Characterizing cool giants in symbiotic binaries using the Gaia EDR3 data

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Introduction

Symbiotic stars are **strongly interacting binaries**, which consist of a **cool giant** of spectral type M (or less commonly K) and a hot compact star, mostly a **white dwarf** (see e. g. the review by Mikołajewska, 2012). Both stellar components radiate at distinct wavelength intervals (see Fig. 1). Their orbital periods range from **hundreds to thousands of days**.

Symbiotic binaries are **unique astrophysical laboratories** in the study of the stellar evolution, mass transfer and accretion processes, stellar winds, jets, dust formation, or thermonuclear outbursts.

***Gaia* observations** made public in the Gaia EDR3 (Gaia Collaboration et al., 2020), as demonstrated in this contribution, could be very suitable for **characterizing the Galactic symbiotic population**.

Positions

The distribution of galactic symbiotics in the sky is shown in Fig. 2 (in galactic coordinates). Almost all galactic symbiotics are located **around the Milky Way equator** (|b| < 15°). In the case of objects in the current version of the database, 89% of confirmed and 83% of candidate symbiotics are in this sky region (Merc et al. 2020a). The distribution in the galactic longitude demonstrates that symbiotics are located **mostly towards the galactic bulge** (56% and 52% for confirmed and candidate symbiotics with |l| < 30°, respectively).

These ratios are though biased by the **selective effect**, as surveys tend to focus around the galactic equator. However, this would certainly also be a consequence of the fact that the density of stars is higher in the galactic disk and symbiotic stars mostly belong to the **old bulge/thick disk population**.

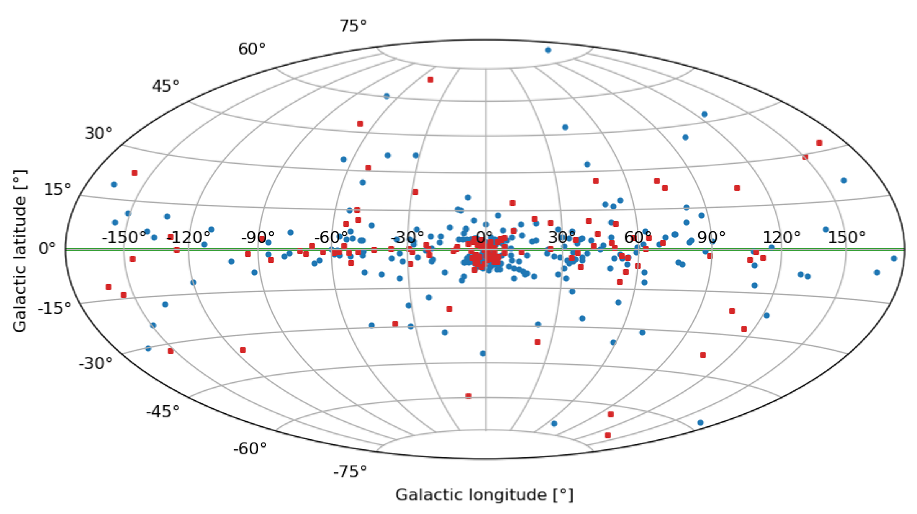

Figure 2. Distribution of galactic symbiotic stars in the sky. The map is in the galactic coordinates. Confirmed and suspected symbiotic stars are denoted by blue and red symbols, respectively (Merc et al., 2020a).

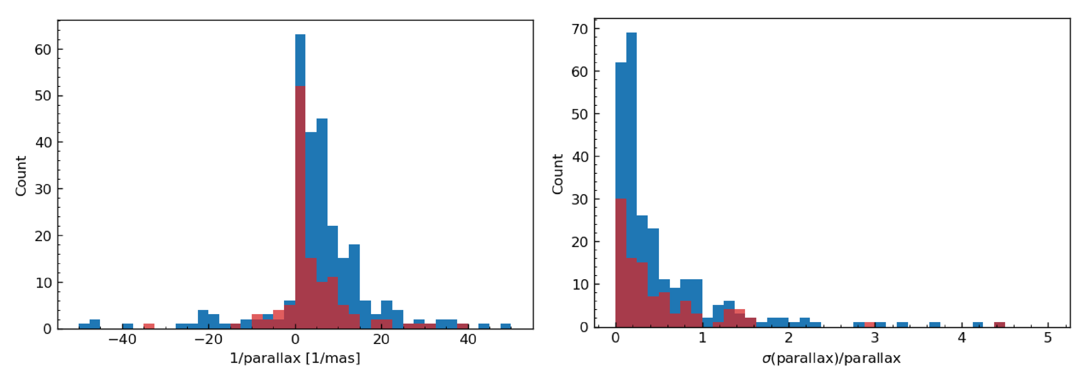

Figure 3. Histograms showing the parallaxes measured by the Gaia satellite (left) and their relative errors (right). Confirmed and suspected objects are shown by blue and red color, respectively.

Database of symbiotics

Thanks to **several programs** focused on discovering symbiotic binaries, the number of known symbiotic stars is **growing rapidly** in the recent decades.

Based on the recent progress in the study of symbiotic stars, we have decided to prepare a **new database** of these interacting binaries (New Online Database of Symbiotic Variables; Merc et al., 2019). The purpose of the database is not only to serve as a **catalogue of data for all known symbiotics** with consistent references, but we have also prepared a **web-portal** for easy access to this information. For the catalogued symbiotic stars, we have prepared **specific object pages** covering all available information included in the database. Making the database **online** allows us to add new objects as soon as they are discovered and update data when new information becomes available.

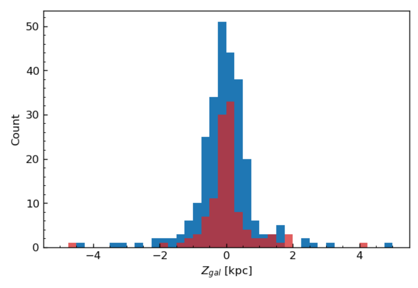

Figure 4. Distribution of the vertical distances of known and suspected galactic symbiotic stars from the Galactic plane.

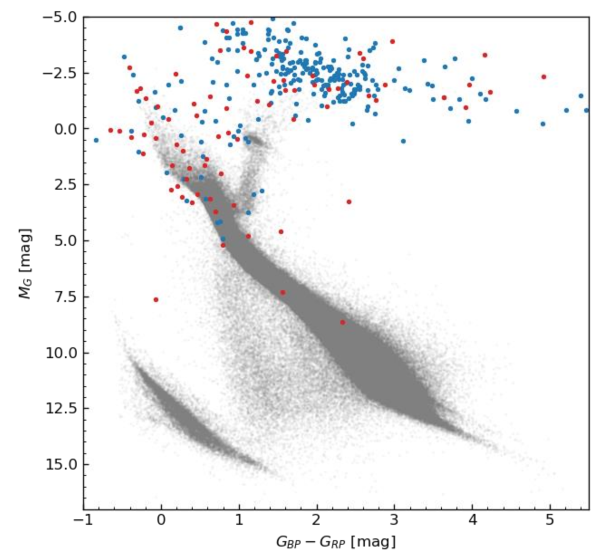

Figure 5. Position of known (blue) and suspected (red) symbiotic stars in the Gaia color-magnitude diagram.

Distances

A factor that significantly limits analysis of the parameters of the components of symbiotic binaries is their **unknown distance**. Astrometric observations of the Gaia satellite can significantly help in this task. However, in the case of symbiotic binaries, many parallaxes are only **poorly measured**: some of them are even negative or are measured with large relative errors (Fig. 3). Moreover, the **zero-point offset** of parallaxes is present in the data (Lindegren et al., 2020). Another issue may be related to the **binarity of symbiotics** and their orbital motion, as the astrometric parameters from Gaia are obtained considering only the one-star model. In nearby long-period binaries, the shift caused by their orbital motion can be **comparable** to the effect caused by their parallax (e. g. as noted for AG Peg by Sion et al., 2019).

Therefore, all the *Gaia* distance measurements for symbiotics must be interpreted with regards to these issues. In Fig. 4, we show the **distribution of vertical distances** of symbiotics from Galactic plane.

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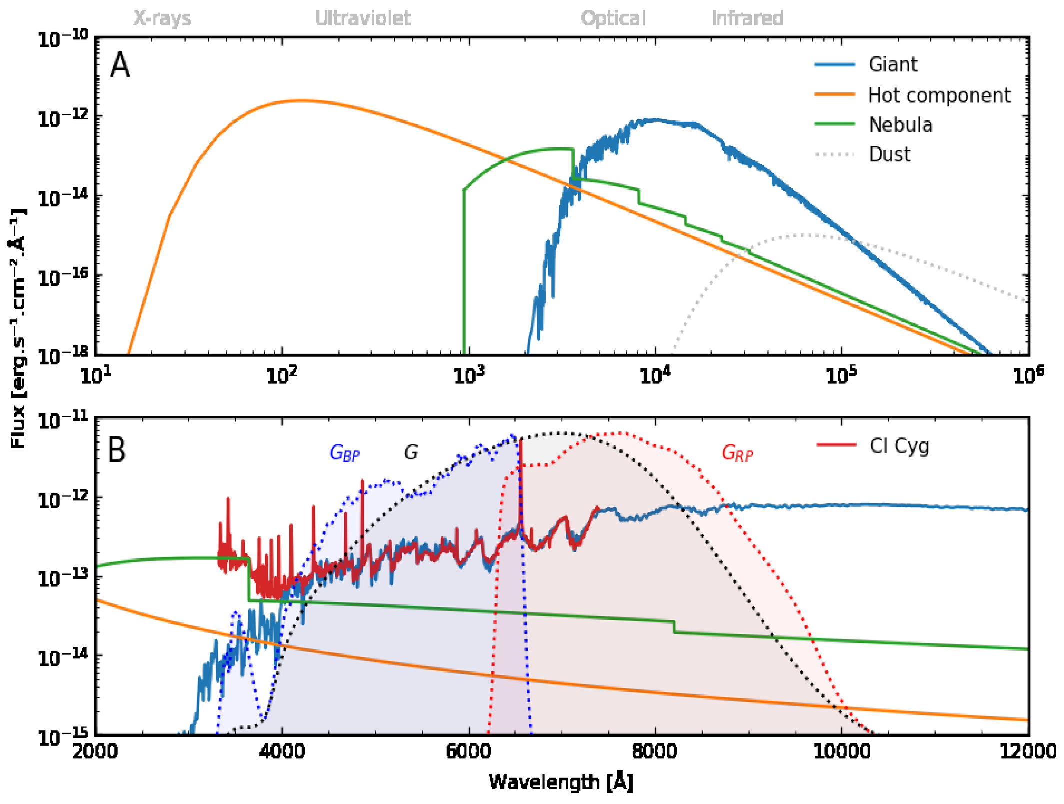

Figure 1. SEDs of symbiotic stars. **A:** Radiation sources observed in the symbiotic spectrum. **B:** Comparison of the observed optical spectrum of CI Cyg (shown in red; Teyssier, 2019) with the one of an M4 giant, together with the transmission curves of Gaia photometric filters (G_{BP}, G and G_{RP} in blue, black and red, respectively; Evans et al., 2018). One can clearly see, that measurements in G and especially in G_{BP} are affected by the nebular radiation.

Photometry

In addition to precise astrometric measurements, photometric data from the Gaia satellite could be used to monitor variable stars (see Merc et al., 2020b for details on **discovery of first Gaia symbiotic star**). In Fig. 5, we present the color-magnitude diagram (i.e. the observational H-R diagram) of a sample of stars together with the confirmed (blue) and suspected symbiotic stars (red symbols). Obviously, while most symbiotic stars occupy the upper regions of the diagram, there are some evident outliers – objects which are probably **incorrectly classified as symbiotic stars**.

We should still bear in mind, that the radiation measured by the *Gaia* satellite is **not exclusively coming from the giant** but there is also an excessive contribution of the nebula and the hot component (see also Fig. 1).

Conclusions

Proper characterization of the whole symbiotic population is needed in order to answer **many open questions** associated with the symbiotic components, their outburst mechanisms, or the evolution of these interacting binaries. One of the steps toward this goal is the creation of a **new, modern, and complex catalog of symbiotic stars**, which is briefly presented here.

The *Gaia* EDR3 data of known symbiotic stars seems to be especially useful in **characterizing the components of symbiotic stars**. The crucial parameter is **the distance** to the systems, however, the *Gaia* EDR3 data are **not sufficiently accurate** for more distant symbiotic objects. We expect that distance determination will improve within the further releases. On the other hand, measured parallaxes or proper motions could **help to identify incorrectly classified objects** (see Fig. 5).

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