Tracing α-Element Enrichment in the Globular Clusters of the Starburst Dwarf Galaxy IC 10

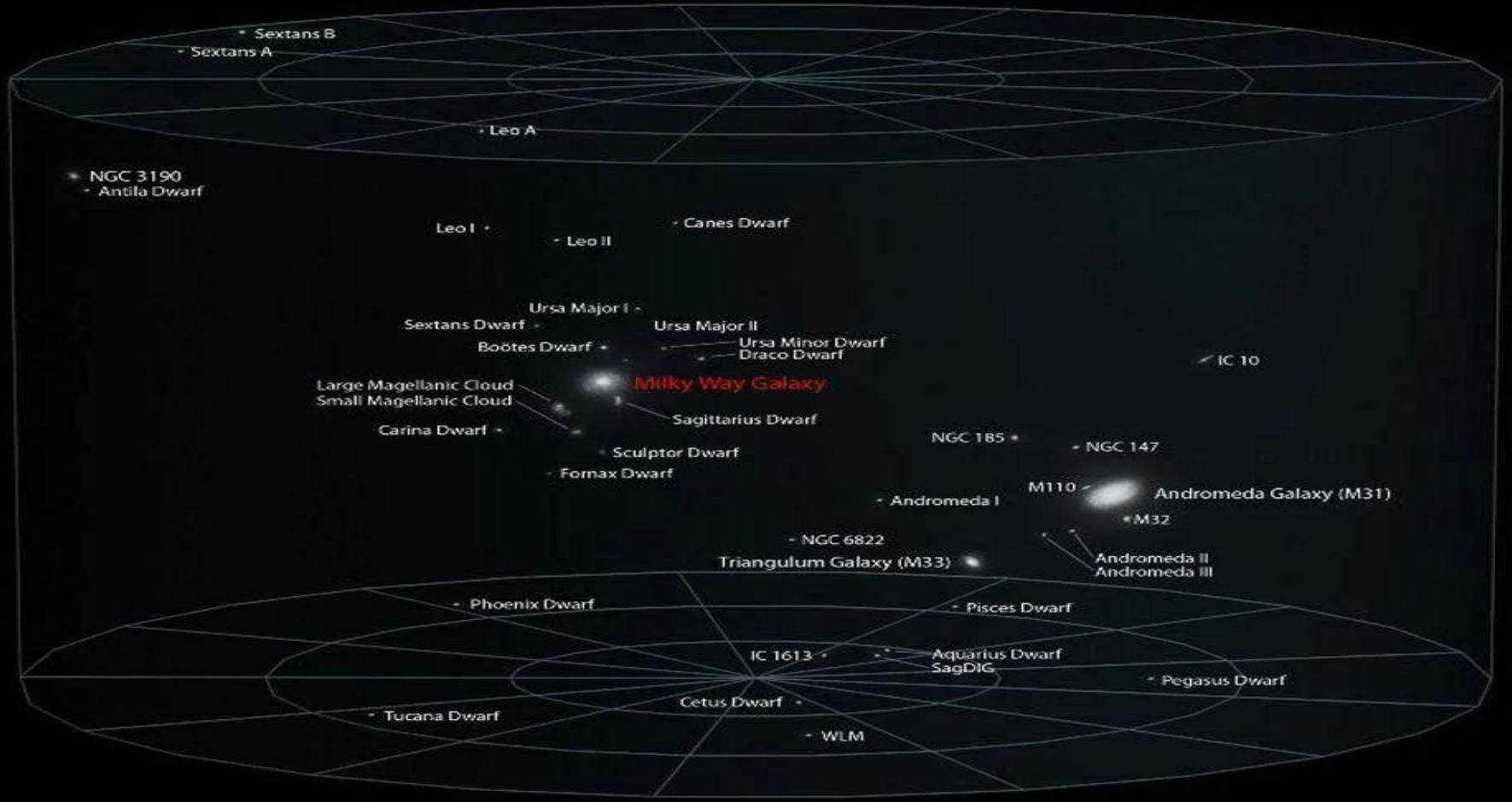
Mahtab Gholami, Benjamin Wehmeyer, Guru prasad, Ewa Niemczurat, and Tobias Bert Fischer

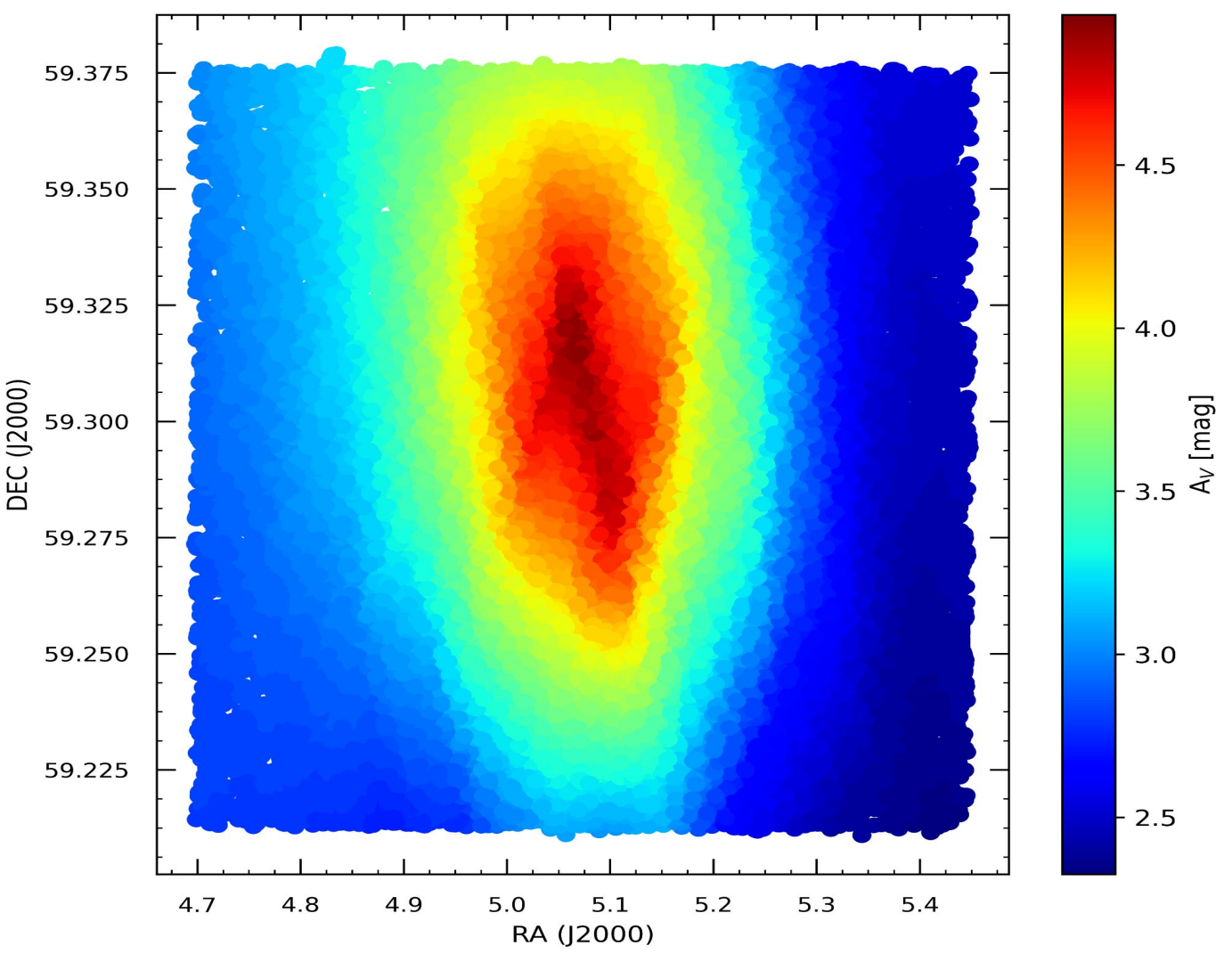
Osservatorio Astronomico di Capodimonte, INAF-OACN, Napoli, Italy.
University of Wroclaw, Wroclaw, Poland.
Polytechnic University of science and technology, Wroclaw, Poland.

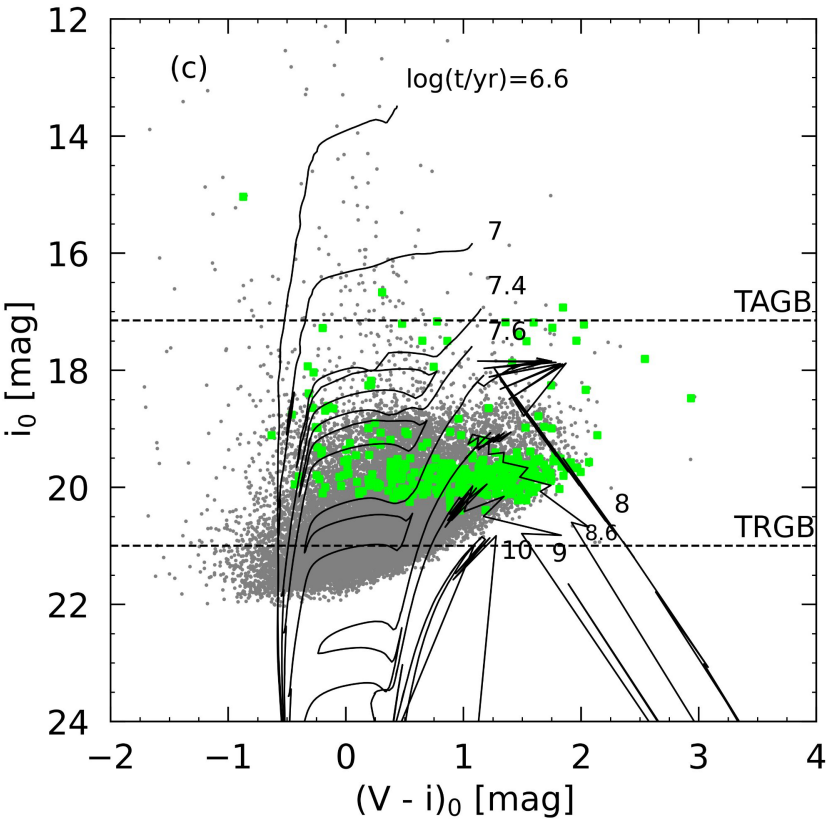
21–25 July 2025
Helmholtz-Zentrum
Dresden-Rossendorf (HZDR)

Credit: P. Massey/Lowell Observatory and K. Olsen/NOIRLab/NSF/AURA/

Local Galactic Group




59.375
59.350
59.325
59.300
59.275
59.250
59.225
DEC (J2000)
4.7
4.8
4.9
5.0
5.1
5.2
5.3
5.4
RA (J2000)
4.5
4.0
3.5
3.0
2.5
A_V [mag]



Gholami et al. (2023, 2025)

- IC 10 is a starburst dwarf irregular galaxy in the Local Group.
- It has complex enrichment and star formation history.
- We investigate its chemical evolution using new spectroscopic data and GCE models.

$$\mathrm{SFE} = \frac{\text{Star Formation Rate (SFR)}}{\text{Gas Mass } (M_{\mathrm{gas}})}$$

The **Kroupa IMF** is a **broken power-law** model, meaning the slope changes for different mass ranges:

$$\xi(m) \propto \begin{cases} m^{-0.3} & \text{for } 0.01 \leq m/M_\odot < 0.08 \quad \text{(brown dwarfs)} \\ m^{-1.3} & \text{for } 0.08 \leq m/M_\odot < 0.5 \quad \text{(low-mass stars)} \\ m^{-2.3} & \text{for } 0.5 \leq m/M_\odot < 100 \quad \text{(high-mass stars)} \end{cases}$$

This form matches observational data better than a single power law like the classic **Salpeter IMF** ($\alpha = 2.35$ for all masses).

Research Objectives

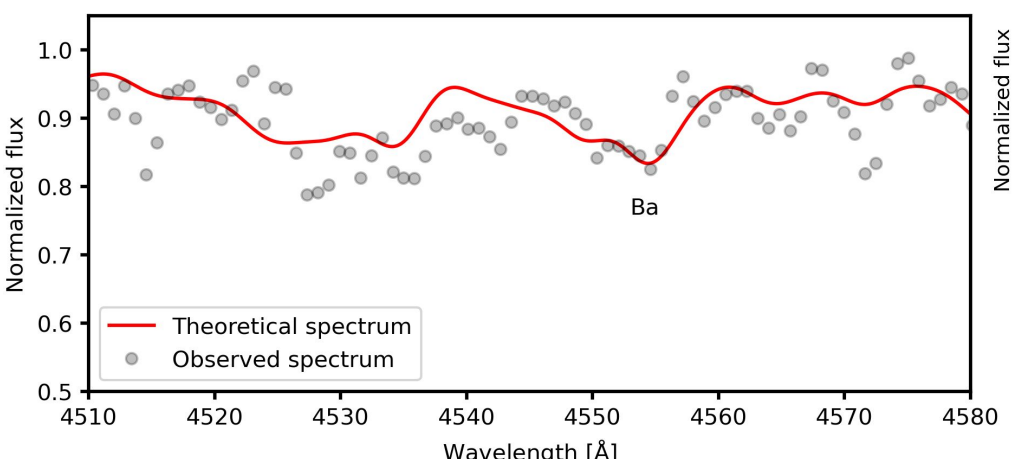
- Derive updated elemental abundances for IC 10’s globular clusters (GCs).
- Model the chemical evolution using **OMEGA** (Côté et al. 2019).
- Compare with existing literature and optimize the GCE parameters.

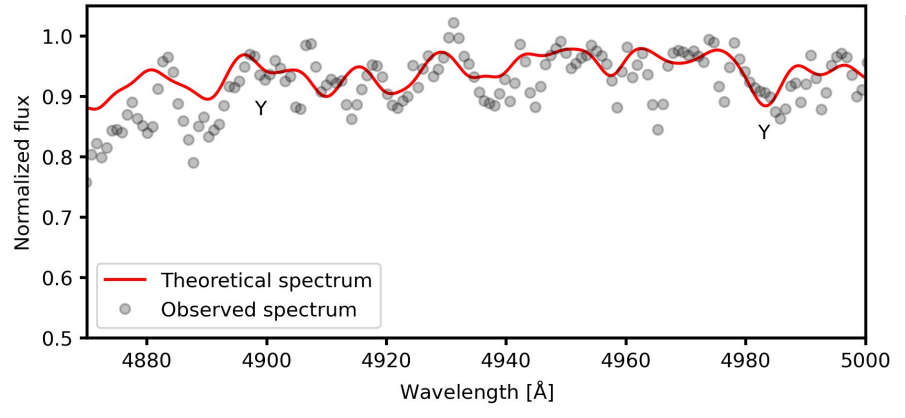
Observational Data

Sharina et al. (2010):

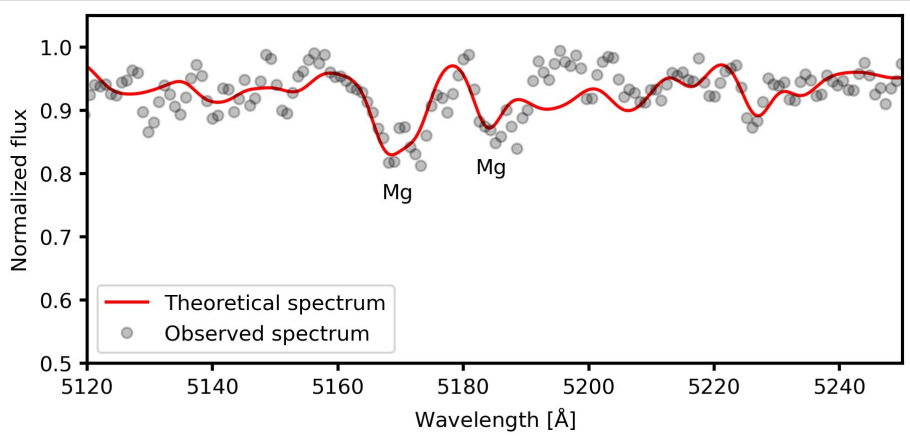
- Low-resolution optical spectra of 4 GCs.
- Metallicity [Z/H] < –0.8, with spread in ages

IC 10 GC Spectral Analysis



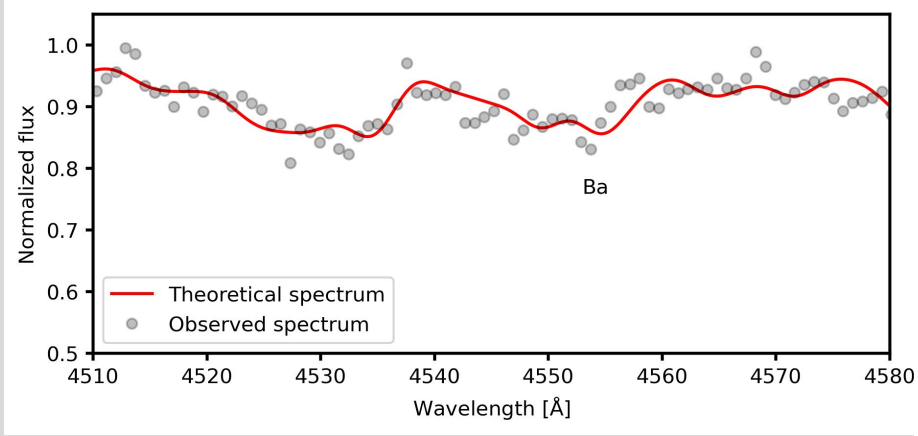


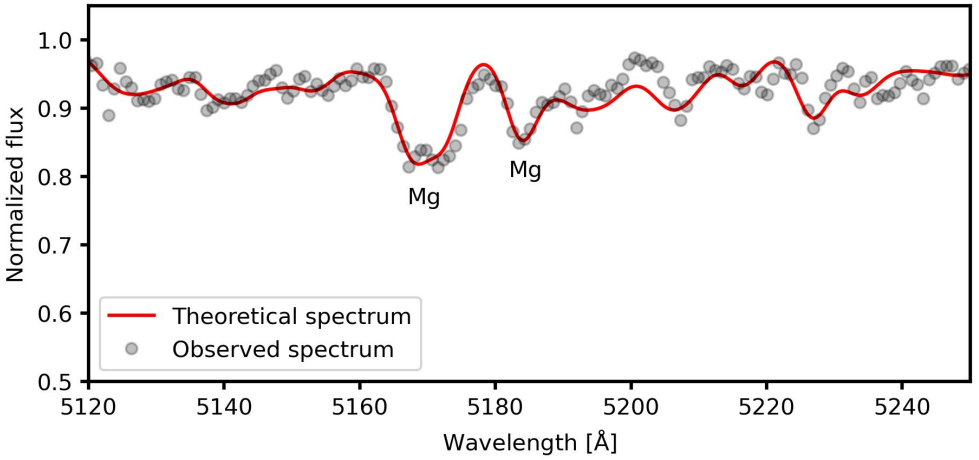
GC22

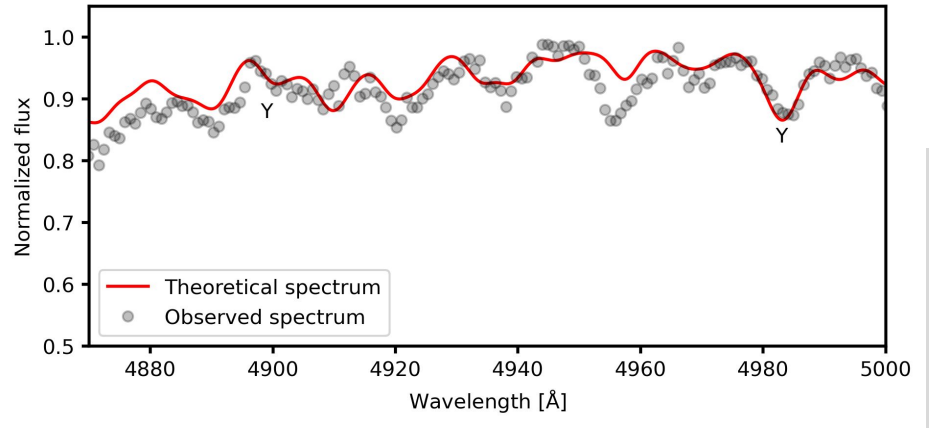


- GC22 and GC37 analyzed using ATLAS9 + SYNTHE.
- Parameters derived via χ^2 minimization:
  - GC22: Teff=5700K, logg=2.0, [Fe/H]=–0.8
  - GC37: Teff=5900K, logg=2.5, [Fe/H]=–0.6
- Elemental abundances: Mg, Y, Ba (using VidmaPy tools).

GC37


Normalized flux
Wavelength [Å]
Ba
Theoretical spectrum
Observed spectrum


Normalized flux
Wavelength [Å]
Mg
Mg
Theoretical spectrum
Observed spectrum


Normalized flux
Wavelength [Å]
Y
Y
Theoretical spectrum
Observed spectrum

Abundance Results

Table 1: Atmospheric parameters and elemental abundances for stars GC 22 and GC 37.

Parameter	GC 22			GC 37		
$T_{\rm eff}$ [K]	5700 ± 200			5900 ± 200		
$\log g$ [dex]	2.0 ± 0.5			2.5 ± 0.5		
[m/H] [dex]	-0.8 ± 0.2			-0.6 ± 0.2		
Element	$\log \epsilon$(X)	[X/H]	[X/Fe]	$\log \epsilon$(X)	[X/H]	[X/Fe]
Mg	−4.59	−0.09	+0.71	−4.39	+0.11	+0.71
Y	−10.63	−0.80	−0.00	−9.43	+0.40	+1.00
Ba	−9.21	+0.66	+1.46	−9.51	+0.36	+0.96
Fe	−5.34	−0.80	0.00	−5.14	−0.60	0.00

- GC22 and GC37 show **strong s-process enhancement**, especially in Ba.
- Suggests influence of intermediate-mass AGB stars in IC 10’s past.

Significance of [Mg/Fe] ≈ +0.71 in IC 10 Globular Clusters

- **Novel Measurement:**
  - First spectroscopic determination of [Mg/Fe] ≈ +0.71 in GCs GC22 and GC37 of IC 10.
  - To our knowledge, this is the first detailed α-element abundance measurement in these clusters.
- **Unusually High [Mg/Fe]:**
  - [Mg/Fe] ≈ +0.7 is exceptionally high for a dwarf irregular galaxy.
  - Comparable values are typically found in early Milky Way halo stars, not in systems like IC 10.
- **Implications for Chemical Evolution:**
  - Suggests rapid early star formation and dominance of core-collapse supernovae (Type II).
  - Indicates minimal contribution from Type Ia supernovae, which usually lower [α/Fe] over time.
- **Deviation from Expected Trends:**
  - Most dwarf galaxies exhibit lower [Mg/Fe] ratios (typically +0.2 to +0.4) due to:
    - Prolonged star formation histories.
    - Delayed enrichment by Type Ia supernovae.
- **Scientific Impact:**
  - Points to a brief, intense early starburst phase in IC 10.
  - Reinforces the hypothesis that chemical enrichment in low-mass galaxies can be extremely inhomogeneous and burst-driven.
- **Literature Context:**
  - Previous studies (e.g., Magrini et al. 2009; Sharina et al. 2010) focused on [Fe/H] and [O/H], not detailed α-element abundances.
  - This result fills a gap in the chemical abundance data for IC 10’s old stellar populations.

Chemical Evolution Model: OMEGA

- One-zone open-box model (Côté et al. 2019).
- Tracks:
  - Gas mass, SFR, outflows/inflows
  - Stellar feedback from CCSNe, AGB, SNe Ia
- Flexible setup for dwarf galaxies.
- Inputs: SFE, inflow law, yields, IMF.

Be sure not to miss Guru Prasad's talk on this topic on Frtiday!

Conclusion

- New abundance determinations in IC 10 globular clusters.
- OMEGA model accurately reproduces observed trends.
- Highlights:
  - Prolonged AGB enrichment
  - Slower chemical evolution in dwarf galaxies

The discovery of [Mg/Fe] ≈ +0.71 in IC 10's globular clusters reveals a previously unrecognized early α-enhanced enrichment episode, offering new insight into the galaxy's rapid and bursty chemical evolution, and marks a significant step forward in understanding stellar populations in dwarf irregular systems.

Credit: IC 10: Image taken by Hubble Space Telescope. © NASA, ESA, F. Bauer [435]