MW-Gaia STSM

Binaries in open clusters, matching Gaia observations to N-body simulations

Dr. Zephyr Penoyre from University of Cambridge spent two weeks (27/06-08/07/2022) at the University of Barcelona thanks to a GP2 STSM grant to collaborate with Dr. Mark Gieles.

The collaboration largest ambition was to identify in the Hyades open cluster a possible central black hole (BH), which models from Mark Gieles and students suggest would likely have a luminous (and thus detectable by Gaia) Main Sequence star (MS) as a companion. The collaboration started by selecting members of the Hyades cluster, from all Gaia sources in the vicinity on sky, based on proper motion, parallax and position. For each of these the existing astrometric RUWE values were combined with derived spectroscopic RUWEs (from estimates of Gaia's measurement errors). From this, inferred periods, mass ratios and companion masses were derived for all stars in RVS, along with some speculative values for stars expected to have radial velocity measurements but which were missing. There are some potential candidates for an intermediate mass BH in the speculative candidates, along with many MS or WD companions among the RVS sample.

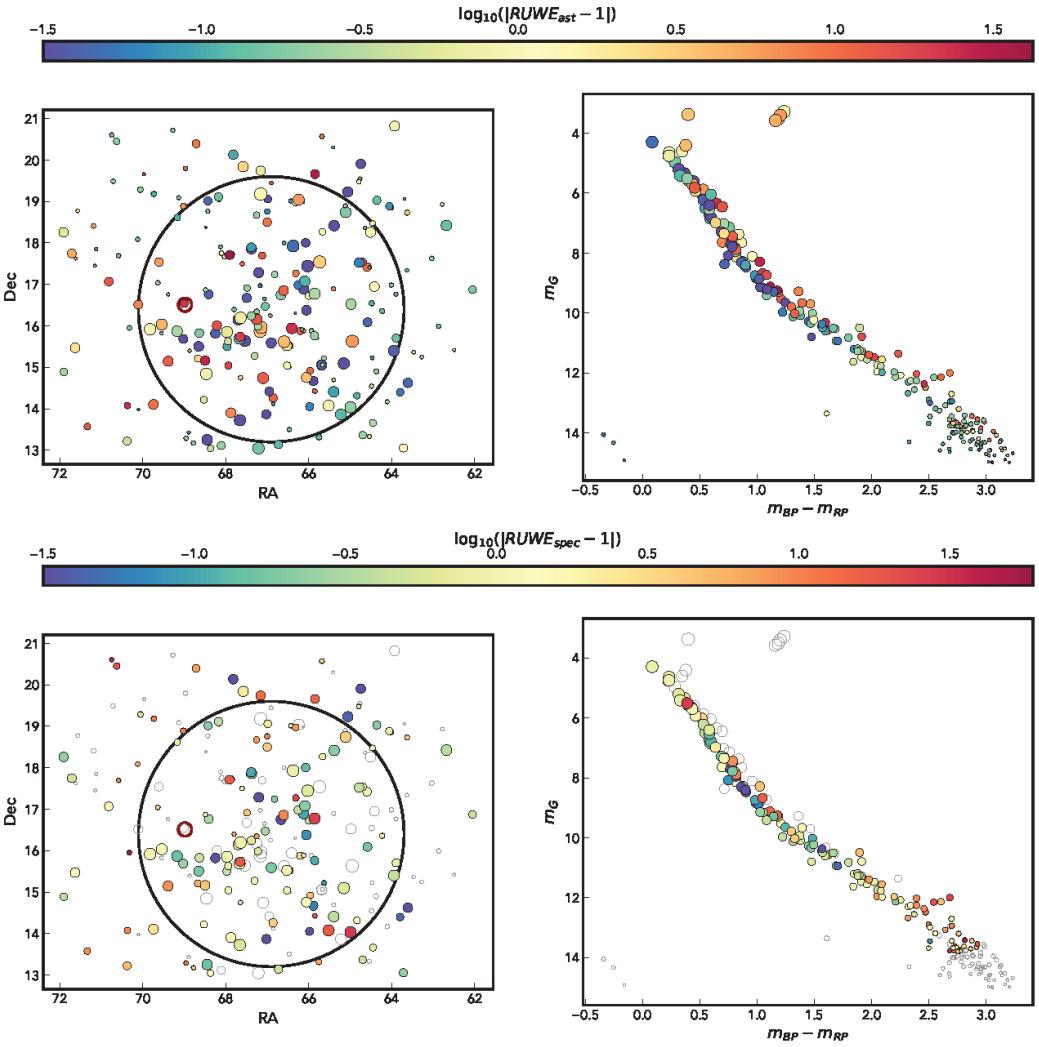
Dr. Penoyre was also able to present work at the ICCUB Weekly Gaia meeting and give the Wednesday Seminar on Astrometric Binaries in Gaia. As well he attended the European Astronomical Society annual meeting to present related work and meet in person (most for the first time) various members of DPAC which lead to fruitful discussions and hopefully future collaborations.

Main achievements

Estimated periods and mass ratios for 39 binary systems in the Hyades were defined, with another 11 speculative candidates (out of 242 members of the cluster). A follow up of these, firstly with a literature search by then ground based measurements if any systems seem promising as being binaries compatible with a BH companion.

Furthermore, the estimated binary population will allow better calculations of the velocity dispersion of the cluster. In the first instance the plan is to remove these systems which will have an extra apparent velocity caused by the binary motion. A step further will be to estimate the extra binary motion and recalibrate these systems (also including the extra mass of the second star) and then re-include them in the velocity dispersion estimate.

The period sensitivity of Gaia astrometry and spectroscopy can only rule out companions in a certain range of periods - so our possible non-detection (if our speculative candidates do not prove fruitful) does not exclude the possibility of a massive BH but does constrain its properties.



Hyades candidates colored by astrometric (top) and spectroscopic (bottom) renormalized-unit-weight-error ($RUWE$). Values significantly above 1 suggest that the system has an extra source of noise, most ubiquitously a binary companion. Many sources don't have radial velocity measurements in the Gaia source catalog, and these are denoted with empty grey circles in the bottom plot.

A successful collaboration that resulted in co-authorship of the published paper:

- ✓ "Stellar-mass black holes in the Hyades star cluster?" S. Tornamenti, M. Gieles, Z. Penoyre et al. MNRAS 524, 1965 (2023) https://arxiv.org/abs/2303.10188

and established a good relationship with the host.