

# Stellar variability, stellar multiplicity: periodicity in time & motion” June 6-8, 2023, Sofia, Bulgaria

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Laurent Eyer, University of Geneva

Sofia, Bulgaria

June 6-8, 2023



# Conference summary

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🌐 In French: A l'impossible nul n'est tenu

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    - ☺ - Put them at the beginning of sessions in the morning

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  - ④ But the problem is turned to an advantage → identification of 2.5 million candidate galaxies

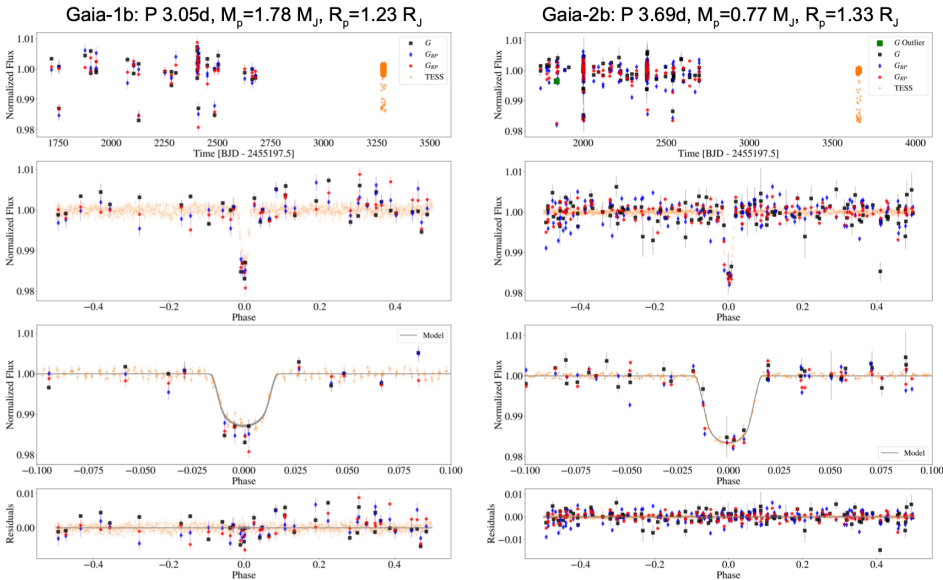
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DR3: 173 candidates, 41 new: 2 confirmed! (Panahi et al, 2022)



Also collaboration with NASA TESS mission to confirm or identify background eclipsing binaries (Panahi et al 2022b)

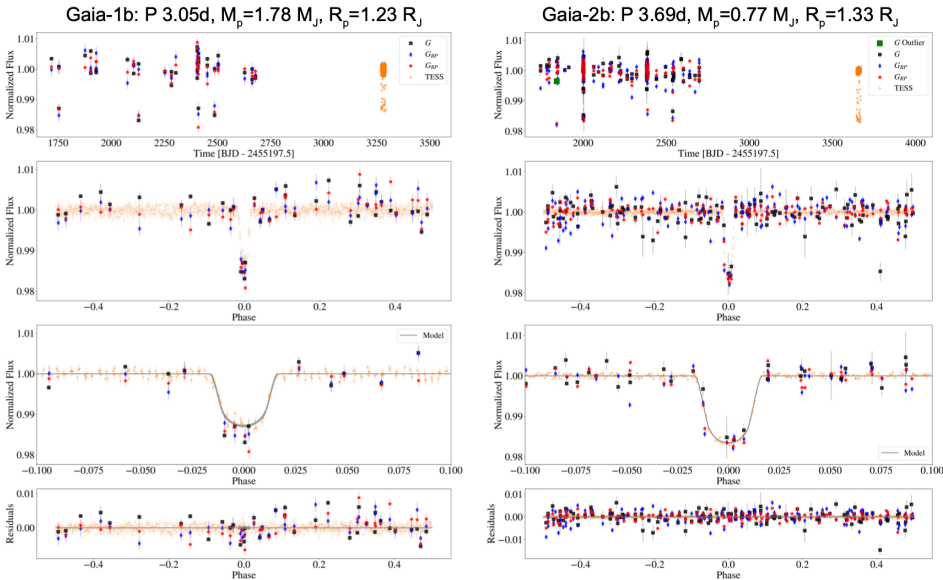
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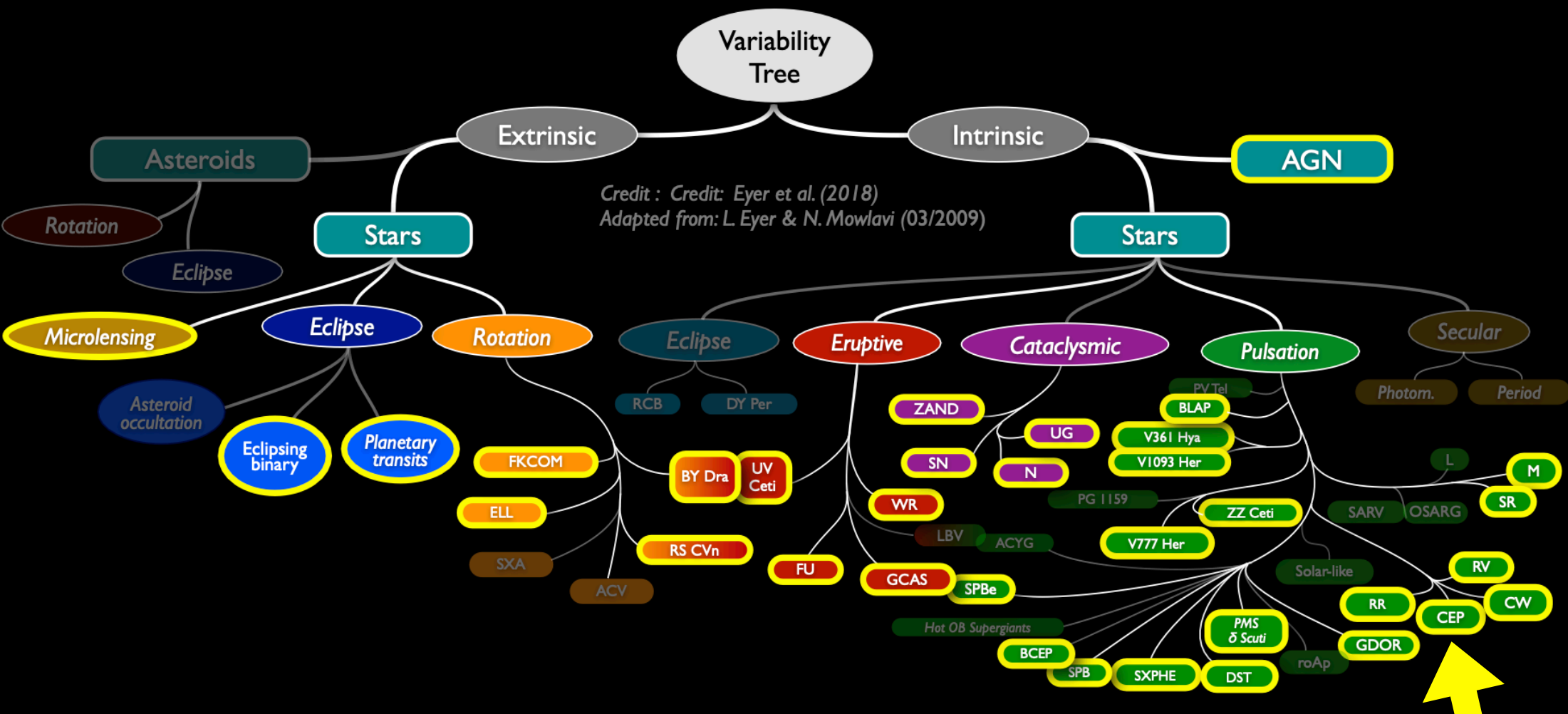
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The screenshot shows the Gaia Vari web interface. At the top, there is a banner that says "Join us on Zooniverse!" with navigation links for "ABOUT", "CLASSIFY", "TALK", and "COLLECT". Below the banner, a message states: "While preparing for the next campaign, we unretired all subjects and increased retirement threshold so the current workflow can continue! We are amazed by your fantastic performance!" and "Great work! Looks like this project is out of data at the moment! See the results or dismiss this message". The main content area is divided into "TASK" and "TUTORIAL" sections. The "TASK" section asks "What type of variable object is it?" and provides buttons for "Eclipsing Binary", "Cepheid", "RR Lyrae", "Long Period Variable", and "None of the above". There is also a "NEED SOME HELP WITH THIS TASK?" section with "Done & Talk" and "Done" buttons. The interface also displays several astronomical plots: a "FINISHED!" badge, an HR diagram (G [Magnitude] vs Absolute G [Magnitude]), a "Colour [Magnitude]" plot, and a "Folded period" plot (G [Magnitude] vs Folded period) with a "Dip" labeled "15.00 hours".





**~10 million variable sources + 2.5 million galaxies\***

\* identified through their scan-angle dependent signals, see later

# Cepheids

(**Marcello Marconi**, **Roberto Molinaro**, Ignacio Negueruela, Vincenzo Ripepi, Teresa Sicignano, Ilaria Musella)

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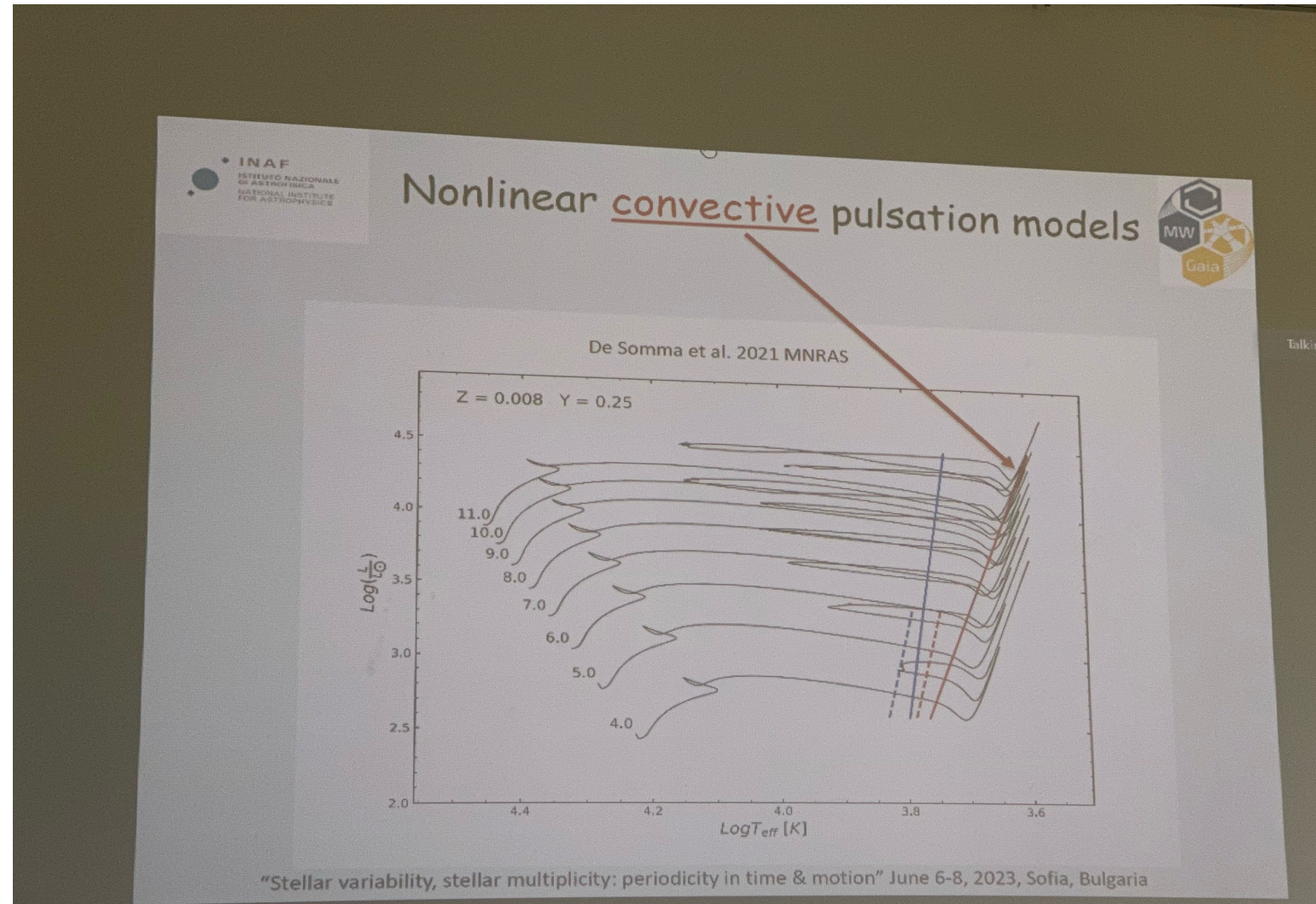
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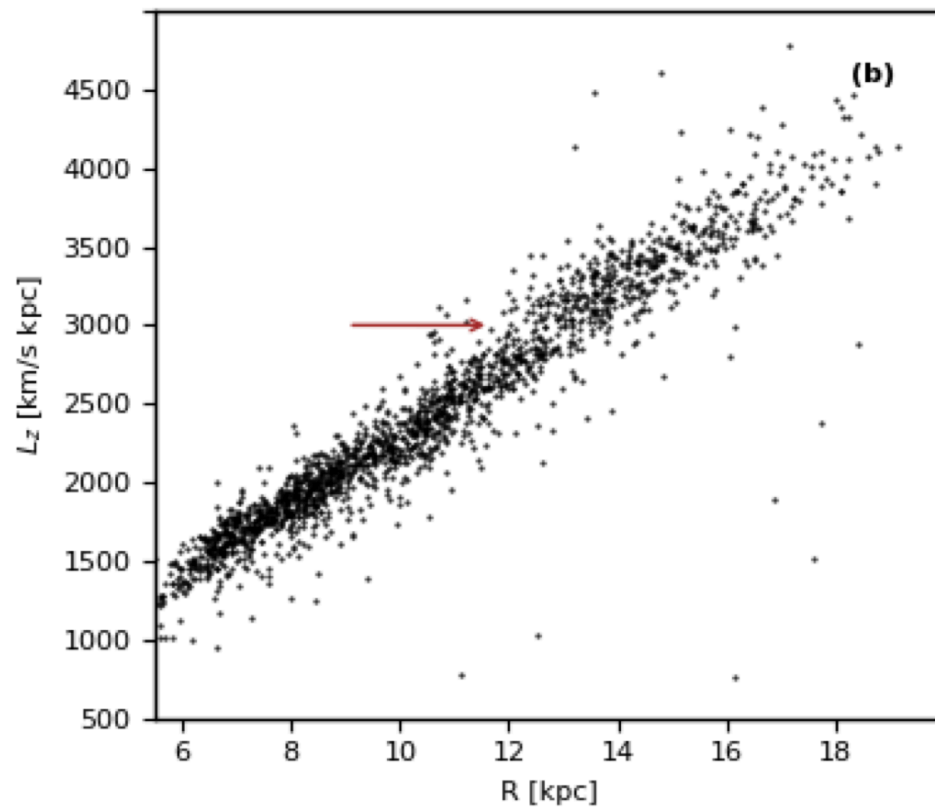
- 🌐 Looking at the Cepheids in our Milky Way, a gap in Lz if found

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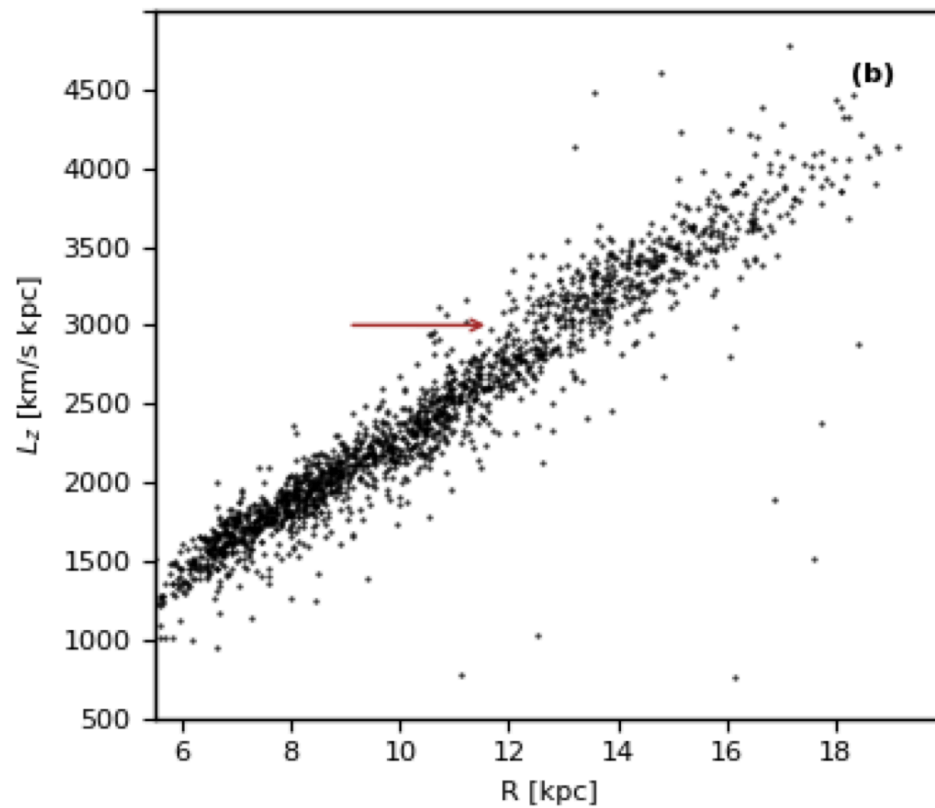
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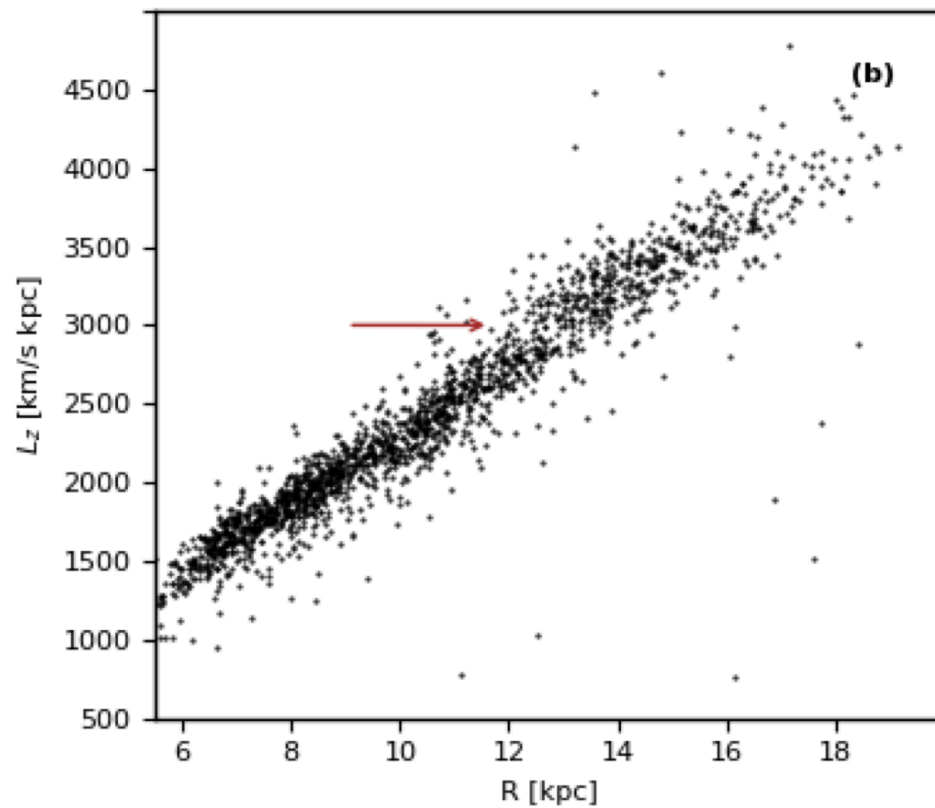


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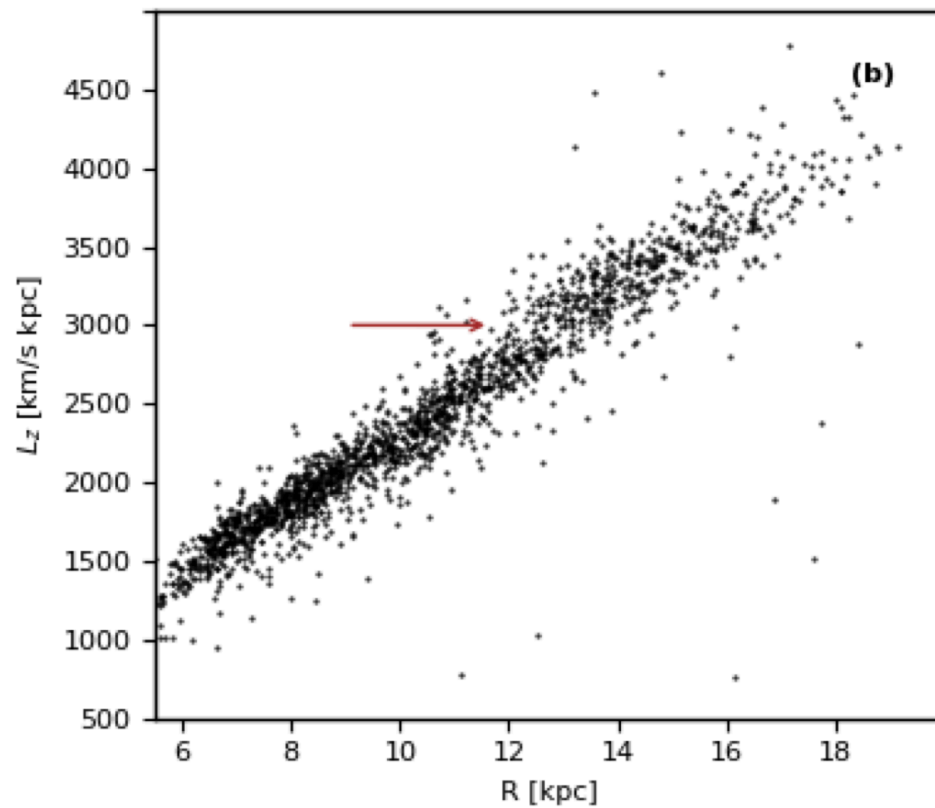
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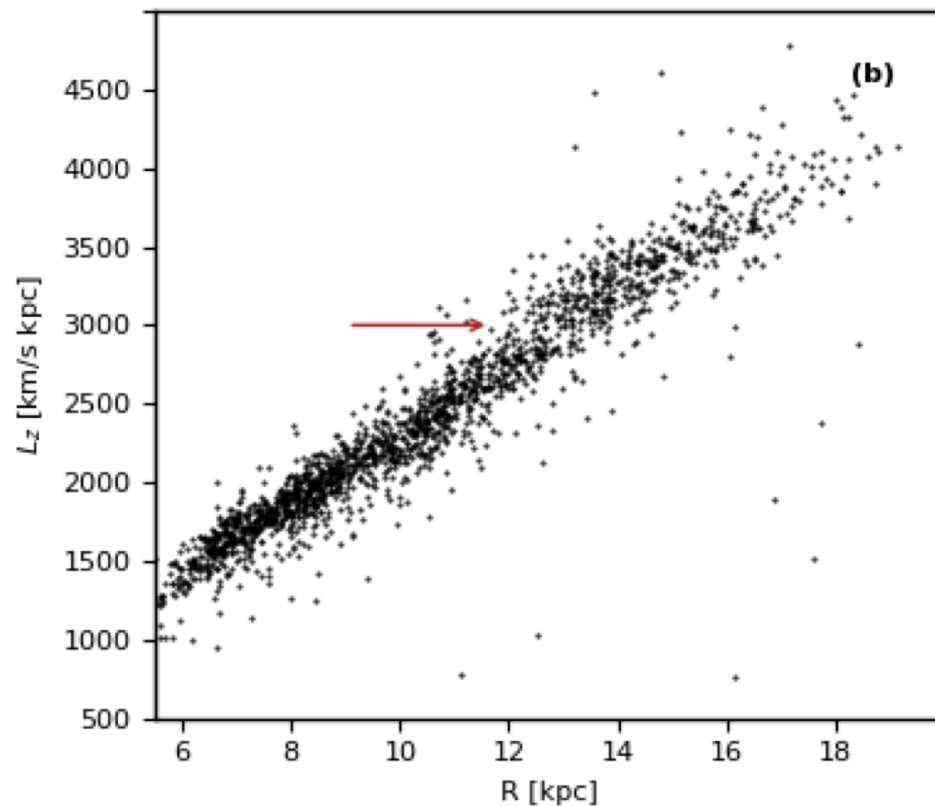


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  - star formation in multiple
  - spiral arm segments

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- ☉ Teresa Sicignano: artillery developed on Classical Cepheids are applied to Type II Cepheids



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## ⦿ Cepheids in Clusters

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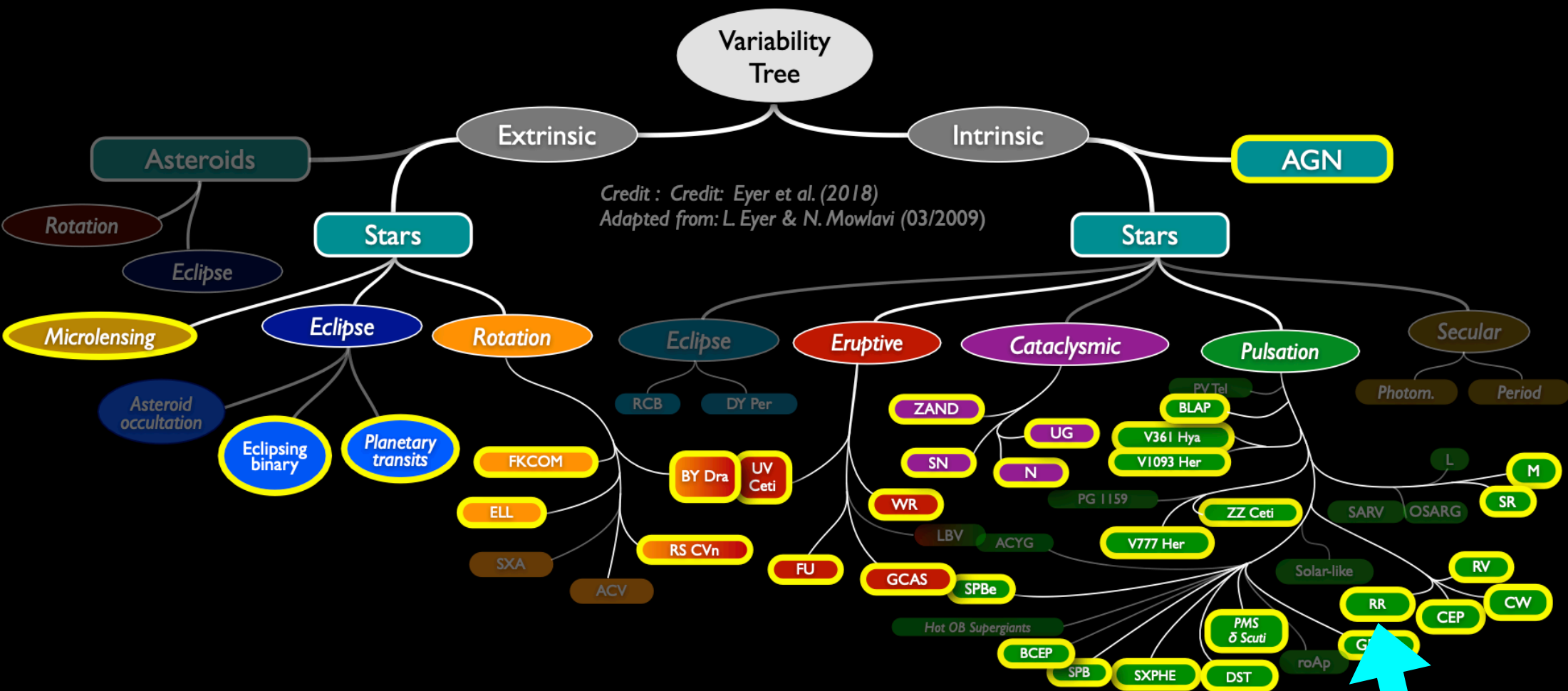
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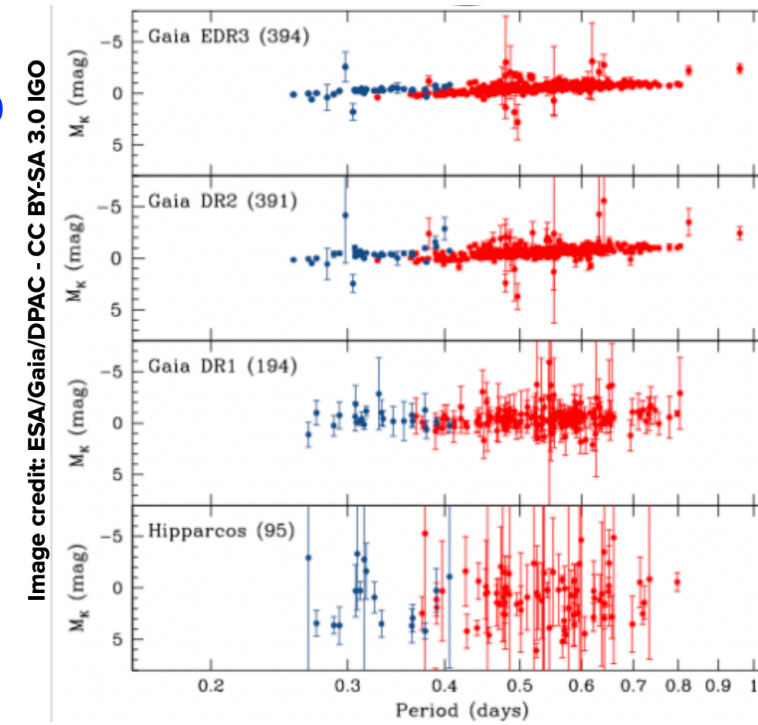
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Alessia Garofalo, Vasily Belokurov, Guiliano Iorio

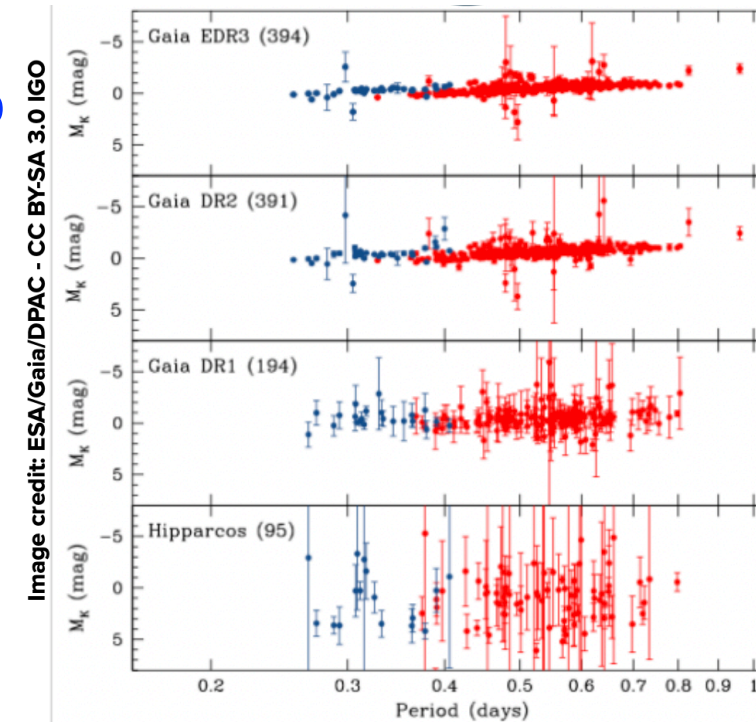
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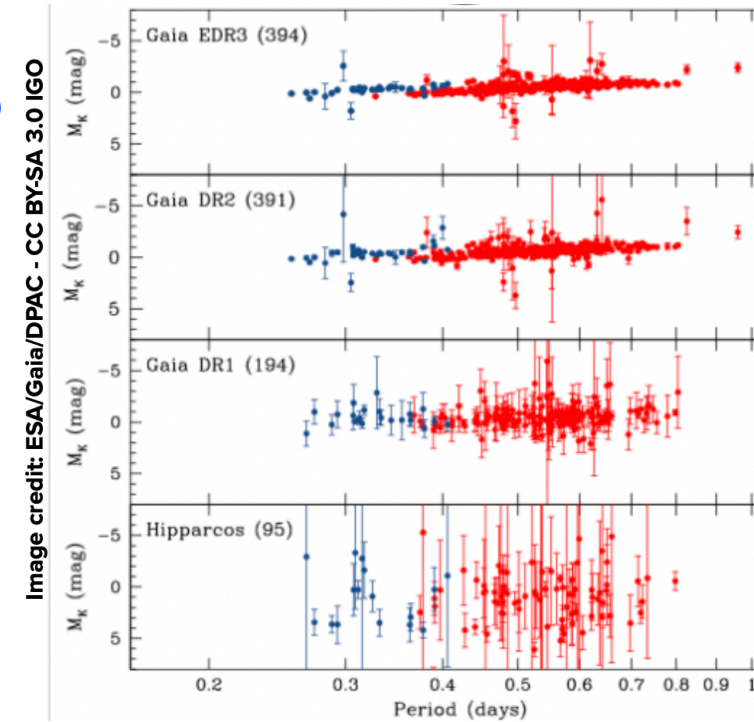
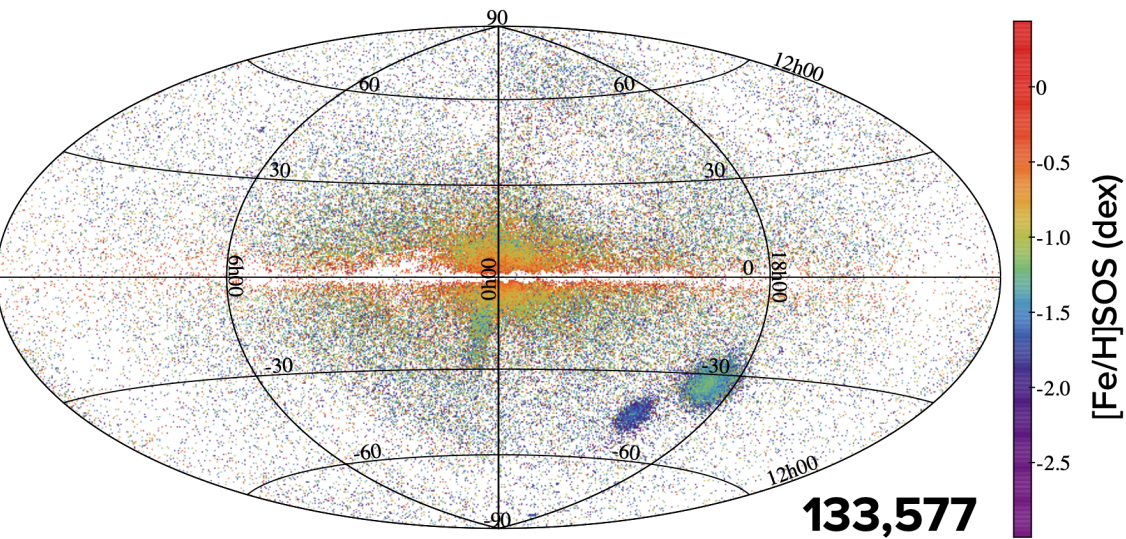
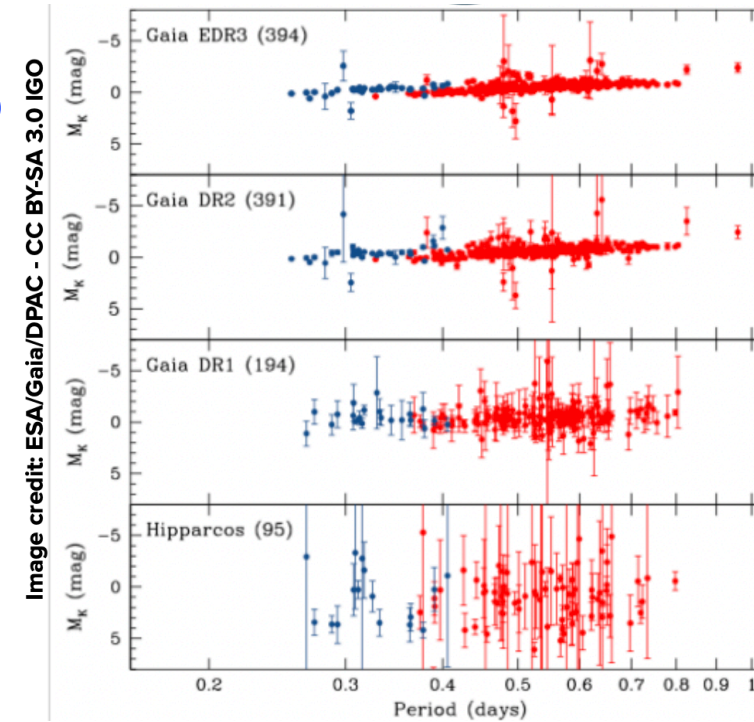
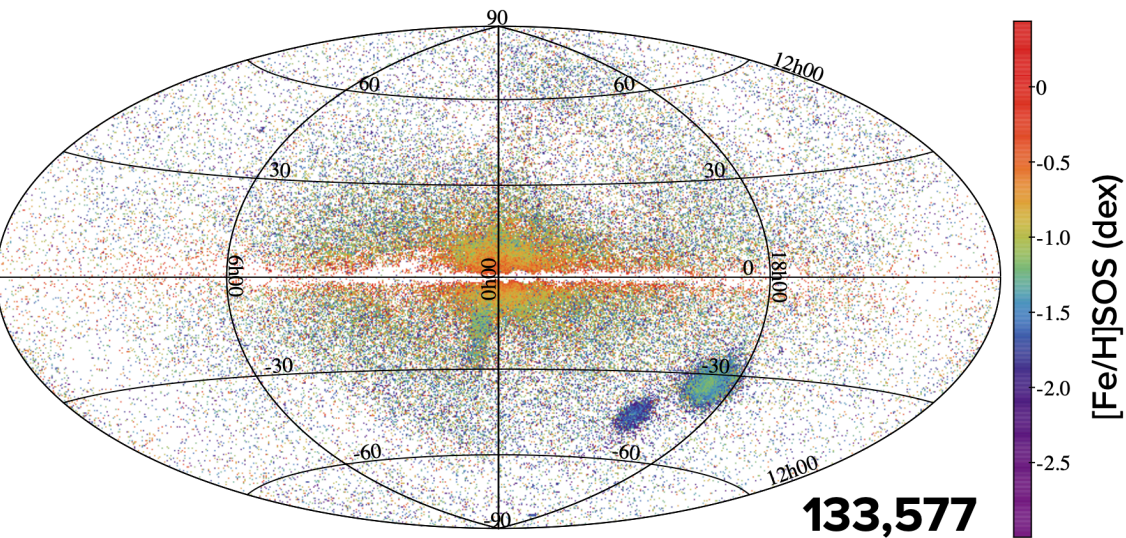


Image credit: ESA/Gaia/DPAC - CC BY-SA 3.0 IGO

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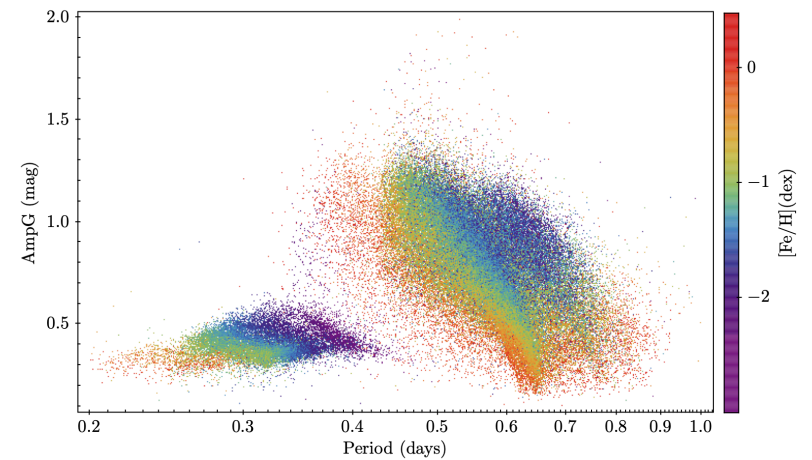
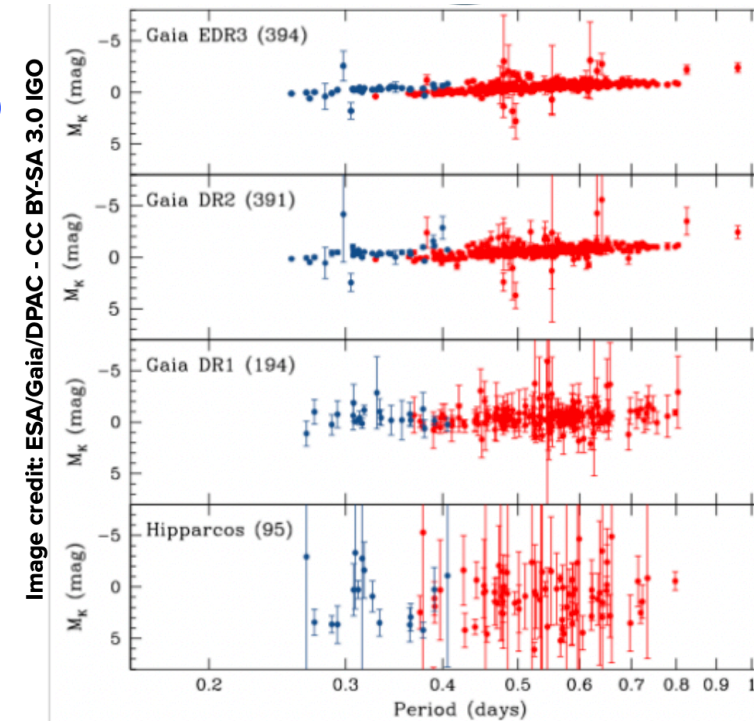
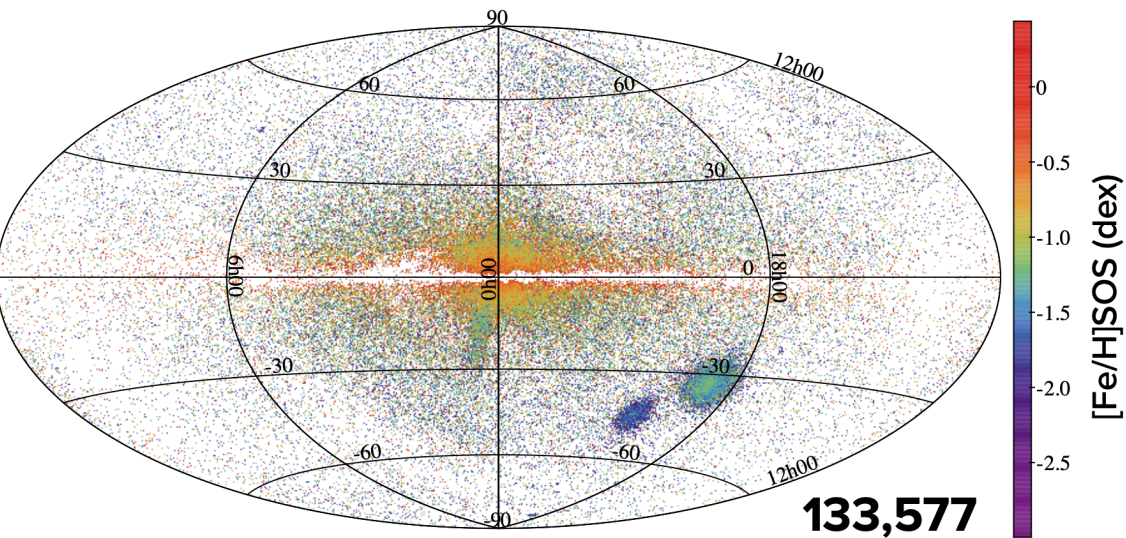
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Systematic (long) pursuit of Vasily  
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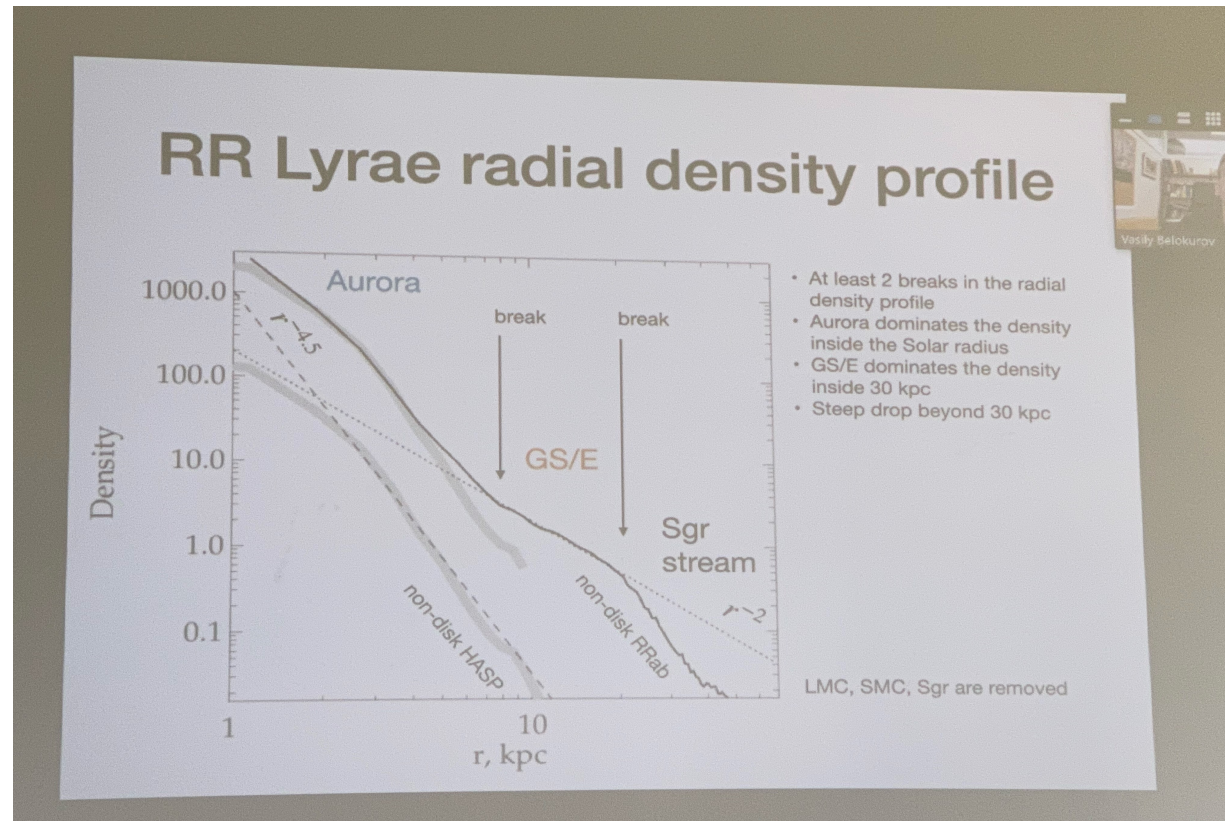
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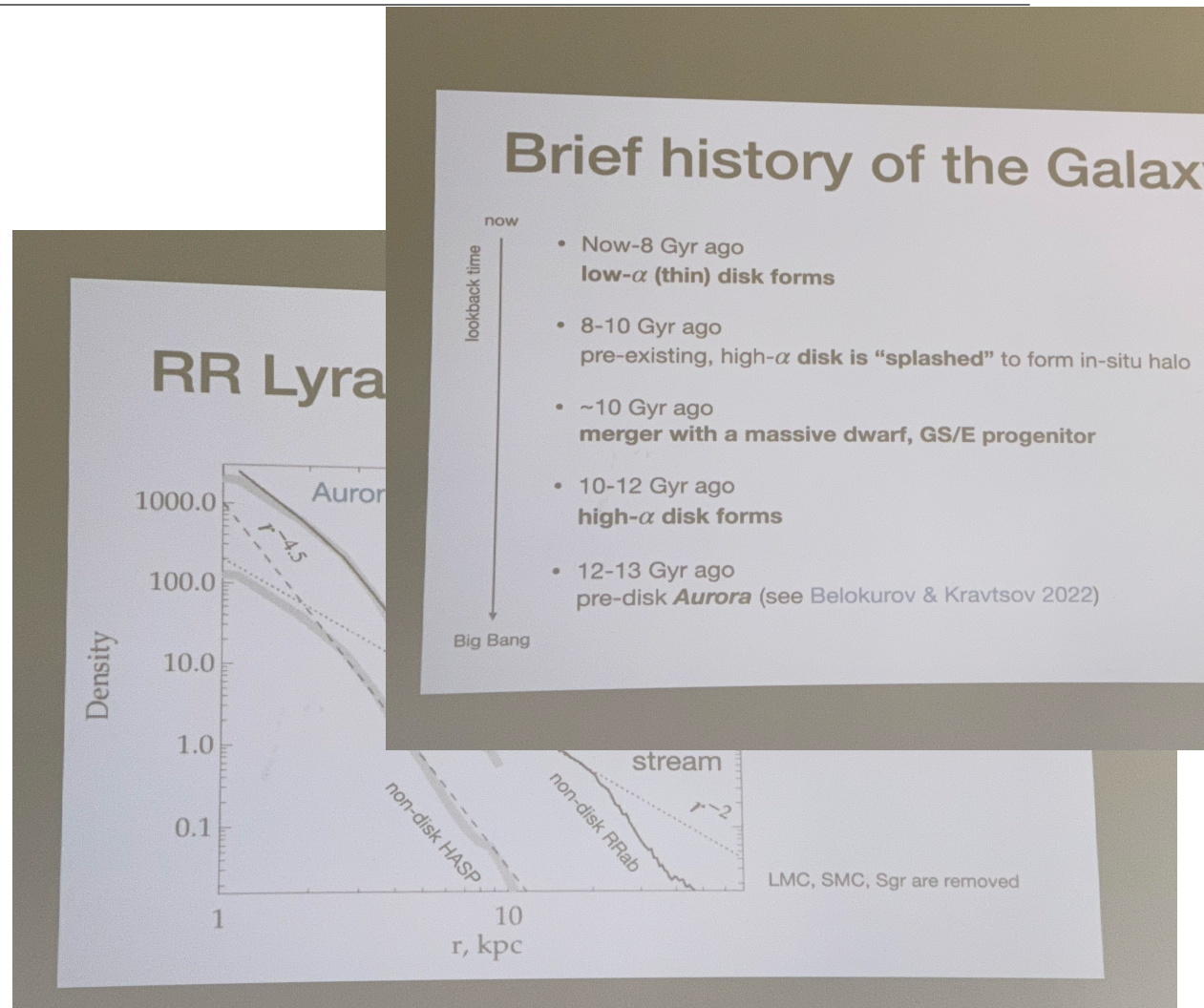
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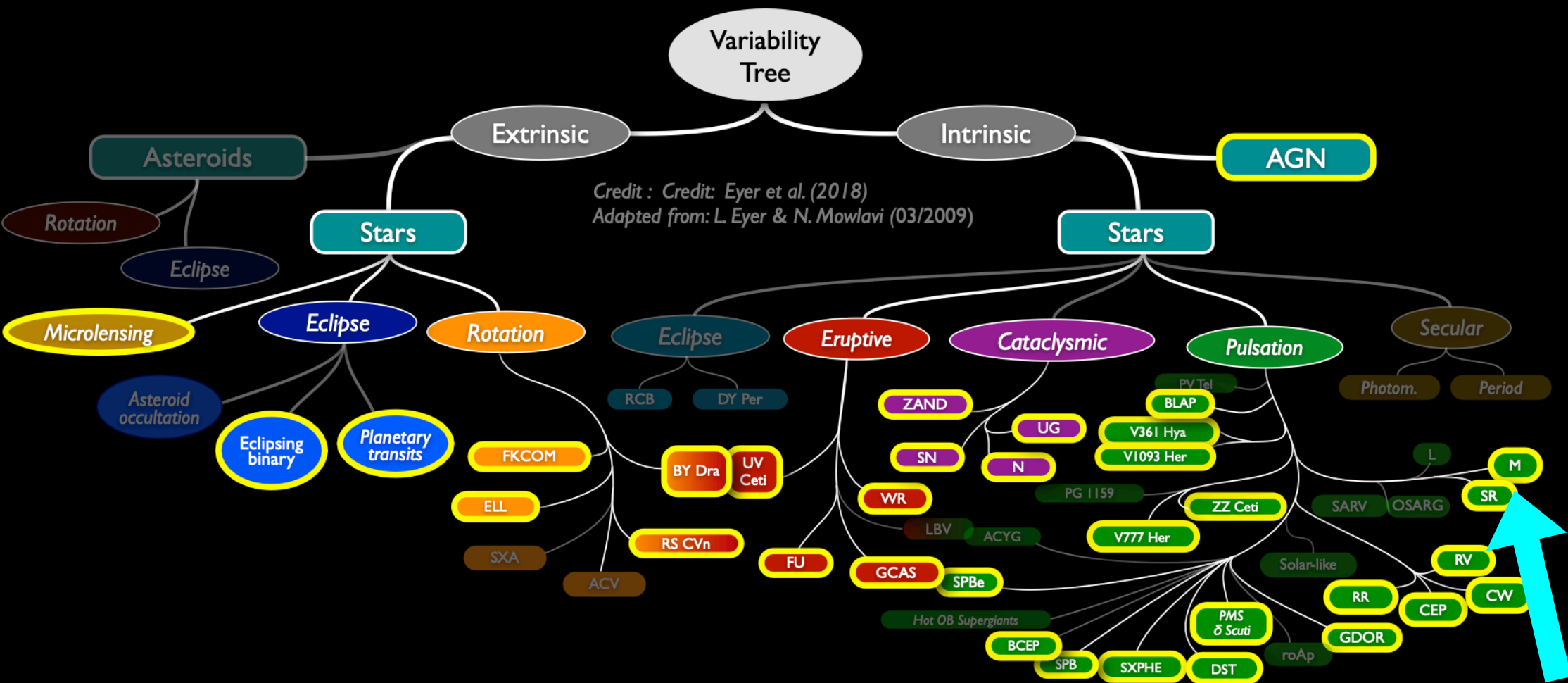
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Metal rich RR Lyrae in the thin disk



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## Long Period Variables

**Thomas Lebzelter, Fran Jiménez-Esteban, Konstantinova-Antova**

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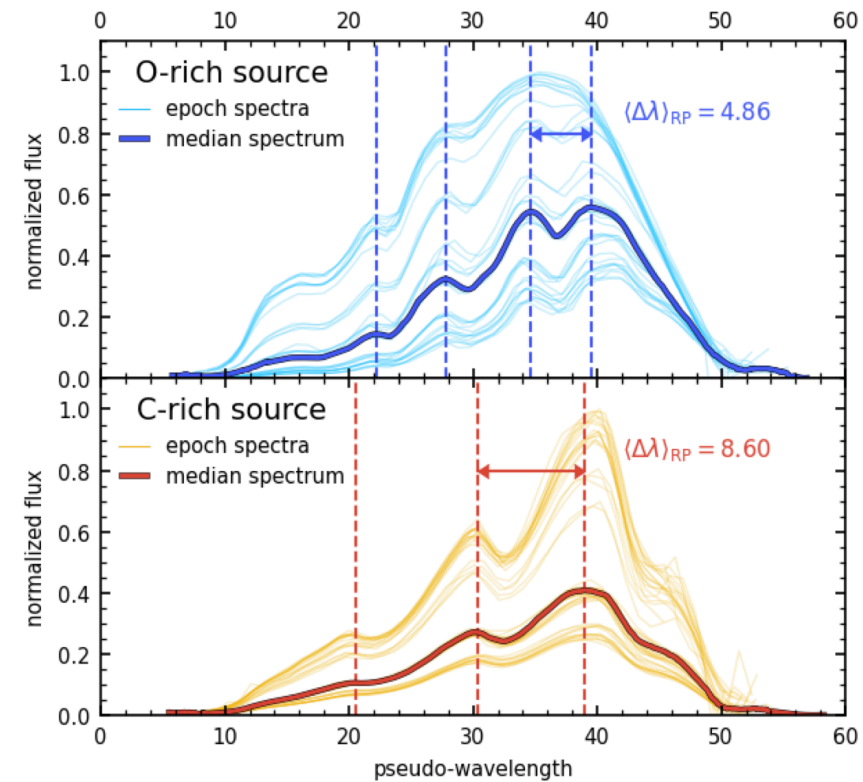


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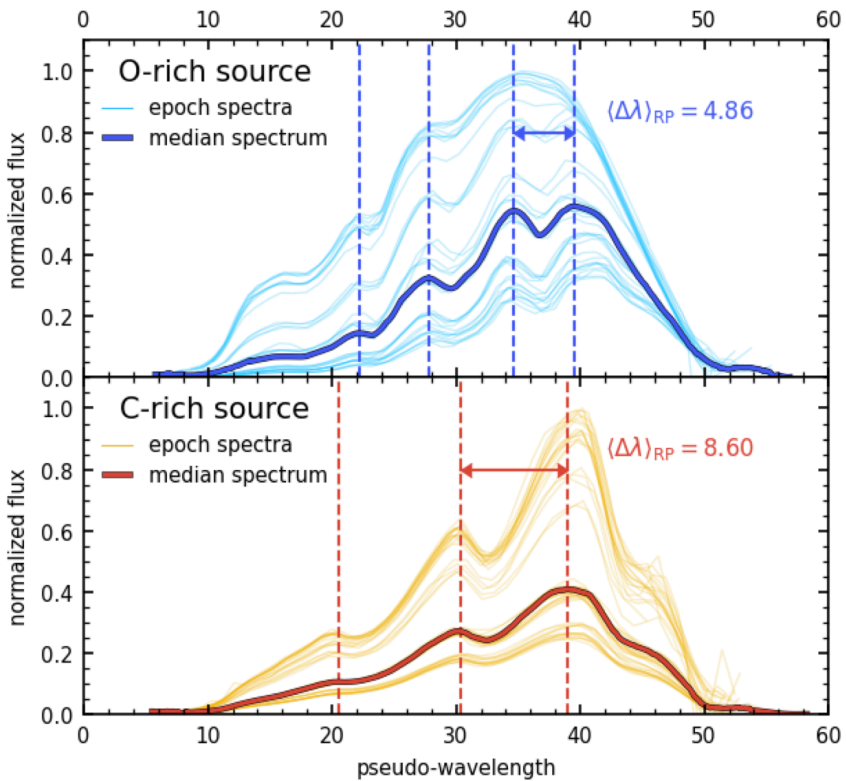
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2MASS/Gaia photometry

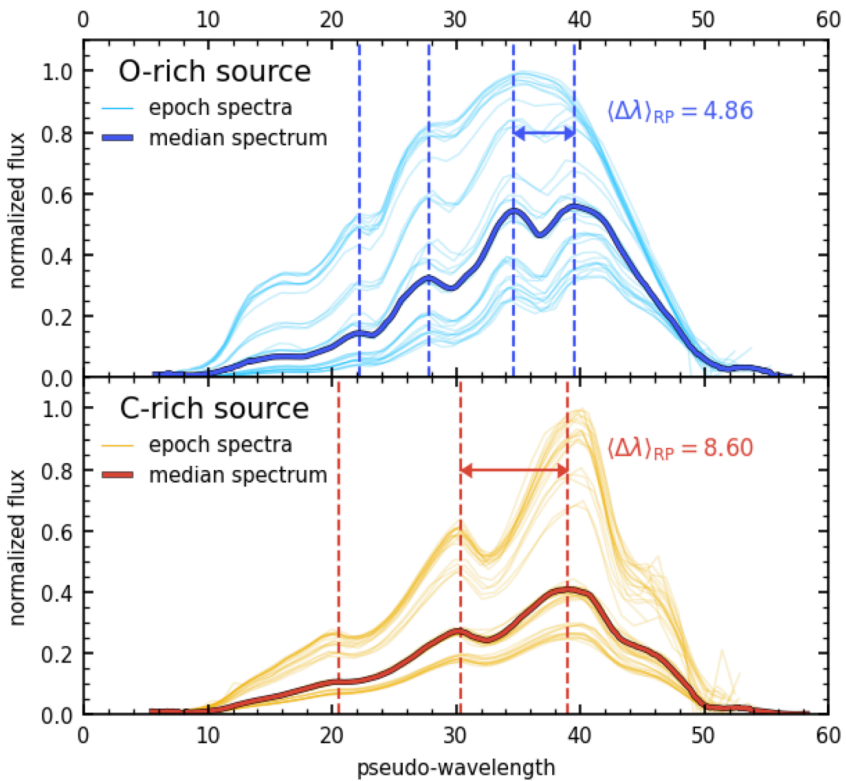


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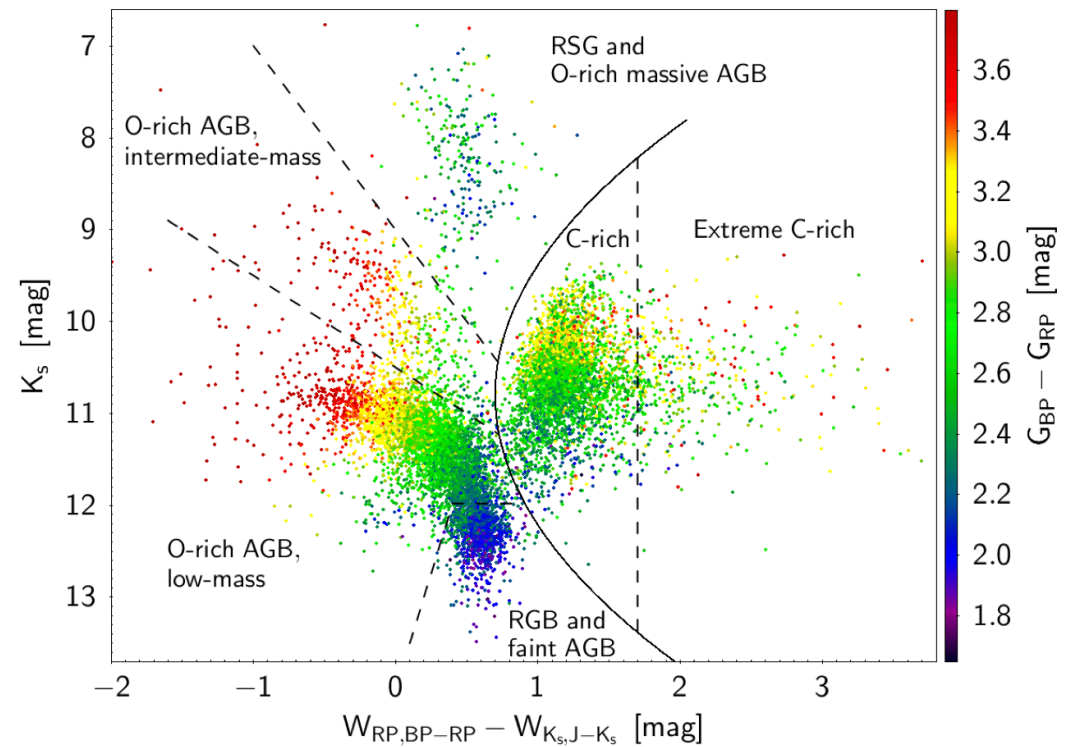
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## 2MASS/Gaia photometry

Gaia DR2 LPVs in the LMC



# ADDENDUM: Long Period Variables

## Focused Product Release

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### Gaia FPR (Focused Product Release) 10 October 2023

The release will be consisting of:

- Updated astrometry for Solar System objects.
- Astrometry and photometry from engineering images taken in selected regions of high source density (only Omega Cen for this FPR).
- The first results of quasars' environment analysis for gravitational lenses search.
- **Extended radial velocity epoch data for Long Period Variables.**
- Diffuse Interstellar Bands from aggregated RVS spectra.
- Pre-main sequence accretion parameters (no longer part of the FPR, postponed to Gaia DR4)

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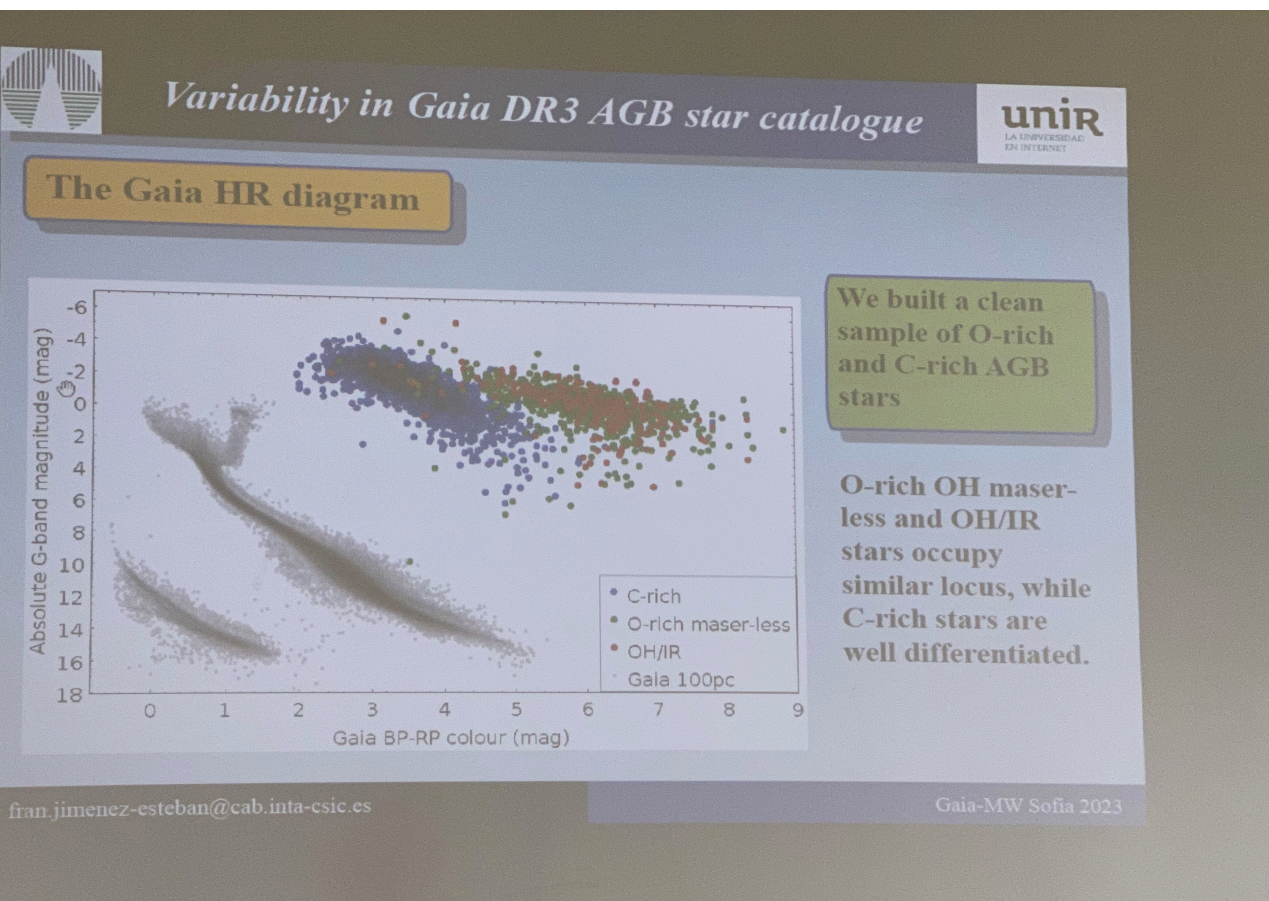
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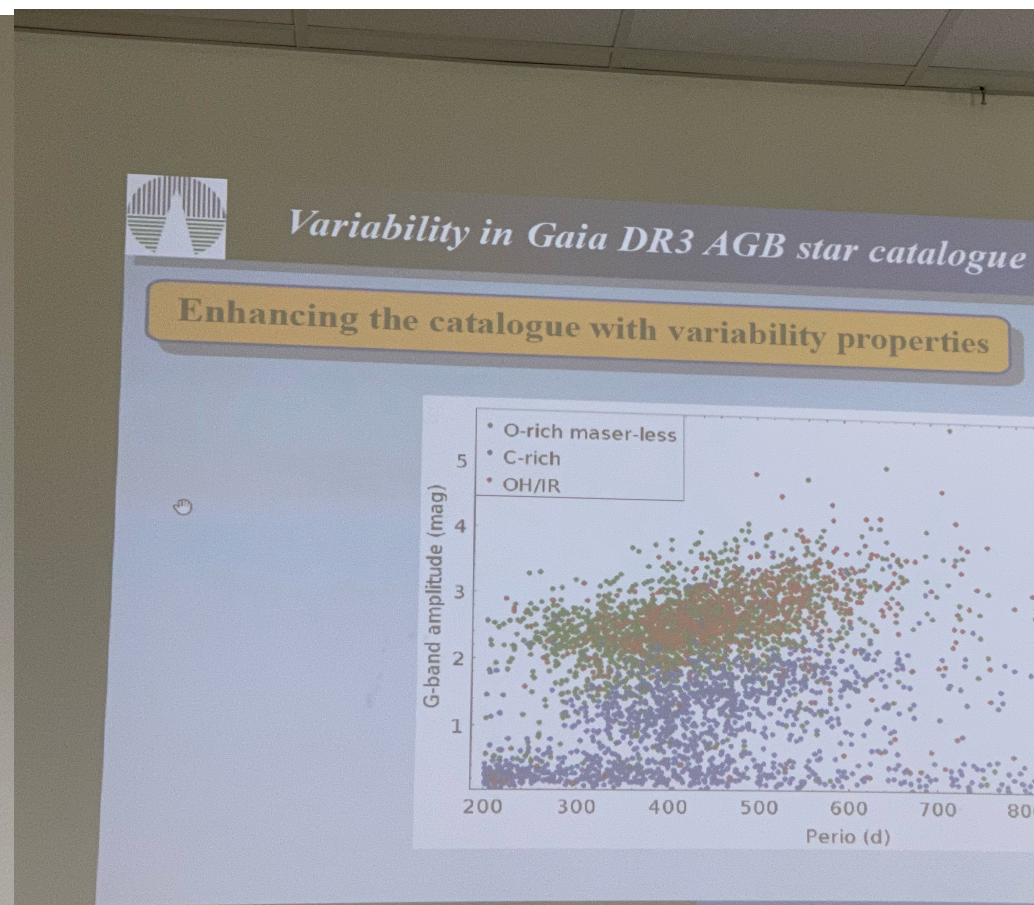
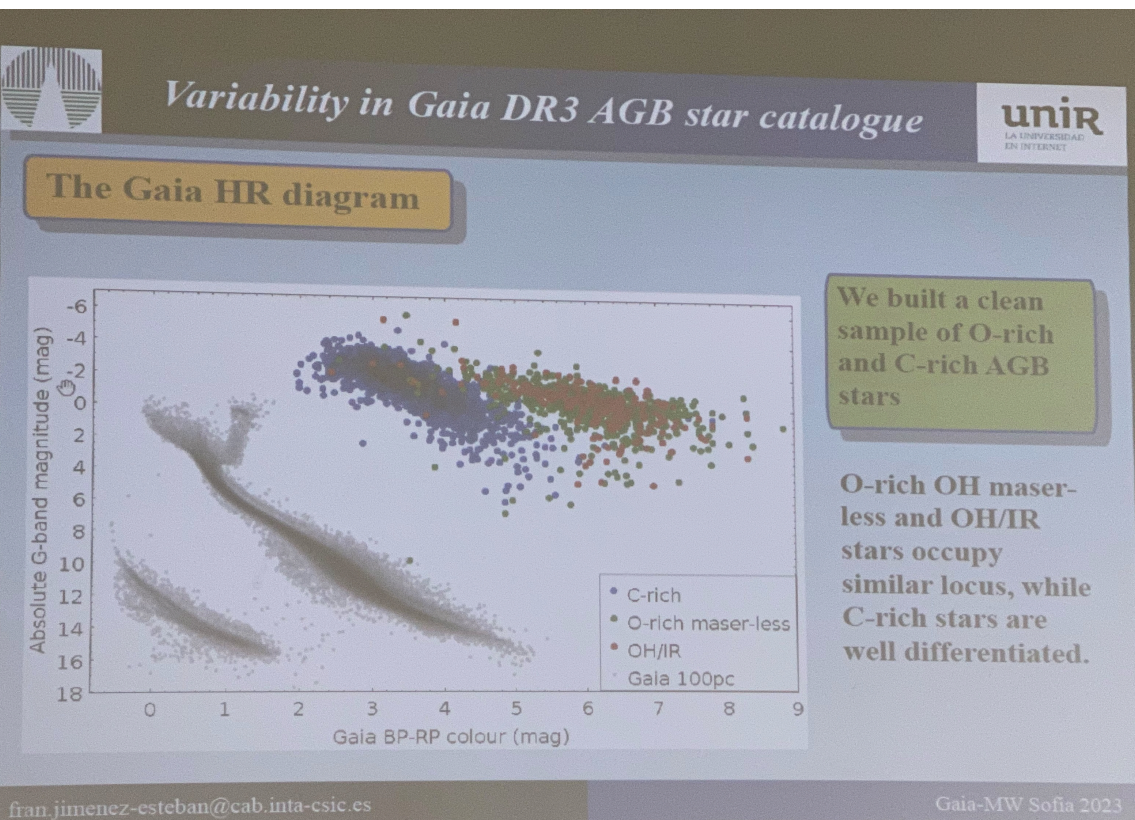
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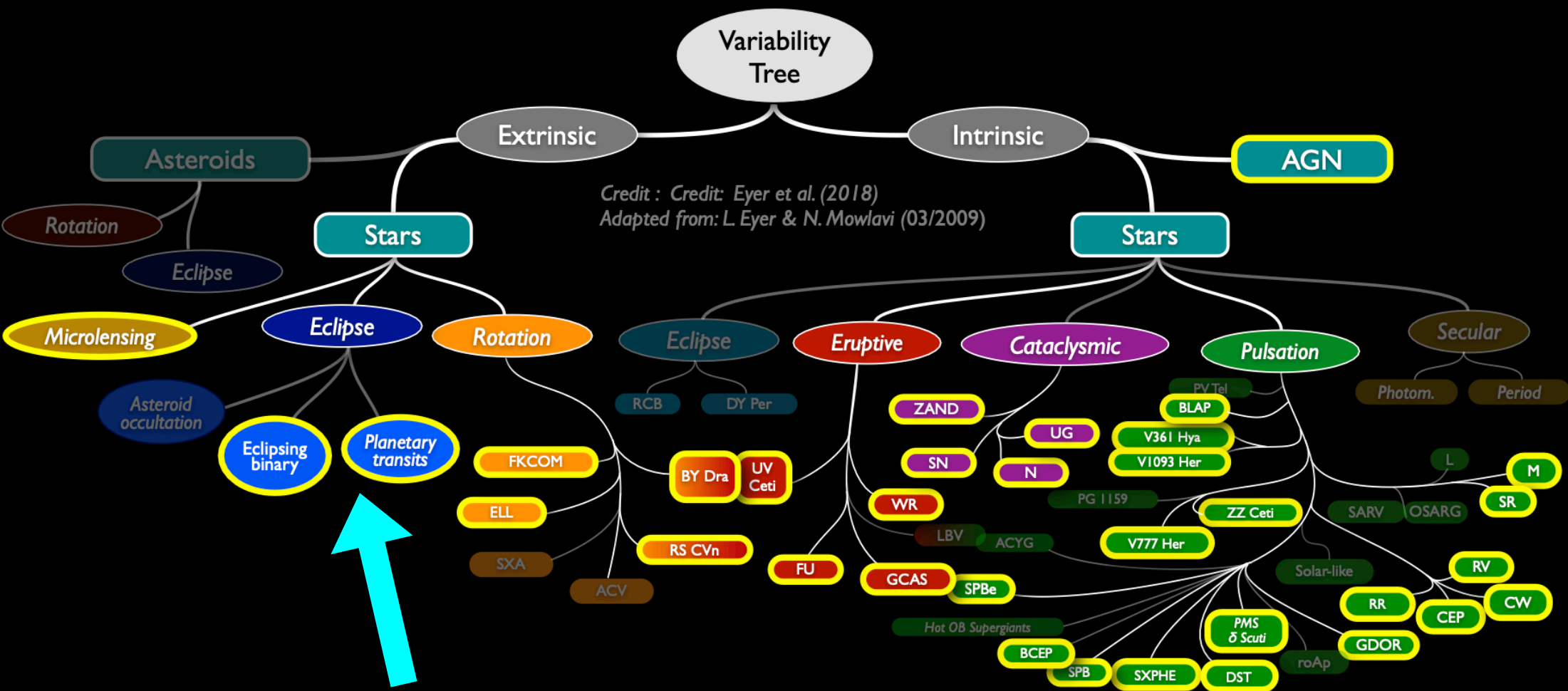
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Thomas Lebzelter, **Fran Jiménez-Esteban**, Konstantinova-Antova

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**~10 million variable sources + 2.5 million galaxies\***

\* identified through their scan-angle dependent signals, see later

# Binaries

**John Southworth**, Laurent Mahy, Alexandre Gallen, Nicolas Lodieu, Judit Donada Oliu, Priya Shah

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🌐 Introduction of John

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**John Southworth**, Laurent Mahy, Alexandre Gallen, Nicolas Lodieu, Judit Donada Oliu, Priya Shah

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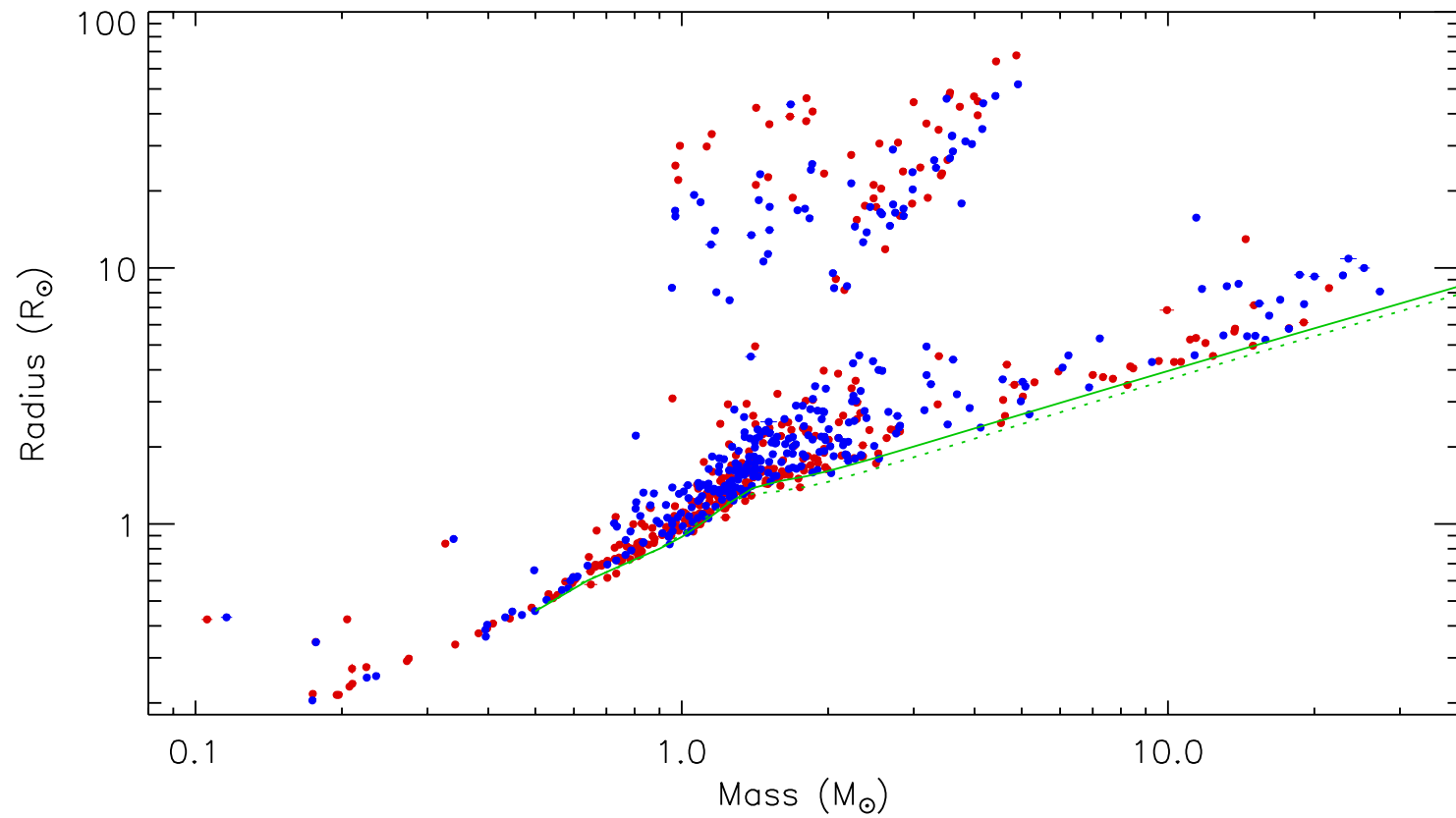
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- ④ Kepler, TESS and PLATO

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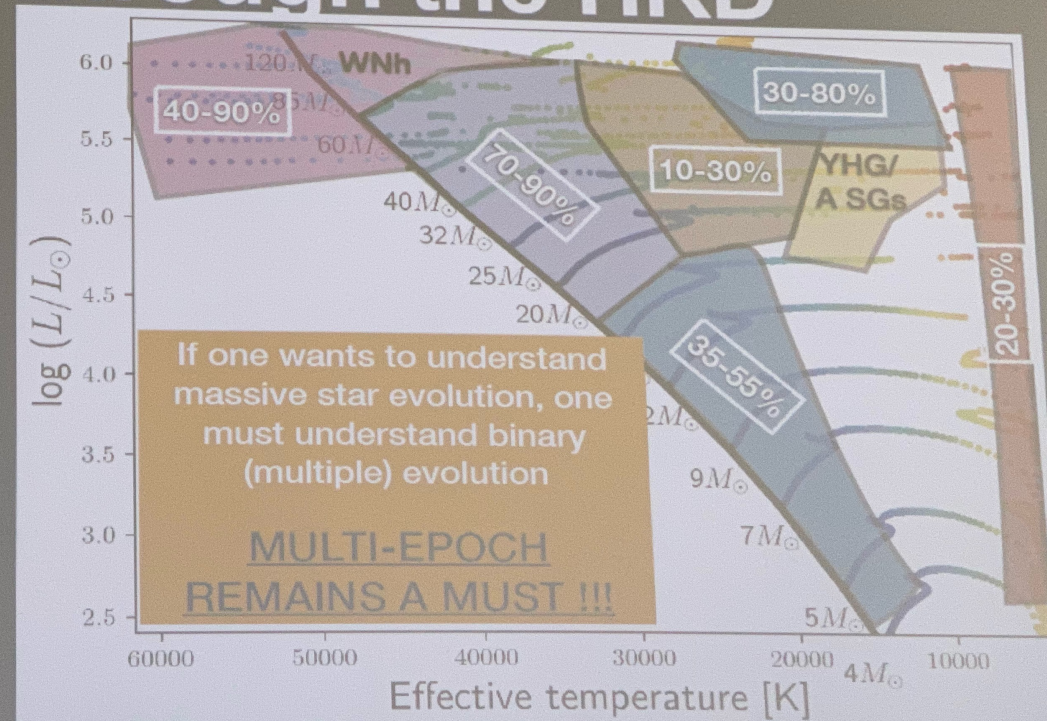
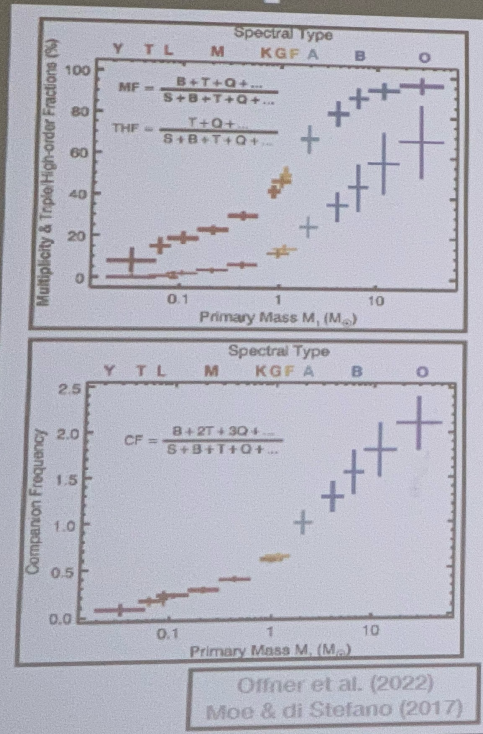
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# Binaries

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## Multiplicity through the HRD





# Binaries

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# Binaries

John Southworth, Laurent Mahy, Alexandre Gallen, Nicolas Lodieu, Judit Donada Oliu, Priya Shah

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🕒 Introduction on interferometry

# Binaries

John Southworth, Laurent Mahy, **Alexandre Gallen**, Nicolas Lodieu, Judit Donada Oliu, Priya Shah

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🕒 Introduction on interferometry

🕒 Binaries

🕒 Comparison with Gaia

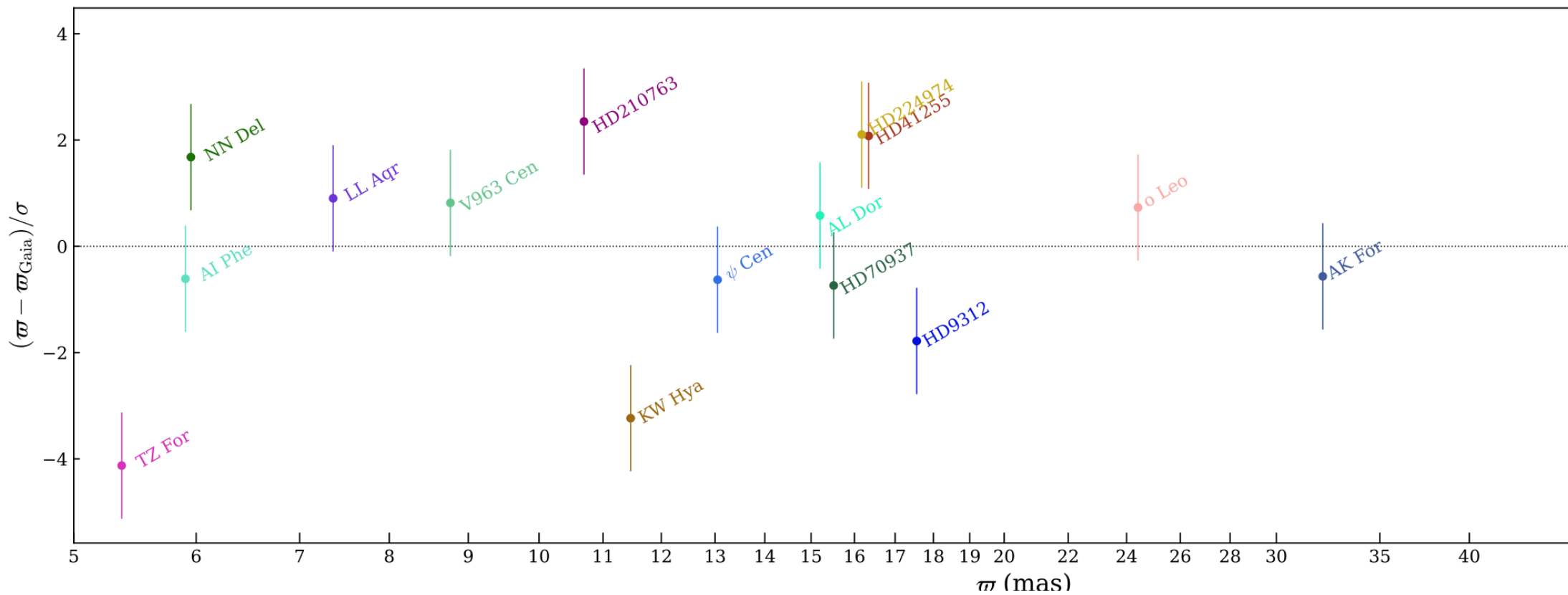
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☉ Introduction on interferometry

☉ Binaries

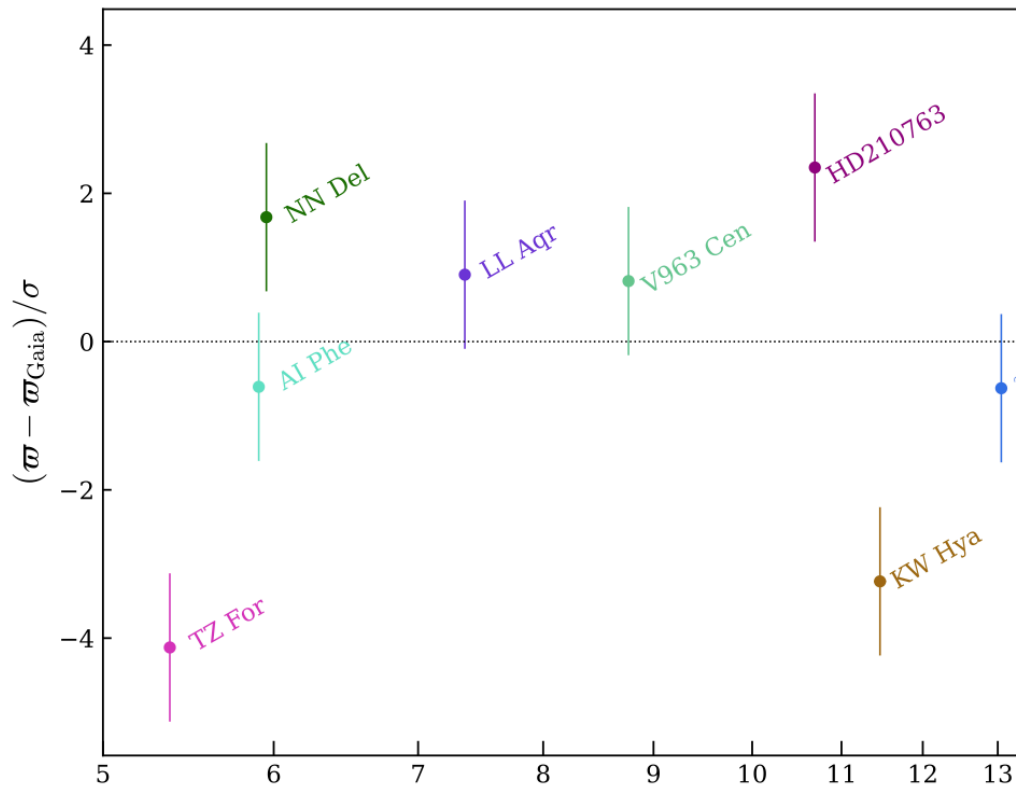
☉ Comparison with Gaia



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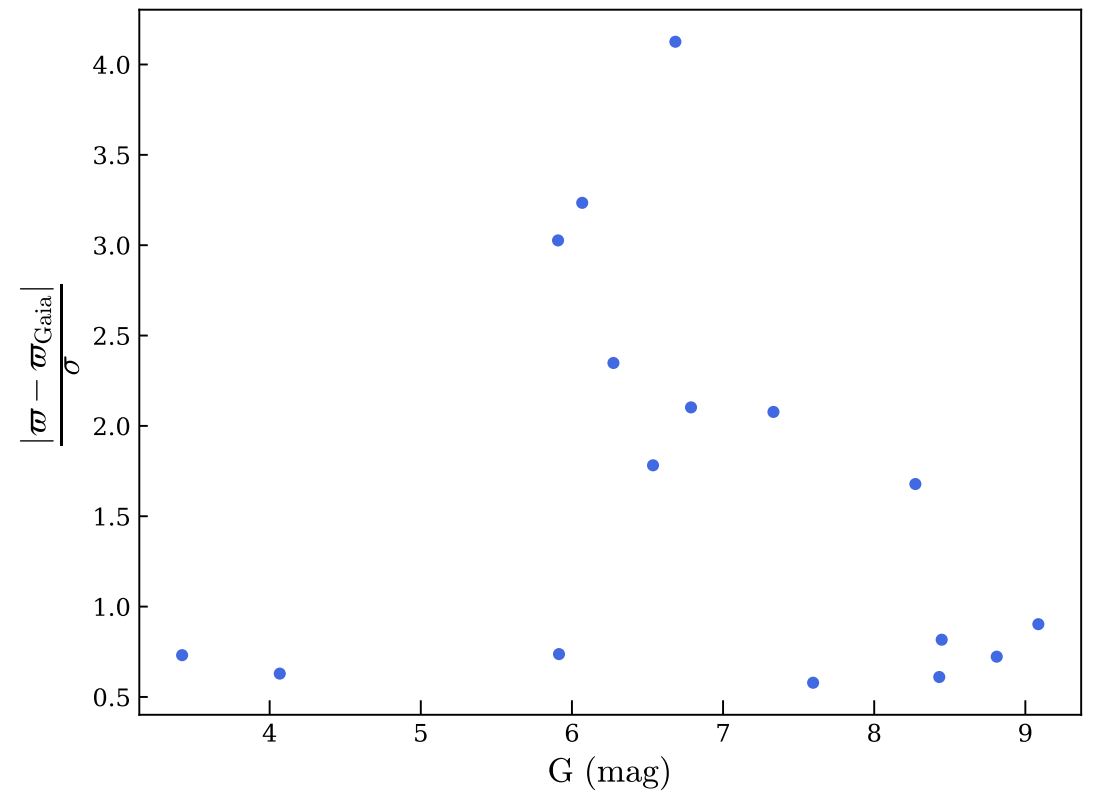
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☉ Binaries

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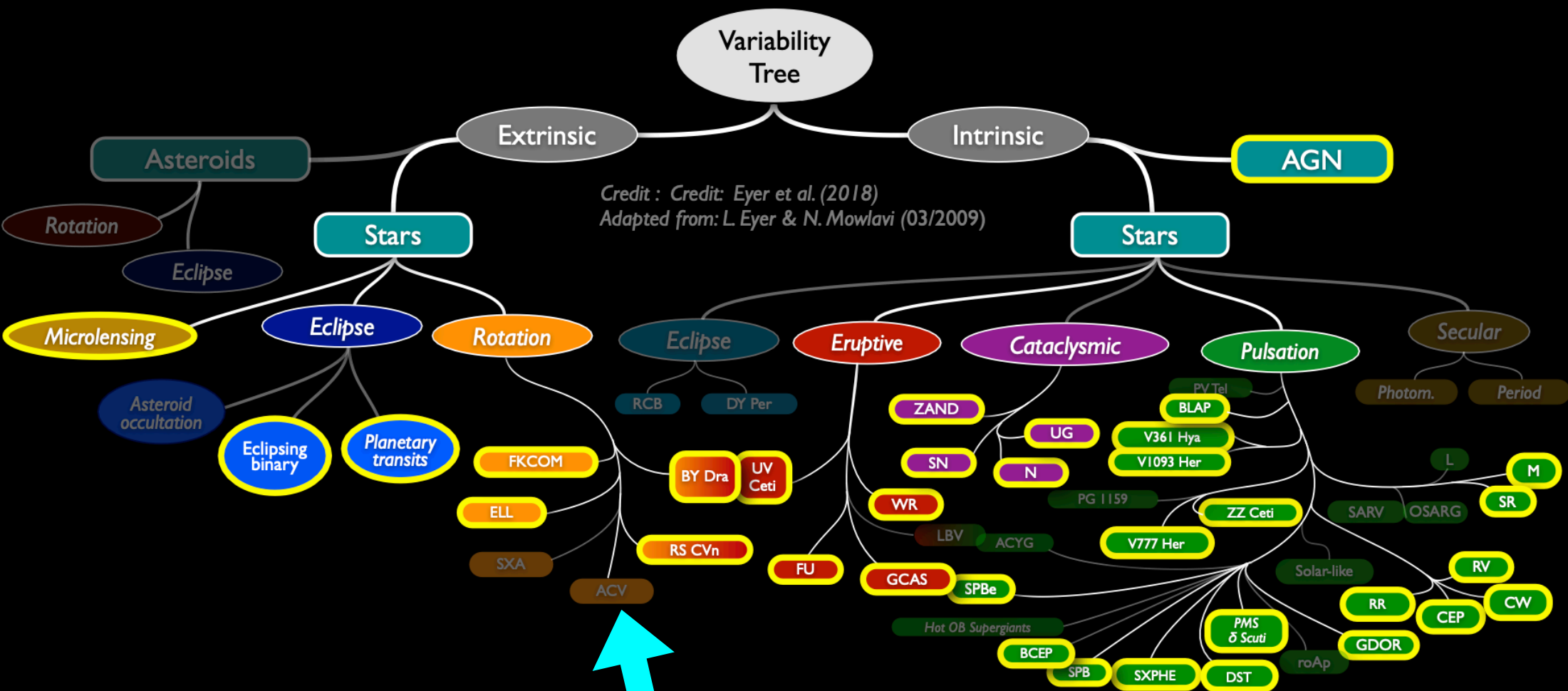
John Southworth, Laurent Mahy, Alexandre Gallen, Nicolas Lodieu, Judit Donada Oliu, Priya Shah

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Clusters

Binarity in clusters

Low-mass and sub-stellar eclipsing binaries in stellar clusters



**~10 million variable sources + 2.5 million galaxies\***

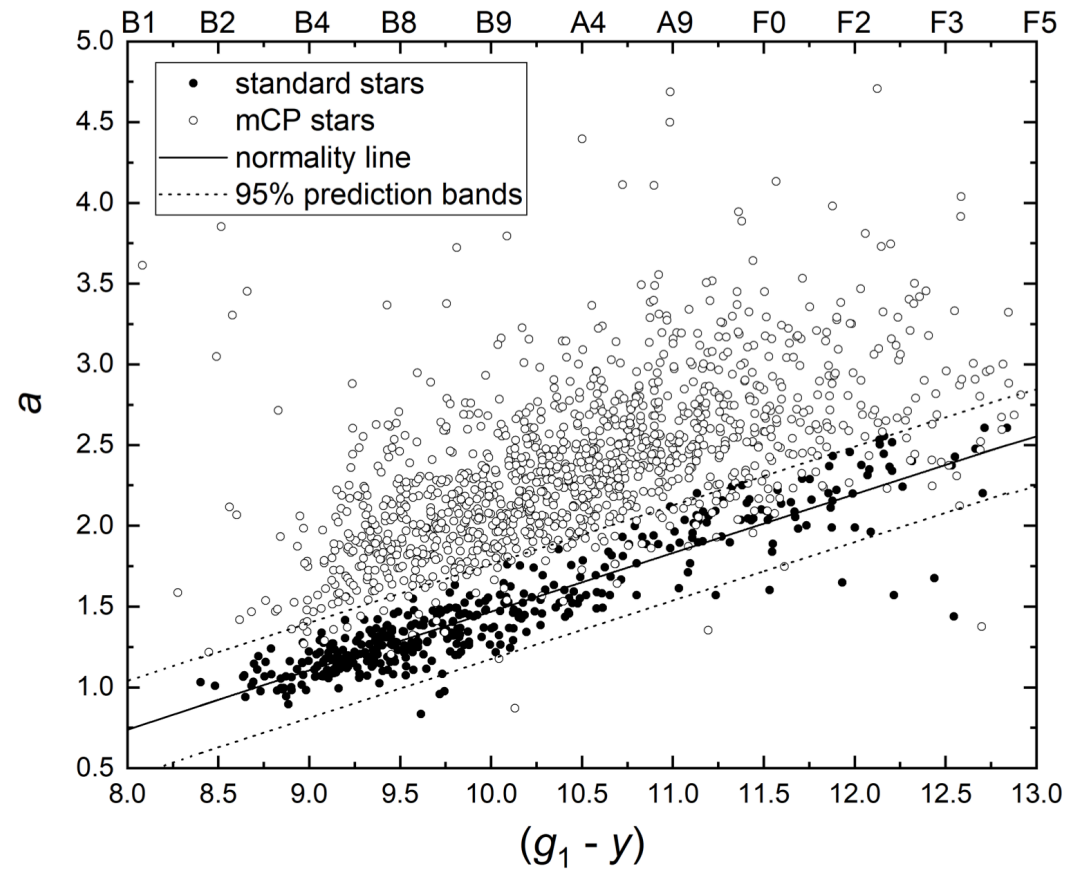
\* identified through their scan-angle dependent signals, see later

# Chemically peculiar stars

Ernst Paunzen, Natalia Posilek, Ewa Niemczura

Identification of CP stars

through photometric bands





# Chemically peculiar stars

Ernst Paunzen, **Natalia Posilek**, Ewa Niemczura

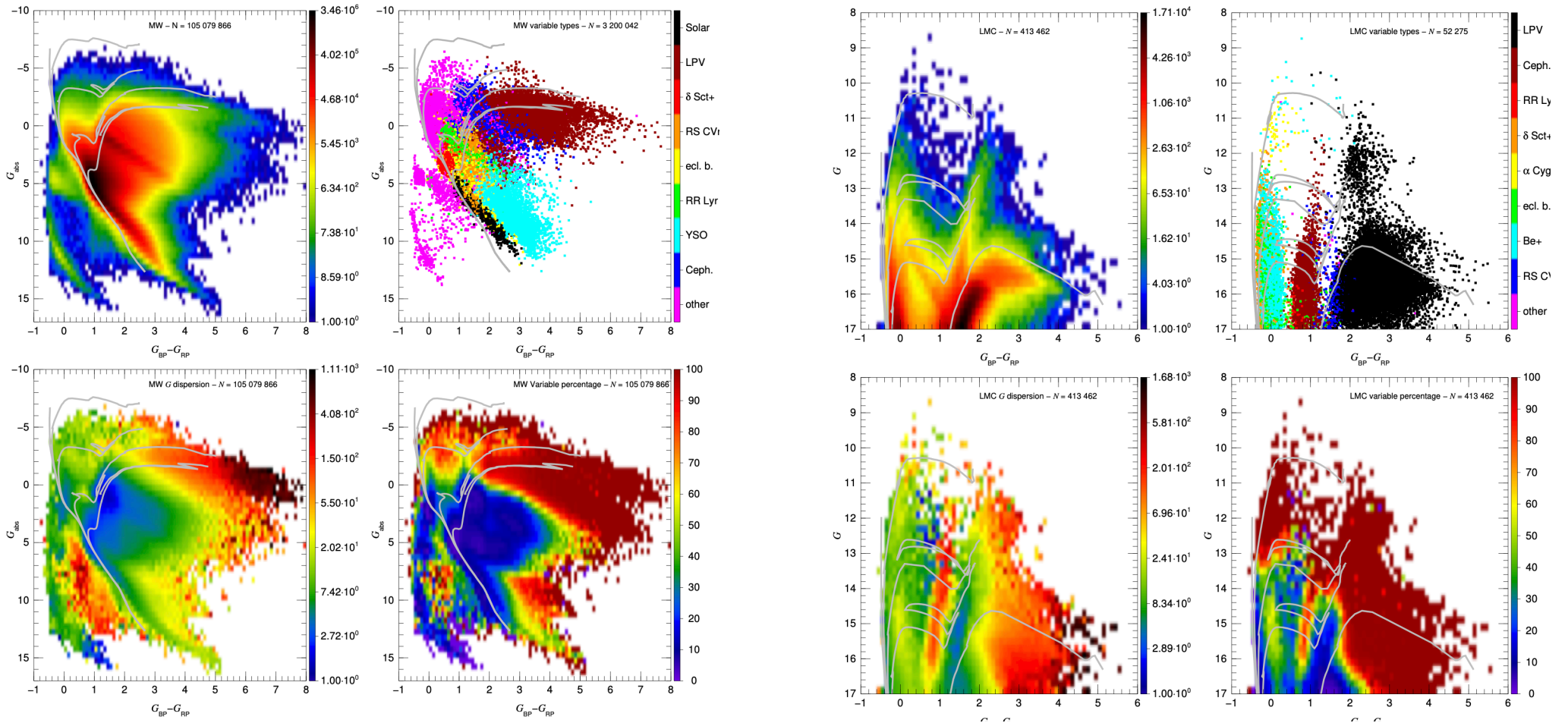
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Am stars

300 Am stars

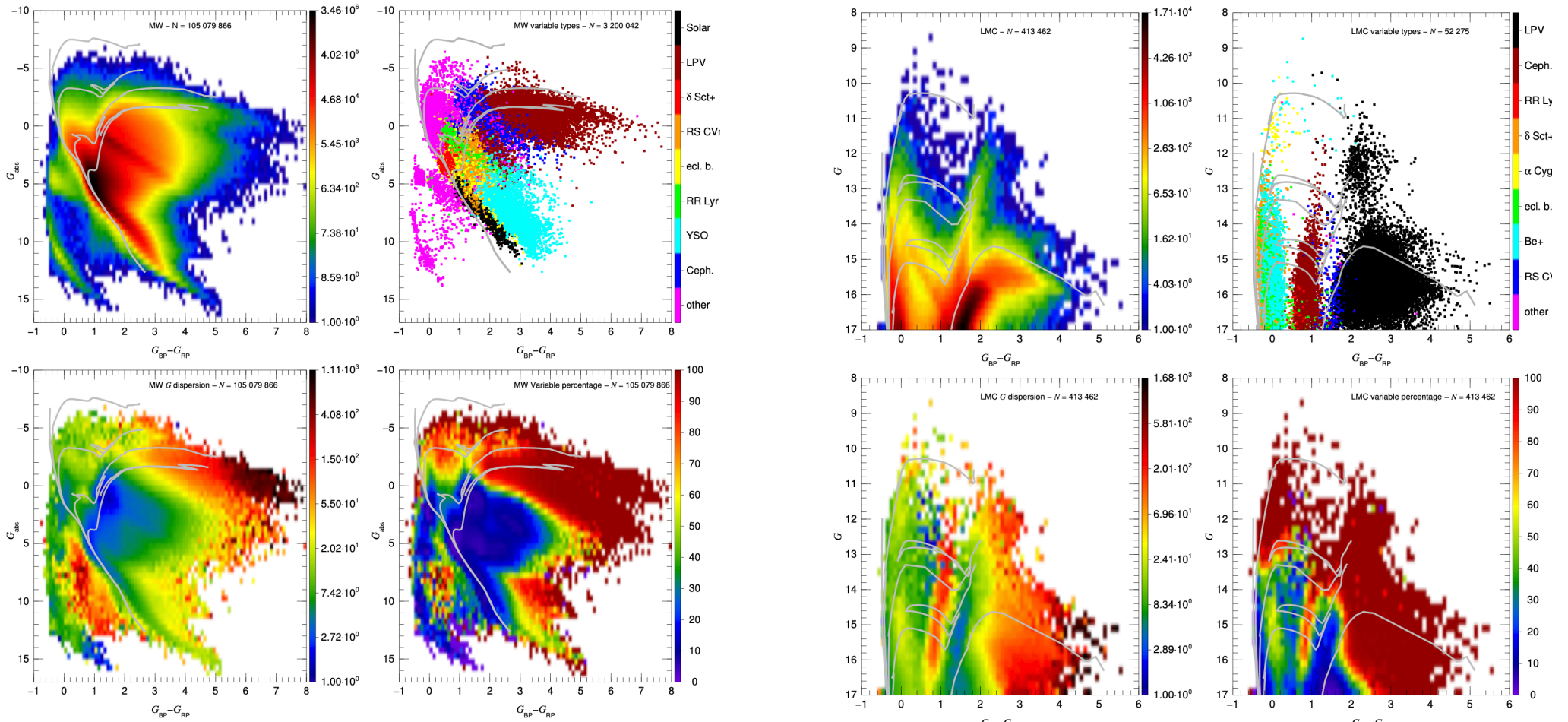
Surprise half of the sample not the Am stars

# General approach



# General approach

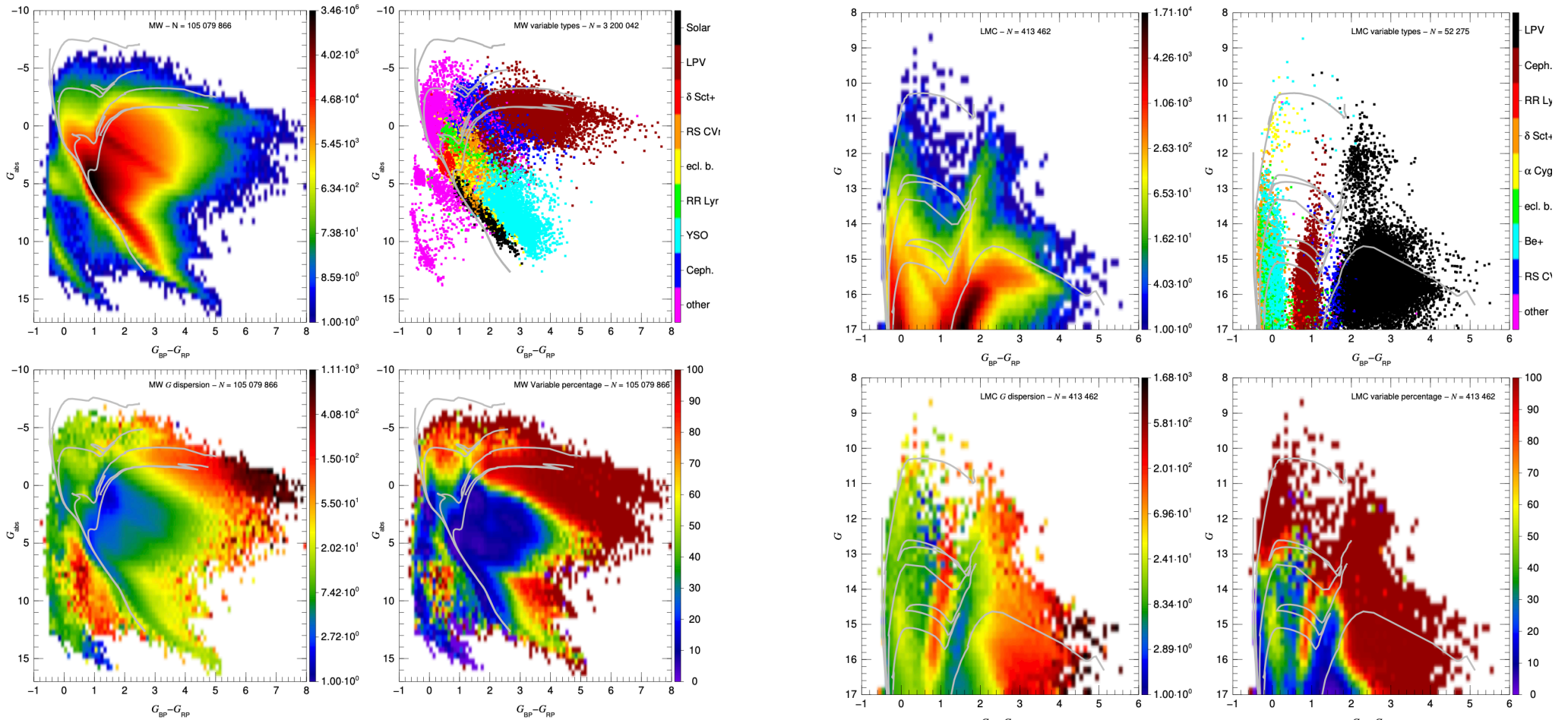
Maiz Appellaniz, Gonzalo Holgado, Ranaivomanana Tahina Princy, Szofia Nagy



# General approach

Maiz Appellaniz, Gonzalo Holgado, Ranaivomanana Tahina Princy, Szofia Nagy

Using excess variance built from the uncertainty on the mean from the Gaia catalogue



# General approach

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Early and late stages of  
evolution

# General approach

🌐 Maiz Appelaniz, Gonzalo Holgado, Ranaivomanana Tahina Princy, **Szofia Nagy**

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Early and late stages of  
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# General approach

☉ Maiz Appelaniz, Gonzalo Holgado, Ranaivomanana Tahina Princy, **Szofia Nagy**

---

Early and late stages of  
evolution

Gaia DR3

# General approach

Maiz Appelaniz, Gonzalo Holgado, Ranaivomanana Tahina Princy, Szofia Nagy

Early and late stages of evolution

Gaia DR3

The Gaia DR3 YSO catalogue

• DR3 YSO  
• KYSO

- Validating the variable YSO candidates (79 375) from *Gaia* DR3 (Eyer et al. 2023)
- Based on color, brightness, distance, apparent position on the sky
- Confirmation, that *Gaia* is more sensitive to more evolved YSOs

*Marton et al. (2023)*

- Around 40 000 sources are newly discovered YSOs
- Upper limit for contamination level: 26.7%

Introduction      Early stages      Late stages      Summary



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Science Alerts

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Early and late stages of evolution

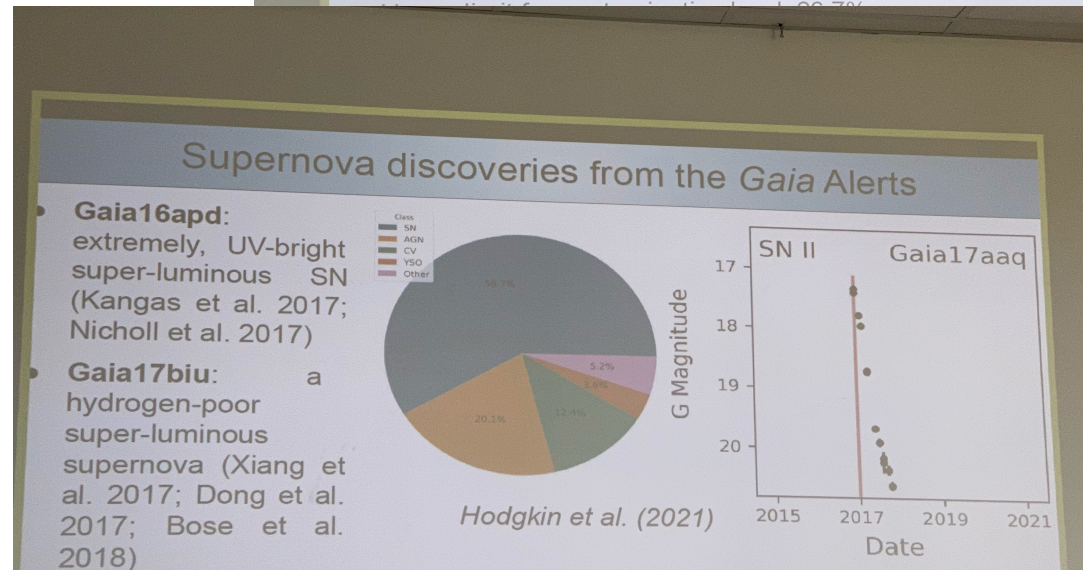
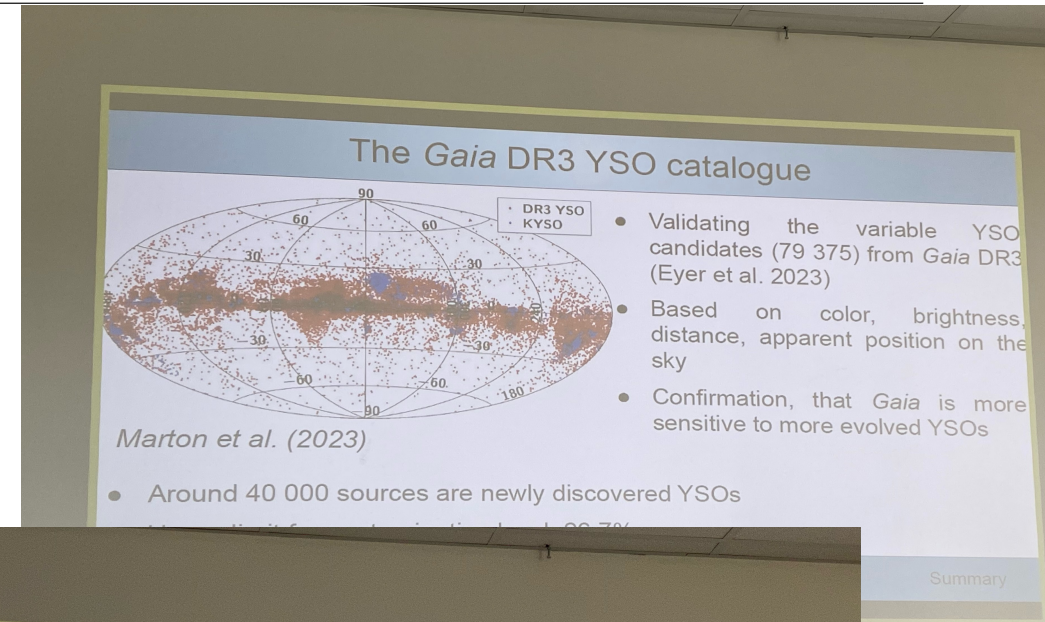
Gaia DR3

Science Alerts

FUors

EXors

Supernovae



## Data - infrastructure

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# Data - infrastructure

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# Data - infrastructure

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Rozhen Semkov



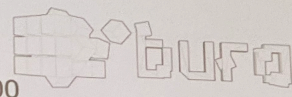


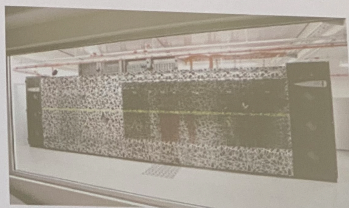
# Data (observatory - infrastructure)


**"Bura" supercomputer**


High performance computing facility → top 500


Rmax:	233.565 TFlop/s
Rpeak:	287.539 TFlop/s
Peak Power (kW):	108.48
Processor:	Xeon E5-2690v3 (12 cores @ 2.6 GHz)
Cores per Node:	24
Nodes:	288

 **cnrm**  
Center for Advanced Computing and Modelling



 **TOP 500** 440  
The List.

 **THE GREEN 500** 175

 **HPCG** 48

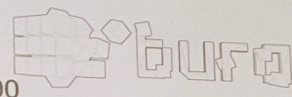
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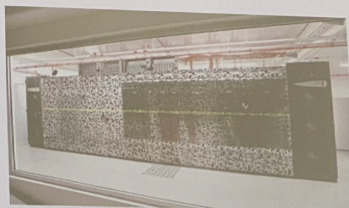
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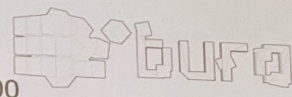
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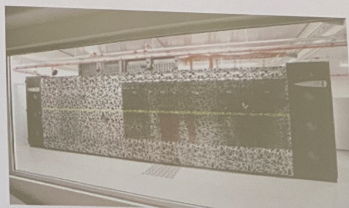
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Evgeni Semkov, Tomislav Juric

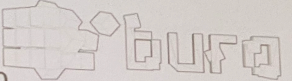
## Supercomputer Bura


LSST

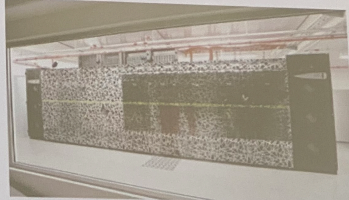
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# Data

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# Data

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# Other surveys


### Gaia DR3 compared to OGLE

	 gaia	OGLE
Number of observed stars	~1.8 billion	~2 billion
Sky coverage	All sky	Galactic bulge and disk, Magellanic Clouds
Total number of photometric measurements	367 billion	1.2 trillion
Time span	~3 years	~10 years (OGLE-IV) ~30 years (OGLE-I – OGLE-III)
Photometric passbands	$G, G_{BP}, G_{RP}$	$V, I$ (Johnson-Cousins system)
Limiting magnitudes	8 – 21 ( $G$ )	12 – 21 ( $I$ )
Median numbers of photometric measurements per star	$G$ : 44 $G_{BP}$ : 40 $G_{RP}$ : 41	$I$ : 500 – 700 $V$ : 50 – 100
Number of variable stars	9 976 881	1 088 111 (+)
Classification methods	Automatic	Automatic + Visual inspection

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Igor Soszyński, Zeljko Ivezic, Lovro Palaversa, Ashish Mahabal

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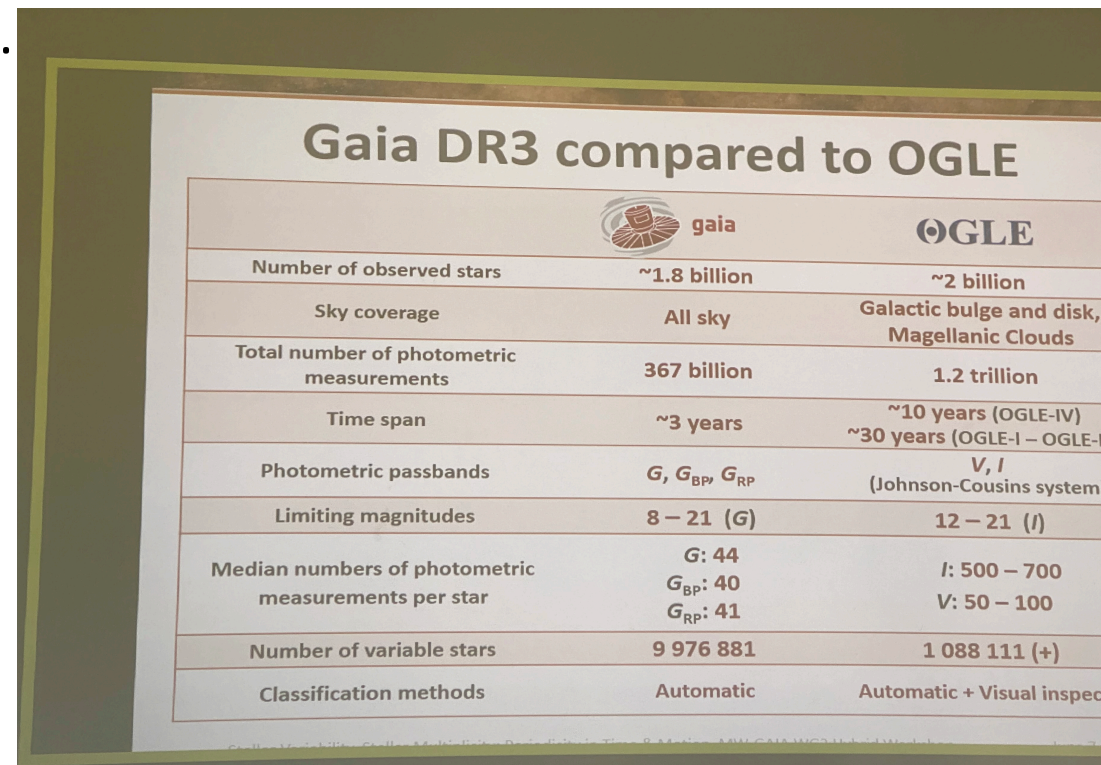
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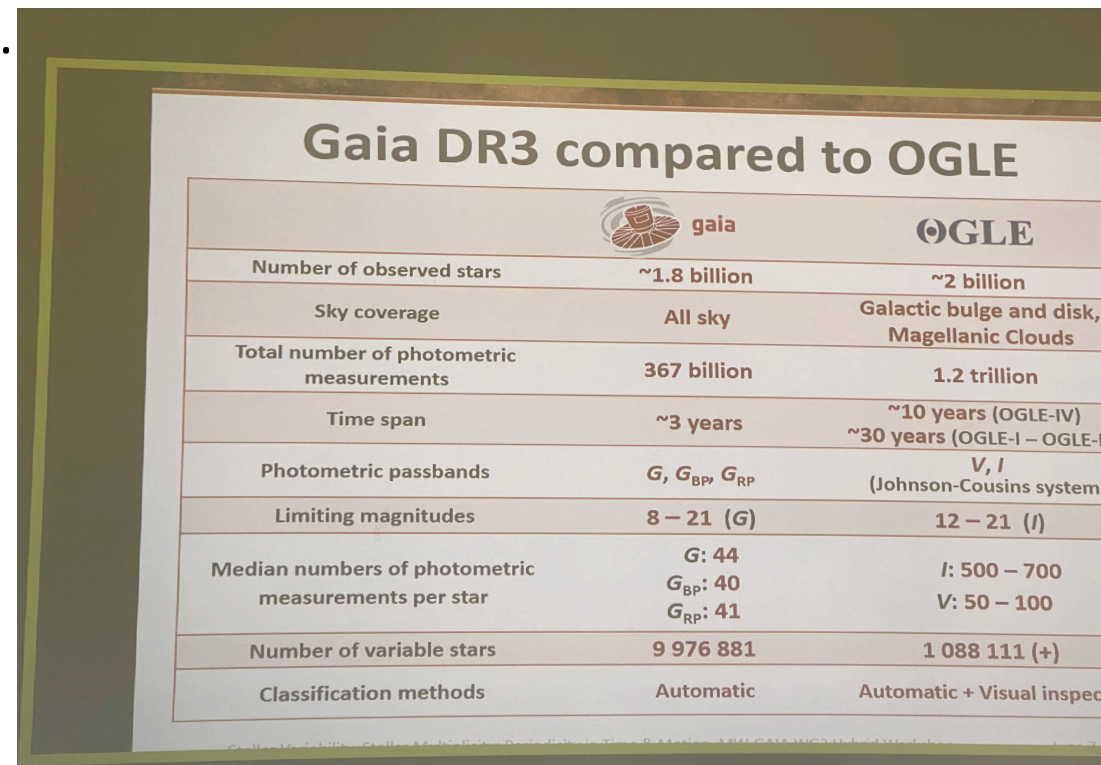
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Your presentation will be very useful for Gaia



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LSST



## Other surveys

🌐 Igor Soszyński, Zeljko Ivezic, Lovro Palaversa, Ashish Mahabal

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LSST

20 billion stars

## Other surveys

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LSST

20 billion stars

20 billion galaxies

## Other surveys

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### LSST

20 billion stars

20 billion galaxies

u, g, r, i, z, y

## Other surveys

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### LSST

20 billion stars

20 billion galaxies

u, g, r, i, z, y

10 years, 1000 times

## Other surveys

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### LSST

20 billion stars

20 billion galaxies

u, g, r, i, z, y

10 years, 1000 times

100 petabytes

## Other surveys

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### LSST

20 billion stars

20 billion galaxies

u, g, r, i, z, y

10 years, 1000 times

100 petabytes

Data release 6 months: 2026

## Other surveys

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## Other surveys

🌐 Igor Soszyński, Zeljko Ivezic, Lovro Palaversa, Ashish Mahabal

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## Other surveys

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Generating LSST synthetic photometry from XP Spectra

## Other surveys

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Generating LSST synthetic photometry from XP Spectra

Good example of synergies between Gaia and LSST

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gaiaxy:

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gaiadr3.synthetic:photometry:gspc

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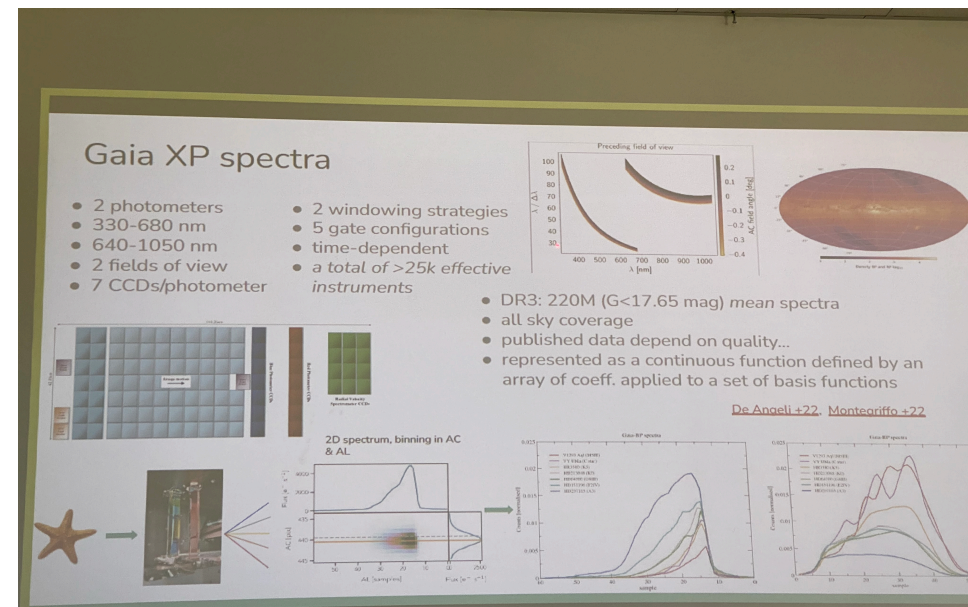
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## Other surveys

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## Other surveys

🌐 Igor Soszyński, Zeljko Ivezic, Lovro Palaversa, Ashish Mahabal

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Many surveys

## Other surveys

🌐 Igor Soszyński, Zeljko Ivezic, Lovro Palaversa, Ashish Mahabal

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CSS/CRTS long from 2005

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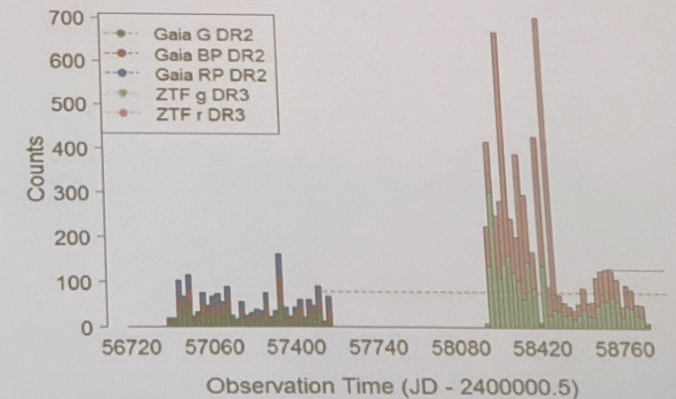
### ZTF - Gaia synergy

From Eyer

Gaia DR2  
DR3 ZTF

With Gaia DR3 close to start  
of ZTF (2018), and with ZTF  
DR17, far ahead in time

In a way, ZTF is look-ahead  
for unreleased Gaia data!



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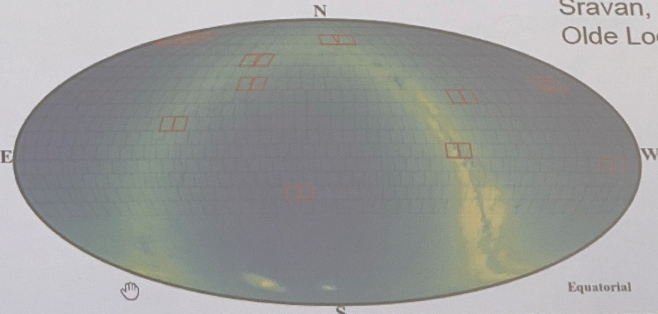
Using the data of several surveys

### Source Classification Project (SCoPe)



- Software/labeling set up based on DR2
- 20 Fields paper (Van Roestel, Duev, Mahabal ++)
- Periods paper (Coughlin, Burdge, Duev ++)

- 34M+ objects
- Features
  - variability characteristics
  - dmdt
  - period searches
  - external data



Van Roestel, Duev, Coughlin, Mahabal, Mr. Hillenbrand, Drake, Grah, Sravan, Szk, Olde Loohu

Van Roestel, Duev, Mahabal et al. 2020

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ZARTH - Pokemon GO  
coming soon

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 **Thanks**

🌐 **Thanks**

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🌐 **to the SOC**

🌐 **TO ALL THE SPEAKERS**