



Gaia Focused Product Release

Medidas de velocidad radial en variables de largo periodo

Colaboración Gaia

Michele Trabucchi, Nami Mowlavi, Thomas Lebzelter, CU7, CU6
presentado por Pedro García-Lario (ESA/ESAC, Gaia SOC)



**UNIVERSITÉ
DE GENÈVE**



UNIVERSITÀ
DEGLI STUDI
DI PADOVA



Dipartimento
di Fisica
e Astronomia
Galileo Galilei





Gaia Focused Product Release

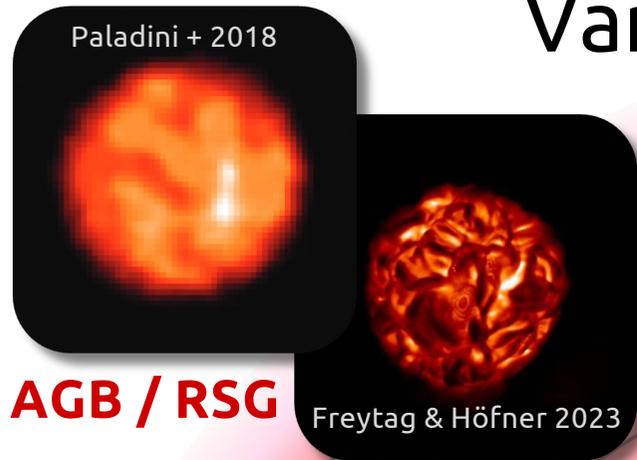
Medidas de velocidad radial en variables de largo periodo

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Variables de largo período



PULSACIÓN

Mezcla convectiva

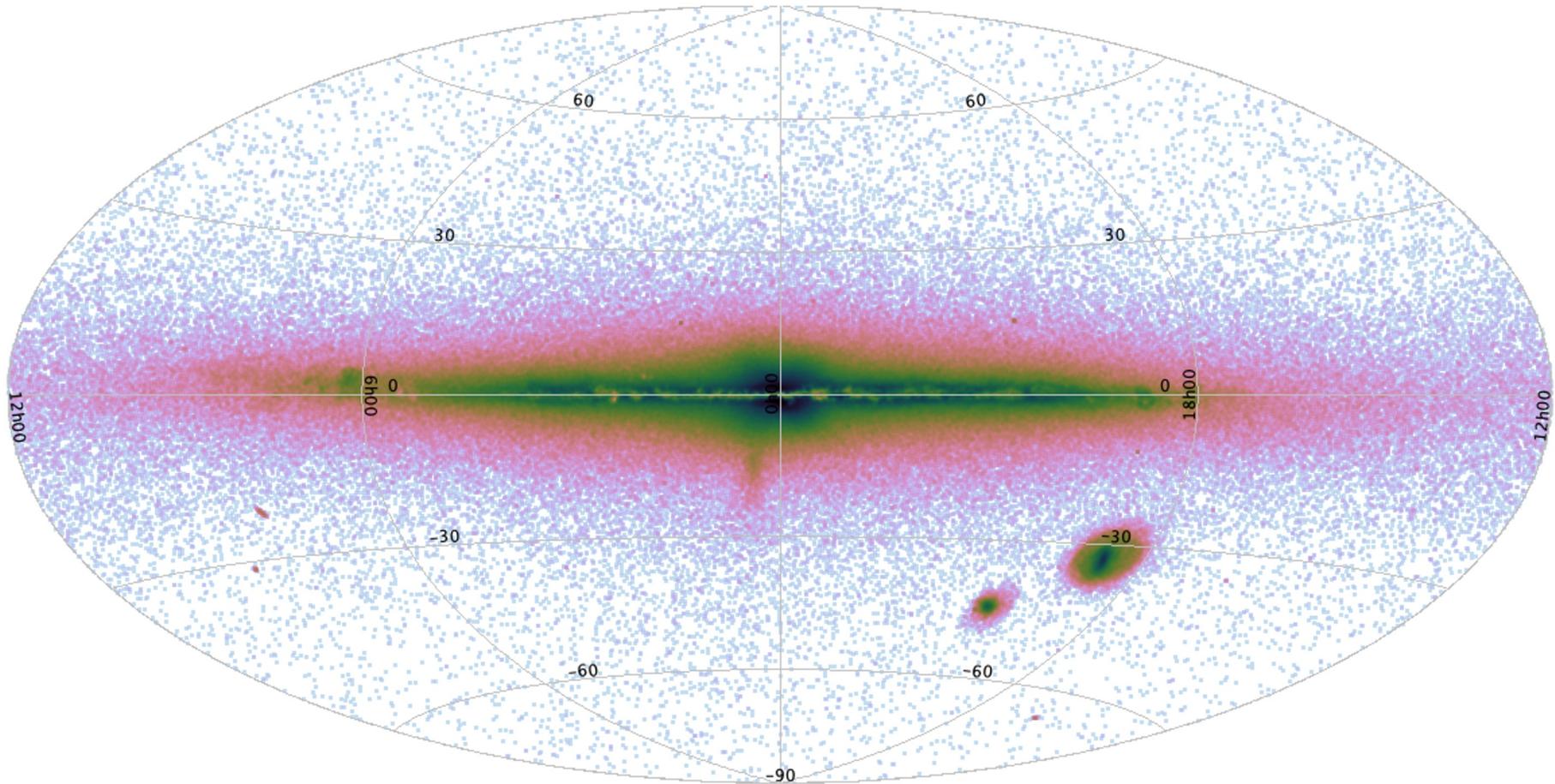
Viento estelar

Pérdida de masa

Formación de polvo

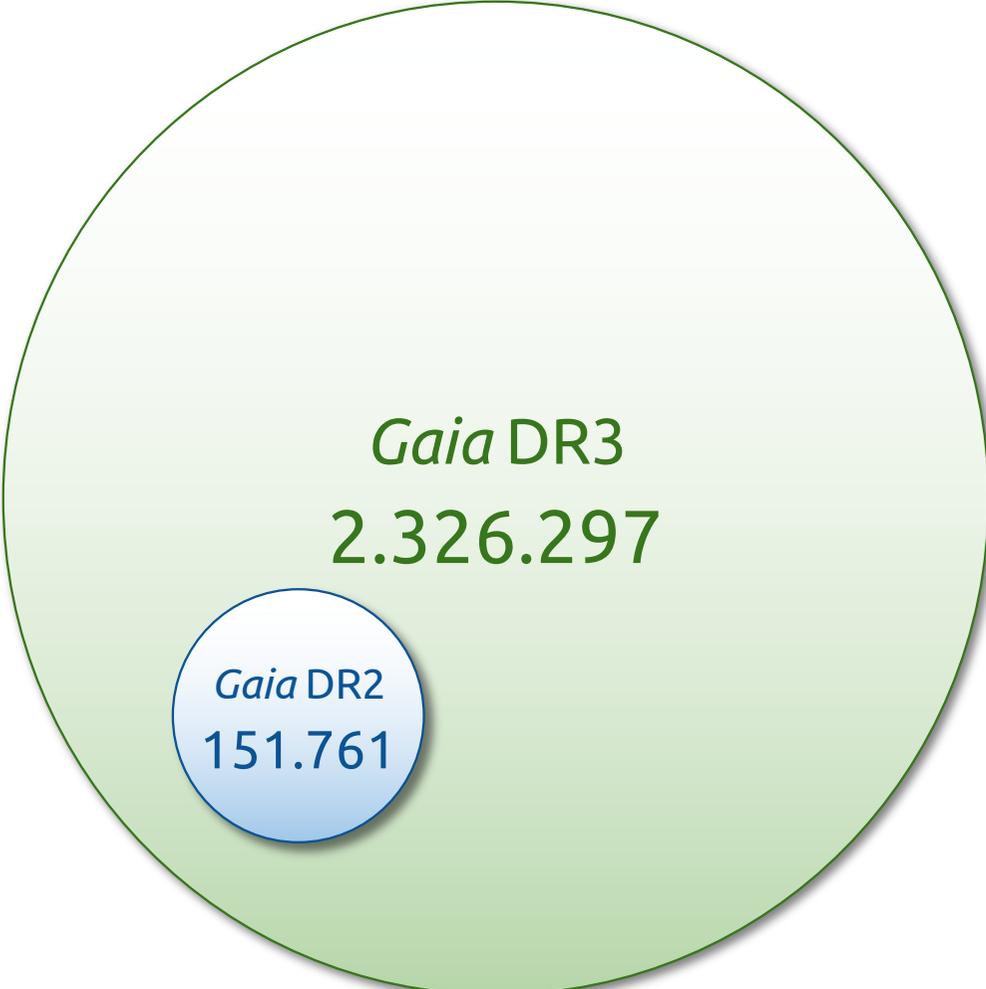
Illustration © Michele Trabucchi

Catálogo *Gaia* DR3 de variables de largo periodo



Lebzelter et al. 2023, A&A 674, A15

Gaia DR2
151.761



Gaia DR3
2.326.297

Gaia DR2
151.761

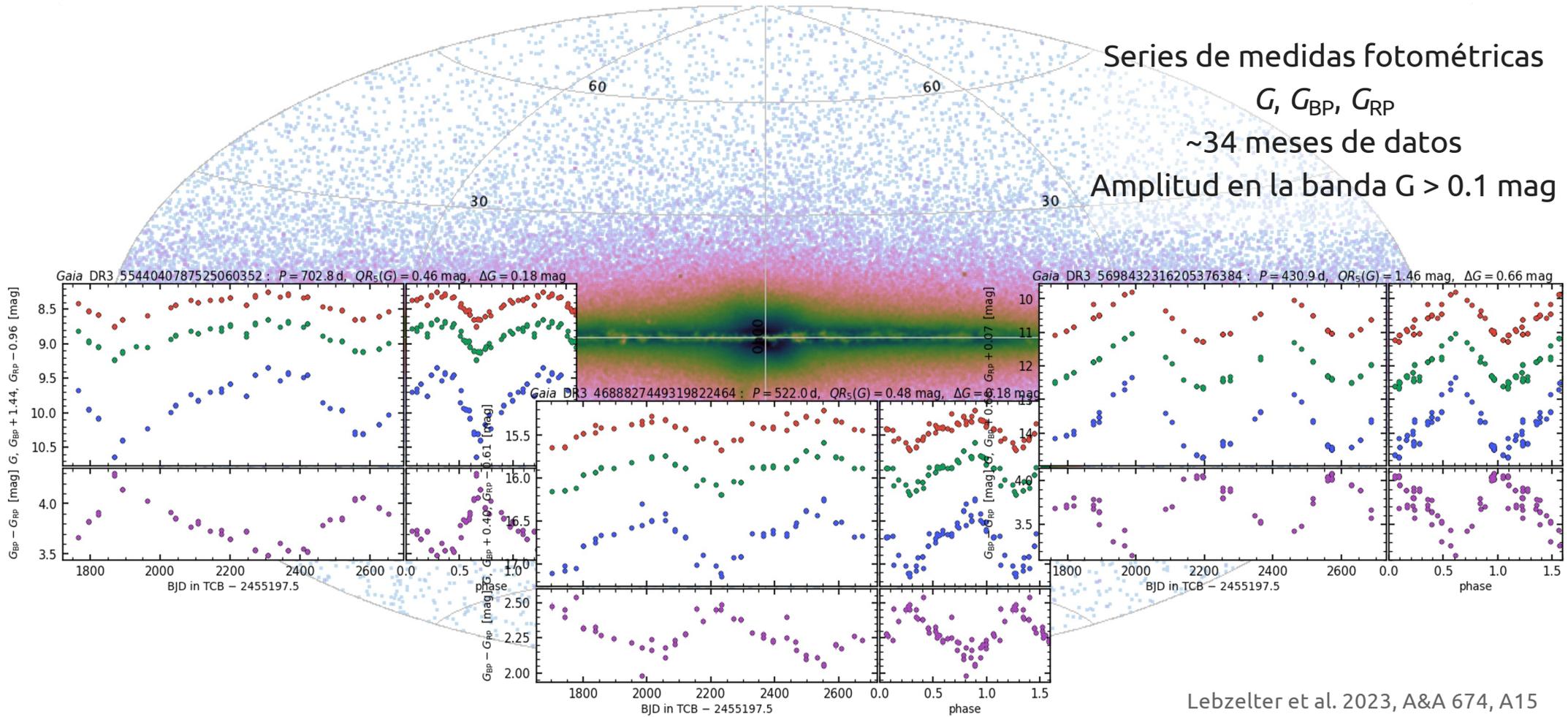
Gaia DR3
2.326.297

Gaia DR2
151.761

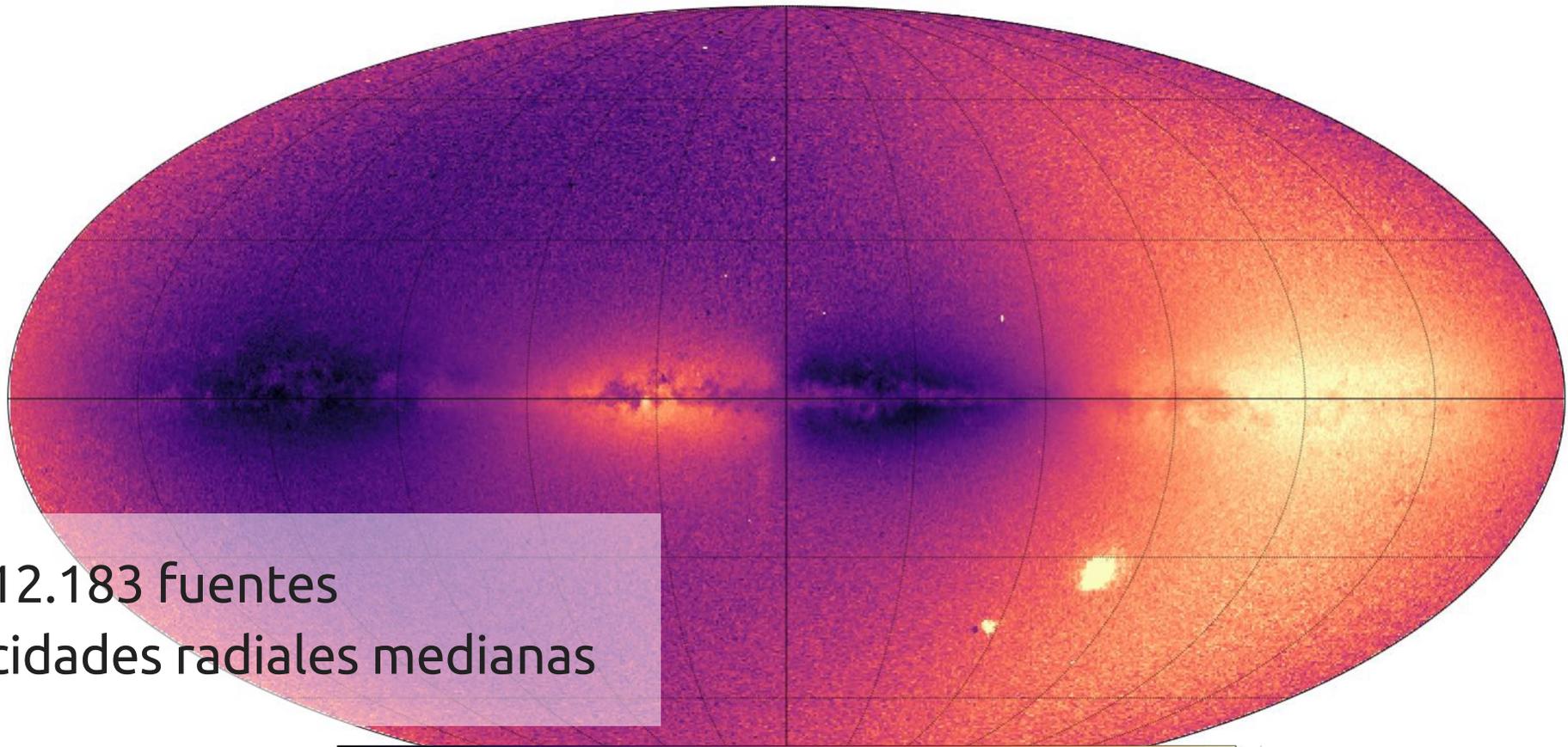
Gaia DR4

???

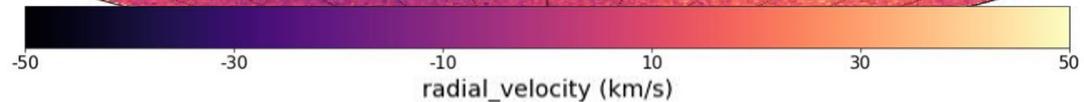
Catálogo *Gaia* DR3 de variables de largo periodo



Mapa del cielo de velocidades radiales en *Gaia* DR3

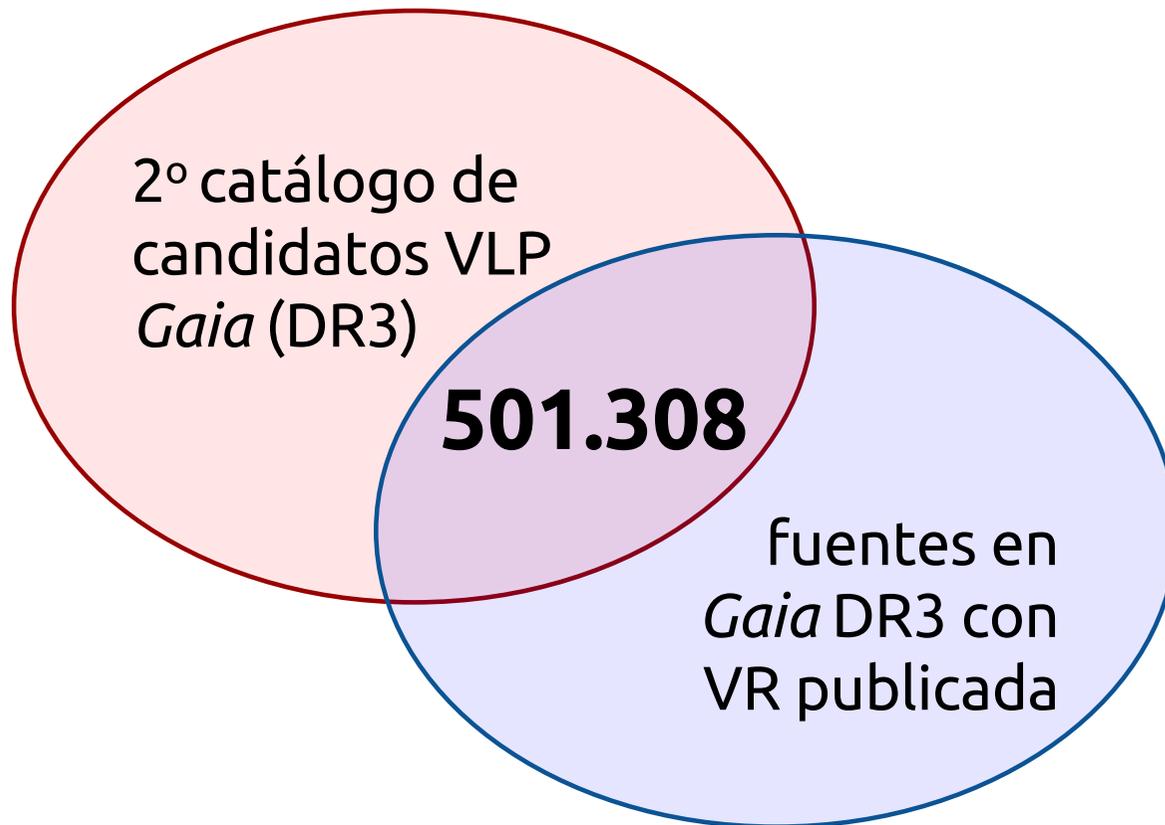


33.812.183 fuentes
velocidades radiales medianas

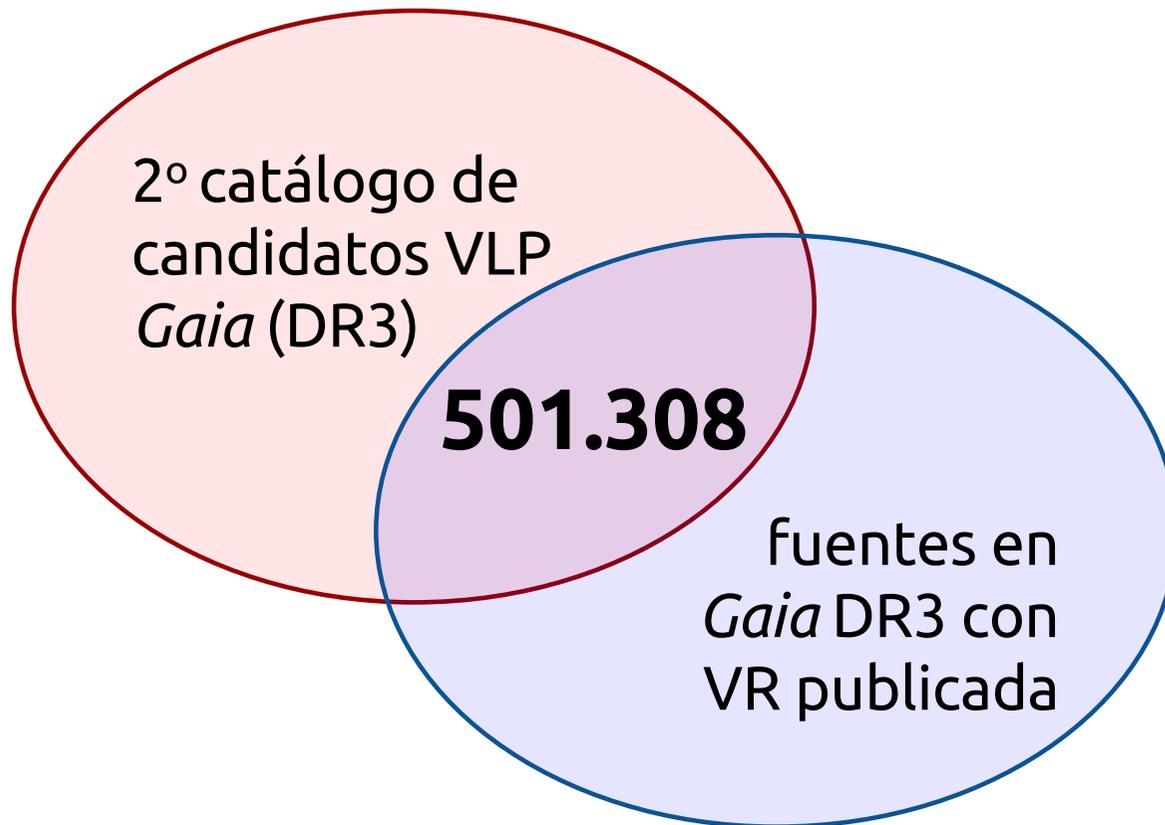


Mapa del cielo de velocidades radiales en Gaia DR3. Crédito: ESA/Gaia/DPAC- CC BY-SA 3.0 IGO. Agradecimientos: ESA/Gaia/DPAC/CU6, D. Katz, N. Leclerc, P. Sartoretti y el equipo CU6.

Construcción del catálogo



Construcción del catálogo



MUESTRA FINAL (publicada):

9.614

MUESTRA DE CALIDAD TOP
(con flag asociado):

6.093

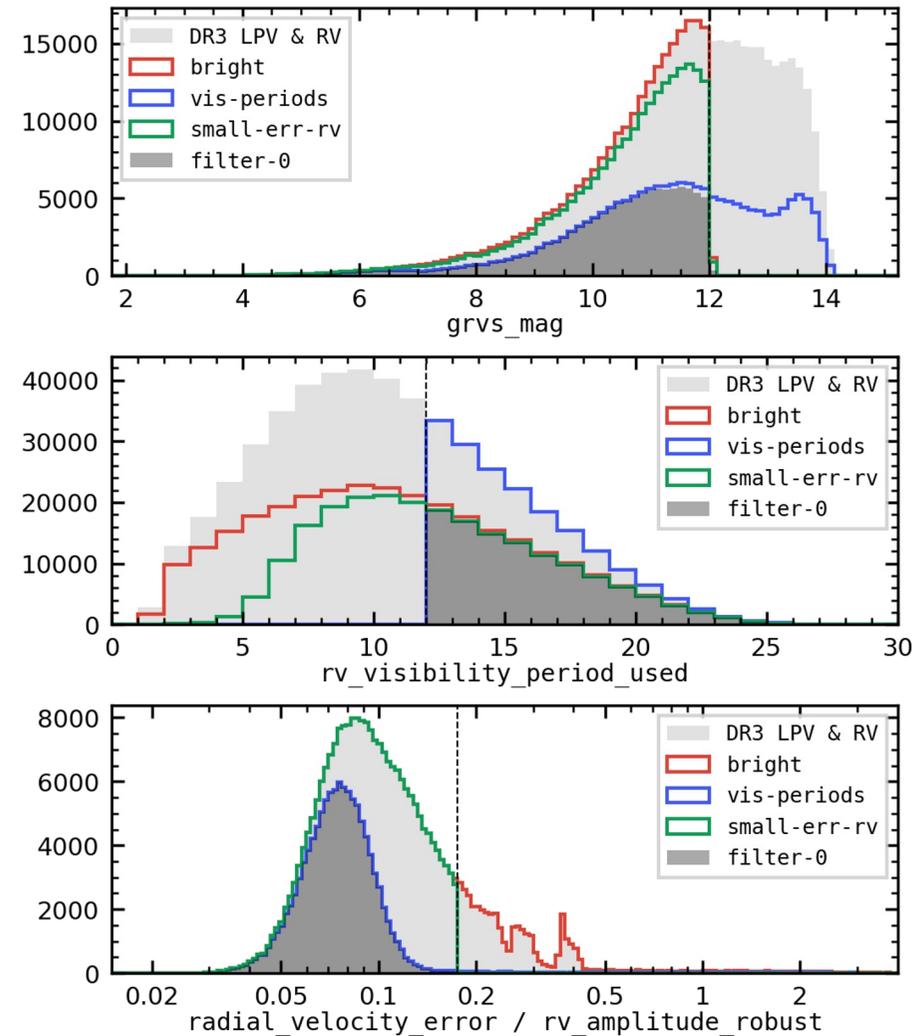
Filtros de calidad

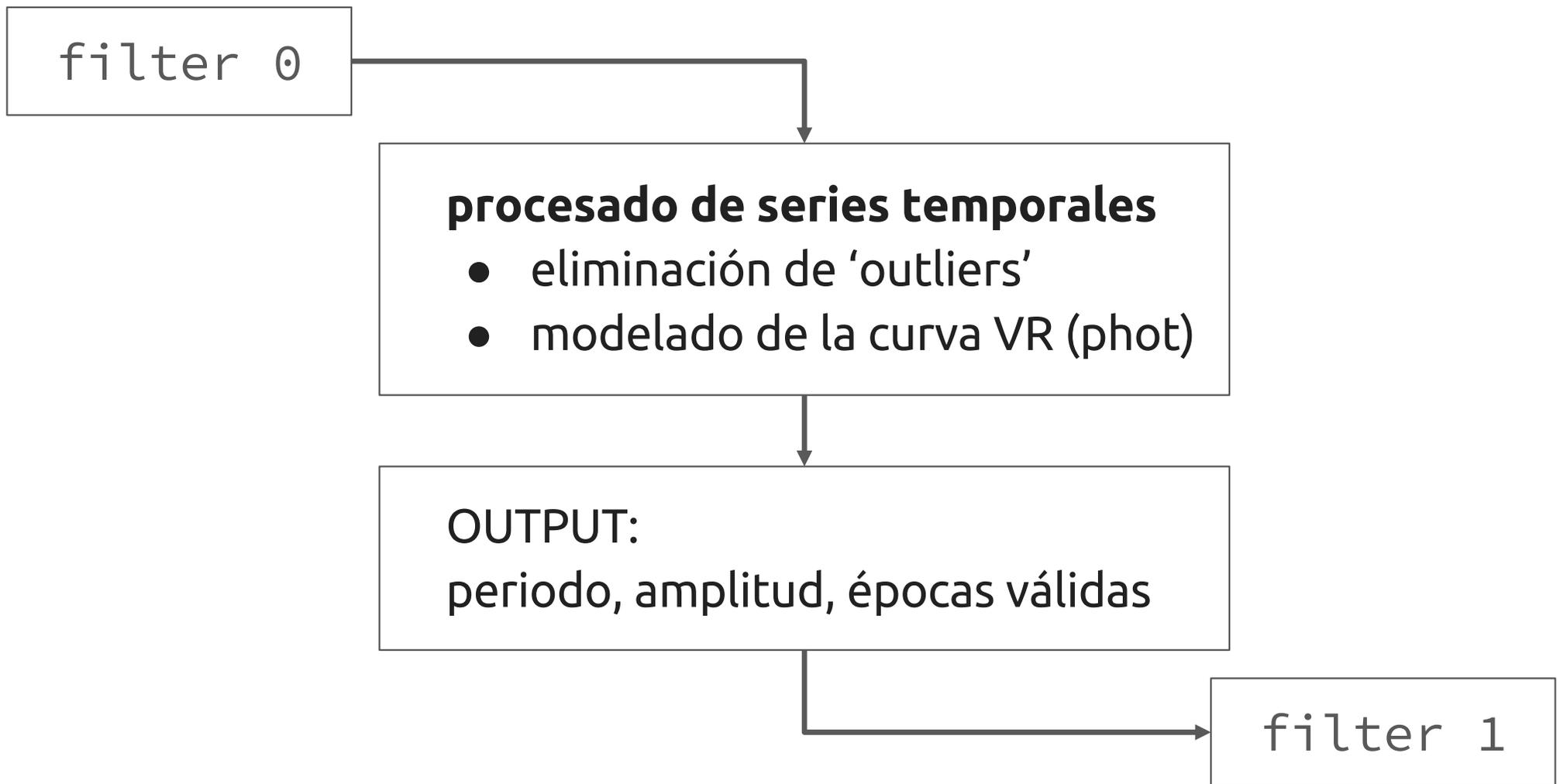
“filter 0”

- estrellas brillantes
 - $G_{RVS} \lesssim 12 \text{ mag} \rightarrow G \lesssim 14 \text{ mag}$
- muchas observaciones
 - más de 12 “épocas” de VR
- alta “S/N” en VR
 - error pequeño frente a amplitud

RESULTADO:

110.654

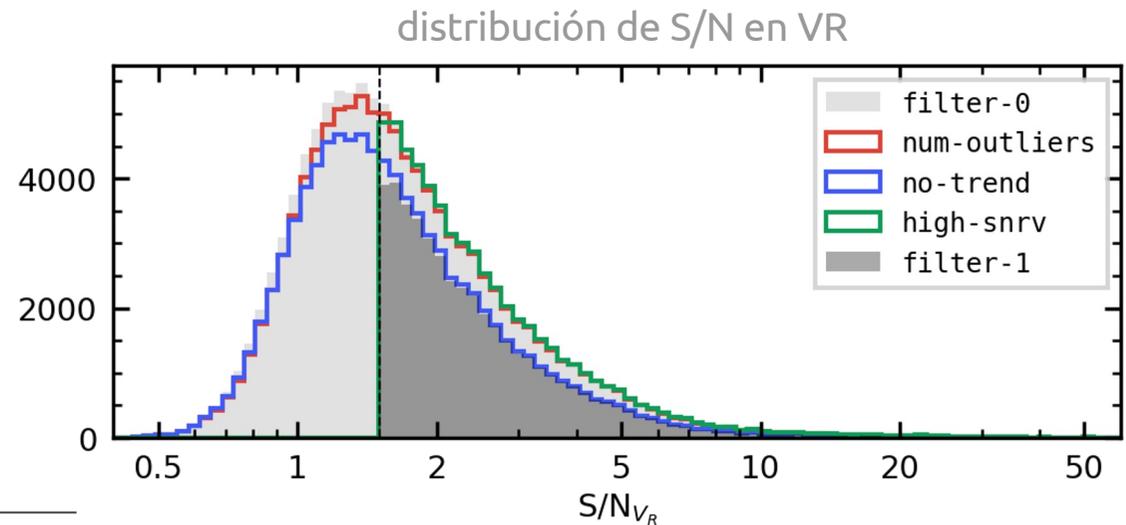




Filtros de calidad

“filter 1”

- pocos ‘outliers’ en VR
 - a lo sumo 1 época rechazada
- series temporales VR “estables”
 - sin tendencias detectadas
- alta S/N
 - $SN(VR) > 1.5$



RESULTADO:

44.216

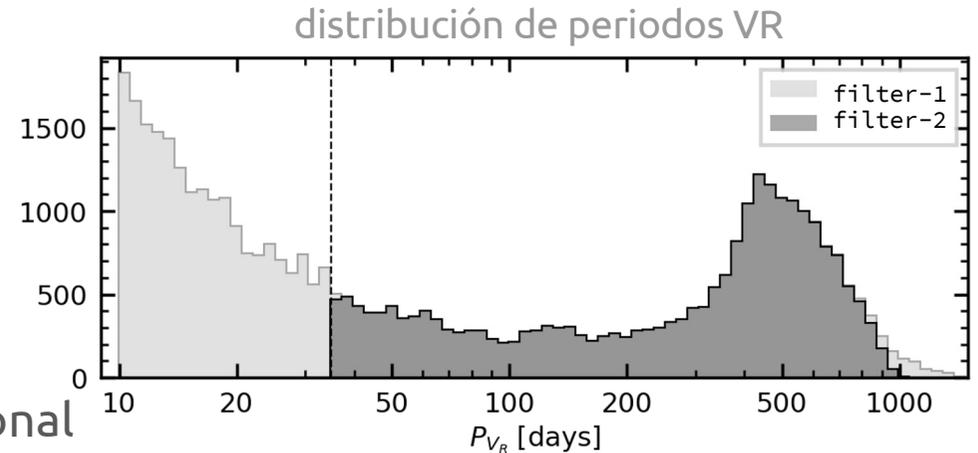
Filtros de calidad

“filter 2”

- límites en el rango de periodos VR
 - $35 \text{ d} < P_{\text{VR}} < \text{línea de base observacional}$

“filter 3”

- consistencia VR - otros periodos fotométricos
 - $P_{\text{VR}} \simeq P_{\text{fot}}$



Filtros de calidad

“filter 2”

- límites en el rango de periodos VR
 - $35 \text{ d} < P_{\text{VR}} < \text{línea de base observacional}$

“filter 3”

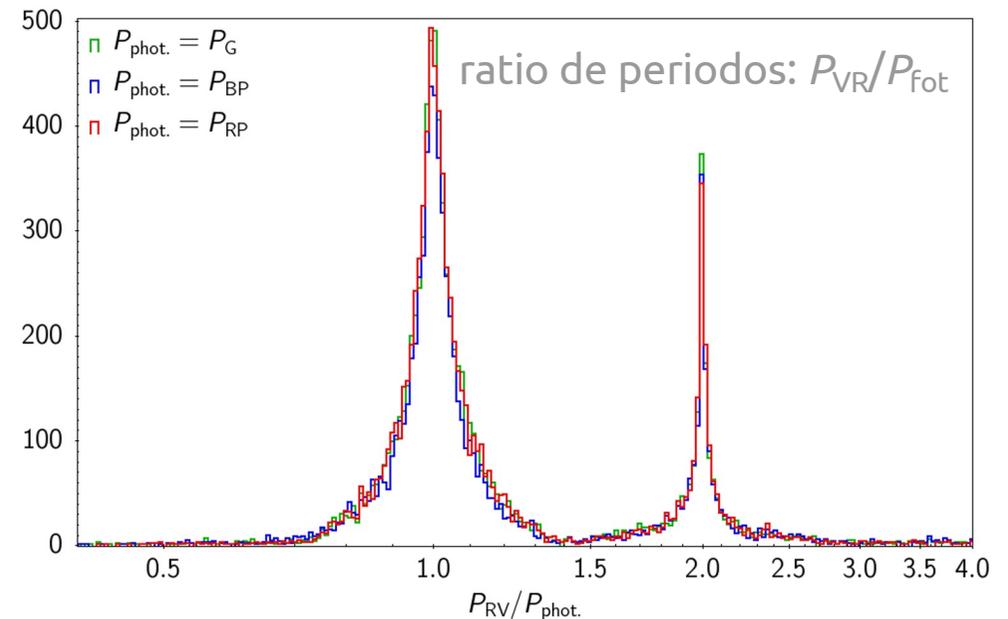
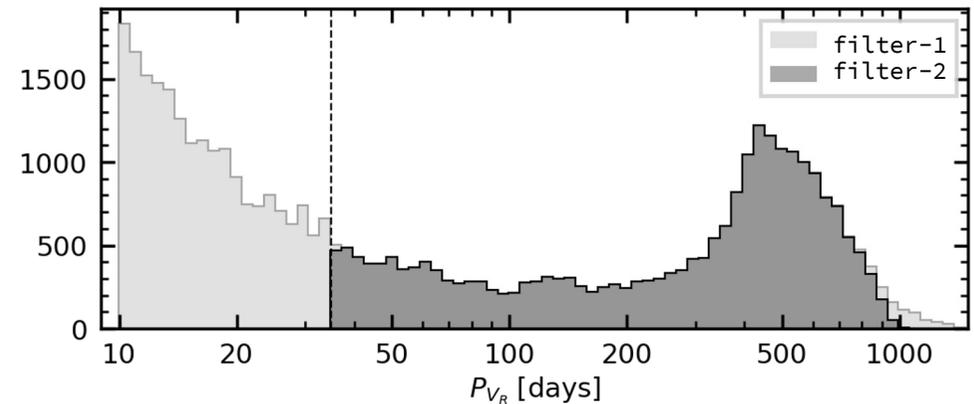
- consistencia VR - otros periodos fotométricos

-
- $P_{\text{VR}} \simeq P_{\text{fot}} \text{ ó } P_{\text{VR}} \simeq 2 \times P_{\text{fot}}$

Contenido en FPR:

9.614

distribución de periodos VR



Filtro de calidad TOP

Señal en las 3+1 series temporales probablemente viniendo del mismo proceso astrofísico

“top-quality filter”

- consistencia VR - **TODOS** los periodos fotométricos

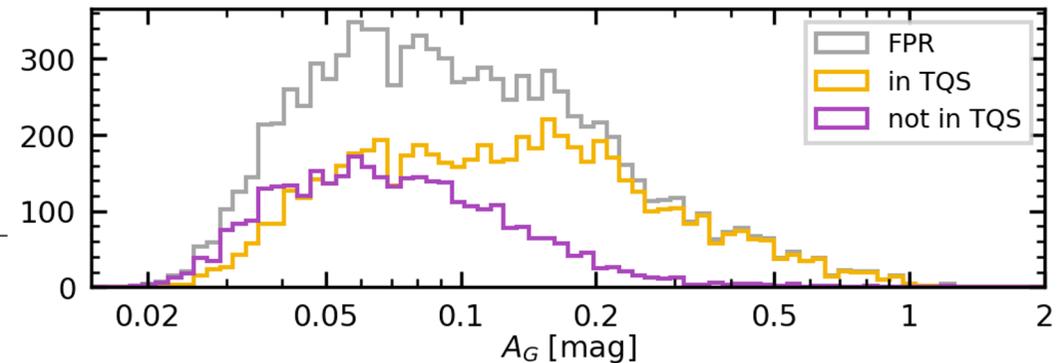
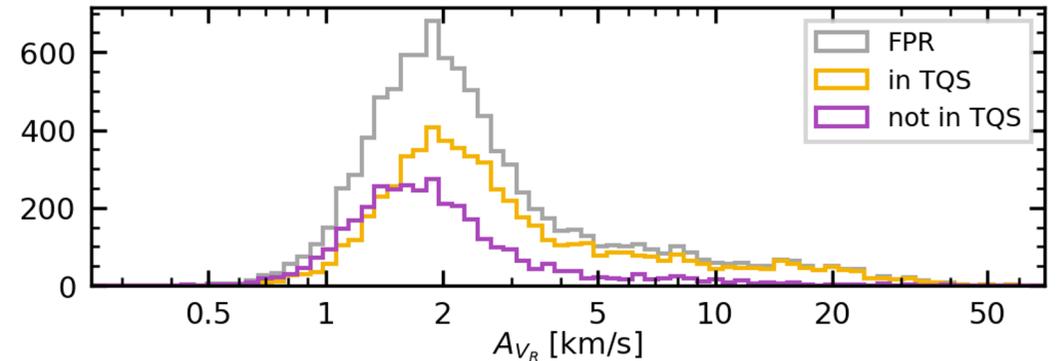
○ $P_{VR} \simeq P_{\text{fot}}$ or $P_{VR} \simeq 2P_{\text{fot}}$

~~$\forall P_{\text{fot}} \in \{P_G, P_{BP}, P_{RP}\}$~~

Muestra calidad TOP:

6.093

Distribuciones finales de VR & amplitudes fotométricas



Tablas de datos

gaiafpr.vari_long_period_variable

- frequency_rv
- frequency_error_rv
- amplitude_rv
- flag_rv

gaiafpr.vari_epoch_radial_velocity

gaiafpr.vari_rad_vel_statistics

The screenshot shows the Gaia Archive Advanced Query Language (ADQL) interface. The left-hand navigation pane is expanded to show the 'Variability' section, with 'gaiafpr.vari_rad_vel_statistics' selected. The main area displays a table with columns: Status, Job, Creation date, Num. rows, and Size. The table is currently empty, showing 'No results found'. The bottom of the interface includes a 'Download format:' dropdown set to 'VOTable', and buttons for 'Apply jobs filter', 'Filter this session', 'Select all jobs', and 'Delete selected jobs'.

Tablas de datos

`gaiafpr.vari_long_period_variable`

- `frequency_rv`
- `frequency_error_rv`
- `amplitude_rv`
- `flag_rv`

`gaiafpr.vari_epoch_radial_velocity`

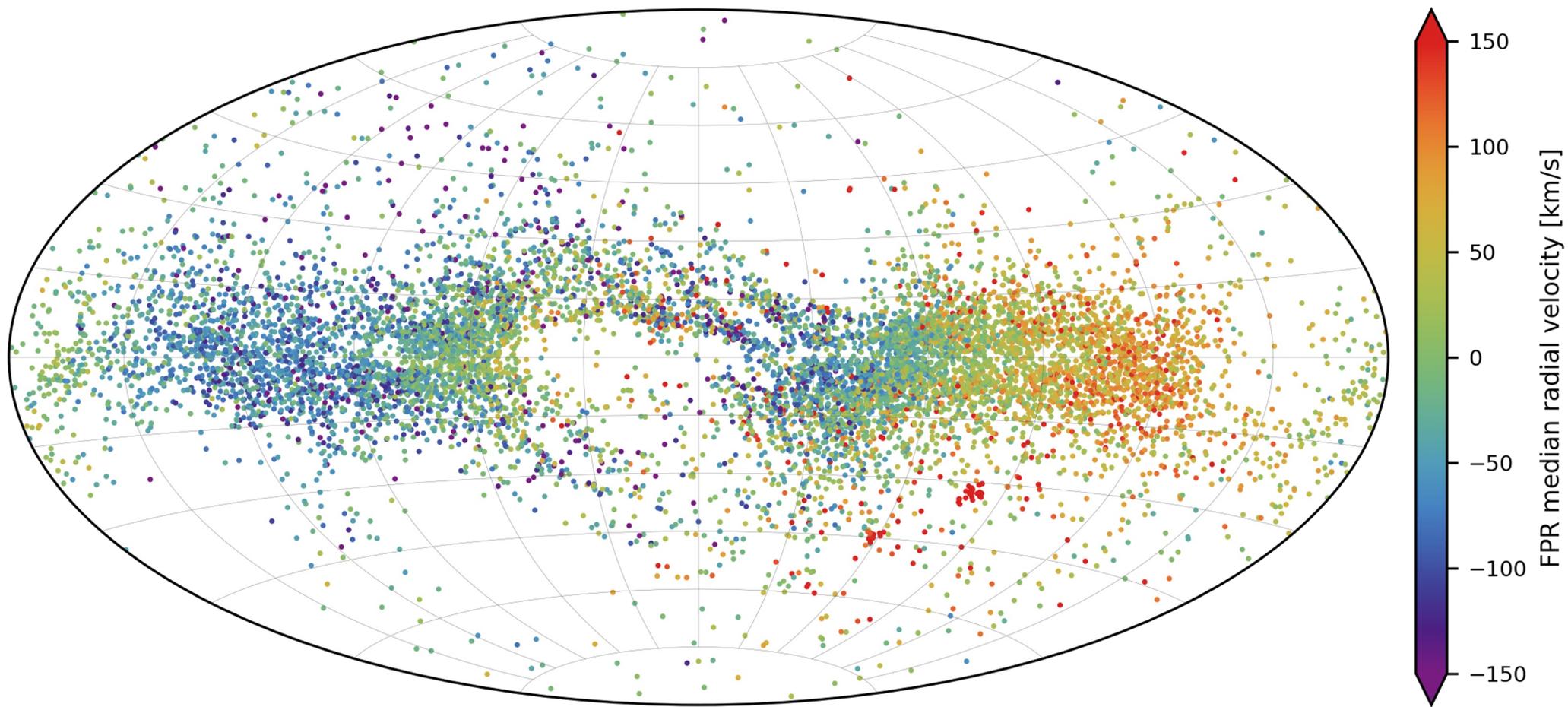
`gaiafpr.vari_rad_vel_statistics`

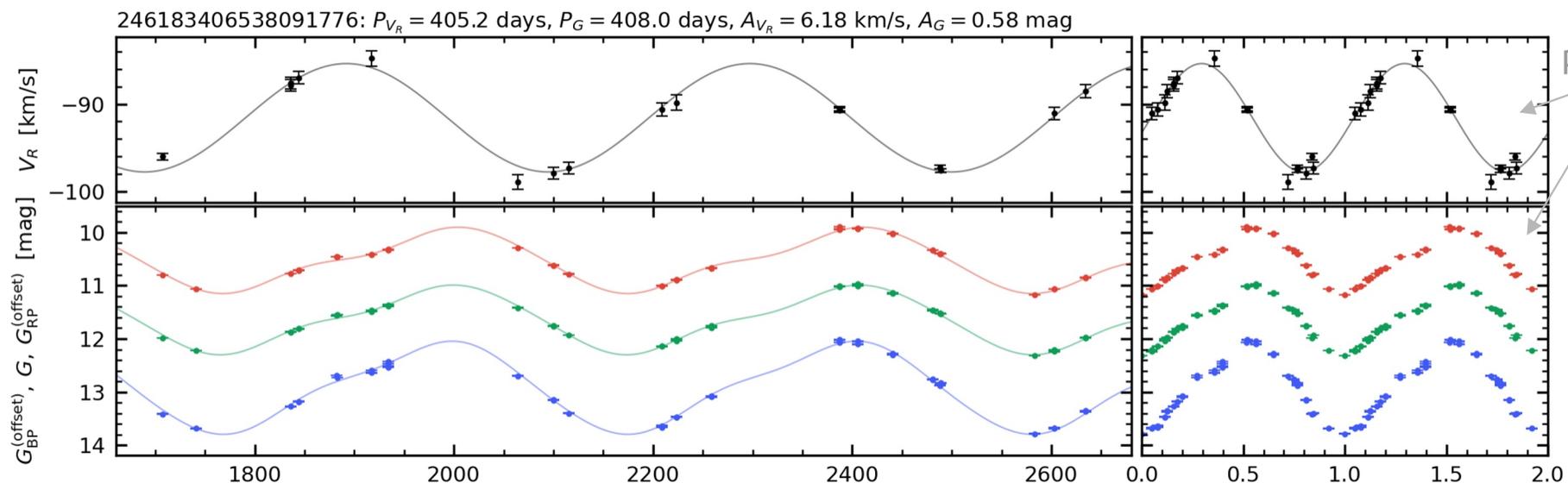


▣ Variability

- +  `gaiafpr.vari_epoch_radial_velocity`
- ▣  `gaiafpr.vari_long_period_variable`
 - `solution_id`
 - `source_id`**
 - `frequency`
 - `frequency_error`
 - `amplitude`
 - `median_delta_wl_rp`
 - `is_cstar`
 - `frequency_rv`
 - `frequency_rv_error`
 - `amplitude_rv`
 - `flag_rv`
- +  `gaiafpr.vari_rad_vel_statistics`

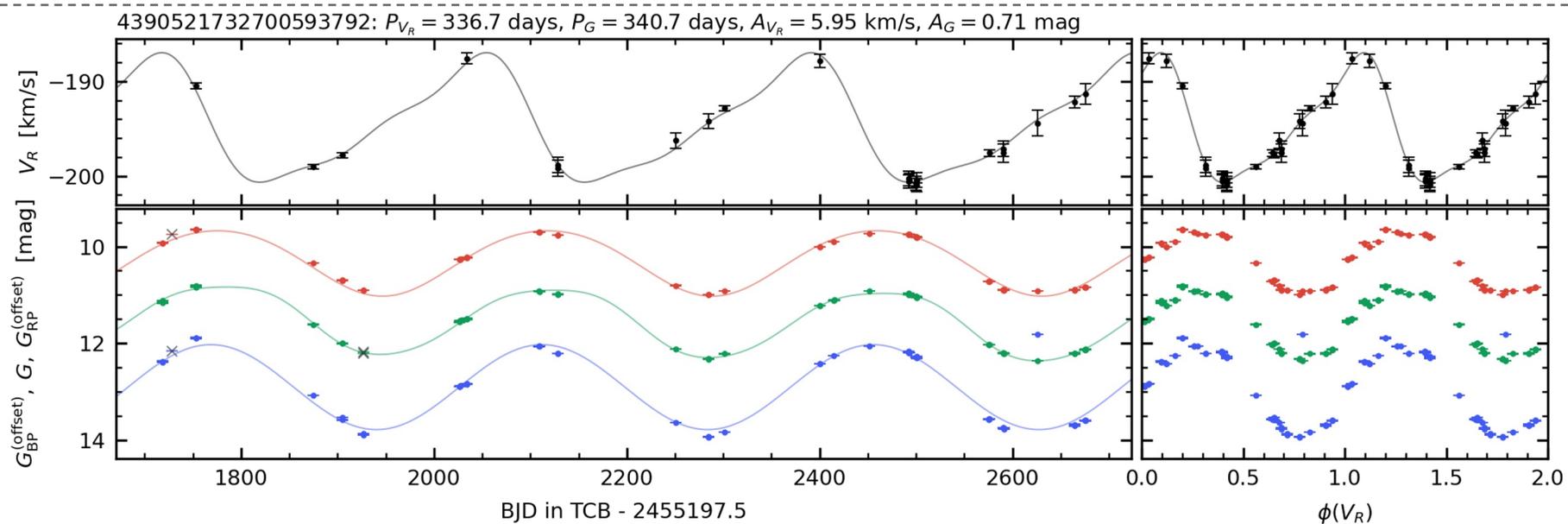


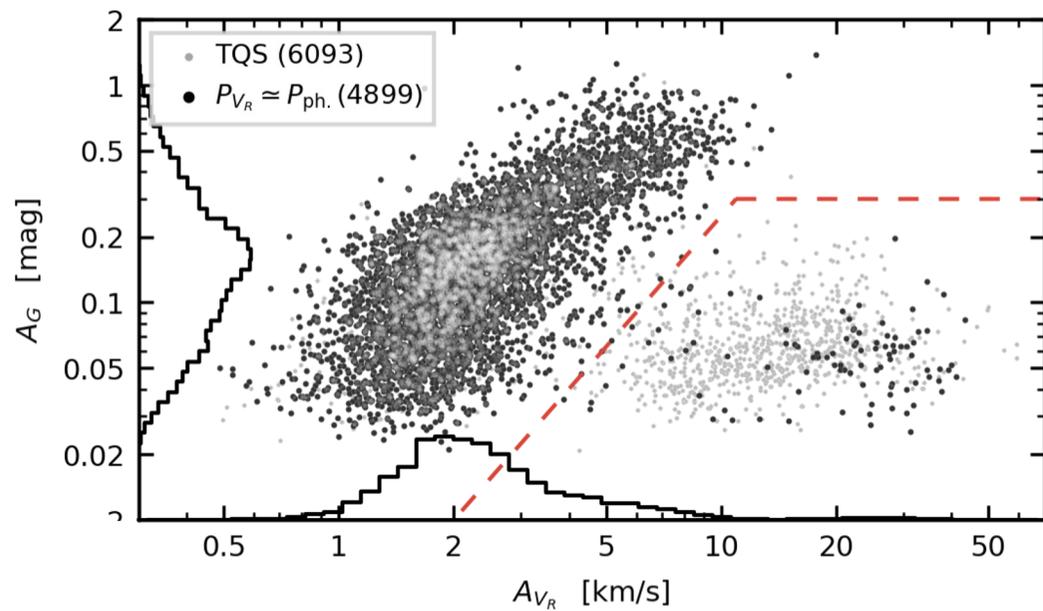


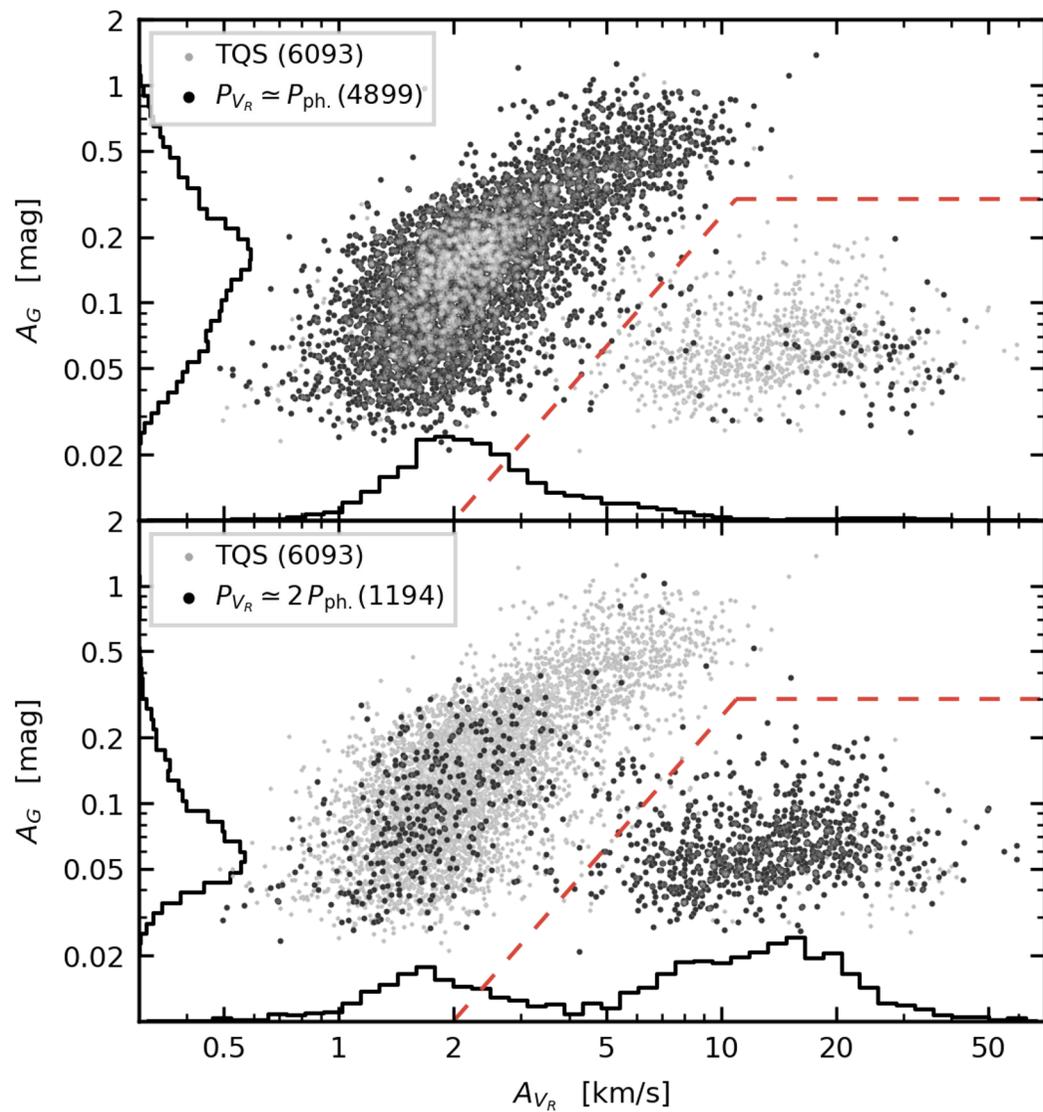


plegada con el
period VR

Ejemplo
de series
temporales:
**Variables
Mira**







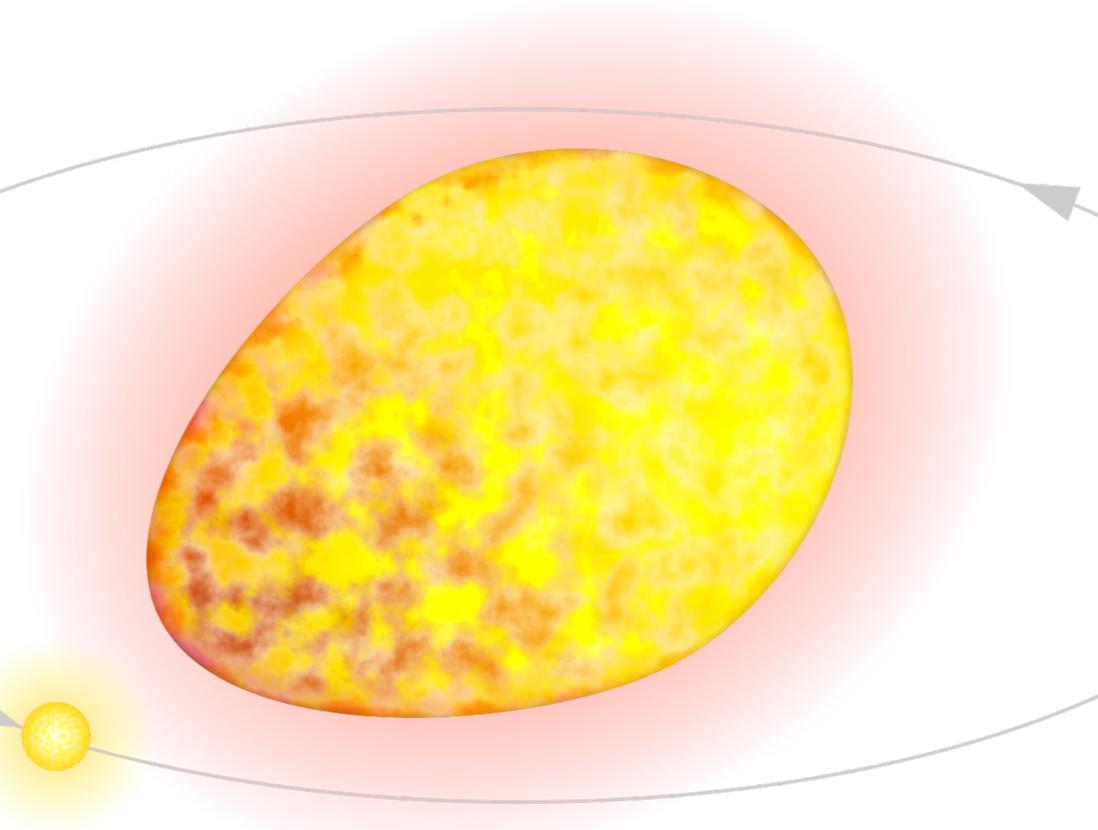
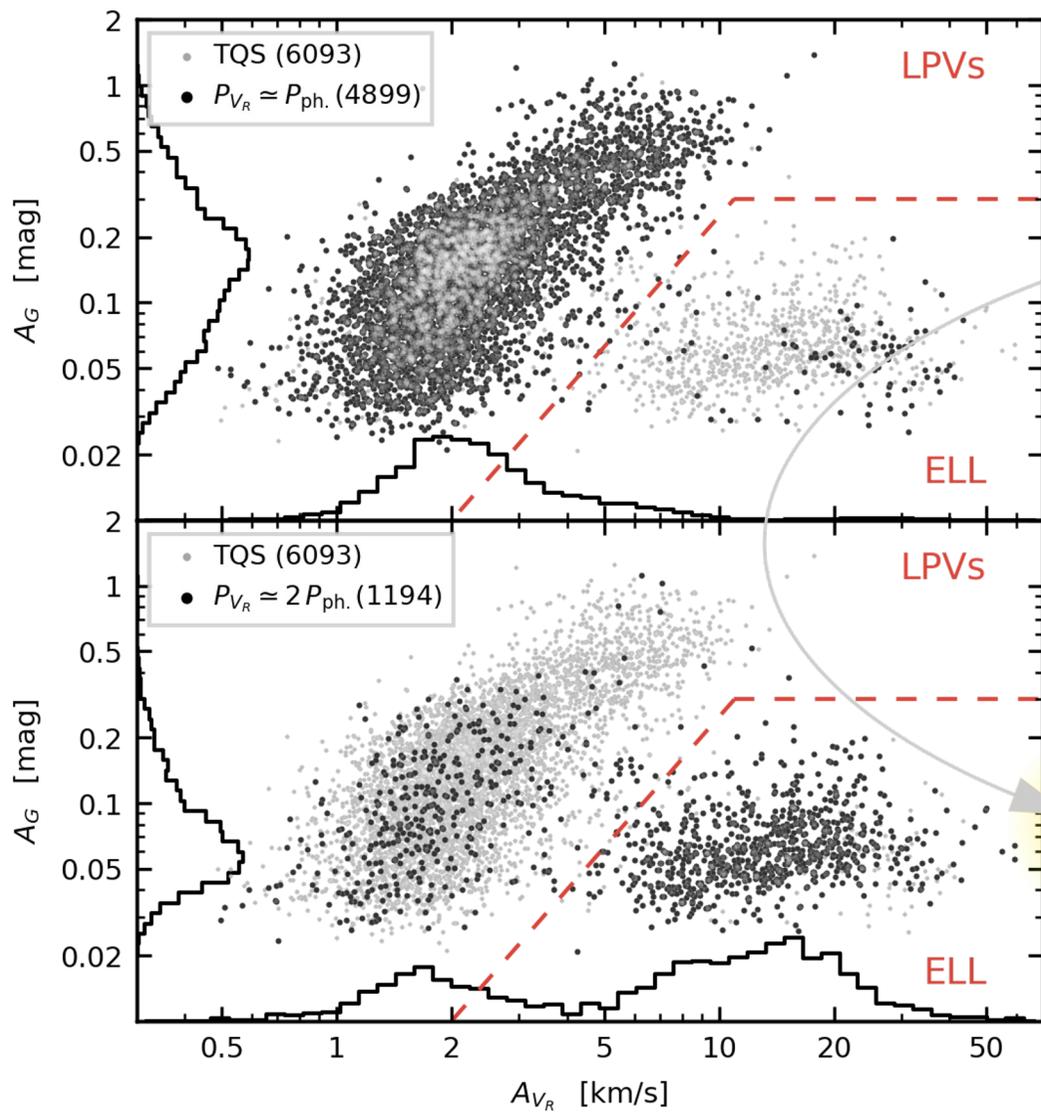
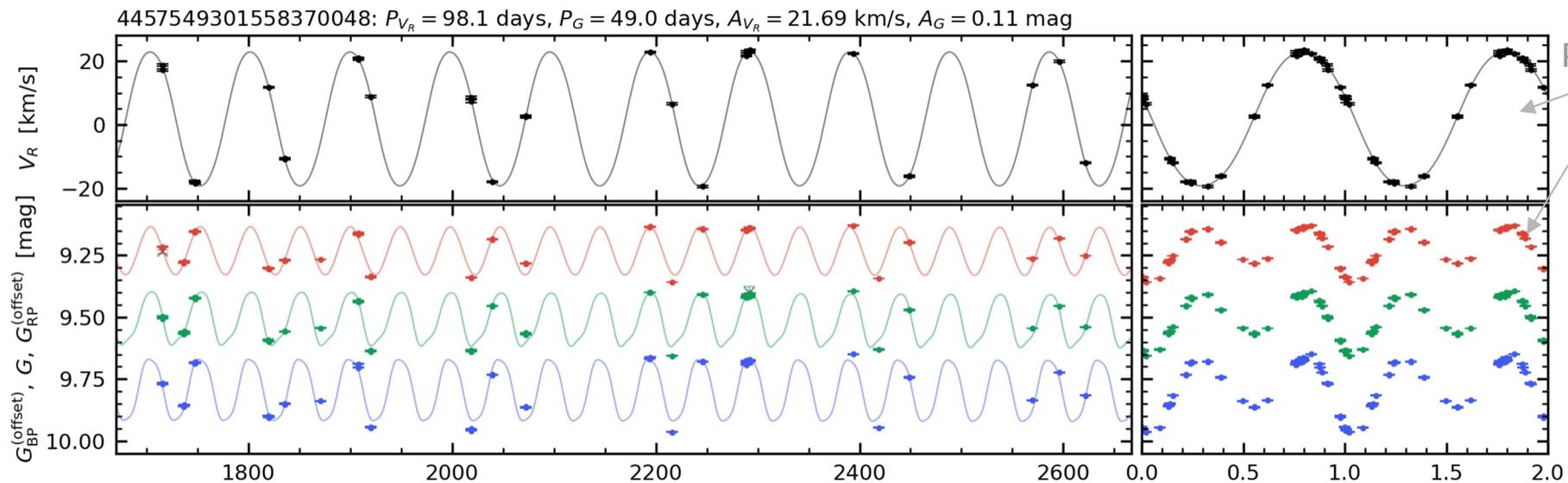
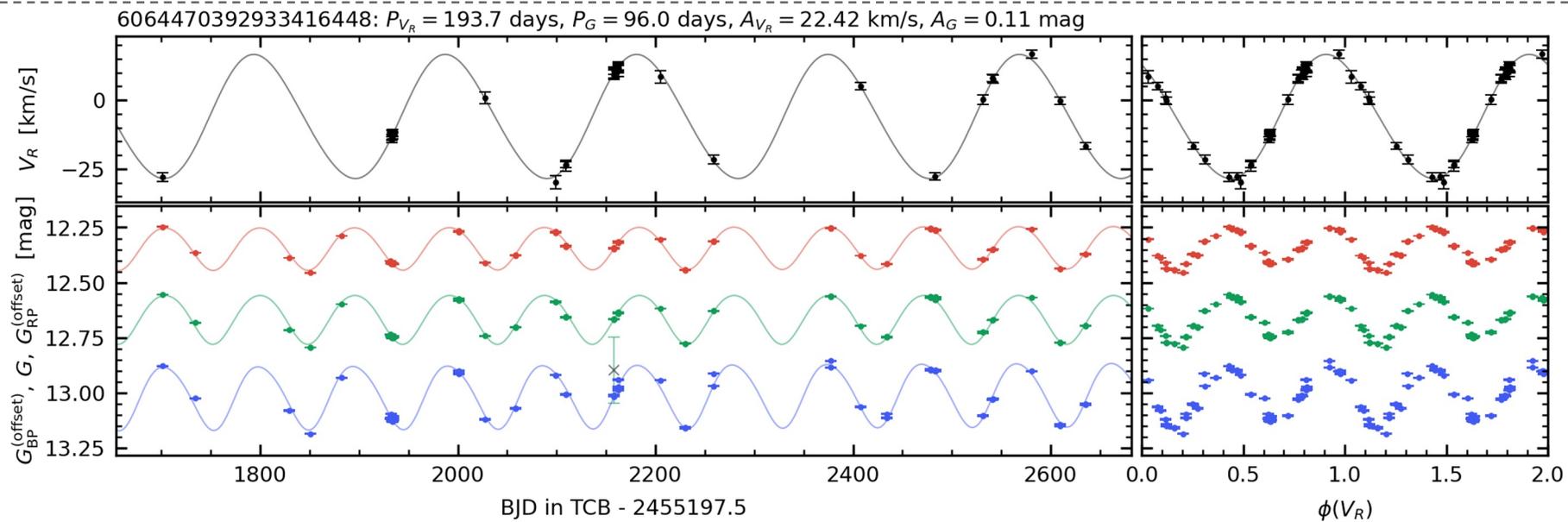


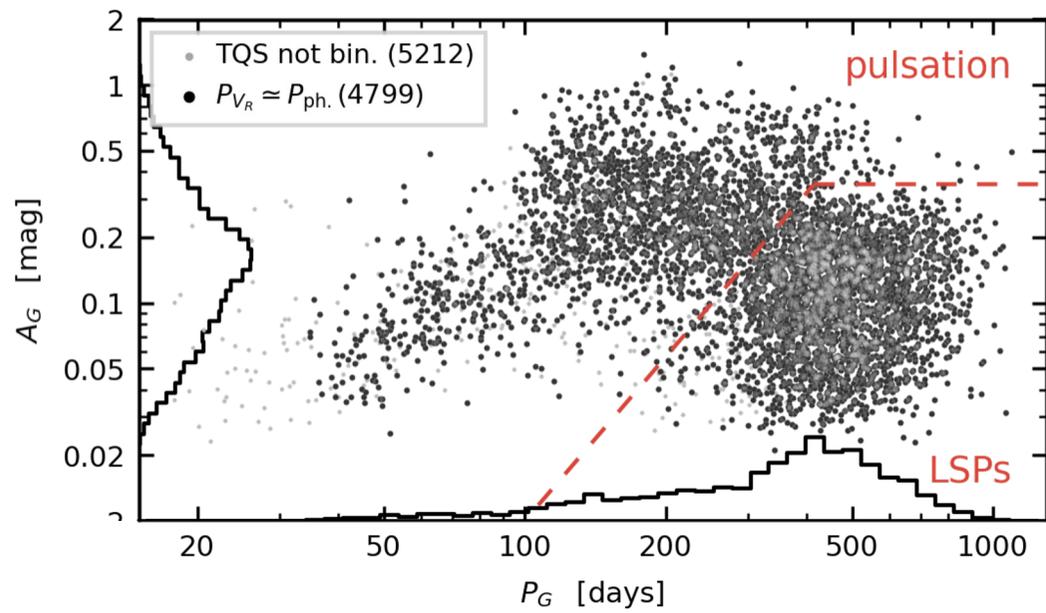
Illustration © Michele Trabucchi

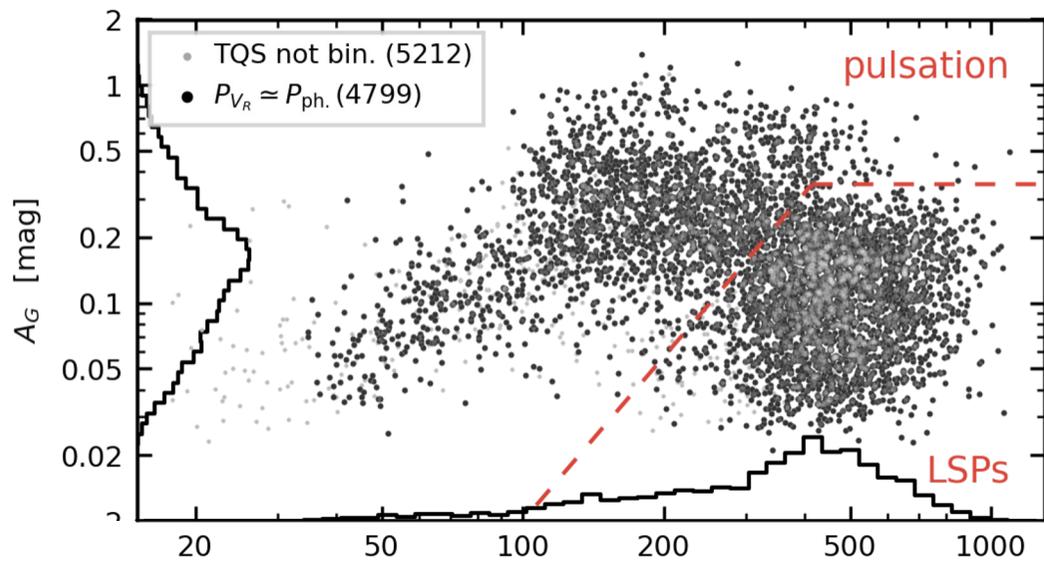


Plegada con el
period VR

Ejemplo de
series
temporales:
**Gigantes
rojas
elipsoidales**







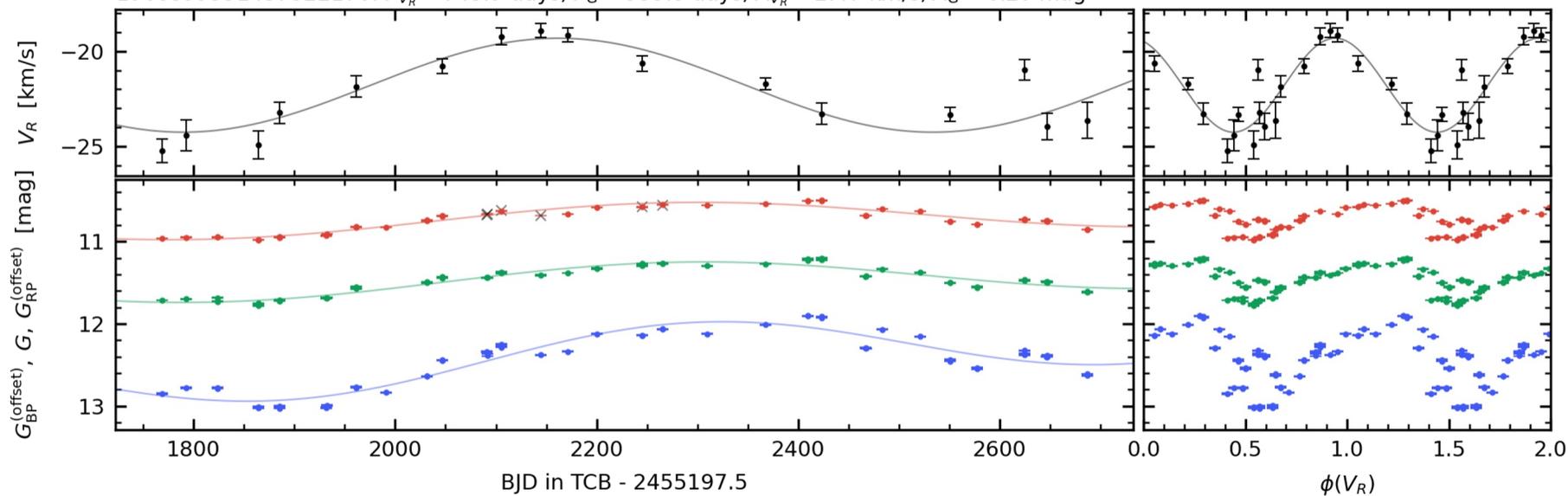
Impresión artística de LSP producido por nubes de polvo

Crédito: Matylda Soszyńska

(Soszyński 2022, XL Polish Astronomical Society Meeting, 12, 154)

1968599531437522176: $P_{V_R} = 743.9$ days, $P_G = 955.8$ days, $A_{V_R} = 2.47$ km/s, $A_G = 0.20$ mag

Ejemplo de series temporales: largos periodos secundarios



GAIA FOCUSED PRODUCT RELEASE

RADIAL VELOCITY TIME SERIES FOR LONG PERIOD VARIABLES



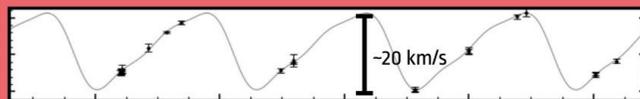
PULSATION

EXPANSION-CONTRACTION



MEDIUM RV AMPLITUDE

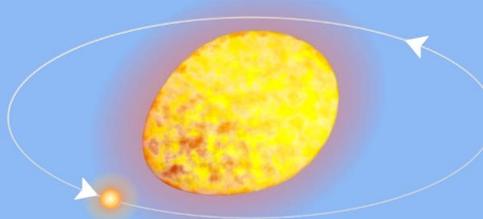
RV vs TIME



1 year

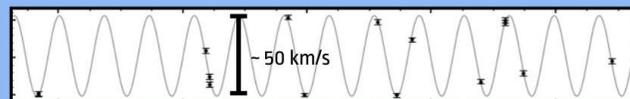
BINARITY

DEFORMATION



LARGE RV AMPLITUDE

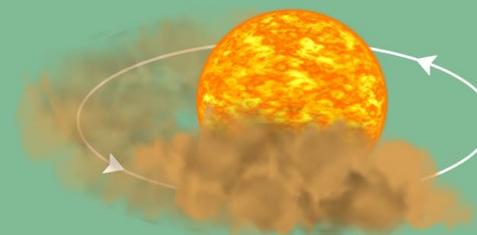
RV vs TIME



1 year

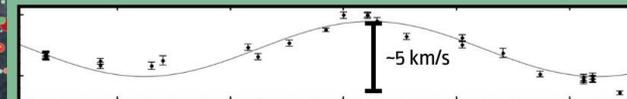
DUST CLOUD?

OCCULTATION



SMALL RV AMPLITUDE

RV vs TIME



1 year

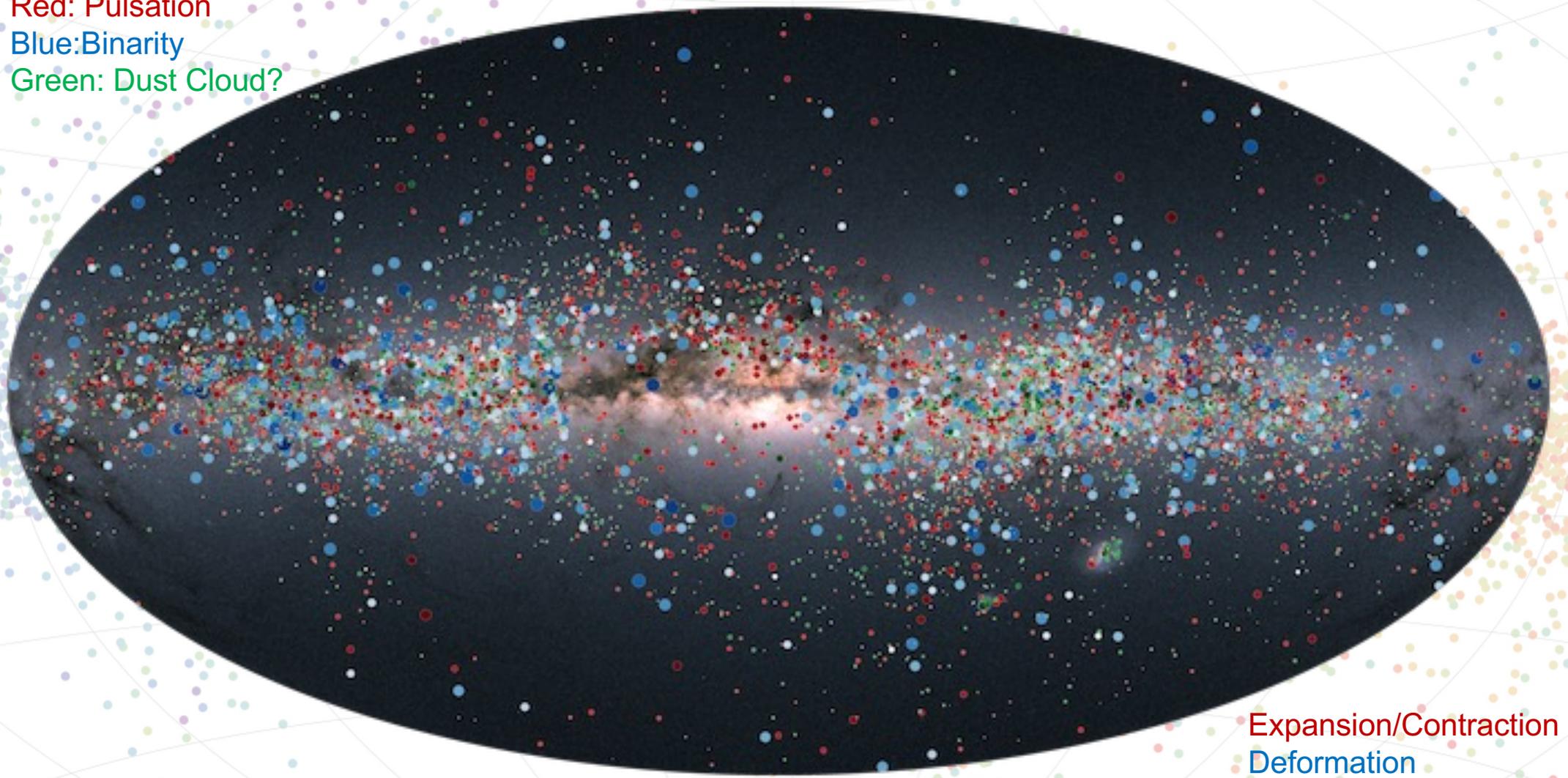
#GaiaFPR



Red: Pulsation

Blue: Binarity

Green: Dust Cloud?



Expansion/Contraction

Deformation

Occultation

Comparación con series temporales VR de la literatura

Series temporales VR de VLPs en la literatura (unas pocas docenas):

1. brillantes y bien estudiadas gigantes cercanas
2. campos celestes específicos (Nubes de Magallanes)

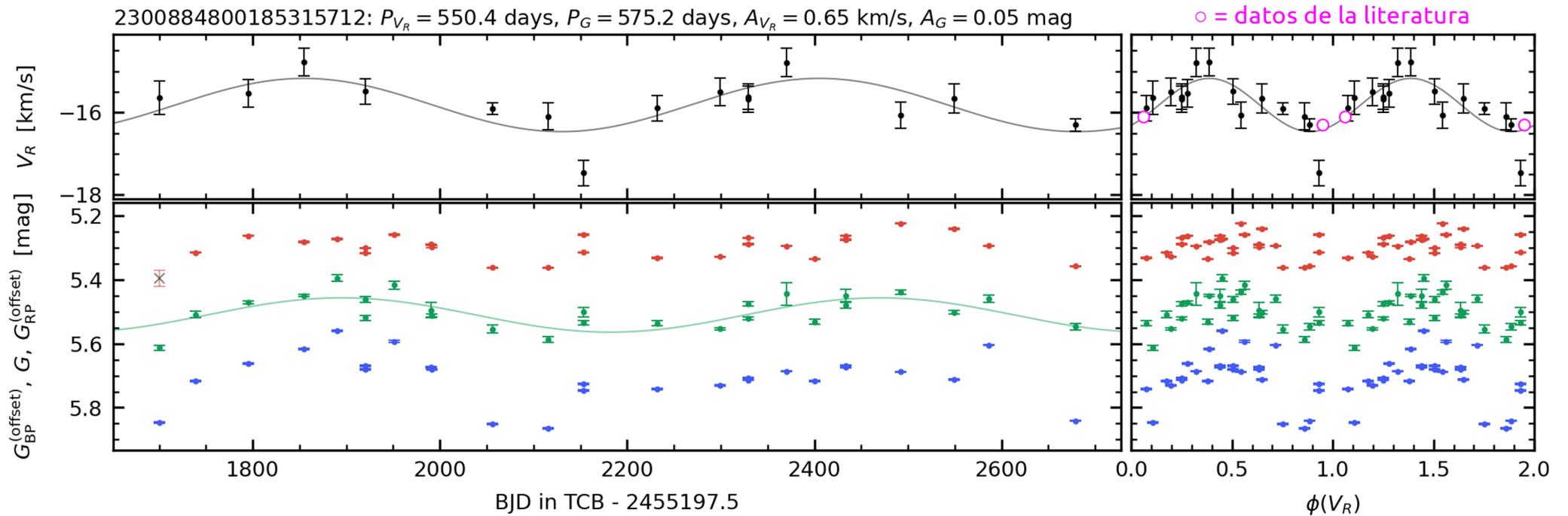
Ninguna de las dos clases pasa fácilmente los filtros FPR

Solo unos pocos cruces con la literatura

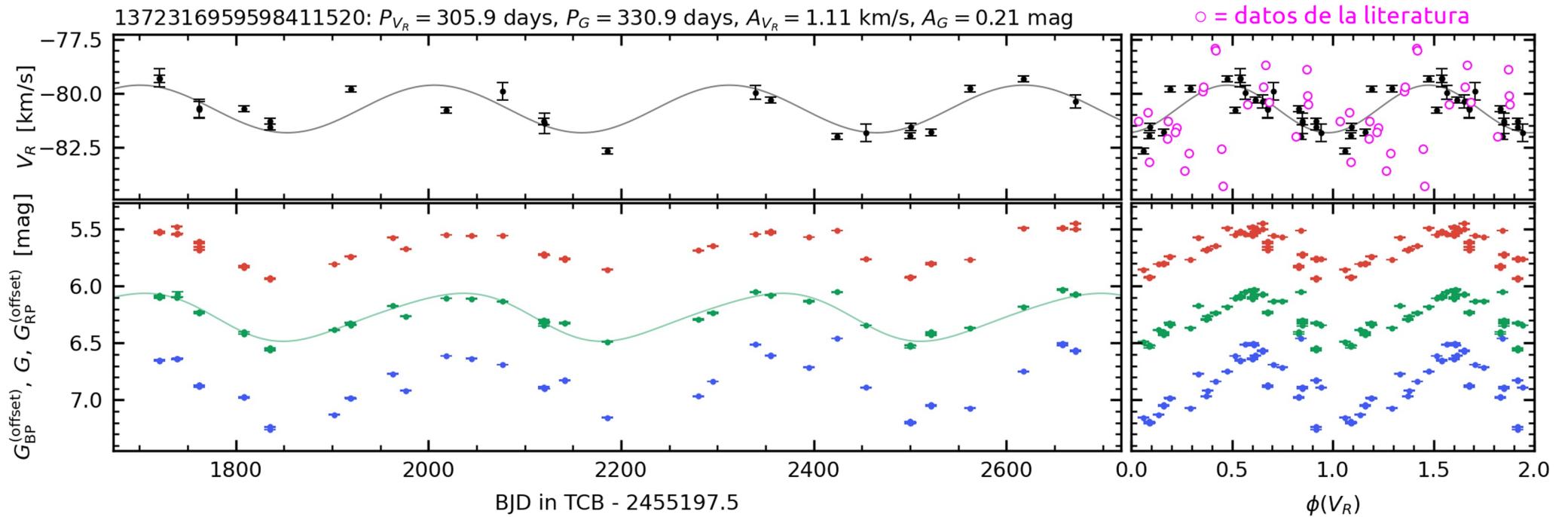
Grandes surveys con medidas VR excluidos: una sola época de observación (o no constituyen realmente una serie temporal)

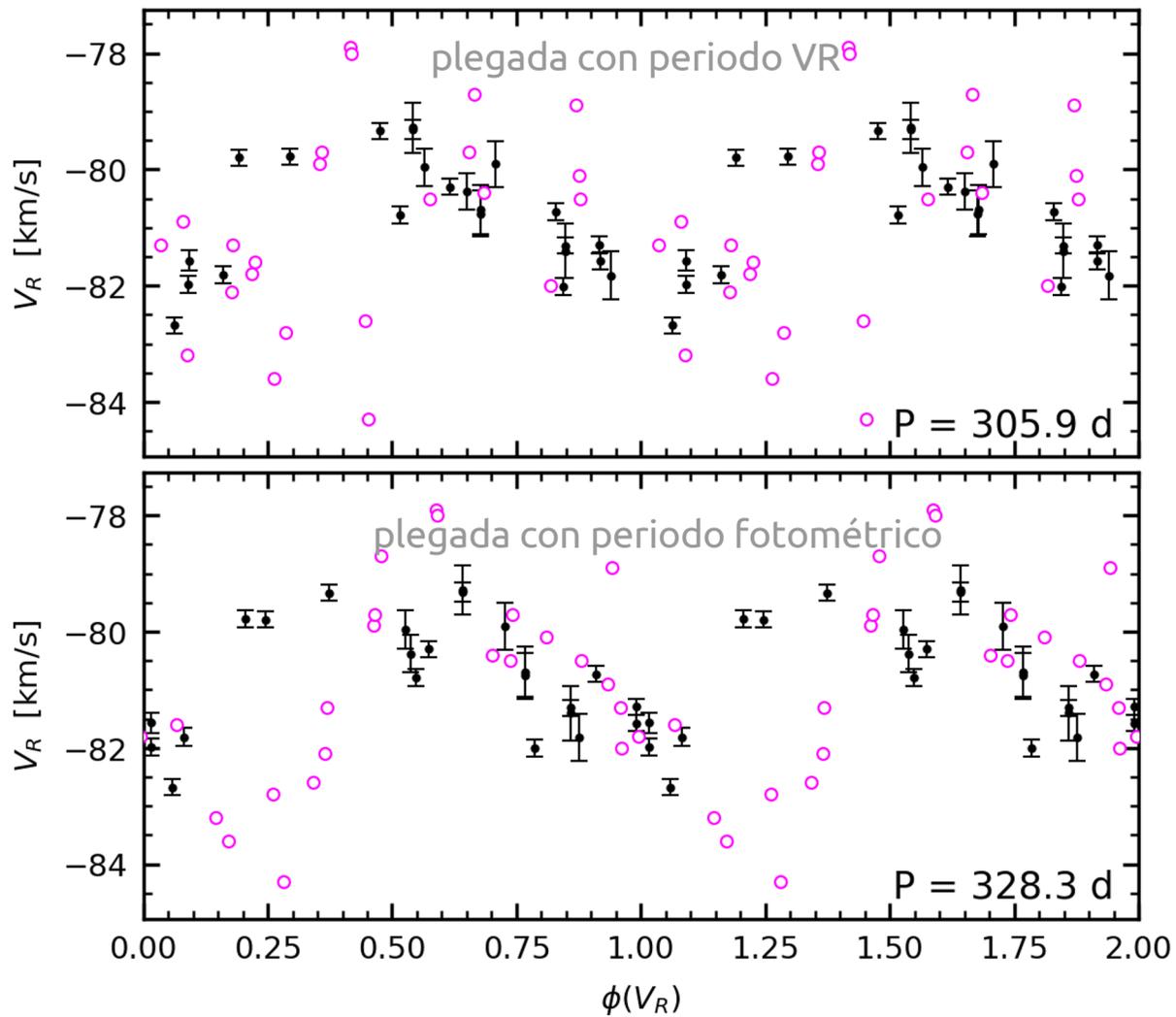
Reference
Alvarez et al. (2001)
Hinkle et al. (2002)
Lebzelter et al. (2005a)

Name	<i>Gaia</i> DR3 source ID	Var. type ^(a)	Sp. type ^(a)	P_G (FPR) days	P_{V_R} (FPR) days	$P_{Lit.}$ days	Reference
AR Cep	2300884800185315712	SRb	M4III	575.2	550.4		Alvarez et al. (2001)
RS CrB	1372316959598411520	SRa	M7	330.9	305.9	328.3 ± 2.6	Hinkle et al. (2002)
R Nor	5985676640941632384	Mira	M3e-M6II	505.5	496.7	507	Lebzelter et al. (2005a)

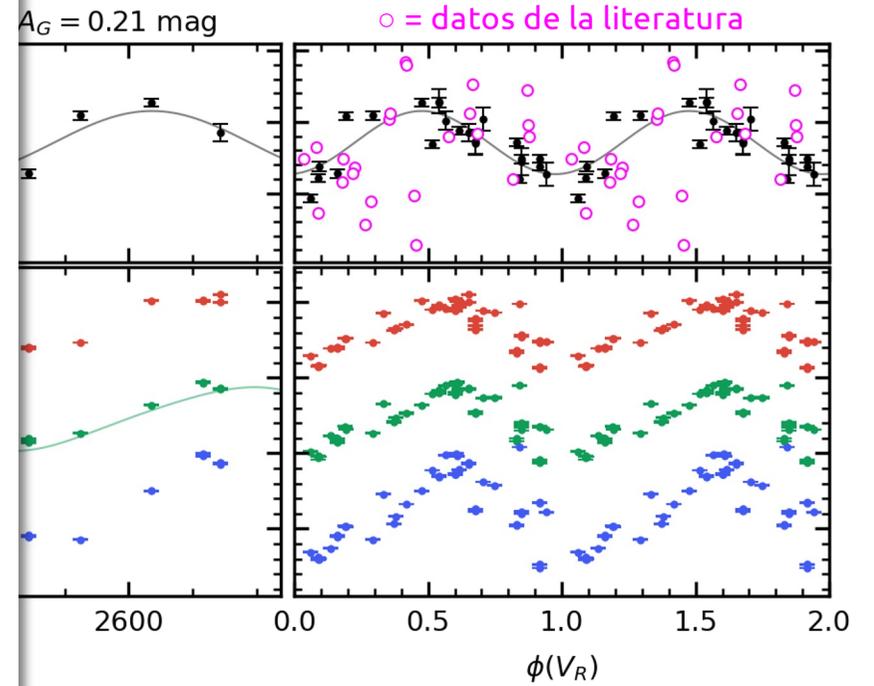


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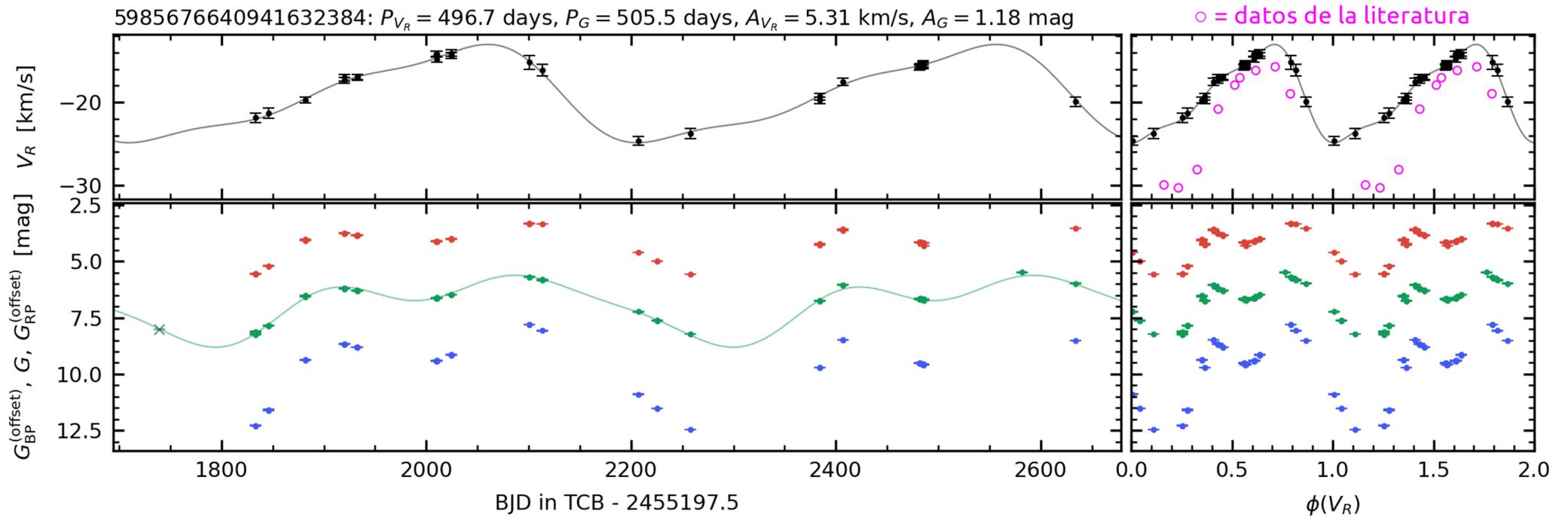


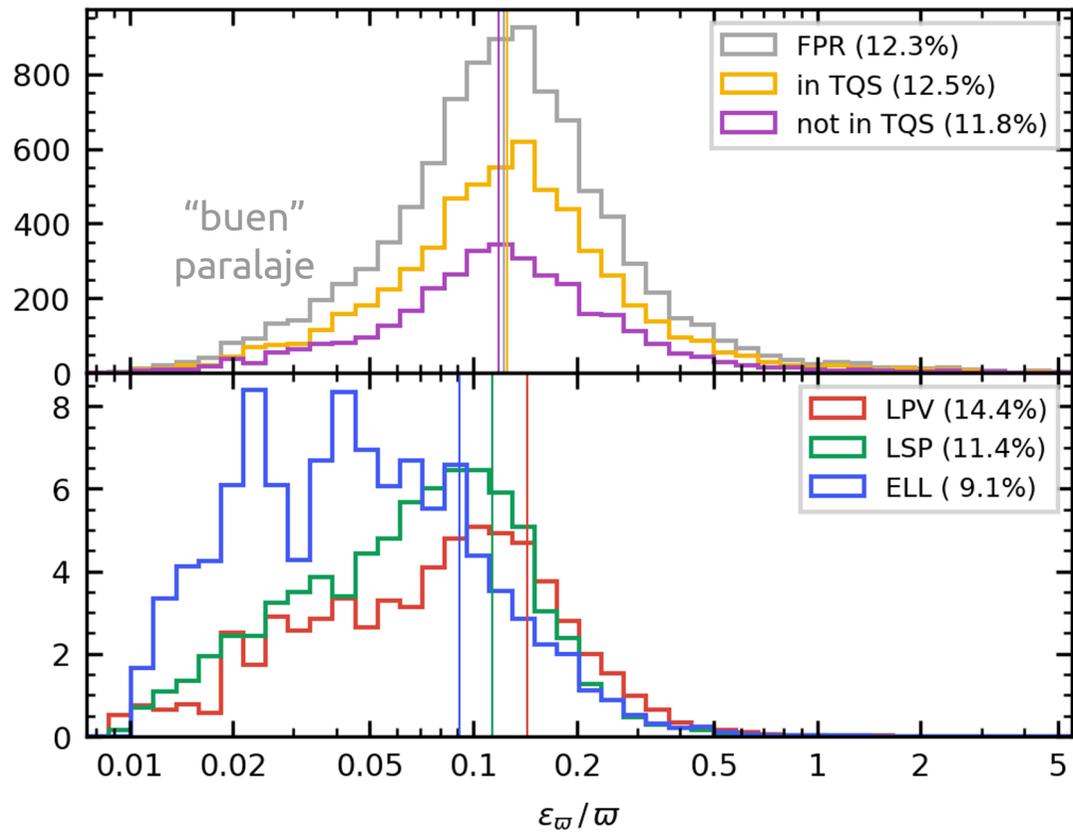


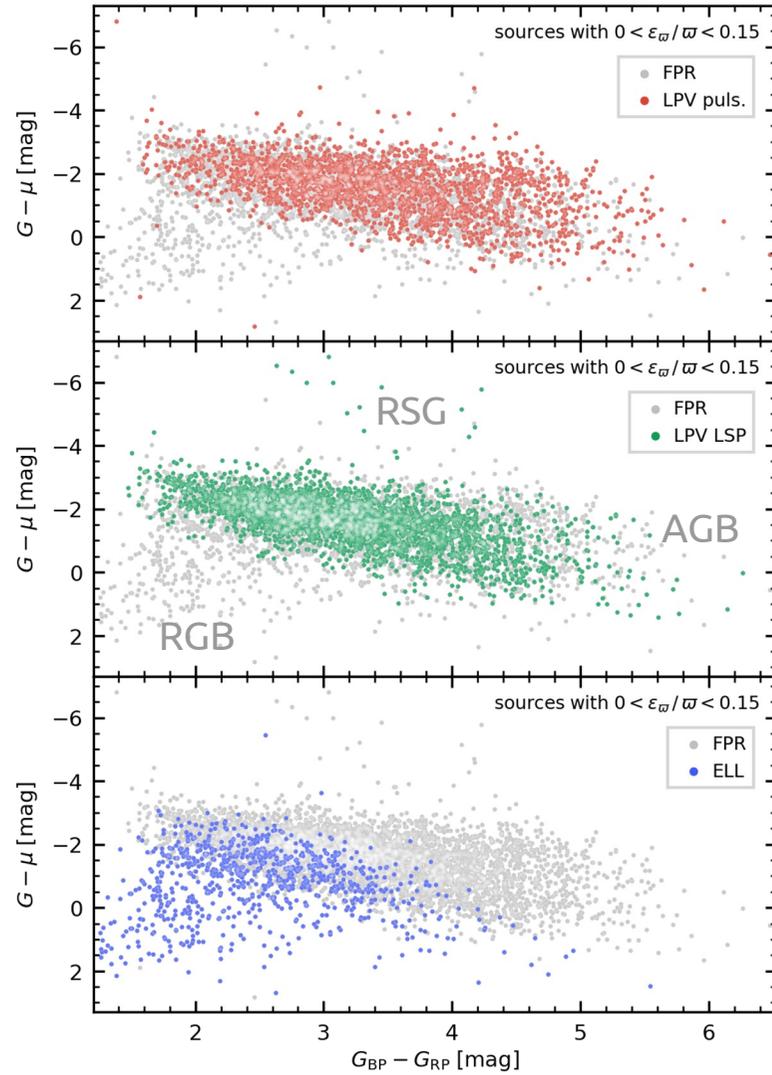
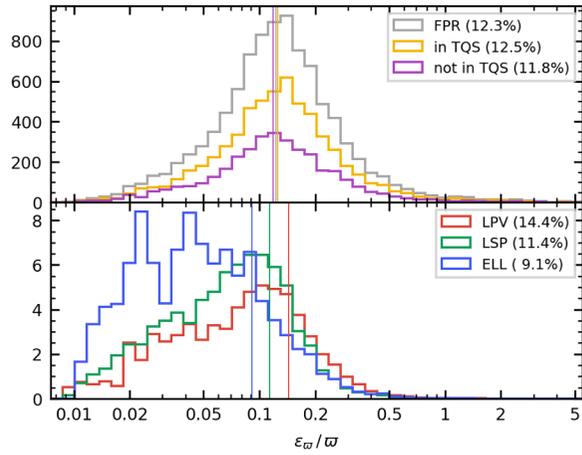
P_{V_R} (FPR) days	$P_{Lit.}$ days	Reference
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305.9	328.3 ± 2.6	Hinkle et al. (2002)
496.7	507	Lebzelter et al. (2005a)

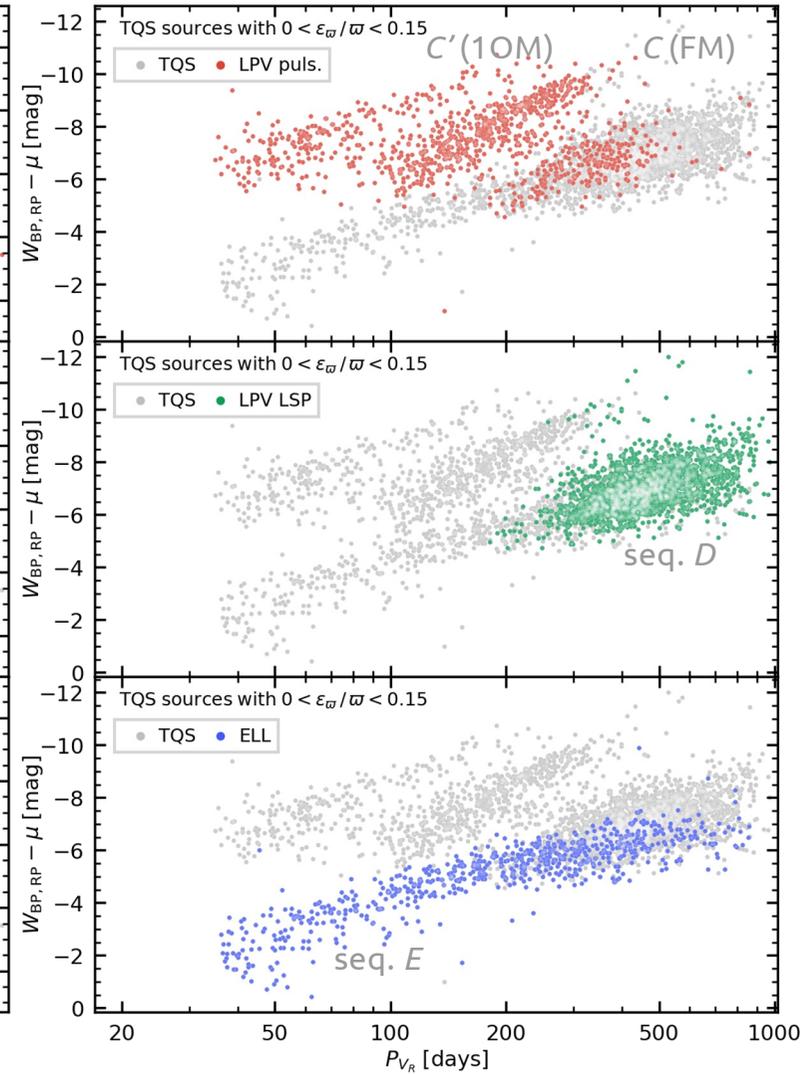
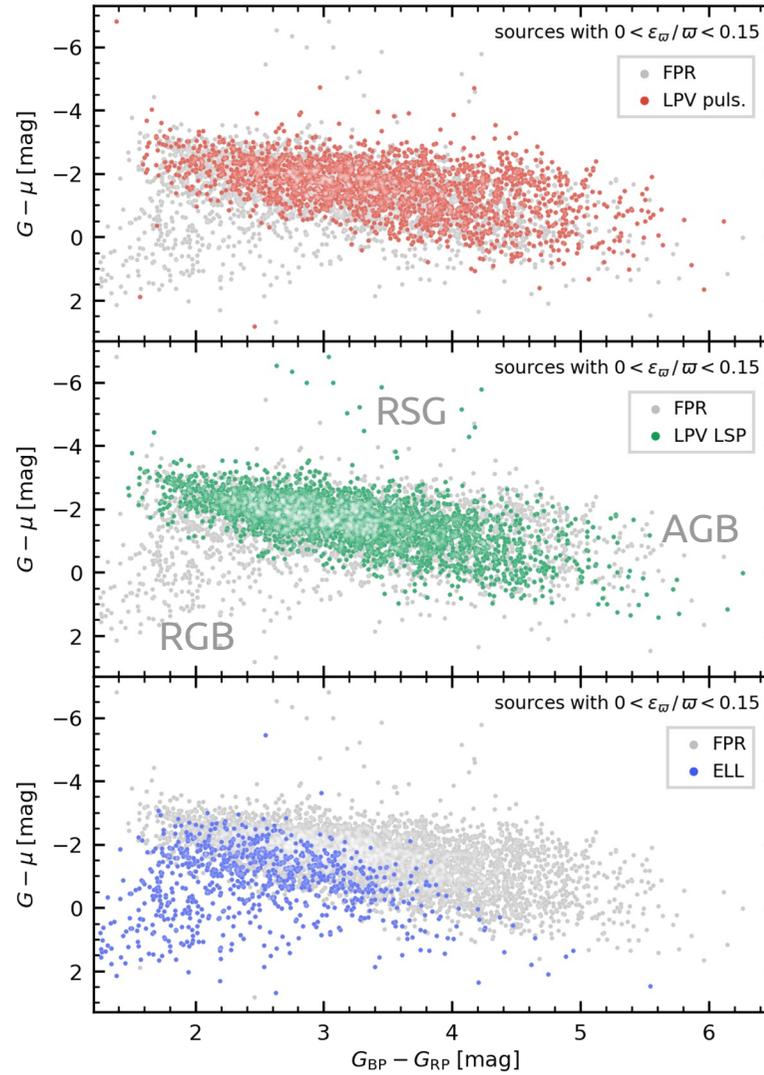
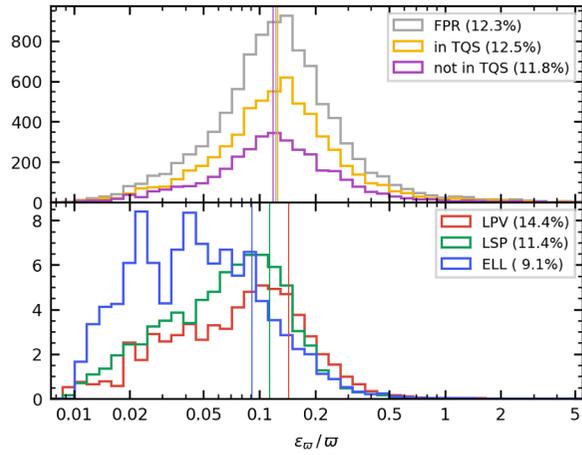


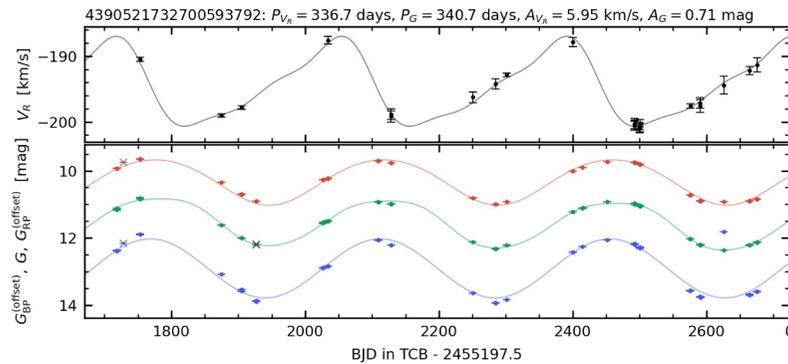
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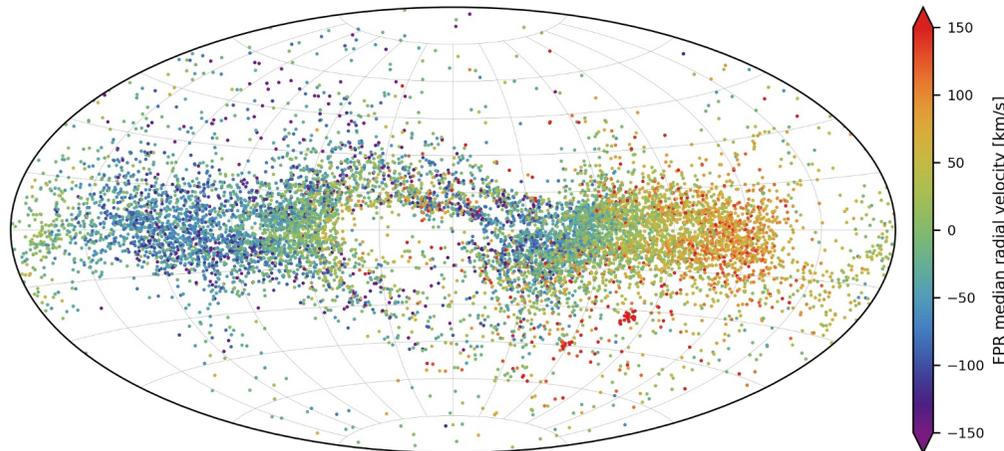






Gaia Focused Product Release

Radial velocity time series of long-period variables



- Medidas de VRs para $\sim 10^4$ VLPs
- Muestra ~ 10 -100 veces mayor que toda la literatura y de alta calidad (top)
- Medidas simultáneas G , G_{BP} , G_{RP} + VR
- 34 meses (> 1000 d) de observaciones
- ~ 20 épocas de VR por serie temporal
- pulsación, LSPs, y GRs elipsoidales
- clasificación consistente con relaciones periodo-luminosidad conocidas
- Preparación para DR4