Tracing in stellar tidal streams in the Milky Way halo with the J-PLUS photometry

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Abstract

Tracing metal-poor stars in the halo of the Milky Way can help detecting stellar tidal streams that provide valuable information about the structure and evolution of our Galaxy.

The work described in this talk can be considered as a first step in the validation of a novel and efficient photometric method, based on narrow and intermediate band filters, to determine the metallicity of metal-poor stars. The method is based on the use of filters sensitive to the Ca HK and Ca II IRT absorption lines, both closely related to the metal abundancies, and benefits from the advantages of photometry wrt spectroscopy, i.e efficiency and depth.

We have obtained such photometry for the globular clusters M3, M5, M13 M15, M92 and Pal5 at the Javalambre Astrophysics Observatory, whose J-PLUS photometric system includes such filters. The observational data have been compared with theoretical predictions obtained with the BaSTI tool and the results show the potentiality of the method to estimate metallicities in a wide range of values.

Context of the Research

- The halo of the Milky Way (MW) is orbited by gravitationally bound satellites (dwarf galaxies, globular clusters).

- The Galaxy's gravitational potential pull exerts a *tidal* force on these objects yielding **tidal stellar streams** that move around the galaxy.

- These streams draw a chemical signature in the galactic halo.

- Narrow-band photometric surveys focusing on the Ca HK and Ca IRT II absorption lines have a great potential to detect metal-poor stars associated to stellar streams.

- Photometric vs spectroscopic surveys: larger field of views, deeper magnitudes and shorter observing times.
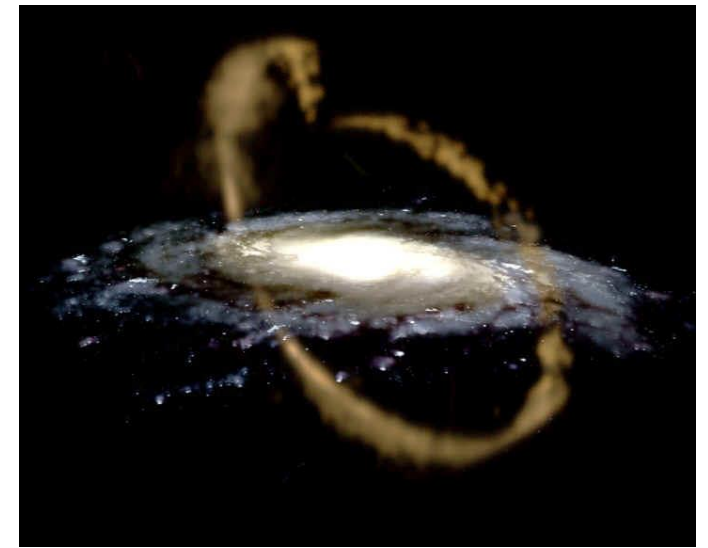
The Sagittarius Dwarf Tidal Stream Drawing, Credit & opyright: David Martinez-Delgado (MPIA) & Gabriel Perez (IAC)
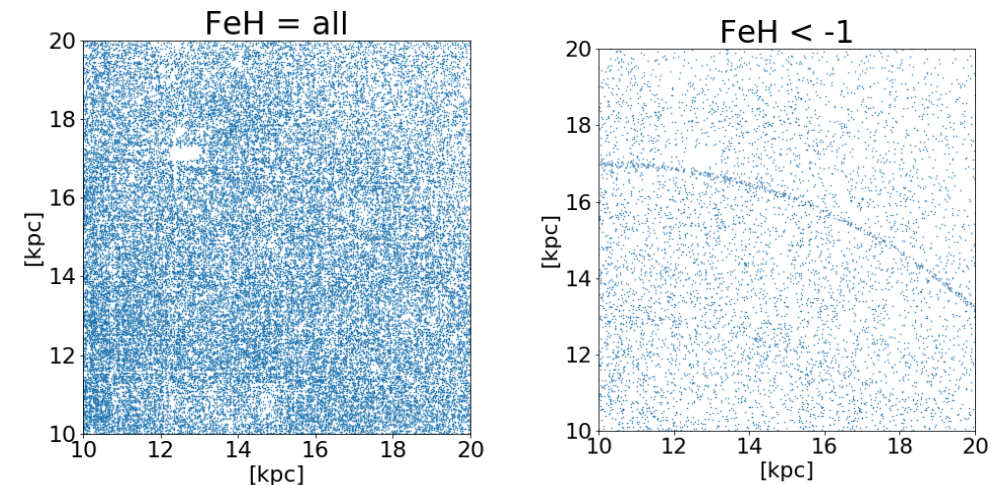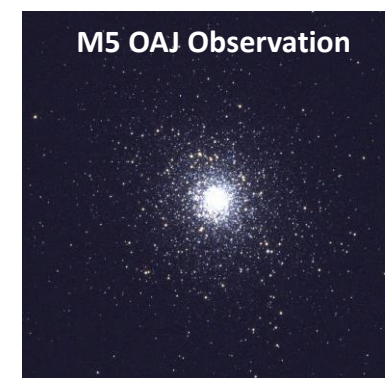

Simulation of a Pal 5-like tidal stream, at a M31 galactocentric radius Rgc = 15 kpc, becoming visible when stars with [Fe/H] < -1.00 are filtered (Pearson et al. 2019)

Description of the work / project / methodologies

- **Observations*** of a sample of globular clusters were carried out making use of the Observatorio Astrofísico de Javalambre (Cenarro et al. 2019) open time with the JAST/T80 telescope mounting T80Cam with a 2 deg^2 FoV. They were used to test and calibrate the method.
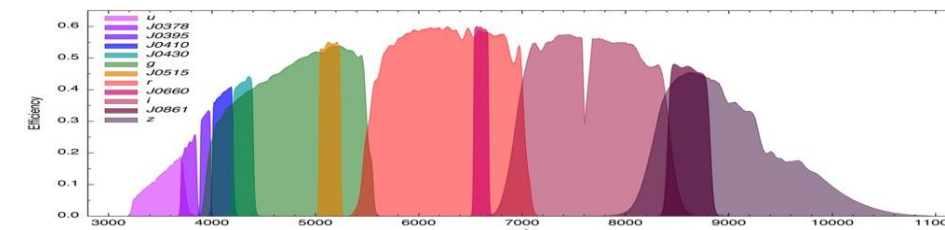
	[Fe/H] Harris (dex)	Distance Harris (kpc)	m-M Harris (mag)	Tidal Radius (arcmin	Absolute Magnitude (mag
M92 (NGC 6341)	-2.31	8.3	14.65	15.17	-8.21
M15 (NGC 7078)	-2.37	10.4	15.39	27.30	-9.19
M3 (NGC 5272}	-1.5	10.2	15.07	38.19	-8.88
M5 (NGC 5904)	-1.24	7.5	14.46	28.4	-8.81
M13 (NGC 6205)	-1.53	7.1	15.33	25.18	-8.55
Pal5	-1.41	23.2	16.62	16.28	-5.17

- **New photometric system**: The new photometric system is composed of 4 broadband (g, r, i & z), 2 intermediate (uJAVA & J0861) and 6 narrow-band filters (J0378, J0395, J0410, J0430, J0515 & J0660) covering the whole optical range (Cenarro et al. 2019). J0395 is sensitive to the Ca HK absorption lines (λc = 3950 Å, FWHM = 100 Å) and J0861 is sensitive to the Ca II IRT absorption lines (λc = 8610 Å, FWHM = 400 Å).

- **Theoretical Predictions** have been generated with the computer tool BaSTI (a Bag of Stellar Tracks and Isochrones), Ver. 5.0.1.

- **GAIA DR2** proper motion data was used for selecting those stars with higher cluster membership probabilities.
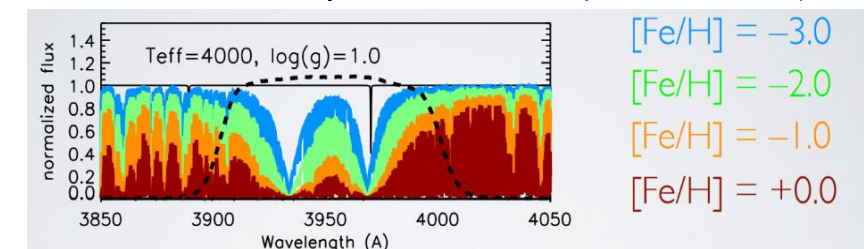
* Images reduced and catalogs produced by the UPAD at the Centro de Estudios de Física del Cosmos de Aragón.

M5 OAJ Observation

Javalambre Astrophysics Observatory

http://basti-iac.oa-abruzzo.inaf.it/

J-PLUS Photometric System Available Filters (Cenarro et al. 2018)

[Fe/H] = −3.0
[Fe/H] = −2.0
[Fe/H] = −1.0
[Fe/H] = +0.0
Absorption lines of Ca HK vs [Fe/H] (Starkenburg et al. 2017)

Gaia second data release

Results (1): Theoretical Predictions

- The **theoretical predictions** used in the present work have been generated with a new version of the BaSTI tool (based on a **Monte Carlo** algorithm) adapted for this project.

- GCs are assumed to experience a single star formation event. Therefore, we suppose **all the stars in a GC have the same metallicity and age.**

- A set of Colour combinations were designed to discriminate quantitatively the stellar metallicity: **metallicity indexes**.

- For the filter centred at the Ca HK absorption lines (J0395), the metallicity index **(J0395-g)-1.5(g-i)** allows to **discriminate the stars by their metallicity** in the RGB (*centre-left*), HB (*centre-centre*) and MSTO (*centre-right*), though for HB at metallicities [Fe/H] < -2.0, the discrimination fades away.

- For the filter centred at the Ca II IRT absorption lines (J0861), the metallicity index **(J0861-z)-1.5(z-i)** shows certain **discrimination on metallicity** in the RGB (*bottom-left*), HB (*bottom-centre*) and MSTO (*bottom-right*), though in the RGB only for [Fe/H] > -1.0.
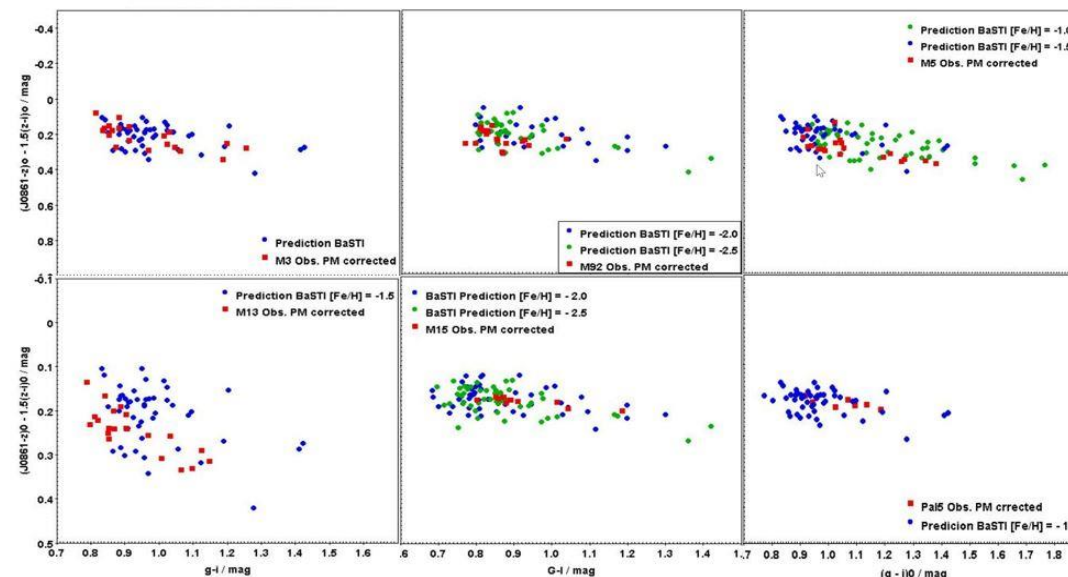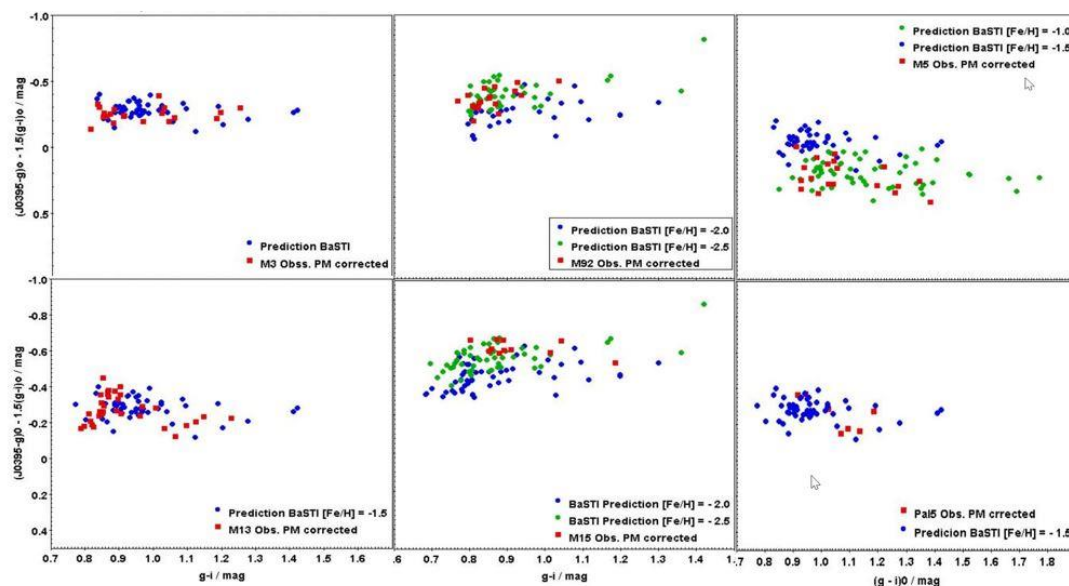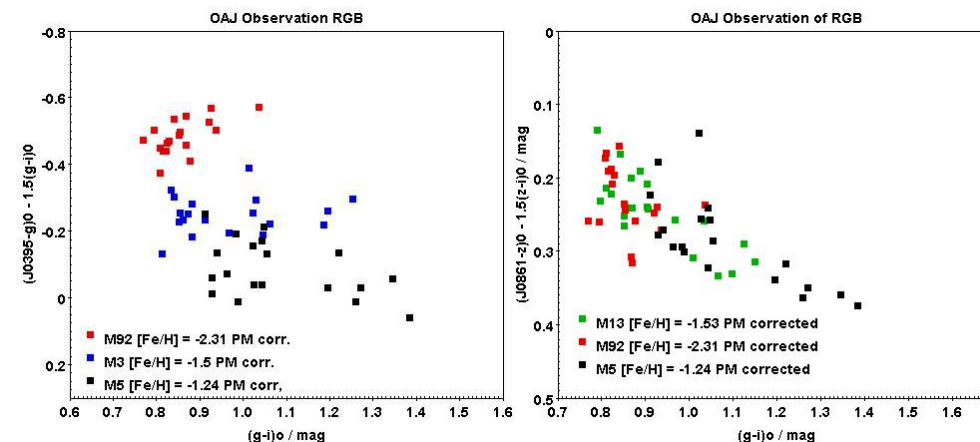

Synthetic CMD with marked HB, RGB and MSTO zones showing the star population distribution as predicted by the BASTI code with the assumptions:

- **fixed age of 13 Gyr**
- **1 star formation event**
- **0.0 >= [Fe/H] >= -2.3 dex**
- **initial mass function as PDF**
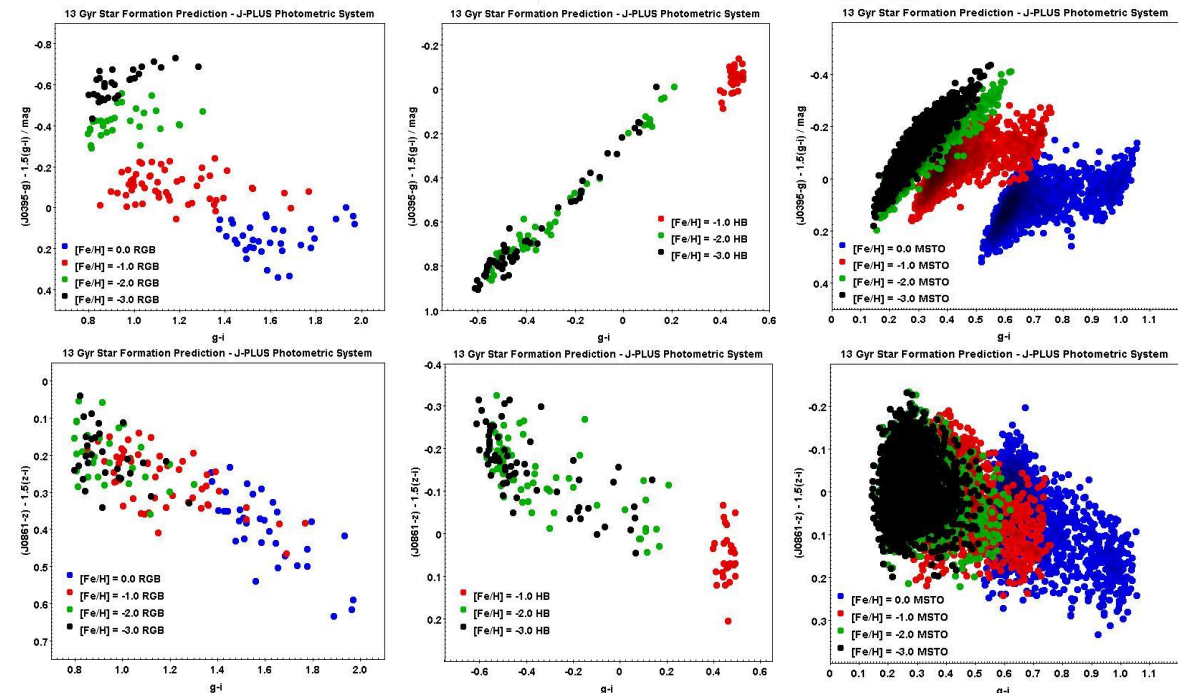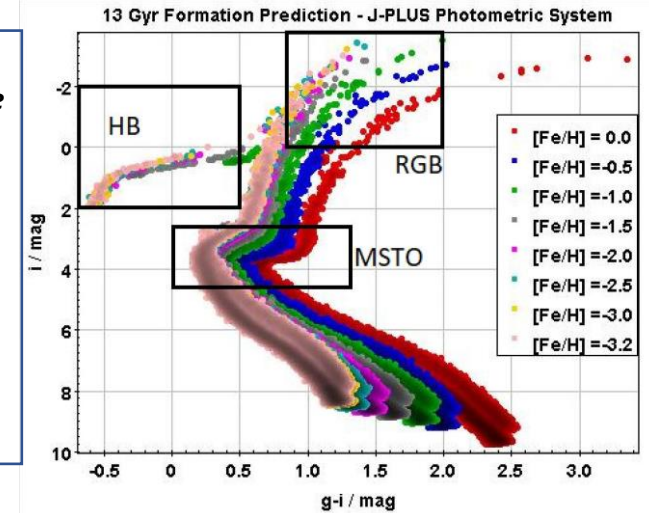
Results (2): Observations

- Due to the distance of the selected GCs (> 7 kpc) **the analysis focused on the RGB stars only.**

- The comparison of the observed metallicity index for Ca HK and Ca II IRT for the selected GCs **confirms the predicted pattern** (*see figures top right*)

- **Comparison of the observed magnitudes with the predictions** for all filters indicated a good match. The observed metallicity indexes were within ~0.2 mag (J0395) and ~0.3 (J0861) from the predicted ones (*see figures*). **Note**: we are using preliminary ZPs for calibration purposes.

Observational data CC diagram for the Ca HK (left) and Ca II IRT (right) absorption lines sensitive filters for the RGB stars in GCs

Comparison between observational data and theoretical prediction for the Metallicity Index Ca HK: M3 (top-left), M92 (Top-centre), M5 (top-right), M13 (bottom-left), M15 (bottom-centre), Pal5 (bottom-right).

Comparison between observational data and theoretical prediction for the Metallicity Index Ca triplet: M3 (top-left), M92 (Top-centre), M5 (top-right), M13 (bottom-left), M15 (bottom-centre), Pal5 (bottom-right)

Impact and Prospects for the Future

- The work described in this paper can be considered as a first step in the validation of a novel, efficient and robust photometric method, to identify metal-poor stars and approximate their metallicity, for further spectroscopic analysis.

- Further observations of the GCs employing OAJ's open time making use of the J-PLUS photometric system are currently obtained in order to complete the validation of the method with an extended data sample in a wider range of metallicities and establish a functional correlation between the metallicity-index and the metallicity of the observed stars in the RGB.

- While the focus of this work so far has been on metal-poor stars belonging to the RGB, extension to the HB stars and RR-Lyrae variables is planned in order to expand the population type of detectable metal-poor stars and to attain different scientific objectives.

- The continued cross-fertilisation between theoretical predictions and observations will ensure that the models can further evolve and improve their prediction range and that photometric surveys can be better defined in advance and their results evaluated.