Searching for runaway massive stars using Gaia data

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ABSTRACT

- **Massive stars** are typically formed in **binary systems**.
  - The most massive star can explode as a **supernova**.
  - The remaining star could become a **runaway star**: in a binary system if it remains bound or isolated if disrupted.
  - **Good-quality data** from ***Gaia*** allows to detect runaways.
- **Gamma-ray binaries** emit at GeV/TeV energies. Some are **runaways** (LS 5039, 1FGL J1018.6-5856, …).
- We **crossmatch catalogs of massive stars with *Gaia* data** to **search** for **runaway** massive stars and **gamma-ray binaries**.

MOTIVATION

Through the detection of **massive runaway stars** we can search for **gamma-ray binary candidates**

Gamma-ray binary systems are poorly understood (only 10 systems known)

- What is the real population?
- Why only O or Be stars?
- Physical parameters to produce GeV/TeV emission?
- What will CTA see?

CATALOGS

GOSC Catalog

- Catalog of Galactic O-type stars
- 643 stars

BeSS Catalog

- Be stars, Herbig Ae/Be stars
- 2330 stars

Cross-match with **Gaia EDR3 Catalog** { Within 1" + quality cuts

Output catalogs

GOSC-*Gaia* EDR3 Catalog

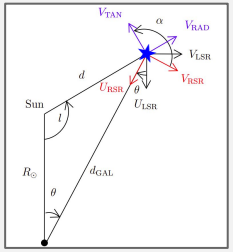
- **430 stars**

BeSS-*Gaia* EDR3 Catalog

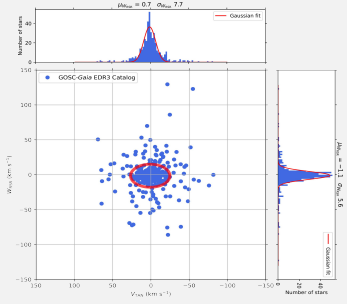
- **1402 stars**

METHODOLOGY

1. Compute the star velocities in different reference systems using their distances (Bailer-Jones+21) and a galactic rotation curve (Reid+19): LSR → RSR → (V_{TAN}, V_{RAD}, W_{RSR}).



2. Plot the 2-D distribution (V_{TAN}, W_{RSR}) and make Gaussian fits to obtain mean values and dispersions (μ_{VTAN}, σ_{VTAN}, μ_{WRSR}, σ_{WRSR}):



3. Define a threshold above which a star would be a runaway

$$E = \frac{(V_{TAN} - \mu_{V_{TAN}})^2}{3\sigma_{V_{TAN}}} + \frac{(W_{RSR} - \mu_{W_{RSR}})^2}{3\sigma_{W_{RSR}}}$$

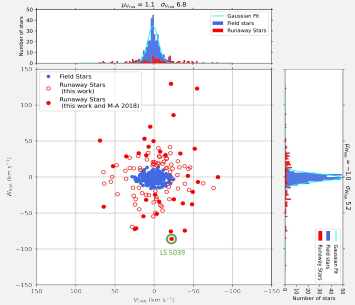
$$E > 1 \Longrightarrow \text{RUNAWAY STAR}$$

- **Stars outside** the red **ellipse** are classified as **runaways**

RESULTS

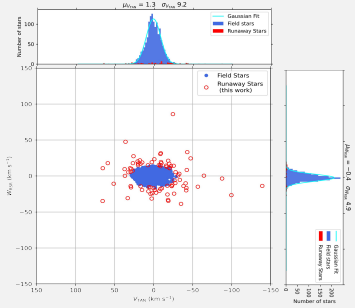
GOSC-*Gaia* EDR3 Catalog

- **110 runaway stars, 25.6%** of the GOSC-*Gaia* EDR3 Catalog.
- Peculiar velocities: 16-290 km s^{-1}
- Dispersions of field stars: σ_{VTAN} = 6.8 km s^{-1}, σ_{WRSR} = 5.2 km s^{-1}
- 37 runaway stars previously known (Maíz Apellániz+18).



BeSS-*Gaia* EDR3 Catalog

- **83 runaway stars, 6%** of the BeSS-*Gaia* EDR3 Catalog.
- Peculiar velocities: 16-140 km s^{-1}
- Dispersions of field stars: σ_{VTAN} = 9.2 km s^{-1}, σ_{WRSR} = 4.9 km s^{-1}



MULTI-WAVELENGTH COUNTERPARTS

- Gamma-ray binaries display non-thermal emission from radio to GeV/TeV energies.
- To search for gamma-ray binaries we cross-match the runaway stars with several radio catalogs (NVSS, VLASS, …).
- We have found that 2% of the runaway stars emit in radio.

CONCLUSIONS

- The unprecedented accuracy of the *Gaia* data has allowed us to find around 200 massive runaway stars.
- Their peculiar velocities reach up to around 300 km s^{-1}.
- Among the runaways we found, those emitting in radio (2%) are the best candidates to be gamma-ray binaries.

FUTURE WORK

- Update the study with improved distances from *Gaia* DR3.
- Cross-match with other multi-wavelength catalogs to search for non-thermal emission.
- Prepare future observations of selected sources (radial velocities, photometry, radio, X-rays).
- Conduct observations to unveil their possible TeV emission.

REFERENCES

- *This work has made use of data from the European Space Agency (ESA) mission Gaia.*
- Bailer-Jones C. A. L., Rybizki J., Fouesneau M., Demleitner M., Andrae R., 2021, AJ, 161, 147.
- Maíz Apellániz, J. et al. (2013), in Massive Stars from α to Ω.
- Maíz Apellániz, J., Pantaleoni González, M., Barbá, R. H., et al. 2018, A&A, 616, A149.
- Neiner, de Batz, Cochard, Floquet, Mekkas & Desnoux, 2011, AJ 142, 149.
- Reid M. J., et al., 2019, ApJ, 885, 131.

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