A scientific guide to Gaia Astrophysical Parameters

Day 2

organized by Coordination Unit 8


ATHENS

ESP-CS Extended Stellar Parametrizer Cool Stars

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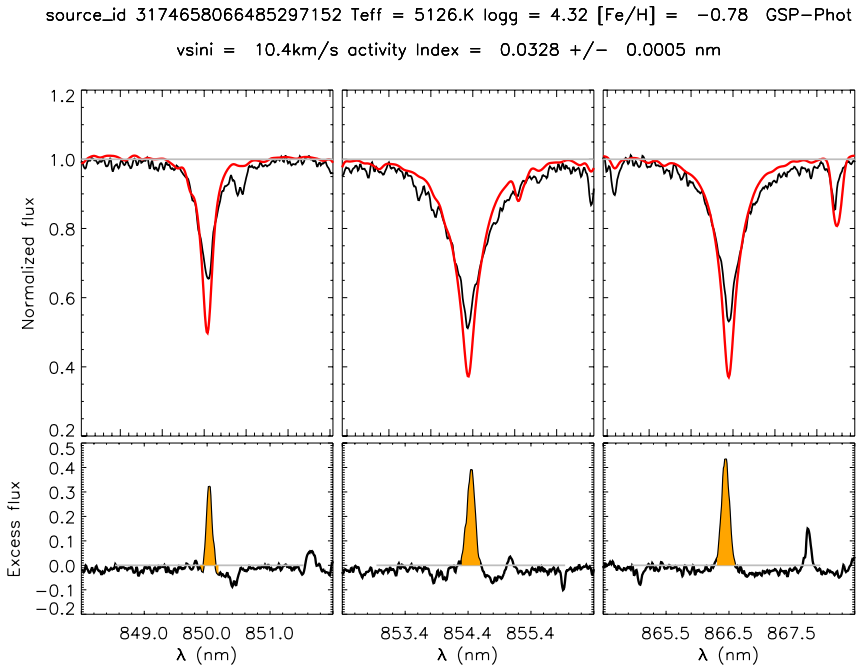
ESP-CS goals and scope (DR3)

- Compute a chromospheric activity index from the Ca II IRT lines in RVS spectra

- $G \leq 13;\ T_{eff} \in (3000, 7000)K;\ \log g \in (3.0, 5.0);\ [\mathrm{M/H}] \in (-0.5, 1.0)$
- Activity index estimated on $\approx 2M$ stars

Method



$$\alpha \equiv \int_{-\Delta\lambda}^{+\Delta\lambda} \left(\frac{r_\lambda^{\mathrm{obs}}}{r_\lambda^{\mathrm{templ}}} - 1 \right) d\lambda ,$$

$$\Delta\lambda = 0.15 \text{ nm}$$

$$r_\lambda \equiv \frac{f_\lambda}{f_\lambda^c} .$$

Method

- Activity index as the **excess equivalent width factor** in the core of the lines.
- It is a proxy of the chromosphere activity or mass accretion in PMS stars
- Radiative equilibrium model spectrum is an interpolation over a grid o MARCS synthetic spectra
- $(T_{\mathrm{eff}}, \log g\ , [M/H])$ from GSP-Spec or GSP-Phot.
- Rotational broadening from $v \sin i$ taken from CU6 (`vbroad`)
- The interpolated rotationally broadened synthetic spectrum is taken as template spectrum

Outputs

- The mean α (over the 3 lines) is stored as `activityindex_espcs` in the `astrophysical_parameters` table in nm units
- Uncertainties are evaluated by propagating the pixel standard error, ignoring theoretical uncertainties (parameter `activityindex_espcs_uncertainty` in nm units in the `astrophysical_parameters` table)
- A flag indicating the source of the input parameters is provided: `activityindex_espcs_input`; "`M1`"=GSP-Spec; "`M2`"=GSP-Phot

Usage / warnings

- α is a raw quantity unsuitable for comparing the activity in stars with different $(T_{\rm eff}, \log g\ , [M/H])$
- Reason: the observed equivalent width depends on a complex interplay between the photospheric radiation and the chromospheric plasma
- The same α value correspond to very different chromospheric heating for different $T_{\rm eff}$ (and to a lesser extent for different $\log g$ or $[M/H]$)
- α can be used in combination with the other fundamental parameters to compare chromospheric activity in a large range of $(T_{\rm eff}, \log g\ , [M/H])$ or discriminate chromospheric activity vs mass accretion
- α can be **negative** both because of parameters' uncertainties or because at low activity level the Ca II IRT **absorption lines can be deeper than the radiative equilibrium model lines**

Comparing activity in stars with different $T_{\rm eff}$

To compare activity in stars with different $T_{\rm eff}$ one must use:

$$R'_{\rm IRT} \equiv \frac{\mathcal{F}'}{\sigma T_{\rm eff}^4}$$

$$\mathcal{F}' = \mathcal{F} - \mathcal{F}_{\rm phot}$$

$$\mathcal{F}' = \mathcal{F}_c \Delta W \simeq \mathcal{F}_c \langle r_\lambda \rangle_{\rm core} \alpha \qquad \Delta W \equiv \int_{-\Delta\lambda}^{+\Delta\lambda} \left(r_\lambda^{\rm obs} - r_\lambda^{\rm templ} \right) d\lambda \qquad \Delta W \simeq \langle r_\lambda \rangle_{\rm core} \alpha$$

$$R'_{\rm IRT} \equiv \frac{\mathcal{F}'}{\sigma T_{\rm eff}^4} \simeq \left(\frac{\mathcal{F}_c \langle r_\lambda \rangle_{\rm core}}{\sigma T_{\rm eff}^4} \right) \alpha$$

$$\log R'_{\rm IRT} \simeq (C_0 + C_1\theta + C_2\theta^2 + C_3\theta^3) + \log \alpha$$

$$\theta = \log T_{\rm eff}$$

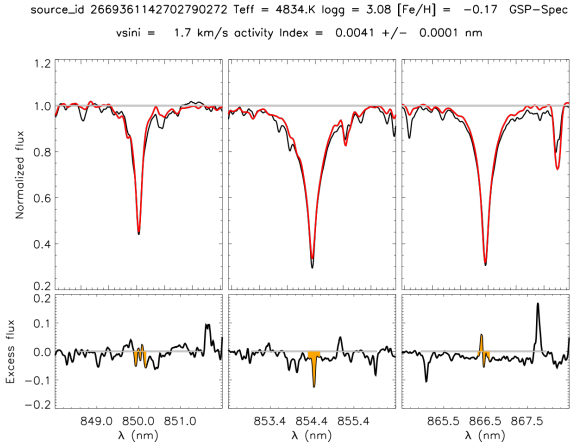
Lanzafame+2023

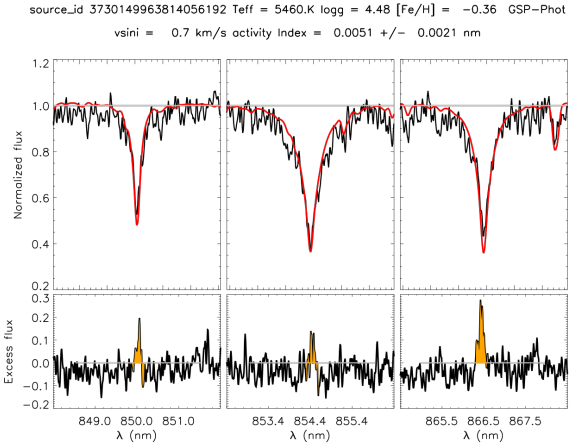
Validation

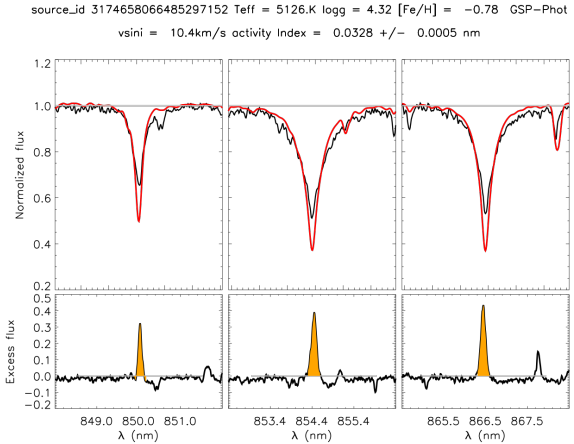
Spectra of

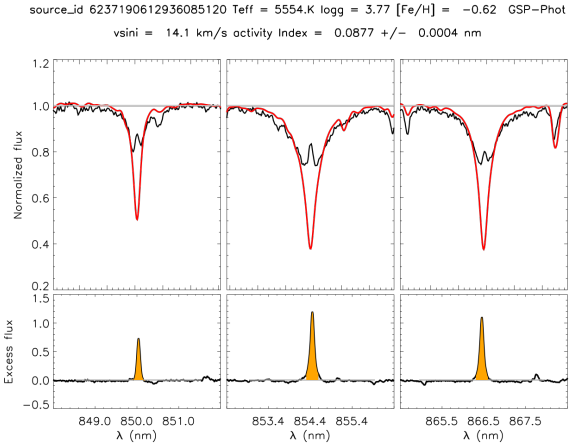
Low / high activity / accretion

stars

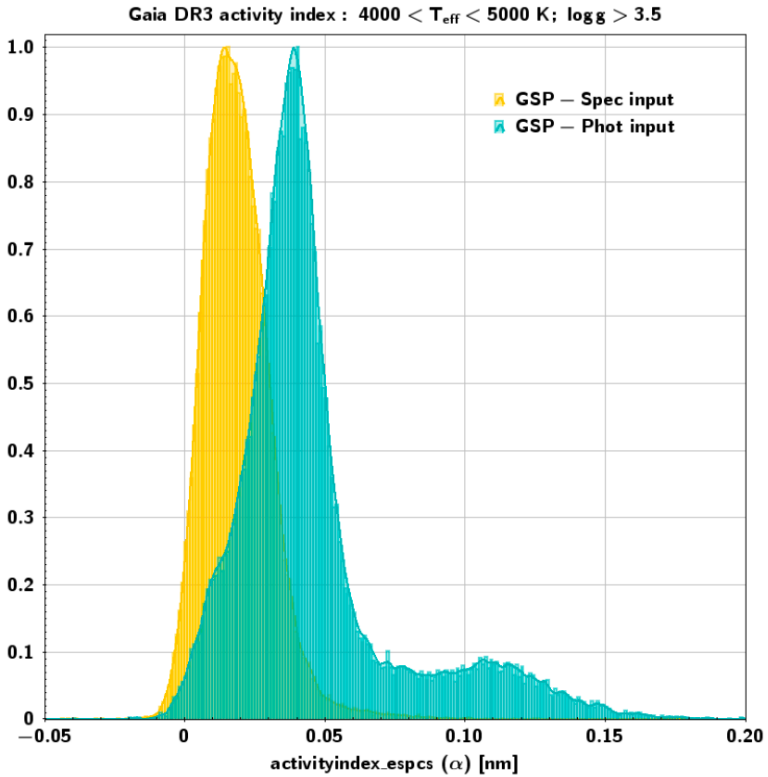


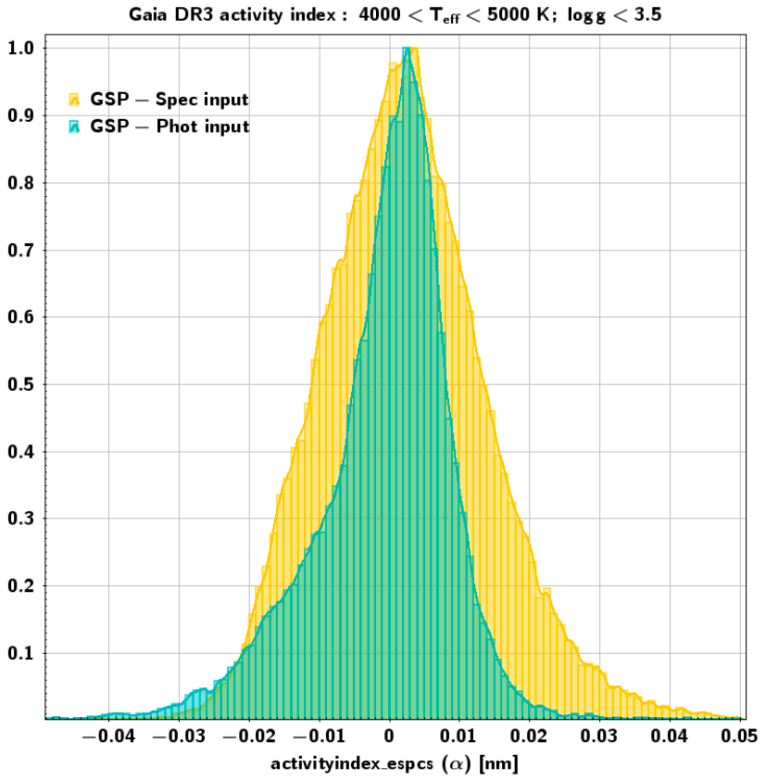






Validation: α hystogram





Validation: R'$_{IRT}$ vs R'HK

Input from GSP-Phot

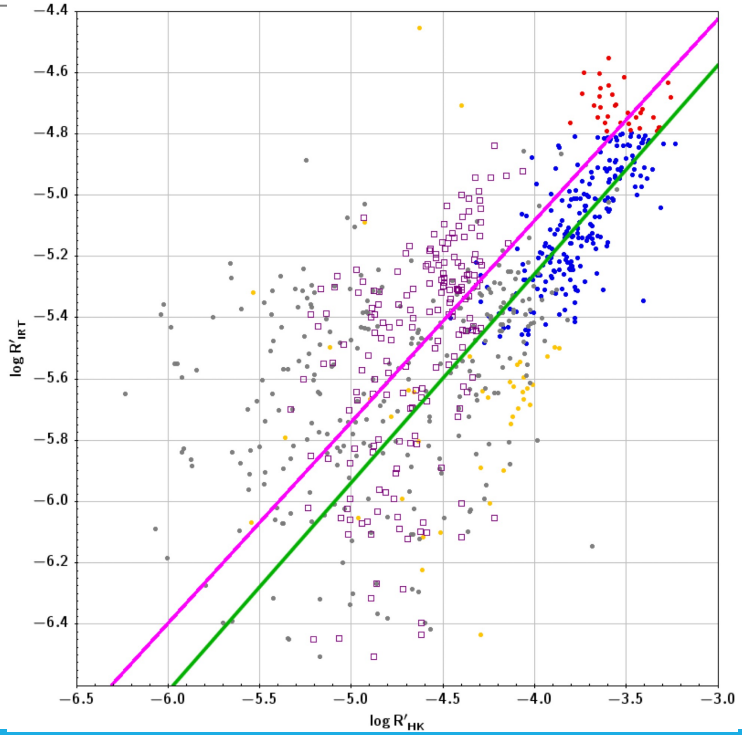
Open squares: Boro Sikia + 2018 $r = 0.5$

$$\log R'_{\mathrm{IRT}} = 0.65691 \log R'_{\mathrm{HK}} - 2.45543$$

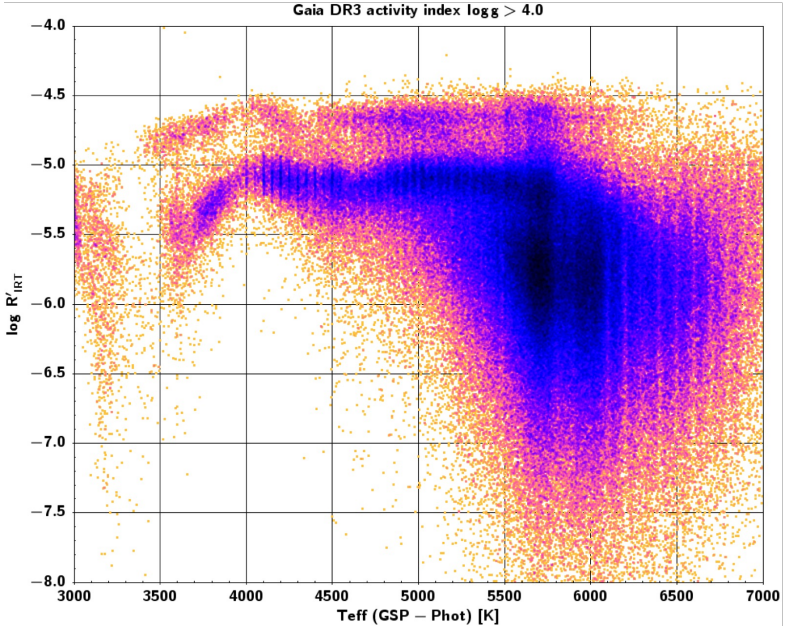
Others: FEROS $r = 0.73$

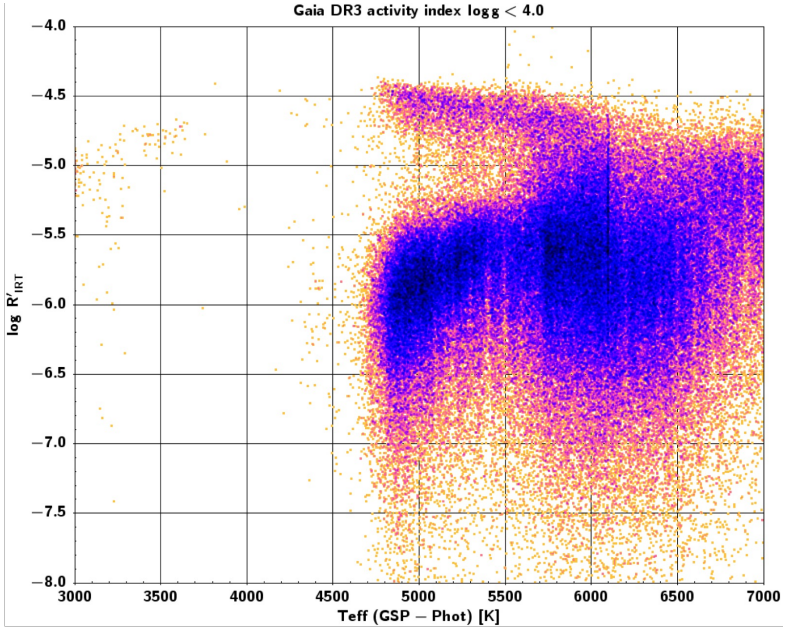
$$\log R'_{\mathrm{IRT}} = 0.68066 \log R'_{\mathrm{HK}} - 2.53461$$

Grey: input from GSP-Spec

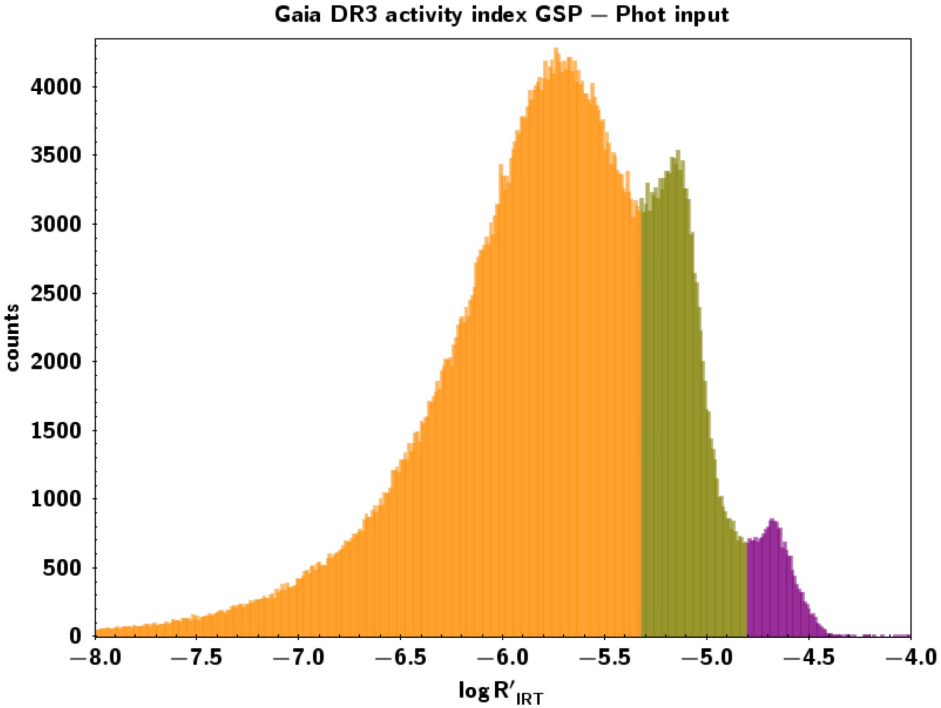


Validation: R'$_{IRT}$ vs T_{eff}

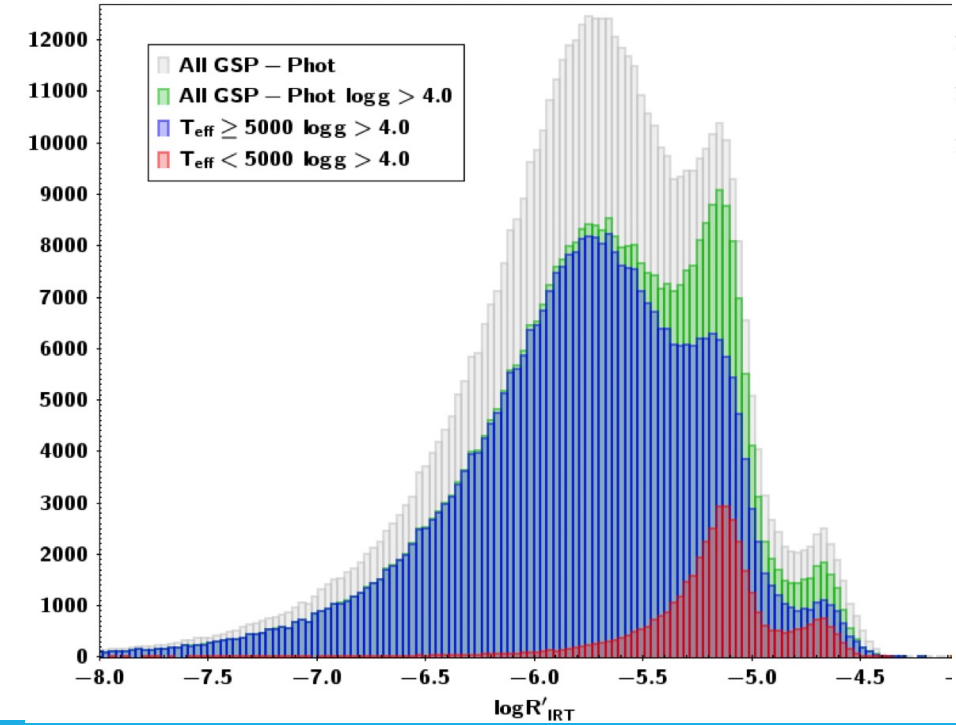


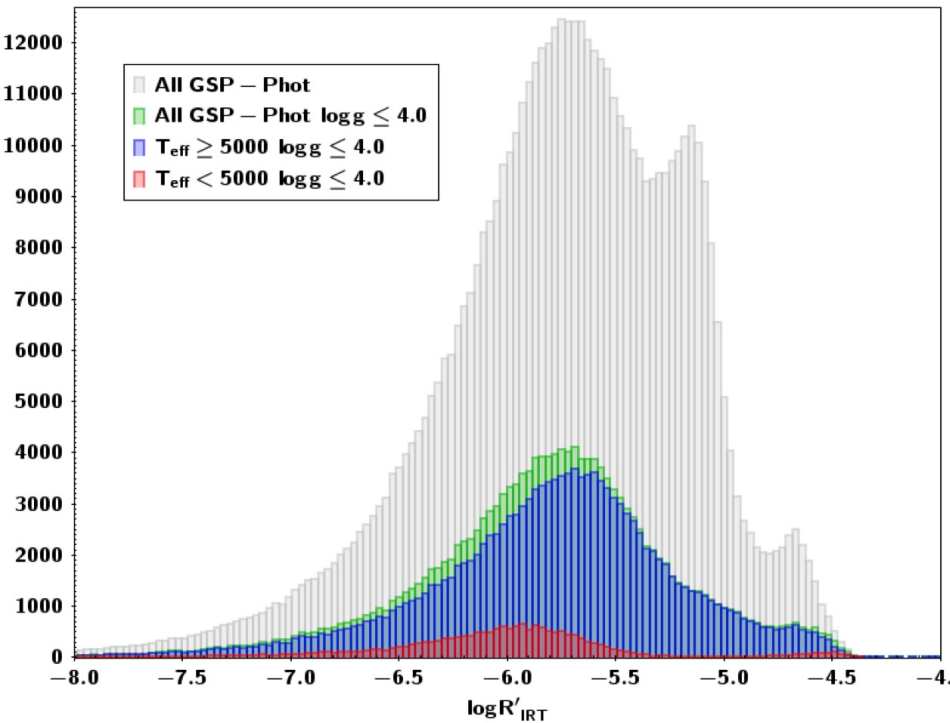


Validation: clustering

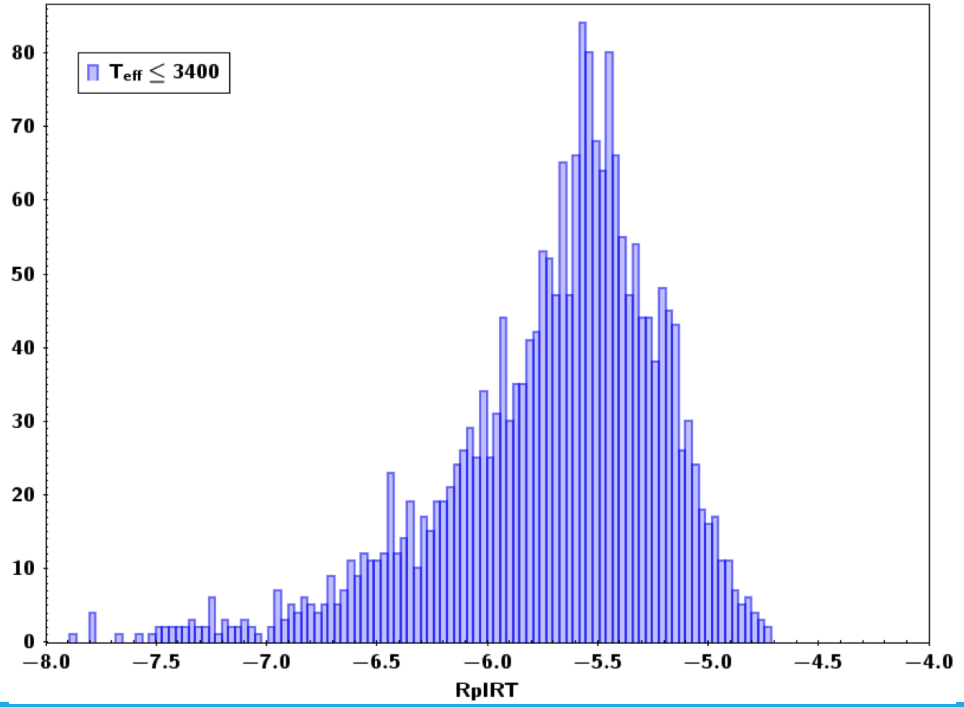


Validation: clustering

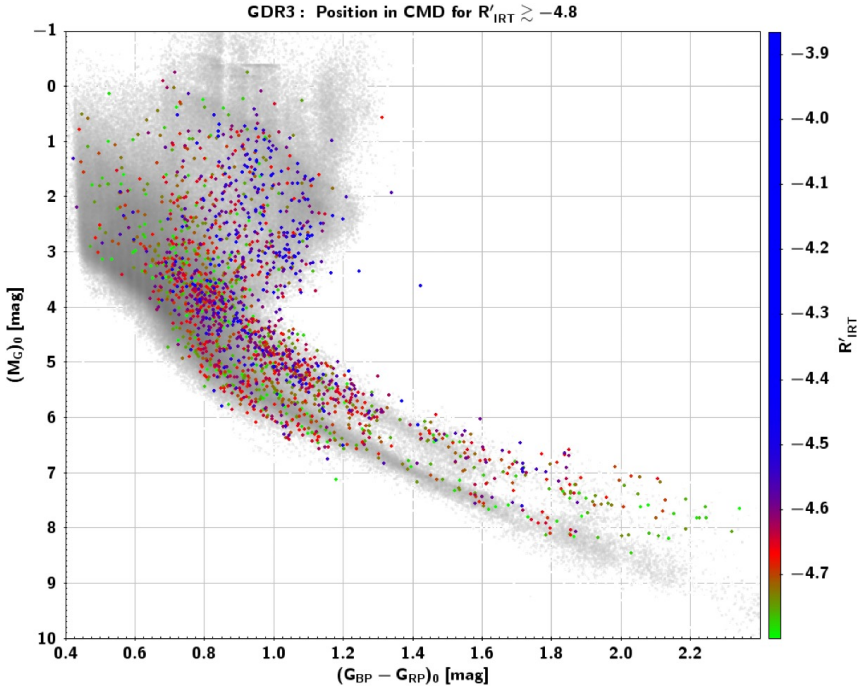


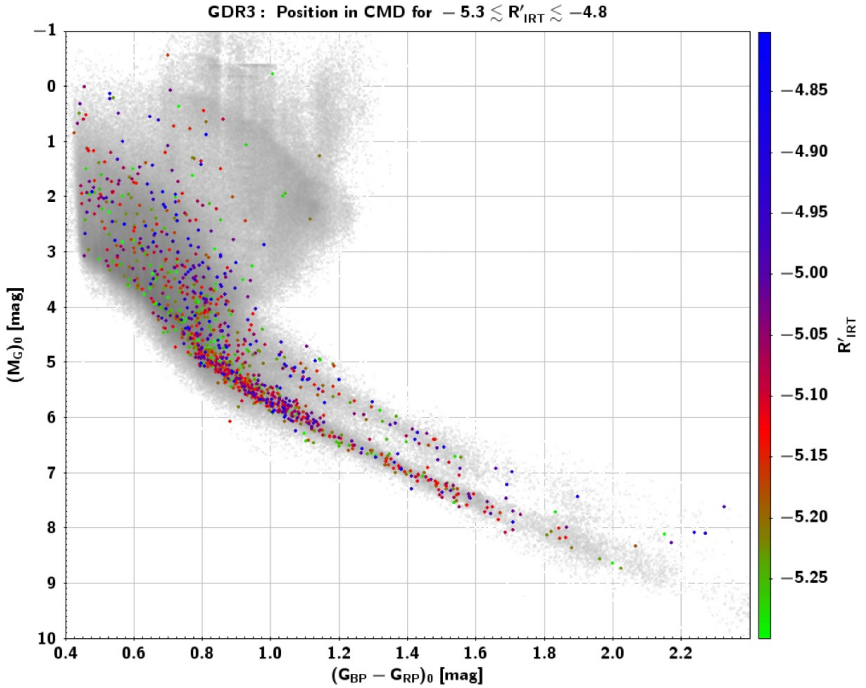


Validation: clustering



Validation: systematics in the CMD





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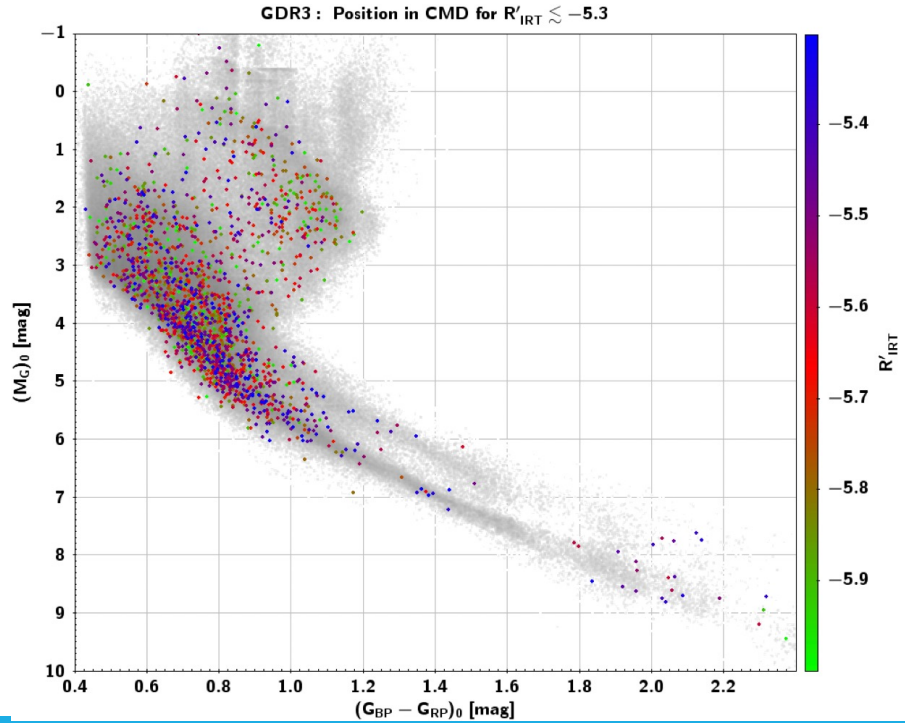
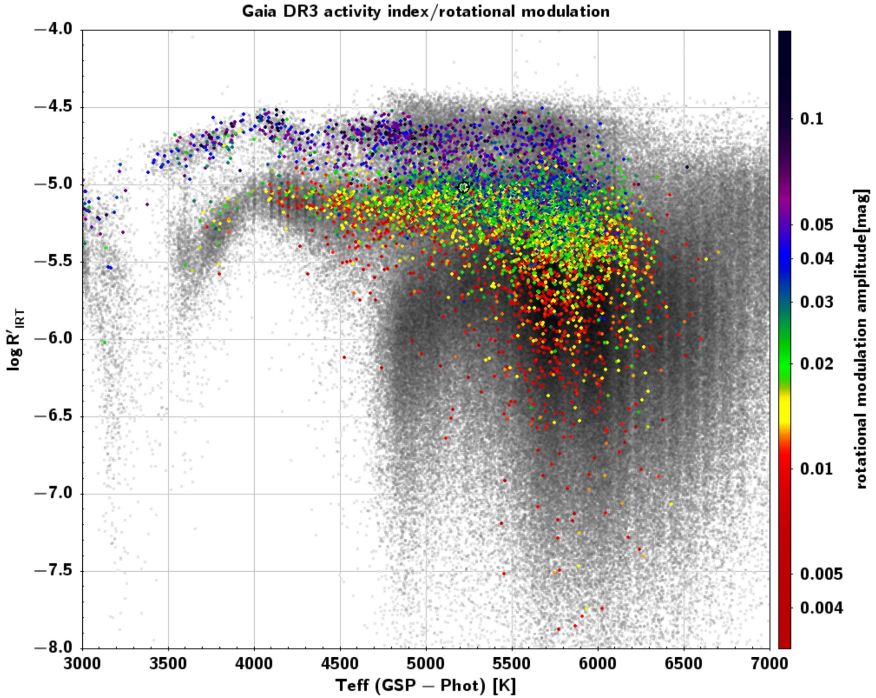
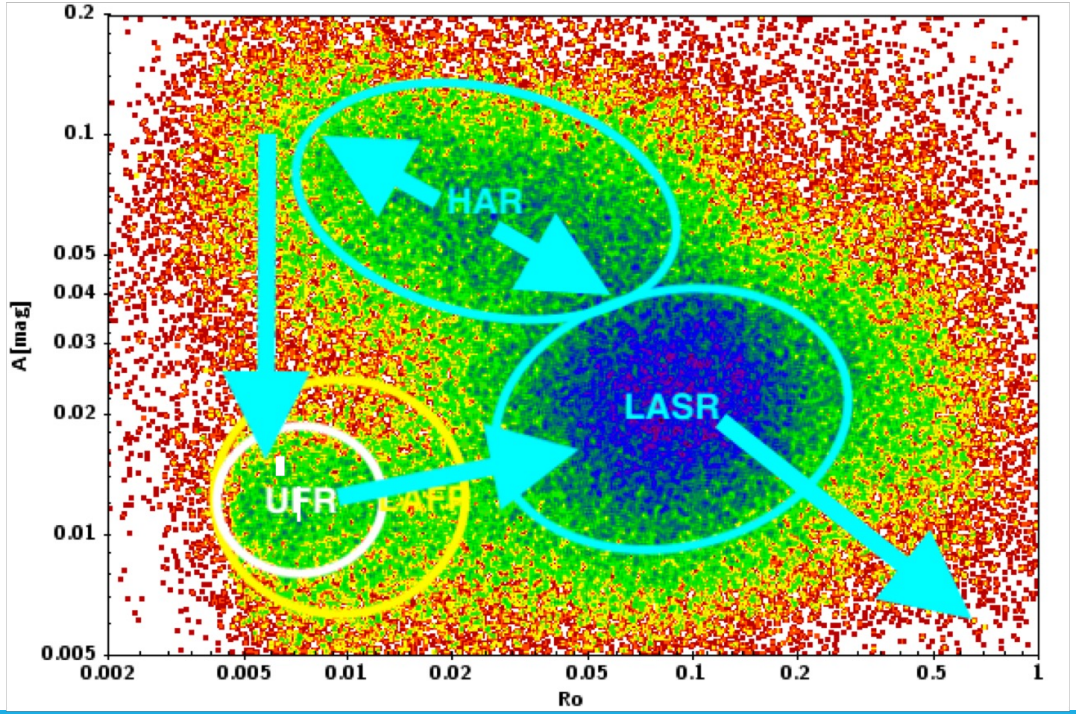


Validation: correlation with rotational modulation



Validation: correlation with rotational modulation



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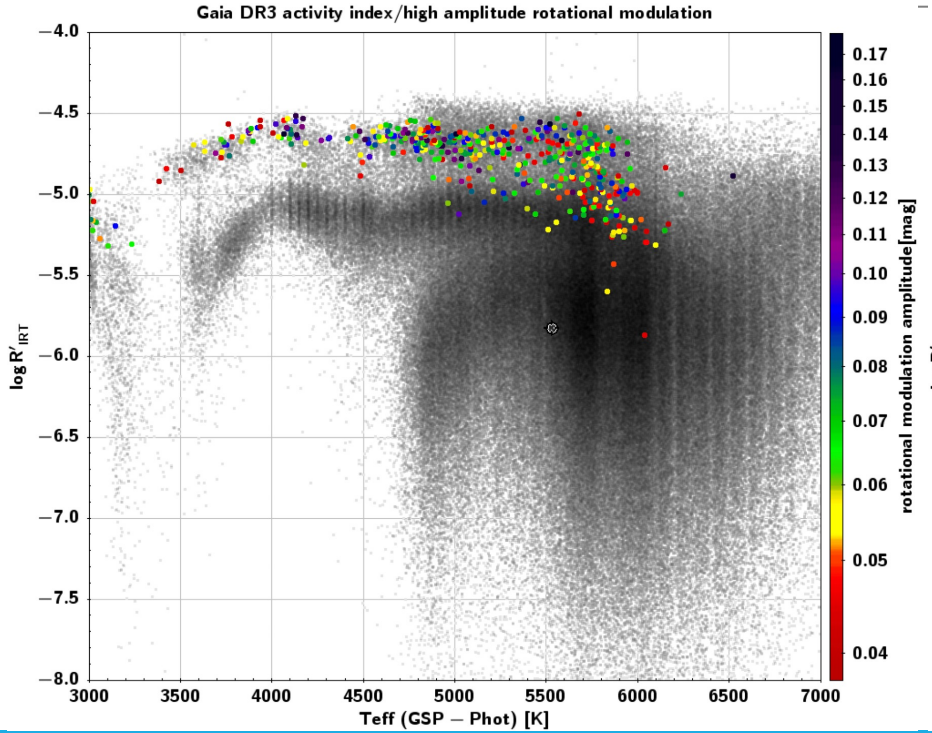
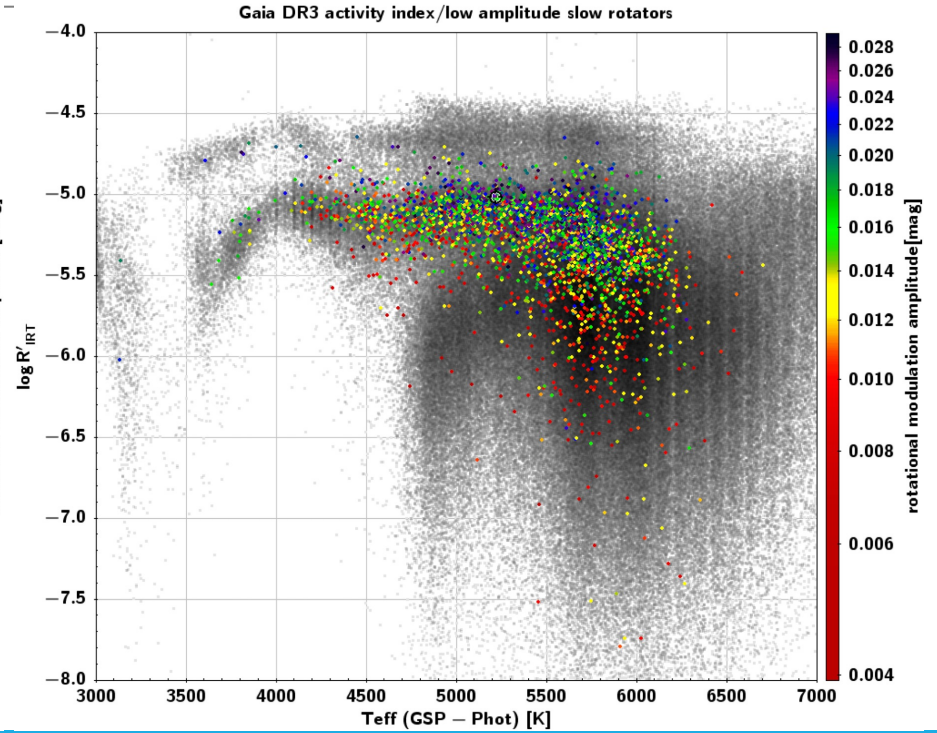
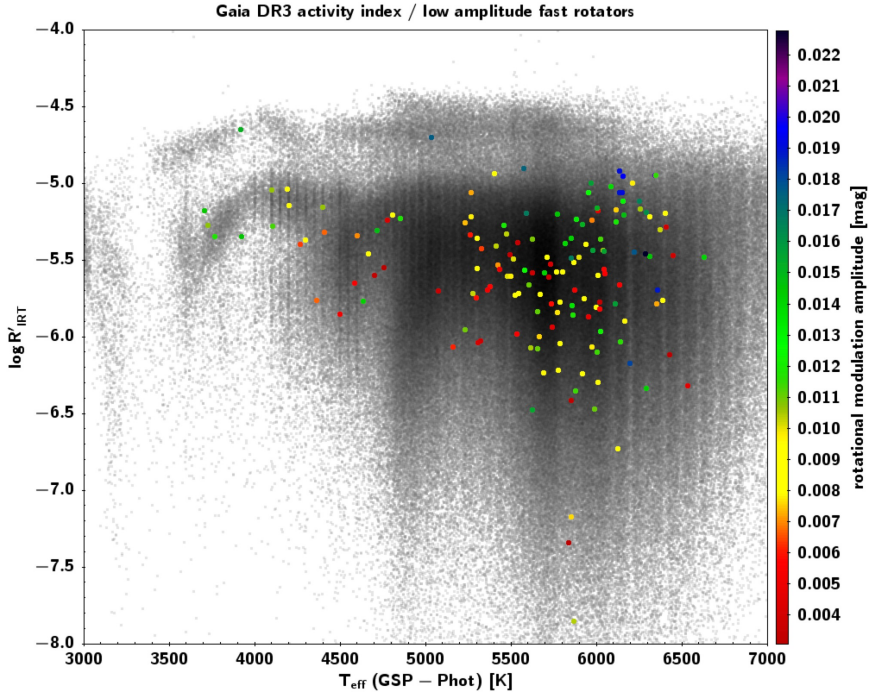




Validation: correlation with rotational modulation

Low amplitude fast rotators have
low photospheric
and
low chromospheric
activity !



Magnetic activity in Gaia DR3

- Chromospheric activity index for 2M stars
- Rotational modulation data for 500K stars
- Unprecedented details on magnetic activity regimes
- Evident correlation with the internal stellar structure
- Fundamental information for the stellar magneto-rotational evolution
- Intriguing issues on fast-rotating stars with low magnetic activity indicators
- Key information for exoplanet-hunters