

Gaia DR4 : Photometric Data and Solar System Objects

杨玉姣

中国科学院大学 天文与空间科学学院

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中国科学院大学

University of Chinese Academy of Sciences

Outline :

- Overview
- Datamodel
- Photometry
- Solar System Objects
- Science cases



overview

There were 3 intermediate Gaia data releases so far



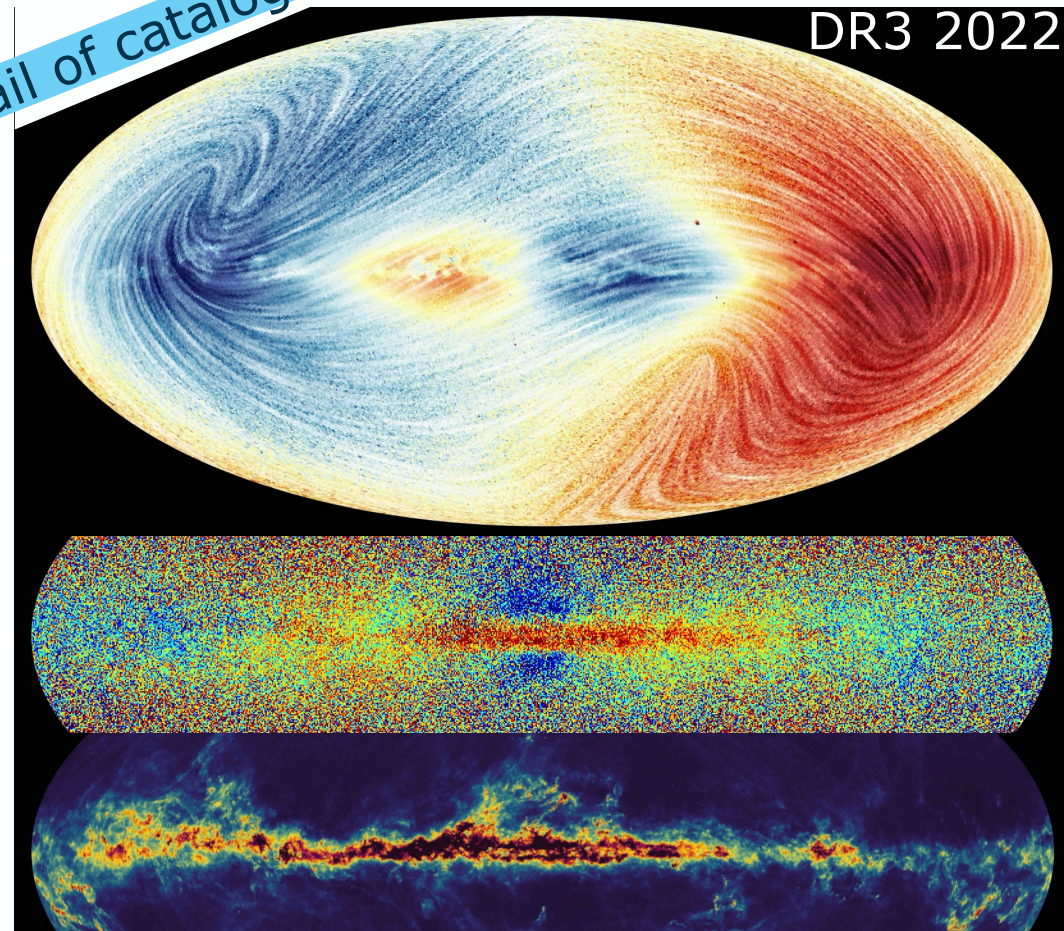
- Iterative process of incremental data releases
- There is no proprietary period on science data for the Gaia collaboration

- <https://www.cosmos.esa.int/web/gaia/data>

- Early DR3 (2020)
- Focused Product Release (5 products, 2023)



DR3 2022



[source](#)

6



→ THE EUROPEAN SPACE AGENCY

Credit : Sahlmann (ESA S7)



overview

The Gaia collaboration is preparing Gaia Data Release 4



- **Gaia DR4 is the first principal data release**
- **High quality data releases:** science-ready, calibrated, and validated data products; extensive documentation



Gaia DR4

(2 December 2026)

- 5.5 years of data ; ~400 TB
 - New data products
- Timeseries for all sources / instruments
- Previews, content, and more
- **New Science!**

DR1 2016

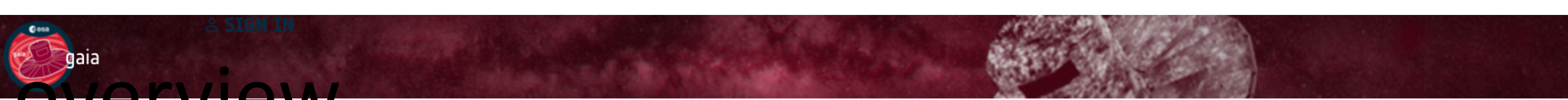
DR2 2018

DR3 2022



→ THE EUROPEAN SPACE AGENCY

Credit : Sahlmann (ESA S7)



overview

~75 papers

GAIA DR4 CONTENTS

A first overview on the Gaia Data Release 4 contents is available now. [End of June 2026](#) an update can be expected specifying number of sources for data products.

GAIA DR4 PAPERS

The papers describing the data processing and verifying the science performance of Gaia Data Release 4 will be published. Few pre-release papers are [available](#). Also the paper themes were published now.

GAIA DR4 DOCUMENTATION

The data release documentation for Gaia Data Release 4, describing the processing of the data from raw to Gaia DR4 will become available from both webpages and a downloadable PDF-file.

GAIA DR4 DATA

Gaia Data Release 4 data will become available from the [Gaia Archive](#) and [its partner data centres](#). Astrometric time series data for a few sources [are pre-released now](#) to help prepare the community.

An epoch_astrometry sample
9 single stars, 3 binaries

GAIA DR4 DATA MODEL

The Gaia DR4 data model explains in further details the tables and columns providing the Gaia data. A [draft version is now available](#).

GAIA DR4 KNOWN ISSUES

Issues found with Gaia DR4 data after publication will be published on a dedicated page. If you find an issue with Gaia data please contact the [Gaia Helpdesk](#).

GAIA DR4 AUXILIARY DATA

Passbands, exoplanet list, solar analogue spectrum, ... Auxiliary data will be published along with Gaia DR4.

GAIA DR4 PREVIEWS

Stay tuned for more previews of Gaia Data Release 4.

PYTHON ACCESS

Gaia data can be accessed using Python. Learn more about the astroquery package for Gaia [here](#).

TUTORIALS AND HELP

Help is available to guide you through the process of getting the data you need. Extensive information on writing [ADQL Queries](#) is provided as well to bring the your code to the data.

GAIA DATA CREDITS

We ask to please acknowledge the work of the people involved in the creation of Gaia DR4 and will provide credits and citation information. Each release comes with its own credit lines and DOI.

GAIA DR4 SOFTWARE TOOLS

Software code accompanying certain data products will be published along with the data. A tool to accompany the Gaia DR4 pre-release is [now available](#).

PUBLIC OUTREACH MATERIAL

An overview of news and stories on the Gaia Mission and Gaia science are given here. The press release by ESA on Gaia DR4 will be published here as well on the release day.

GAIA DR4 STORIES

Stay tuned for a selection of stories summarising the many data products of Gaia Data Release 4. These will be published on the release day.

GAIA DR4 DATA RELEASE EVENTS

Overview of the Gaia DR4 release events will be published in due time to allow the community to tune in to press releases in their own language.

QUESTIONS

Read our [FAQ](#) or contact the [Gaia Helpdesk](#).

overview : Contents



The Gaia DR4 content overview is available



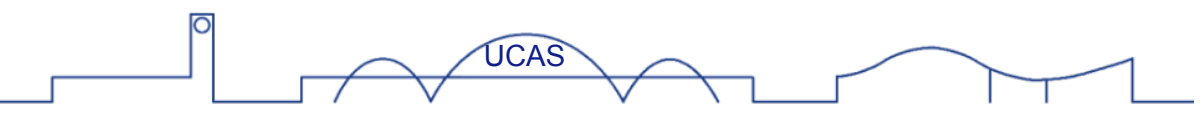
Table of data products at <https://www.cosmos.esa.int/web/gaia/dr4>

Id	Data model chapter / GACS section	Gaia Archive Table Name	Description	Category	New in DR4	Data level	Label	Access	Size	Volume
01.01	Gaia Data Release 4	gaia_source	Sources considered to have both high-quality astrometry and high-quality photometry. In contrast to previous data releases, the parameters in this table are consolidated from several different processing modules.	Main		DL3	General	TAP	2,000,033,276	586 GB
03.01	Astrometry	epoch_astrometry	Time series of astrometric data, i.e. individual astrometric measurements for all sources treated in the main astrometric processing.	Epoch	NEW	DL2	Astrometry	DataLink	129,625,750,708	62 TB



gaiadr4.gaia_source is different from gaiadr3.gaia_source

Talks by Brown, Vallenari



Credit : Sahlmann (ESA S7)



overview : Contents



1 Main source catalogue

1.1 gaia_source

1.2 spurious_signal

2 All-source catalogues

2.1 all_source_astrometry

2.2 all_source_flags

2.3 all_source_match

2.4 all_source_photometry

2.5 all_source_rvs

2.6 crowded_field_source_environment_map

3 Astrometry

3.1 epoch_astrometry

3.2 epoch_image

4 Astrophysical parameters

4.1 ap_chem

4.2 ap_class

4.3 ap_class_ir .DSC.

4.4 ap_emission

4.5 ap_hot

4.6 ap_rvs

4.7 ap_rvs_epoch

4.8 ap_xp

4.9 ap_xp_epoch

4.10 ap_xp_supp

4.11 interstellar_medium_params

4.12 interstellar_medium_spectra

4.13 mcmc_samples_gsp_phot

4.14 oa_neuron_information

4.15 oa_neuron_xp_spectra

4.16 total_galactic_extinction_map

4.17 total_galactic_extinction_map_opt

4.18 training_sources_dsc

4.19 training_sources_uca_oa

4.20 uca_neuron_information

4.21 uca_neuron_xp_spectra

5 Auxiliary

5.1 bam_observation

5.2 commanded_scan_low

5.3 gaia_gap

5.4 gbot_observation

5.5 onboard_detection_af_xp

5.6 onboard_detection_rvs

6 Bright stars

6.1 bright_source_astrometry

6.2 bright_source_epoch_astrometry

7 Cross match

7.1 catwise2020_best_neighbour

7.2 catwise2020_neighbourhood

7.3 dr3_neighbourhood

7.4 gaia_eso_survey_best_neighbour

7.5 gaia_eso_survey_join

7.6 gaia_eso_survey_neighbourhood

7.7 hipparcos2_best_neighbour

7.8 hipparcos2_neighbourhood

7.9 panstarrs1_best_neighbour

7.10 panstarrs1_join

7.11 panstarrs1_neighbourhood

7.12 ravedr6_best_neighbour

7.13 ravedr6_join

7.14 ravedr6_neighbourhood

7.15 sdssdr13_best_neighbour

7.16 sdssdr13_join

7.17 sdssdr13_neighbourhood

7.18 skymapperdr2_best_neighbour

7.19 skymapperdr2_join

7.20 skymapperdr2_neighbourhood

7.21 tmass_psc_xsc_best_neighbour

7.22 tmass_psc_xsc_join

7.23 tmass_psc_xsc_neighbourhood

7.24 tycho2tdsc_merge_best_neighbour

7.25 tycho2tdsc_merge_neighbourhood

8 Crowded fields

8.1 crowded_field_coverage_map

8.2 crowded_field_epoch_astrometry

8.3 crowded_field_epoch_photometry

8.4 crowded_field_image

8.5 crowded_field_image_summary

8.6 crowded_field_source

9 Extra-galactic

9.1 galaxy_candidates

9.2 galaxy_morphology_input_list

9.3 grav_lens_combination

overview : Contents



9.4 grav_lens_component	11.2 epoch_photometry_ccd	15.4 sso_xp_epoch_spectrum	18.5 vari_compact_companion
9.5 grav_lens_input_list	11.3 synthetic_photometry_gspc		18.6 vari_eclipsing_binary
9.6 grav_lens_observation		16 Source environment SEAPipe	18.7 vari_epoch_flags
9.7 grav_lens_outlier	12 Reference frame	16.1 gaia_source_environment	18.8 vari_flaring_star
9.8 grav_lens_redshift	12.1 frame_rotator_source	16.2 residual_image	18.9 vari_gvd_classifier_feature
9.9 grav_lens_xp_mean_spectrum	12.2 gaia_crf4	17 Spectroscopy	18.10 vari_long_period_variable
9.10 qso_candidates	12.3 gaia_crf4_external_names	17.1 rvs_epoch_parameters_dou	18.11 vari_microlensing
9.11 qso_morphology_input_list	13 Science alerts	17.2 rvs_epoch_parameters_sing	18.12 vari_planetary_transit
10 Non-single stars	13.1 alerts_mixedin_sourceids	17.3 rvs_epoch_spectrum	18.13 vari_pms_oscillator
10.1 nss_acceleration_astro	13.2 science_alerts	17.4 rvs_mean_spectrum	18.14 vari_rad_vel_statistics
10.2 nss_epoch_flags	13.3 sso_alerts	17.5 rvs_transit_description	18.15 vari_rotation_modulation
10.3 nss_masses	14 Simulation	17.6 rvs_two_body_orbit	18.16 vari_rrlyrae
10.4 nss_multiple_orbits	14.1 gaia_source_simulation	17.7 xp_continuous_mean_spec	18.17 vari_short_timescale
10.5 nss_multiplicity	14.2 gum_galaxy	17.8 xp_epoch_crowding	18.18 vari_summary
10.6 nss_non_linear_spectro	14.3 gum_mw	17.9 xp_epoch_spectrum	18.19 vari_unsupervised
10.7 nss_resolved_pair	14.4 gum_qso	17.10 xp_summary	18.20 vari_yso
10.8 nss_two_body_orbit	14.5 gum_sn	18 Variability	
10.9 nss_vim_fl	15 Solar System	18.1 vari_agm	
10.10 optical_pair	15.1 sso_observation	18.2 vari_cepheid	
11 Photometry	15.2 sso_reflectance_spectrum	18.3 vari_classifier_feature	
11.1 epoch_photometry	15.3 sso_source	18.4 vari_classifier_result	

overview : Contents

Gaia DR4: major table structure change



**2.8 billion sources
no filtering**

all_source_astrometry

nss_astrometry

crowded_field_source

gaia_source_environment

all_source_photometry

all_source_rvs

nss_spectroscopic

variability_tables

astroph. parameter tables

extragalactic_tables

all_source_flags

**2 billion sources
reliable, 'best' parameters**

gaia_source

astrometry

photometry

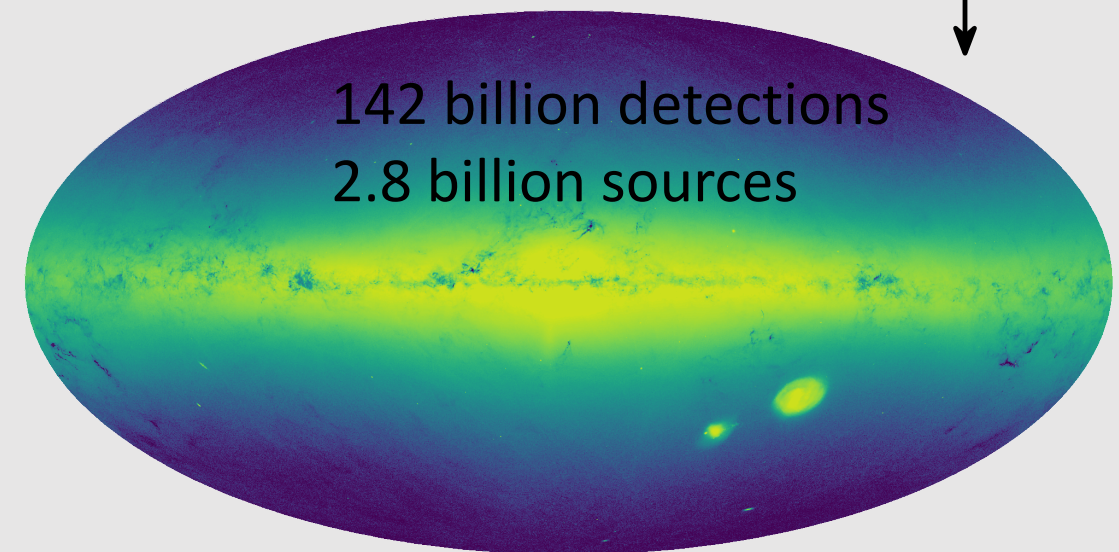
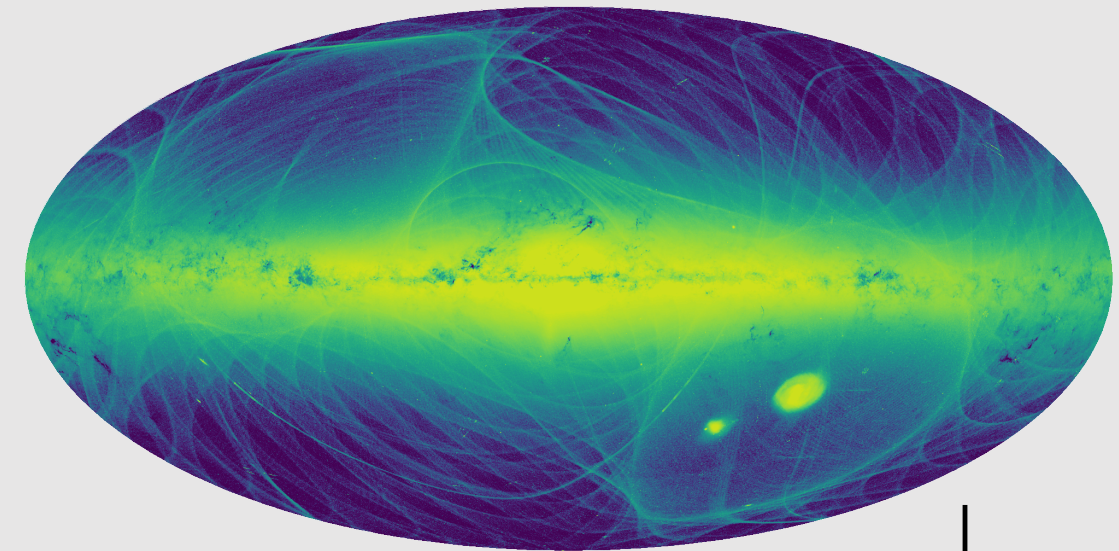
radial velocity

variability

astrophysical parameters

extragalactic

flags



overview : data sample

We pre-released 12 Gaia DR4 astrometric timeseries



Data for 12 sources available via FTP, see <https://www.cosmos.esa.int/web/gaia/dr4-prerelease>

Gaia DR4 source_id	Name	Group	Approx. G Magnitude	Approx. parallax (mas)
2309425390592896		magnitude	14.0	0.9
20694084440761600		magnitude	14.1	4.9
1663617687609809280	LSPM J1324+6124	magnitude	14.3	10.1
4318465066420528000	Gaia BH3	orbit	11.2	2.0
1457486023639239296	Gaia-4	orbit	11.9	13.6
3937211745905473024	HD 114762	orbit	7.2	25.6
435469040545191680		parallax	14.0	1.0
3926186255616949504		parallax	19.0	1.0
4181040337841125632	HD 183633	parallax	9.0	1.0
2237987199365376		qso	19.8	0.0
10973744521070720		qso	19.9	0.0
60730287810150016		qso	20.1	0.0



Credit : Sahlmann (ESA S7)



overview :



	DR3	DR4
数据大小	~10 TB	~400 TB
观测时间	~34 months	~66 months
DataModel	source-level	time-resolved



DataModel : time-resolved data

Measurement → Time-resolved observation → Source-level catalogue → Physical interpretation

DL1 (Detector / Image level)

- CCD samples / images

DL3 (Source level)

- Position & Parallax
- Proper motion
- G/BP/RP
- Radial velocity

DL2 (Epoch / Transit)

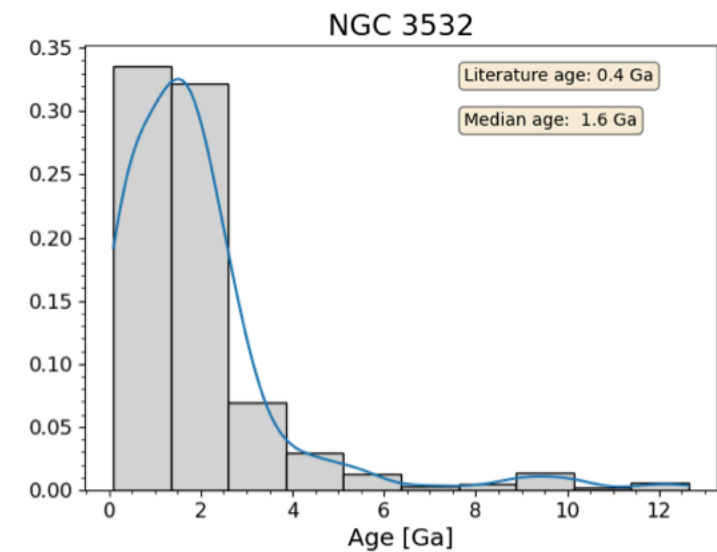
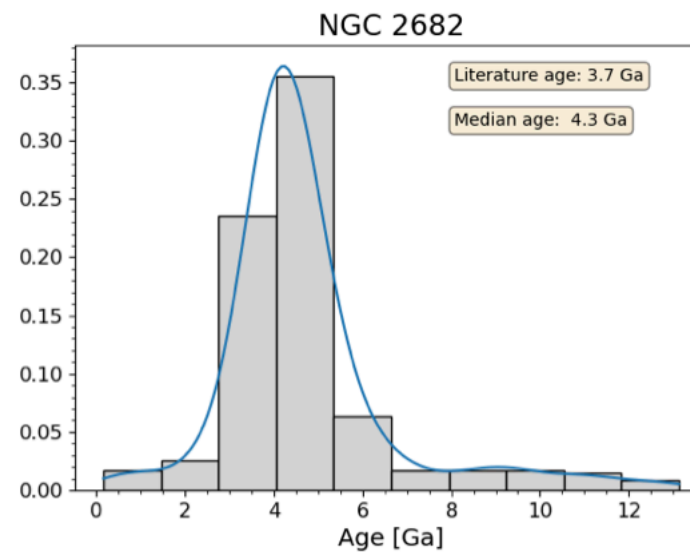
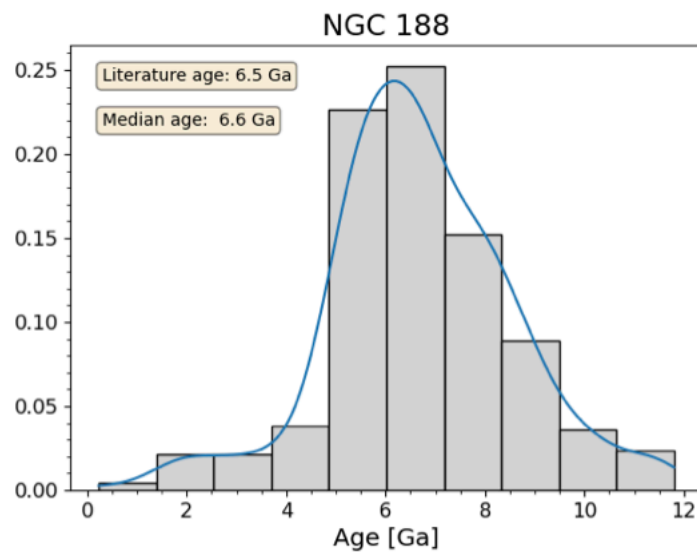
- Epoch astrometry
- Epoch photometry
- Epoch spectroscopy/RV

DL4 (Astrophysical parameters)

- T_{eff} / $\log g$ / $[M/H]$
- Extinction / Luminosity
- Stellar properties

DataModel : FLAME

- Final Luminosity Age Mass Estimator (FLAME), Creevey 2026, 500M stars
- Analytical : luminosity, radius, radial velocity
- Model inference : mass, age, evolutionary stage (BaSTI)



Credit : Creevey (ESA S7)

DataModel : FLAME

- Final Luminosity Age Mass Estimator (FLAME), Creevey 2026, 500M stars

- Input

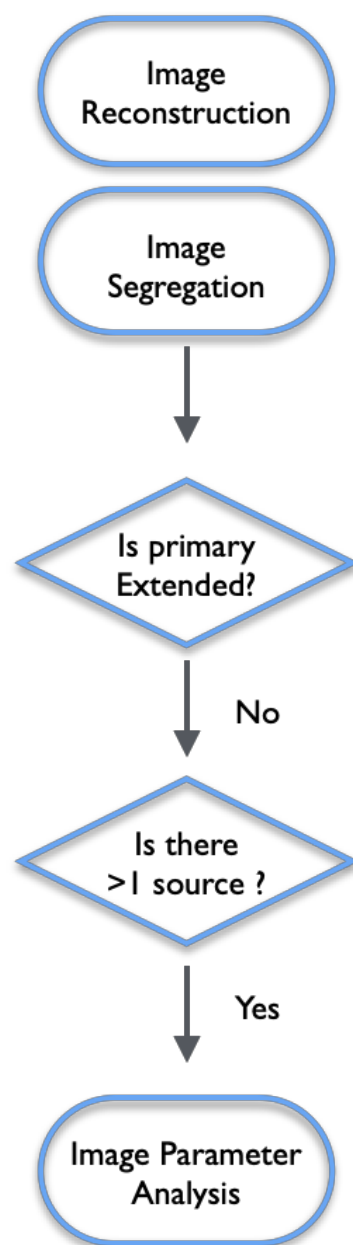
XP	RVS
d	ϖ
G	G
T_{effXP}	T_{effRVS}
$\log g_{\text{XP}}$	$\log g_{\text{RVS}}$
$[M/H]_{\text{XP}}$	$[M/H]_{\text{RVS}}$
–	$[\alpha/\text{Fe}]_{\text{RVS}}$
$A_{G\text{XP}}$	$A_{G\text{XP}}$

- Output

Parameter	description	XP	RVS
L	luminosity	lum_flame	lum_flame_spec
R	radius	radius_flame	radius_flame_spec
V_{GR}	radial velocity correction due to the gravitational redshift	gravredshift_flame	gravredshift_flame_spec
BC	bolometric correction	bc_flame	bc_flame_spec
M	mass	mass_flame	mass_flame_spec
τ	age	age_flame	age_flame_spec
ϵ	evolution stage	evolstage_flame	evolstage_flame_spec
$[M/H]$	model metallicity	mh_flame_model	mh_flame_model_spec
$\log g$	model $\log g$	logg_flame_model	logg_flame_model_spec
T_{eff}	model T_{eff}	teff_flame_model	teff_flame_model_spec
L	model L	lum_flame_model	lum_flame_model_spec

Credit : Creevey (ESA S7)

DataModel : SEAPipe



Source Environment Analysis : SEAPipe

Identify extended sources

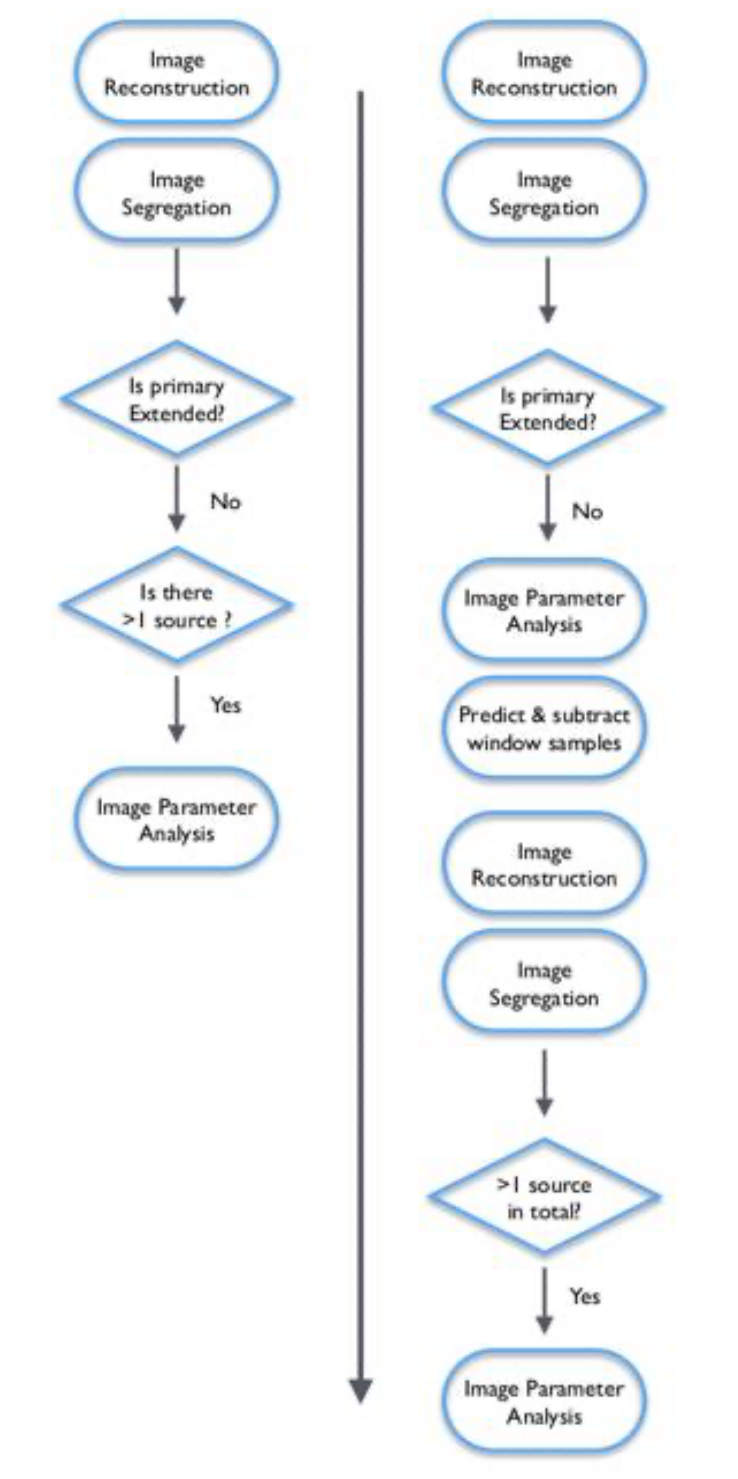
Find additional sources in the windows of Gaia sources (on-board detection)

Solve for the flux and astrometric parameter (position, proper motion, parallax) for the additional sources together with their parent source (the one detected on-board)



Credit : Harrison (ESA S7)

DataModel : SEAPipe



SEAPipe: we can find fainter, closer companions

An image subtraction version of SEAPipe was also developed

Gaia data processing SEAPipe: The source environment analysis pipeline

[A&A, 679 \(2023\) A158](#)

Residual images



Credit : Harrison (ESA S7)

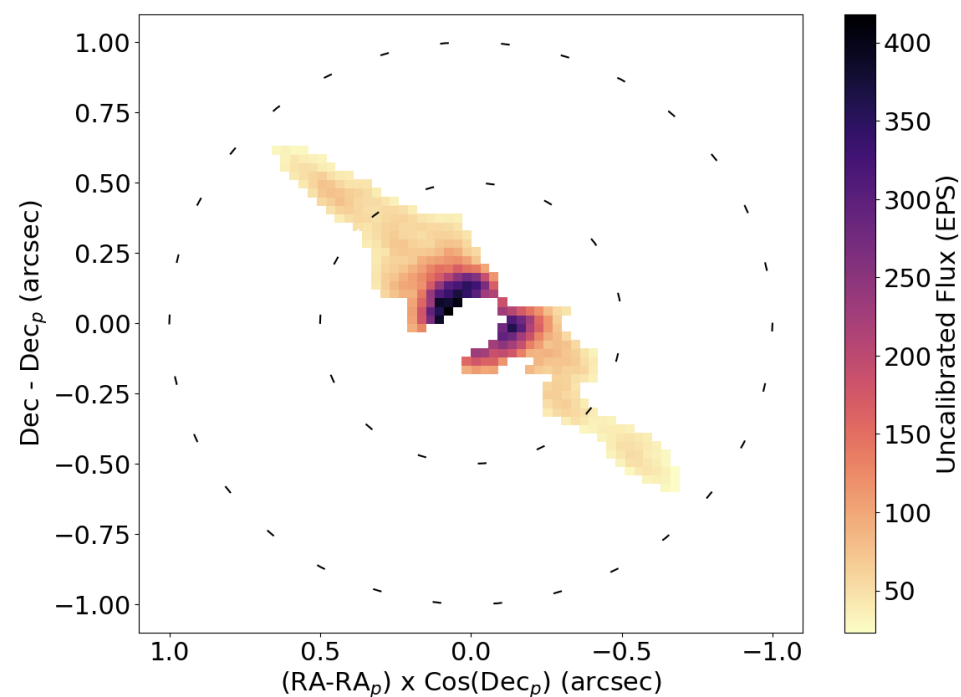
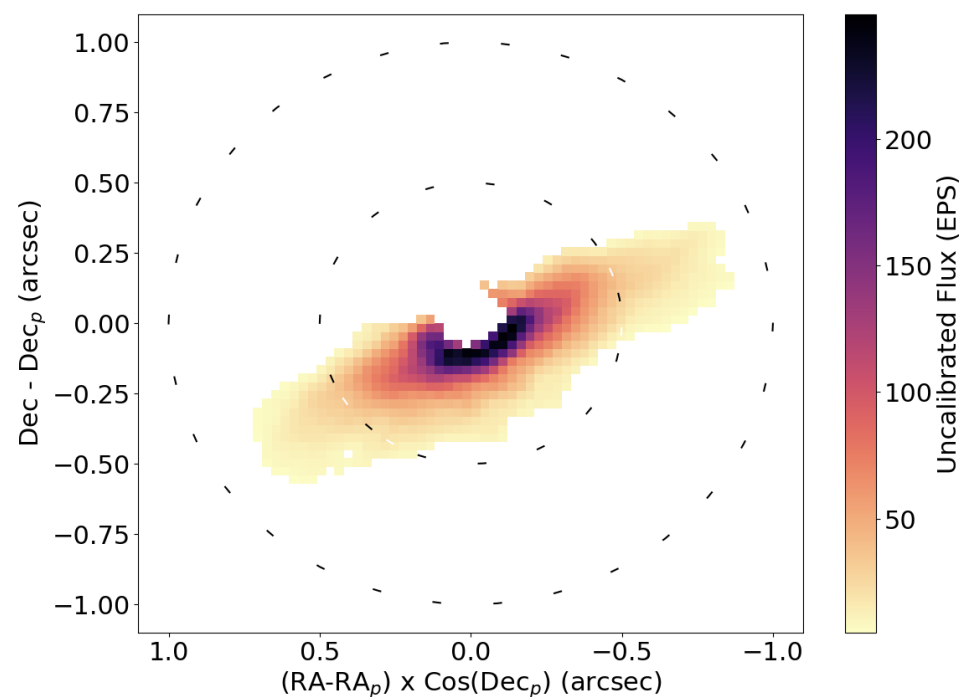
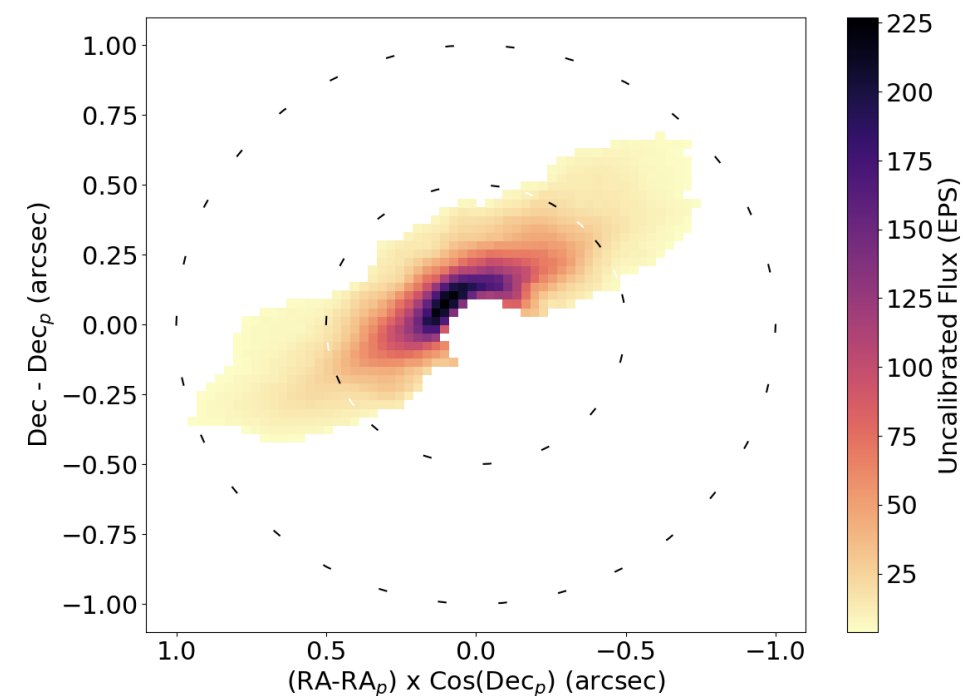


DataModel : SEAPipe



We can see scattered light

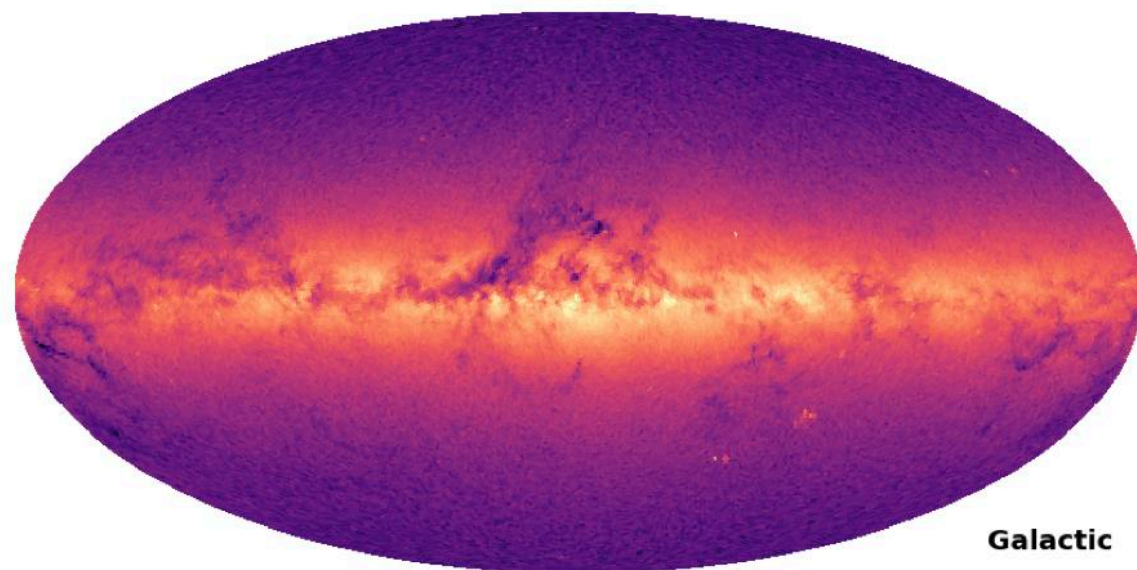
Examples of debris disks in Gaia with alignments which agree with polarised intensity observations



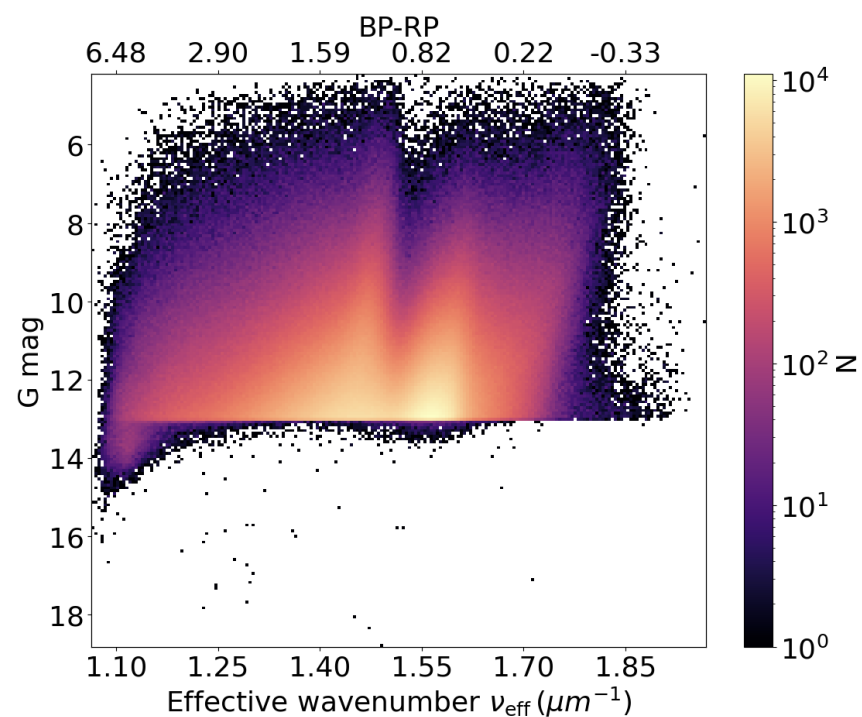
Credit : Harrison (ESA S7)



DataModel : SEAPipe



11 No. of residual images 1377



Residual image product

~ 7 million residual images distributed over the whole sky will be available in DR4

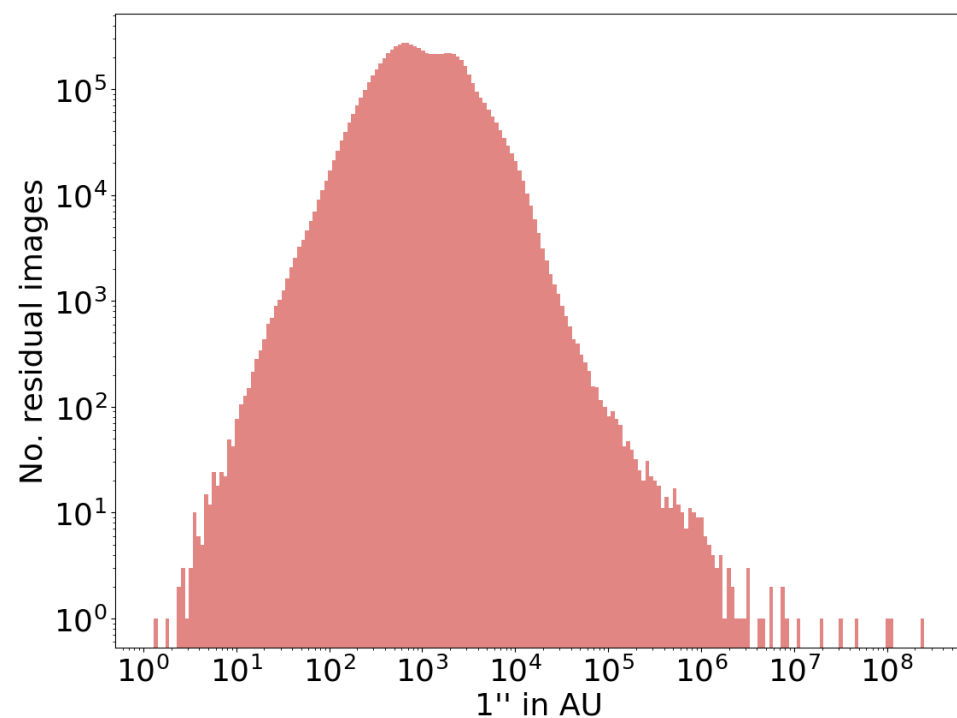
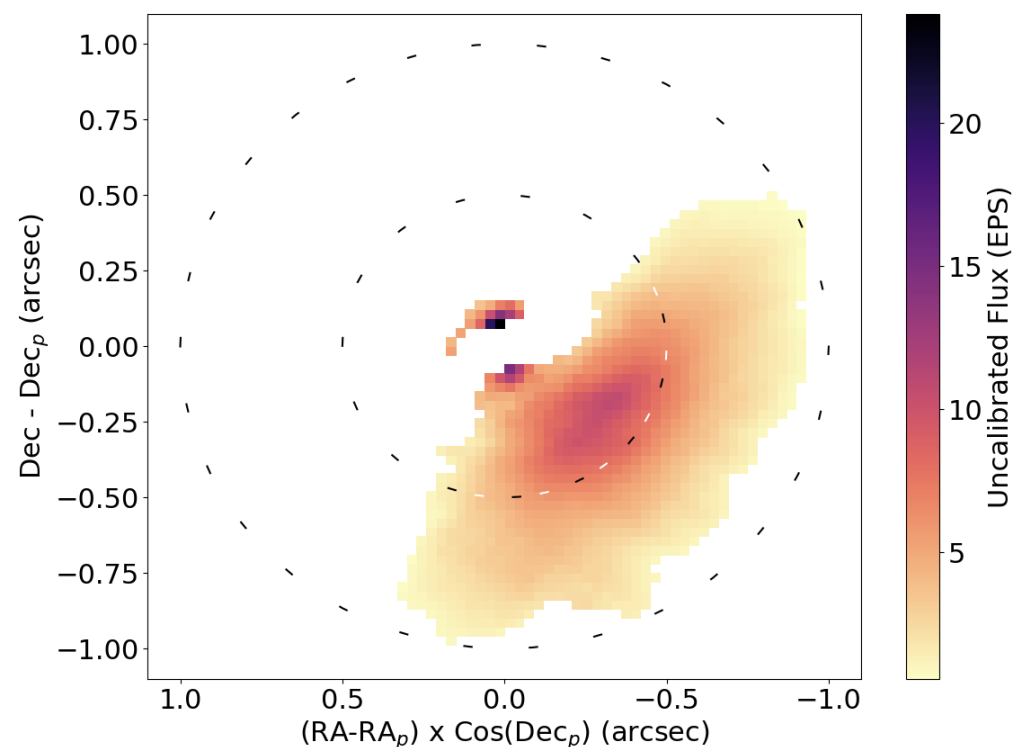
Majority $G < 13$ however a few will be fainter

If a source was assigned enough 2D windows, it is processed by DiffuseLightPipe and will have a residual image



Credit : Harrison (ESA S7)

DataModel : SEAPipe



Residual image product

Size of the images is restricted to the height of the AF windows in combination with how well the windows are centred on the Gaia source

Radius $\sim 1.1''$ to $1.2''$

Some disks maybe too big to see... or to see all or it.



Credit : Harrison (ESA S7)

DataModel : SEAPipe



Summary

Residual images is a new product for [DR4](#) (December 2026)

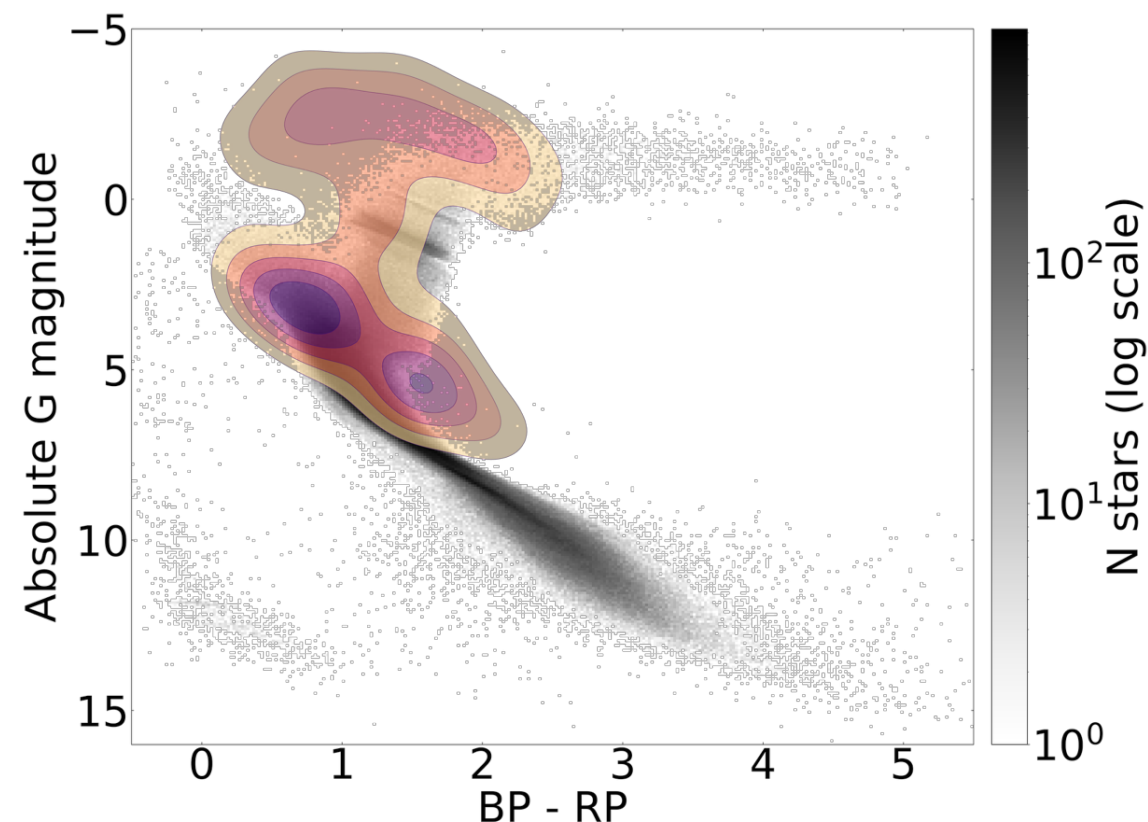
Available for majority of $G < 13$ Gaia sources

Full-sky survey of scattered light

The accompanying paper

Will characterise the sensitivity of these images (So, absence of emission will also be informative)

Will present the most visually obvious case of diffuse emission and describe how these were found



Credit : Harrison (ESA S7)



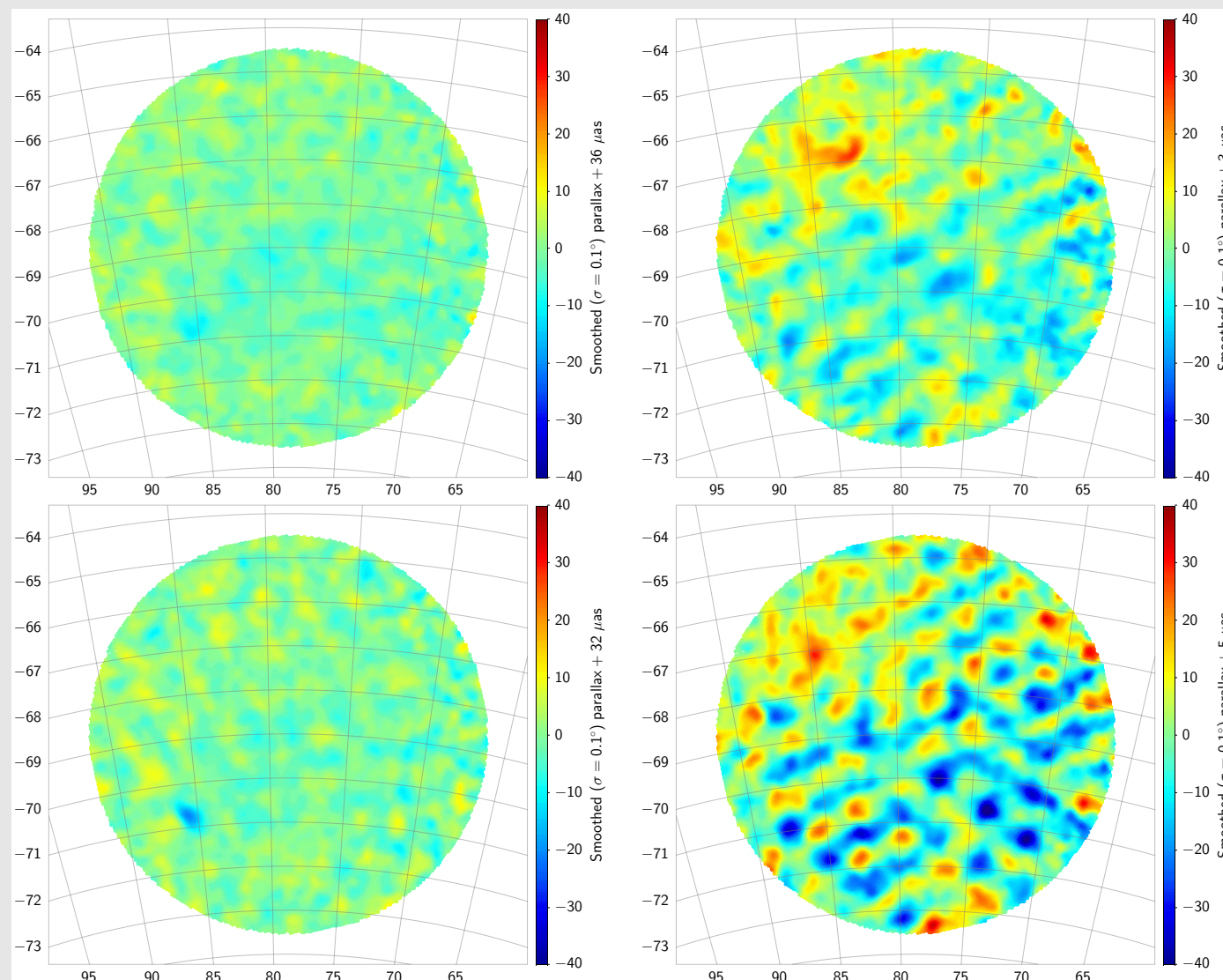
Photometry :

Suppressed systematic errors



DR4

DR3



- Parallaxes in 4.5° radius region around LMC centre
- Top $G = 16-18$ (826k sources)
- Bottom $G = 18-20$ (6.38M sources)
- Maps smoothed with 0.1° Gaussian kernel
- Median subtracted from each map

DPAC/CU3/DPCE/DPCB team

Gaia DR4 Gaia DR4 performance Major changes Conclusions

EAS2026 - 2026.06.29 - 7/18

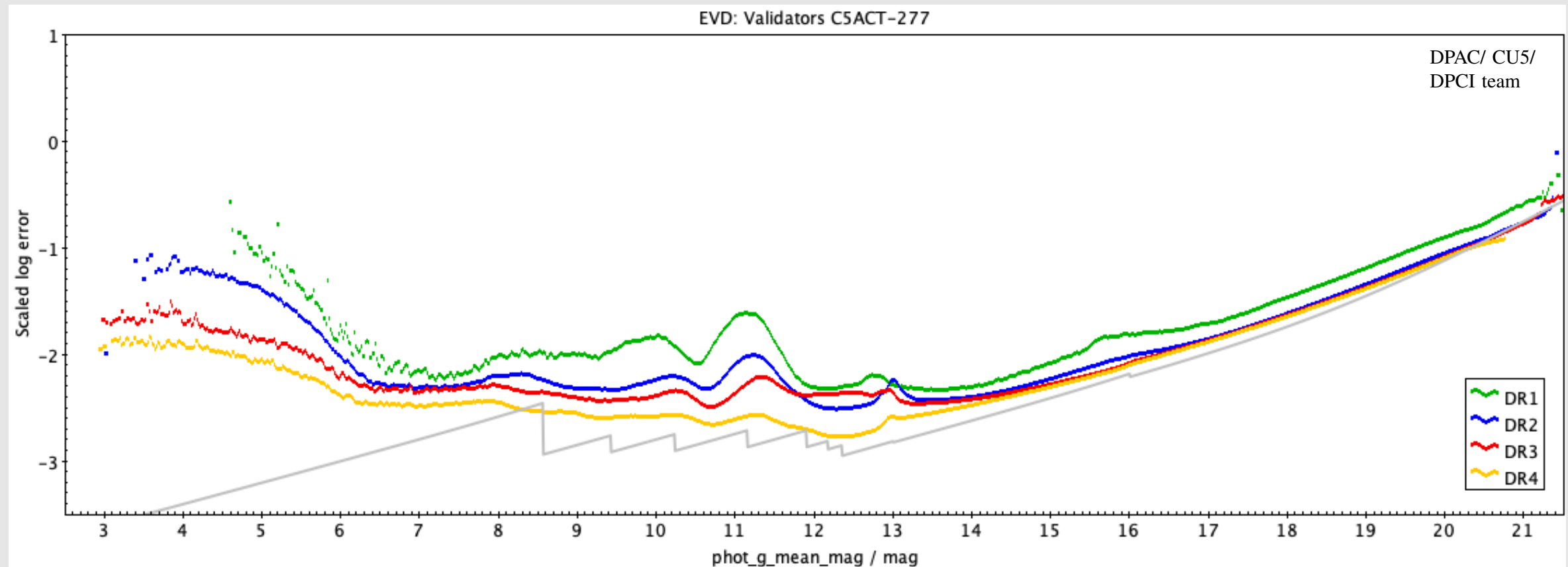


Credit : Brown (ESA S7)



Photometry : validation

Photometry: uncertainties across releases

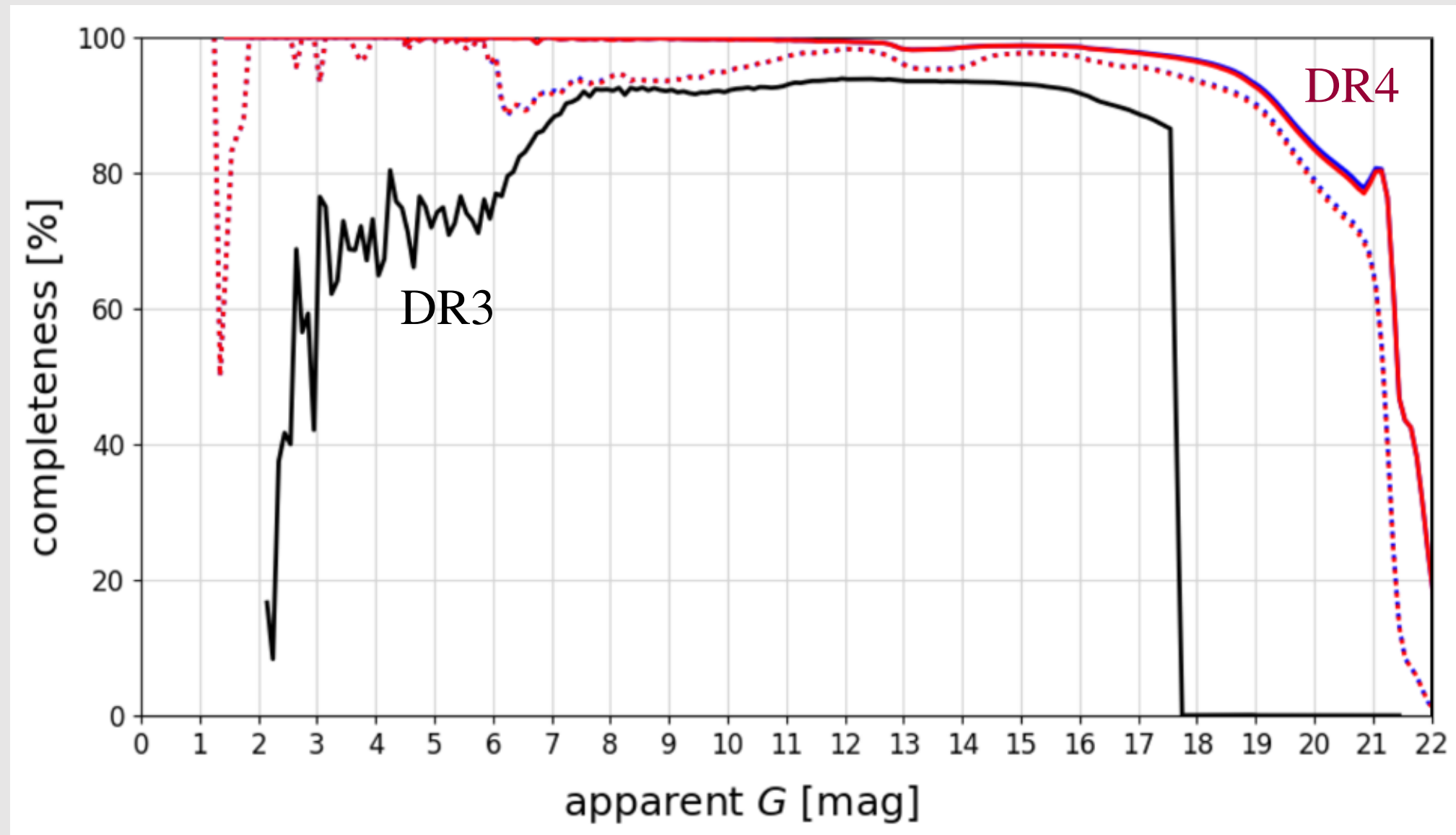


- Uncertainties are scaled to single CCD transit
 - ▶ shows the improvements in photometric processing from one release to the next
- Uncertainties on the means will include effect of increasing number of observations



Photometry : validation

Completeness with respect to catalogue



DPAC/ CU5/
DPCI team

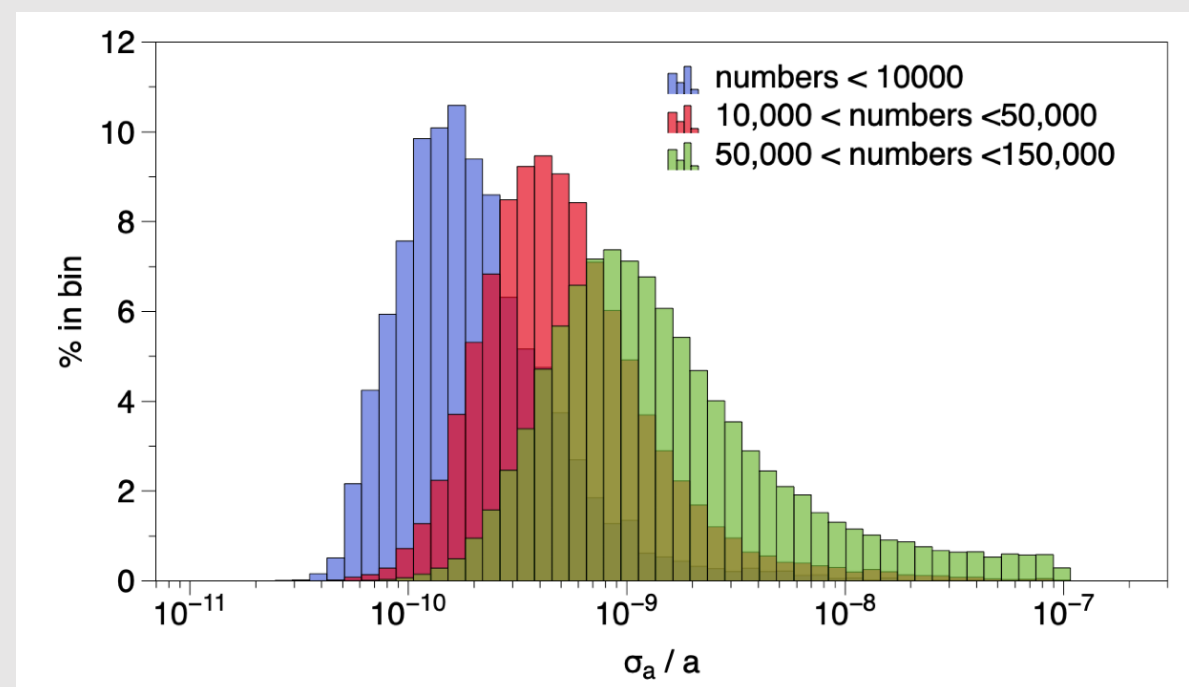
Credit : Brown (ESA S7)

Solar System Objects :

Solar system content

- 8 283, 838 transits of 436 551 objects
 - ▶ 7 149 713 have a calibrated G
- 100 648 objects with reflectance spectrum
- 215 000 orbits with $\sigma_a/a < 10^{-7}$
 - ▶ 345 000 in total
- Science applications
 - ▶ Determine the precise mass for several tens of asteroids (Gaia only observations)
 - ▶ Enable new stellar occultations by small objects
 - ▶ Detect non-gravitational effects on asteroids and comets
 - ▶ Improve dynamical models of planetary satellite orbits
 - ▶ Find satellites around asteroids

Object category	Object count
Natural satellite	42
Asteroid	434 237
Comet	314
Unidentified SSO	1 957



DPAC/CU4-SSO/DPCC team

Solar System Objects :

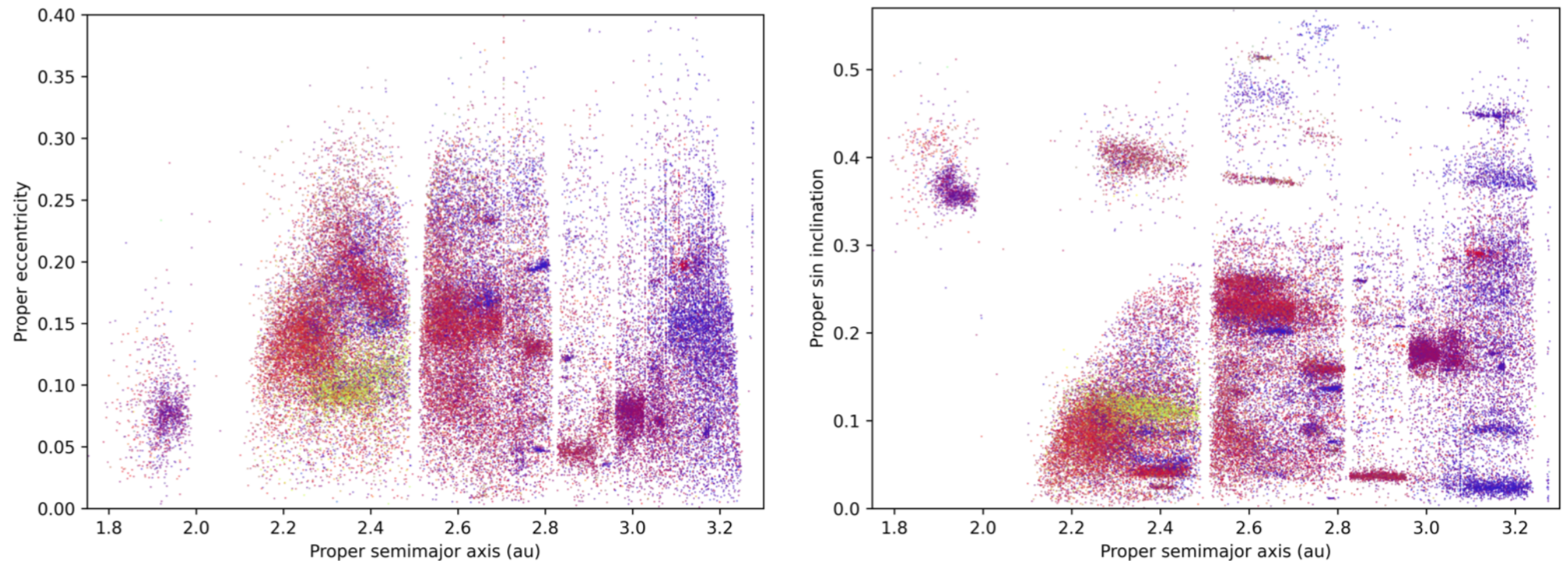


Fig. 12. Plot of the proper semi-major axis vs. proper eccentricity and sin of proper inclination for *Gaia* DR3 SSOs of the main-belt and Hungaria region. The colour of each dot is representative of the object's colour measured by *Gaia* according to the colour scheme defined in Section 4.2.

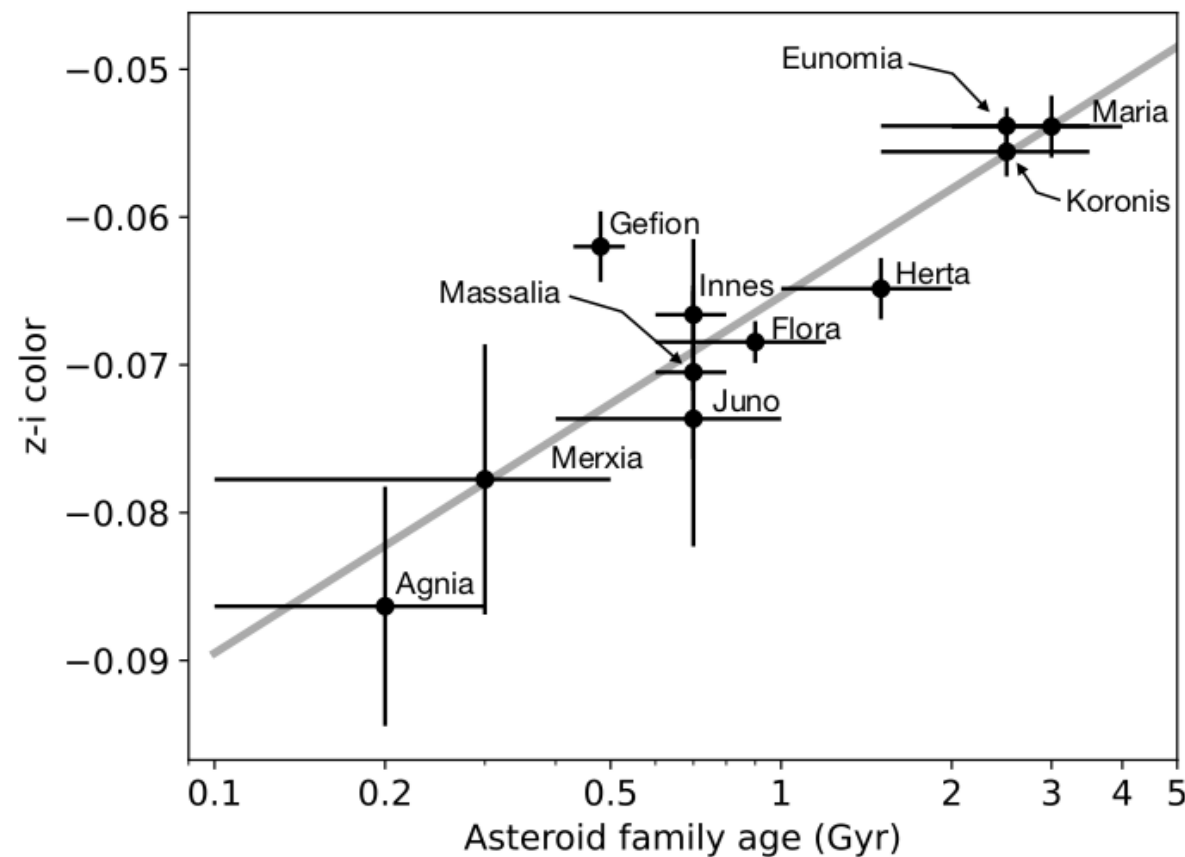
Gaia Collaboration, Galuccio et al. 2023

Color coding according to the position in the *i-z* vs. slope plot. S-complex is red to brown, C-complex blue, V-types green, D- and L- are red, X- and K-types magenta.

Solar System Objects :



Family ages



Gaia Collaboration, Galuccio et al. 2023

Galuccio et al. 2023:

- Correlation between z-i colour and the logarithm of the family age has a correlation coefficient of 0.91
- Correlation between spectral slope and the log of family age has a correlation coefficient 0.67
- weak correlation between phase angle and spectral slope (0.3) and between phase angle and depth of the 0.9 micron band (-0.1) for S-complex asteroids

DL4 : Astrophysical Parameters



Astrophysical Parameters in Gaia

- Extra-galactic
 - Galaxy and quasar classifications, probabilities, and redshifts
- Stellar
 - Atmospheric: T_{eff} , $\log g$, $[M/H]$, $v \sin i$, stellar activity, emission
 - Evolutionary: Radius, Mass, Age, luminosity, RV correction for grav. redshift
 - Chemistry: metallicities and elemental abundances
 - Classifications: Spectral types, emission line stars
 - Distances
- Interstellar medium
 - Line of sight extinction and reddening (in various bands)
 - Total galactic extinction map (2D) at various healpix levels
 - Diffuse interstellar band



Credit : Creevey (ESA S7)



DL4 : Astrophysical Parameters



Astrophysical Parameters in

- In Gaia DR3
 - Classifications on 1.8 billion sources
 - 500 million APs from XP spectra
 - 350 million APs with assumption of composite
 - 280 million evolutionary parameters
 - 230 million spectral type classifications
 - 6 million APs from RVS spectra
 - 2 million activity index from Ca lines
 - 1.8 million redshifts for quasar candidates
 - 1.3 million redshifts from unresolved galaxy car
 - 0.8 million vsini of OBA stars Hot
 - 95 thousand teff for ultra-cool dwarfs
 - 60 thousand emission line star classifications
 - 2D extinction map to HealPix level 9

Gaia Data Release 3

+  gaiadr3.gaia_source

+  gaiadr3.gaia_source_lite

Astrophysical parameters

+  gaiadr3.astrophysical_parameters

+  gaiadr3.astrophysical_parameters_supp

+  gaiadr3.oa_neuron_information

+  gaiadr3.oa_neuron_xp_spectra

+  gaiadr3.total_galactic_extinction_map

+  gaiadr3.total_galactic_extinction_map_opt

Extra-galactic

+  gaiadr3.galaxy_candidates

+  gaiadr3.galaxy_catalogue_name

+  gaiadr3.qso_candidates

+  gaiadr3.qso_catalogue_name

MCMC GSP-Phot -- source_id (696)



MCMC MSC -- source_id (997)



eas 2026
Lausanne



Credit : Creevey (ESA S7)

DL4 : Astrophysical Parameters



Astrophysical Parameters in Gaia

- In Gaia DR4
 - Classifications on (1.8 →) **2.2** billion sources
 - (500 →) **1000** million APs from XP spectra
 -
 - (280 →) **500** million evolutionary parameters
 - (230 →) **340** million spectral type classifications
 - (6 →) **36** million APs from RVS spectra
 - (2 →) **20** million activity index from Ca lines
 - (1.8 →) **4.7** million redshifts for quasar candidates
 - (1.3 →) **6.4** million redshifts from unresolved galaxy candidates
 - (0.8 →) **1.1** million vsini of OBA stars Hot
 - (95 →) **1700** thousand teff for ultra-cool dwarfs
 - (60 →) 33 thousand emission line star classifications
 - 2D extinction map to HealPix level (9 →) **11**
 - Diffuse interstellar band parameters and spectra
 - + **many new products and tools**, see next slides



Credit : Creevey (ESA S7)



DL4 : Astrophysical Parameters



Astrophysical Parameters in Gaia

- New table structure in Gaia DR4 for astrophysical_parameters(_supp):
 - ap_xp, ap_rvs, ap_hot, ap_emission, ap_chem, ap_xp_supp
 - ap_class, ap_class_ir
- Properties based on time series
 - ap_epoch_rvs, ap_epoch_xp → issue with time stamps, see known issue
- Many tools and notebooks
 - Bolometric corrections
 - Extinction as a function of (l,b)
 - Extinction conversion between different photometric bands
 - Optimal Healpix extinction map generator (new in GDR4)
 - Classical T Tauri star Probability Estimator (new in GDR4)
 - Notebooks focussed on exploitation of the APs (new in GDR4)
- Auxiliary data and models
- Papers and online documentation
 - Some known issues (as with all massive catalogues)



Credit : Creevey (ESA S7)



DL4 : Astrophysical Parameters



Astrophysical Parameters in Gaia

- New products in Gaia DR4
 - All Stars: Extinction in Johnson, 2MASS and WISE bands
 - Cool stars: Young active pre-main sequence star emission from XP spectra
 - Ultra cool dwarfs (UCD): Youth index indicating pre-main sequence
 - Hot stars: metallicity and extinction parameter determination
 - Mass and age determinations with removed solar-prior
 - Epoch parameters for Cepheids, RR Lyrae, and UCD emission stars
- Purer extra-galactic object classifications
- Extra-galactic classification using Gaia + IR data
- Galaxy and qso redshifts of gravitational lens candidates
- Unsupervised classification of objects using a self-organised map
- Diffuse interstellar band parameters and spectra
- Additional flags and parameters for cleaning samples



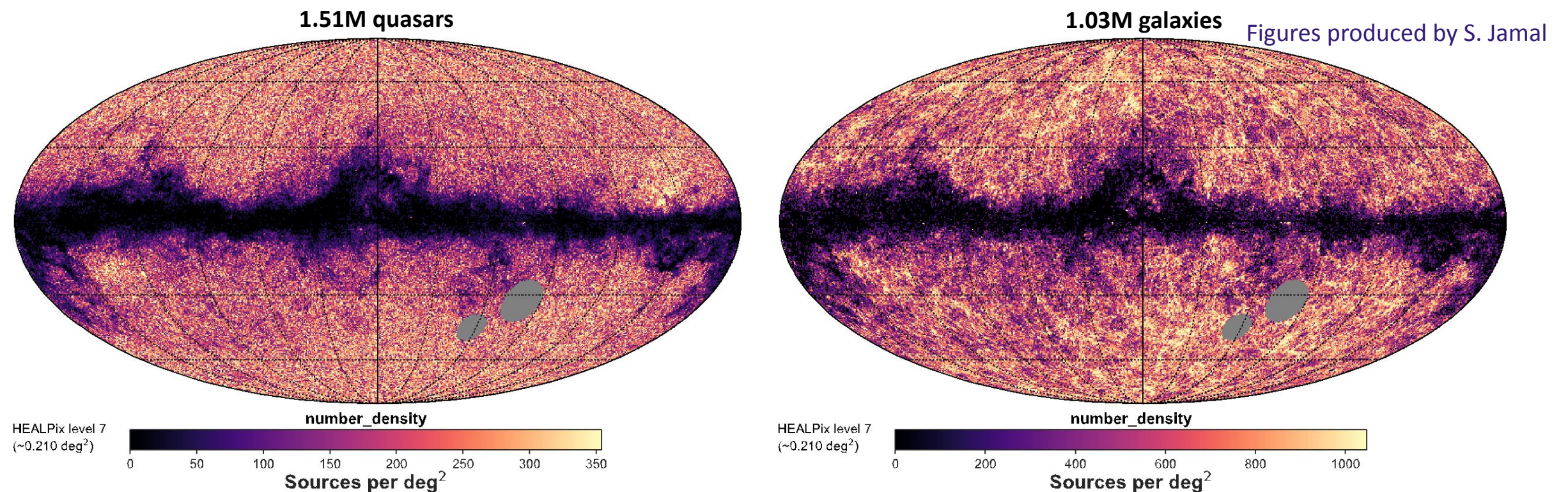
Credit : Creevey (ESA S7)



DL4 : Astrophysical Parameters

Discrete Source Classifier (DSC)

Prob./classification of extra-galactic objects DSC



DR4 Quasar and galaxy candidates identified by the DSC Combmod classifier

Detections here exclude sources in the Magellanic Clouds (masked in grey). A quality cut on the photometry ($\text{phot_}[bp,rp]_n_obs \geq 10$) is applied to correct for stellar contamination in the Galactic bulge and the Gaia scanning law pattern.

Jamal et al. 2026, accepted and available: [DOI: 10.1051/0004-6361/202658965](https://doi.org/10.1051/0004-6361/202658965)

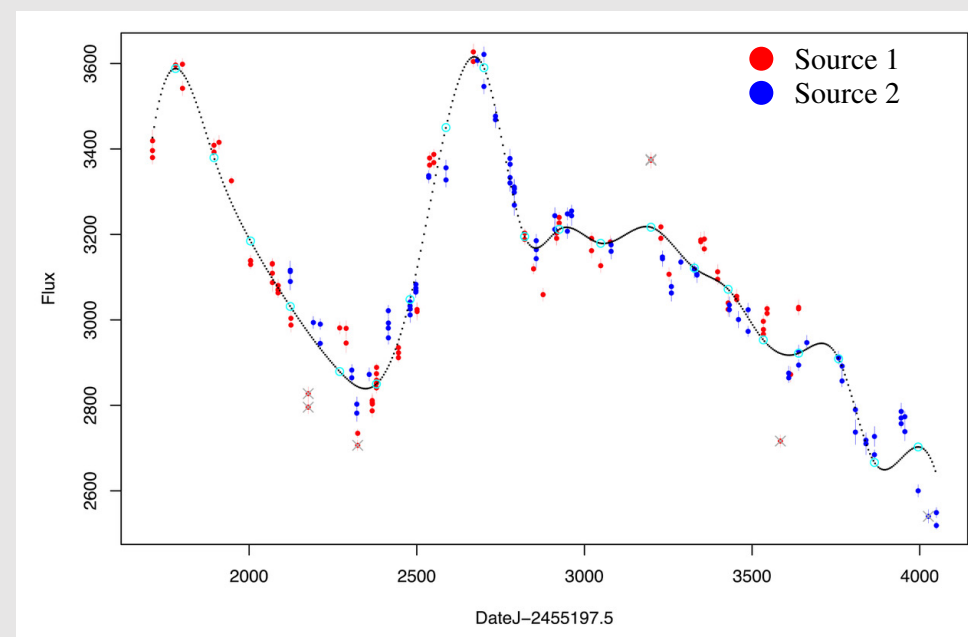
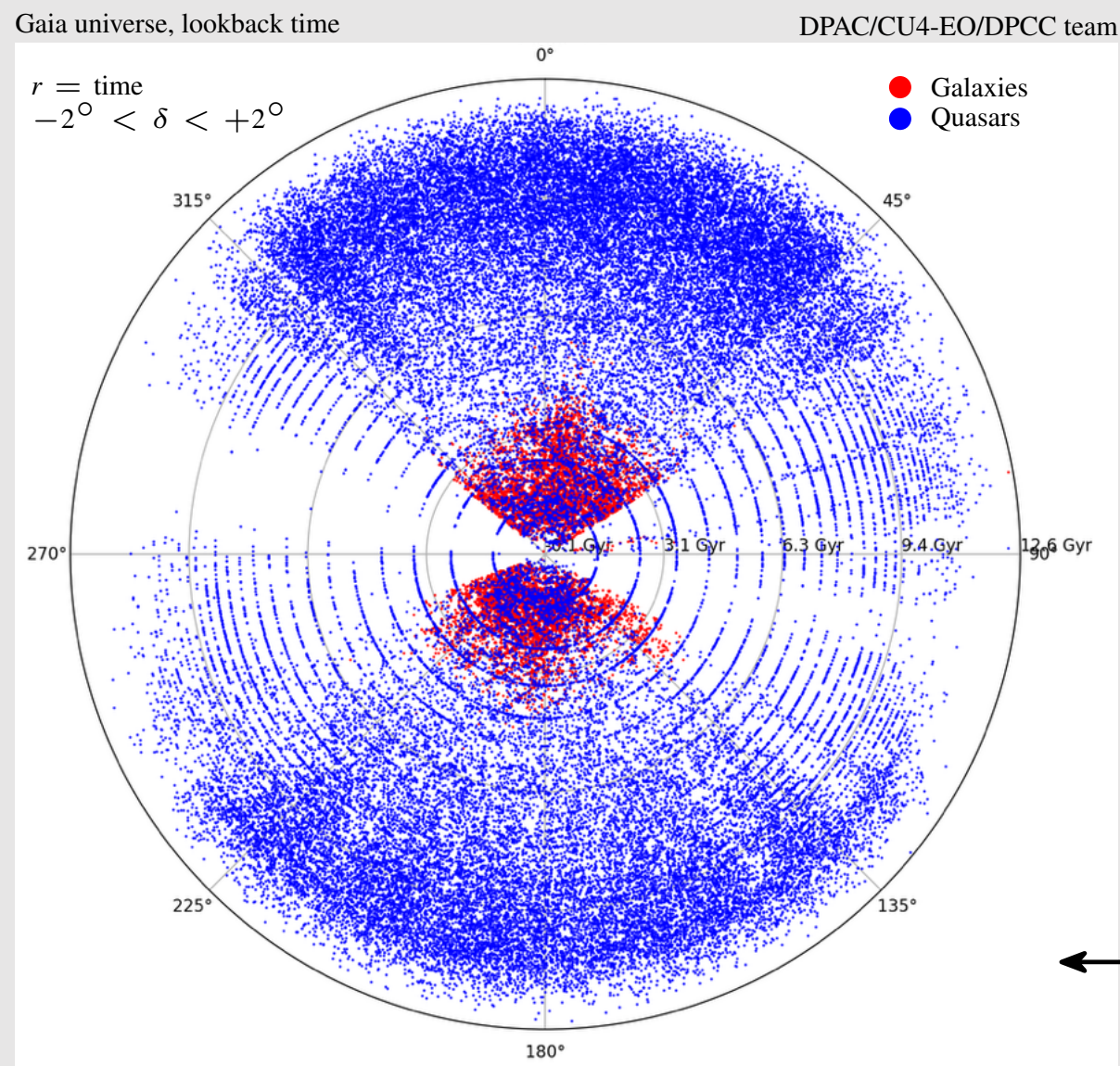
(astrometry, photometry, low-resolution spectra) —> (quasar,
galaxy, star)

Credit : Creevey (ESA S7)



DL4 : Astrophysical Parameters

A peak into Gaia DR4 extragalactic content



- New: gravitational lens detection from source clustering, BP/RP spectra, correlated variability
- Time delays measured for known lenses, including new delay measurements
- 4.5 million QSOs analysed, 163 000 host galaxy profiles determined (Sérsic, $z < 0.4$)
- Profiles of 3.4 million galaxies determined ($Z < 0.2$, Sérsic, de Vaucouleurs, bulge+disk)

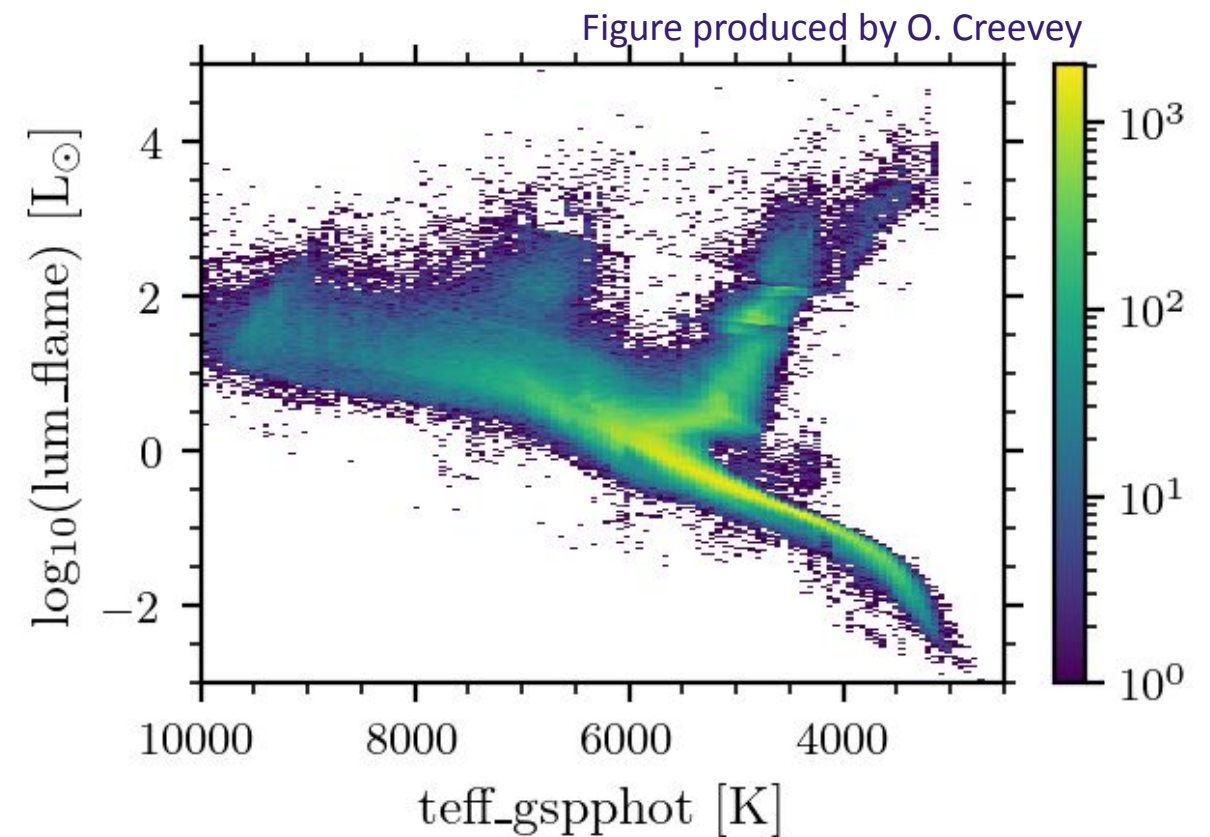
DL4 : Astrophysical Parameters



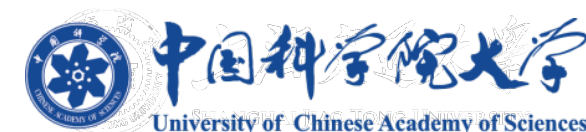
HR diagram from XP spectra

- gaiadr4.ap_xp

```
select top 1_000_000 teff_gspphot, lum_flame,  
flags_flame from ap_xp as ap  
inner join gaiadr4.all_source_astrometry as gs on  
gs.source_id = ap.source_id  
where lum_flame > 0 and random_index < 90_000_000  
and parallax>0
```



Credit : Creevey (ESA S7)



DL4 : Astrophysical Parameters



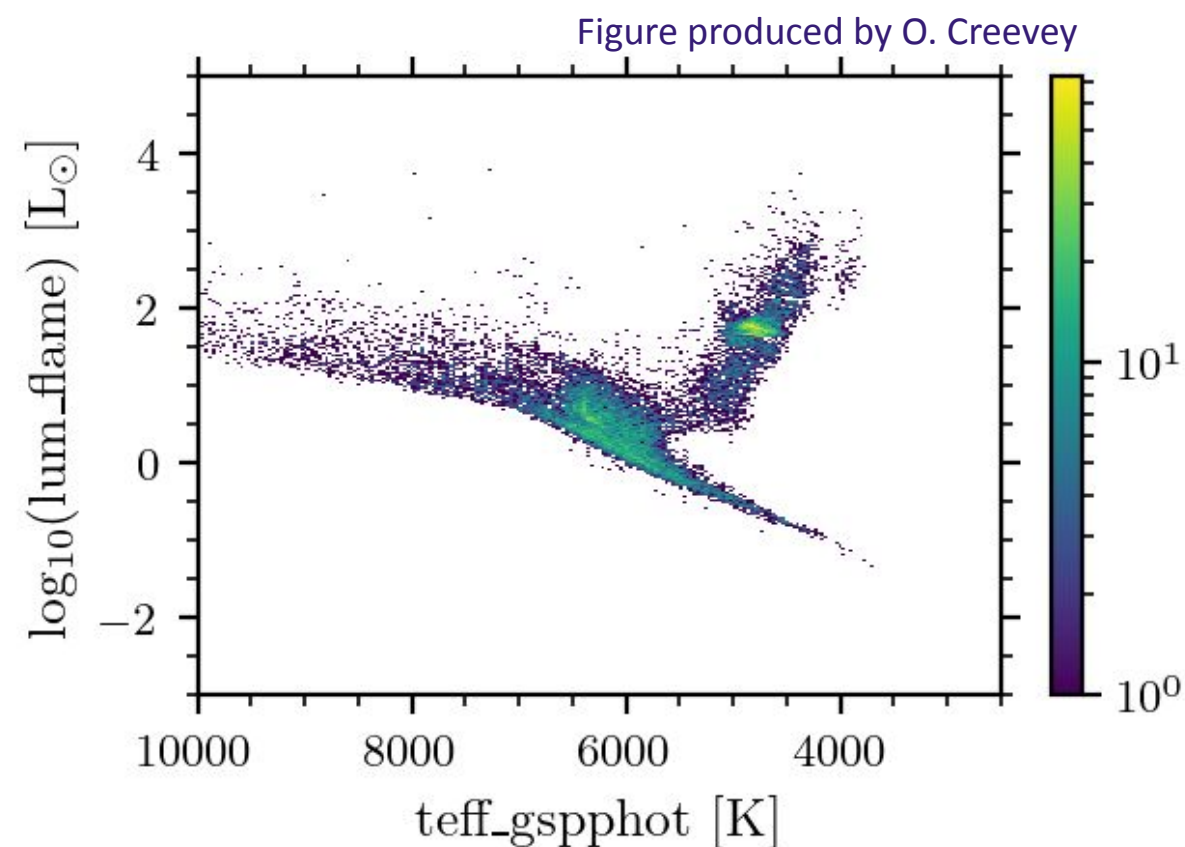
HR diagram from XP spectra

- gaiadr4.ap_xp

```
select top 1_000_000 teff_gspphot, lum_flame,  
flags_flame from ap_xp as ap  
inner join gaiadr4.all_source_astrometry as gs on  
gs.source_id = ap.source_id  
where lum_flame > 0 and random_index < 90_000_000  
and parallax>0
```

- Filtering on high quality astrometric and spectro-photometric data

```
flags_flame like '0____'
```



Credit : Creevey (ESA S7)



DL4 : Astrophysical Parameters



Stellar APs from XP spectra

- GSPPhot predicts 1 billion APs (Teff, logg, [M/H], ...)
- Thanks to the improved instrument model for the XP spectra [M/H] has improved significantly

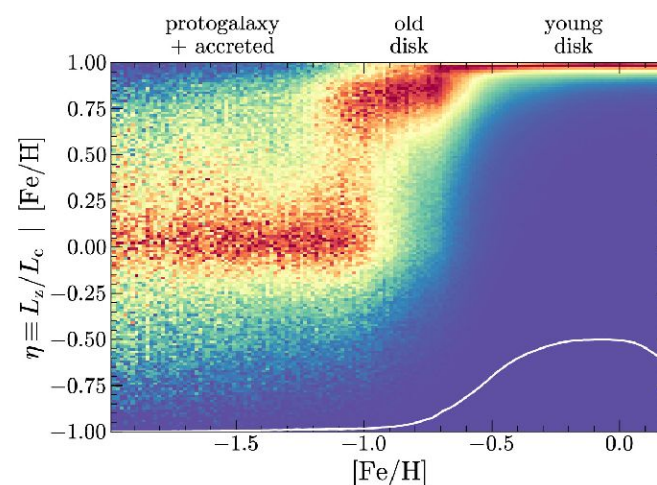
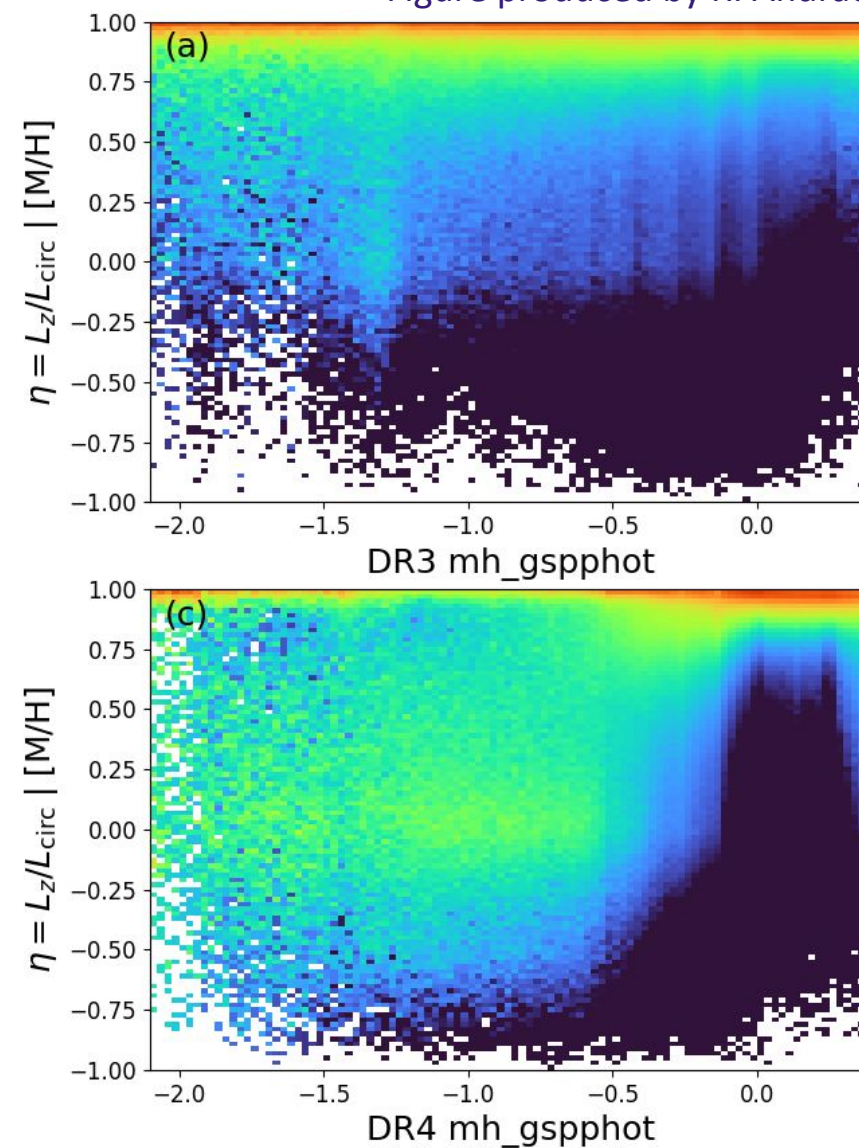


Figure: Using η from [Chandra et al. \(2024\)](#) GSPPhot can recover the three phases of the Milky Way

Figure produced by R. Andrae



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Lausanne

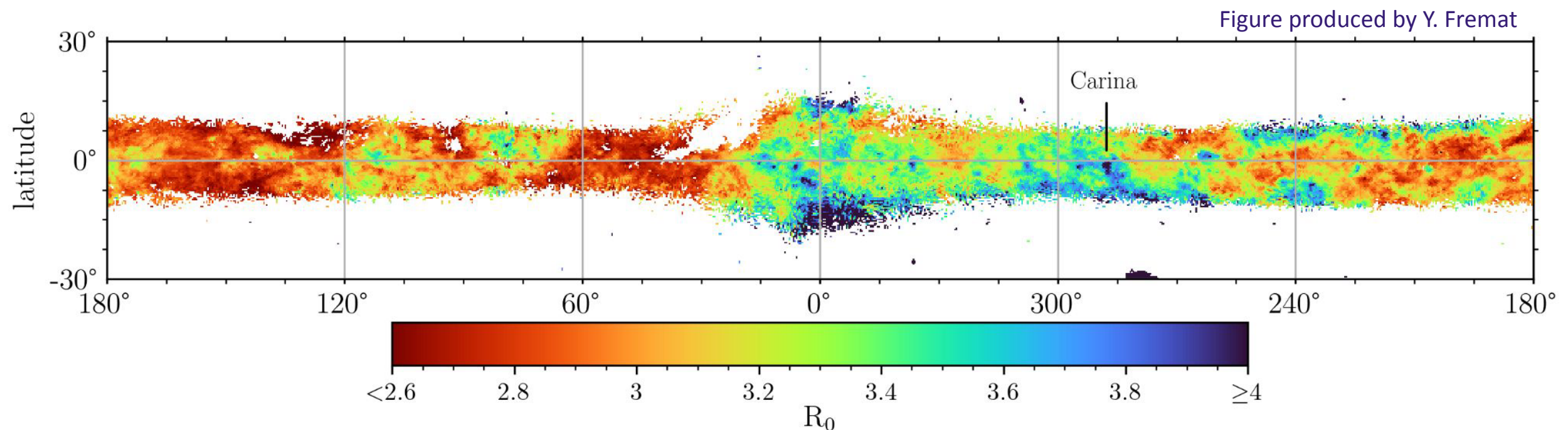


Credit : Creevey (ESA S7)

DL4 : Astrophysical Parameters



Extinction parameter from XP for hot stars



ESP-HS processes XP spectra and when available also RVS spectra for stars of spectral types O, B, A. `rzero_esphs` is a new product in the `ap_hot` table. It is shown as a function of galactic longitude and latitude



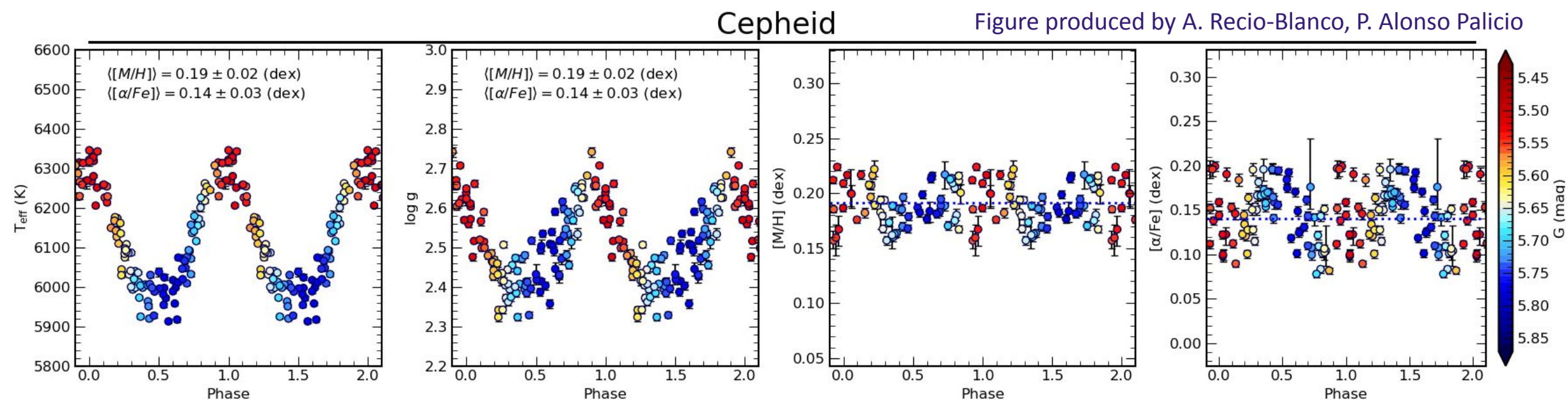
Credit : Creevey (ESA S7)



DL4 : Astrophysical Parameters



Epoch properties for Cepheids and RR Lyrae



GSP-Spec analyses the RVS spectra to provide T_{eff} , $\log g$, $[M/H]$, $[\alpha/Fe]$ for 36 million sources and abundances for 3.5 million sources.

In DR4 it also processes the time series of RVS spectra for several thousand Cepheid and RR Lyrae.



Credit : Creevey (ESA S7)



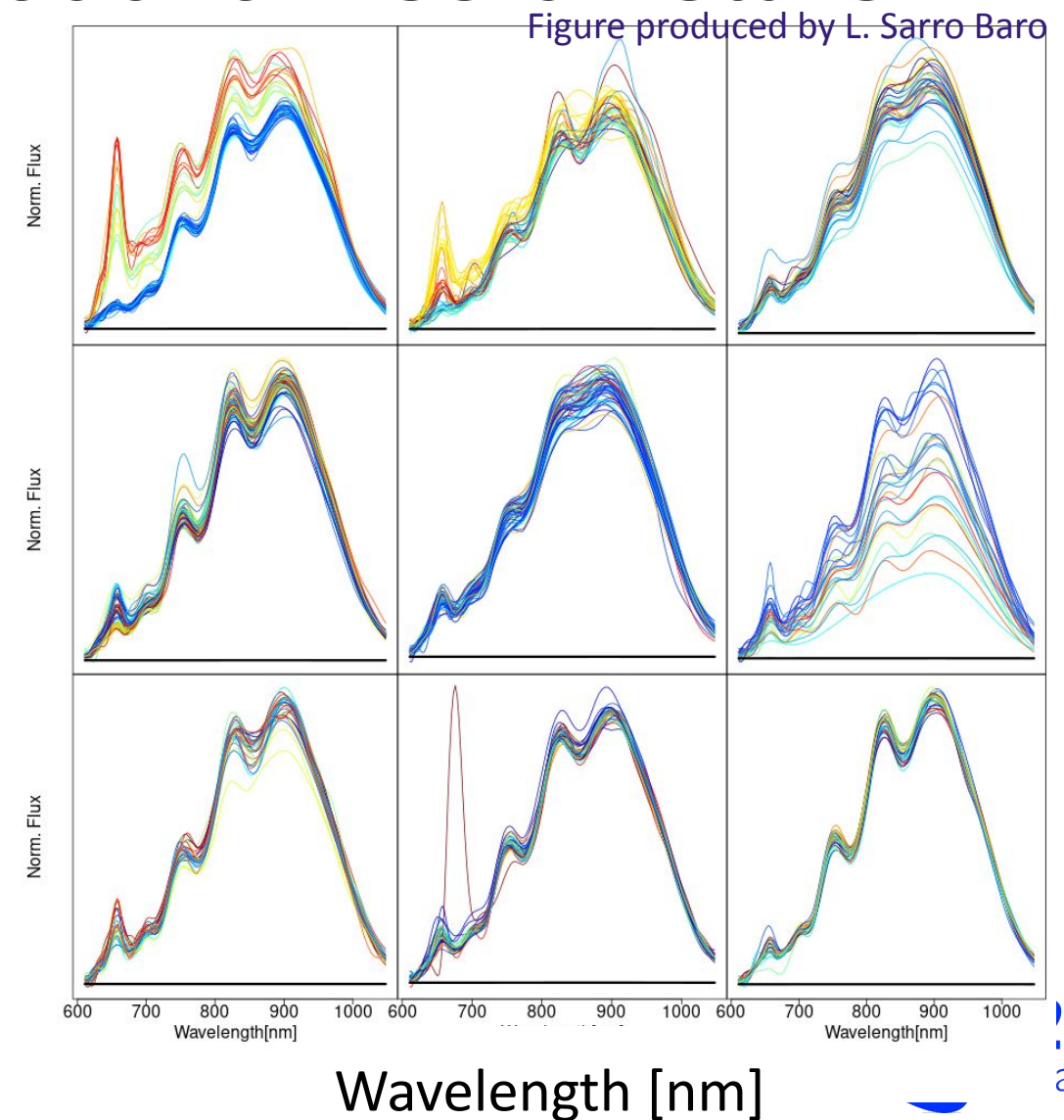
DL4 : Astrophysical Parameters



Epoch properties for ultra cool emission stars

- ESP-UCD analyses ultra cool dwarfs
- It produces T_{eff} and a youth index for 1.7 million sources
- It also analyses epoch data for 8796 cool sources and produces an equivalent width (known issue)

Epoch XP spectra for 9 stars. Colour-code indicates time. One can appreciate issues with spectra and how a mean spectrum may be difficult to derive.



16
anne



Credit : Creevey (ESA S7)

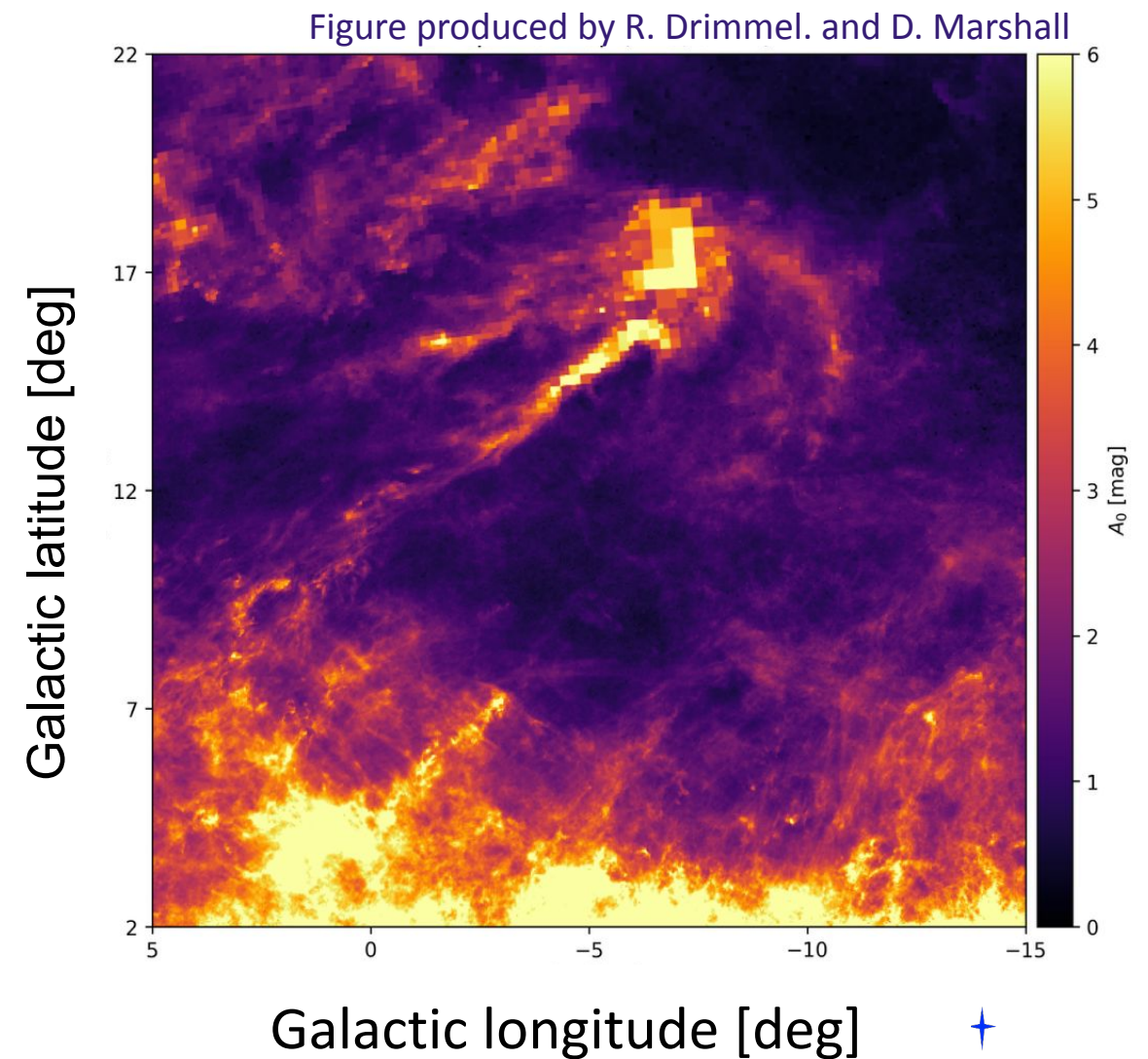
DL4 : Astrophysical Parameters



Total galactic extinction

- TGE exploits a0_gspphot for tracers of total galactic extinction
 - giants $G < 19$ mag
 - any star $G < 15$ if > 300 pc above or below the galactic plane or galactocentric radius $R_g > 14$ kpc
- HEALPix levels 6 – 11

rho Oph region at the smallest HEALPix level (≤ 11) with a minimum of four tracers



Credit : Creevey (ESA S7)

DL4 : Astrophysical Parameters



Summary

- Astrophysical parameters for 2.2 billion sources (1 billion for stellar parameters)
- Important increase in number and quality of parameters (and flags)
- New table structure of `gaiadr3.astrophysical_parameters(_supp)`:
 - All sources: `ap_class`, `ap_class_ir`
 - Stars: `ap_xp`, `ap_xp_supp`, `ap_rvs`, `ap_hot`, `ap_emission`, `ap_chem`
- New epoch APs
- Reading:
 - Gaia Data Release 4: The astrophysical parameters, Creevey et al. 2026
 - Gaia Data Release 4: Scientific validation of the astrophysical parameters, Heiter et al. 2026
 - Online documentation Chapter 16, section 3 describes each module incl caveats
- Tools, notebooks, auxiliary data
- High and low quality results (automatic processing on source-by-source)
 - detailed descriptions, flags, uses and limitations (online doc)
 - caveats and known issues for tables

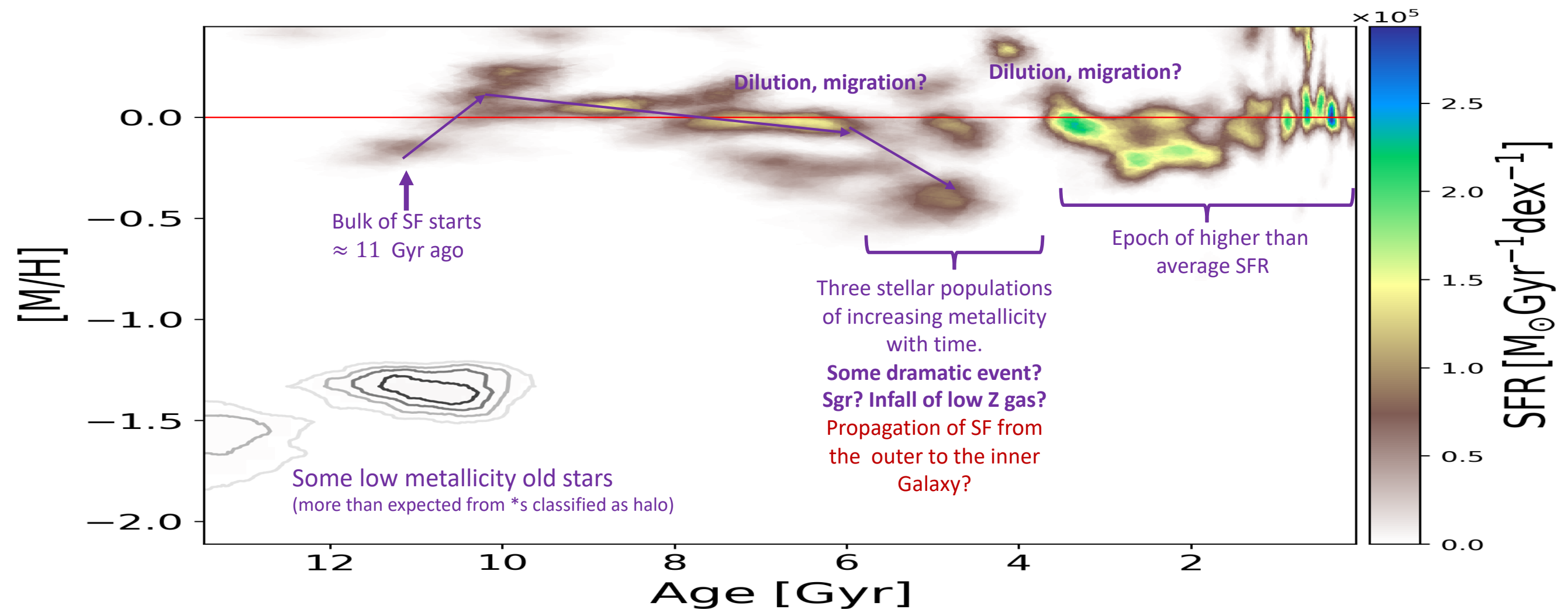


Credit : Creevey (ESA S7)



Science cases : SFHs of the MW

The deSFH of the solar neighbourhood



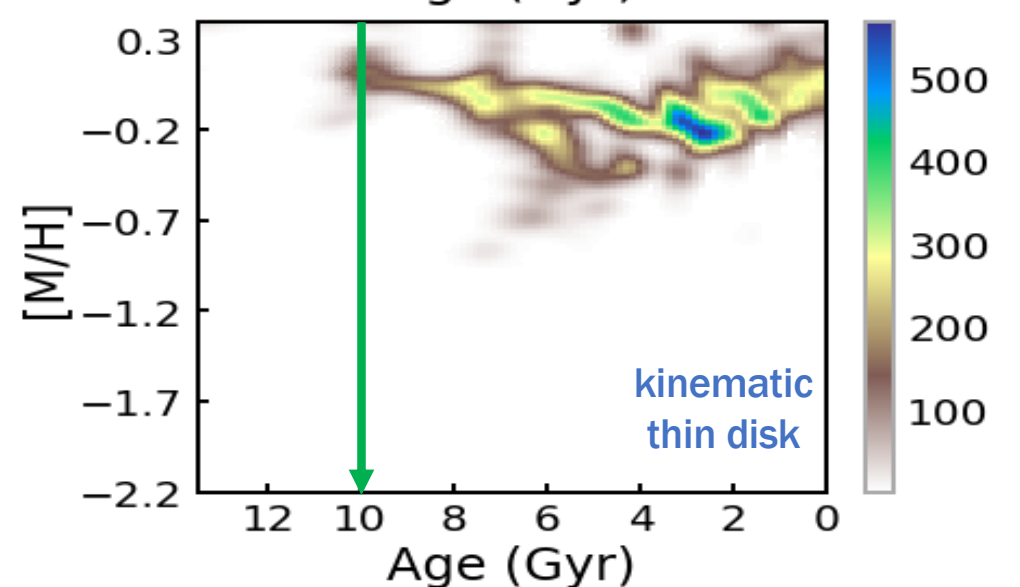
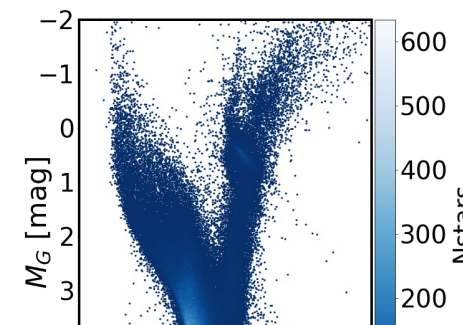
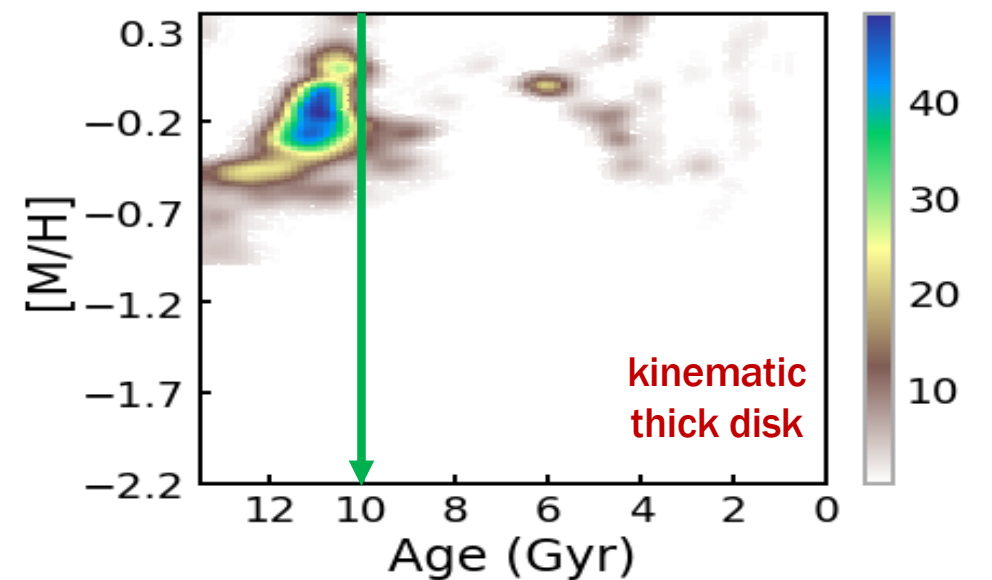
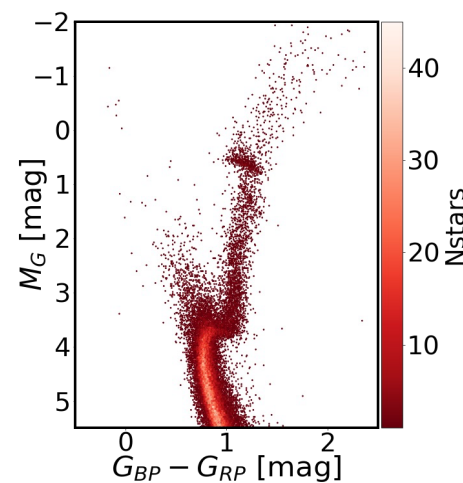
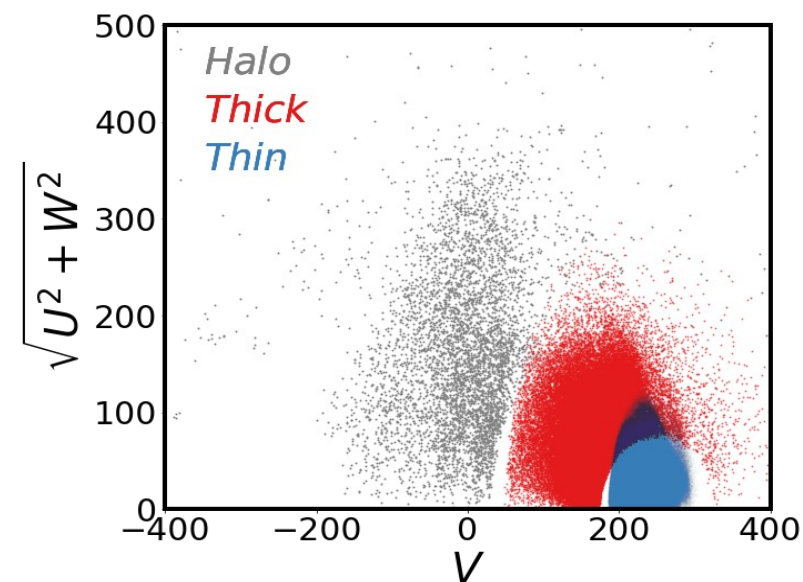
Credit : Gallart (ESA S7)

Science cases : SFHs of the MW

Kinematically selected thin and thick disk populations

Fernández-Alvar & ChronoGal, 2025, A&A

Cylinder of $R_{\odot}=250\text{pc}$ and $|Z|<1\text{ kpc}$



Question: when did a kinematic transition occur in the Milky Way disk?

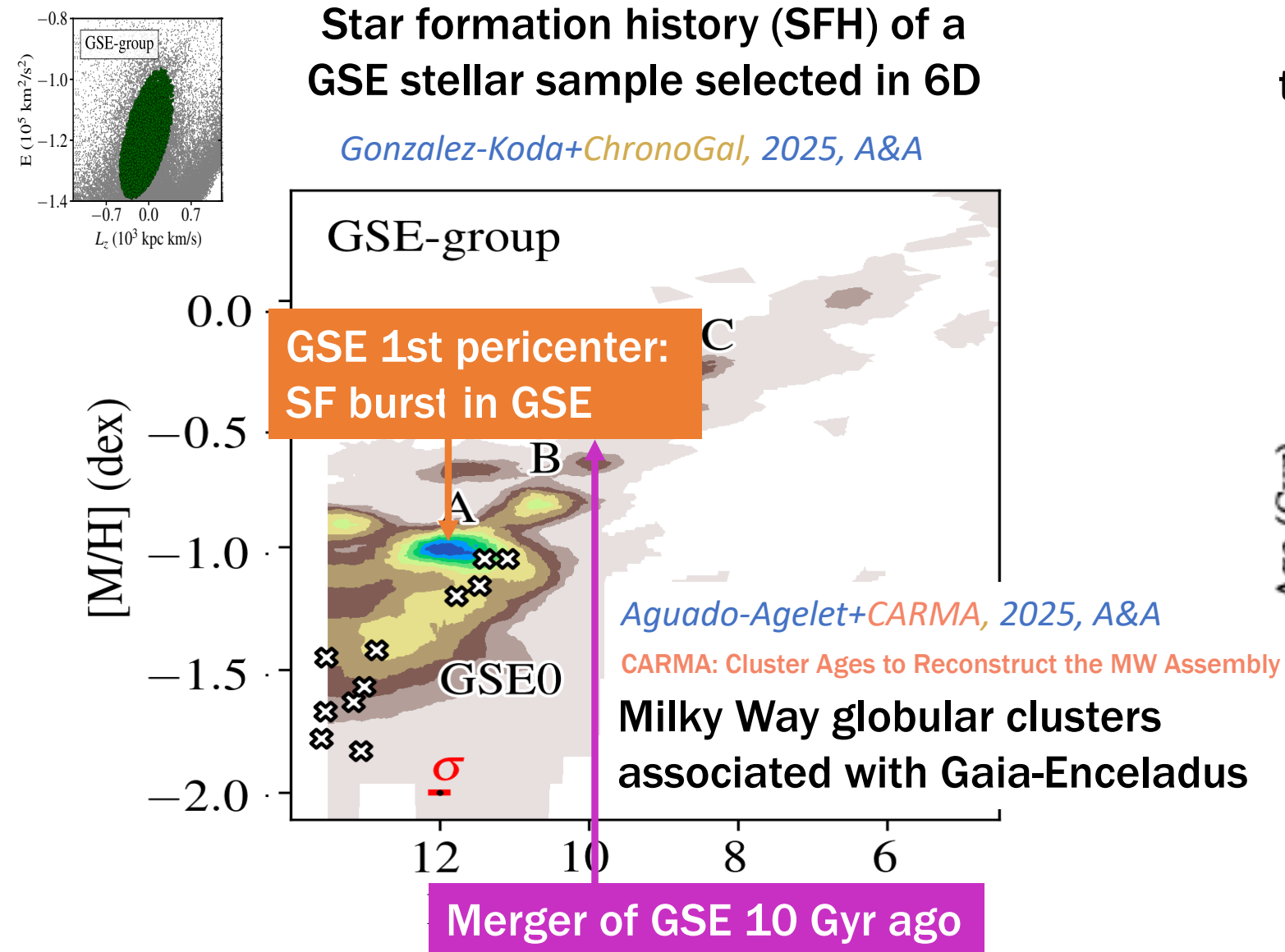
Answer: 10 Gyr ago

<<

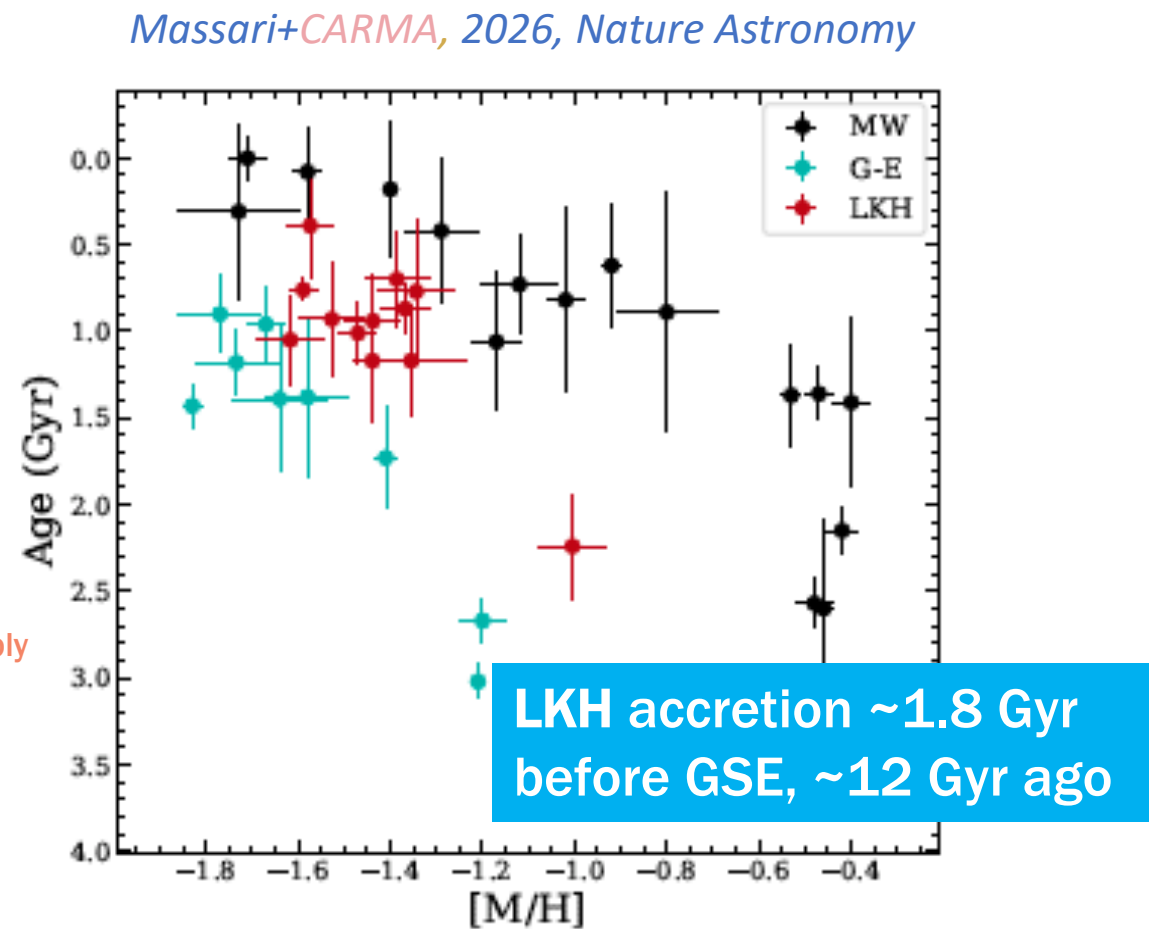
Credit : Gallart (ESA S7)

Science cases : SFHs of the MW

The infancy of the Milky Way through the mergers with
Low-Energy Kraken Heracles (LKH) and Gaia-Sausage-Enceladus (GSE)



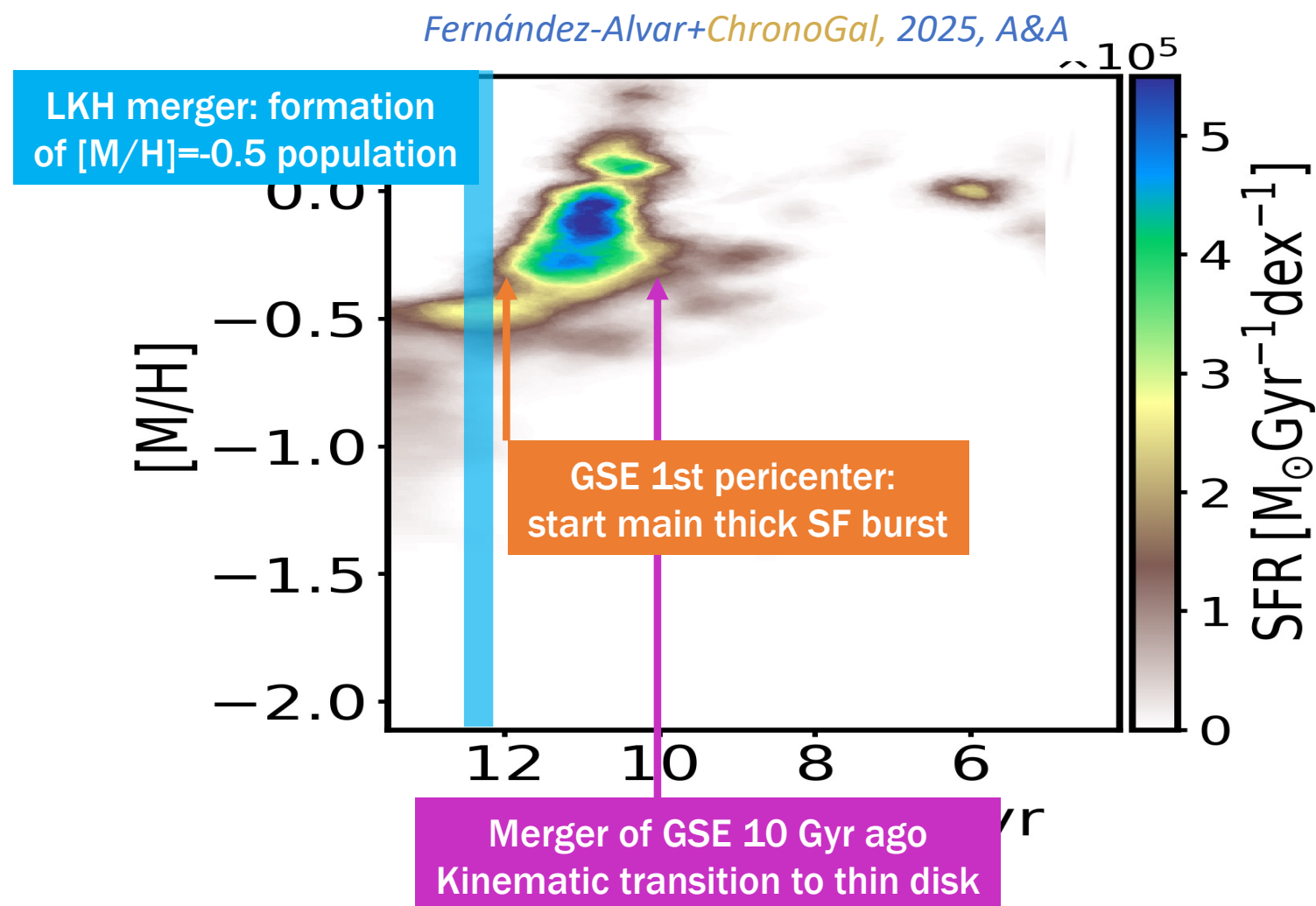
Discovery and characterization of LKH through the AMR of its globular clusters



Credit : Gallart (ESA S7)

Science cases : SFHs of the MW

The infancy of the Milky Way through the mergers with
Low-Energy Kraken Heracles (LKH) and Gaia-Sausage-Enceladus (GSE)



Question: What is the role of mergers (particularly GSE) in the MW disk formation and evolution?

Formation and evolution of the Milky Way thick disk:

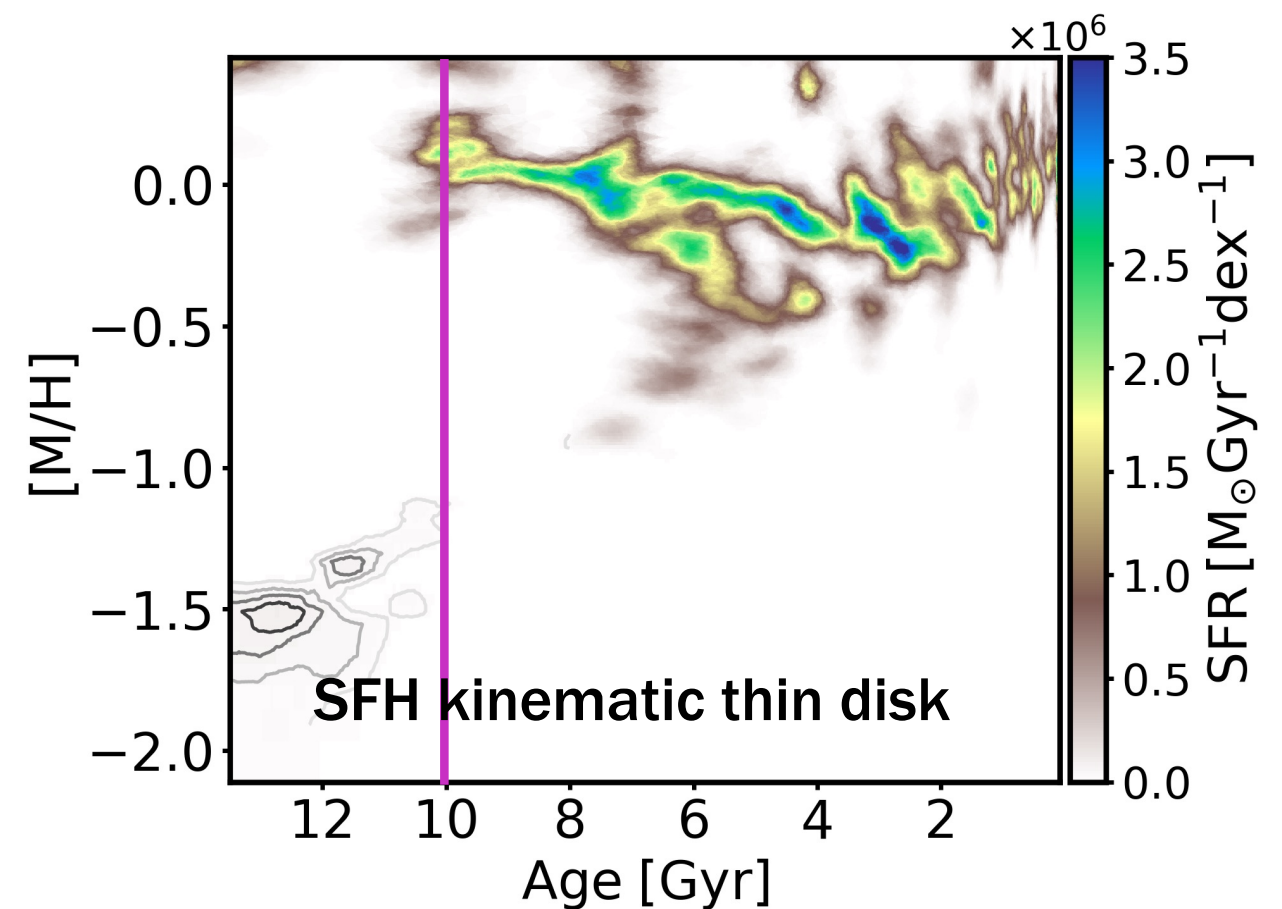
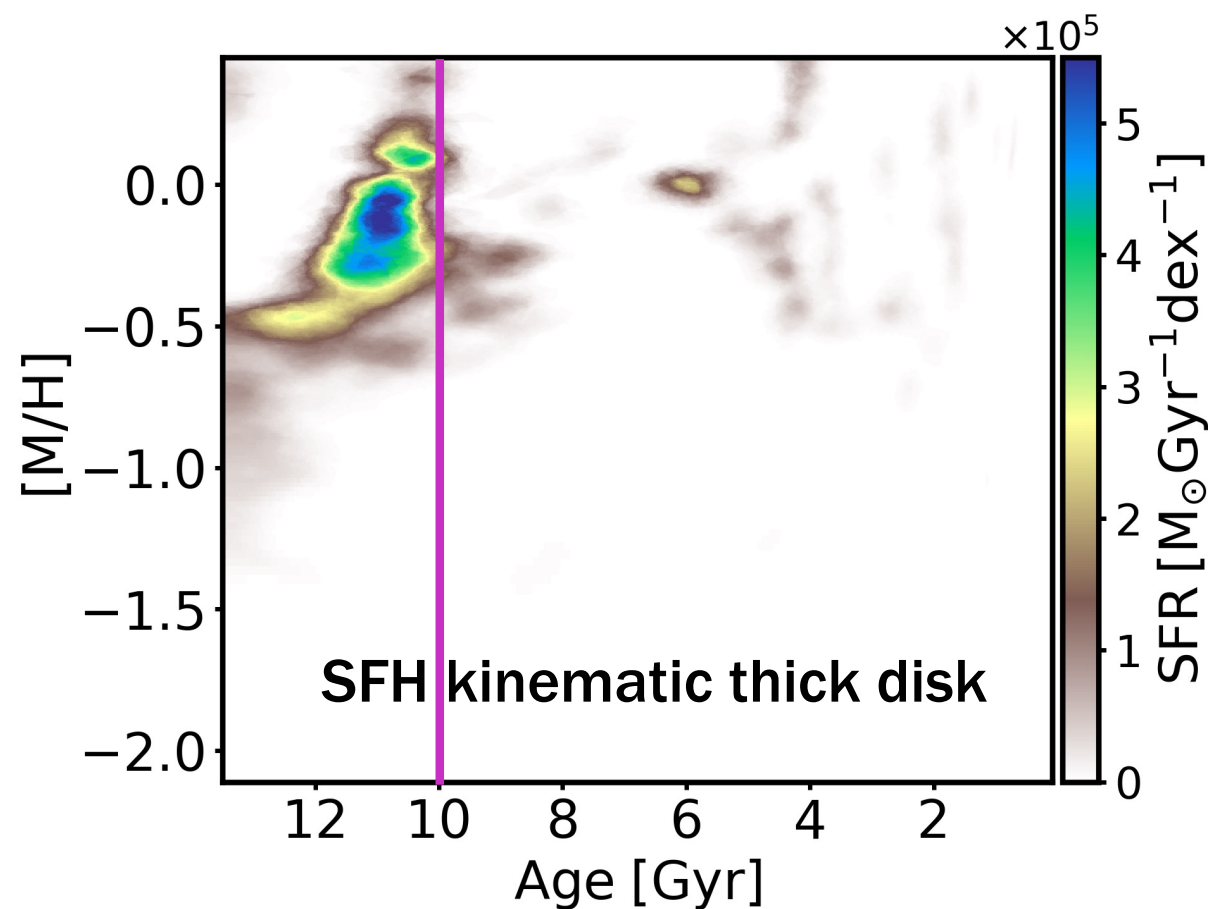
- Milky Way main progenitor ($[M/H]<-0.5$)
- burst of SF triggered by LKH ($[M/H]=-0.5$)
- main episode of star formation between the 1st pericenter and the merger of GSE

Credit : Gallart (ESA S7)

Science cases : SFHs of the MW

From Milky Way's infancy to the present time

End of GSE merger: kinematic transition thick-thin disk

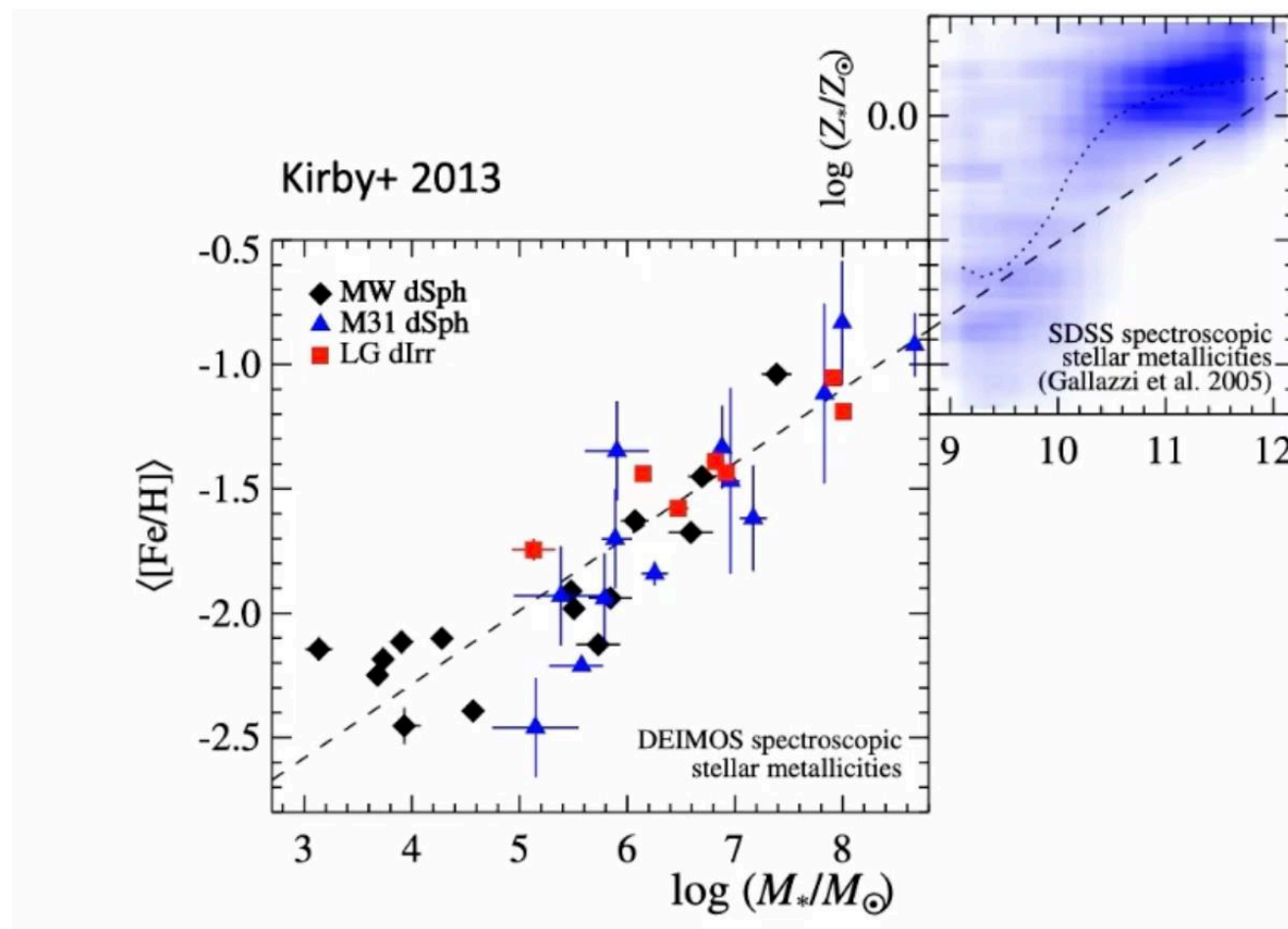


Fernández-Alvar+ChronoGal, 2025, A&A

Credit : Gallart (ESA S7)

Science cases : mass assemble history

Metallicity as a fossil record of accreted mass



Decomposing a metallicity distribution

- Assume the overall metallicity distribution is a mixture of the distributions of the accreted galaxies
- Lower mass galaxies contribute more metal poor stars
- Number of stars proportional to the luminosity/mass

Based on Deason et al. (2023)

Credit : Dodd (ESA S7)

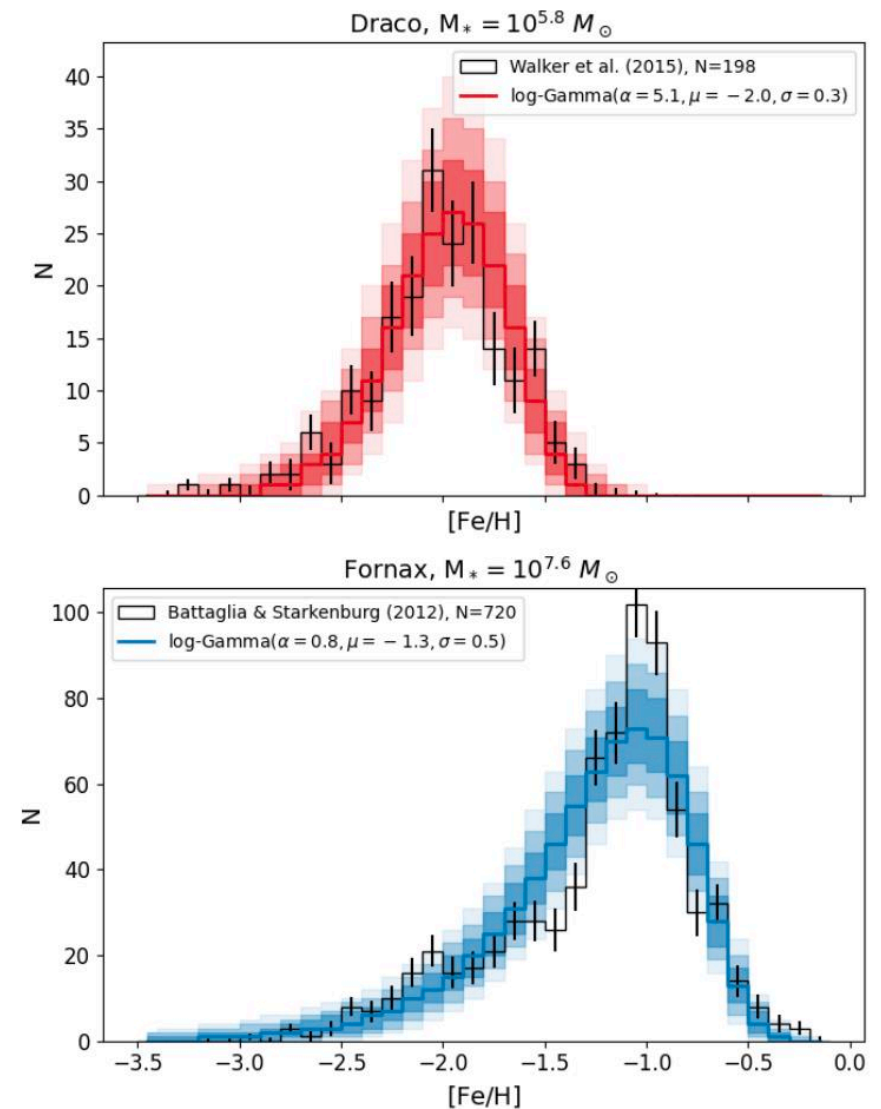
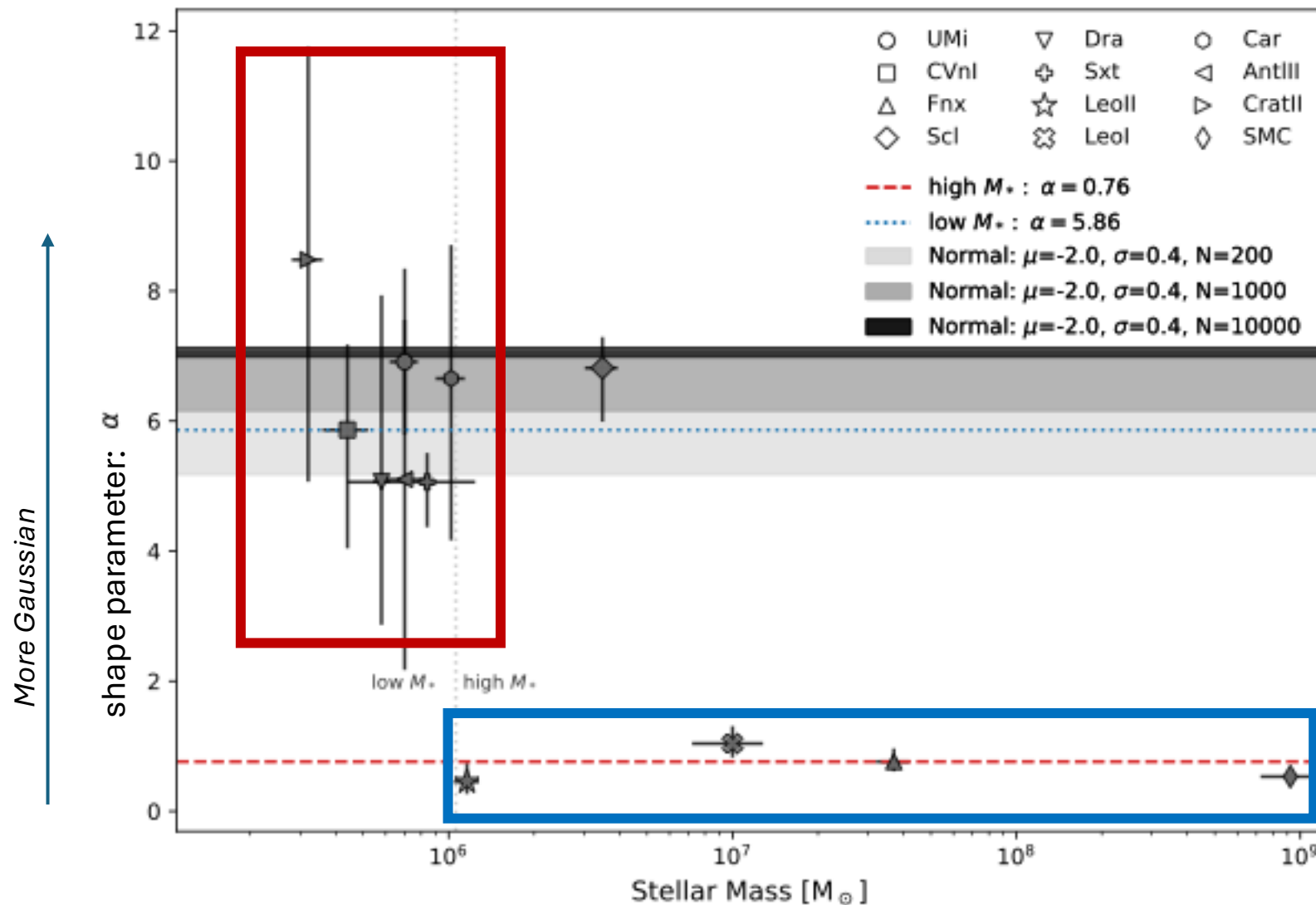
Science cases : mass assemble history

MDF shapes

Lower mass e.g. Draco more Gaussian like MDFs, higher mass e.g. Fornax, a significant MP tail

$$f(z | \alpha, \mu, \sigma) = \frac{1}{\Gamma(\alpha) \sigma} \exp\left(\alpha \frac{z - \mu}{\sigma} - e^{\frac{z - \mu}{\sigma}}\right)$$

with $z = [\text{Fe}/\text{H}]$
Alpha controls the shape of the distribution



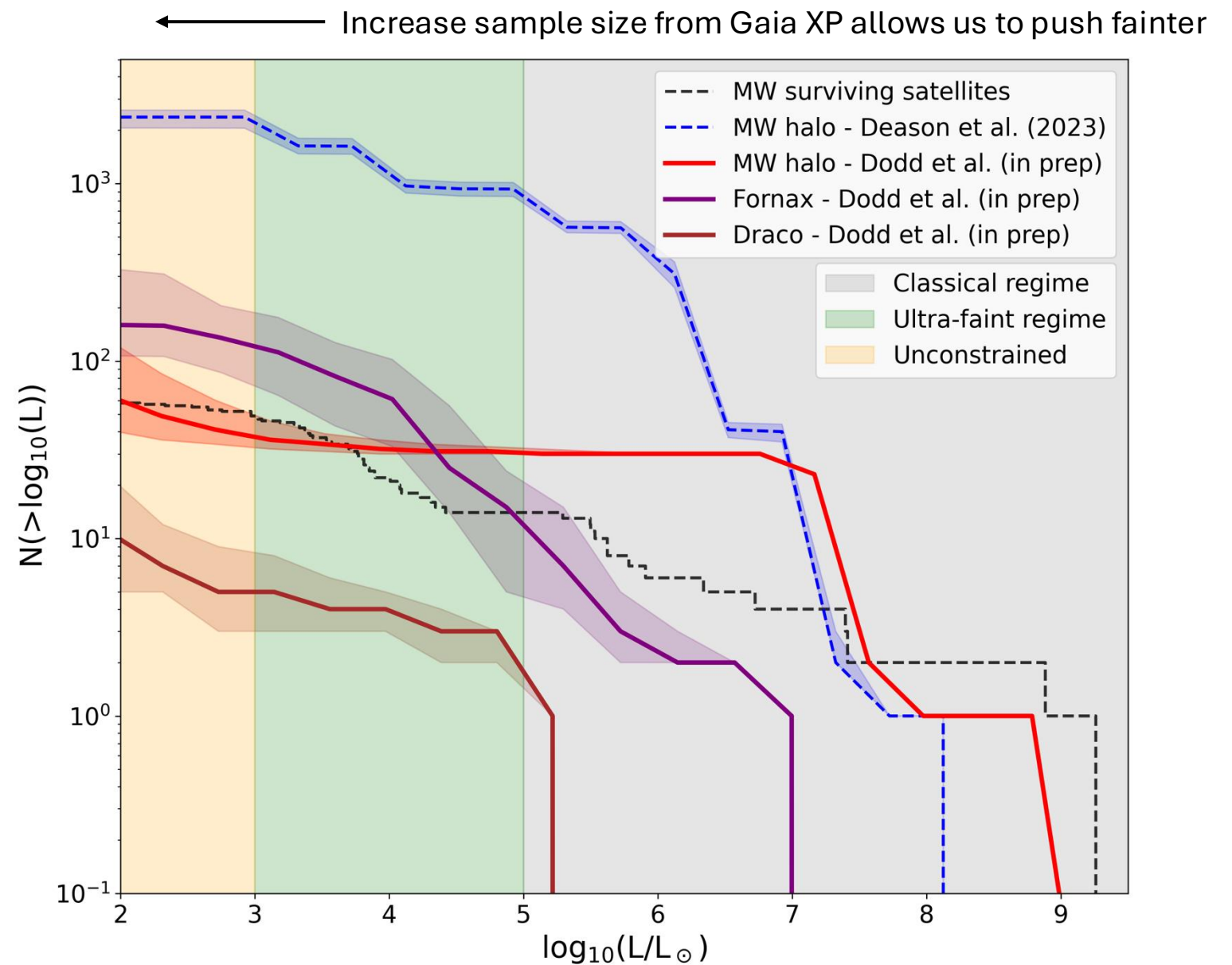
Credit : Dodd (ESA S7)

Science cases : mass assemble history

The luminosity function of destroyed dwarf galaxies

Cumulative luminosity function of the number of accreted components contributing to the **Milky Way halo**

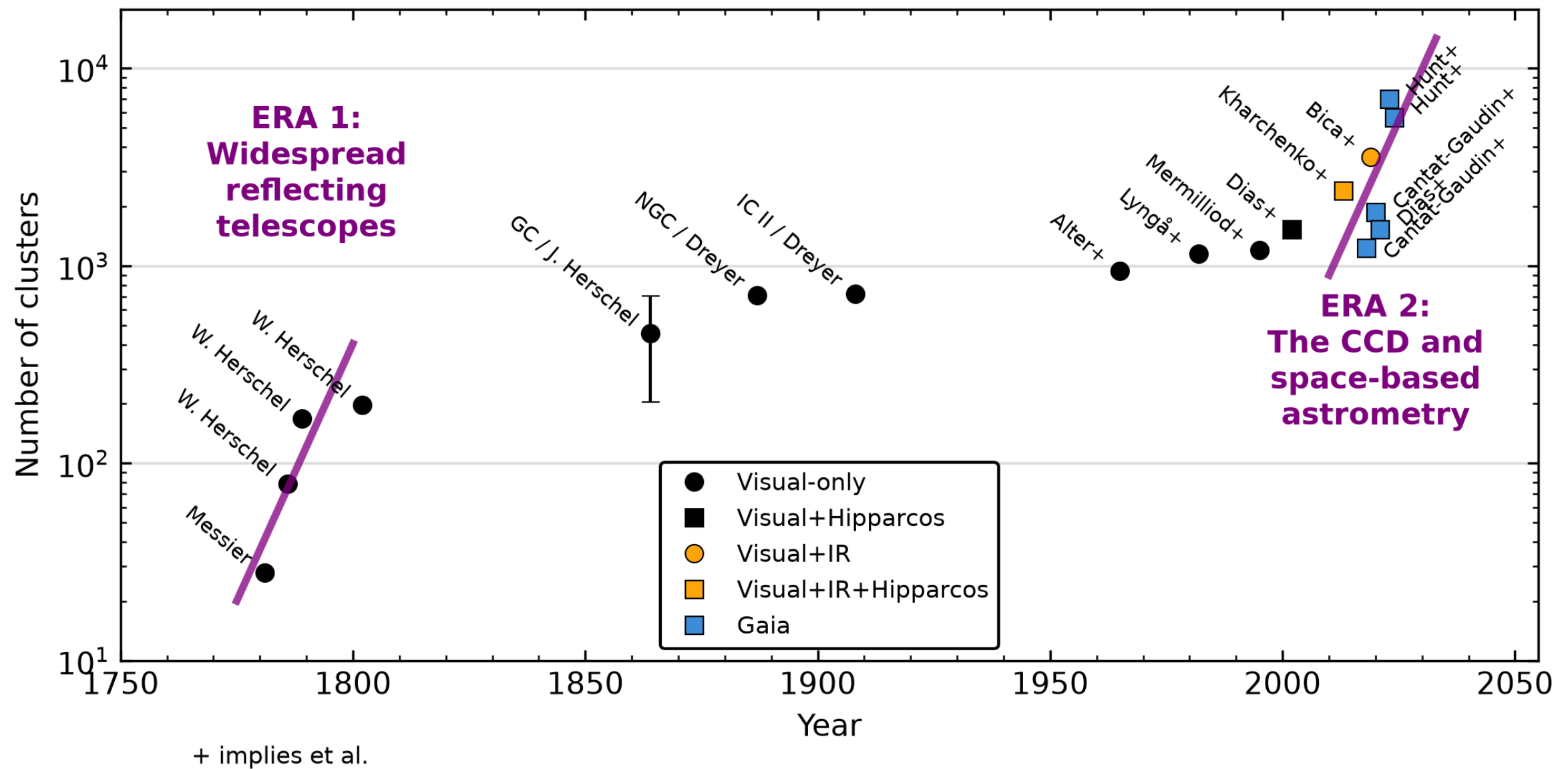
Surviving dwarf satellites from Drlica-Wagner et al. (2020)



Credit : Dodd (ESA S7)

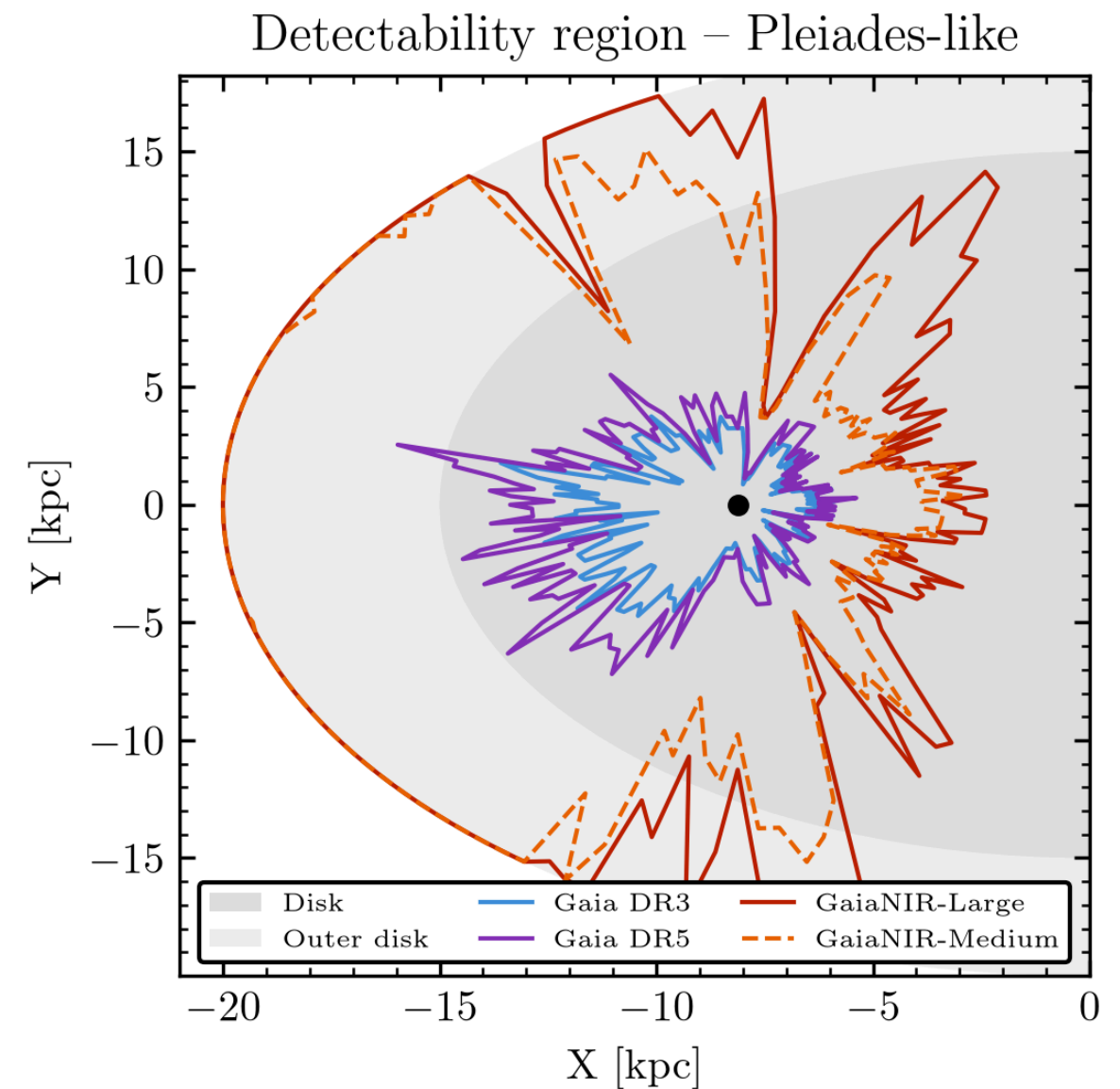
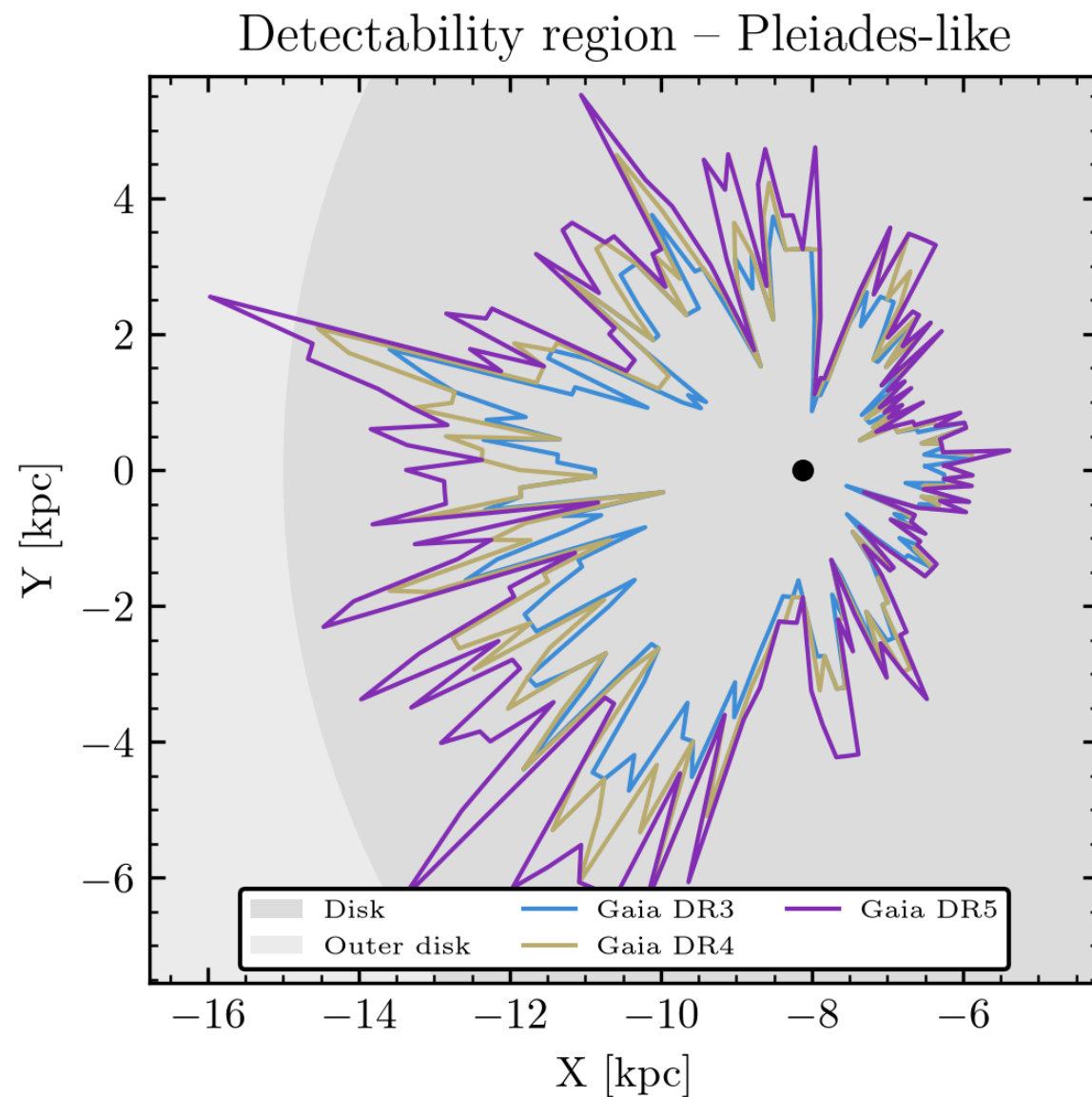
Science cases : star clusters

Gaia has revolutionized the star cluster census



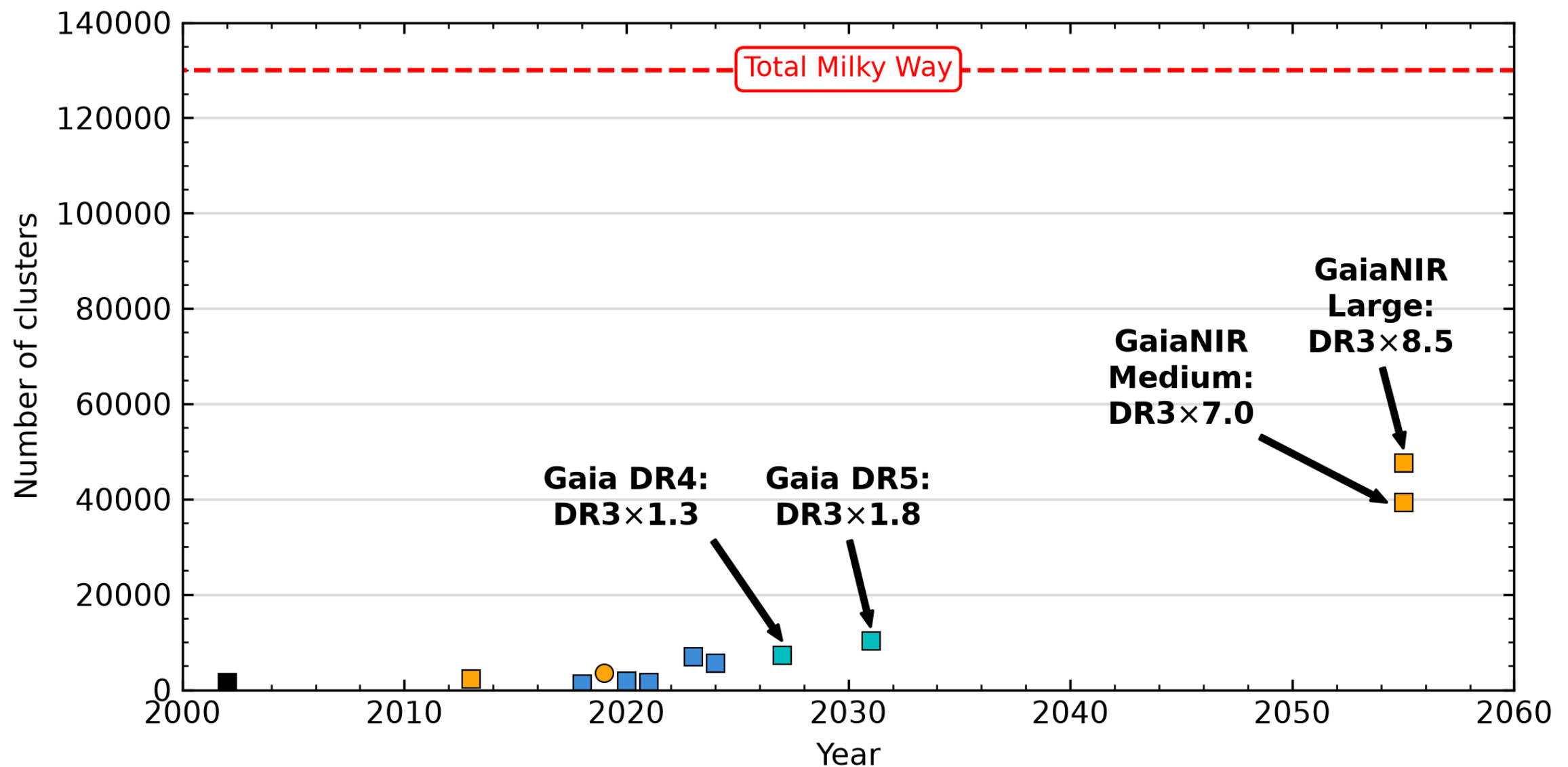
Science cases : star clusters

GaiaNIR would reveal ~1/3 of the Milky Way's disk.



Science cases : star clusters

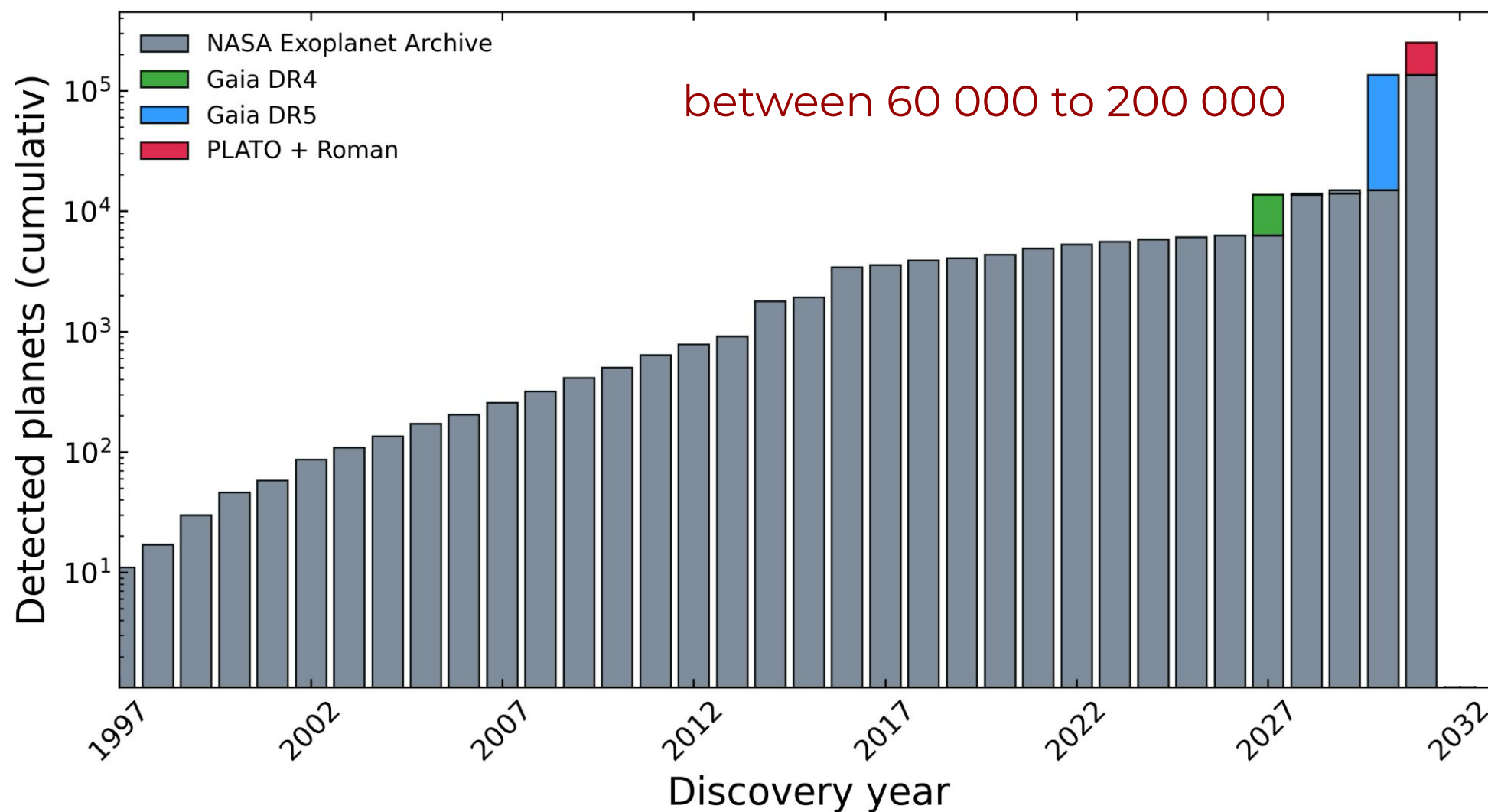
Open clusters in 2055?



Science cases : Exoplanets

On the verge of a new era

Lammers & Winn, 2026
Matuszewski+, 2023
Wilson+, 2023



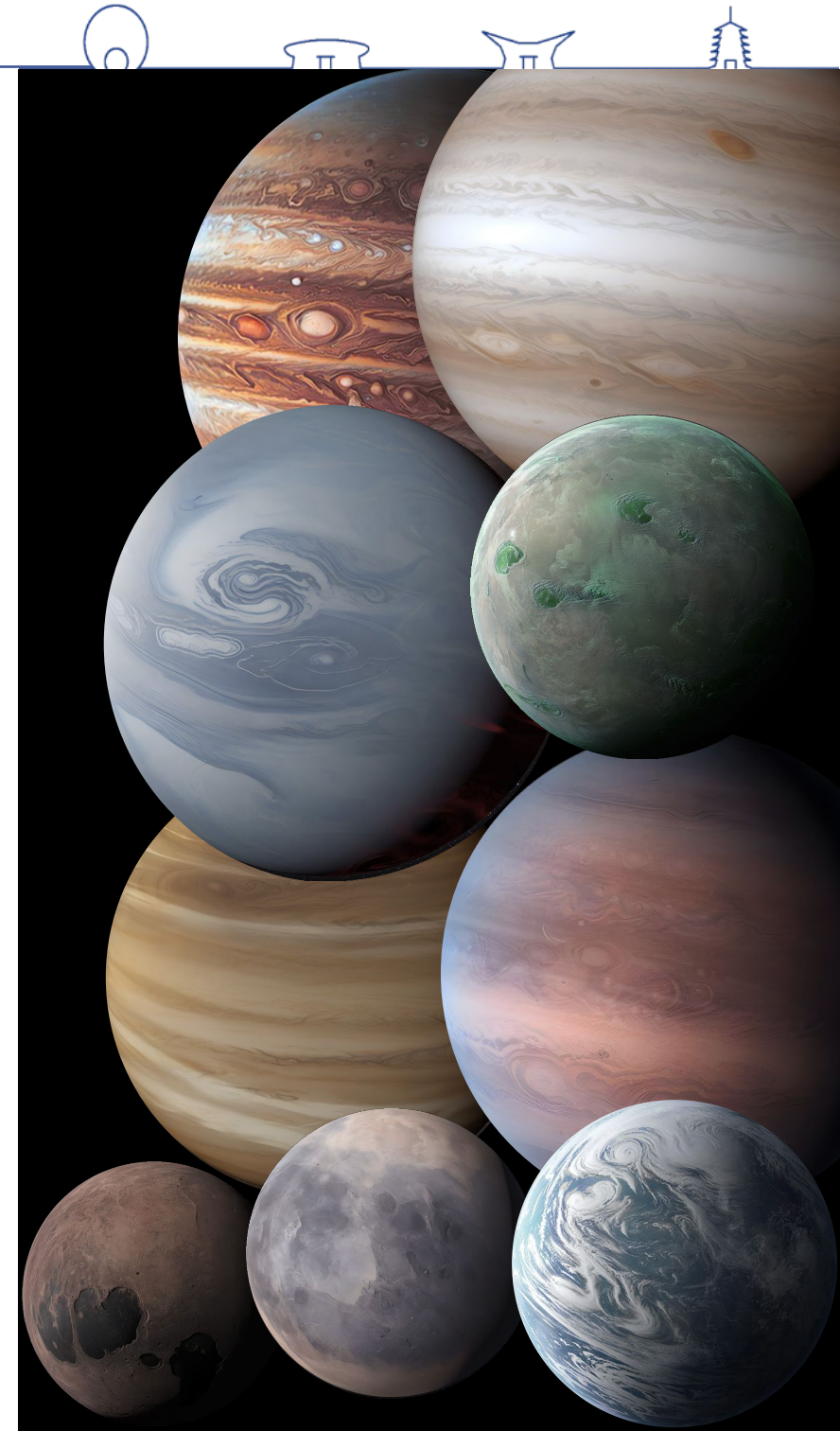
Science cases : Exoplanets

On the verge of a new era

- **The next 5 years**

- Exoplanet **discovery** will **no longer** be the **bottleneck**
- Planet **occurrence** must be **linked to**
chemistry, kinematics, age, and environment
- **goal:** connect planet formation to the Milky Way

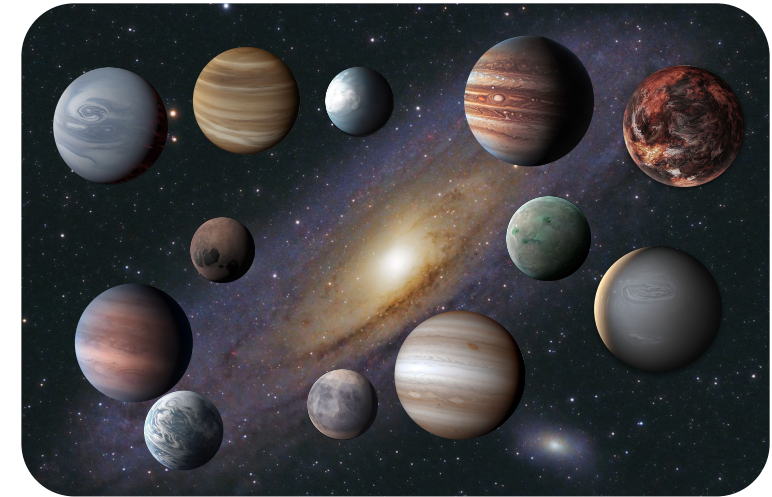
➔ **population-level** interpretation of **planet formation**
“exoplanet archeology”



Science cases : Exoplanets

Galactic planet formation

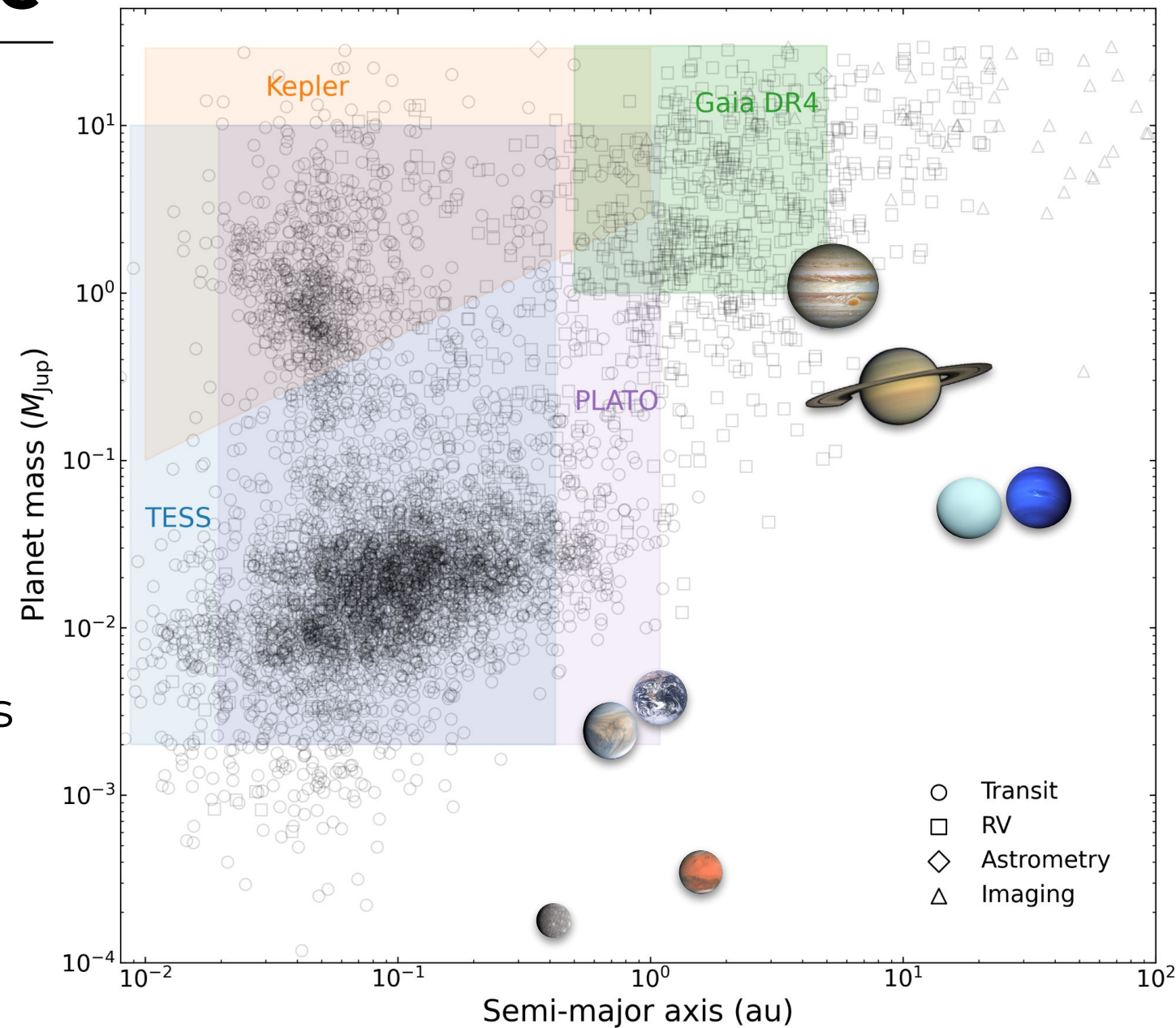
- **Chemistry**
→ Which elements, beyond iron, control planet formation?
- **Time**
→ How does planet occurrence change with stellar age and Galactic epoch?
- **Environment**
→ Do planets form differently in different environments / stellar populations?
- **Dynamics**
→ How do multiplicity, cluster environment, and migration shape system architectures?
- **Controls**
→ Can we separate true planet-formation signatures from Galactic chemical evolution?



Science cases : Exoplanets

Gaia DR4 detection space

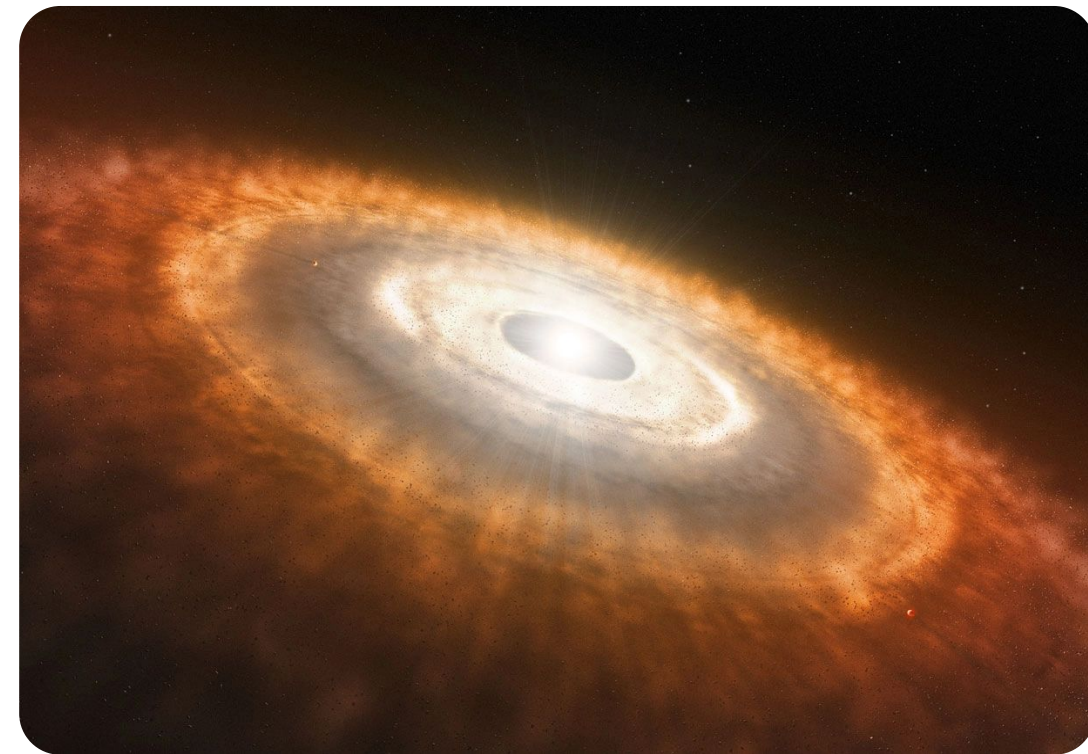
- **Best sensitivity**
 - giant planets at **~ 0.5 to 4 au**
 - epoch **RVs**, inclinations ***i*** & true masses **M_{pl}**
- **Improvements**
 - large number of “new” targets
 - complements transit & RV surveys
 - connects RV giants to directly imaged systems



Science cases : Exoplanets

Stellar chemistry & planet formation

- Occurrence - $[\text{Fe}/\text{H}]$ & α -overabundance
(e.g. Fischer+, 2005; Wang+, 2015; Adibekyan+, 2012)
- Eccentricity - $[\text{Fe}/\text{H}]$
(e.g. Dawson & Murray-Clay, 2013; Mills+, 2019)
- Planets / architectures - refractory depletion
(e.g. Rathsam+, 2023; Yun+, 2024)
- M_{pl} and ρ_{pl} - stell. chem. composition
(e.g. Tautvaišienė+, 2022, Sharma+, 2024, 2026; Behmard+, 2025)
- Planet occurrence likely not uniform across MW
(e.g. Bashi+, 2022; Padois+, 2025)



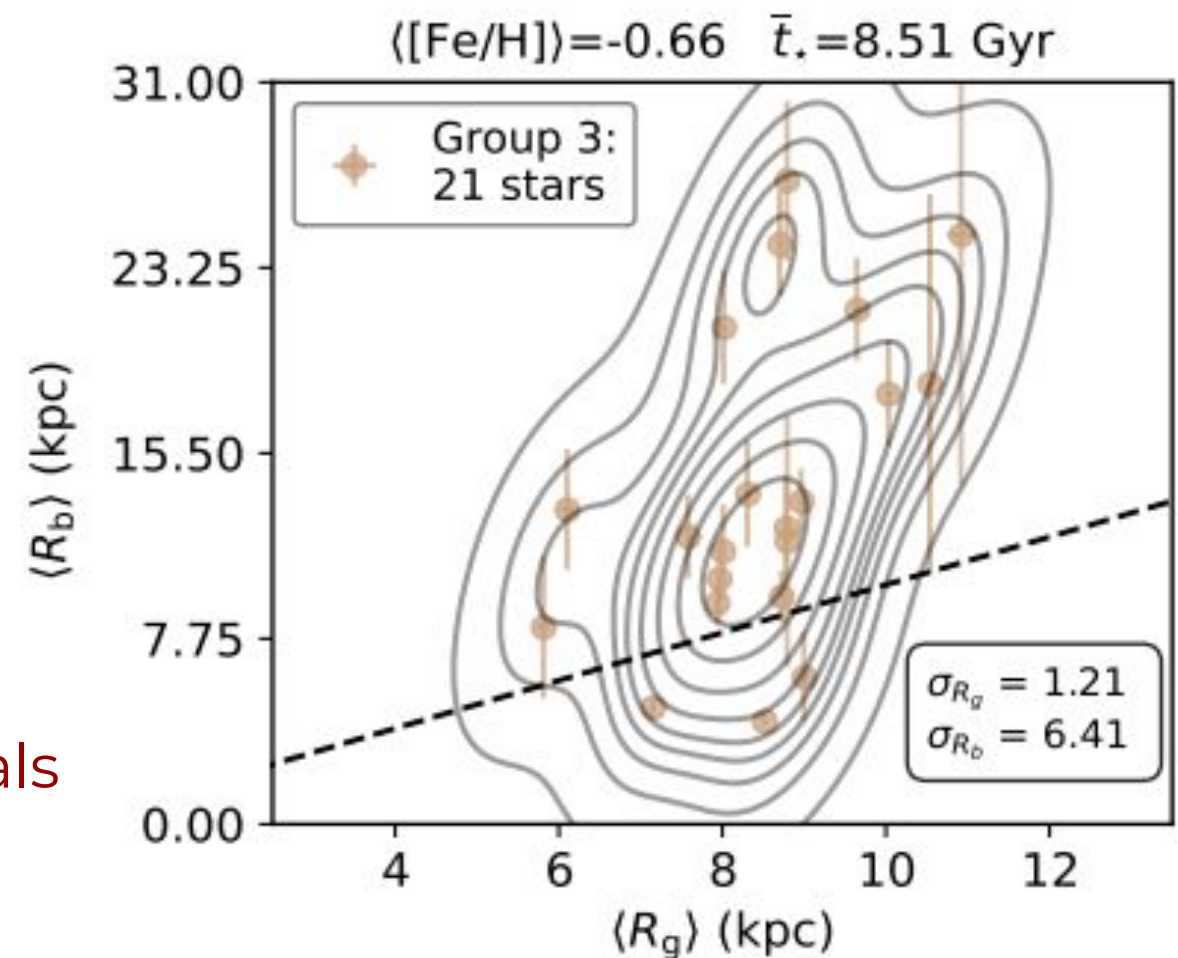
ESO / L. Calçada



Science cases : Exoplanets

Tracing planet host origins

- **Radial migration**
 - stars migrate in- and outward
 - complicates observed metallicity trends
- **Migration histories**
 - chemistry and age provide birth-radii
 - helps untangling Galactic chemical signals from local effects



adapted from Dantas +, 2025

Science cases :



The billion ways of using the Gaia data

Tineke Roegiers¹

Solar System

Though Solar System science is not the primary goal for Gaia, a lot is achieved on this front since Gaia started releasing its data. When scanning, Gaia captures any object it scans across and thus observes many asteroids next to stars and galaxies.

Read more Gaia data on Solar System

Earth orbit and L2

Some spacecraft orbiting Earth or located at L2 are powerful in studying a specific target with great detail. To make most efficient use of these telescopes, pointing them to the most promising sources is important. This is where Gaia helps out. Gaia, being an all-sky homogeneous survey, brings the perfect catalogue to make a first selection of interesting

Earth

On Earth, life has improved for astronomers following up on stellar occultations. With the star positions and motions of Gaia's first data release came improved predictions of the stellar occultation shadow paths on Earth. These shadow paths and their timing predictions are used to deploy the ground observations of these events. With each

Sun

Though Gaia never looks at the Sun with its telescopes, it is capable of observing the Sun nonetheless. Close watch is kept on all temperature changes affecting the Gaia spacecraft as they have the potential of influencing the observations captured. The small drop in Solar irradiance caused by the transit of a cooler sun spot can be measured with

The Solar System. Credit: NASA-JPL Caltech Source: ESA

Stars

The large, homogeneous all-sky Gaia catalogue of stars is a treasure chest for new discoveries, and brings substantial samples of special stars for detailed investigation. A taste of studies, discoveries and opportunities where Gaia helps out is given below. This is only a tiny selection of the many topics touched by the scientific community related to

25pc sample

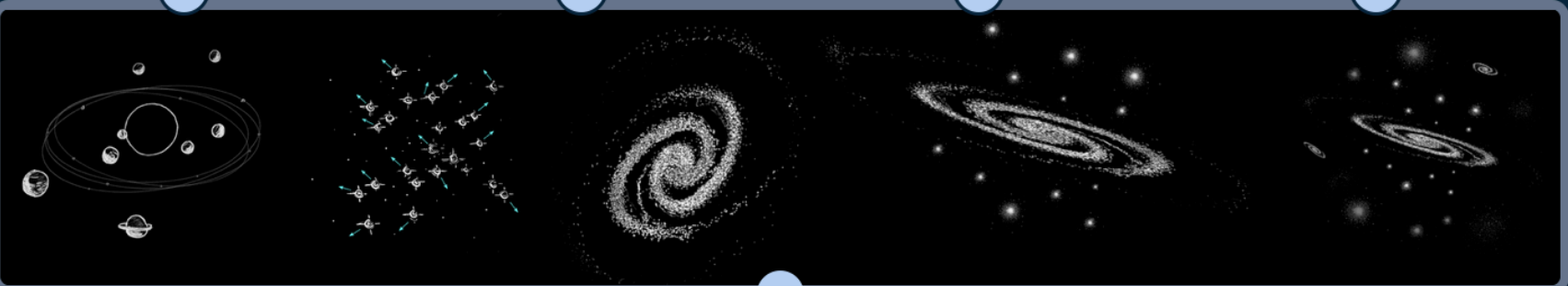
Early 2023 brought an update to the catalogue of nearby stars: CNS5. Within a sphere with 25pc radius around the Sun a total of 5931 objects are known now. This catalogue strives for completeness and was updated with the star information from Gaia's Early Data Release 3. The CNS5 is a great sample to study the Milky Way. This catalogue can be used to test a

Milky Way

Mapping the Milky Way is the core goal of Gaia and so it does, in full detail, in many dimensions. Stars and structures in the Milky Way are mapped, as well as dust and interstellar matter in between the stars. Gaia also maps the astrophysical information such as stellar ages, metallicity, and more. This variety of Milky Way mapping is highlighted in Gaia's

Galaxies

Next to stars, asteroids, moons, comets, spacecraft, quasars, Gaia also observes galaxies. If observed as a whole, they show up as extended objects. First results from the processing of these extended objects were published with Gaia Data Release 3, leading to 4.8 million galaxy candidates (20% of which have redshift estimations).



Star groups

Some stars belong together. They travel together through space bound by a mutual gravitational attraction. In June 2022 Gaia published a catalogue of multi-star systems, containing stars with few companions. Gaia's full catalogue of over 1.8 billion stars is also heavily used to discover and improve our knowledge of stellar clusters, star groups composed of

100pc sample

As part of Gaia's Early Data Release 3, the Gaia Catalogue of Nearby Stars (GCNS) was published. With this catalogue, a unique census of stars within 100 pc of our Sun became available. At this distance, the coolest stars become too faint for Gaia's survey limit. Choosing 100pc hence allows to get a complete census of Gaia stars, including the

Milky Way Halo

Following Gaia's first data release, an extended study was performed revealing rich structures of the nearby stellar halo. More studies followed soon, when more and better data became available with each Gaia data release. Below a small selection is given to demonstrate Gaia's impact on our knowledge of the Milky Way halo.

Quasars

Gaia also observes distant quasars, many of them billions of lightyears away from the Sun and the Milky Way. The Gaia catalogue contains 1,614,173 quasars used to construct the Gaia Celestial Reference Frame. With the high quality of Gaia EDR3, Gaia was for the first time capable of observing the tiny effect of the acceleration of the solar

Cavities in space

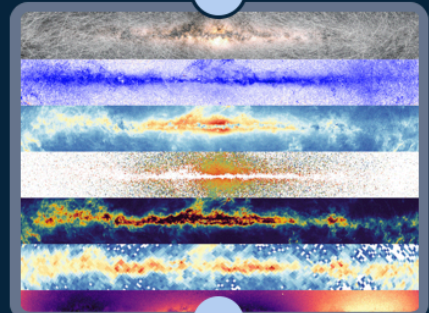
There is something to be learned from the absence of stars as well. A gigantic cavity in space was found by combining Gaia's 3D information with powerful new data science techniques in order to map molecular clouds in 3D gas density space. This led to the discovery of a gigantic cavity in space.

Local Bubble

Local Bubble has a radius of about 500 lightyears or 150pc. The Sun happens to be travelling through this bubble on its journey through the Milky Way. While known for decades, only with help from Gaia's Early Data Release 3 we finally understood its origine and the impact it has on the gas around it. It turns out that the Local Bubble is a source of our

MW satellites

When Gaia maps the stars, it continues to do so beyond the edge of the Milky Way. As long as the sources are bright enough, they are observed. The Gaia catalogues thus includes samples of stars from the Milky Way satellites and neighbouring galaxies. These samples are interesting to study historical events that shaped our Milky Way.



<https://k-poster.kuoni-congress.info/eas-2023/poster/77628391-074f-4689-867f-79d6342116fc>

UCAS

Links :

- Gaia DR4 Overview : <https://www.cosmos.esa.int/web/gaia/data-release-4>
- Gaia Meeting S7 : <https://great.ast.cam.ac.uk/Greatwiki/GreatMeet-PM19>
- Science topics : <https://k-poster.kuoni-congress.info/eas-2023/poster/77628391-074f-4689-867f-79d6342116fc>
- Gaia-MW : <https://www.mw-gaia.org/>

