The Origins of Be Stars: Investigating the Intra-cluster Environments of NGC 663 and NGC 7419

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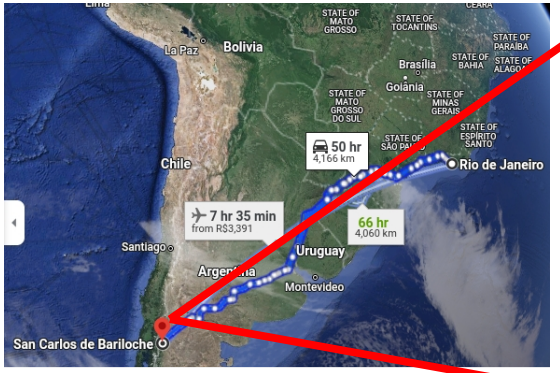
5.Universidad de Ingenieria y Tecnologia- UTEC, Lima, Peru.

Río de Janeiro, June 25th. Massive Stars 2024

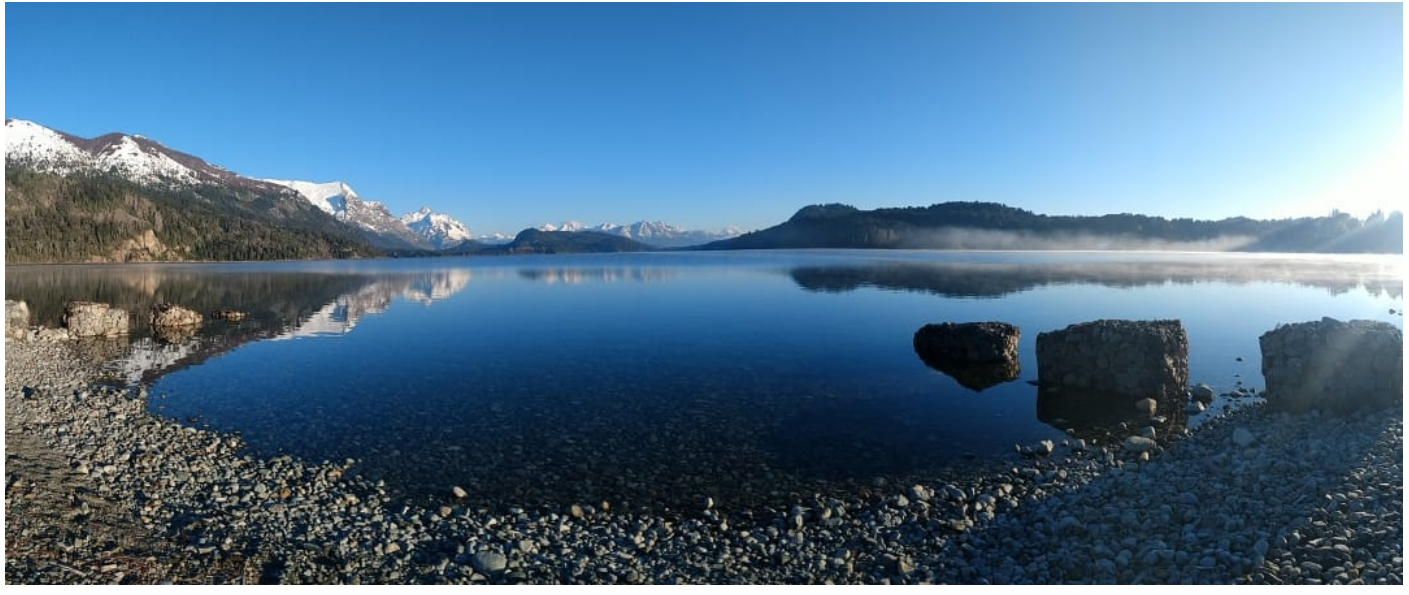


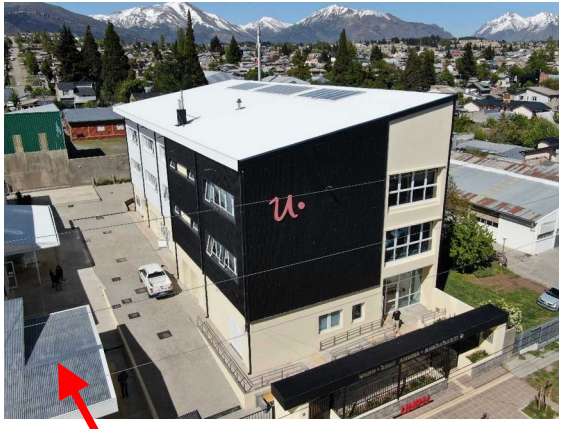
SAN CARLOS DE BARILOCHE

RIO NEGRO

ARGENTINA

RÍO NEGRO
UNIVERSIDAD NACIONAL





Laboratorio de Investigación Científica en Astronomía

The Origins of Be Stars: Investigating the Intra-cluster Environments of NGC 663 ~~and NGC 7419~~

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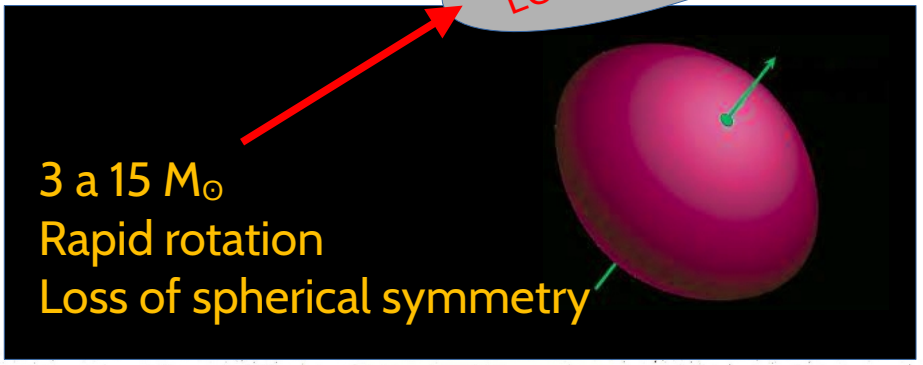
Motivation: Be Stars

...OR HIGHER MASSES AT LOWER METALLICITIES!!

Main Sequence B-type stars.

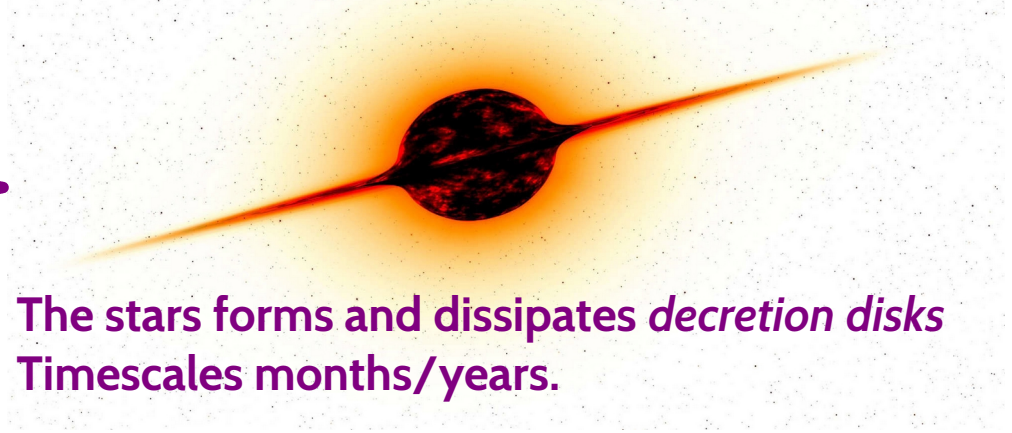
Usually, broad photospheric lines.



H-emission lines, mild near-IR excesses.

Variable in all timescales.

(e.g. Review by Rivinius et al 2013)



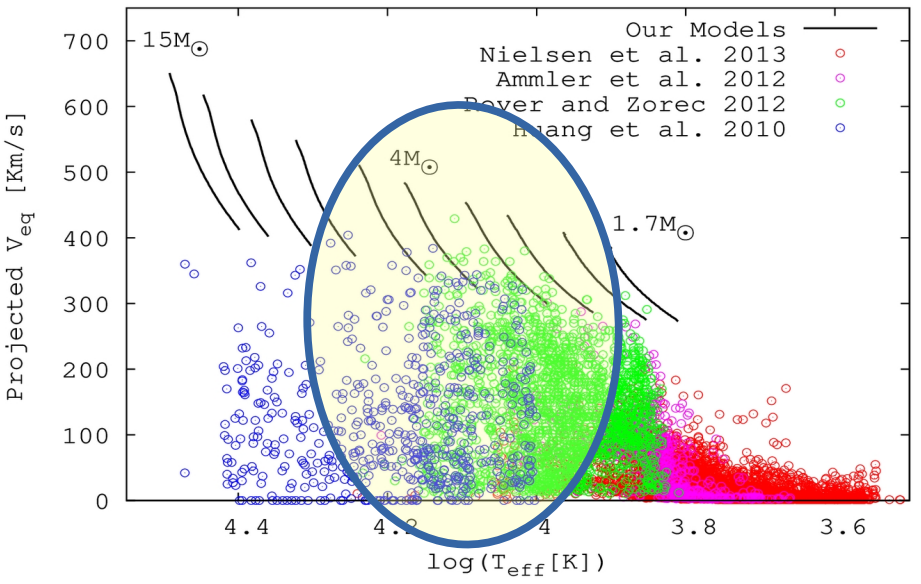
The stars forms and dissipates *decretion disks*
Timescales months/years.

Motivation: Be Stars

Be stars are excellent laboratories to study :

- Physics of extreme stellar rotation.
- Accretion/decretion disk processes.

Are these rare objects?



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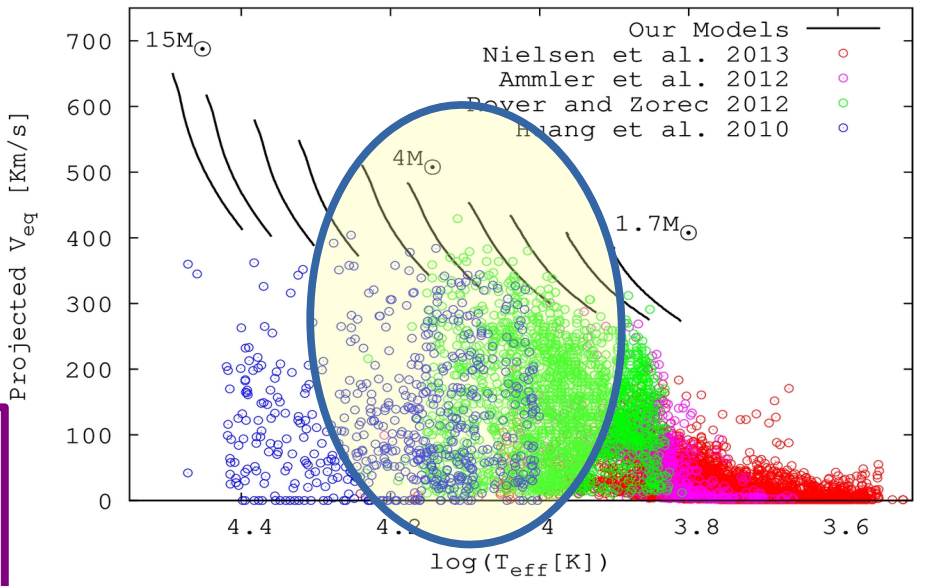


In some Open Clusters, 40% of early B stars are Be.

Motivation: Be Stars

Some Open questions

How Be stars acquire their rapid rotation.

Binarity? Large initial angular momentum content? Formation Ambient?

Mechanisms involved in the formation and evolution of the disk

Stellar Winds*? Pulsations? Stellar activity? Binarity? Others?*

Goal: Improve our knowledge of Be Stars

Understand the characteristics of *Ambients where Be stars Form and evolve*

Compare the intra cluster medium of clusters rich in Be stars and those of similar age and composition where Be stars are not abundant.

Start with the OCs with largest amount of Be stars: **NGC 663**

→ GAIA PHOTOMETRY + ISM TRACERS

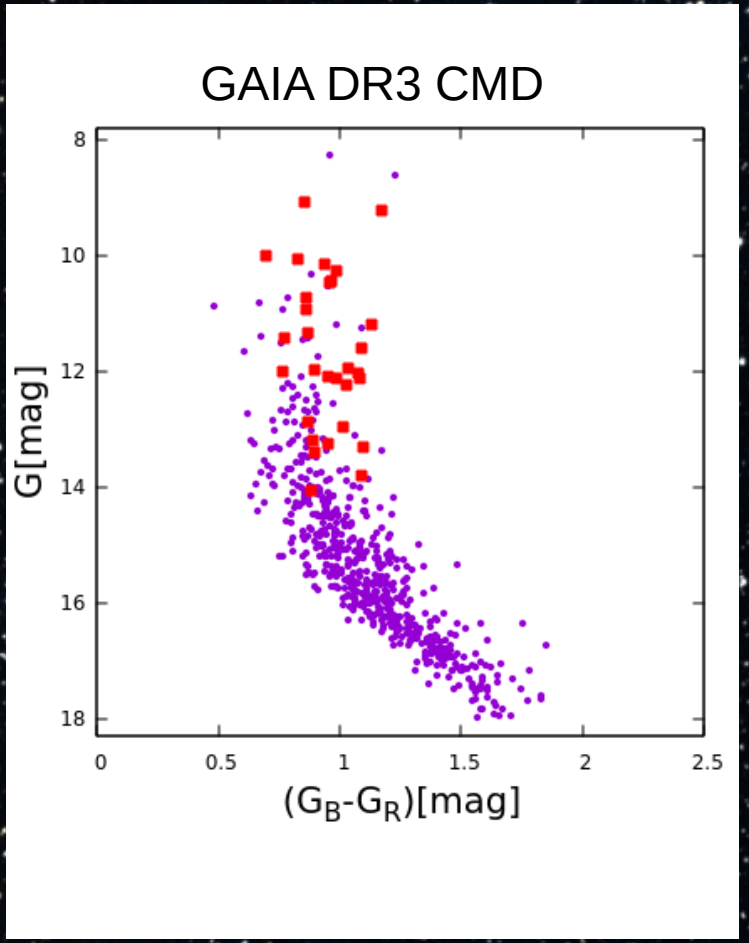
NGC 663: a cluster rich in Be stars

Distance: ~2900pc [Cantat-Gaudin 2018]

log(age[yr]): 7.0– 7.7
[Pigulski, 2001, Pandey 2005, Cantat-Gaudin 2018, Paron 2021. etc.]

Mean value of E(B-V) = 0.8
[Pigulski, 2001, Pandey 2005]

Multiple Stellar Populations? (ages)
[(Valcarce & Catelan 2011; Li et al. 2016, Paron et al. 2021.]



NGC 663: a cluster rich in Be stars

NGC 663: a cluster rich in Be stars

What kind of material is it?

Are all stars of the cluster embedded there?

Are all clusters rich in Be stars like this one?

RED: WISE 24μm

NGC 663: a cluster rich in Be stars

What kind of material is it? → S. Parón

Are all stars of the cluster embedded there?

Are all clusters rich in Be stars like this one?

RED: WISE 24μm

NGC 663: un cúmulo rico en estrellas Be

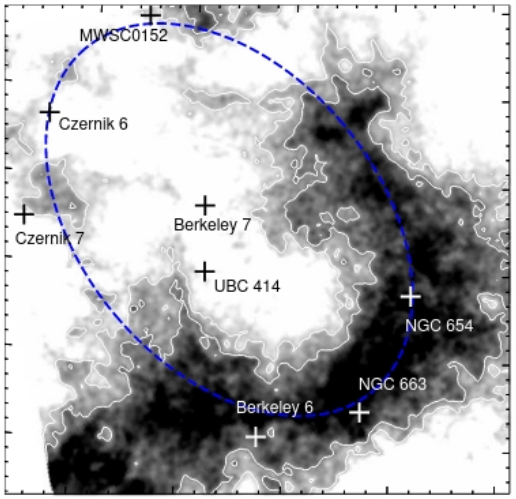


Figure 6. HI emission integrated between −28 and −36 km s^{-1}. The contour levels are 320 and 380 K km s^{-1}. The positions of the clusters are indicated. The blue dashed ellipse remarks the HI shell.

N

E

The ISM in the region around NGC 663 did not seem to have anything special...

Studying the interstellar medium to look for relics of triggered star formation among stellar clusters

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[2] *Centro Interdisciplinario de Telecomunicaciones, Electrónica, Computación y Ciencia Aplicada (CITECCA), Sede Andina, Universidad Nacional de Río Negro, Anasagasti 1463, San Carlos de Bariloche, R8400AHN Río Negro, Argentina*

E 24µm

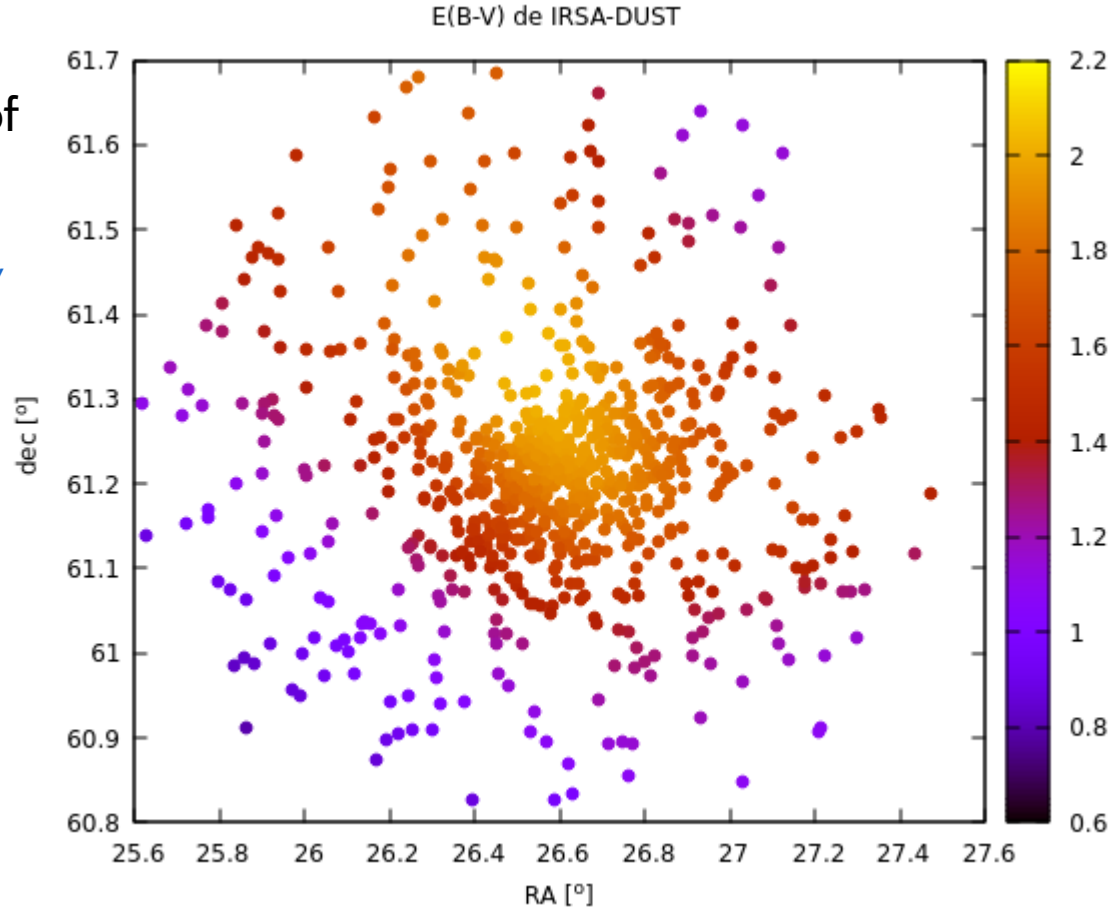
Intra Cluster Medium of NGC 663

Dust reddening in the direction of sight

https://irsa.ipac.caltech.edu/applications/DUST/

WIDELY USED IN LITERATURE.

Stars P>0.5 of NGC 663 (Cantat Gaudin 2018).



Galactic dust extinction from Schlafly and Finkbeiner (2011)

Intra Cluster Medium of NGC 663

Dust reddening in the direction of sight

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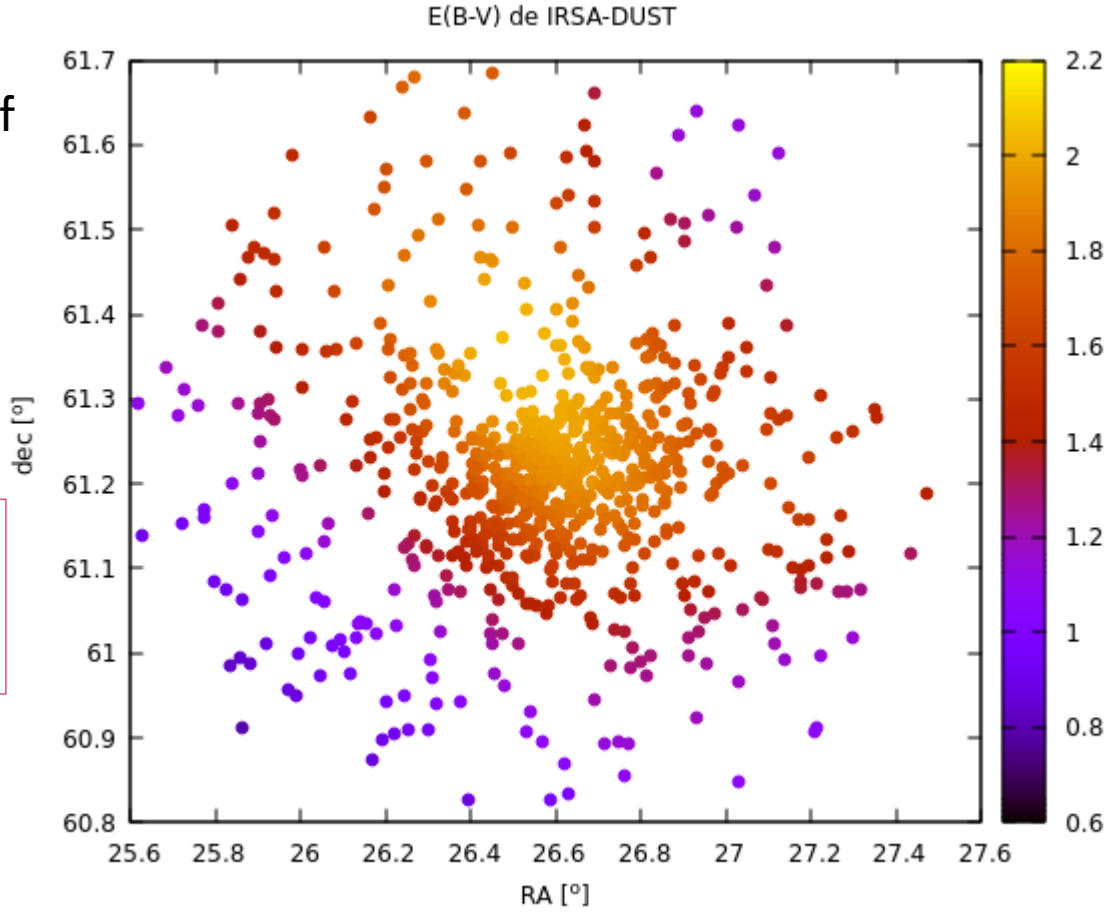
These $E(B-V)_{IRSA}$ values can not be used as tabulated, derived from integration of dust column

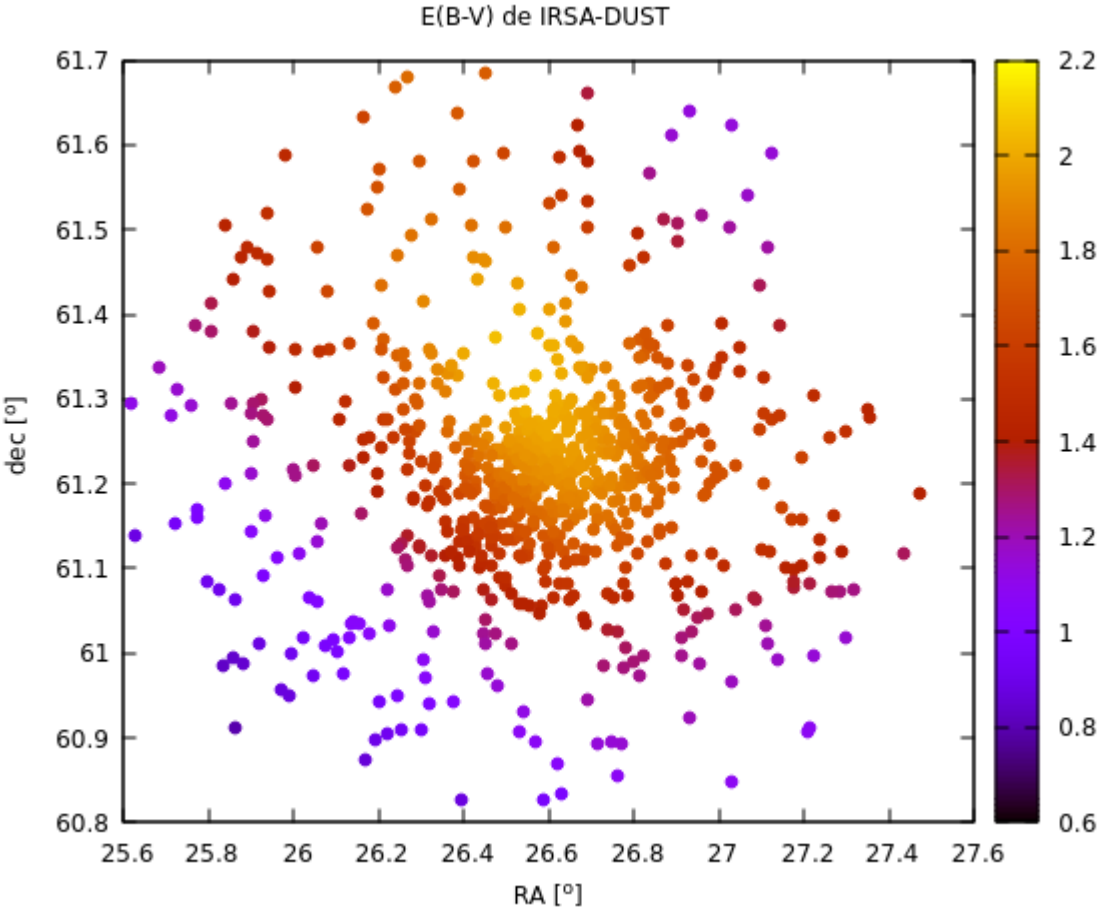


Galactic dust extinction from Schlafly and Finkbeiner (2011)

Intra Cluster Medium of NGC 663

We assume that stars close in angular distance having similar tabulated $E(B-V)_{IRSA}$, are equally affected by interstellar matter

We use this quantity as a feature to cluster the data and then deredden each group.



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Intra Cluster Medium of NGC 663

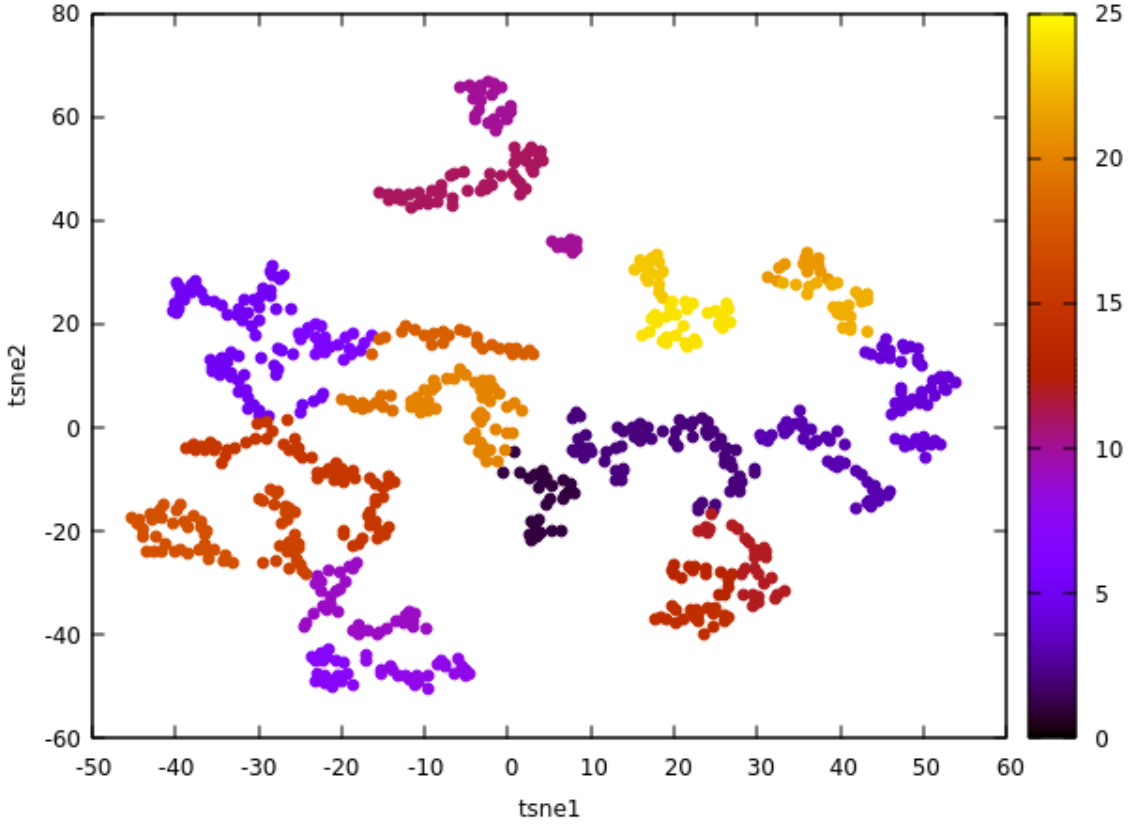
We use ML dimensionality reduction (t-SNE) methods to group stars according to their characteristics.

Features used: RA, dec, E(B-V).

Reduction with t-SNE to 2D.

Other reduction methods such as UMAP produce similar groupings.

Matías Núñez "explores nature With ML"



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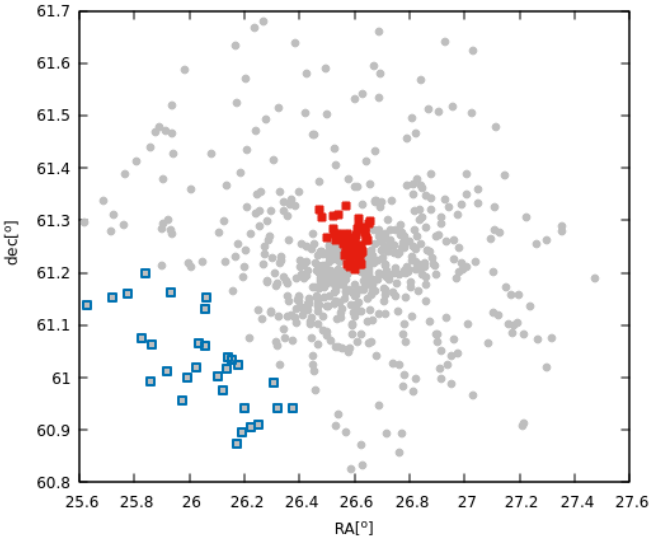

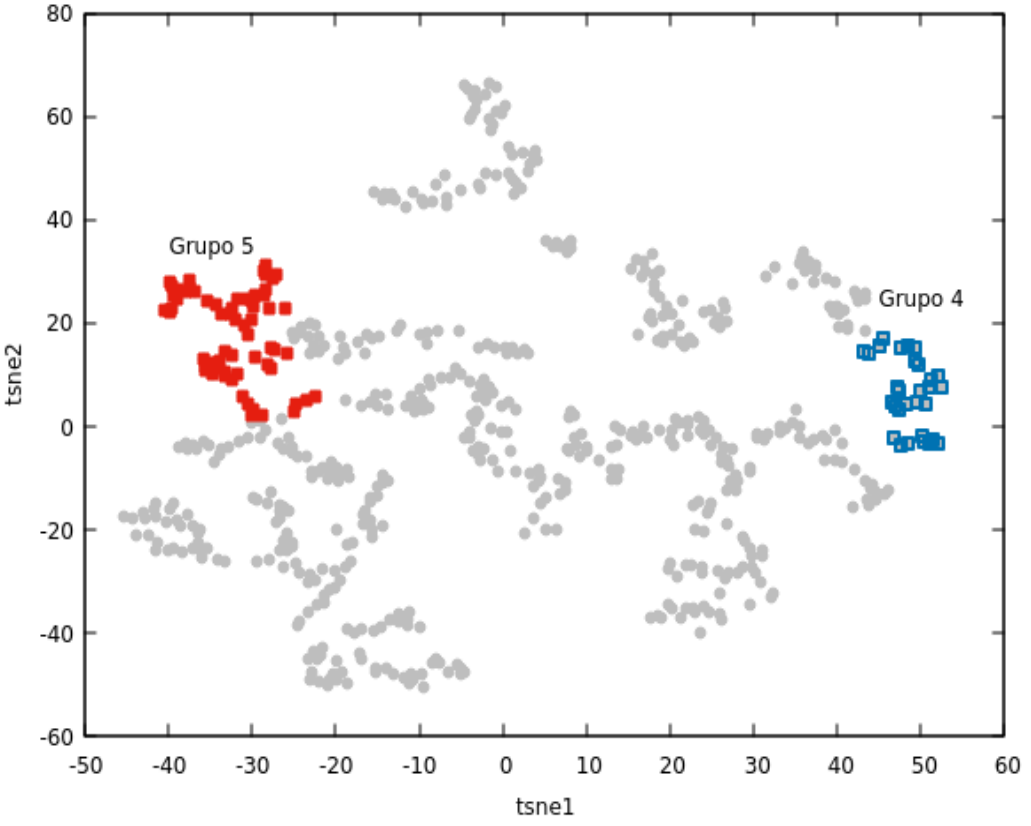

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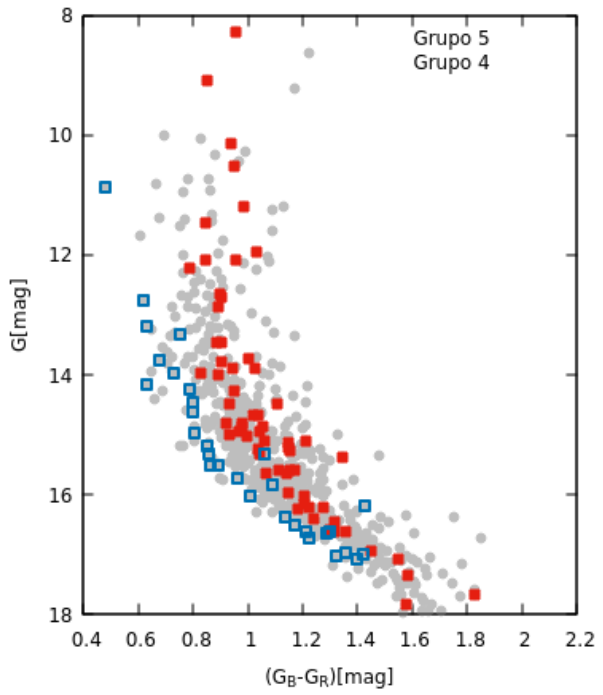
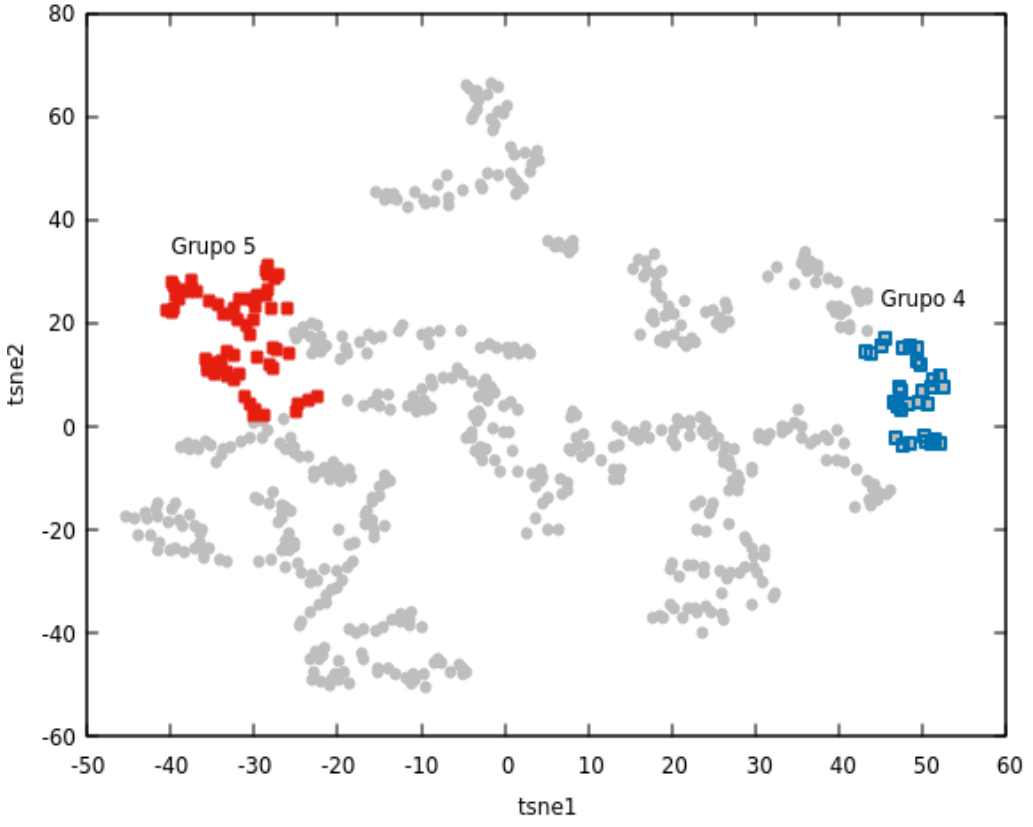
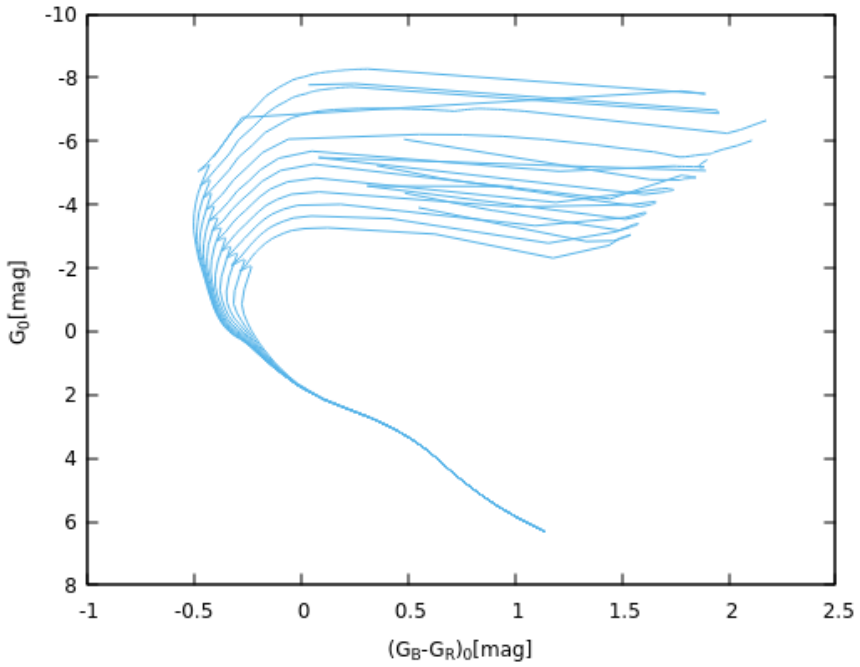


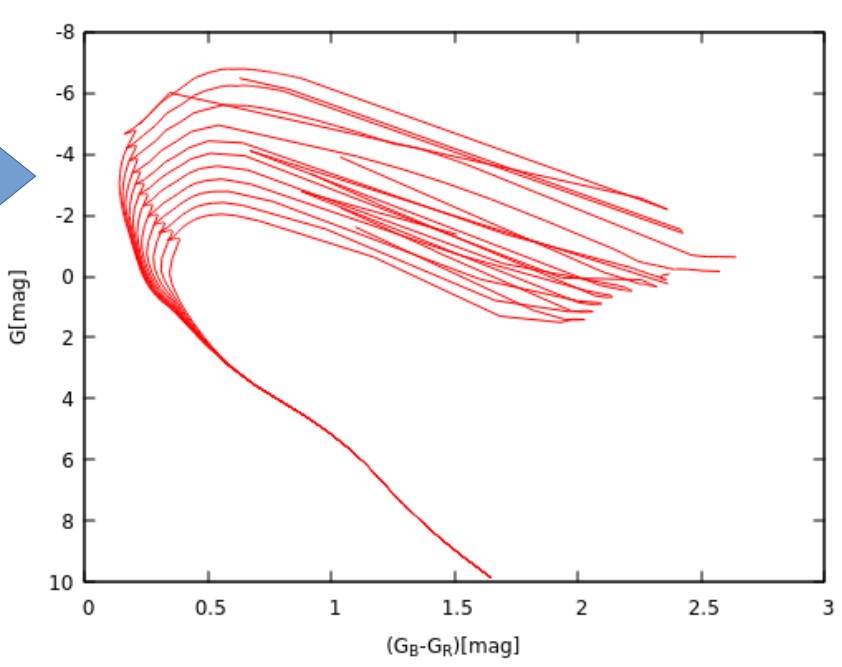


Reddening Isochrones

Isochrones of 10 to 100 Myr in Gaia system



Reddened Gaia Isochrones

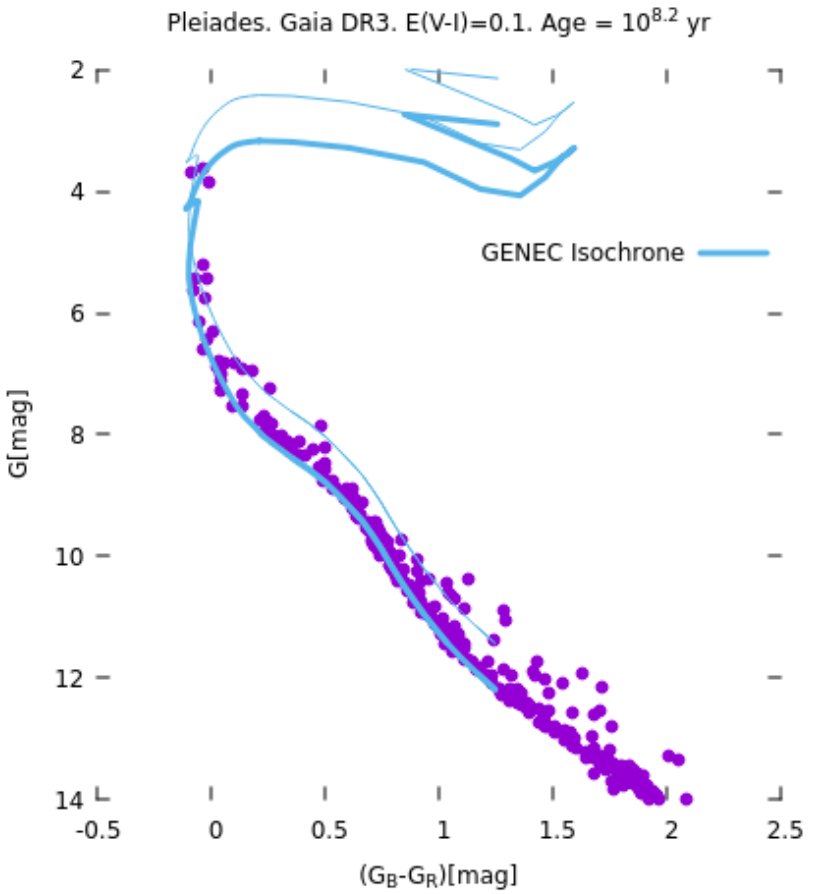


Isochrones Ekström (2012) → G-V=f(V-I), G_B-G_R=g(V-I) .

https://gea.esac.esa.int/archive/documentation/GEDR3/Data_processing/chap_cu5pho/cu5pho_sec_photSystem/cu5pho_ssec_photRelations.html

See also Riello et al. 2021.

Test in Pleiades



The reddened isochrones provide an adequate fit of Gaia DR3 data.

Dereddening NGC 663

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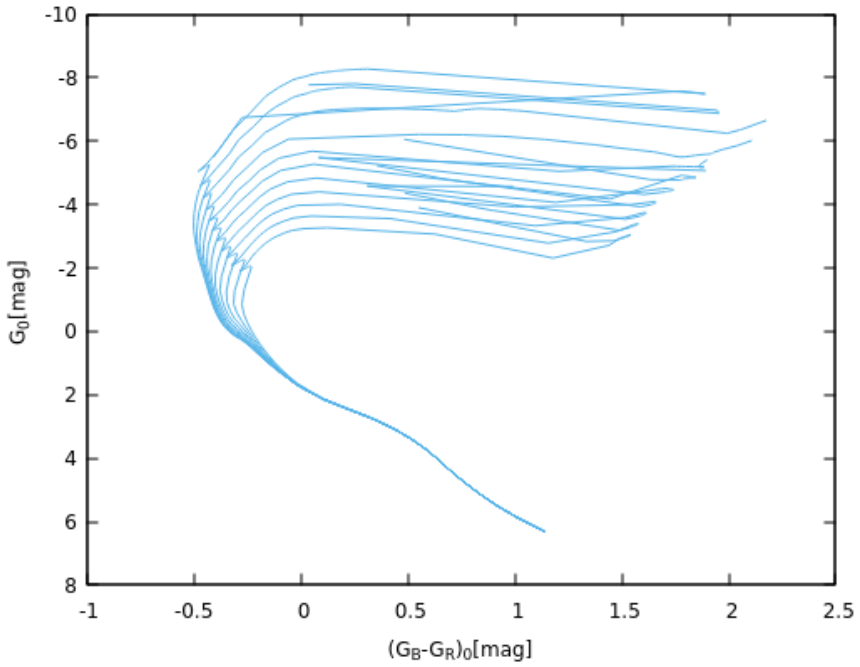

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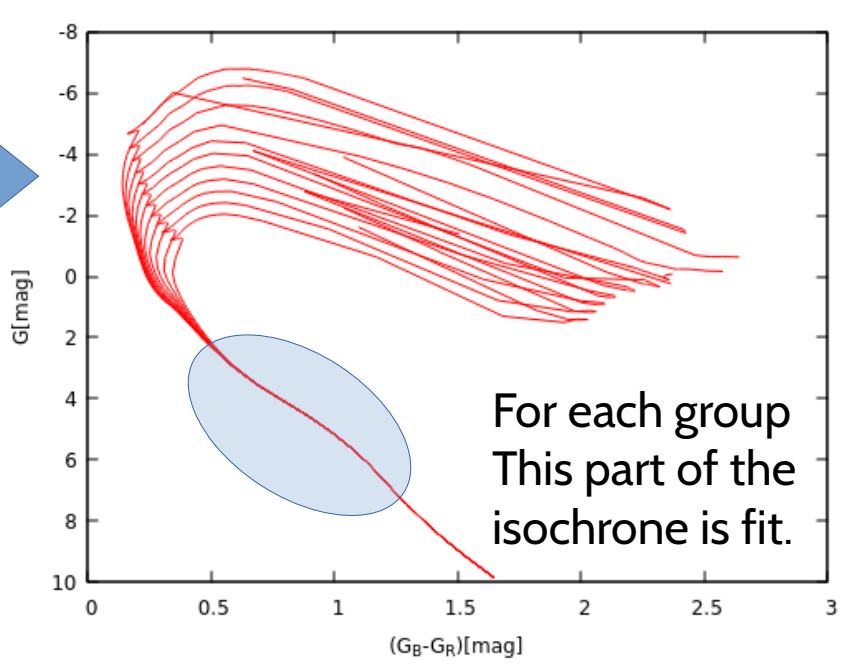

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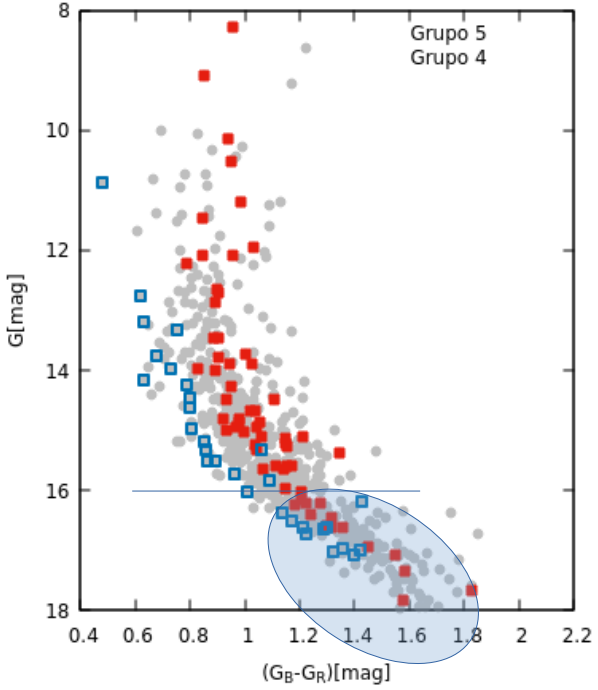

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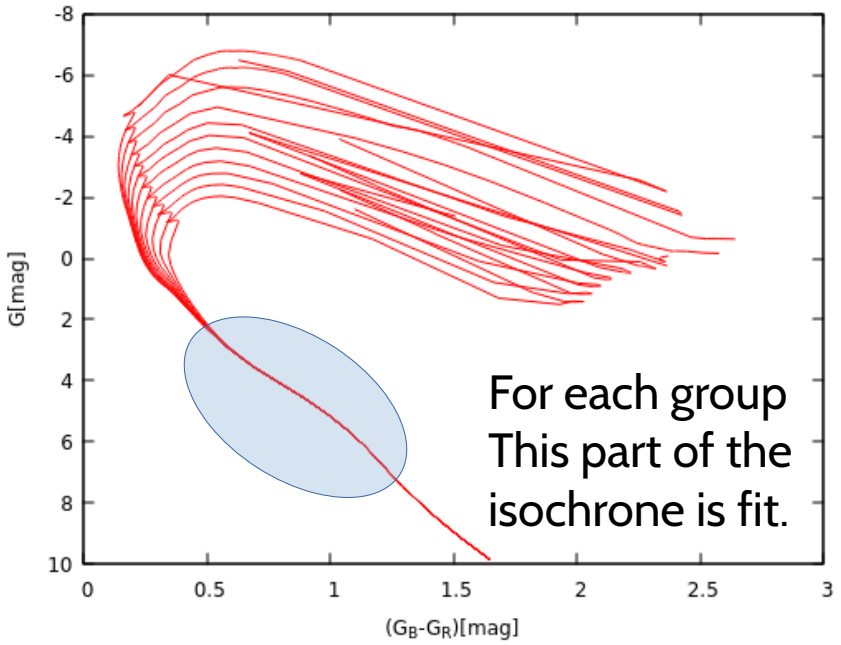
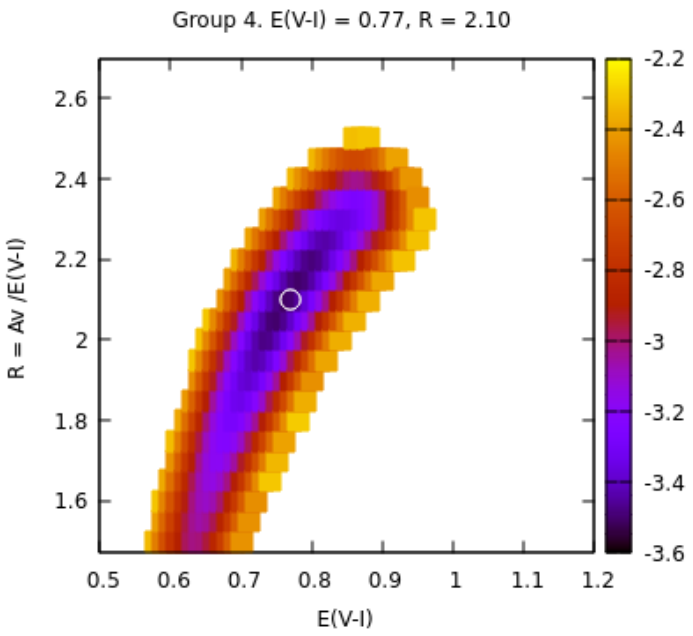
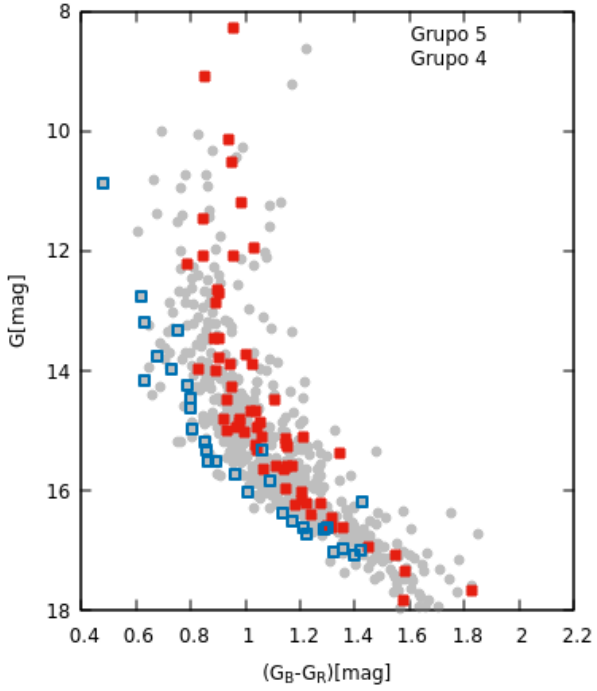
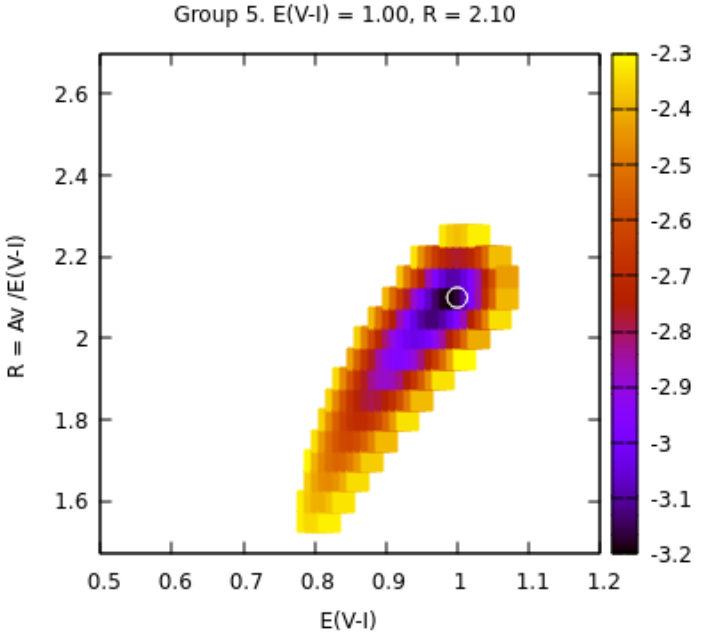


RESULTS

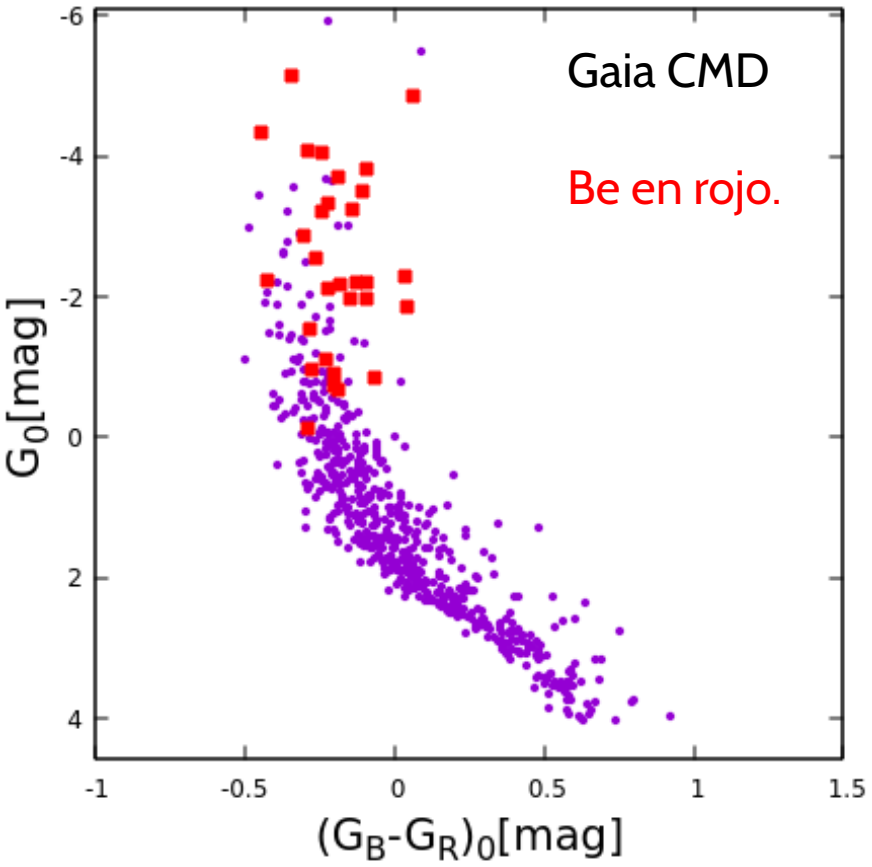


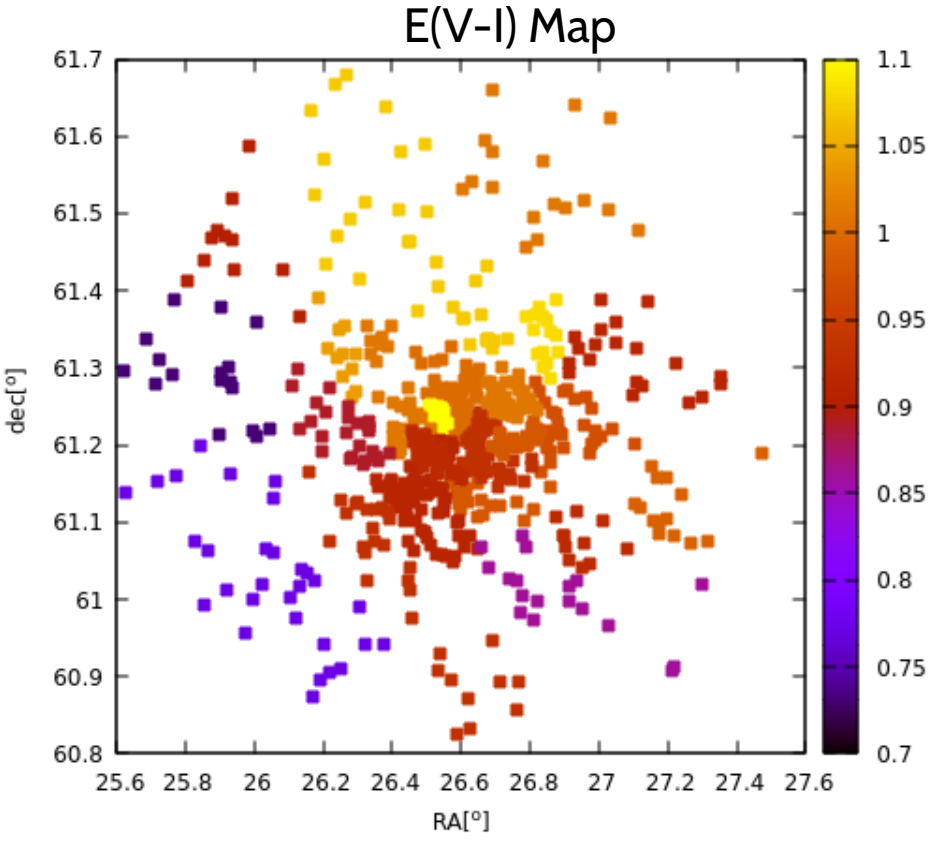




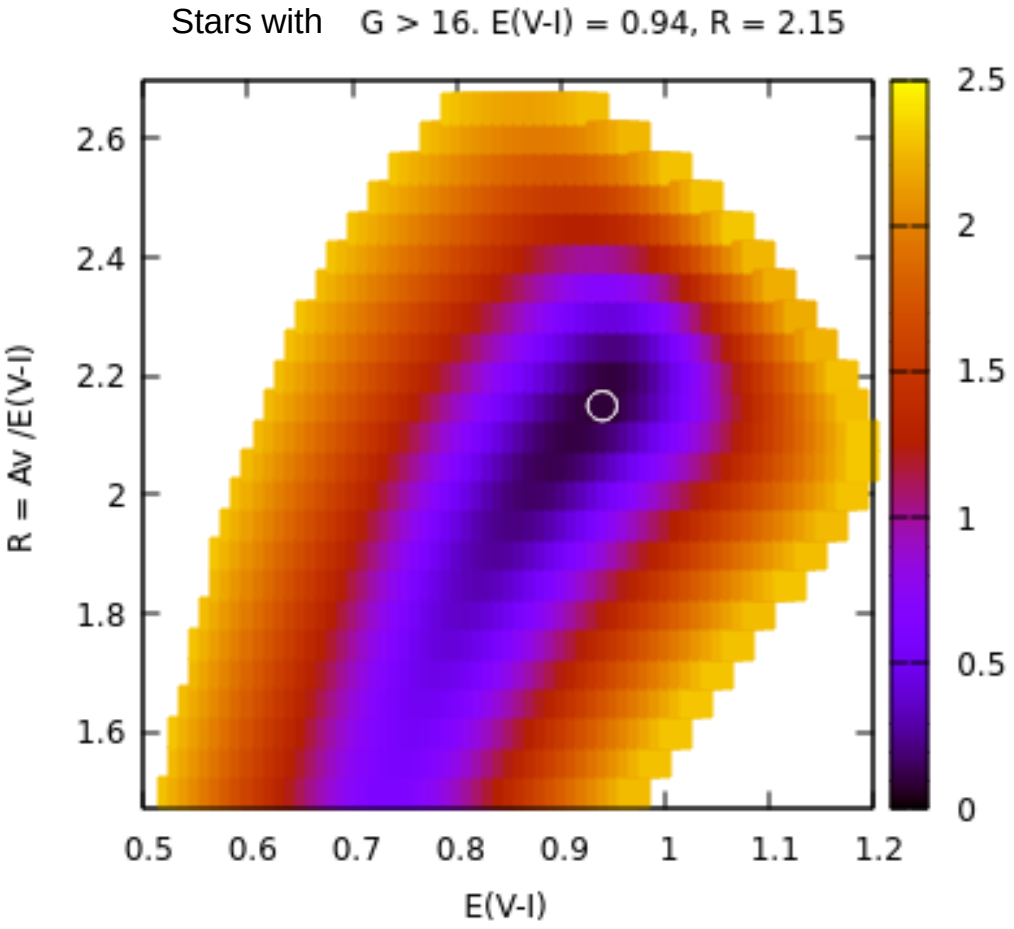
For the 24 Groups, we found E(V-I) and R=Av/E(V-I)

RESULTS


Gaia CMD
Be en rojo.
G_0[mag]
$(G_B-G_R)_0$[mag]
-6
-4
-2
0
2
4
-1
-0.5
0
0.5
1
1.5


E(V-I) Map
dec[°]
RA[°]
61.7
61.6
61.5
61.4
61.3
61.2
61.1
61
60.9
60.8
25.6
25.8
26
26.2
26.4
26.6
26.8
27
27.2
27.4
27.6
1.1
1.05
1
0.95
0.9
0.85
0.8
0.75
0.7

RESULTS



Mean value E(V-I)=0.94 compatible with literatura (Pigulski, 2001, Pandey 2005).

Mean value of R=Av/E(V-I)=2.15, smaller than Normal ISM value (R = 2.48)

Considering E(B-V)=0.8 → Av = 2.53 E(B-V)

→ ***R value due to small size dust particles ?***

THE PROCEDURE PROVIDES RELIABLE DATA!

Ongoing work

Follow the described procedure with other Ocs.

NGC 7419
NGC 3766
Double Cluster
etc.

Pleiades