A stellar quadruple as a possible progenitor of SNIa

Thibault Merle[1], A. S. Hamers[2], S. Van Eck[1] & A. Jorissen[1] & M. Van der Swaelmen[3], K. Pollard[4], R. Smiljanic[5], D. Pourbaix[1], T. Zwitter[6], G. Traven[6], G. Gilmore[7], S. Randich[3], A. Gonneau[7], A. Hourihane[7], G. Sacco[3], C. C. Worley[7]

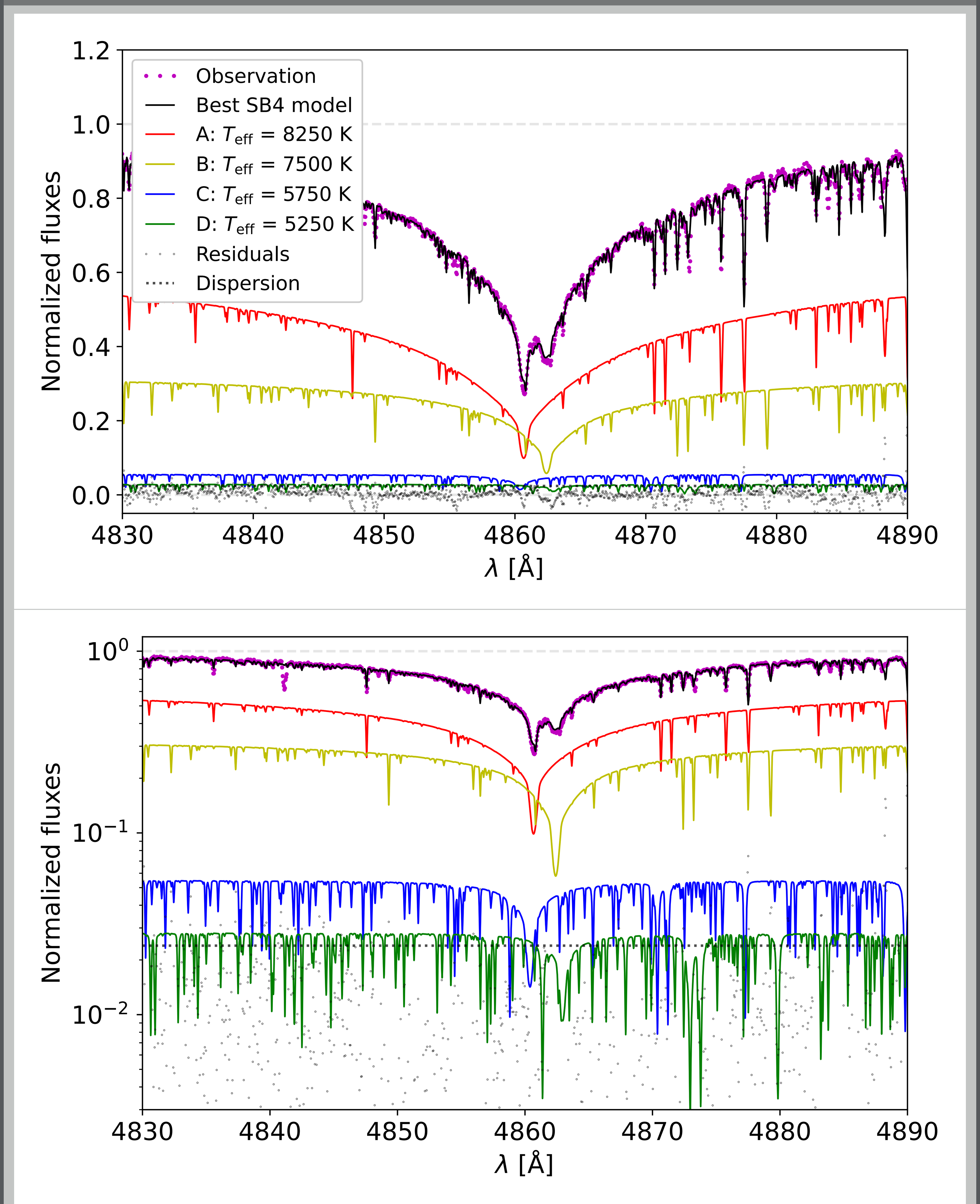
[1] Université Libre de Bruxelles, Belgium – [2] MPIA, Germany – [3] INAF, Italy – [4] University of Canterbury, New-Zealand – [5] Nicolaus Copernicus Astronomical Center, Poland – [6] University of Ljubljana, Slovenia – [7] University of Cambridge, UK

SCAN ME

Scientific context

Type Ia supernovæ (SN Ia) are one of the most energetic events in the Universe produced by processes occurring in tight binaries including at least one CO white dwarf (WD). But the origin of such binaries could emerge from the dynamical evolution of high-multiplicity stellar systems such as the young spectroscopic quadruple HD 74438, recently detected in the Gaia-ESO Survey (Merle et al. 2017). Follow-up spectroscopic observations in South Africa and New-Zealand as well as the use of Gaia astrometry and photometry allow us to characterize its orbital and astrophysical parameters. Modelling the dynamical evolution of stellar quadruples shows that such systems can produce WD mergers, possible progenitors of SN Ia. Here we present some highlights with the full details provided through our *Nature Astronomy* letter (Merle et al. 2022, view-only access at `https://rdcu.be/cNqC2` or via the QR code in upper right corner).

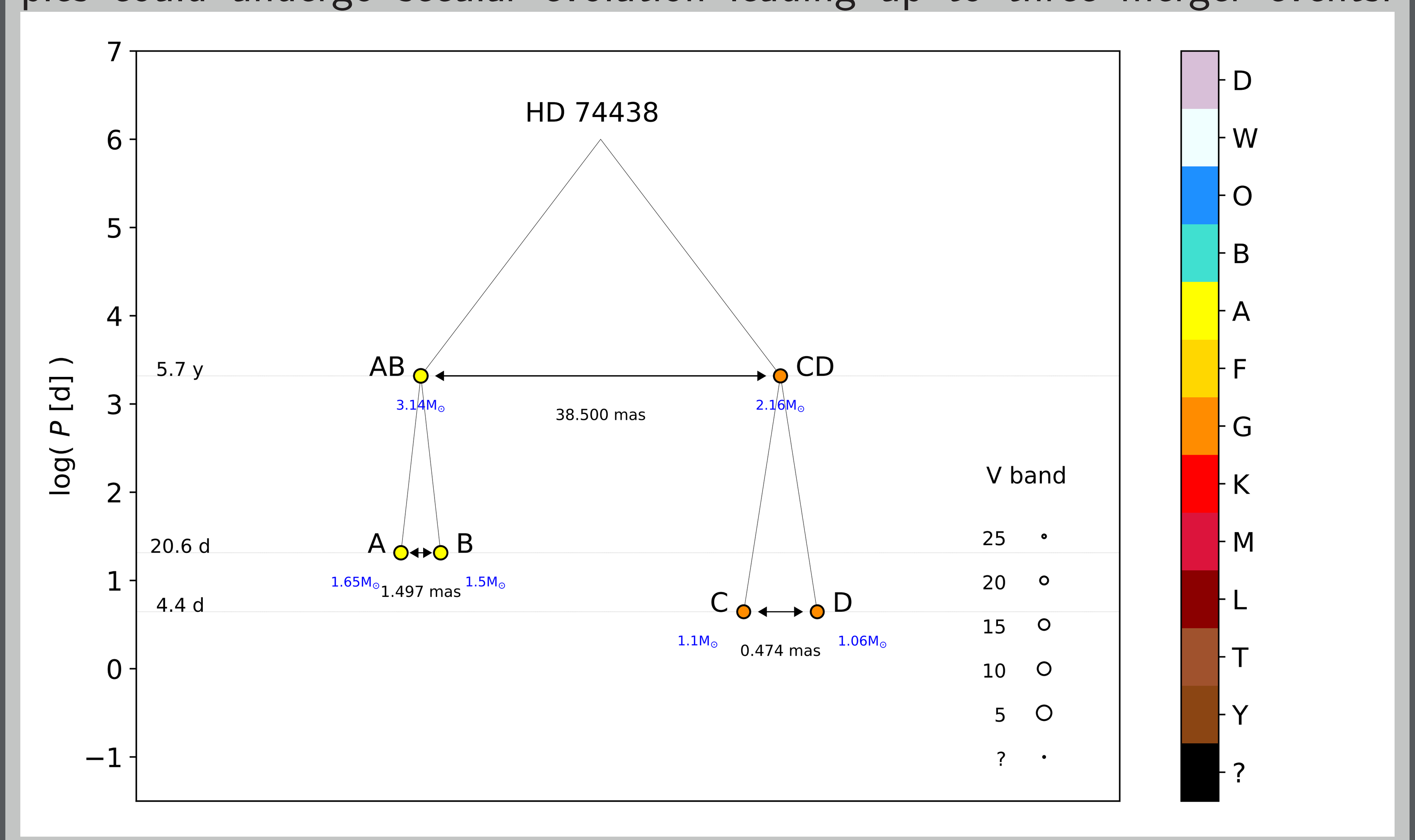
A composite spectrum with 4 components



Spectral fitting of the HRS/SALT (Southern Africa Large Telescope) observed composite spectrum (magenta dots, $R \sim 65000$) taken on 2018 December 31, around Hβ with a S/N∼100. The best fitted composite model with 4 components is shown in black. The individual spectra are also shown and color-coded as given in the legend; they give an idea of the contribution of each component to the total flux. Normalized fluxes are represented on a linear scale (top) and a logarithmic one (bottom). The residuals (grey dots) and their dispersion (black dotted horizontal line) are shown and looking at the logarithmic version (bottom panel) we can see that the flux contribution of the weakest component D (in green) is higher than the 1% contribution of the noise and the 2% dispersion of the residuals, giving credit to the derived temperatures.

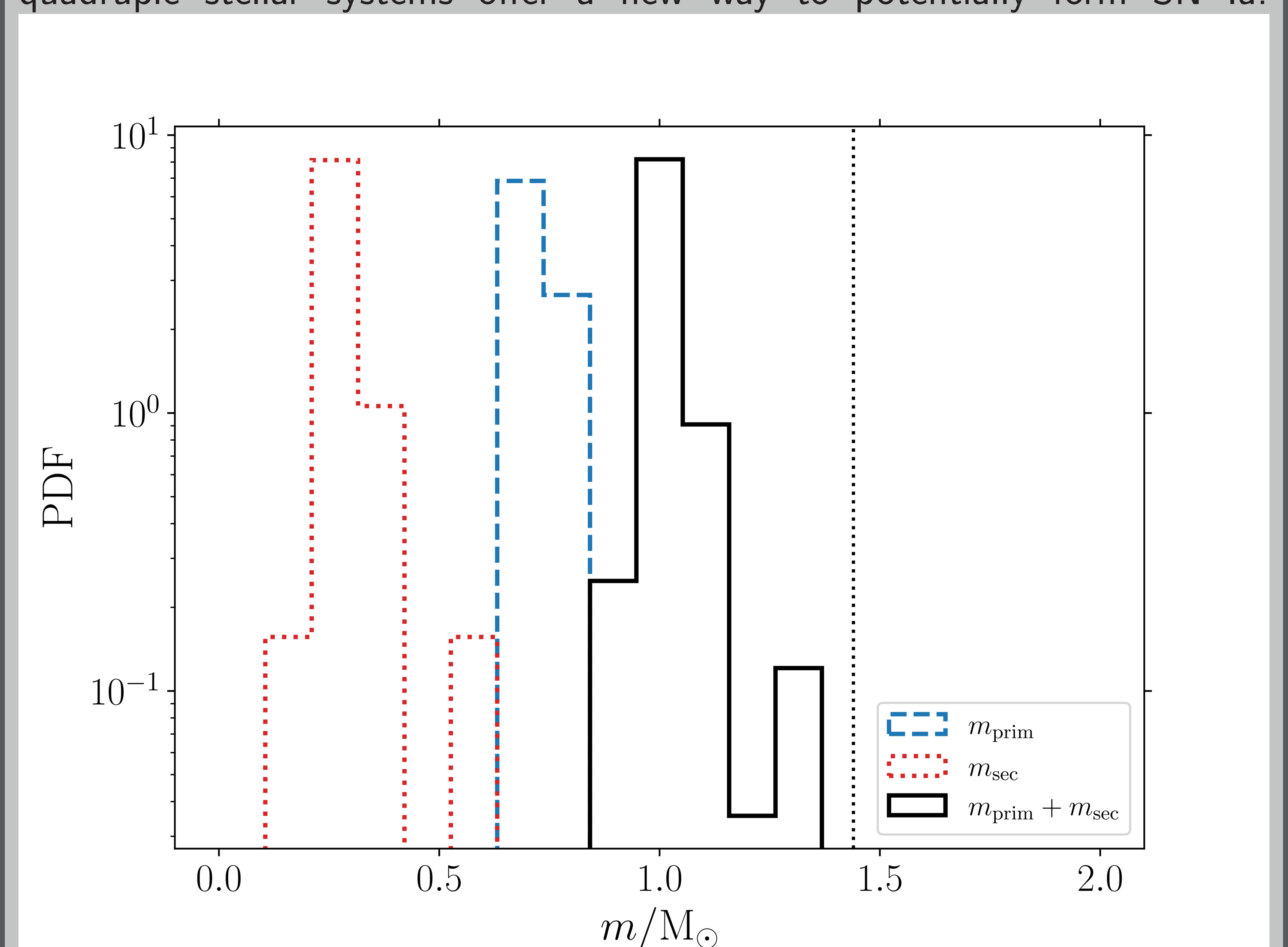
Architecture of HD 74438

Mobile diagram of the 2+2 spectroscopic quadruple stellar system HD 74438. A binary of 4 d made of G-type stars is orbiting a binary of 21 d made of A-type stars in almost 6 y. The total mass of the system is $5.3 \pm 0.1\,\mathrm{M}_\odot$. Simulations show that such quadruples could undergo secular evolution leading up to three merger events.



Dynamical evolution

We simulated the future evolutions of HD74438 using state-of-the art Multiple Star Evolution code (Hamers et al. 2021) that includes gravitational dynamics with direct N-body integration and secular evolution, stellar evolution effects, and binary and triples interactions in eccentric orbits (like mass/angular momentum transfer and common envelope evolution). Simulations based on the derived orbital parameters and their uncertainties show that in half of the cases, at least one merger event occurs. In $\frac{1}{4}$ of cases, inner binaries will merge producing a double WD that also will ultimately merge leaving a WD with a sub-Chandrasekhar mass. Simulations of future evolutions of HD 74438 show that tight quadruple stellar systems offer a new way to potentially form SN Ia.



Probabilty distribution function (PDF) of the merging WDs in simulations: in red for the brightest pair, in blue for the dimmer pair, in black for a third merger event. In case of 3 merger events, the total mass is below the Chandrasekhar limit, compatible with the sub-Chandrasekhar mass channel that could potentially explain 70-85% of all SN Ia (Eitner et al. 2020, Flörs et al. 2020, Eitner et al., arXiv:2206.10258).