# Unveiling Extragalactic Globular Clusters: Insights from X-Shooter Spectra and NIR Abundances

**Emílio Zanatta**, T. Moura, B. Barbuy, M. Villegas-Pérez, M. Trevisan

IAU 395 - Paraty, Brazil - 2024

# About Me

## Emílio Zanatta

B.Sc. (Physics): UFJF (Brazil, 2014)

MSc, PhD: UFRGS (Brazil, 2021)

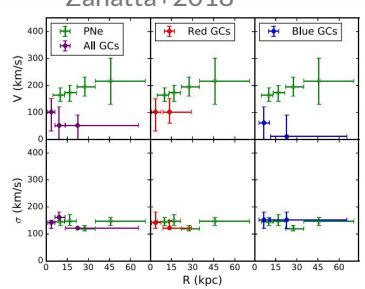
Post-Doc: IAG/USP (Brazil, Current)

## Research Interests

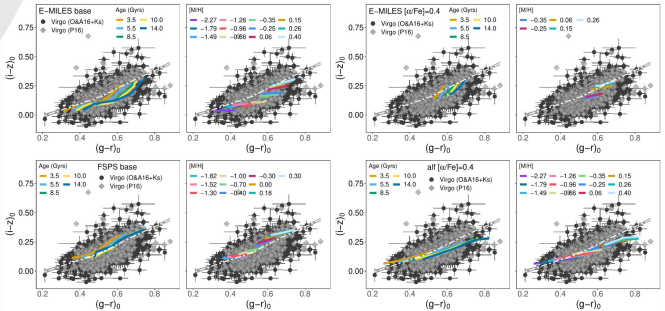
**Star Clusters** as tools to study **Galaxy Evolution**

### Globular Clusters (GCs)

Zanatta+2018




PhD. Thesis (2021)



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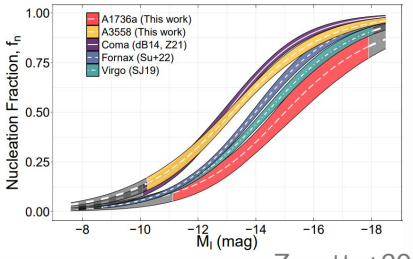
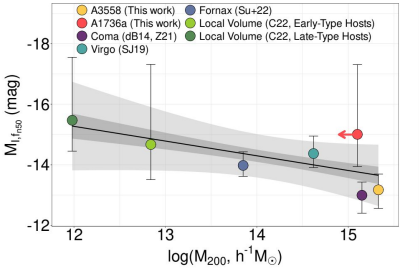



Zanatta+2021
Zanatta+2024



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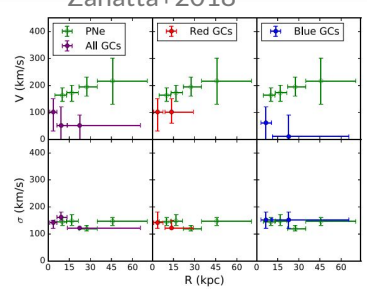


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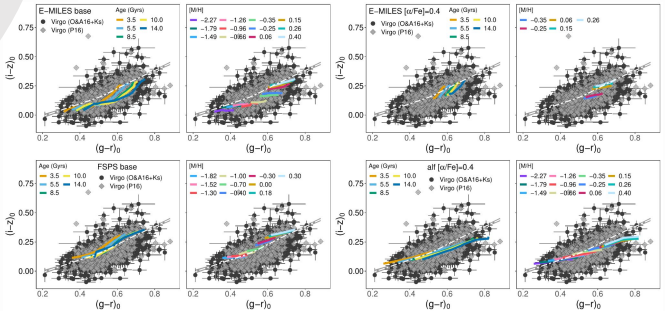

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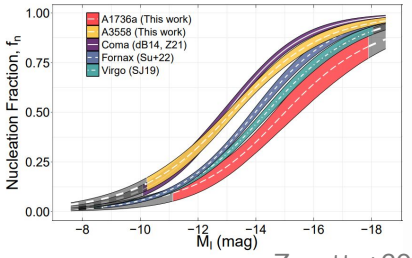


Zanatta+2021
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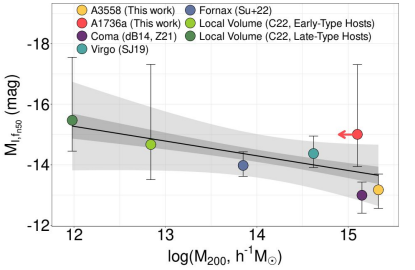
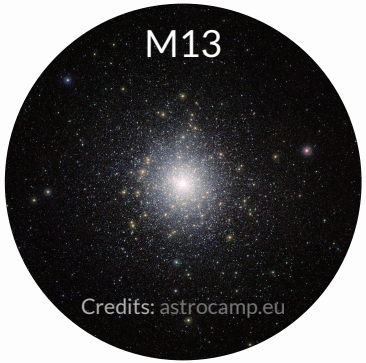
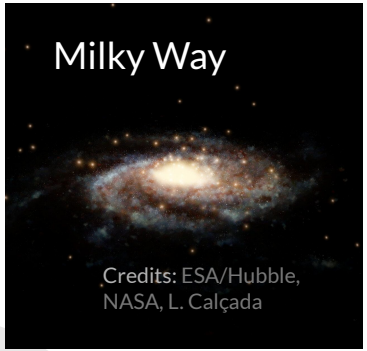


# Why are Extragalactic GCs important?

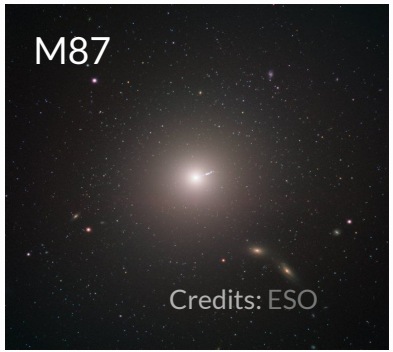


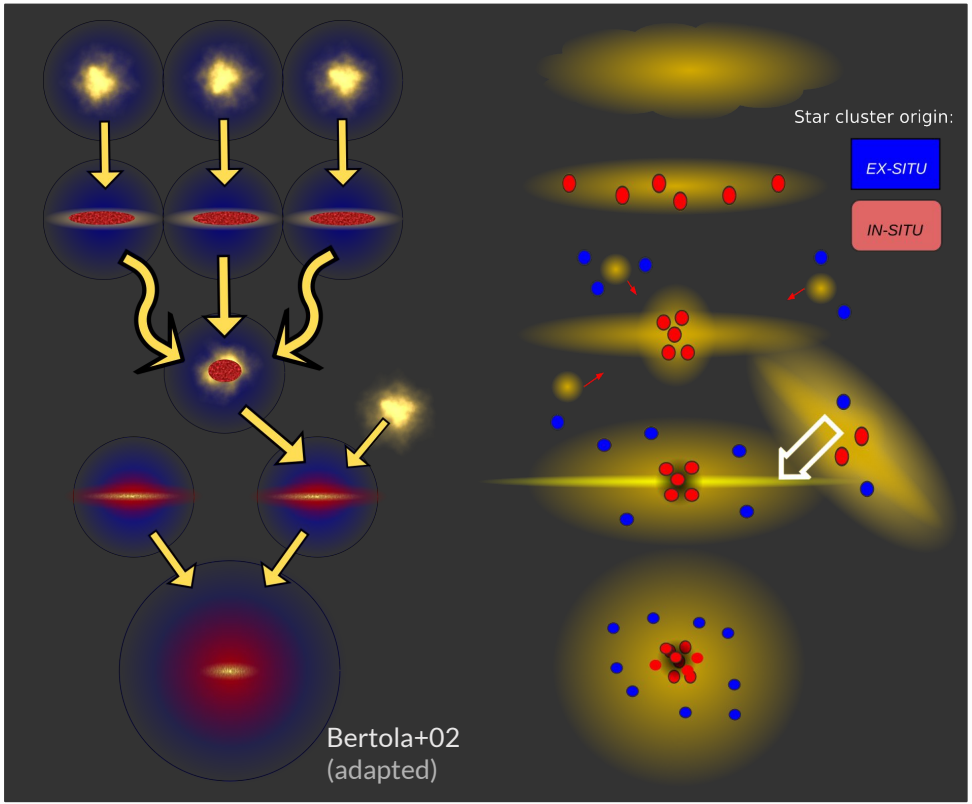

*This is a GC*



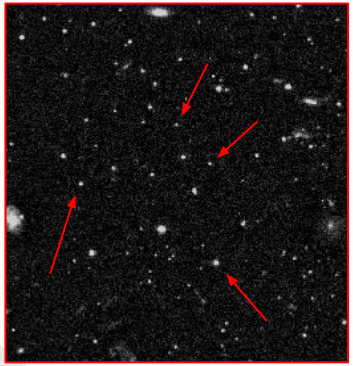

< 200 GCs

> 15.000 GCs

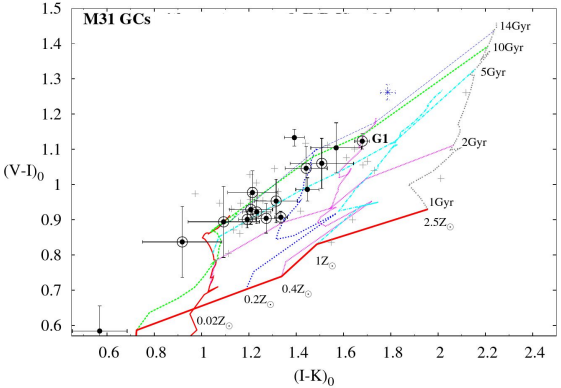


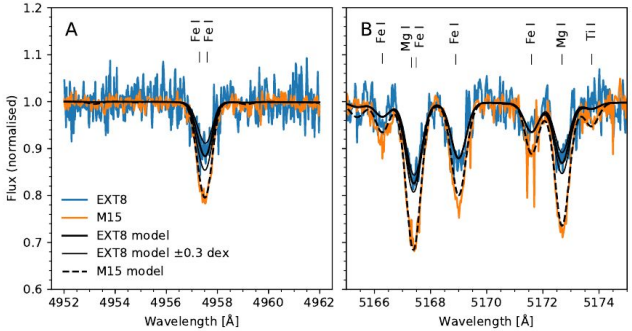
# Studying Extragalactic GCs



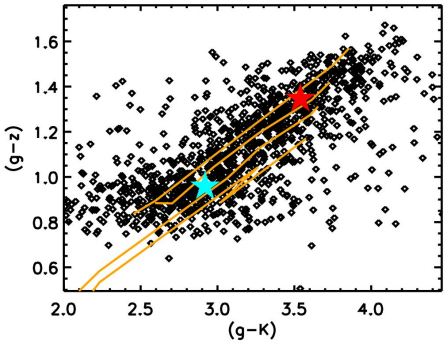
Georgiev+2011



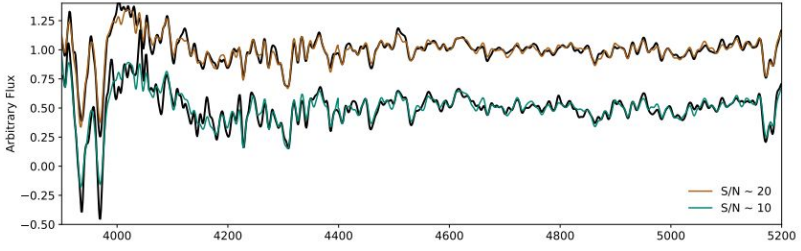

Larsen+2020



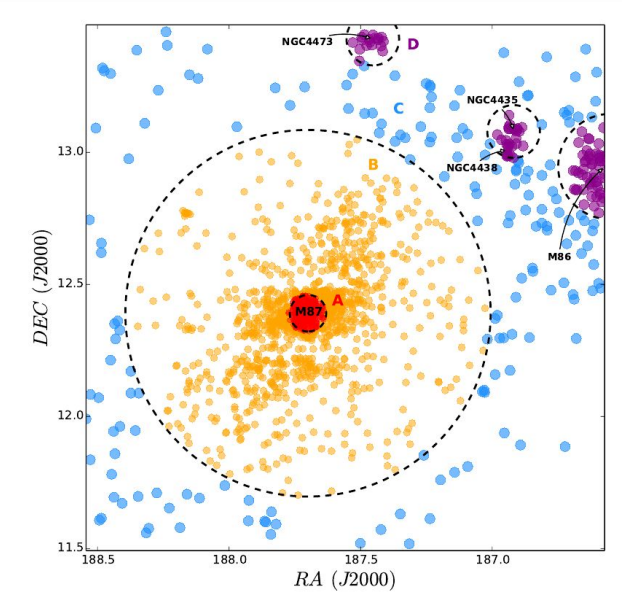

Chies-Santos+2011




Villaume+2019

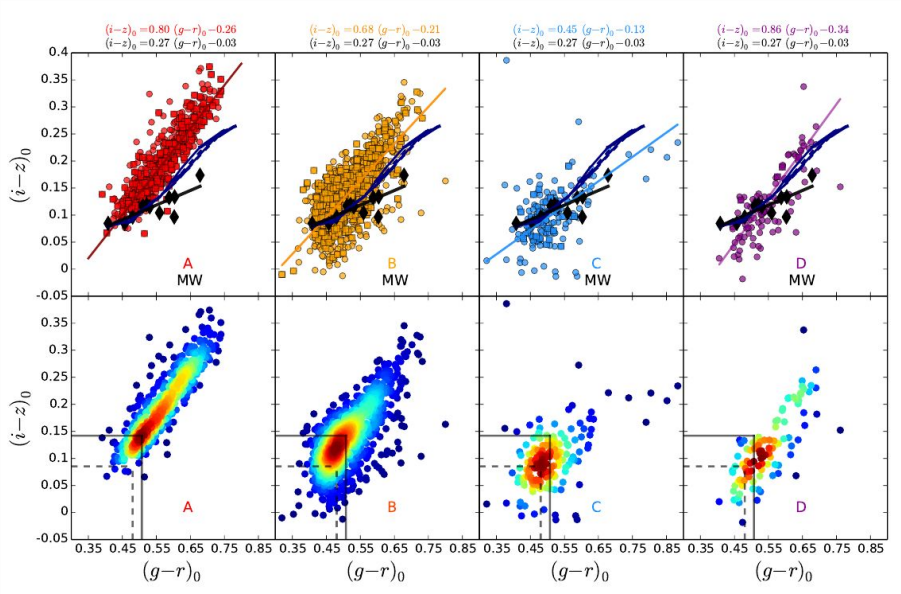


# SSP Models and Extragalactic GCs: A Struggle




Powalka+2016b

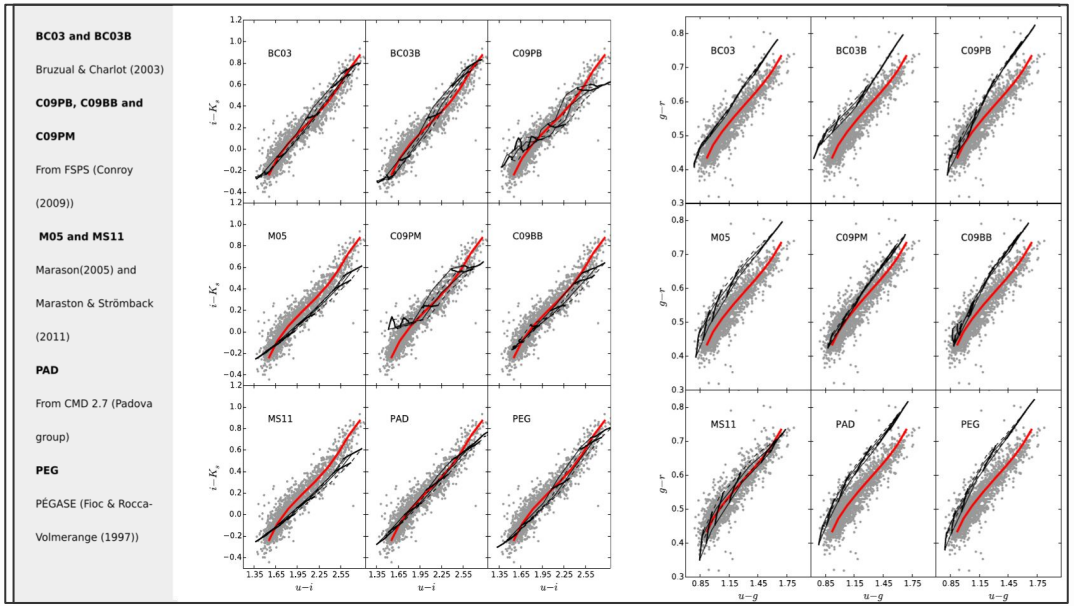
To the center of M87




MW GCs

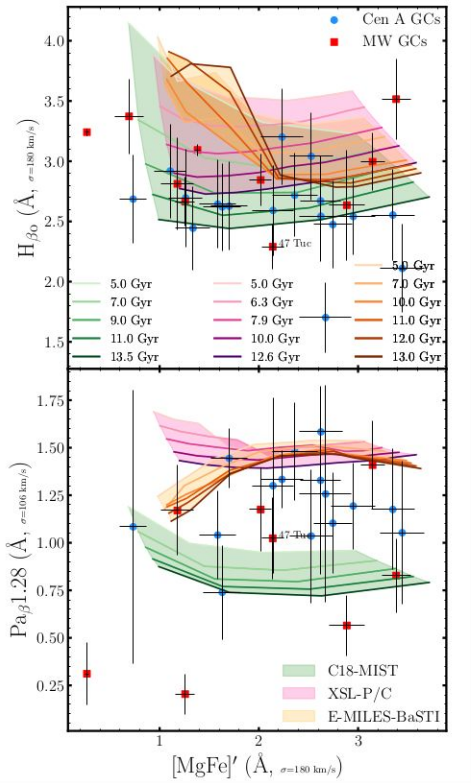
Bruzual & Charlot+2003
0.0002 < Z < 0.03
6 < age < 13 Gyrs

# SSP Models and Extragalactic GCs: A Struggle




Powalka+2016a

Eftekhari+2025 (submitted)



# Where can we improve?

## Improve Abundance Predictions

Extragalactic GC stellar populations are expected to not be well described by **solar-scaled models**, due to their horizontal branch morphology (He abundances), Na and Alpha enhancement, to name a few.

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Stellar spectra from MW regions such as the bulge and halo, as well as GC integrated spectra for objects in nearby galaxies.

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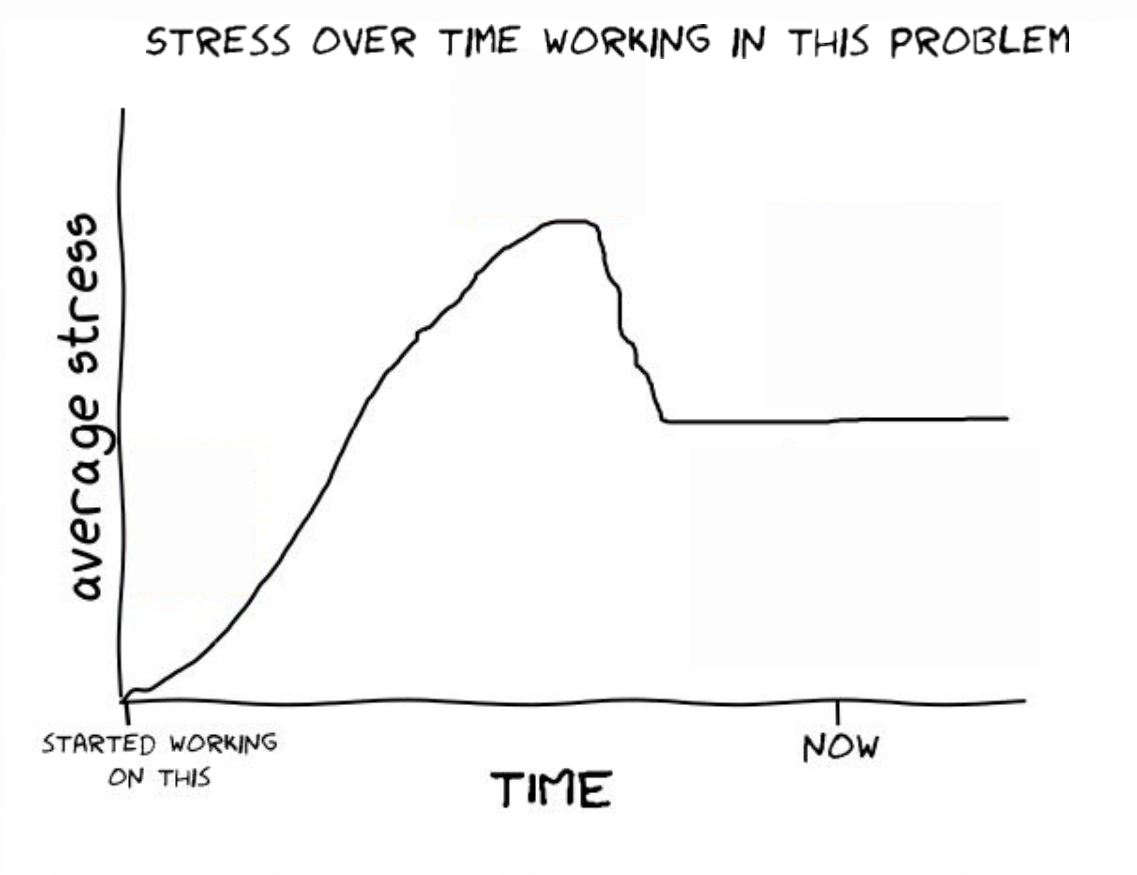
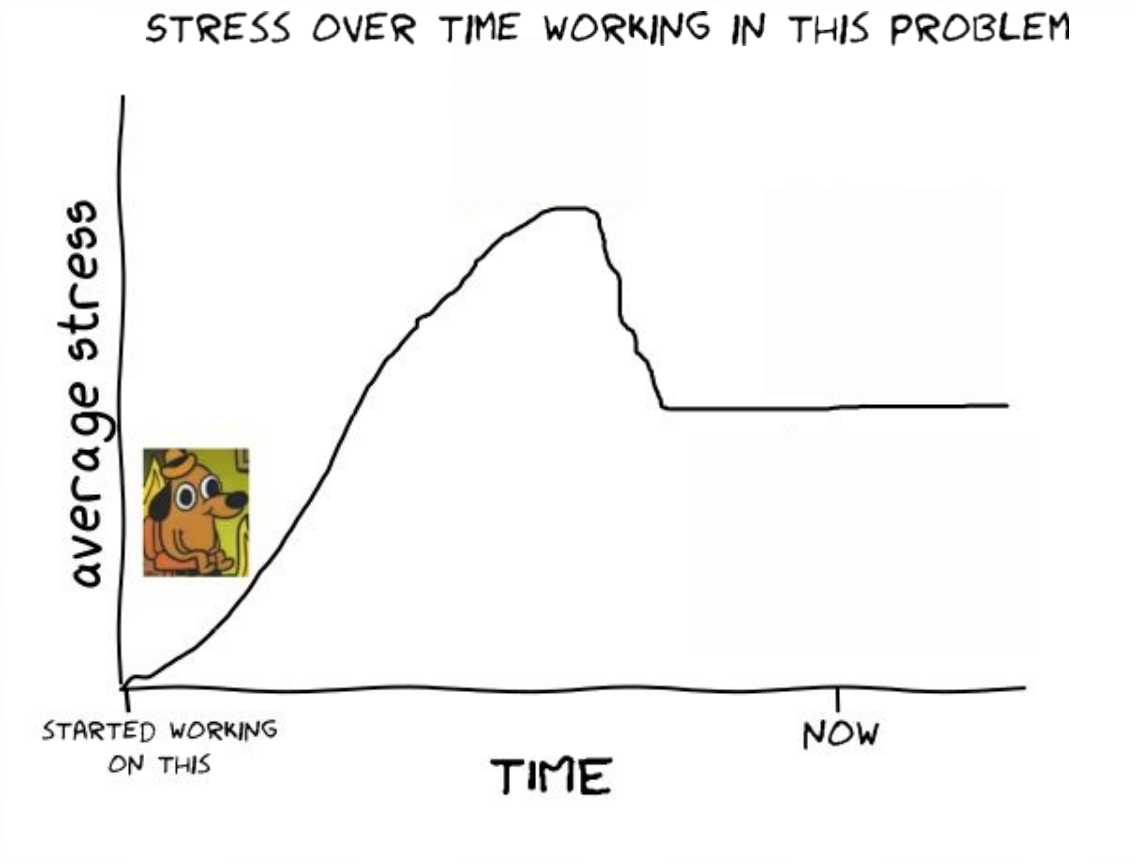
## Explore the Near-Infrared (NIR)

- Short-lived red supergiants
- TP-AGB
- Red giant branch stars

Soften or resolve optical limitations (dust reddening, age/metallicity degeneracy, etc); Molecular and Atomic features, and make use of data from NIR telescopes such as the JWST, Euclid and the Nancy Grace Roman Space Telescope.


STRESS OVER TIME WORKING IN THIS PROBLEM
average stress
STARTED WORKING ON THIS
NOW
TIME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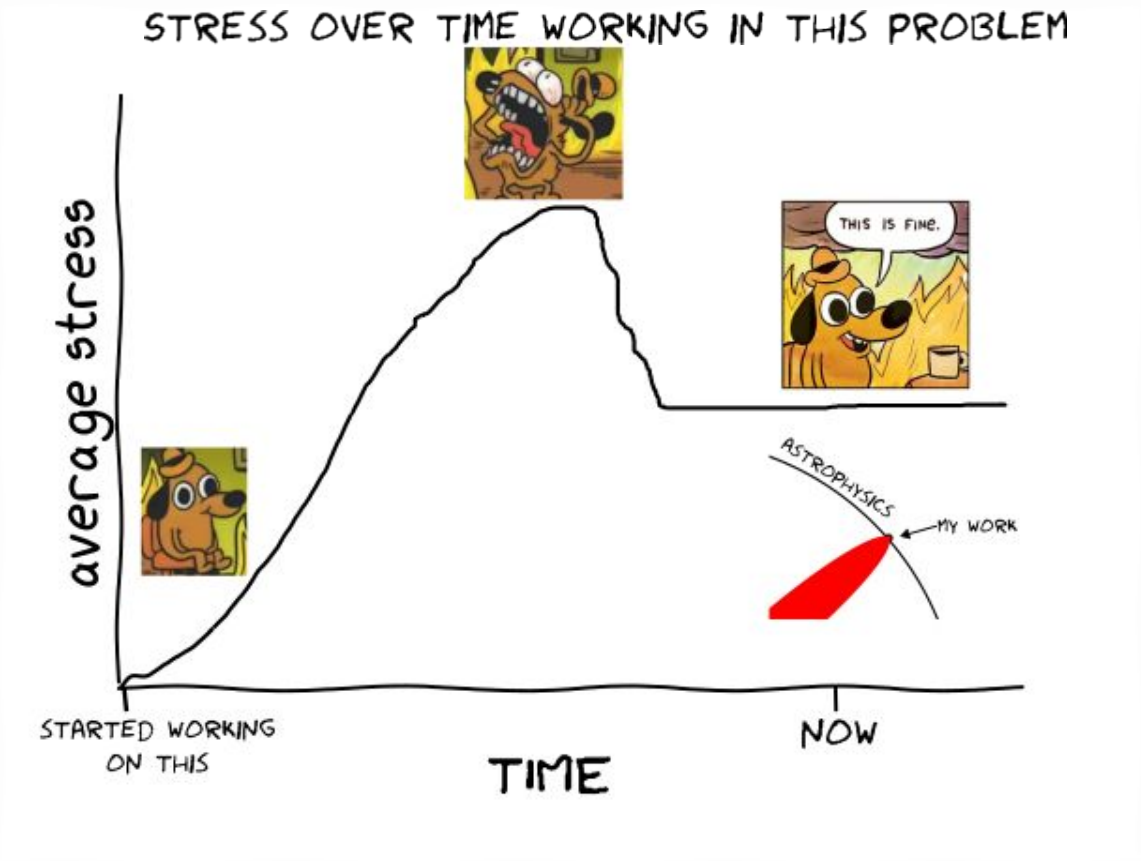
STRESS OVER TIME WORKING IN THIS PROBLEM
average stress
THIS IS FINE.
ASTROPHYSICS
MY WORK
STARTED WORKING ON THIS
NOW
TIME

# Current Work *In Progress!*

## Goal:

1. Increase the amount of precise **abundance estimates** in the NIR for **old and metal-poor stars** beyond the Sun neighborhood.

2. Test SSPs with custom abundances with **Extragalactic GC Photometric** and **Spectroscopic** data.

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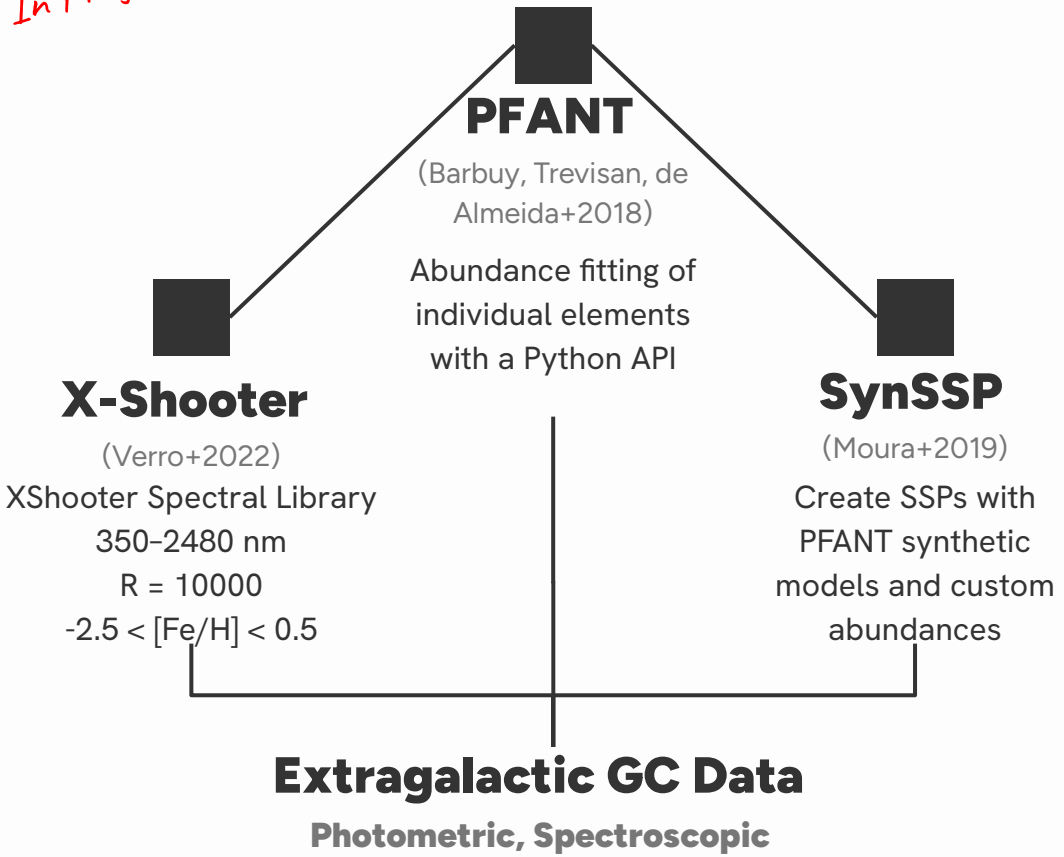


# X-Shooter Spectral Library

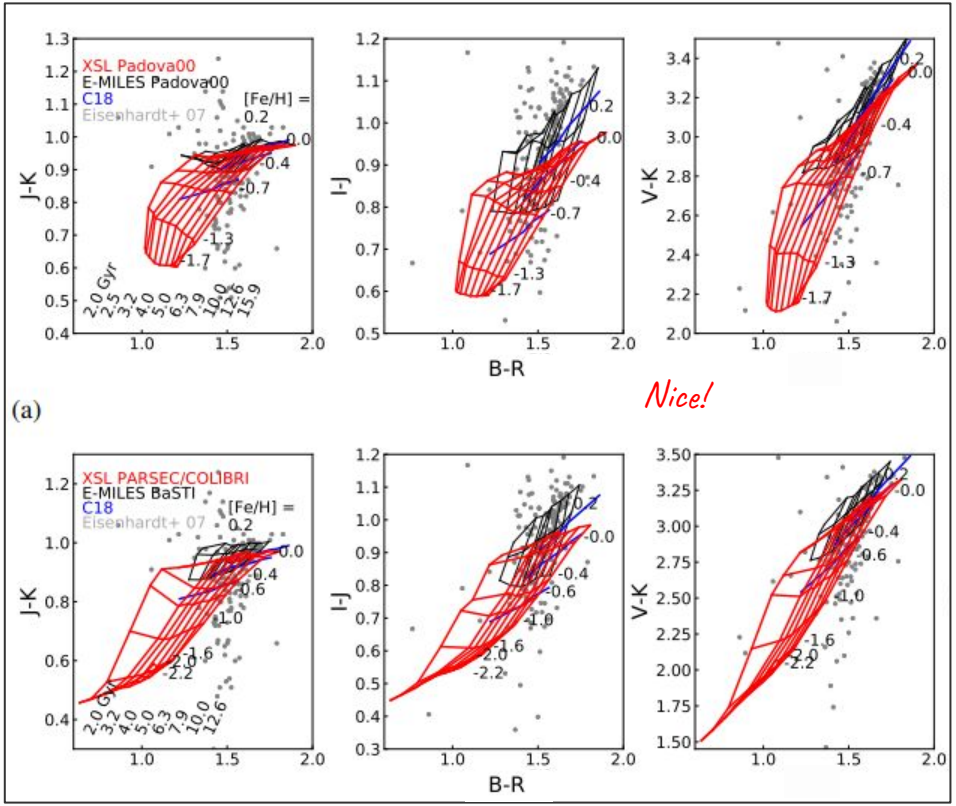
**Data**

- XSL DR3 - 683 Stars
- 350–2480 nm
- R = 10000
- -2.5 < [Fe/H] < -0.5 (Arentsen+2019)

**XSL SSPs** (Verro+2022b)

Solar-Scaled

Verro+2022b, *Coma Dwarf Galaxies*




Nice!

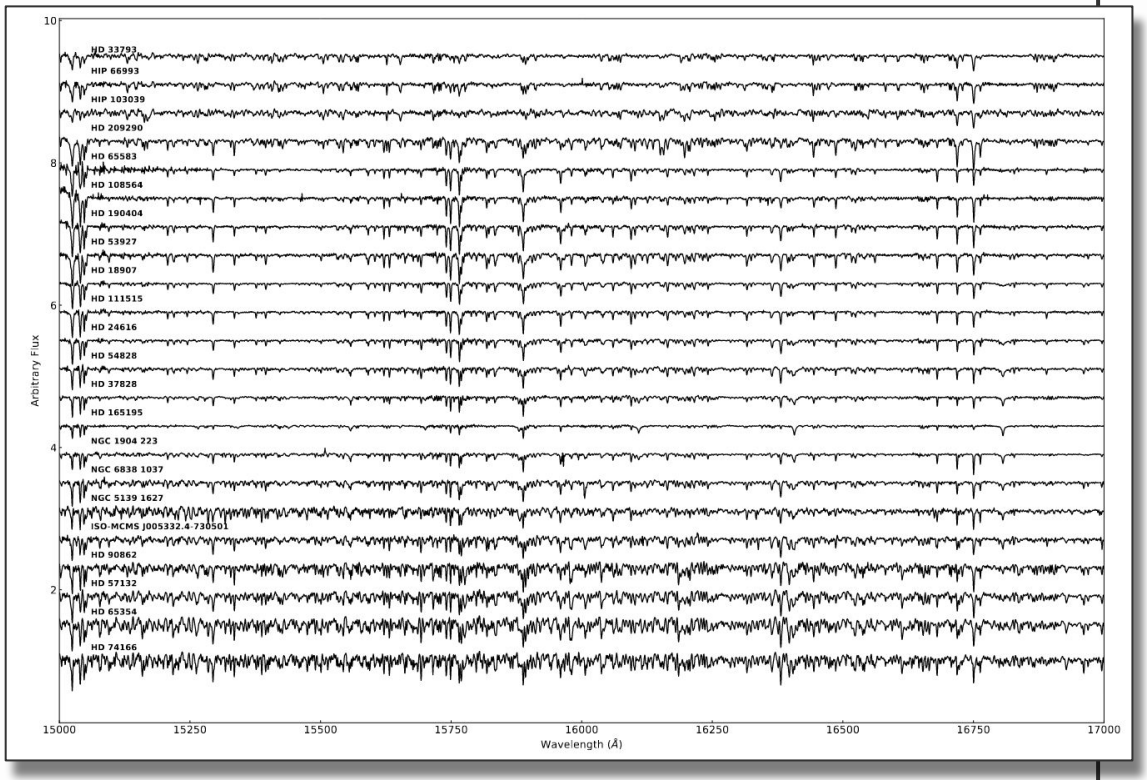
# XSL GKM Star Abundances in the NIR

Zanatta+25 (*in prep*)
H-band (1500 - 1700 nm)

- Line-Strength Fitting
- > 200 **GKM** Stars *Good S/N!*
- **-2.35 < [Fe/H] < 0.57**

**Features**

- Molecules
  - CN, OH, CO
- **Alpha Elements**
  - **Mg, Si, Ti, Ca**
- Other
  - Al, K



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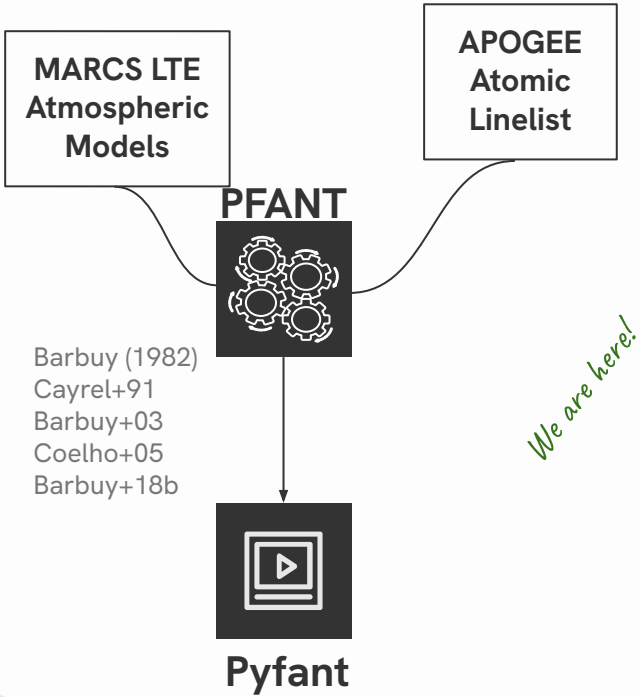
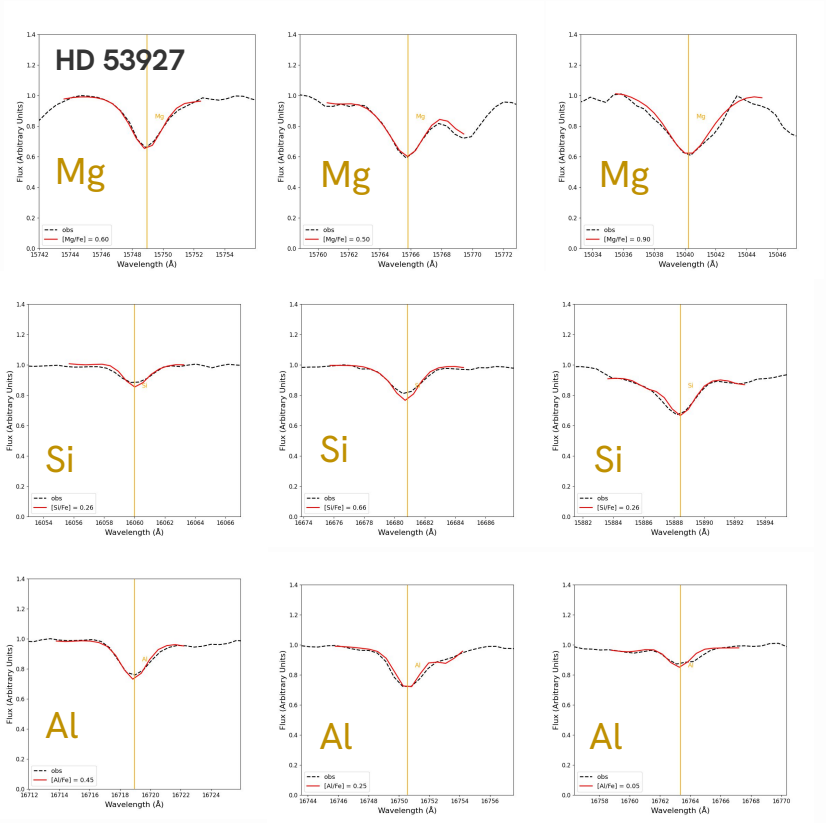
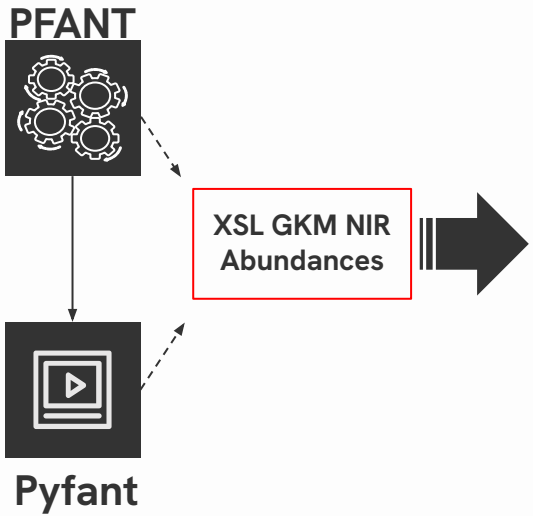


# Perspectives

*Next steps!*




https://github.com/trevisanj/pyfant

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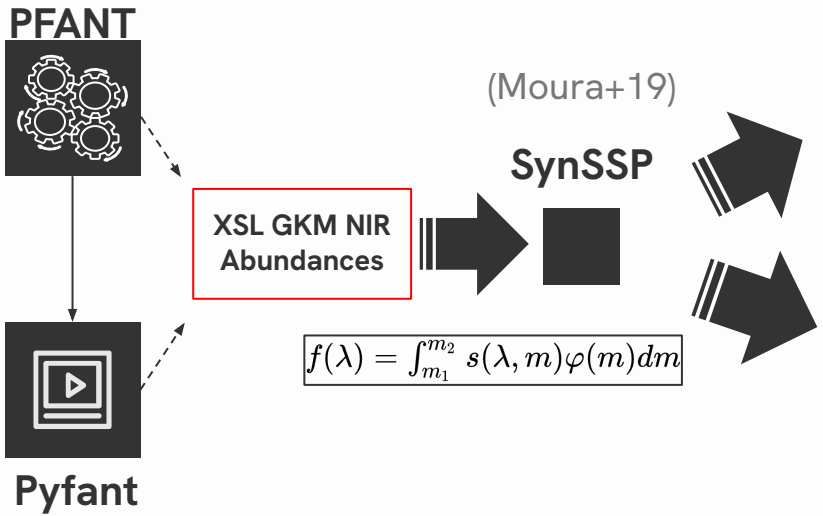


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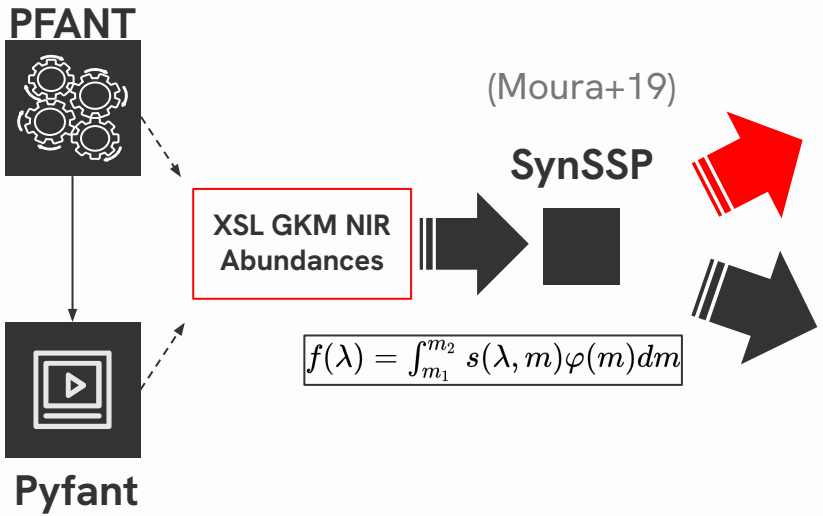
# Perspectives

## Photometric Data

*Next steps!*

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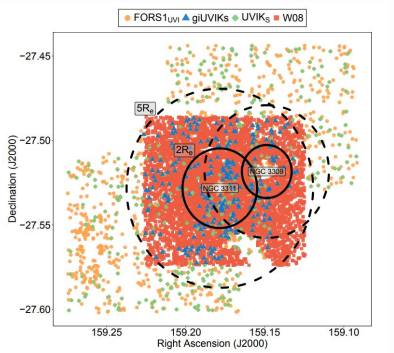
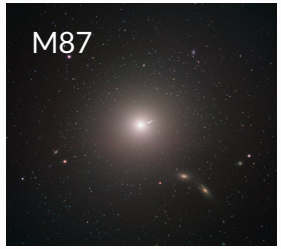
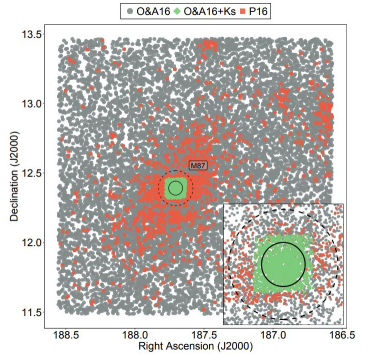
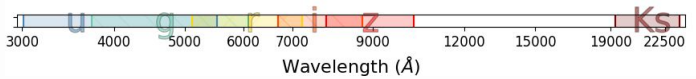


# Perspectives

## Spectroscopic Data

*Next steps!*

PFANT

(Moura+19)

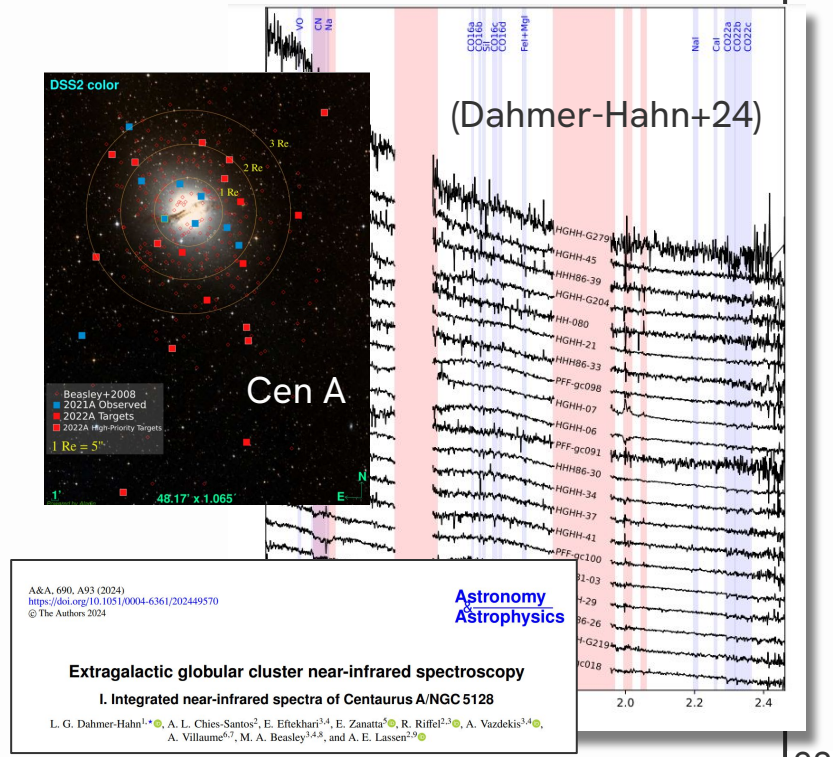
SynSSP

XSL GKM NIR Abundances

$$f(\lambda) = \int_{m_1}^{m_2} s(\lambda, m)\varphi(m)dm$$

Pyfant

https://github.com/trevisanj/pyfant





A&A, 690, A93 (2024)
https://doi.org/10.1051/0004-6361/202449570
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Astronomy & Astrophysics

**Extragalactic globular cluster near-infrared spectroscopy**

**I. Integrated near-infrared spectra of Centaurus A/NGC 5128**

L. G. Dahmer-Hahn[1,*], A. L. Chies-Santos[2], E. Eftekhari[3,4], E. Zanatta[5], R. Riffel[2,3], A. Vazdekis[3,4], A. Villaume[6,7], M. A. Beasley[3,4,8], and A. E. Lassen[2,9]

# Take away message

1. **Extragalactic GCs** are **important** for galaxy evolution
2. We are entering a **“big data”** moment for **NIR photometry/spectroscopy**
3. There is **a big offset** between current SSP models and Extragalactic GC observed properties and we don’t know exactly why.
4. **There is plenty of work to be done here!**
5. 



*A Special Thanks to:*

**Beatriz Barbuy**
**Marina Trevisan**
**Júlio Trevisan**
**Tatiana Moura**


# Thanks for your attention!


*Contact Me!*

**emiliojbzanatta@gmail.com**