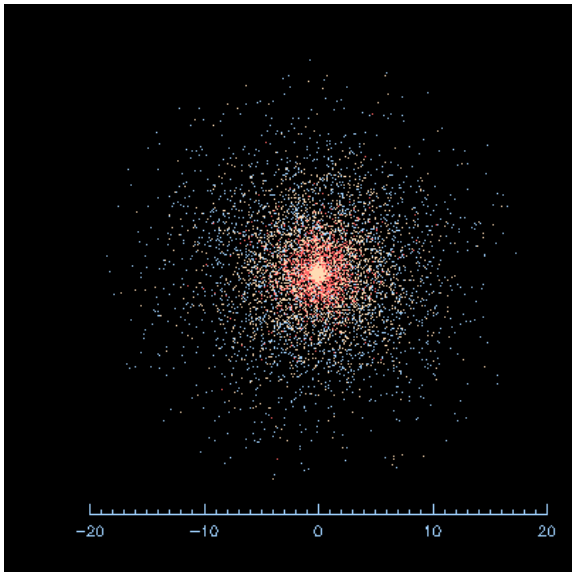
- IMF

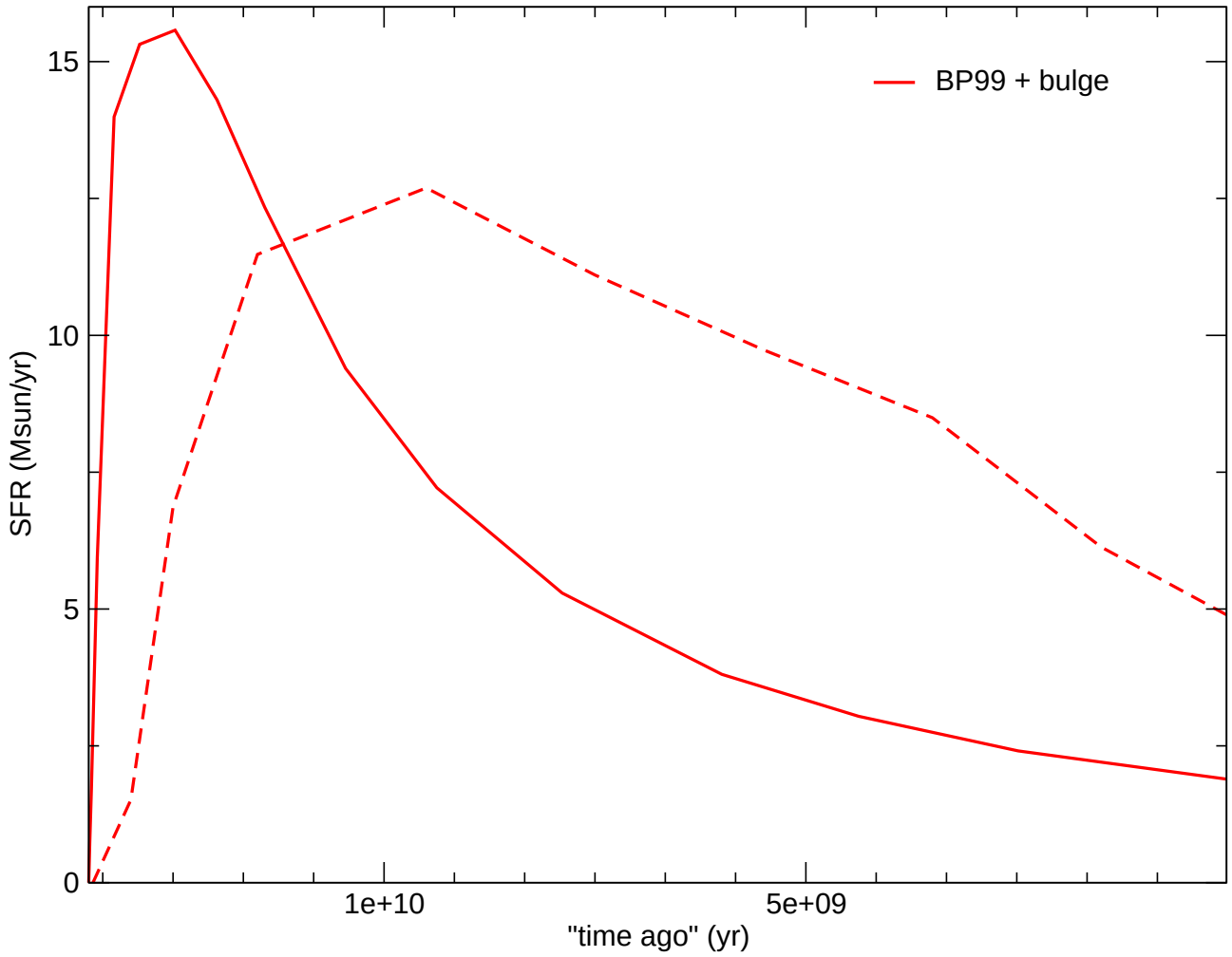
  Kroupa, Tout & Gilmore, MNRAS, 262, 545

- Galactic model

  Boissier & Prantzos, 1999, MNRAS, 307, 857

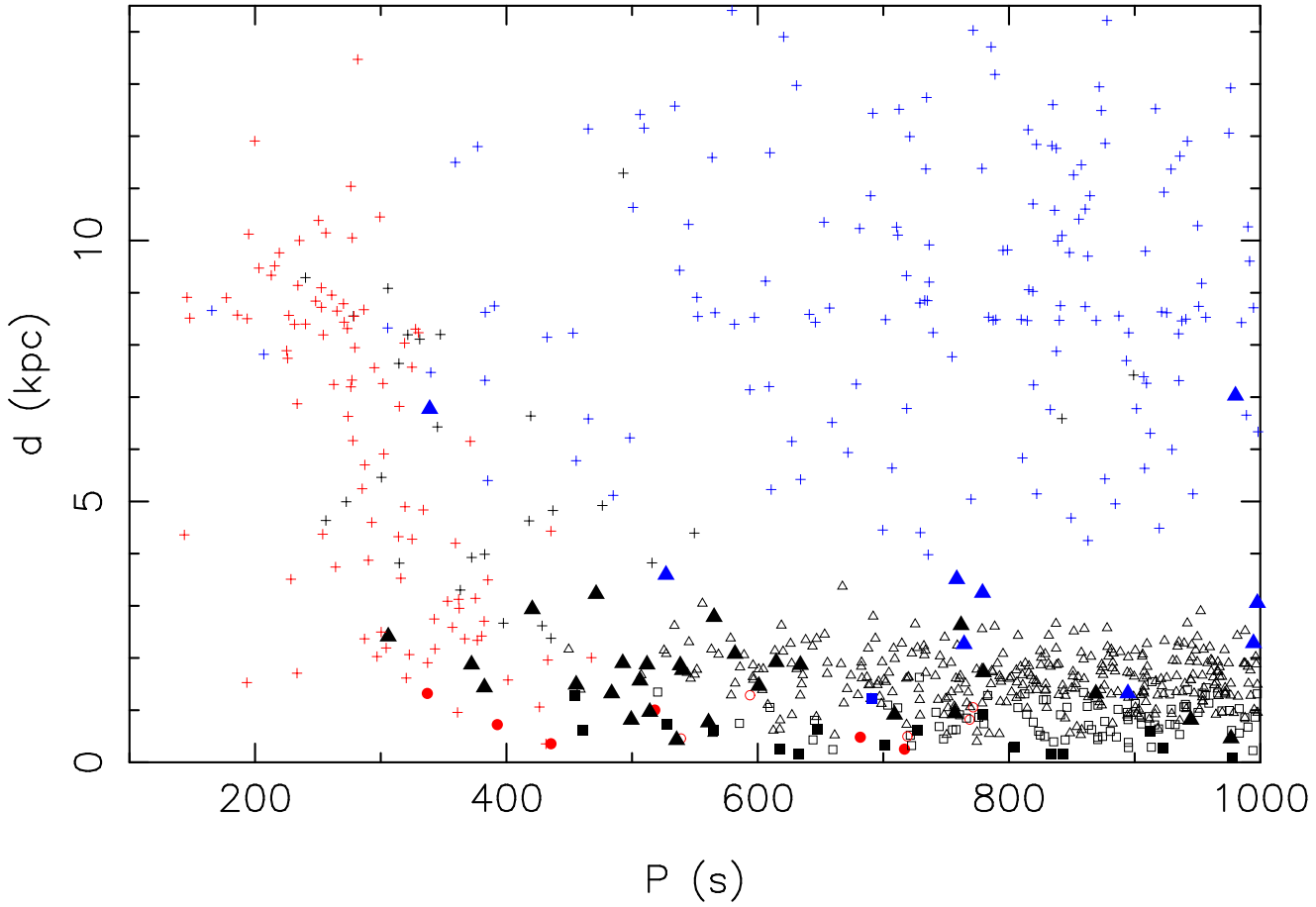
  - Inside out disc formation
  - SFR$(R,t) \propto \Sigma_{\rm G}^{1.5} R^{-1}$
  - Added bulge: mass consistent with dynamics and micro-lensing



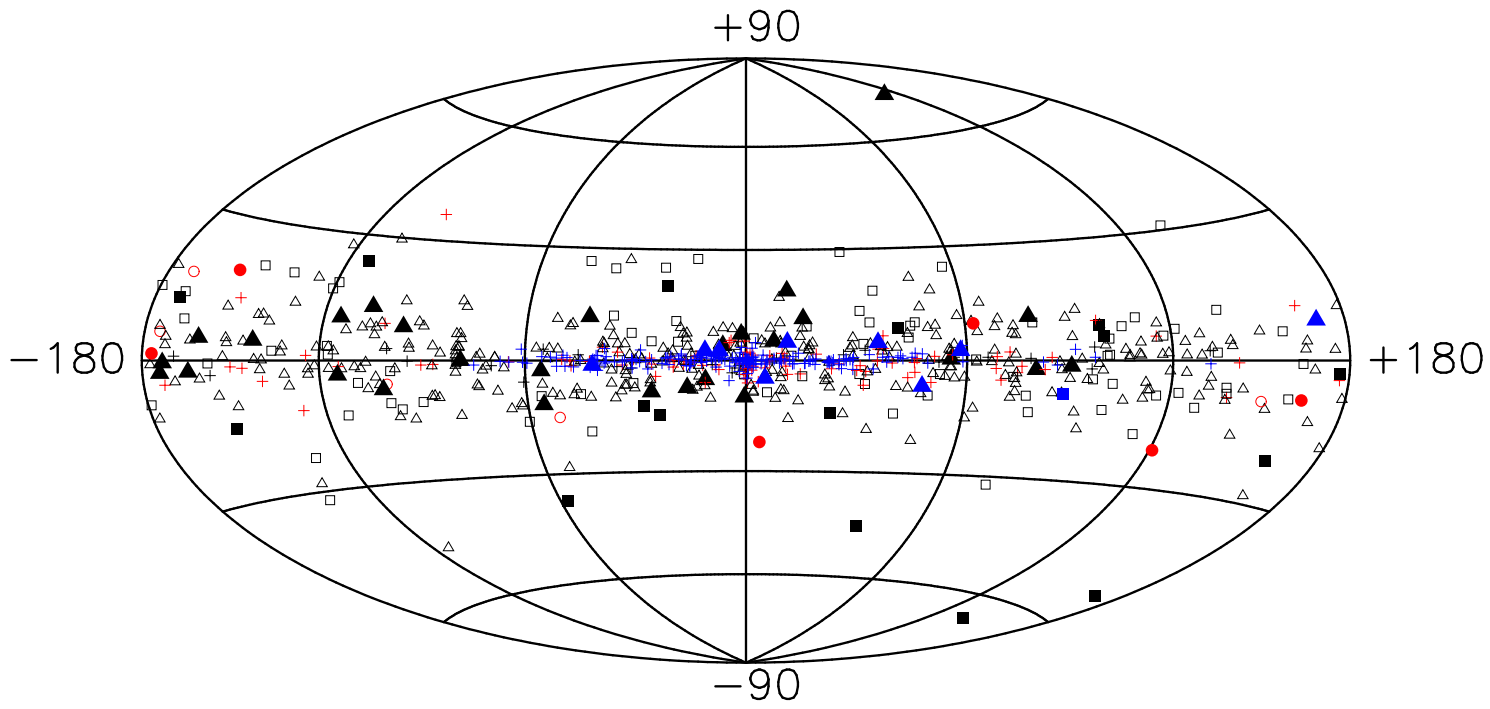

BP99 + bulge
SFR (Msun/yr)
15
10
5
0
1e+10
5e+09
"time ago" (yr)

Comparison with (future) observations: selection effects

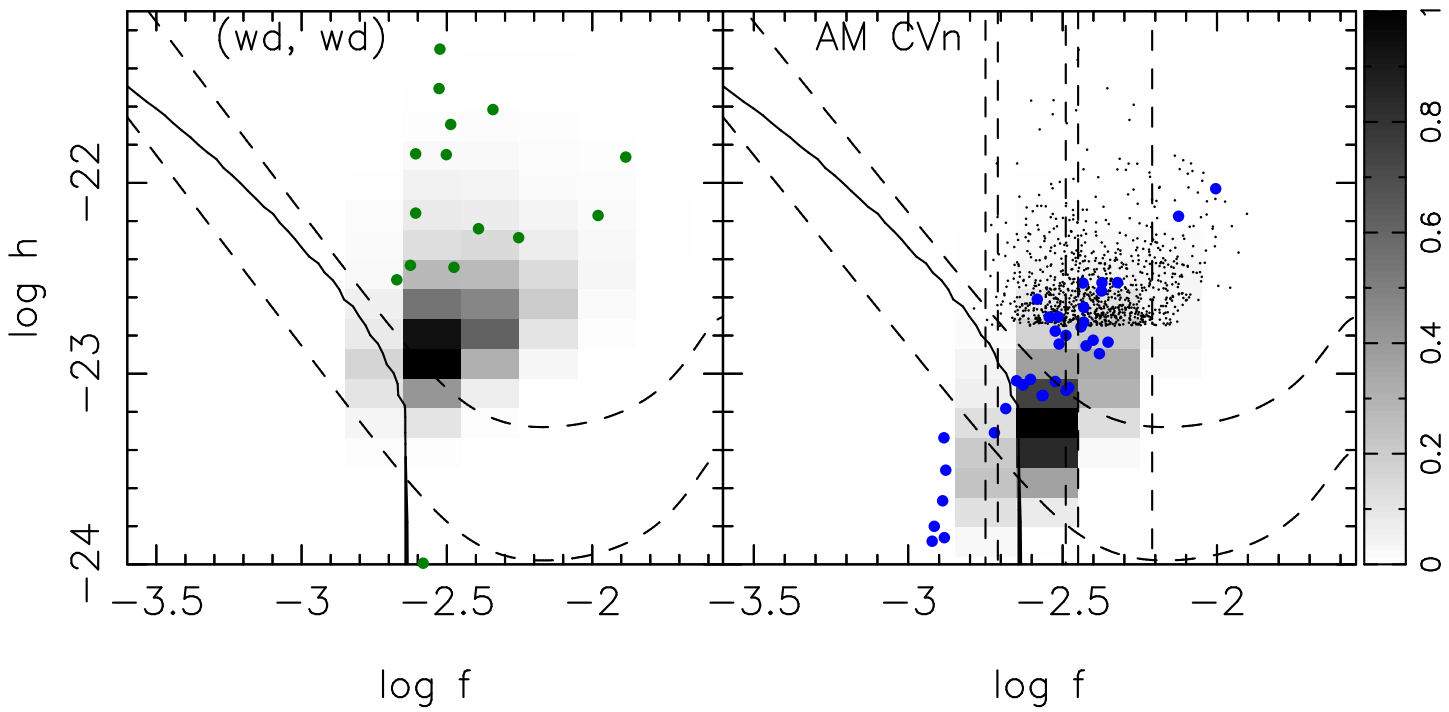
- Optical
  - Emission from direct impact
  - Disc emission
  - Emission from donor: white dwarf cooling (no irradiation yet)
- X-ray
  - Emission from direct impact
  - Emission from disc/boundary layer
- Reddening and interstellar absorption
- GWR: resolved binaries



birth rate	(yr^{-1})
AM CVn (direct impact)	1.8×10^{-3}
UCXB's	9.0×10^{-5}


+90
−180
+180
−90

Gravitational waves from ultra-compact binaries



Resolved: ∼10 000 AM CVn, ∼ 10 000 double white dwarfs, ∼35 ultra-compact X-ray binaries, ∼20 neutron star binaries

Conclusions

- AM CVn systems and ultra-compact X-ray binaries similar in formation and evolution
- Simple emission mechanisms and selection effects give interesting results:
  - Many ultracompact-binaries to be found (in X-rays)
  - Direct impact systems with optical from donor
  - AM CVn systems that have relatively bright donor
- Many AM CVn systems and few tens ultra-compact X-ray binaries are sources for LISA *and* possibly detected in optical/X-ray