Variability properties of Galactic O- and C-rich AGB stars as seen by Gaia

F. Jiménez-Esteban et al.

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Variability of O- and C-rich AGB stars by Gaia

Collaboration

F. Jiménez-Esteban, Spanish Virtual Observatory

B. López Martí, Universidad San Pablo CEU

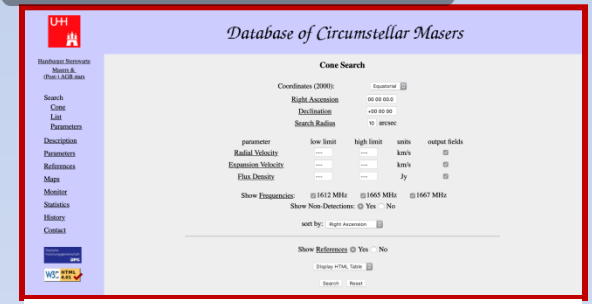
D. Engels, Universität Hamburg

P. García-Lario, European Space Agency

Variability of O- and C-rich AGB stars by Gaia

The *Gaia* Catalogue of Galactic AGB stars

Starting Point



Engels & Bunzel 2015; Engels 2022



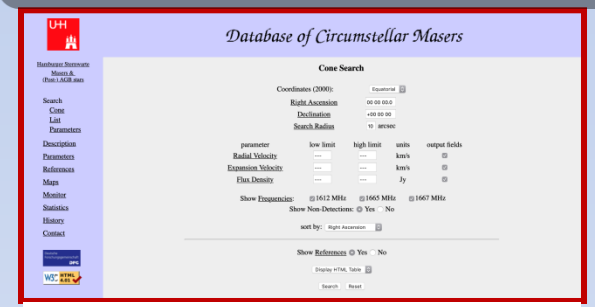
Suh 2021

- **2857 OH/IR (O-rich AGB) star candidates** from a compilation of **OH masers** from the literature by Engels & Bunzel 2015 and Engels 2022
- **4106 O-rich AGB star candidates with no detected OH** maser emission from a compilation of **IRAS sources** by Suh 2021
- **3580 C-rich AGB star candidates** from a compilation of **IRAS sources** by Suh 2021

Variability of O- and C-rich AGB stars by Gaia

The *Gaia* Catalogue of Galactic AGB stars

Gaia counterpart identification



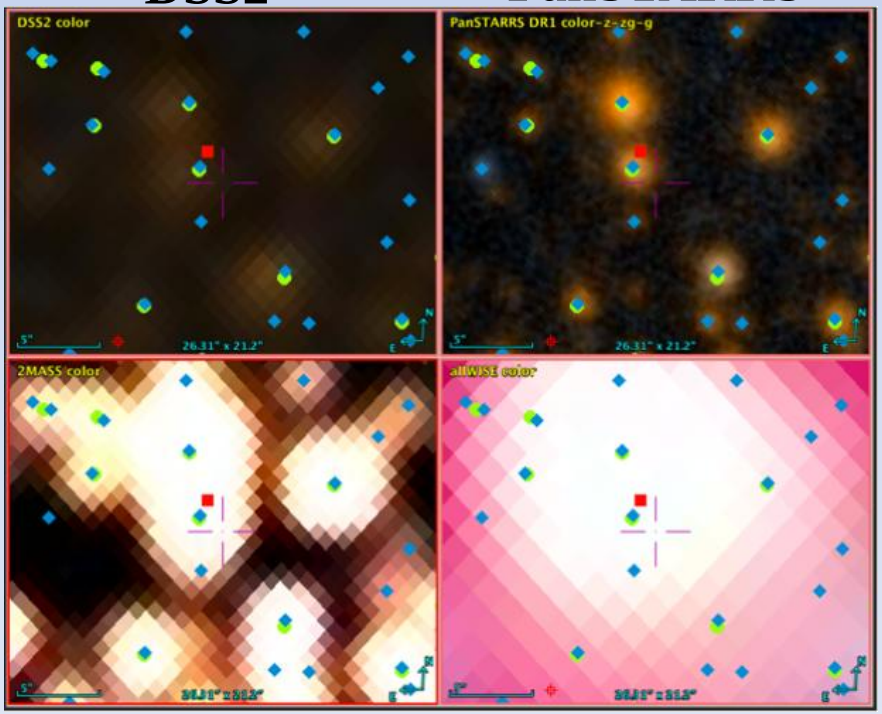
Engels & Bunzel 2015; Engels 2022



Suh 2021

The main difficulty is the high coordinate uncertainty

DSS2 **PanSTARRS**



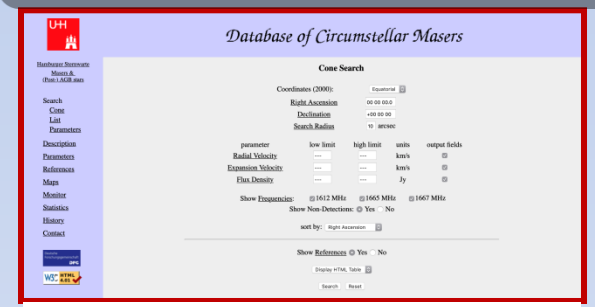
2MASS **WISE**

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Gaia counterpart identification



Engels & Bunzel 2015; Engels 2022

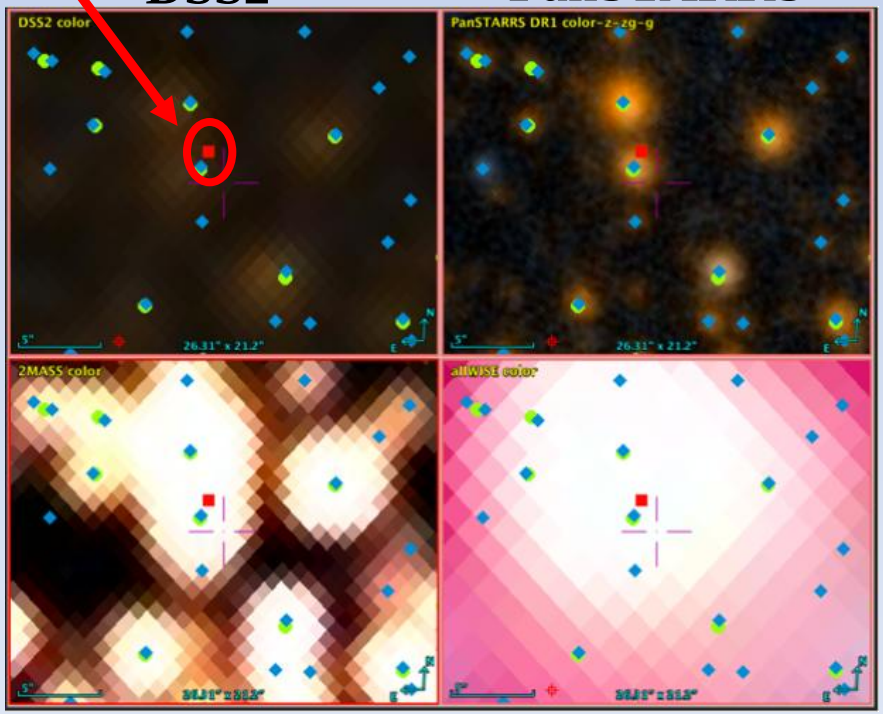


Suh 2021

The main difficulty is the high coordinate uncertainty

Coordinates

DSS2 **PanSTARRS**

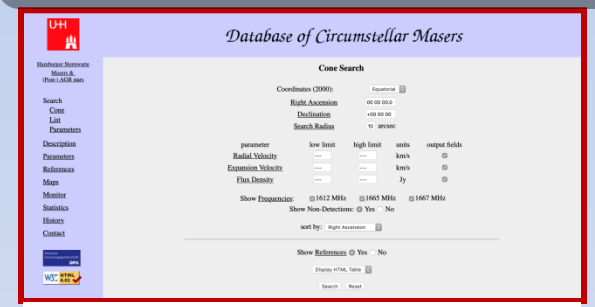


2MASS **WISE**

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Gaia counterpart identification



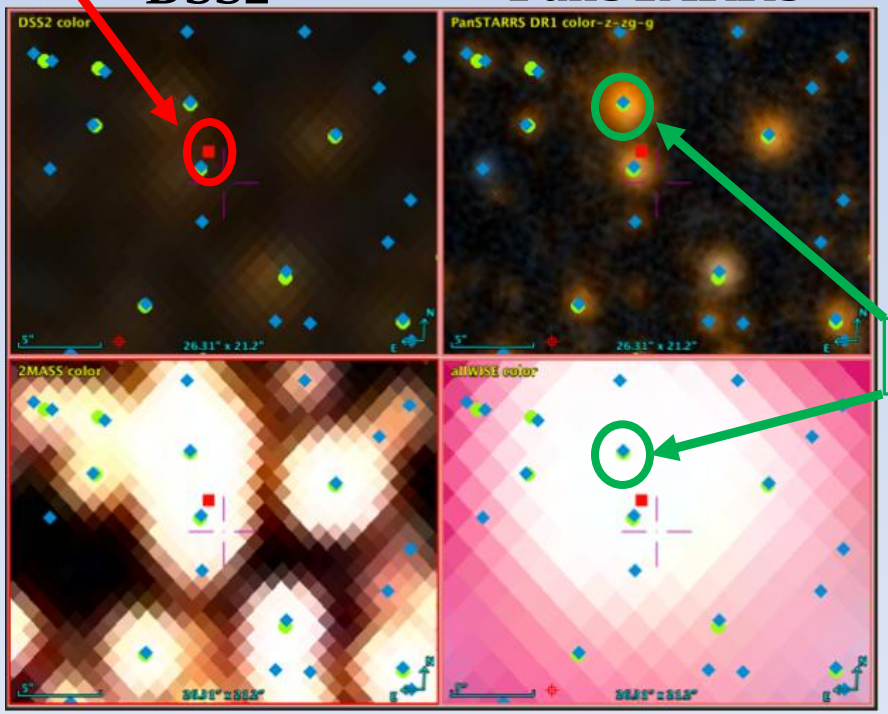
Engels & Bunzel 2015; Engels 2022



Suh 2021

The main difficulty is the high coordinate uncertainty

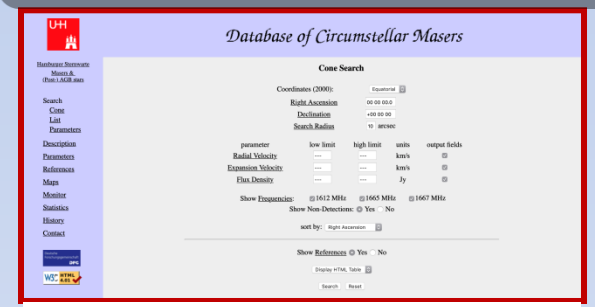
Coordinates



Variability of O- and C-rich AGB stars by Gaia

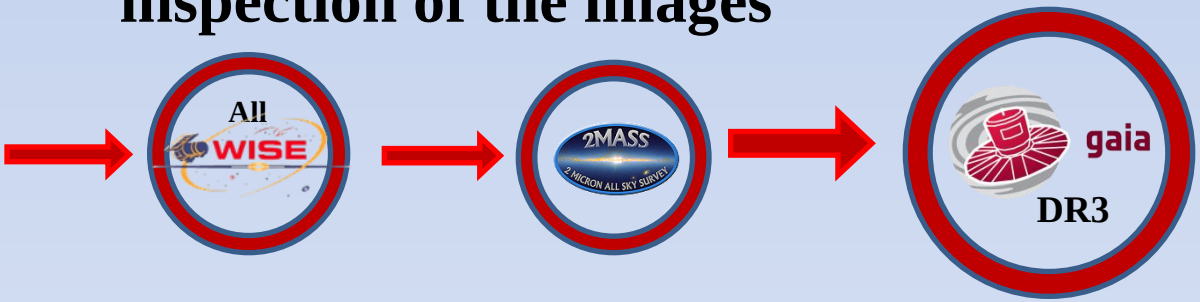
The *Gaia* Catalogue of Galactic AGB stars

Gaia counterpart identification



Engels & Bunzel 2015; Engels 2022

Refining coordinates by visually inspection of the images





Suh 202

All AGB star candidates in the *Gaia* DR3:

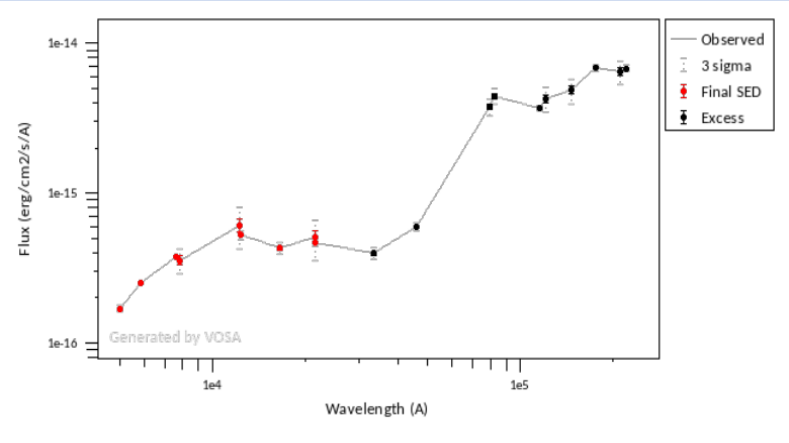
1487 OH/IR & 3691 O-rich (noOH) & 3430 C-rich

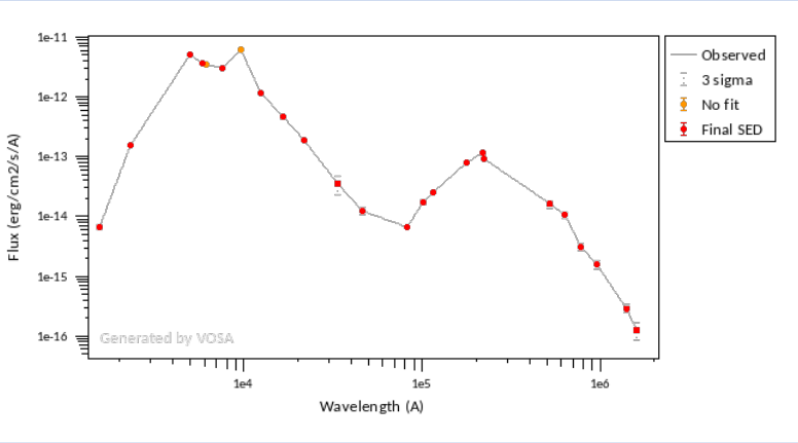
fran.jimenez-esteban@cab.inta-csic.es

The *Gaia* Catalogue of Galactic AGB stars

Contamination mitigation

1. **Cross-matching with SIMBAD**
   - Interlopers: PNe, RSGs, RCoBV, YSO, Symb., WRs, etc
2. **SED Analysis:**
   - Photometry from public catalogues in the VO





Variability of O- and C-rich AGB stars by Gaia

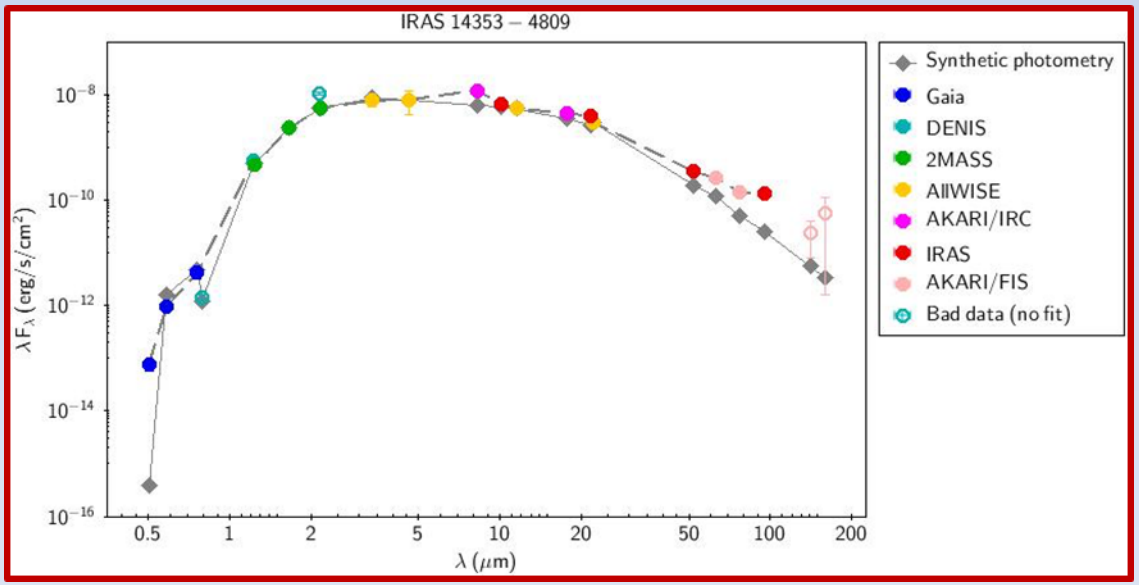
The *Gaia* Catalogue of Galactic AGB stars

Physical characterization

VOSA VO SED Analyzer

Physical parameters from SED fitting to GRAMS models
(Sargent et al. 2011; Srinivasan et al. 2011)

Bolometric flux



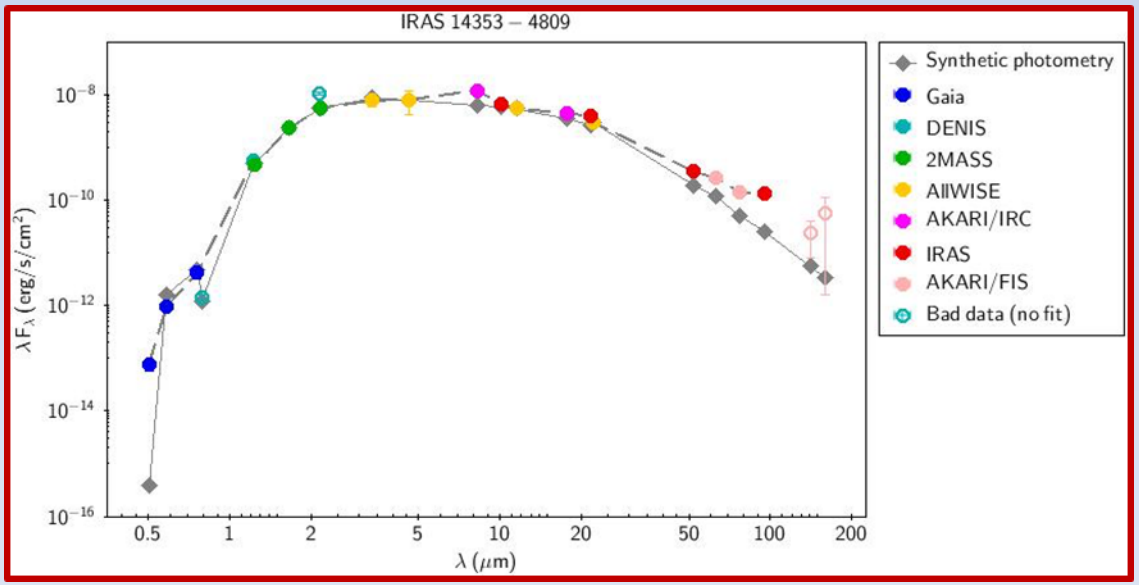
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Variability of O- and C-rich AGB stars by Gaia

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Physical characterization

VOSA VO SED Analyzer



Physical parameters from SED fitting to GRAMS models
(Sargent et al. 2011; Srinivasan et al. 2011)

Bolometric flux

Reliable distance subsample

- σ_π< 20% & aen <1.5
- Geometric distance
  (Bailer-Jones et al. 2021)
- Interstellar extinction
  (Lallement et al. 2022)

Luminosity

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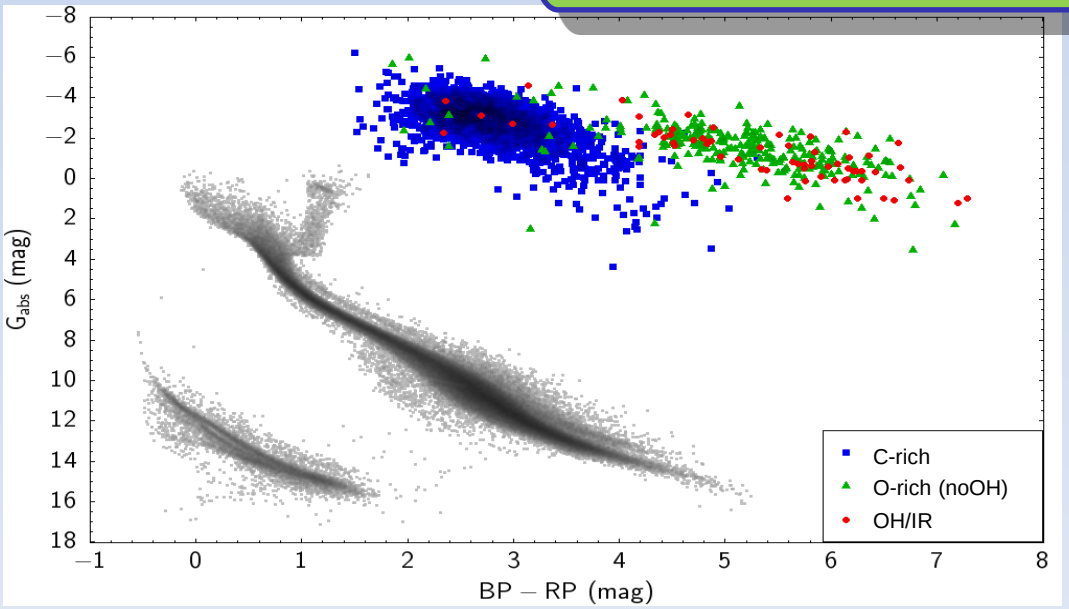
Variability of O- and C-rich AGB stars by Gaia

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Composition

We built a clean sample of AGB stars

Sample	OH/IR	O-rich	C-rich	**Total**
N	1171	3522	3202	**7895**
D & L	221	857	2274	**3352**



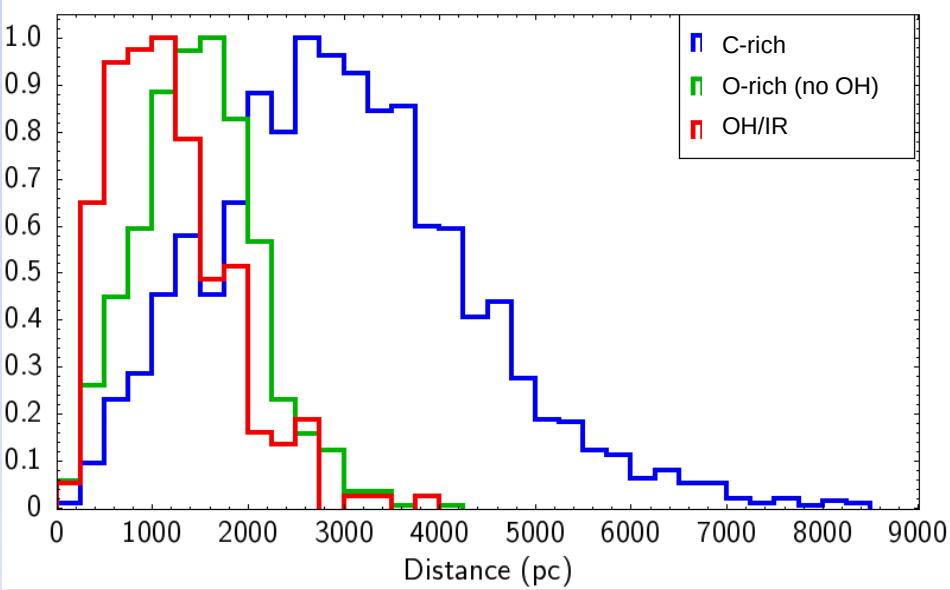
- López Martí et al. 2025, A&A, 698, 109L.
- Jiménez-Esteban et al. 2026, A&A, under revision

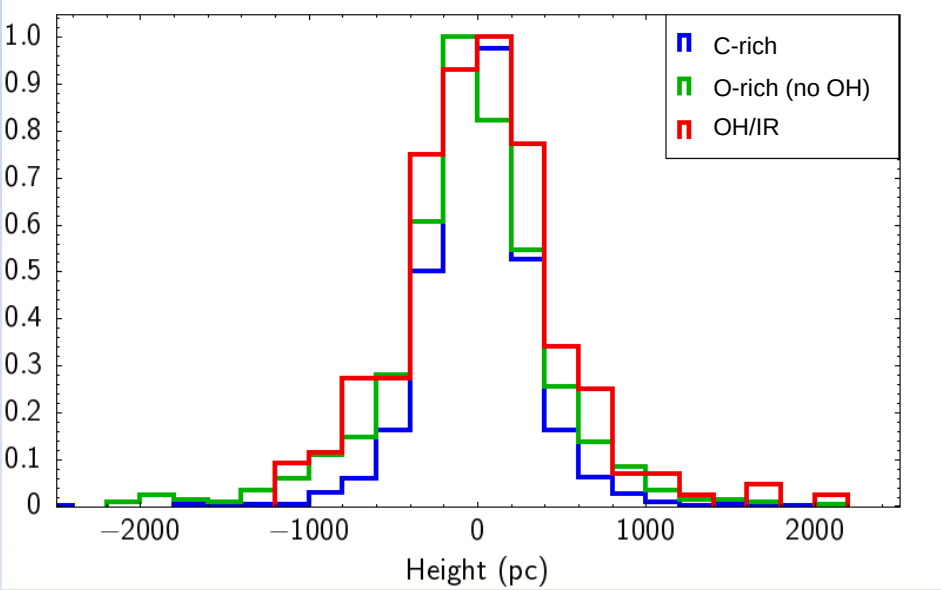
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The *Gaia* Catalogue of Galactic AGB stars

Properties: location

C-rich are generally located twice as far as OH/IR or O-rich
The three samples represent thin Galactic disc population





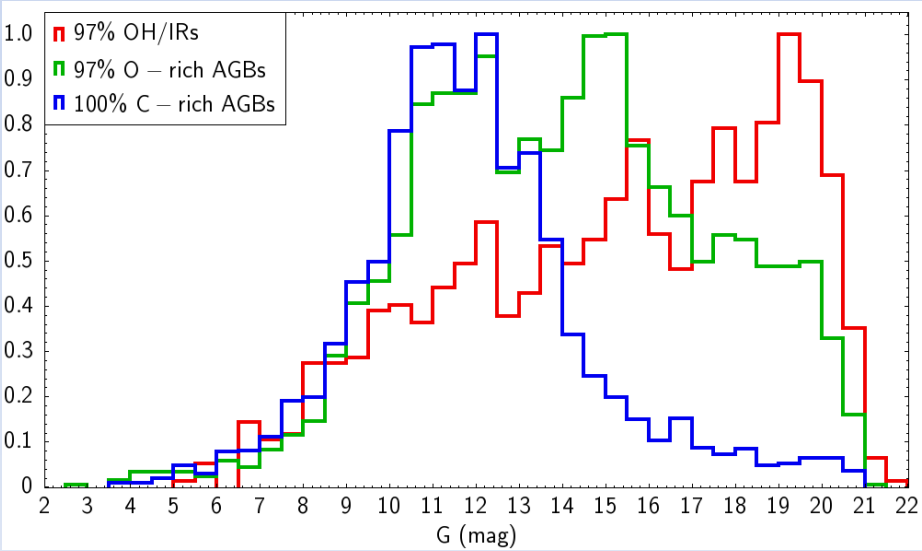
fran.jimenez-esteban@cab.inta-csic.es

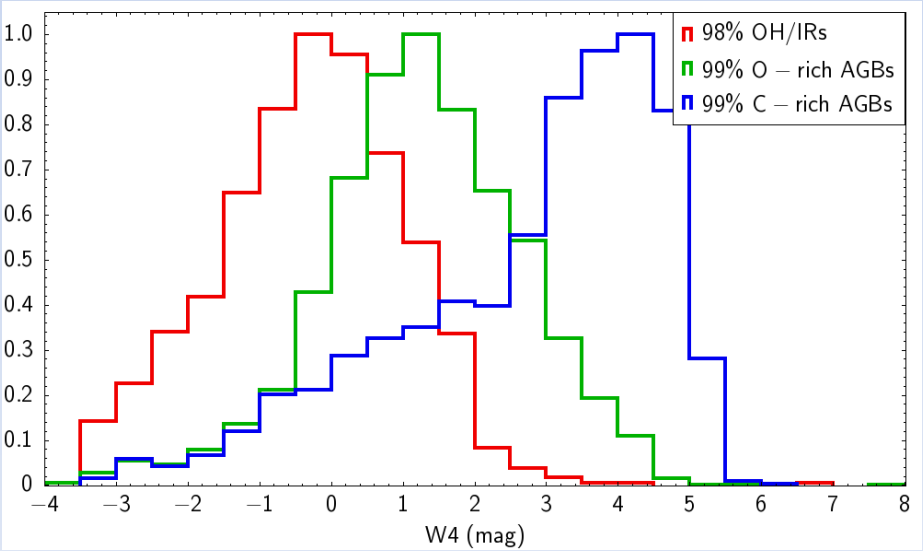
Variability of O- and C-rich AGB stars by Gaia

The *Gaia* Catalogue of Galactic AGB stars

Properties: brightness

C-rich sample is the brightest in the optical but the faintest in the mid-IR
OH/IR sample is the faintest in the optical but the brightest in the mid-IR



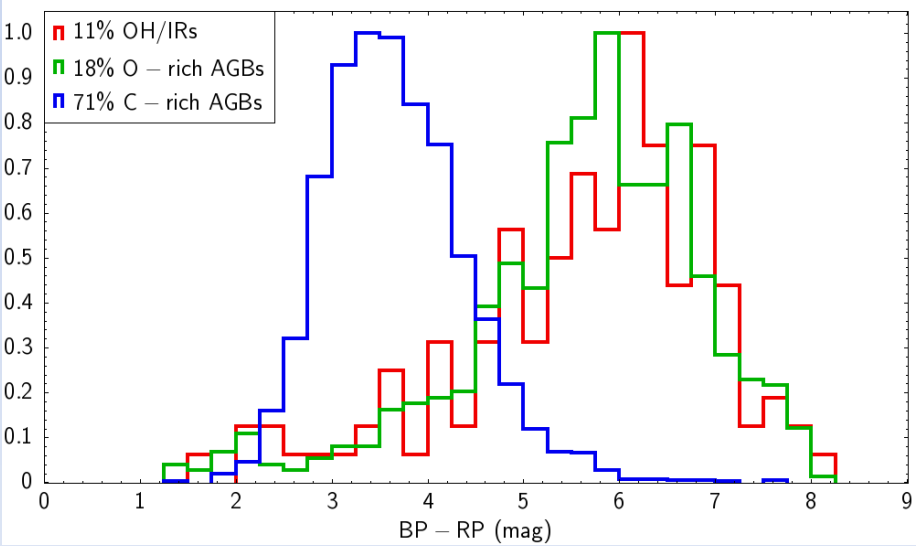


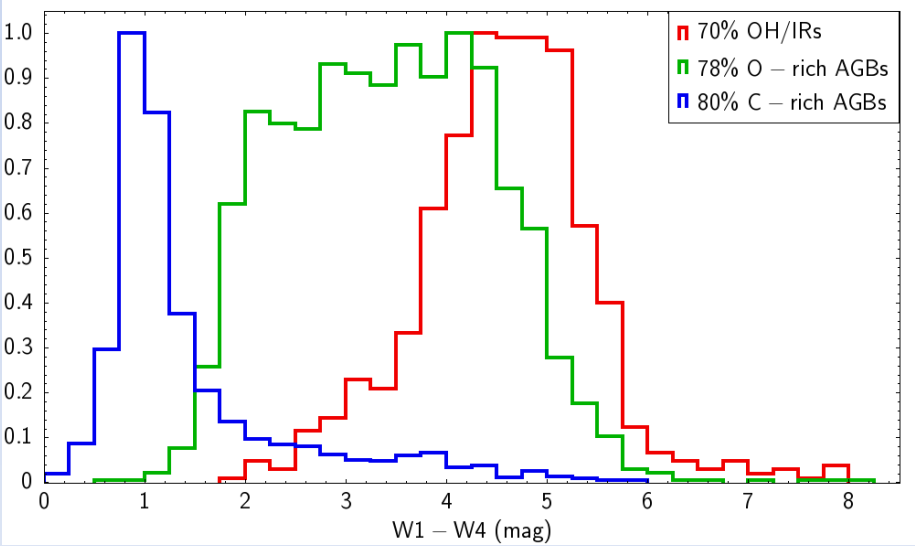
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The *Gaia* Catalogue of Galactic AGB stars

Properties: colours

C-rich sample is the bluest in the optical and in the mid-IR
OH/IR sample is the reddest in the optical and in the mid-IR





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Variability of O- and C-rich AGB stars by Gaia

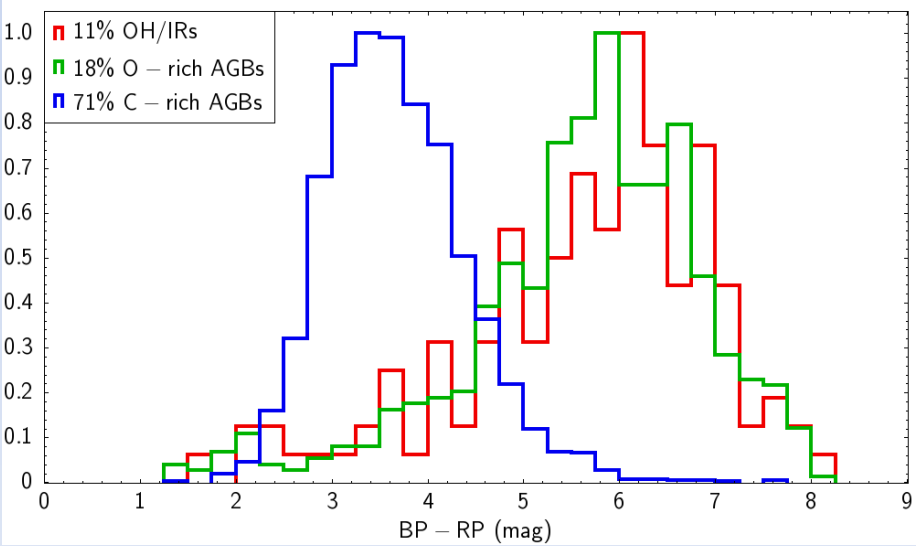
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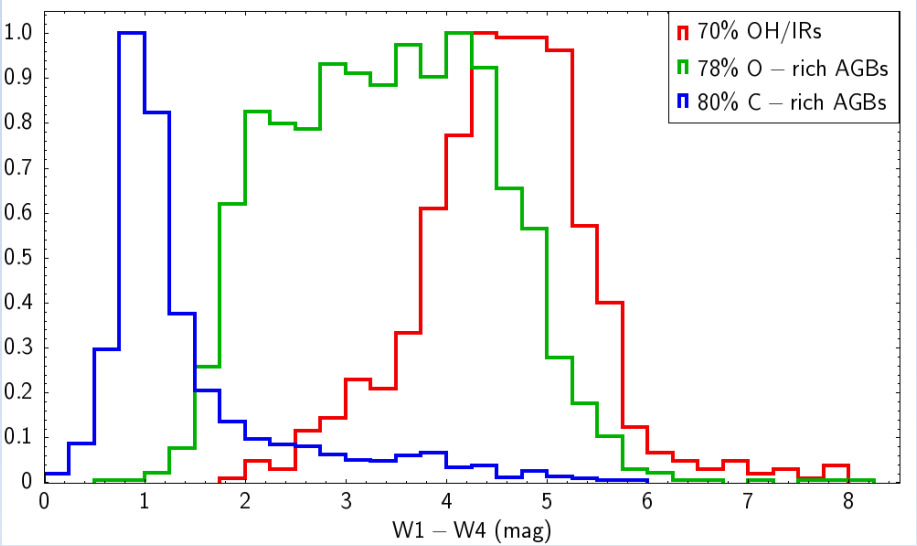
Properties: colours

C-rich sample is the bl
OH/IR sample is the re

OH/IR sample has the thickest CSE

C-rich sample has the thinnest CSE



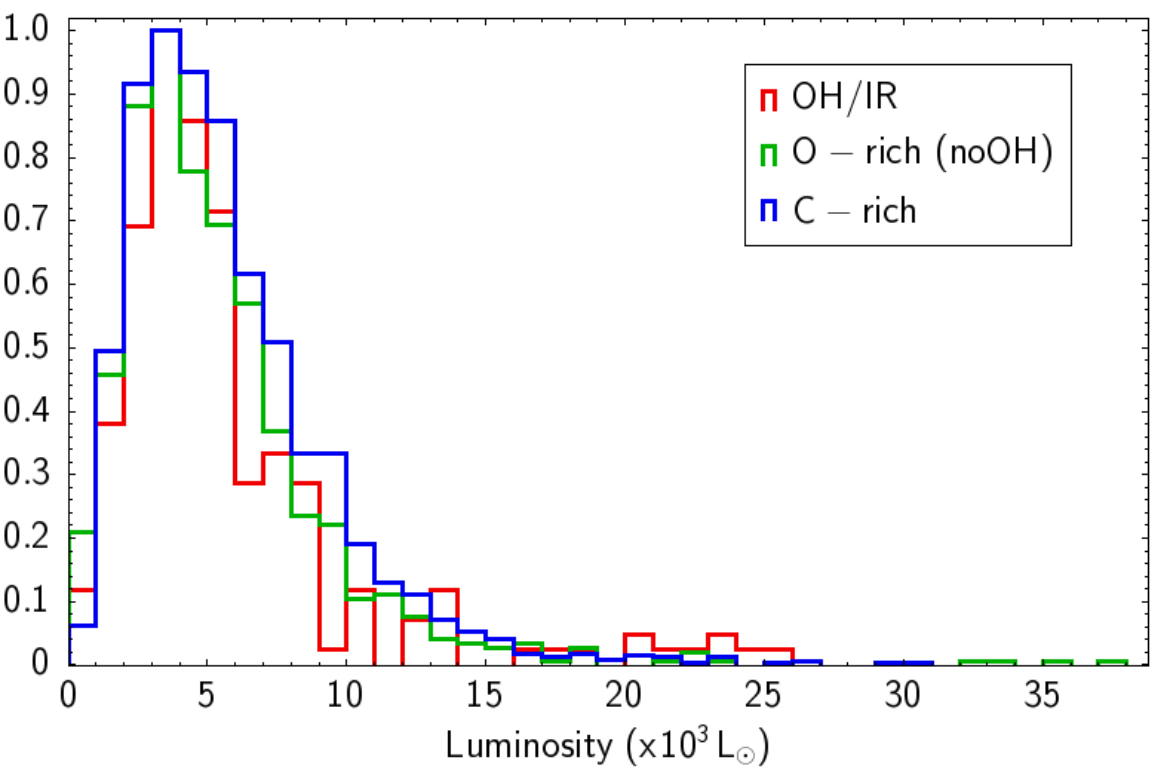


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Variability of O- and C-rich AGB stars by Gaia

The *Gaia* Catalogue of Galactic AGB stars

Properties: luminosity



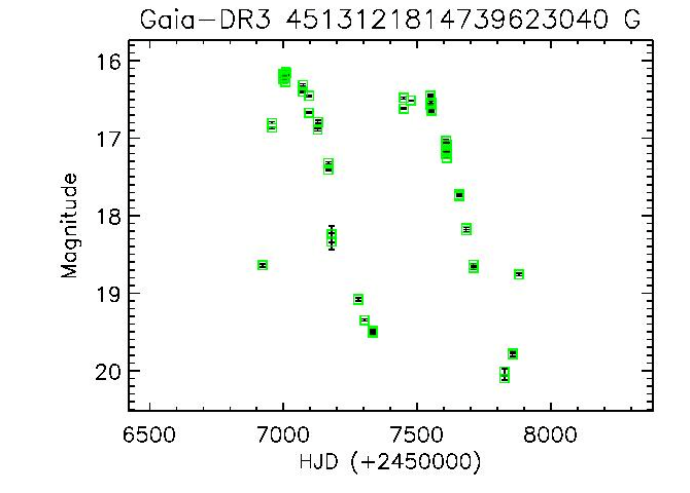
Luminosity distributions are similar and typical for AGB stars

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Variability of O- and C-rich AGB stars by Gaia

Variability analysis of the samples (preliminary work)

***Gaia* DR3 epoch photometry:** G-band with an error flux < 20%



***Gaia* DR3 light curves:**

- 989 OH/IRs
- 3053 O-rich (noOH)
- 3072 C-rich

Asymmetric cosine light curve model (Jiménez-Esteban et al. 2021)

$$m(t_i) = \overline{m} + \frac{A}{2} cos\left(2\pi\Omega(t_i)\right)$$

$$\Omega(t_i) = \begin{cases} \frac{t_i - t_0}{2Pf} & \text{when } 0 \leq \frac{t_i - t_0}{P} < f \\ \frac{t_i - t_0 - P}{2P(1-f)} + 1 & \text{when } f \leq \frac{t_i - t_0}{P} < 1 \end{cases}$$

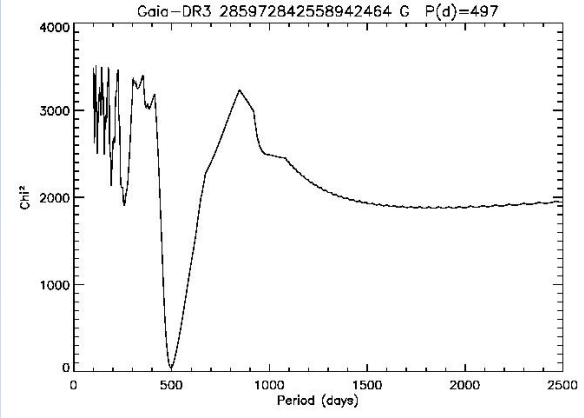
rising branch
- f < 0.5 → steeper
- f > 0.5 → shallower

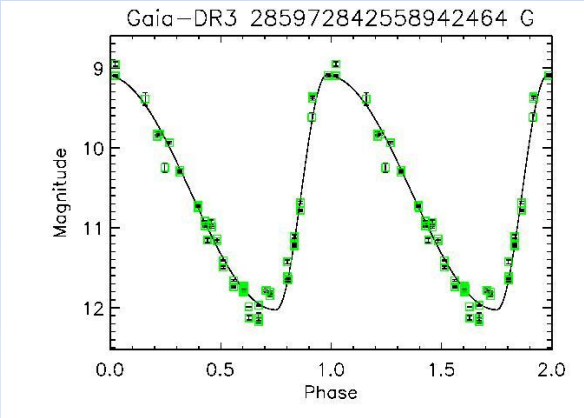
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Variability of O- and C-rich AGB stars by Gaia

Variability analysis of the samples (preliminary work)

***Gaia* DR3 epoch photometry:** G-band with an error flux < 20%





Filter out results:

- $N_{obs} > 20$
- $200 < P < 700$ d
  (2/3 of Gaia obs time range)

***Gaia* DR3 periods:**

- 795 OH/IRs
- 2722 O-rich (noOH)
- 1951 C-rich

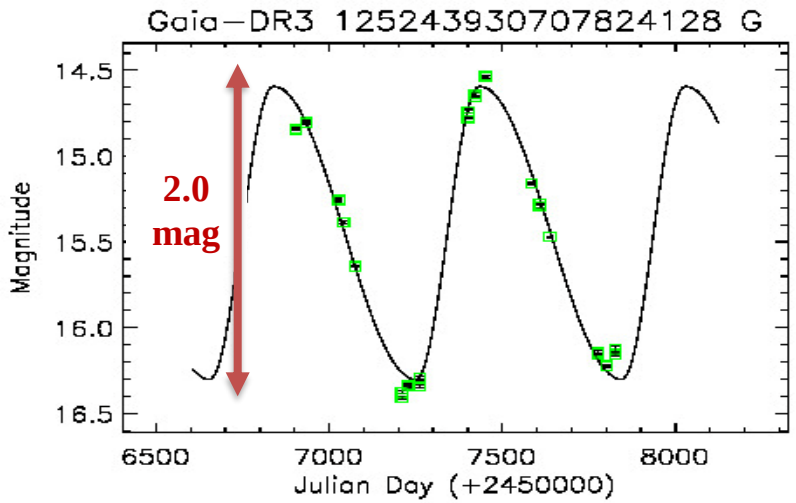
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Variability properties

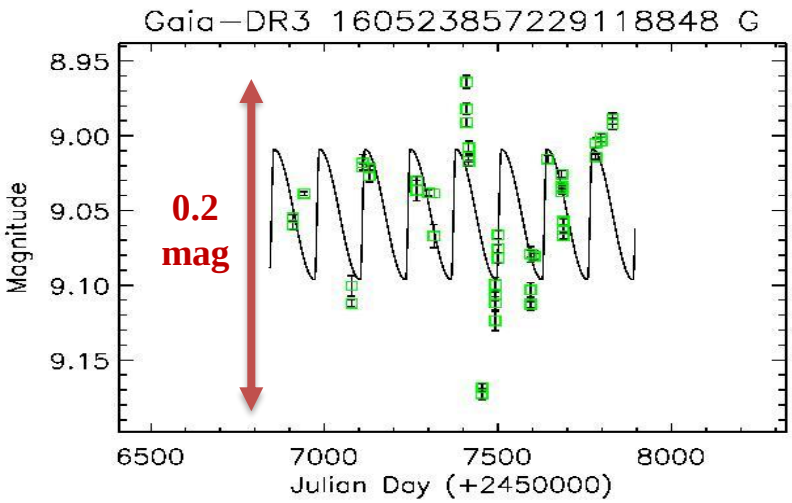
Two types of variables:

- Large amplitude regular variables
- Small amplitude semiregular variables

Large amplitude regular variable



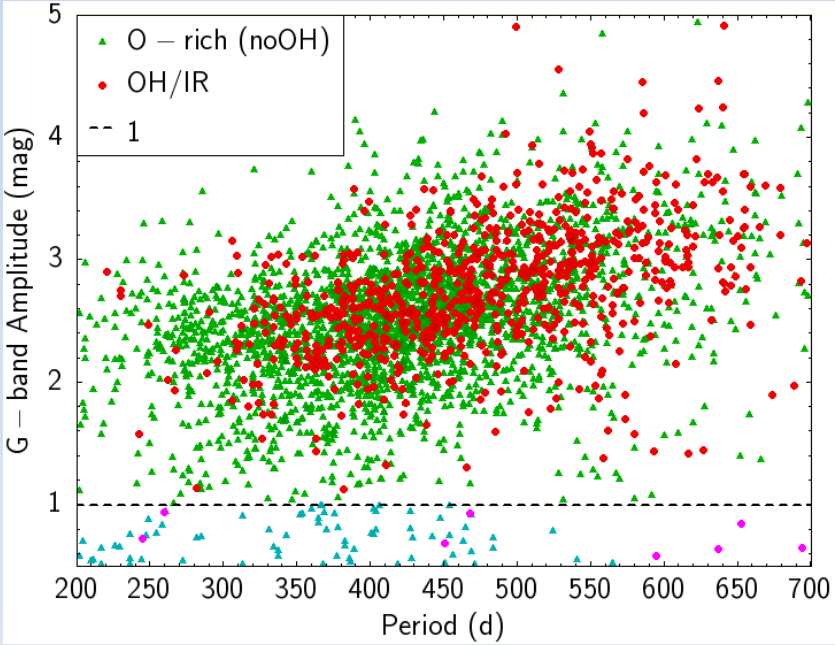
Small amplitude semiregular variable

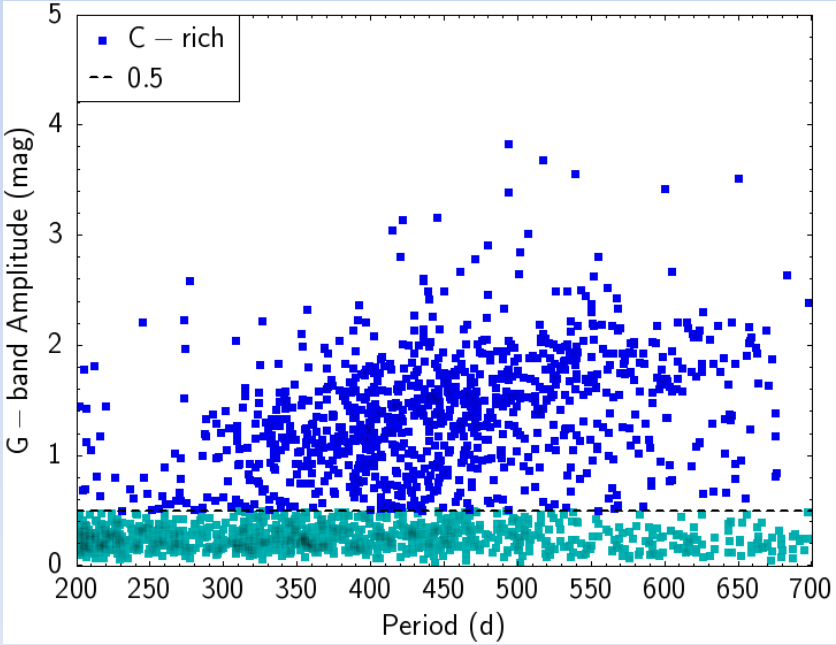


Variability properties

Two types of variables:

- Large amplitude regular variables: Almost all (>94%) of OH/IR and O-rich (noOH)
- Small amplitude semiregular variables: ~50% of C-rich





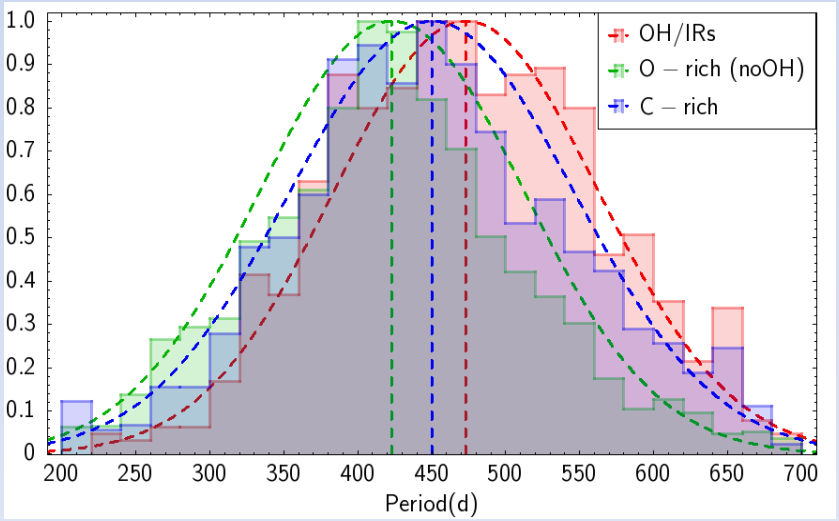
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Variability of O- and C-rich AGB stars by Gaia

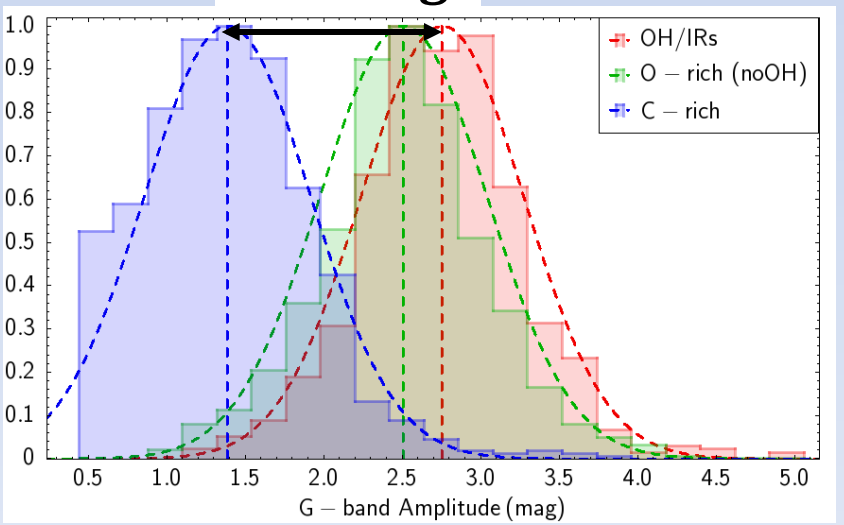
Variability properties

Large amplitude regular variable

- **Similar period distributions** ($P_{O\text{-rich}} < P_{C\text{-rich}} < P_{OH/IR}$)
- **Amplitude is smaller for C-rich** ($A_{C\text{-rich}} < A_{O\text{-rich}} < A_{OH/IR}$)



1.3 mag



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Variability of O- and C-rich AGB stars by Gaia

Variability properties

Period-Abs. mag. relation for regular variables

Lebzelter et al. 2022 (Gaia DR3 Coll.)

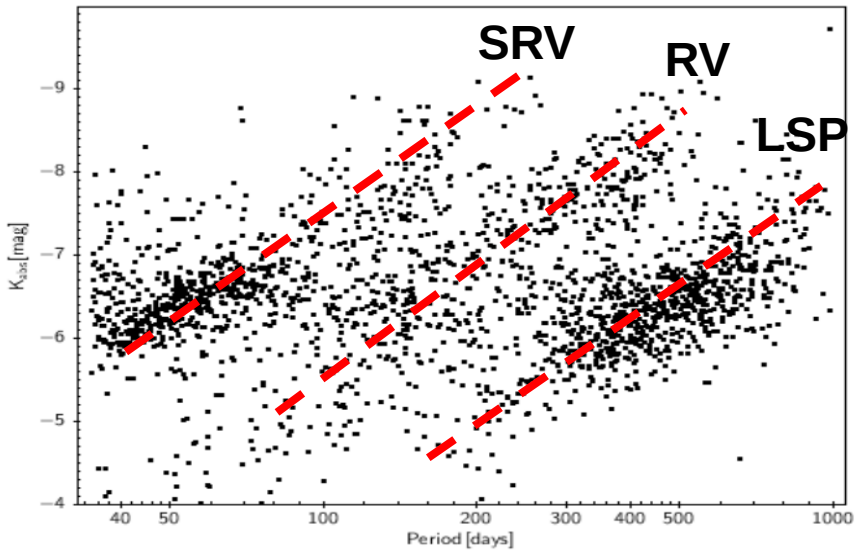


Fig. 32: logP-K diagram for solar neighbourhood LPVs. For this diagram, only stars with $0<\sigma_\pi/\pi<0.05$ have been chosen.

- 5% parallax error
- Semiregular variable
- Mira-like Regular variable
- Long secondary period

Variability of O- and C-rich AGB stars by Gaia

Variability properties

Period-Abs. mag. relation for regular variables

Lebzelter et al. 2022 (Gaia DR3 Coll.)

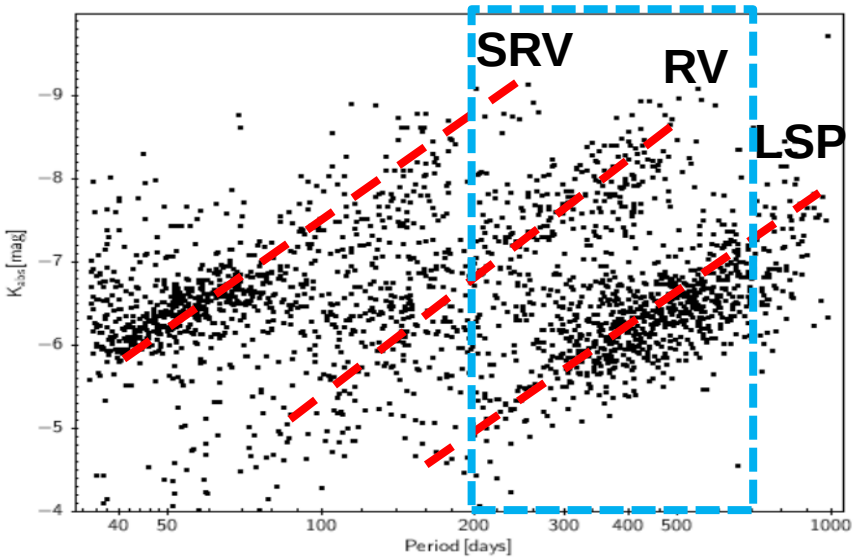


Fig. 32: logP-K diagram for solar neighbourhood LPVs. For this diagram, only stars with $0<\sigma_\pi/\pi<0.05$ have been chosen.

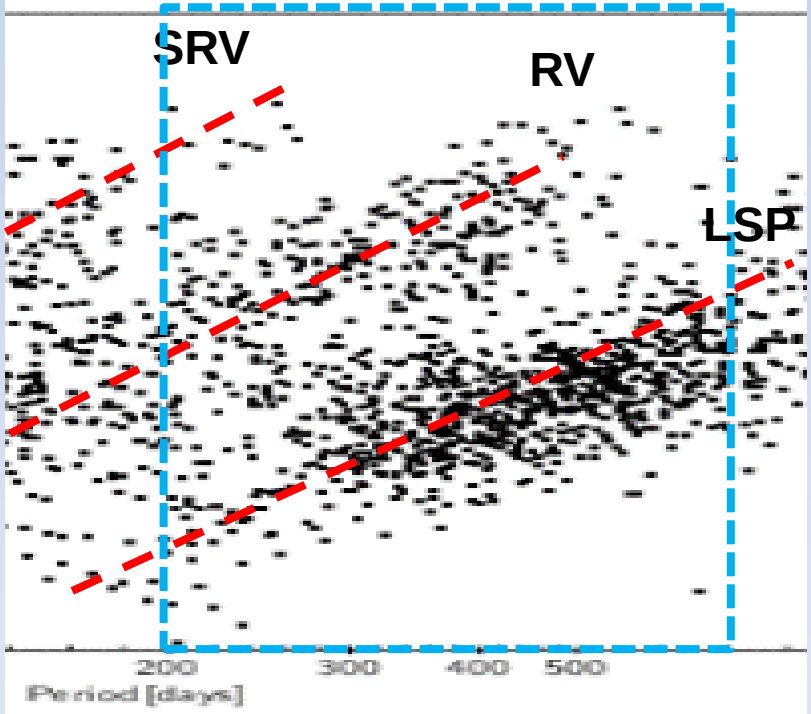
- 5% parallax error
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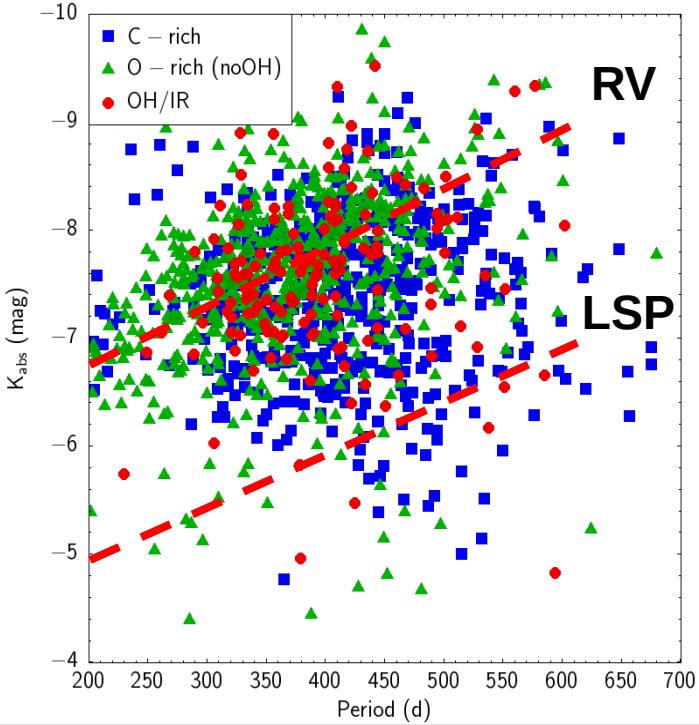
Variability properties

Period-Abs. mag. relation for regular variables

Lebzelter et al. 2022 (Gaia DR3 Coll.)



This work: 20% parallax error



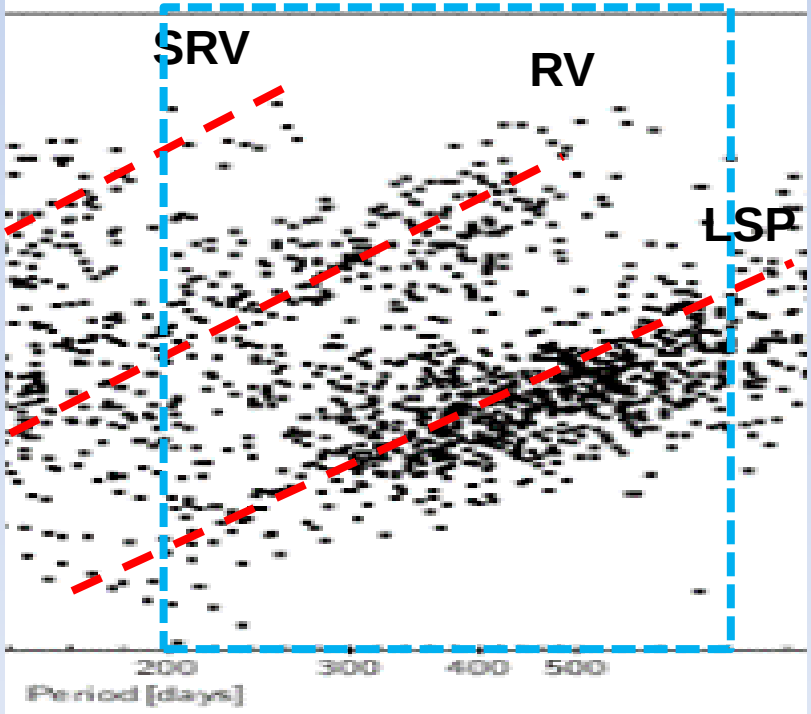
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Variability of O- and C-rich AGB stars by Gaia

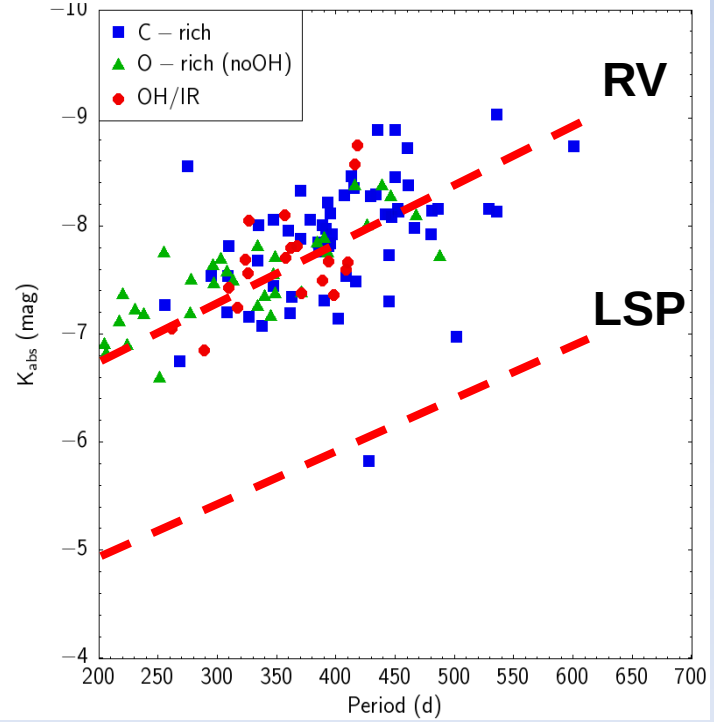
Variability properties

Period-Abs. mag. relation for regular variables

Lebzelter et al. 2022 (Gaia DR3 Coll.)



This work: 5% parallax error

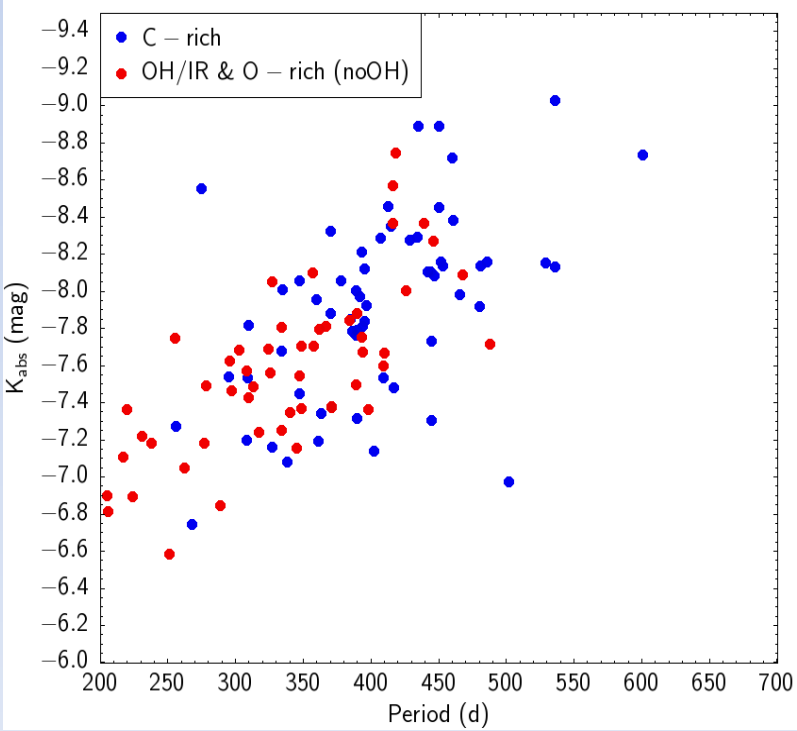


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Variability of O- and C-rich AGB stars by Gaia

Variability properties

Period-Abs. mag. relation for regular variables



5% parallax error.

Two chemistries:

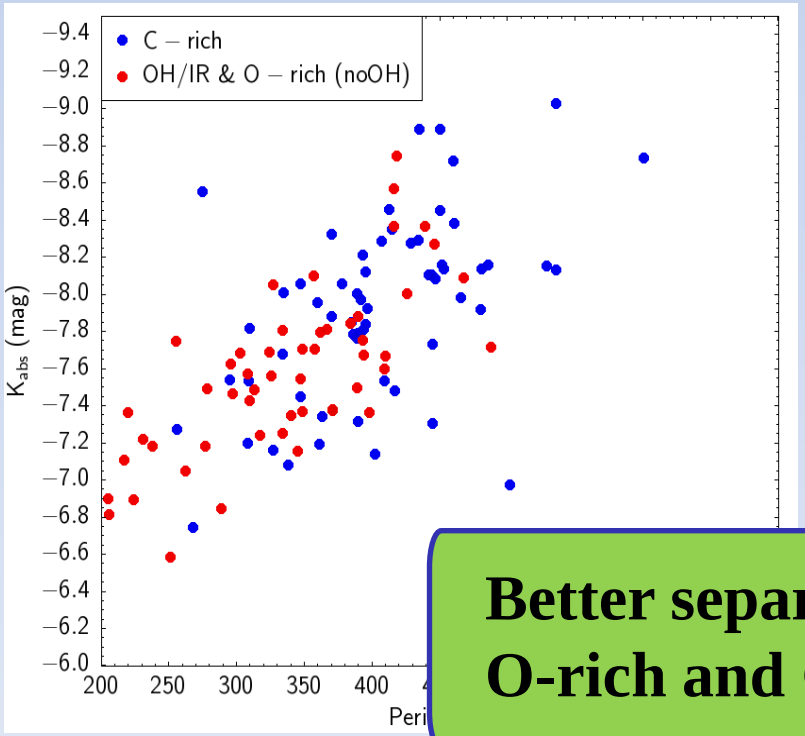
- C-rich
- O-rich: OH/IR & O-rich (noOH)

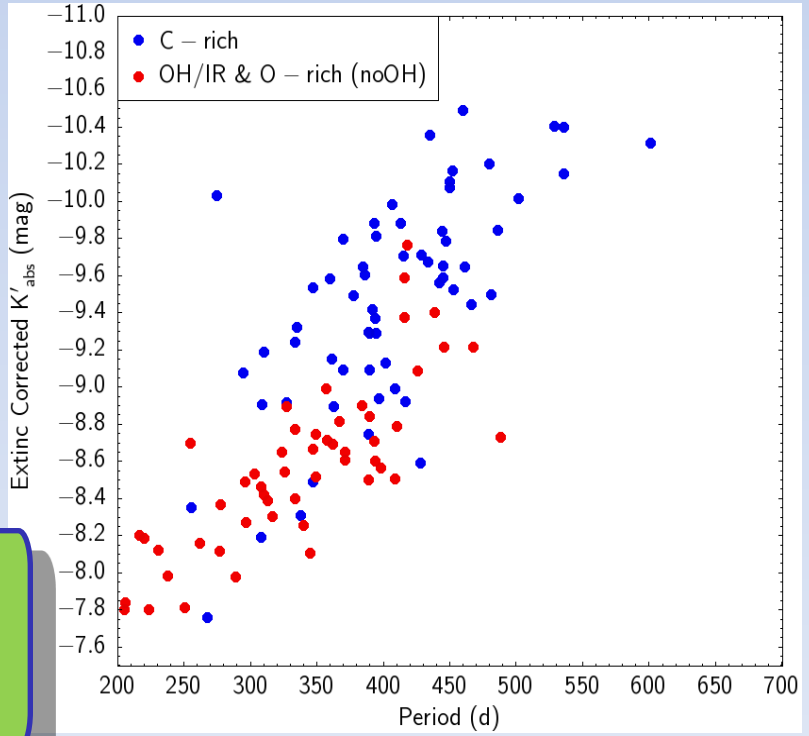
Variability of O- and C-rich AGB stars by Gaia

Variability properties

Period-Abs. mag. relation for regular variables

Wesenheit function to correct for extinction K' = K-0.686*(J-K)





Better separation O-rich and C-rich

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C-rich

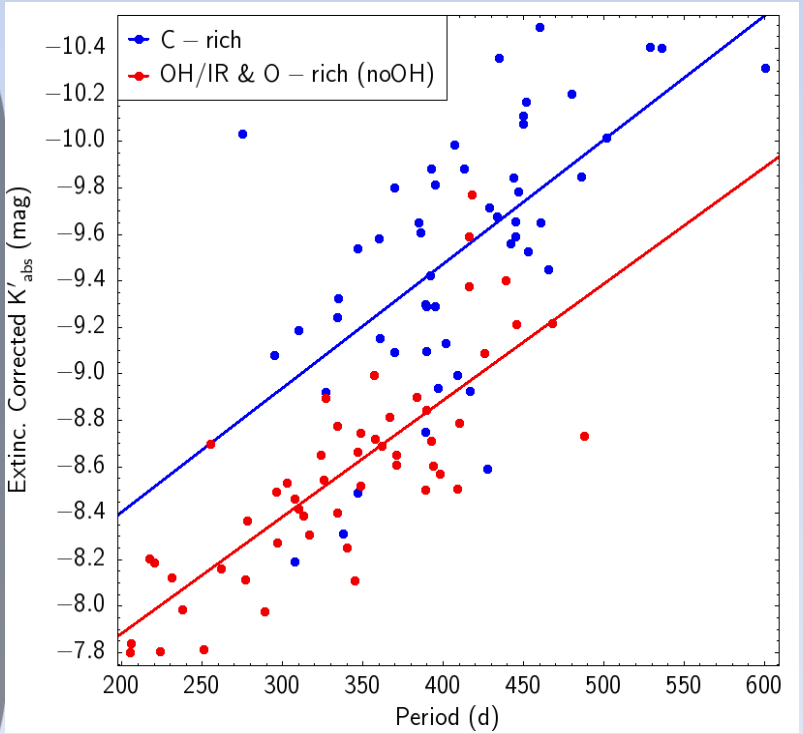
K'_{abs} (mag) = -4.86*logP(d) +3.15

Corr = 0.60; valid 300<P<600d

O-rich

K'_{abs} (mag) = -3.67*logP(d) +0.66

Corr = 0.79; valid 200<P<500d



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Conclusions

- Using Gaia DR3 and the VO we have created a **clean and reliable catalogue of galactic AGB stars** with OH/IR, O-rich (noOH) and C-rich chemistry
- We obtained the **luminosity from SED** model fitting and Gaia parallaxes
- For **Mira-like regular variables**
  - We **recover the Period-K_{abs}** relation from Lebzelter
  - We **better separate chemistries using Wesenheit function**
- **Prelaminar results that will be updated with Gaia-DR4**