

Multi-band photometry of Be stars using HDUST (and SPLUS)!

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Current state on Active B stars researching

Most part of current research on active B stars relies on some of these topics:

- Magnetic Fields on O, B and A stars
 - B stars with magnetosphere emitting
- Hot stars and mass loss mechanisms (i.e. stellar winds)
- Classical Be stars
 - Be/X-ray Binaries
 - Gamma Cas objects
- B[e] supergiant stars

The majority focuses on all possible observational variabilities and how it applies to the studied system.

Me? I study Classical Be stars.
They are awesome, ok? ☀

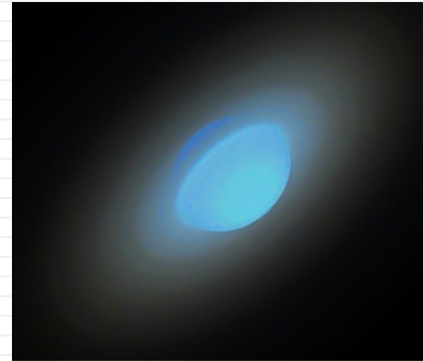


Figure 1: True color representation of a Classical Be star. Credits: Dr. D. Faes Moser.



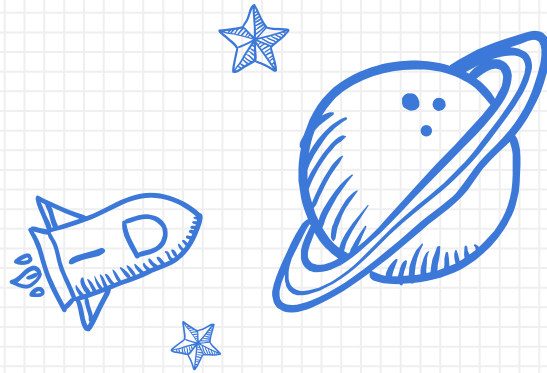
Importance of Classical Be stars in Astronomy

- ✗ They rotate really quickly!
- ✗ They present a complex mechanism of mass ejection;
- ✗ Circumstellar material ejected from the star forms a Keplerian disk, which interacts with the star in a variety of ways.

Their origin is still up to debate. And, for example, we still are not completely sure how Be stars populations change according to metallicity, and what really is the binary fraction.

Also, they can be useful for disks studies and evolution of rotating stars.





HDUST modelling and Stellar Populations

HDUST: General information

HDUST is a 3D non-LTE Monte Carlo radiative transfer code, which solves the statistical equilibrium for hydrogen populations. It is very powerful in modelling disks around Be stars, and also capable of modelling only central stars, without circumstellar matter and interactions.

It allowed us to build synthetic grid models, with well defined input parameters, for both central star and disk. The two main outputs of HDUST is detailed in Figures 2 & 3.

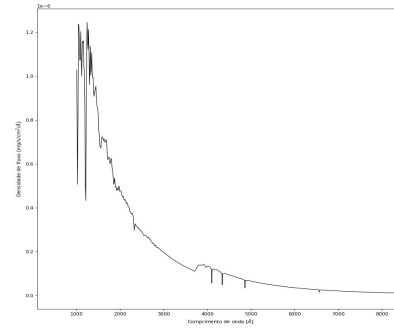


Figure 2: Synthetic spectra of a pure H7 solar mass star.

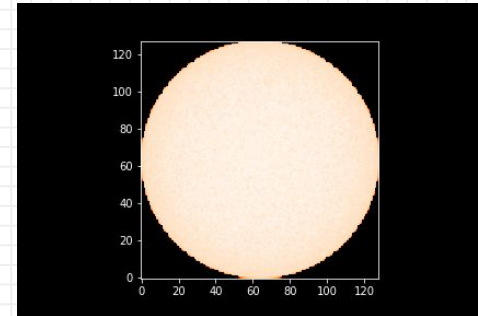


Figure 3: 128 pixel resolution image of a synthetic star.



Stellar Population Synthesis ✨

In the Galaxy, we have a great number of regions containing populations of stars with their own formation history. Any galaxy has imprinted in their spectrum for example contributions from many different sources.

For example, Milky Way presents old globular clusters, a variety of open clusters, and also streams of stars accreted in past mergers.

Open clusters are ideal when talking about Be stars. As they present young populations, we can observe main sequences presenting B stars. Some authors in the past studied methods of resolving Be stars and candidates within a cluster;

We wish to build different synthetic populations using HDUST models to study diagnostic tools, such as color diagrams, using a variety of filters => SPLUS coming in hot!



Let's portrait it a little bit!

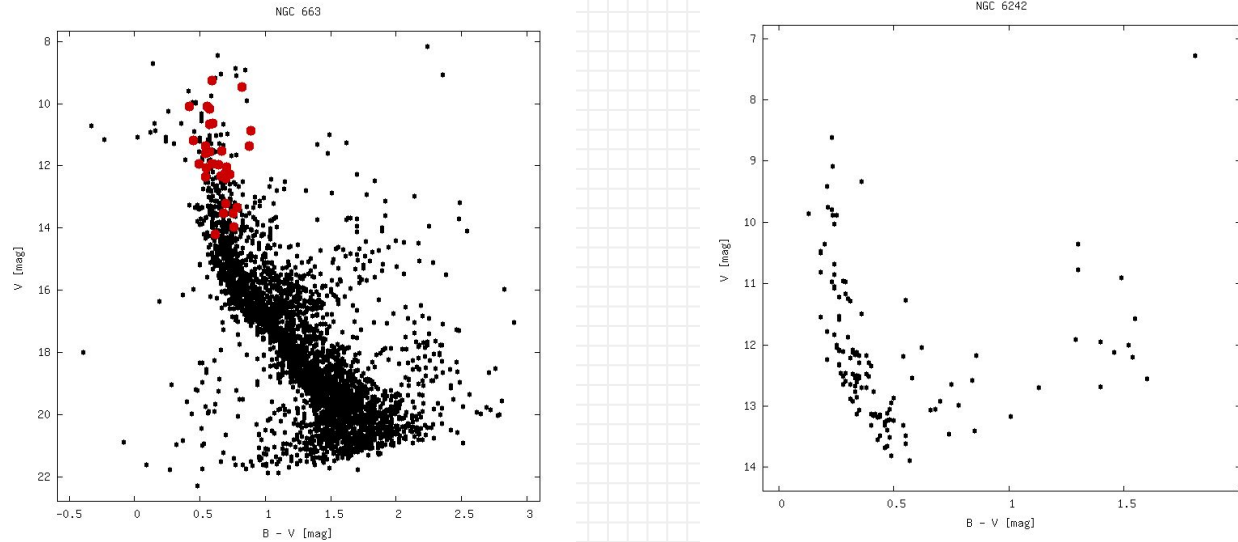


Figure 4: Galactic open clusters NGC 663 (left) and NGC 6242 (right). In the left, confirmed Be stars are plotted in red. Extracted from: WEBDA database.



How do we expect B stars to distribute along an observational color–magnitude diagram?

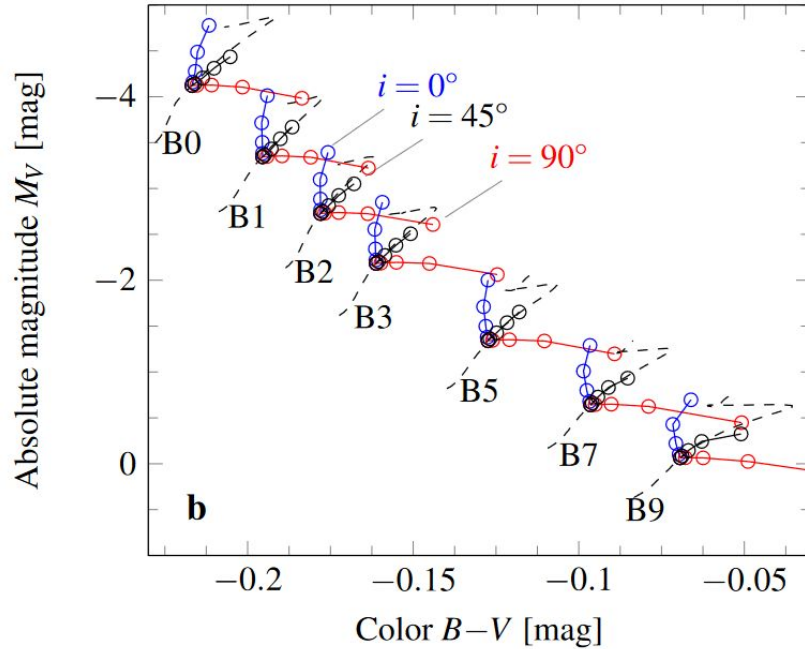


Figure 5: The increasingly different appearance of rapidly rotating B stars from the non-rotating case in the photometric Hertzsprung-Russell diagram, for $W = [0.00, 0.20, 0.41, 0.64, 0.93]$ and three different inclinations: $i = 0^\circ$ (blue), 45° (black) and 90° (red).

Figure extracted from the 2013 review on Classical Be stars, from Rivinius, Carciofi & Martayan.



Color-magnitude diagrams examples using SOAR's B, V filters set and many B stars (diff. rotation rates and inclination angles)

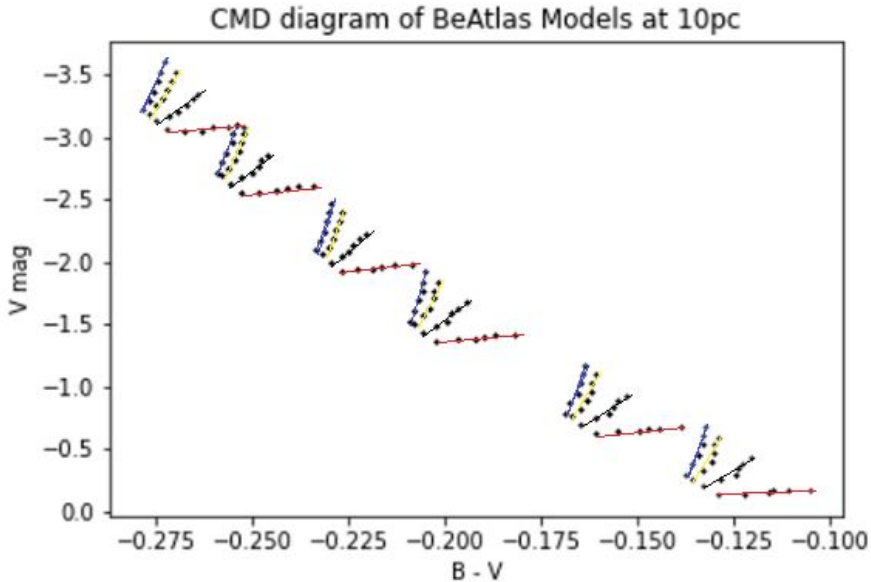


Figure 6: BeAtlas models (HDUST calculated), for 10 different rotation rates linearly evenly spaced from $W = [0.50 \text{ to } 0.85]$ and four different inclinations:
 $i = 0^\circ$ (blue), 30° (yellow), 45° (black) and 90° (red).

What if we include disk models?

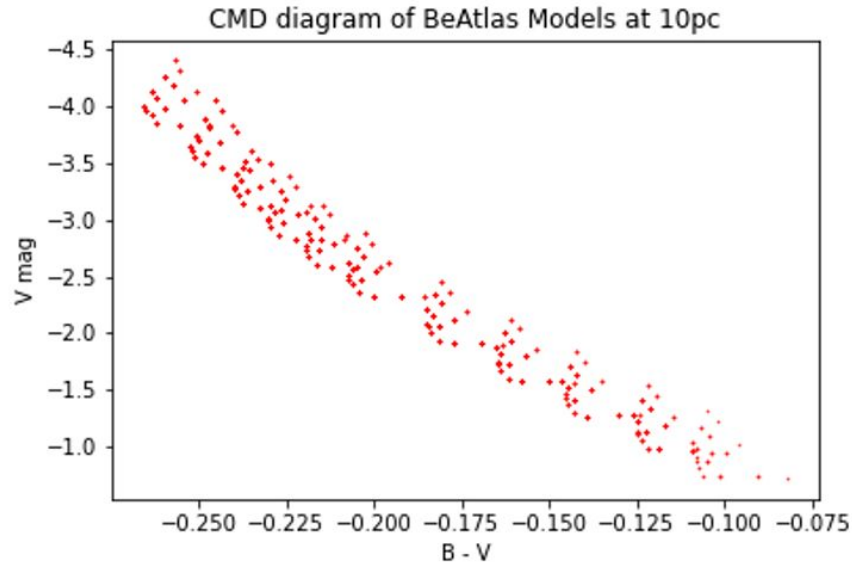


Figure 7: BeAtlas models (HDUST calculated), for 10 different rotation rates linearly evenly spaced from $W = [0.50 \text{ to } 0.85]$ and four different inclinations:

In this case, we have Keplerian disks with same value of surface density and following the same radial density profile.





Perspectives

What are we leaping forward to?





Model extension

Use external models for a variety of spectral type stars, in order to build trustful stellar populations.

Reliable analysis

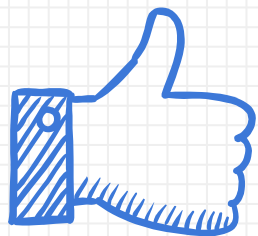
Find ways to make automatized analysis on the problem.

Filter testing

Search for the best diagnostic tools that help the most in disentangling active Be and their counterpart, B-type stars.

Usage of real data

SPLUS will be a worthy source of information for us, as it is bringing good data for fields in the Galaxy and in the Magellanic Clouds.



Thanks!

Any questions?

You can find me at

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Bibliography

Carciofi, A. C. and Bjorkman, J. E., “Non-LTE Monte Carlo Radiative Transfer. I. The Thermal Properties of Keplerian Disks around Classical Be Stars”, *The Astrophysical Journal*, vol. 639, no. 2, pp. 1081–1094, 2006. doi:10.1086/499483.

Rivinius, T. and Carciofi, A. C. and Martayan, C., “Classical Be stars”, *The Astronomy and Astrophysics Review*, vol. 21, no. 1, 2013. doi:10.1007/s00159-013-0069-0.

Netopil, M., Paunzen, E., and Stütz, C., “Developments of the Open Cluster Database WEBDA”, in *Star Clusters in the Era of Large Surveys*, 2012, vol. 29, p. 53. doi:10.1007/978-3-642-22113-2_7.

Mota, B., “BeAtlas: A grid of synthetic spectra for Be stars”, 2019, PhD thesis, IAG-USP.

