An extremely metal-deficient globular cluster in the Andromeda Galaxy

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Authors: Søren S. Larsen, Aaron J. Romanowsky, Jean P. Brodie, Asher Wasserman

Speaker: Jiaxin Tang 唐佳欣

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Outline

- Introduction to GCs & metallicity
- RBC EXT8
- Significance of the study & follow-ups
- Summary

What are GCs?

- Gravitationally bound systems of thousands to millions of stars
- For spiral galaxies, GCs are mostly found in halo
- Older, denser, fewer heavy elements compared to open clusters

- Stars in the same GC roughly have the same age and composition
- The H-R diagram suggests the initial mass and age of the cluster

M22, found in 1665
Credit: ESA/Hubble & NASA

Why study GCs?

GCs are related with oldest compositions of the galaxies

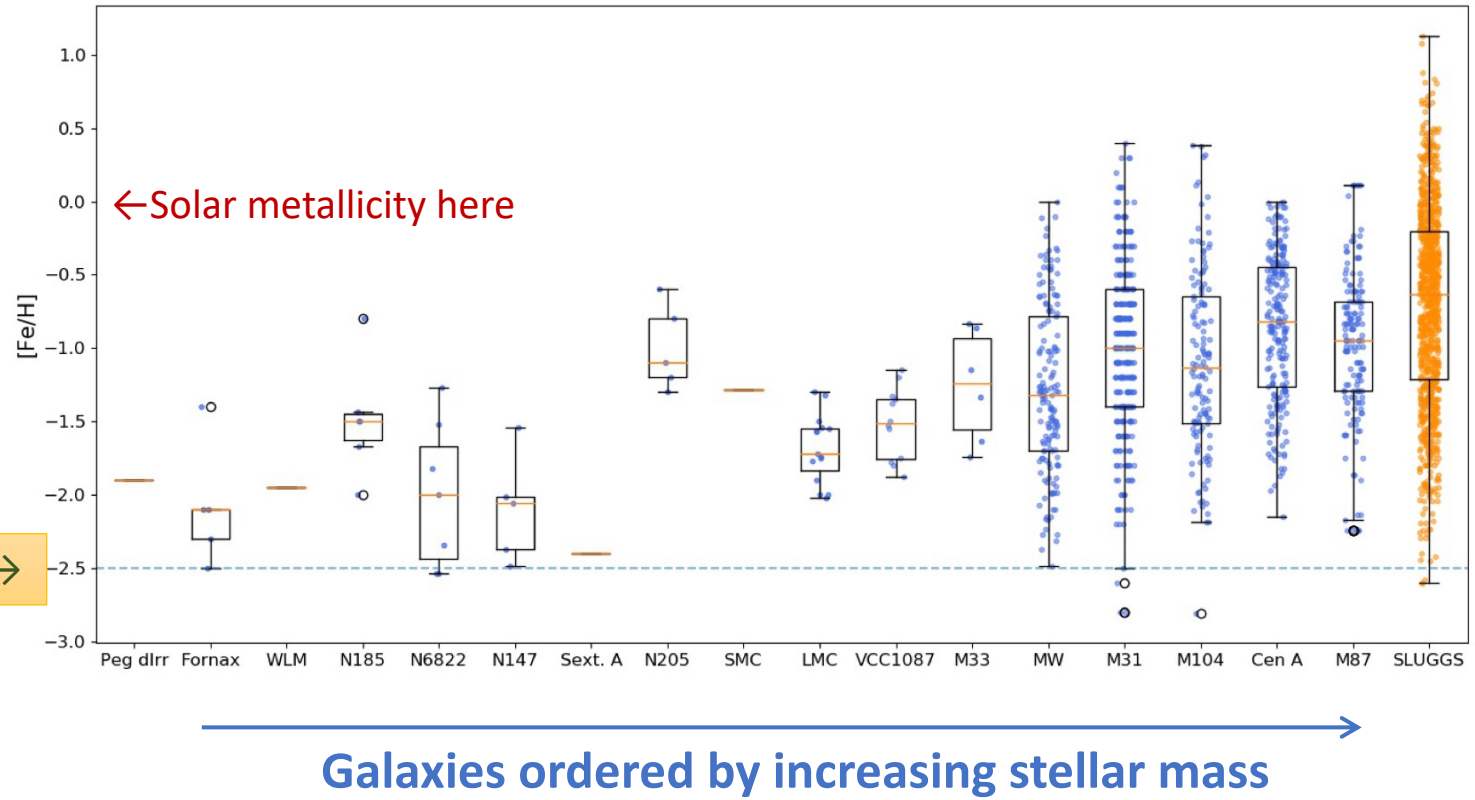
-- the measurements will help us study the chemical composition of early universe

Metallicity of GCs

- Seems to be a metallicity upper bound at solar metallicity

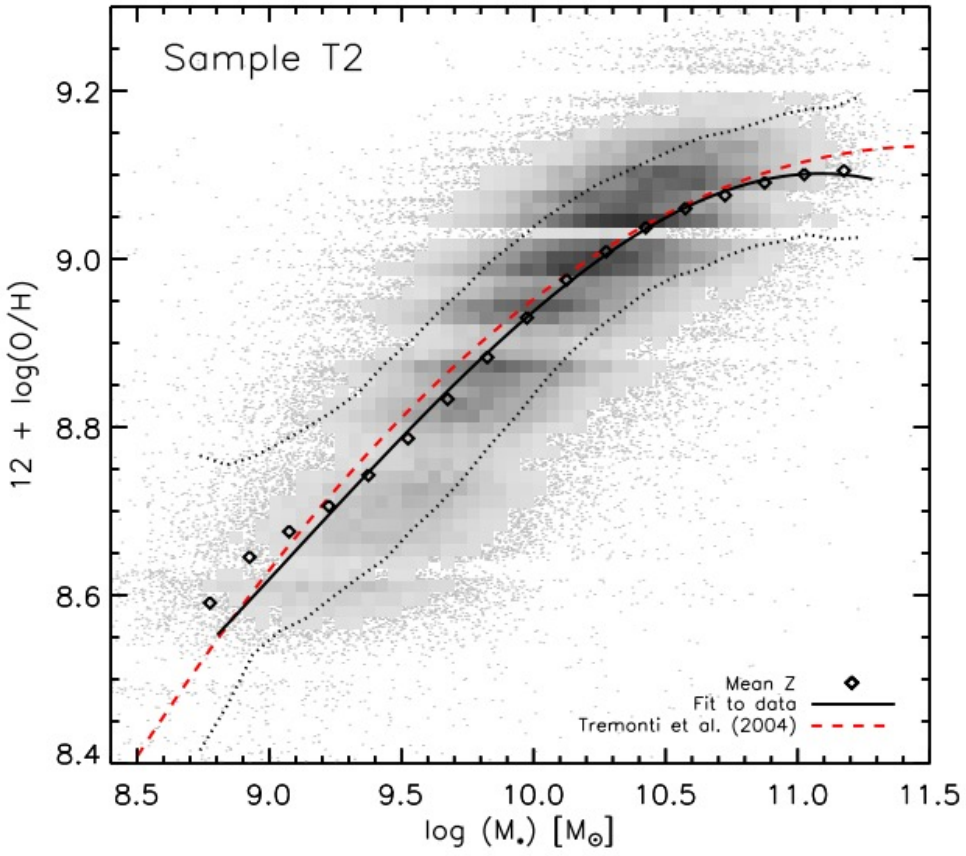
–2.5 metallicity here→

- Metallicity floor at [Fe/H] ~ -2.5, independent of galactic mass



Beasley et al. 2019

Metallicity of GCs



Tremonti et al. 2004; Yates et al. 2011

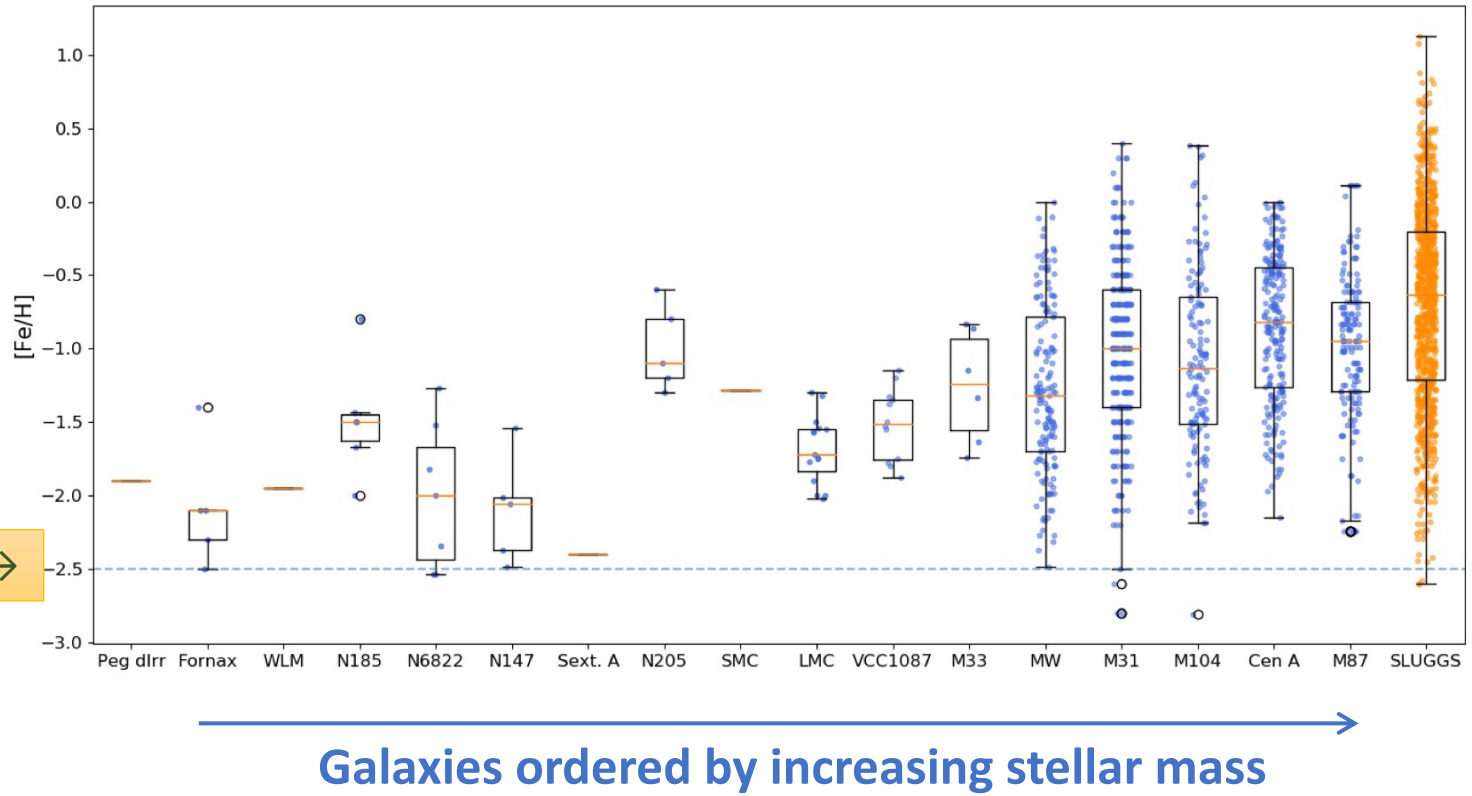
- Massive galaxies have higher metallicity
- We will expect more metal-poor GCs in less massive galaxies
- Scenario: Less massive galaxies convert gas reservoirs into stars over longer timescales, thus have higher gas-to-stellar ratio

Metallicity of GCs

- Metal-poor galaxies are not massive enough to support formation of any clusters that can survive till now

–2.5 metallicity here→

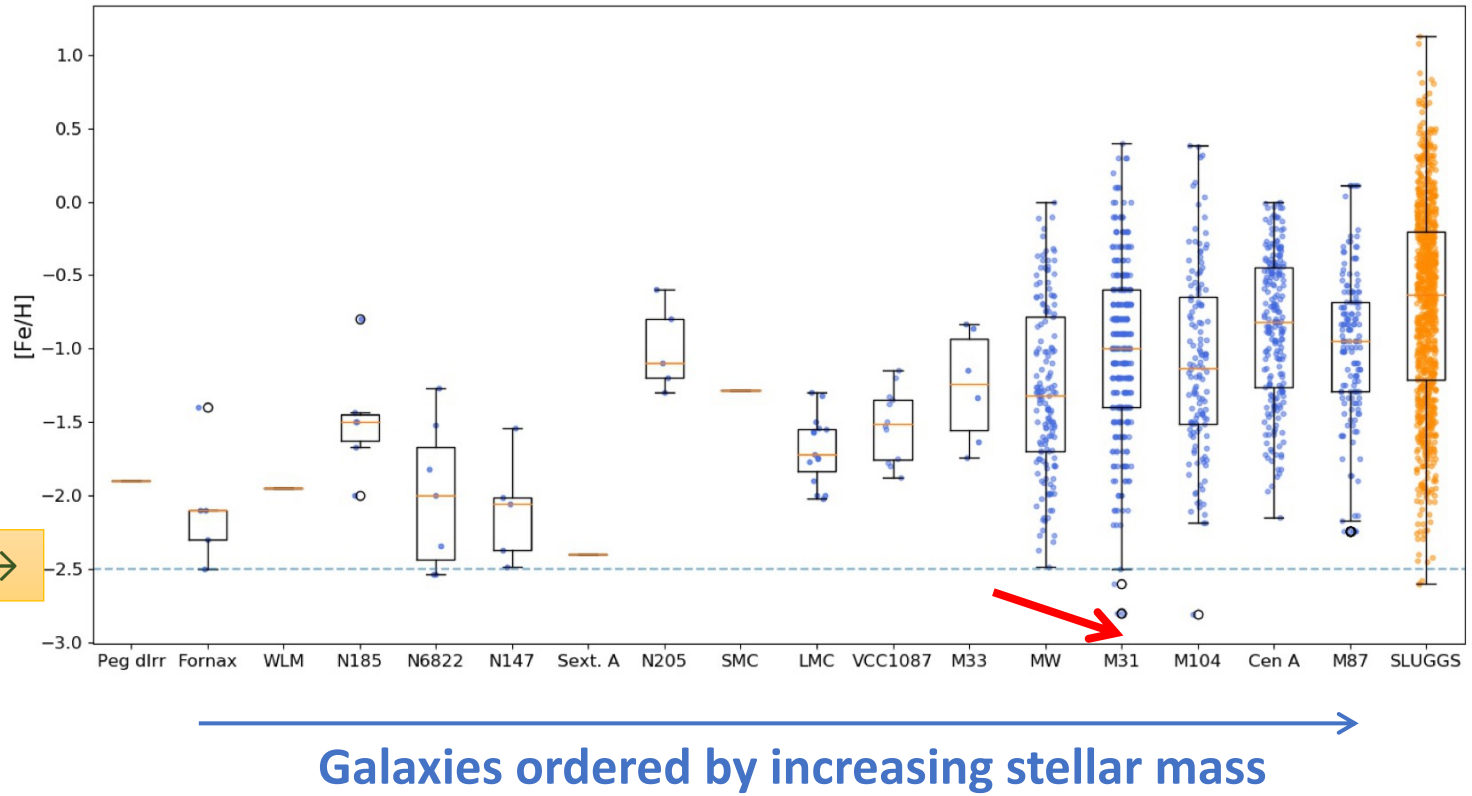
- Metal-poor ISM enriches sufficiently quickly that there is insufficient time to form EMPGCs



Beasley et al. 2019

Take-home-message

- An **old** and **massive** GC, **RBC EXT8 (hereafter EXT8)** located in M31, is **extremely metal-poor**



–2.5 metallicity here→

- It **challenges** the previously claimed **metallicity floor**

Beasley et al. 2019

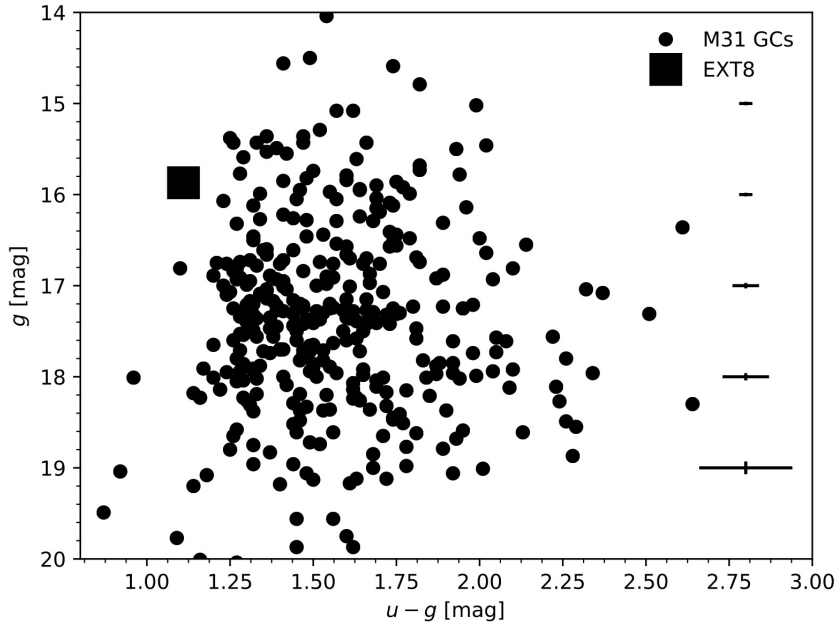
Detection method

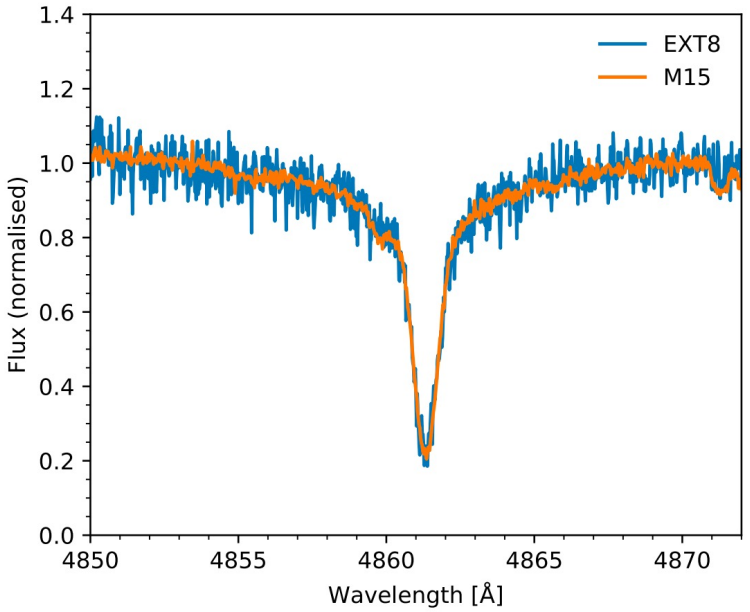
- Obtained a spectrum of the integrated light of **EXT8** with the High-Resolution Echelle Spectrometer (HIRES) on the Keck I telescope

- Compared with the spectrum of **M15**, observed by Ultraviolet and Visual Echelle Spectrograph (UVES) on VLT

EXT8 is an old, blue GC

- Much bluer than the other GCs, suggesting lower metallicity
- About the same age as M15, which is ~12 billion years

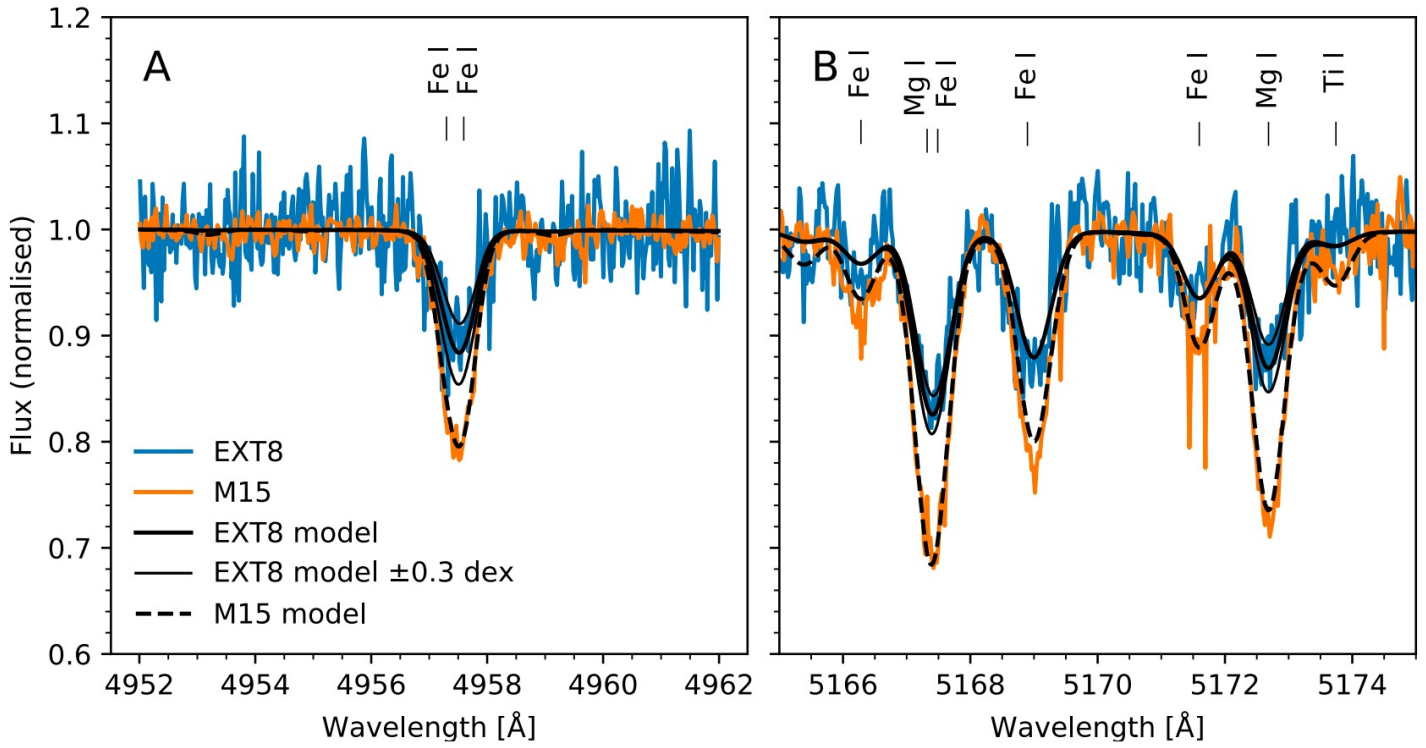




Larsen et al. 2020

EXT8 is extremely metal-poor

- A massive GC in Andromeda Galaxy (M31) that is extremely depleted in heavy elements
- Iron abundance of [Fe/H]=−2.91±0.04 for EXT8 from model fitting, compared to -2.39 of M15
- It is also Mg-poor with [Mg/Fe] ~ −0.35 ± 0.05

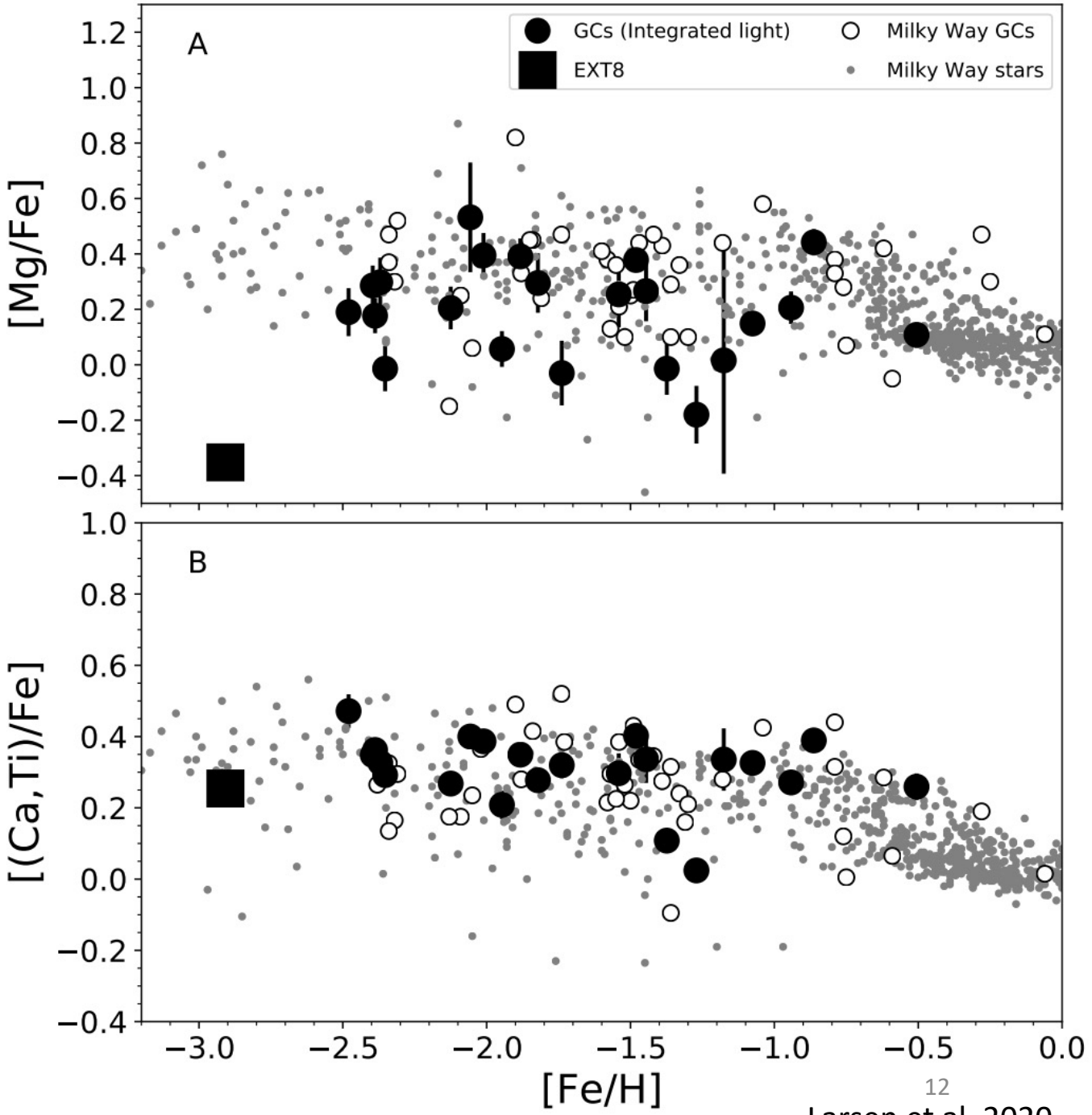


Larsen et al. 2020

EXT8 is extremely metal-poor

- EXT8 is an outlier of [Mg/Fe] vs. [Fe/H] plot.
- [α/Fe] overlaps with those seen in individual metal-poor stars and in other GCs
- Two populations?

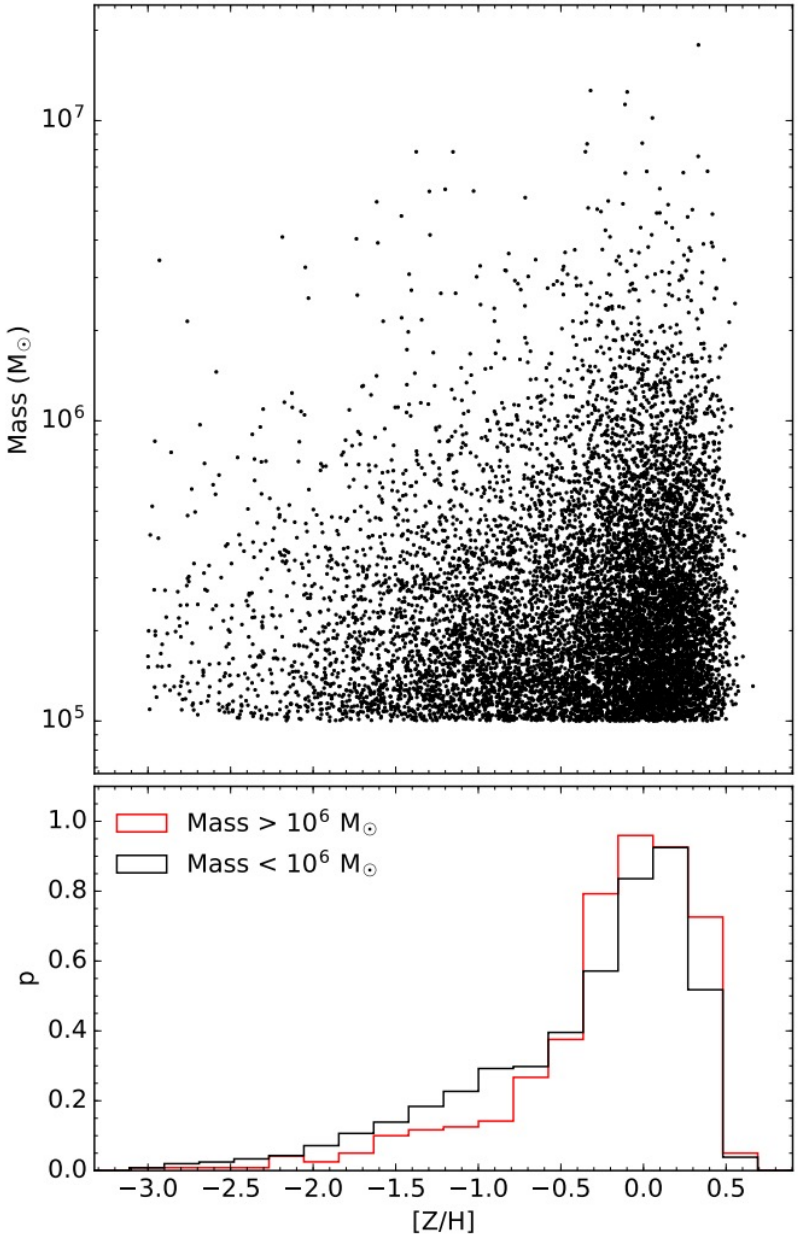
  with [Mg/Fe] ~−1.0 & +0.3



Larsen et al. 2020

EXT8 is massive

- EXT8 mass is (1.14±0.16) × 10^6 $M_\odot$
- The mass-metallicity correlation imprints a maximum mass for EXT8 at 10^5 $M_\odot$
- 3 out of 10,553 GCs have [Fe/H] < -2.5 and M> 10^6 $M_\odot$
- If half of the 400–500 GCs in M31 are more massive than 10^5 $M_\odot$, 6-7% of finding a single GC as massive and metal-poor as EXT8



Usher et al. 2018

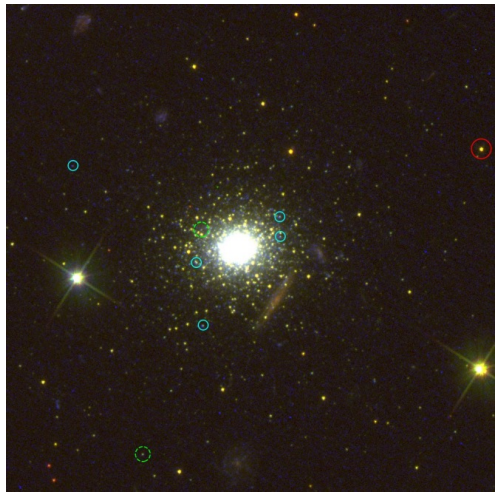
Significance of the study

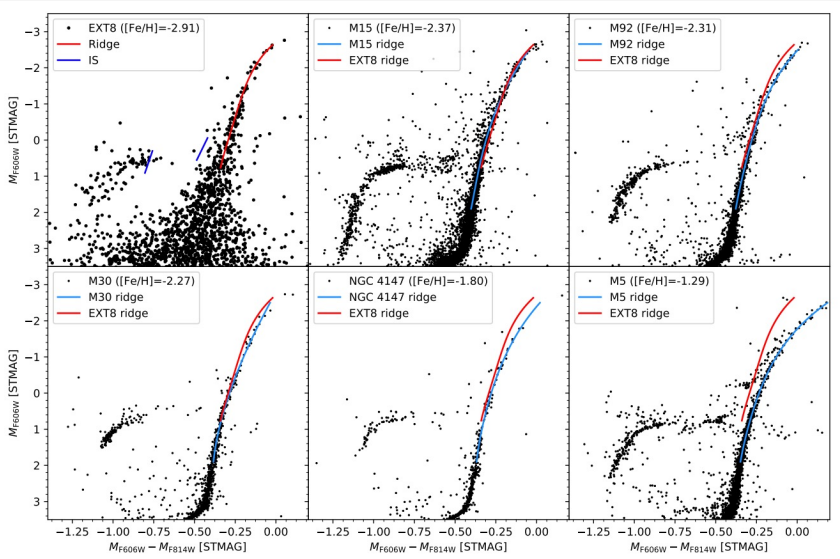
Challenges the current theory of metallicity floor for GCs

Scientists should re-examine the framework of the theory for massive GC formation

Follow-ups

- Color image of EXT8 produced from the HST/WFC3 images
- Color-magnitude diagram confirming its low metallicity
- Hope to find more metal-poor GCs and solve the mystery about their origin





Larsen et al. 2021

Summary

- GCs are related with oldest compositions of the galaxies, which will help us study the chemical composition of early universe
- GCs tend to be metal-poor, and there seems to be a theoretical metallicity floor according to previous model
- The most recent discovery of the old, massive and extremely metal-poor GC, RBC EXT8, which may include two populations of stars, challenges the metallicity floor and the theoretical model
- We could expect more massive metal-poor GCs to be found

Possible questions

- What is SLUGGS galaxy in the box-and-whisker plot?
- How come a bluer color suggests a lower metallicity?
- How was the age of M15 measured?
- If the 6-7% is true, why didn’t we see more of these massive metal-poor GCs before?