# Resolved Stellar Populations: Gaia – Variable Stars

## MA2 @ OAS BOLOGNA
## 17-18 DECEMBER 2018
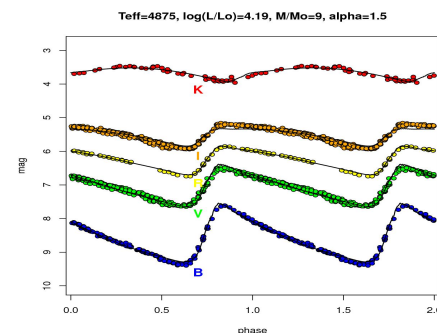
gaia

Teff=4875, log(L/Lo)=4.19, M/Mo=9, alpha=1.5

K
I
V
B

mag

phase

ISTITUTO NAZIONALE DI ASTROFISICA
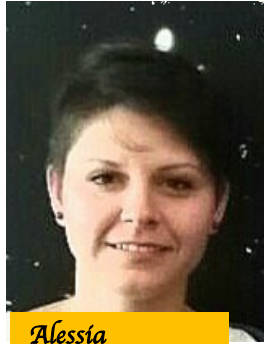OSSERVATORIO DI ASTROFISICA E SCIENZA DELLO SPAZIO DI BOLOGNA
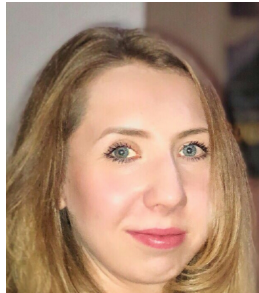
INAF

# Who is who in …

## … Gaia &
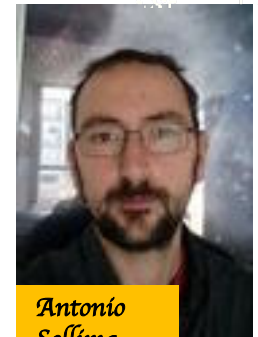## Variable Stars
## @ OAS



Gisella Clementini

Alessia Garofalo (PhD)

Tatiana Muraveva (PostDoc)

Felice Cusano (TD)

Giuliana Fiorentino
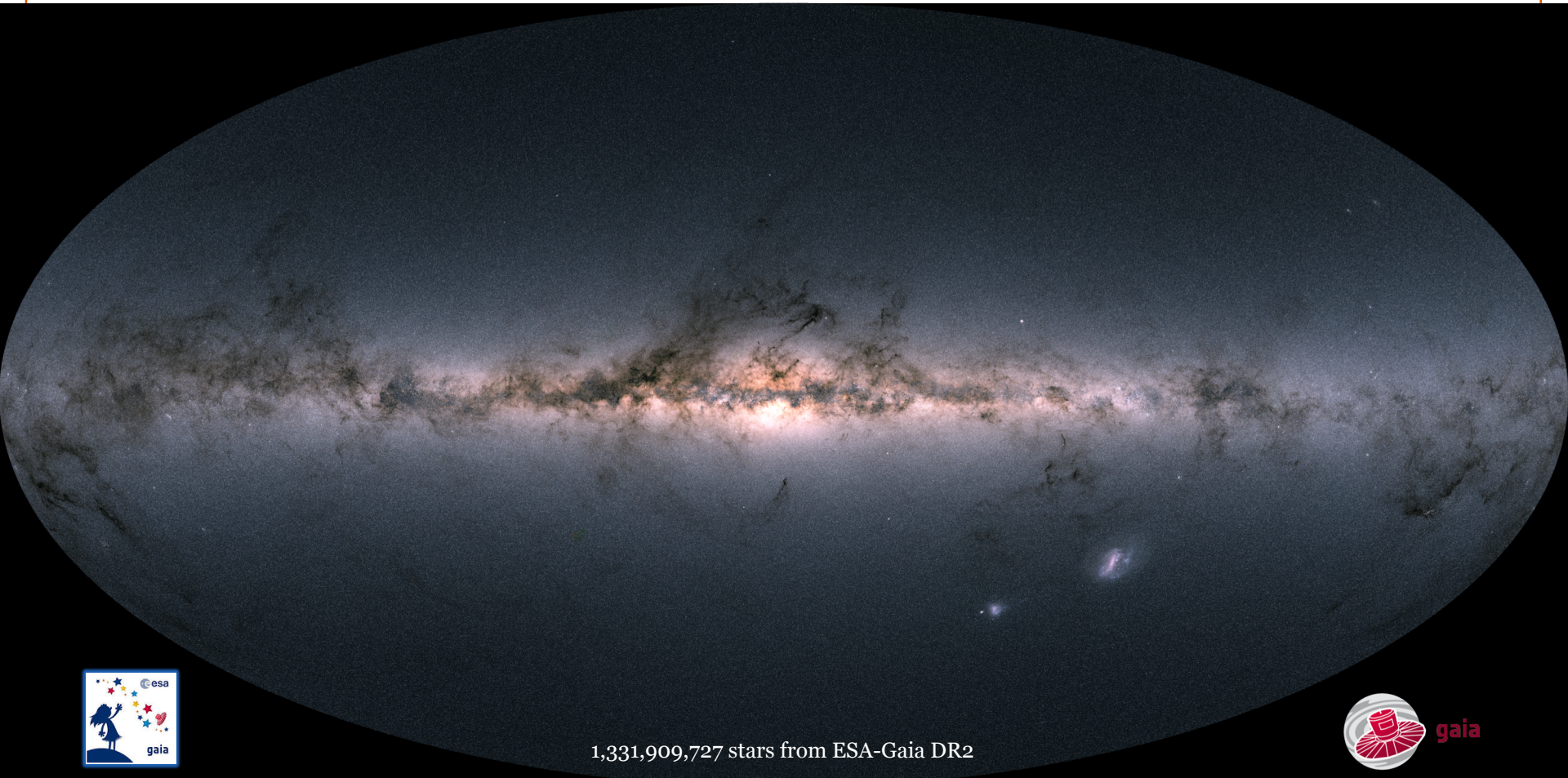
Antonio Sollima

Paolo Montegriffo

Carla Cacciari (ret.)

Michele Bellazzini

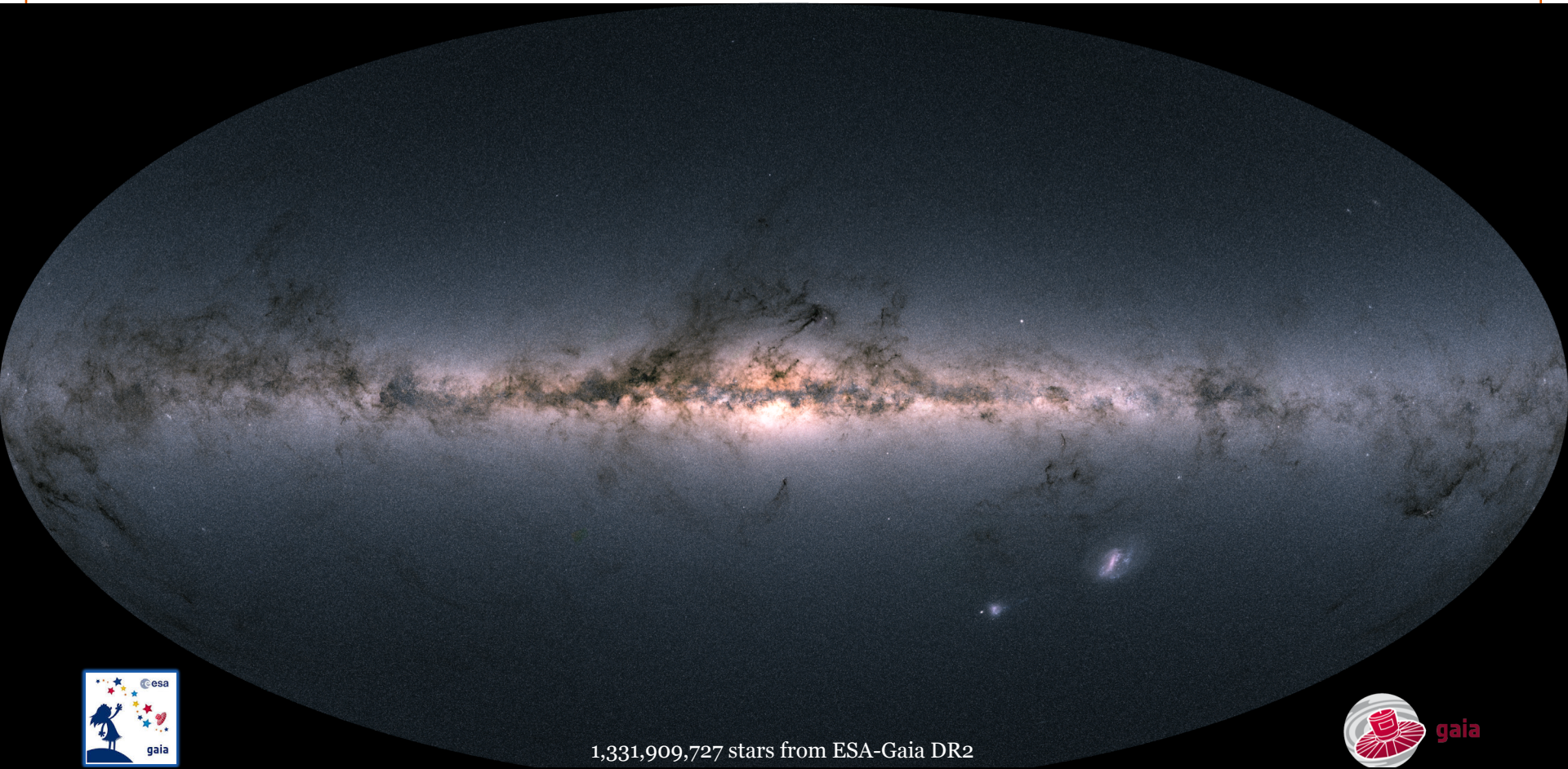Angela Bragaglia

gaia

# Gaia



1,331,909,727 stars from ESA-Gaia DR2

# Gaia



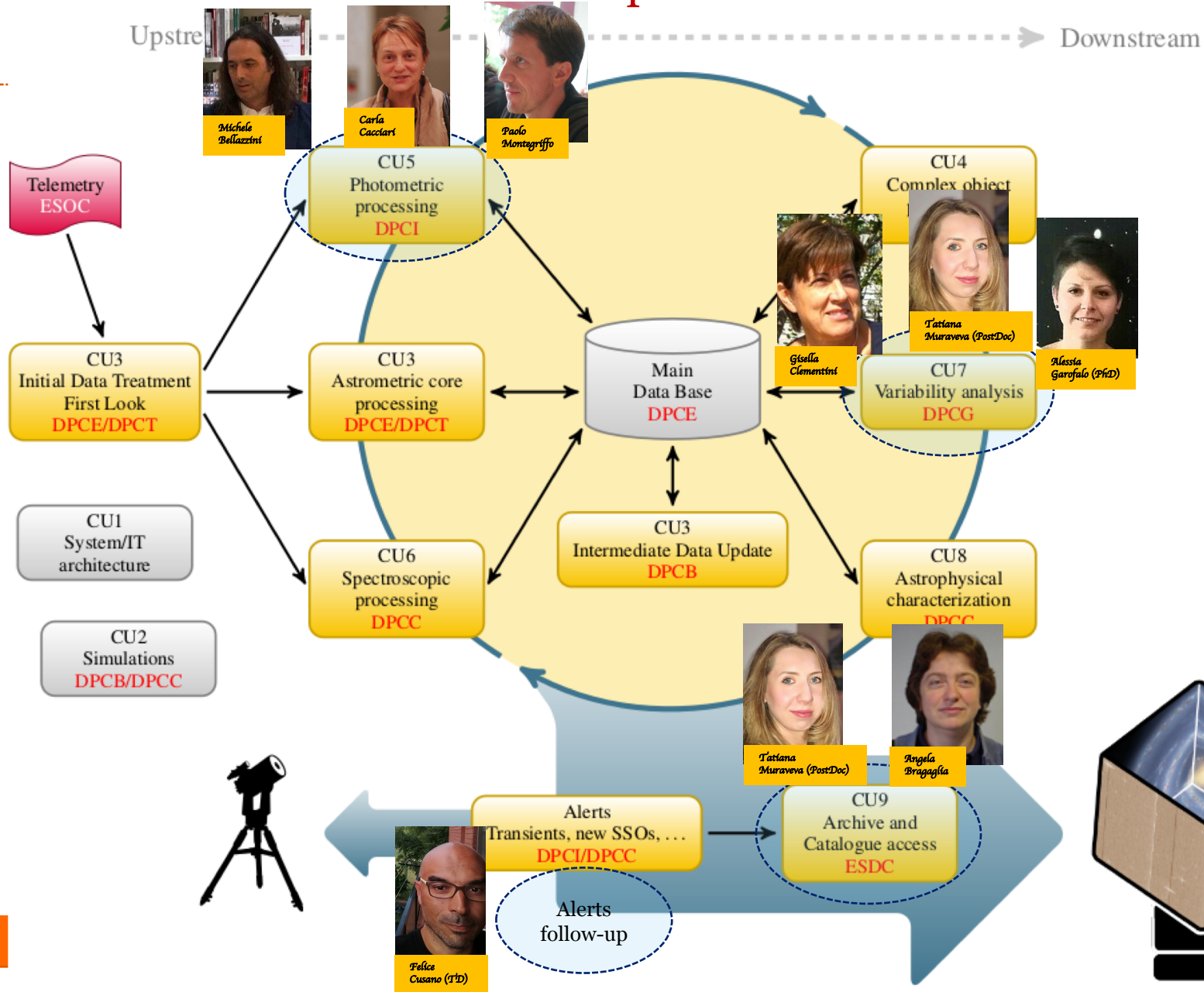1,331,909,727 stars from ESA-Gaia DR2

*M. Bellazzini, A. Bragaglia, C. Cacciari, G. Clementini, F. Cusano, A. Garofalo, P. Montegriffo, T. Muraveva*

Resolved Stellar Populations: **Gaia** - Variable Stars

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OAS Days 17-18 Dec 2018

# OAS - contribution to Gaia Data Processing: CU5 – CU7 – CU9, follow-up of Gaia alerts

# Gaia SPSS survey

Aim: to create a reference catalogue of ~200 spectro-photometric standard stars (SPSS) whose flux is measured to 1-3% accuracy, to calibrate Gaia spectrophotometric observations

The survey in numbers:

➢ 5064 hours observing time
  (967 nights – 66 runs – 10 years since 2007)
➢ 7 different telescopes/instruments
➢ 3272 calibration frames
➢ 53340 pre-reduced frames
➢ 6444 extracted spectra
➢ 173 SPSS monitored (found 8 variables)
  ~ 9 ≤ V ≤ ~ 15 across the sky, all spectral types, from WDs to late types
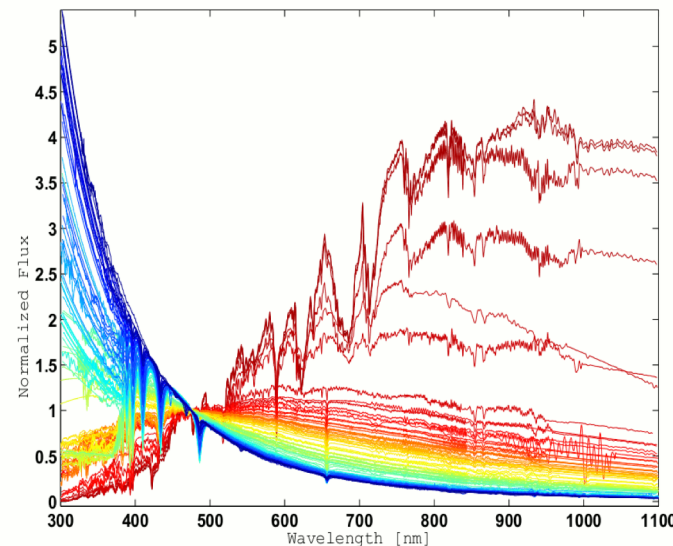


V1 internal release: 94 SPSS

*E. Pancino*, *G. Altavilla*, **M. Bellazzini**, *A. Bragaglia*, **C. Cacciari**, *G. Cocozza, L. Federici, S. Galleti, S.Marinoni, S. Ragaiani*
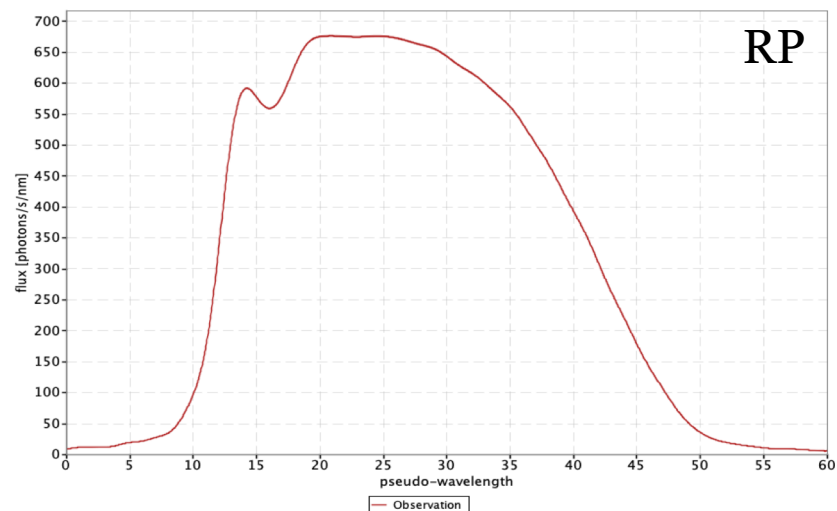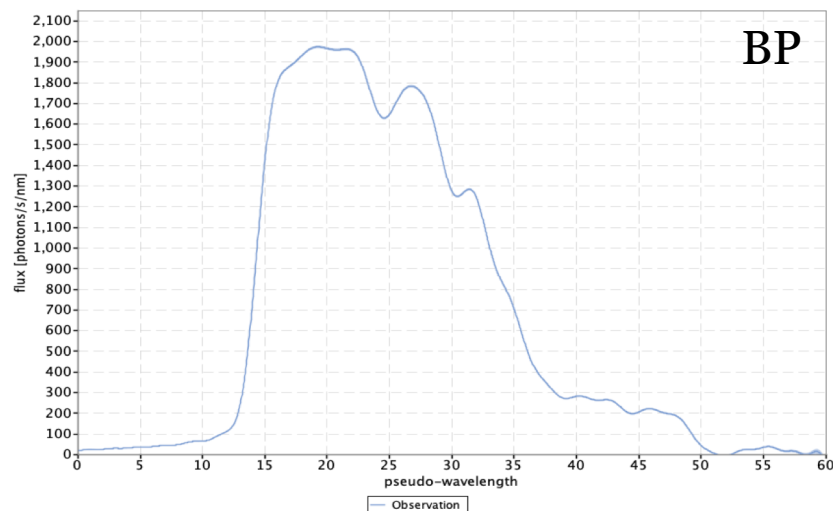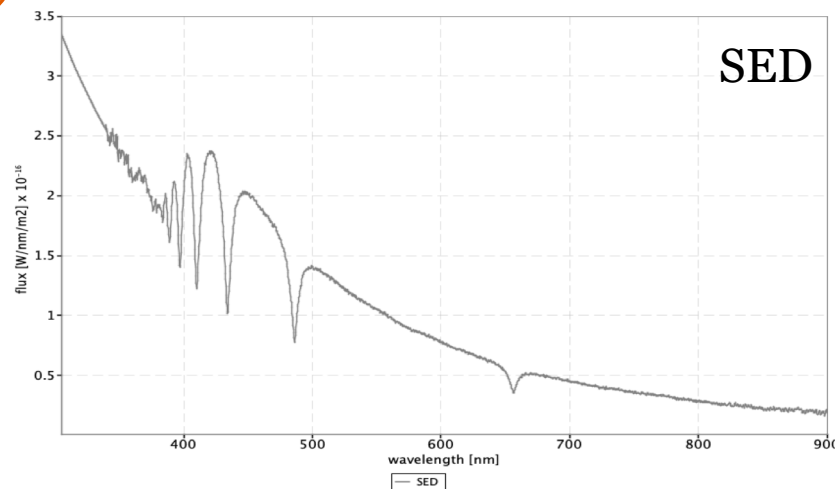
# Gaia: external calibration

## CU5  Photometric Processing

Provide an **instrument model** to allow for physical interpretation of internally calibrated mean observations

*M. Bellazzini, C. Cacciari, P. Montegriffo, S. Ragaini*

*Problem: relate Gaia spectra with source SED obtained from independent observations or stellar models*
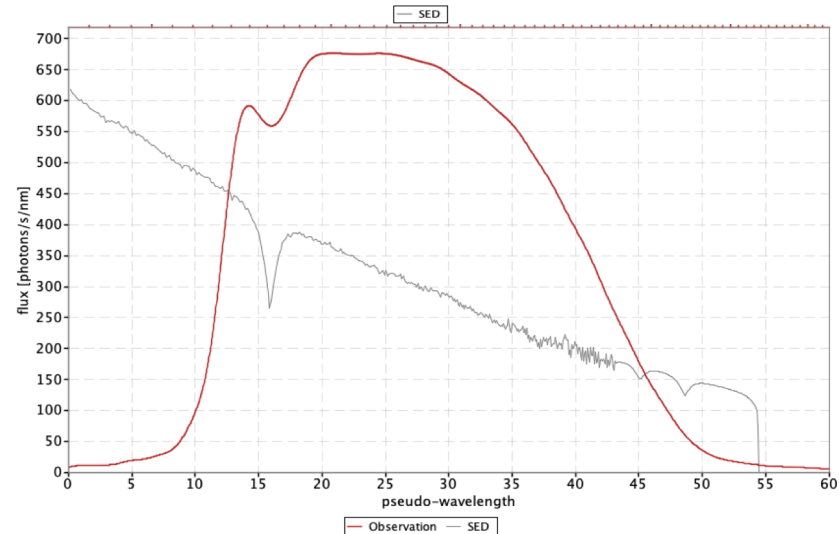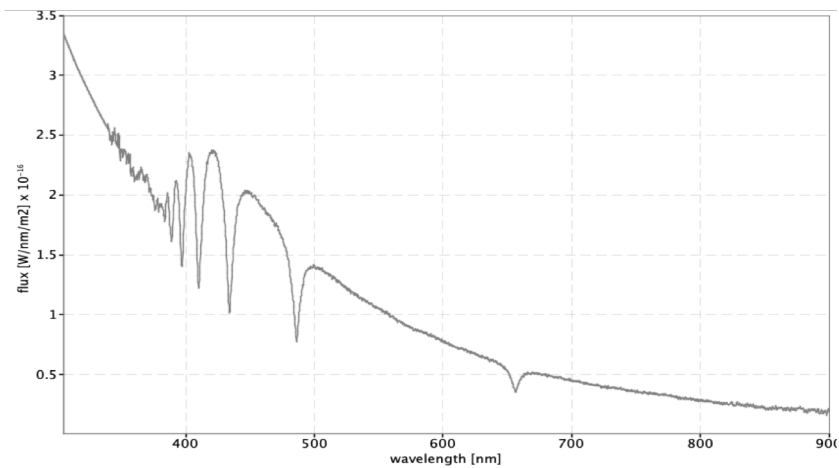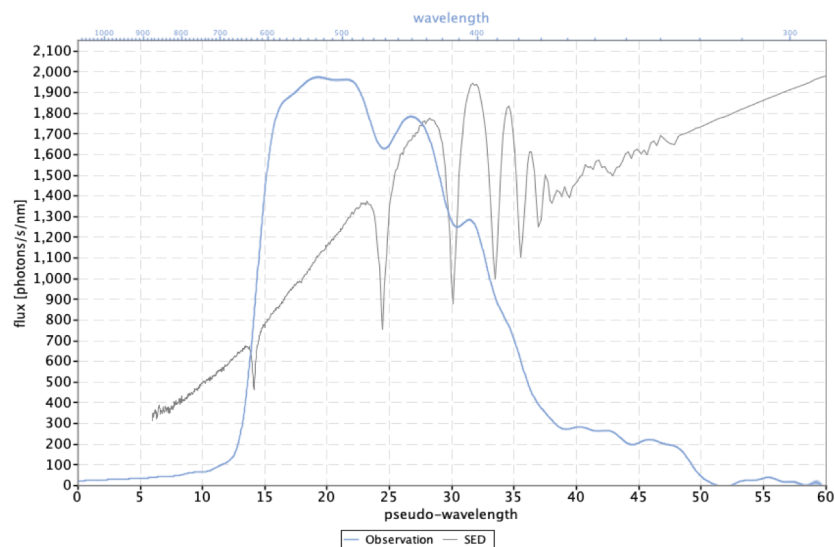


SED



BP



RP

# Gaia: external calibration

1 : The dispersion relation is needed to link samples to wavelengths

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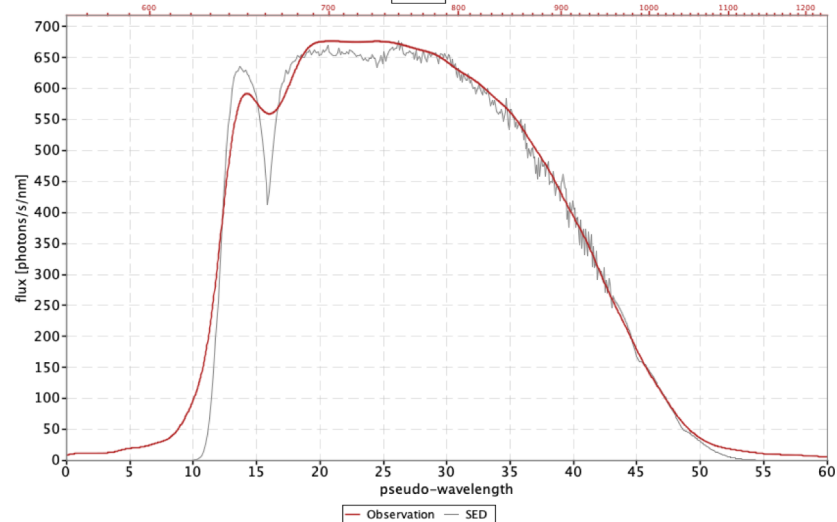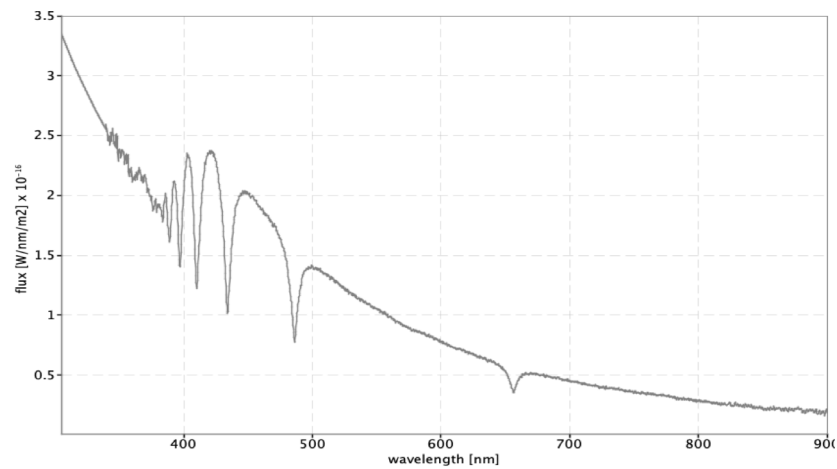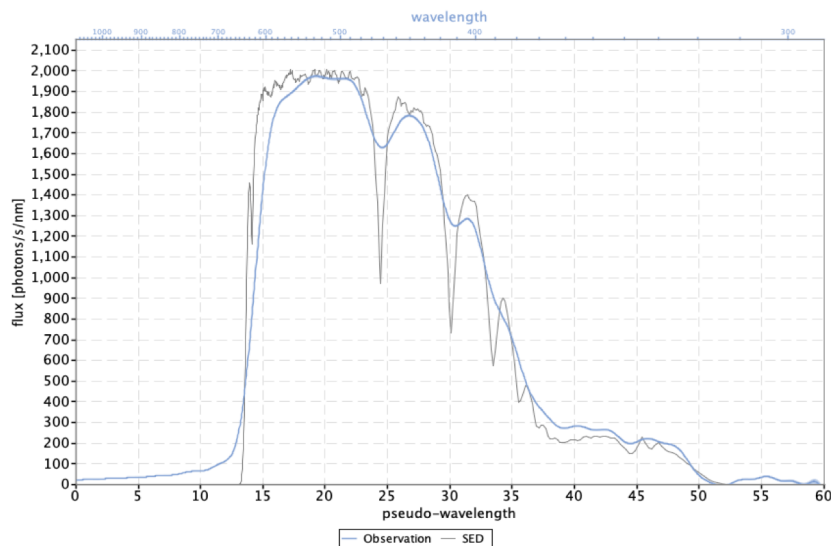# Gaia: external calibration

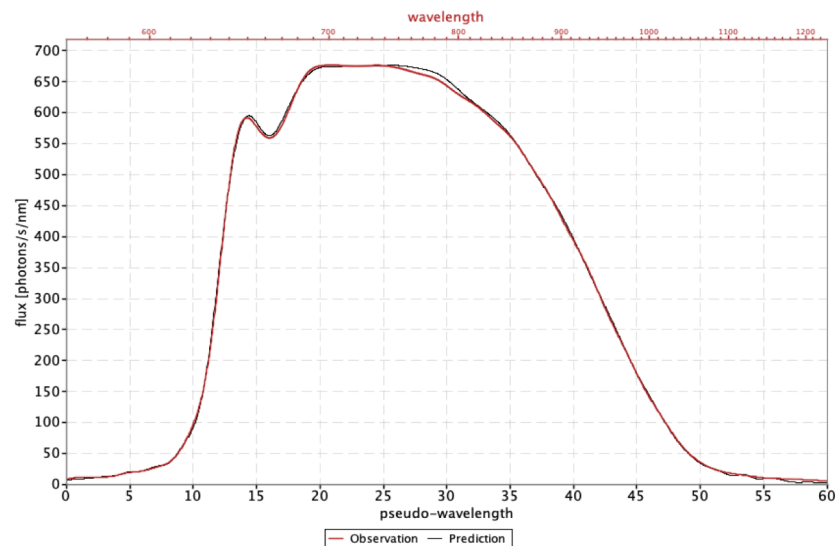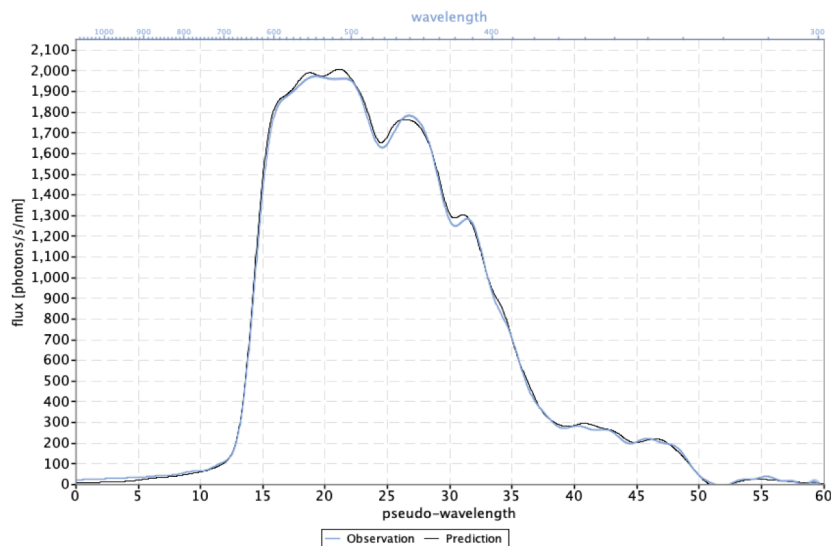2 : The instrument overall response is needed to rescale the flux levels to observed values

# Gaia: external calibration

3 : Finally the LSF model is needed to model the photon smearing effect

- The instrument model is a linear operator that transform SEDs to their counterparts in the Gaia observational plane

- This forward model approach is used by CU8 to provide Gaia astrophysical parameters

- A tool will be provided to DR3 users to allow for this kind of modelling

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# Gaia: external calibration

Provide a method (and tools) to allow for conversion from mean BP/RP spectra to spectra energy distributions in absolute units.

*Two examples: on left columns the mean BP/RP spectra; on the right ones the reconstructed SEDs compared against the true one.*
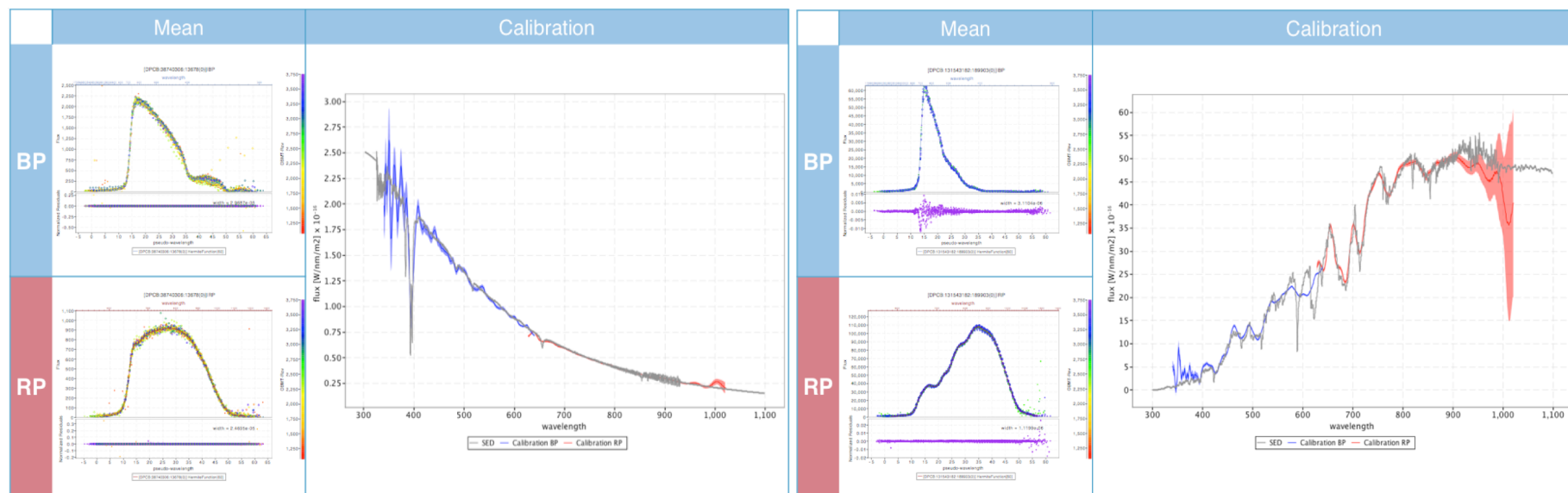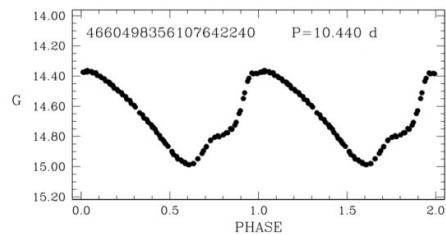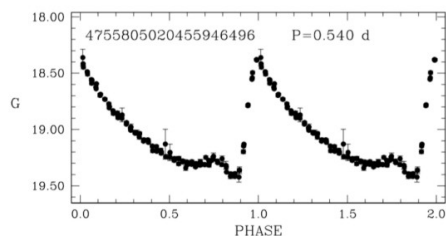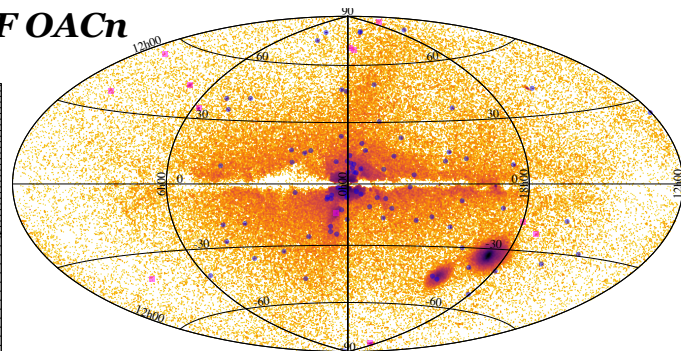
# Gaia: variable stars

Processing, validation and characterization of Cepheids and RR Lyrae stars observed by Gaia

*G. Clementini, A. Garofalo, T. Muraveva + colleagues at INAF OACn*



**Gaia DR1:** G-band light curves for 3194 RR Lyrae & Cepheids in the LMC

Clementini et al. 2016

~223,000 RRLs, ~50,000 new discoveries by Gaia

~8,900 Cepheids, ~350 new discoveries by Gaia

**Gaia DR2: 140,784 RR Lyrae & 8,900 Cepheids, multiband light curves, all-sky maps**

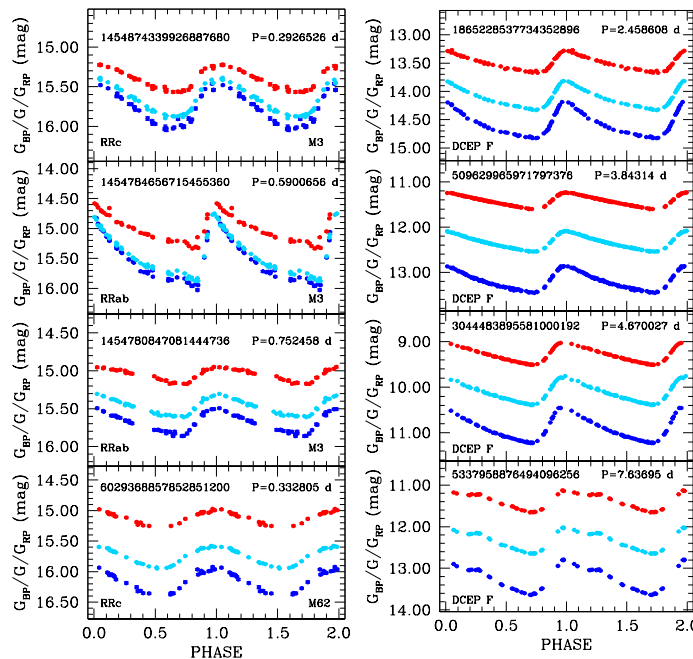Clementini et al. 2018b

# Gaia: variable stars

Processing, validation and characterization of Cepheids and RR Lyrae stars observed by Gaia

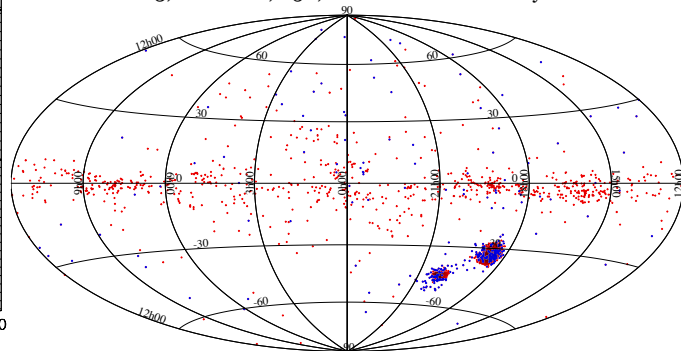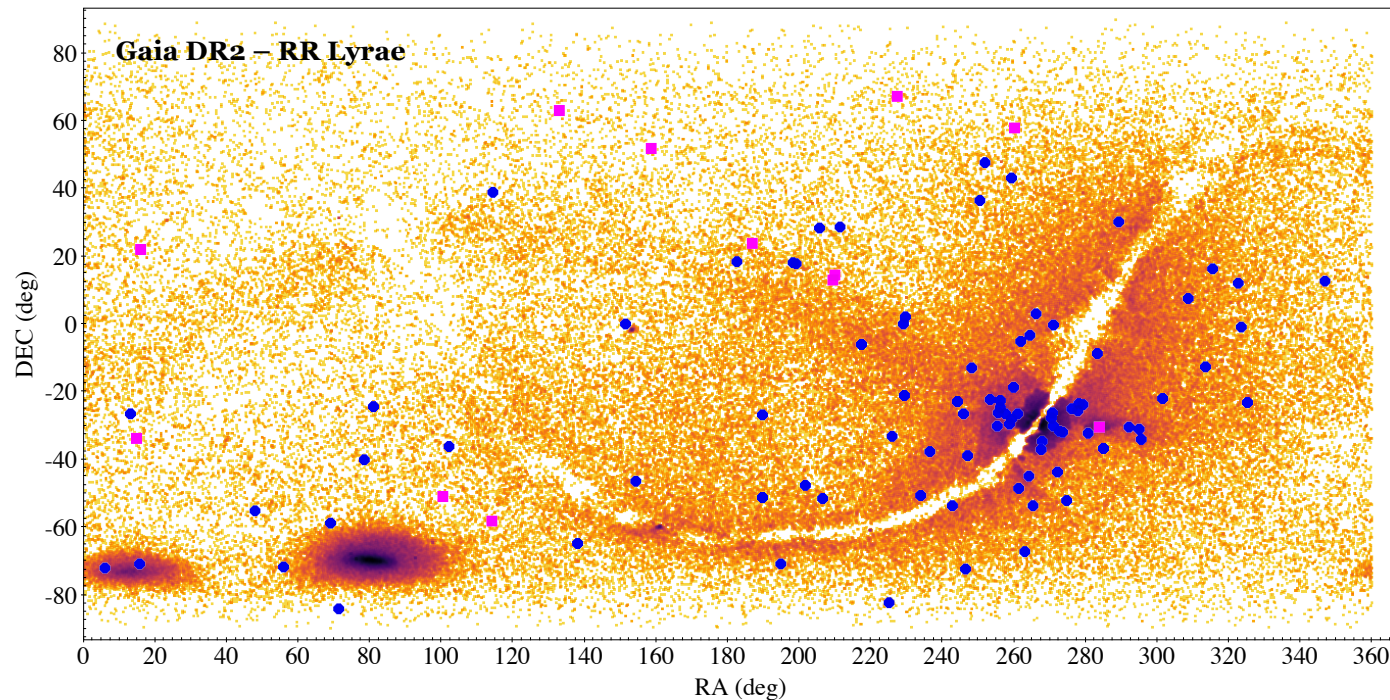*G. Clementini, A. Garofalo, T. Muraveva + colleagues at INAF OACn*



**Gaia DR2 – RR Lyrae**

~223,000 RRLs, ~50,000 new discoveries by Gaia

Clementini et al. 2018b

# Gaia: Catalogue validations

CU9  Archive & Catalogue Access

**Validation of Open Clusters observed by Gaia**

*Angela Bragaglia*    *(see Angela's talk)*

**Validation of results & data products for variable stars of all types observed by Gaia**
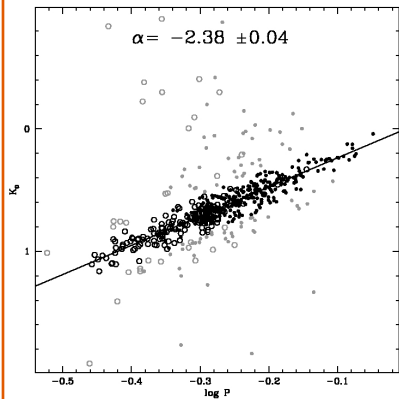
*Tatiana Muraveva*

# Gaia Science  Alerts

**Follow-up of Gaia Science Alerts with the 152 and 60 cm telescopes in Loiano**
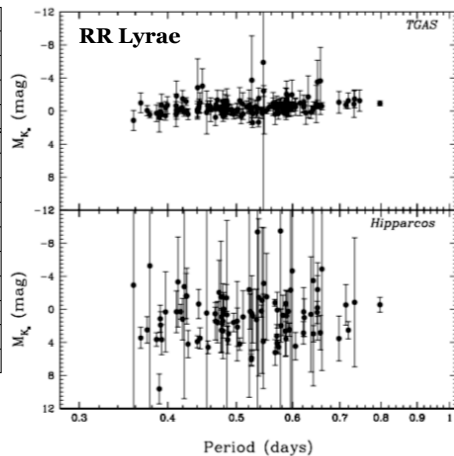
*Felice Cusano, Giuseppe Altavilla*

# Variable stars as standard candles
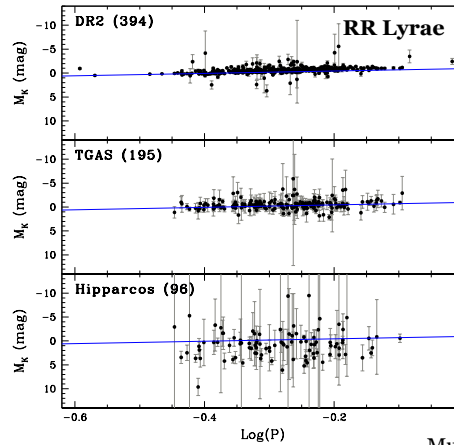
**RR Lyrae PL$_K$ relation**

Hipparcos vs TGAS ............ vs Gaia DR2



Sollima et al. 2006



Gaia Collaboration, Clementini et al. 2017



**Gaia DR2 – RR Lyrae**

PL$_K$Z relation

Muraveva et al. 2018c

**RR Lyrae M$_V$-[Fe/H] relation**



$V_0 = 0.214([Fe/H]+1.5)+19.064$
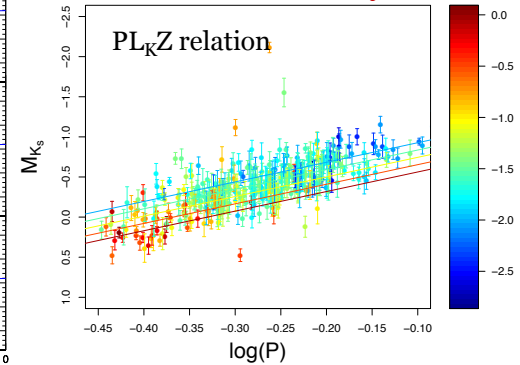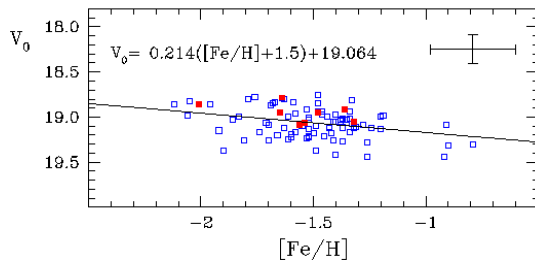
Gratton et al. 2004,
Clementini et al. 2003

**Gaia DR2 – RR Lyrae**

M$_V$-[Fe/H] relation
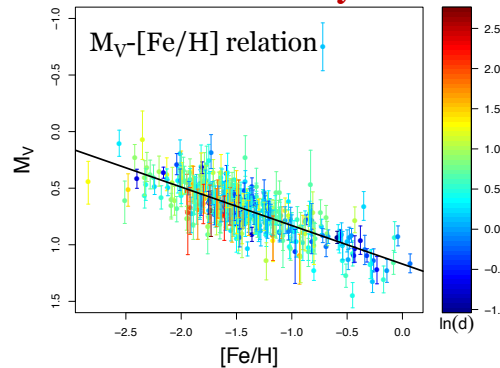
Muraveva et al. 2018c

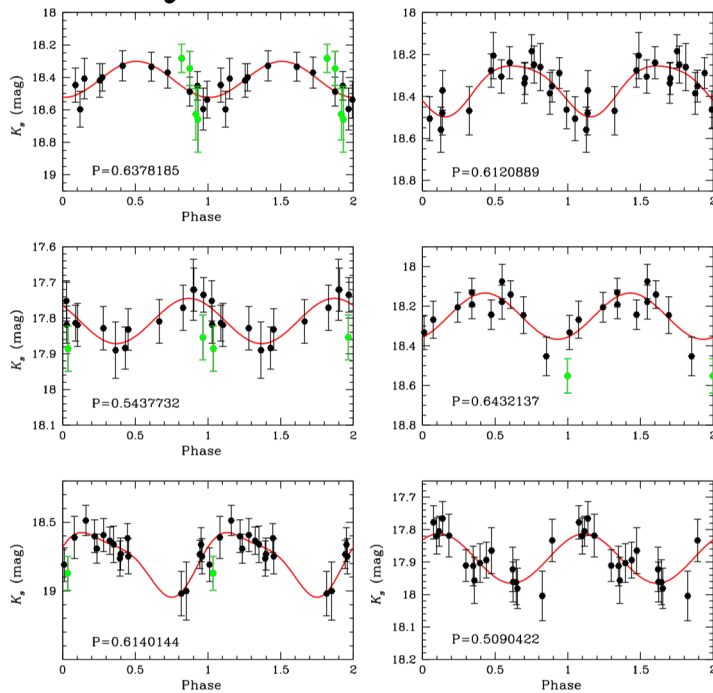**Cepheids PL$_K$ relation**
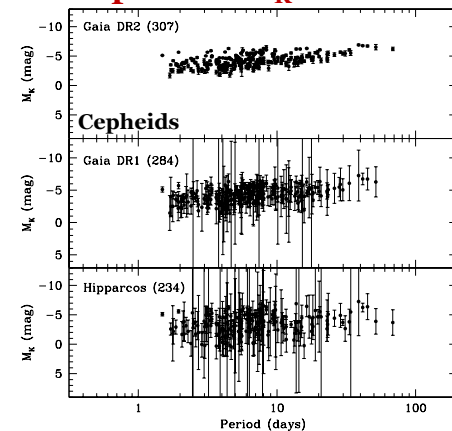


Clementini et al. 2018a

# RR Lyrae stars as standard candles

PI M.-R. Cioni

**G. Clementini, F. Cusano, T. Muraveva**

## RR Lyrae stars in the SMC



Muraveva et al. 2018a

ISTITUTO NAZIONALE DI ASTROFISICA
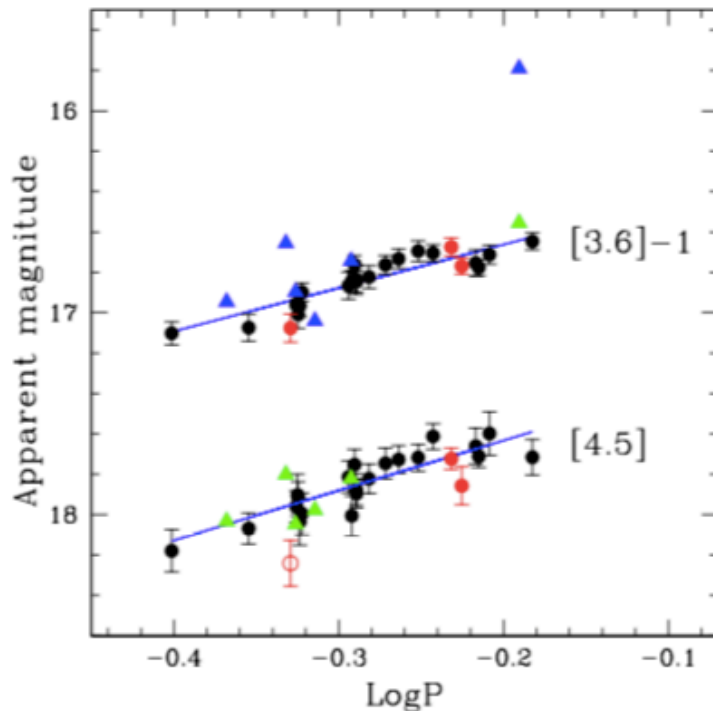OSSERVATORIO DI ASTROFISICA E SCIENZA DELLO SPAZIO DI BOLOGNA
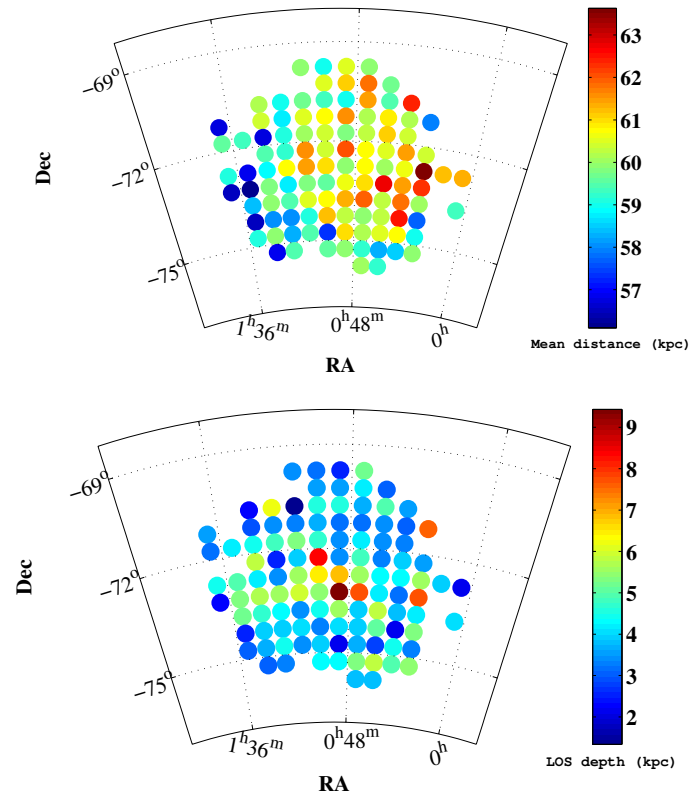
# RR Lyrae stars as standard candles

**CRRP@Spitzer** PI W. Freedman, 779h - **SMHASH@Spitzer** PI K. Johnston, 664h
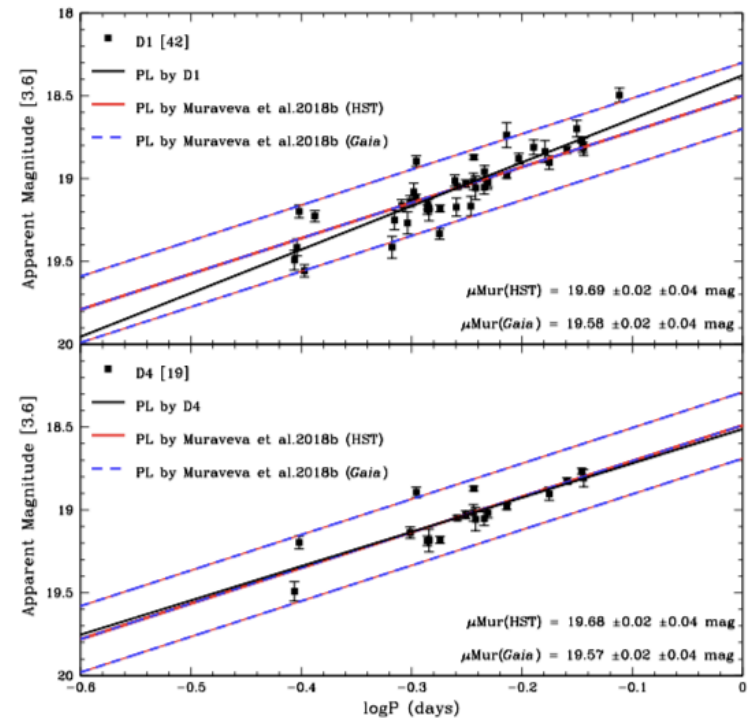
**G. Clementini, A. Garofalo, T. Muraveva**

## RR Lyrae stars in Reticulum Mid-IR PL relations



Muravera et al. 2018b

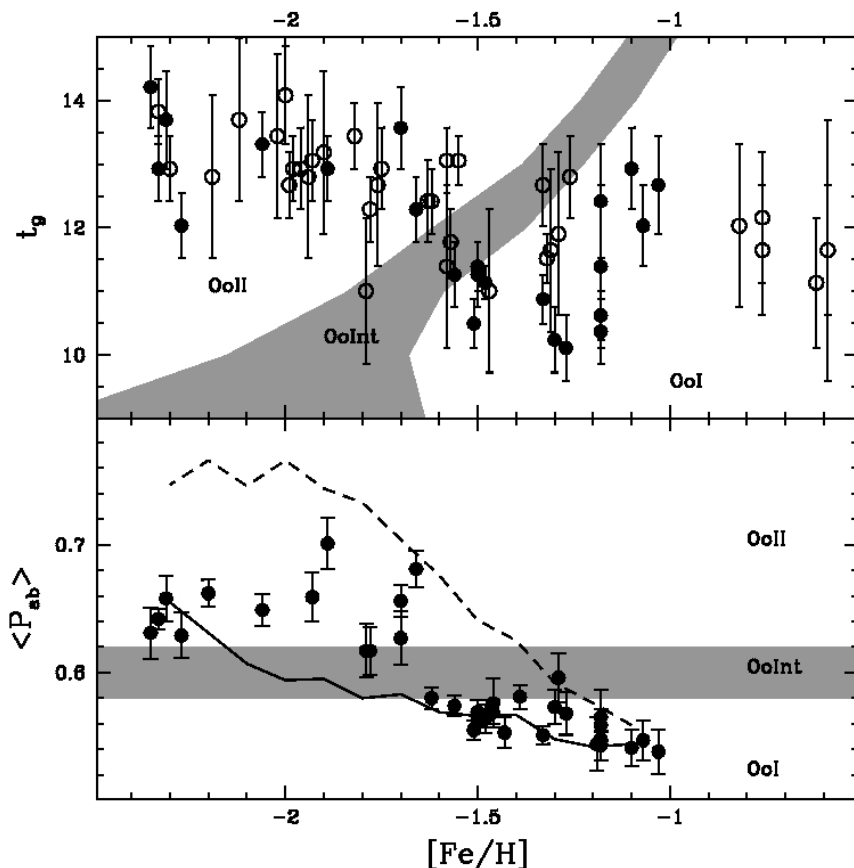## RR Lyrae stars in Sculptor Mid-IR PL relations



Garofalo et al. 2018

# Galactic archealogy with RR Lyrae stars: Oosterhoff dichotomy

Synthetic models of stellar populations + non-linear pulsational models to simulate the period distribution of RR Lyrae in 19 GGCs



The locus of GCs with mean periods within the Oostheroff gap corresponds to a region in the age-metallicity plane devoid of clusters

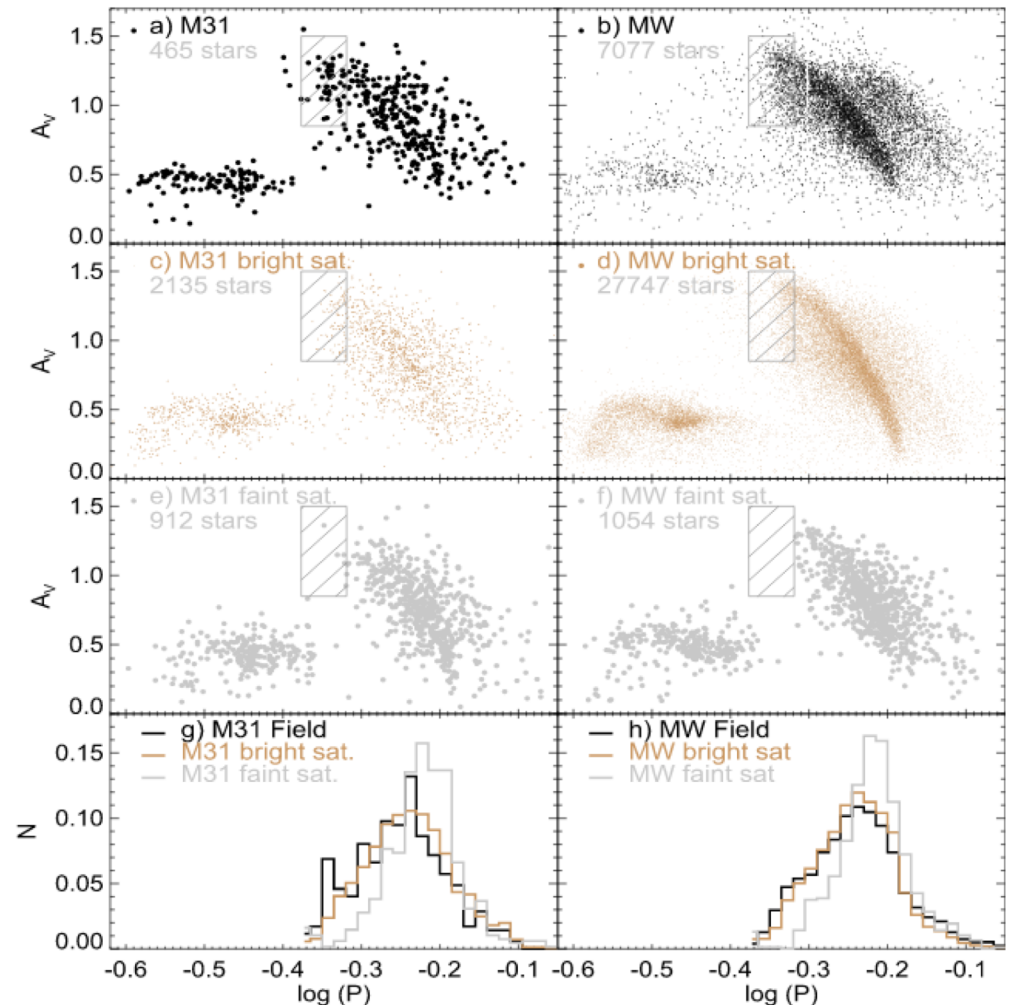The Oostheroff dichotomy seems to be strictly linked to the hierarchical assembly of the halo

*Sollima et al. (2014)*

# Connection Halos and dwarfs

RR Lyrae pulsation properties can tell us about the size of halo building blocks:

**"Big bricks (Sgr dSph or LMC-like) are favored in building up the Galactic Halo" The same happens in M31.**

Giuliana Fiorentino

Andromeda/M31



Monelli, Fiorentino et al. 2017

Resolved Stellar Populations: **Gaia - Variable Stars** INAF ISTITUTO NAZIONALE DI ASTROFISICA OSSERVATORIO DI ASTROFISICA E SCIENZA DELLO SPAZIO DI BOLOGNA

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# REddening – DIstance and MEtallicity

REDIME: Omega Cen as a test-case

An iterative method that uses theoretical metal dependent period luminosity (PLZ) functions in near infrared and optical bands to constrain at the same time reddening, distance and metallicity with high accuracy.
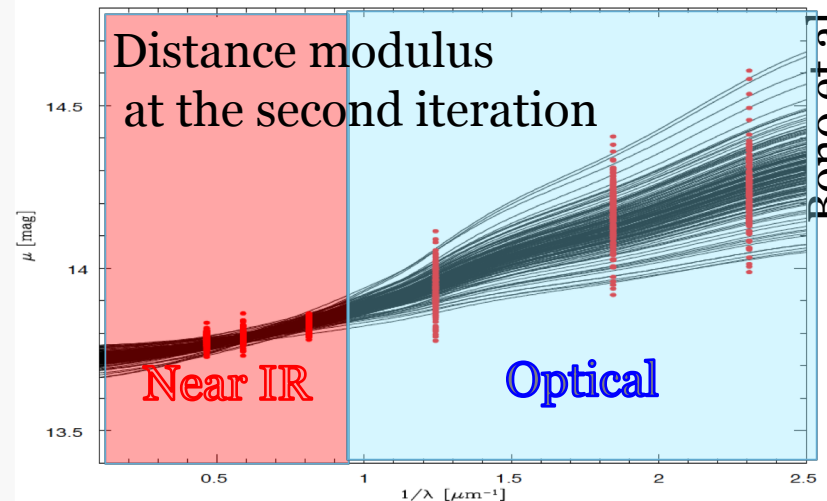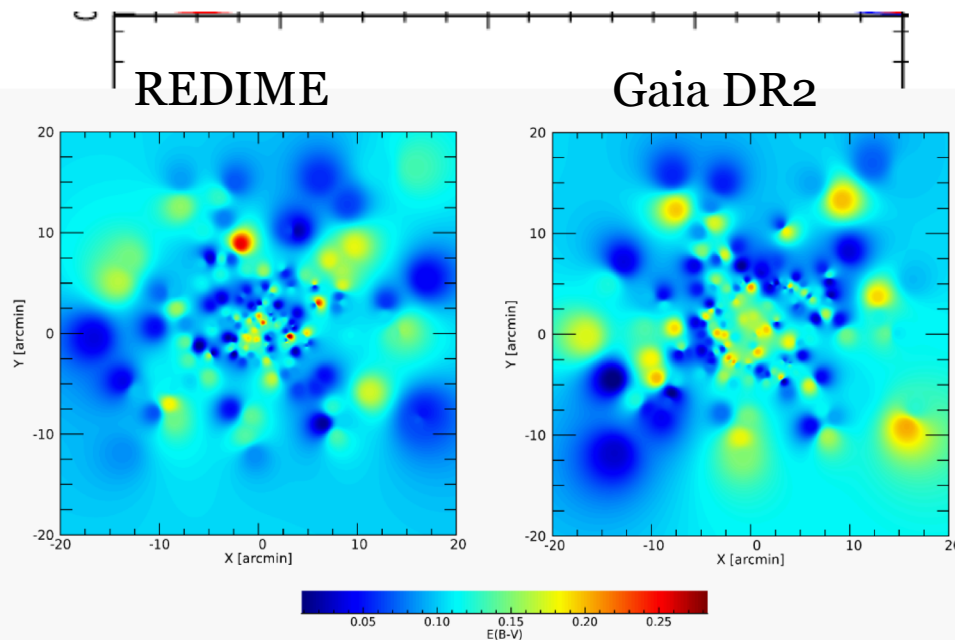
# REddening – DIstance and MEtallicity

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An iterative method that uses theoretical metal dependent period luminosity (PLZ) functions in near infrared and optical bands to constrain at the same time reddening, distance and metallicity with high accuracy.



REDIME    Gaia DR2

Distance modulus at the second iteration
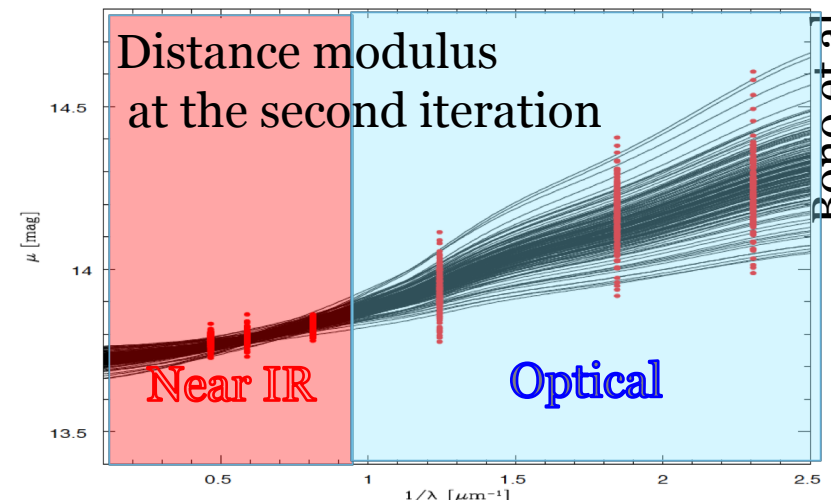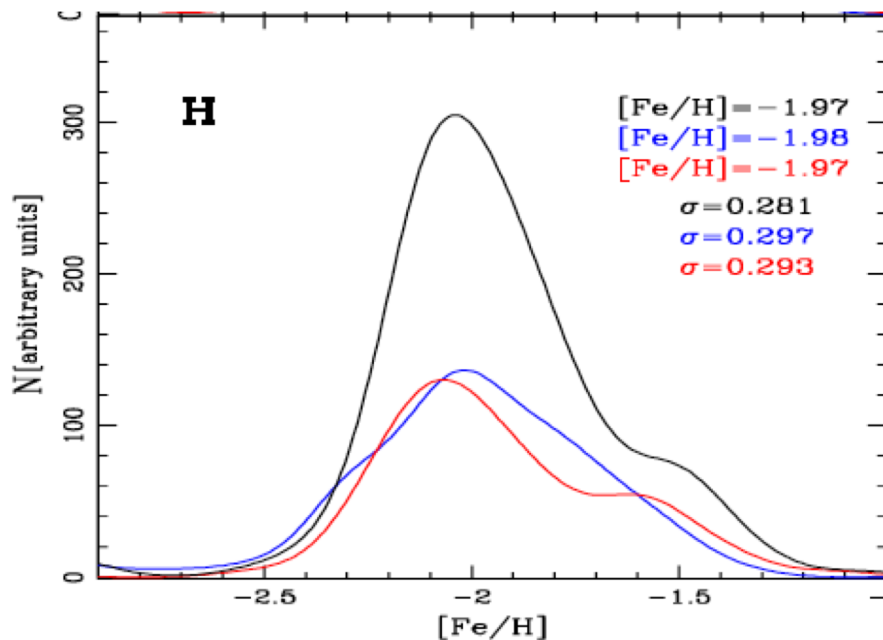
Near IR    Optical

Bono et al. 2018
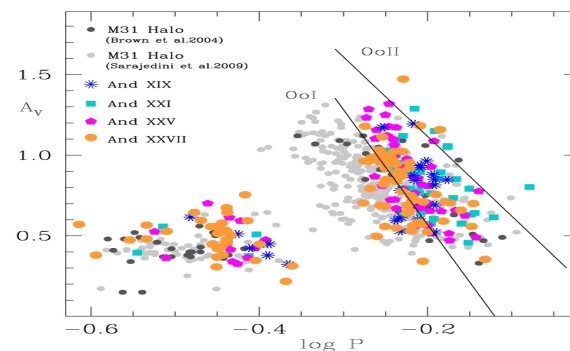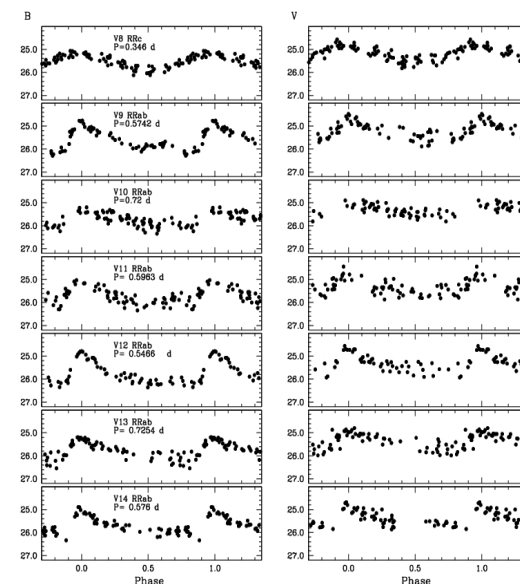
# Galactic archealogy with RR Lyrae stars: M31 dwarf satellite galaxies
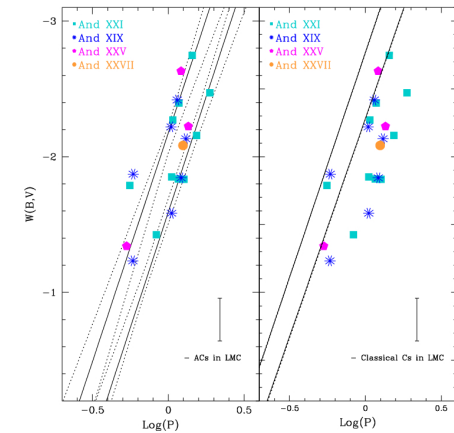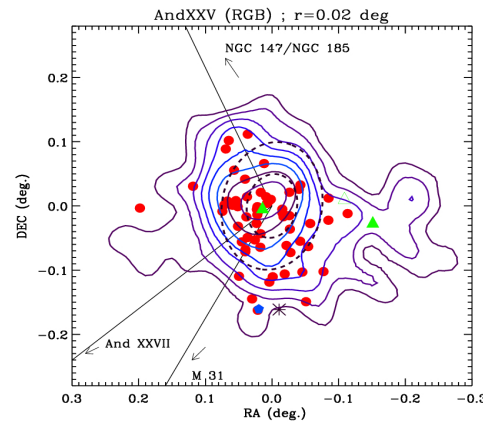
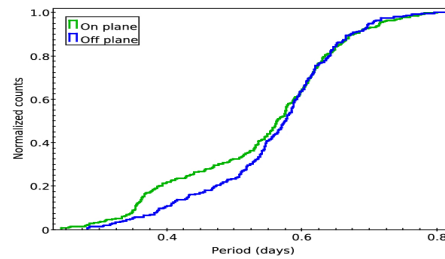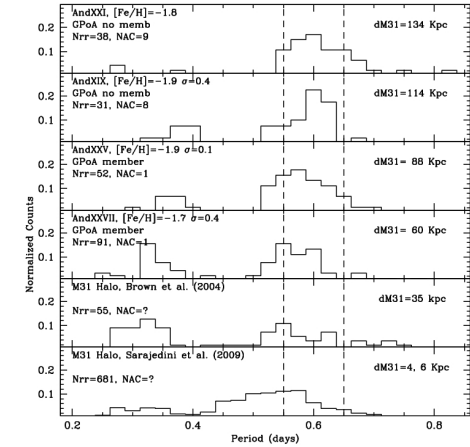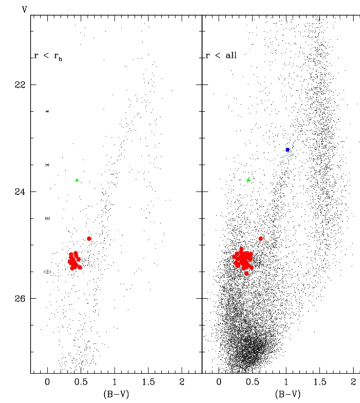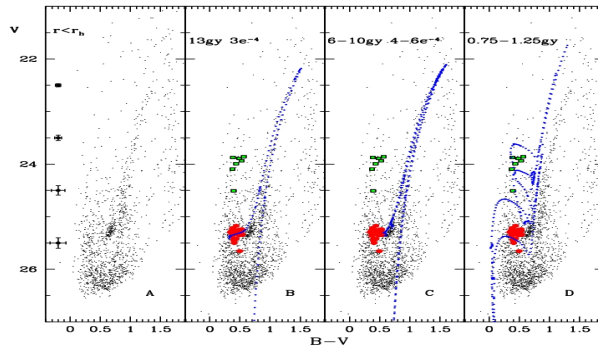**G. Clementini, F. Cusano, A. Garofalo**

Time series photometry in the
B & V bands of the M31 halo and
satellite galaxies obtained with
The LBC@LBT:

➤ We discovered a total of 218 RR Lyrae
  stars and 19 ACs in four M31 satellites
➤ The galaxies that we investigated
  are Oosterhoff -intermediate systems,
  in agreement with the halo
➤ With variables and CMDs we identified
  multiple-stellar populations
➤ Distances and structures of these
  galaxies from RR Lyrae stars and
  isodensity contours
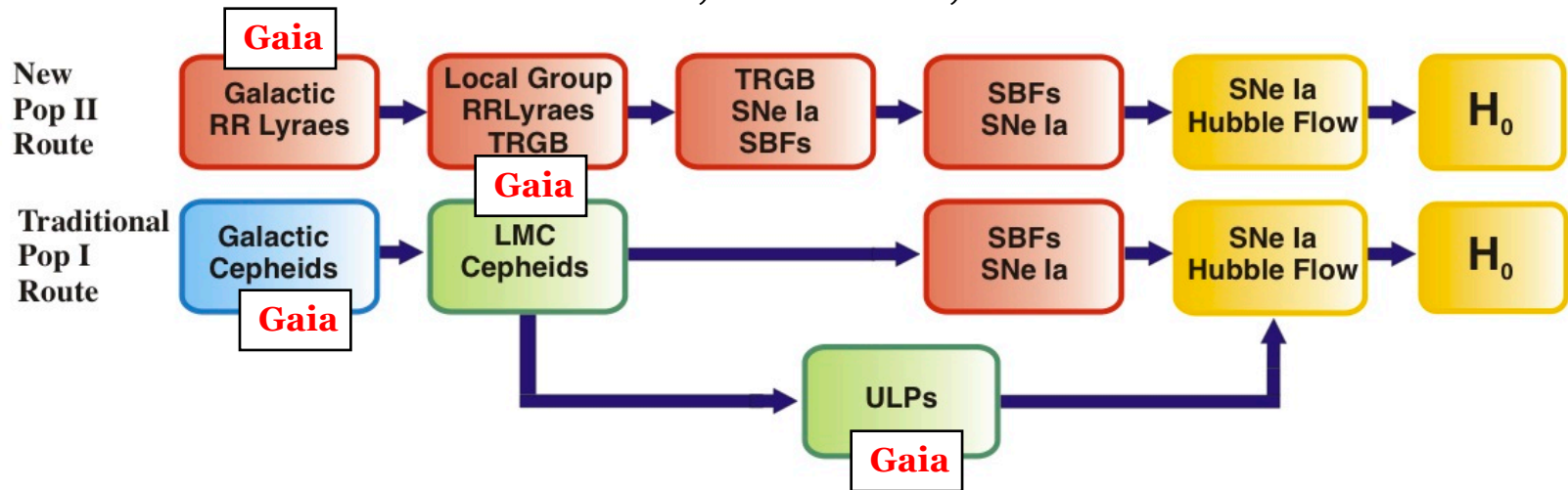
**Cusano et al. (2013, 15, 16, 17)**

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# Present & Future Projects



**CCHP2@HST** PI W. Freedman, 132 orbits
G. Clementini, A. Garofalo, T. Muraveva

**LSST project: The Gaia-LSST Synergy**
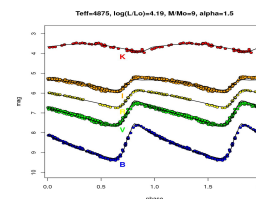G. Clementini, F. Cusano, A. Garofalo, T. Muraveva

# Thank you for your attention!

Michele Bellazzini
Angela Bragaglia
Carla Cacciari
Gisella Clementini
Felice Cusano
Giuliana Fiorentino
Alessia Garofalo
Paolo Montegriffo
Tatiani Muraveva
Antonio Sollima

Michele Bellazzini

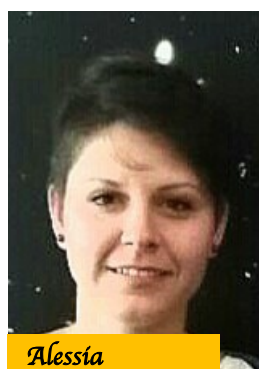Angela Bragaglia

Carla Cacciari (ret.)
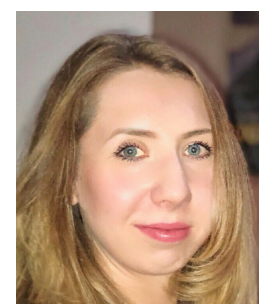
Gisella Clementini

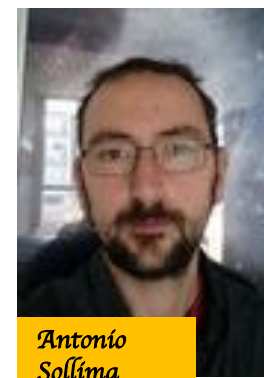Felice Cusano (TD)

Giuliana Fiorentino

Alessia Garofalo (PhD)

Paolo Montegriffo

Tatiana Muraveva (PostDoc)

Antonio Sollima