Exploring the Chemical Evolution Pathways of the Extremely Metal-poor Dwarf Galaxy Leonessa

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Introduction

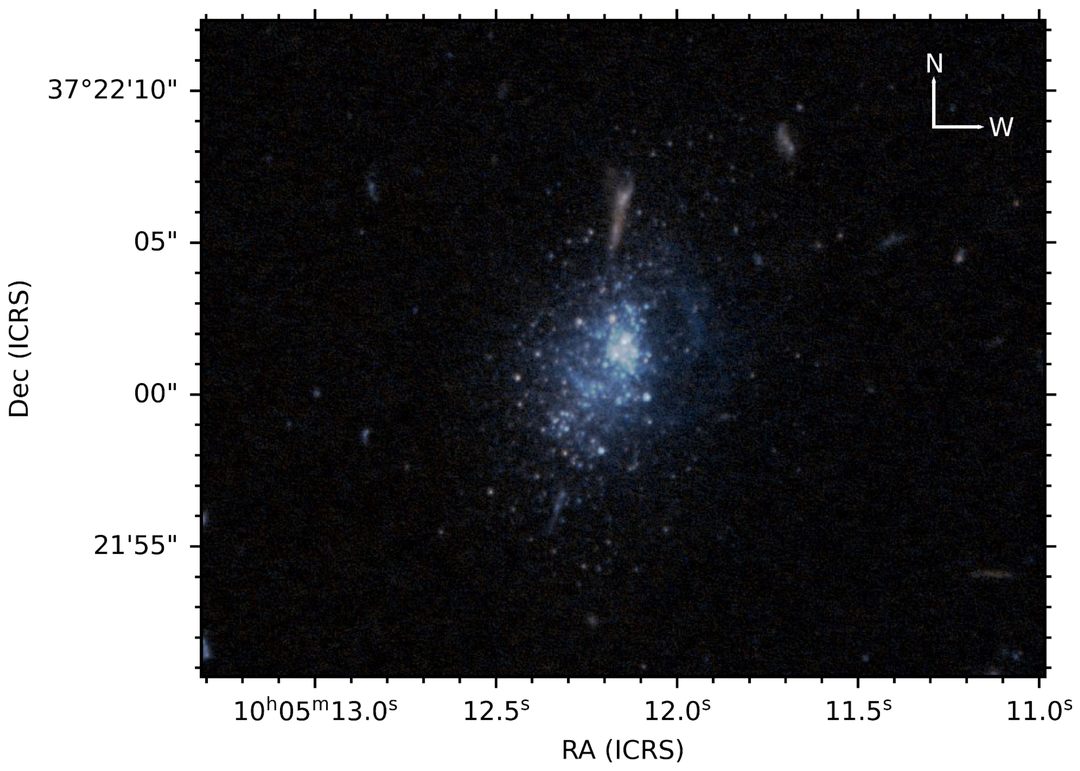
Extremely metal-poor (XMP) galaxies (gas-phase oxygen abundances of 12+log(O/H)≤7.35) in the nearby universe are low-mass, gas-rich systems that occupy the faint-end of the galaxy luminosity function. This makes them excellent laboratories for investigating galactic chemical evolution in the low-metallicity regimes of the mass- and luminosity-metallicity relations (MZR and LZR, respectively).

Here we present results from recent HST, GBT, KCWI, and HET observations of a newly discovered XMP galaxy, Leonessa. From these observations we quantify several of Leonessa's properties (see table for values). We then compare Leonessa, along with a sample of dwarf galaxies taken from the literature, to well-established MZR, LZR and nitrogen-to-oxygen (N/O-O/H) trends found for nearby low-mass field dwarf galaxies [2,6,7]. We also add gas-to-stellar mass ratios where reported.

Key Findings:

- **Leonessa XMP galaxy (12+log(O/H)=7.32±0.04) 15.92±0.66 Mpc away. It agrees with the MZR trend, but disagrees with the LZR trend.**
- **M_{HI}/M_* anti-correlates to 12+log(O/H)**
- **Large scatter in XMP regime of LZR and N/O-O/H.**

Figure 1: Color Image



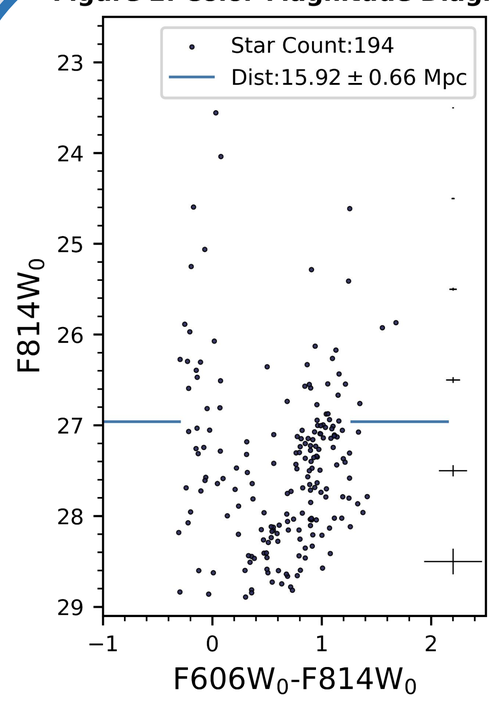
Properties of Leonessa

Parameter	Value
R.A. (J2000)	10:05:12.154
Dec. (J2000)	+37:22:01.55
12+log(O/H)	7.32 ± 0.04
log(N/O)	-1.41 ± 0.2
M_g (mag)	-11.92 ± 0.09
Distance Modulus (mag)	31.01 ± 0.09
Distance (Mpc)	15.92 ± 0.66
S_{HI} (mJy km s^{-1})	29.59 ± 6.73
M_{HI} ($M_\odot$)	(1.76 ± 0.46) × 10^6
M_* ($M_\odot$)	(1.32 ± 0.23) × 10^6
M_{HI}/M_*	1.33 ± 0.47

- **Fig. 1** presents a color image of Leonessa created from the HST ACS observations (F606W, and F814W filters).
- Young, massive stars can be seen occupying the central star forming region, while redder stellar populations exist in the outskirts of the galaxy.
- To the NW and SE of the central star forming region, we see strong nebular emission defining faint, curve-like structures.

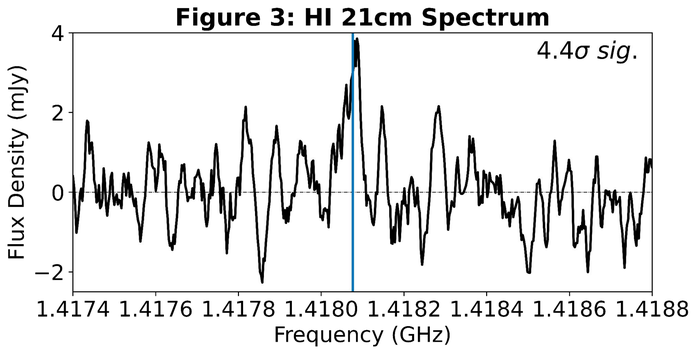
Data & Results

Figure 2: Color-Magnitude Diagram



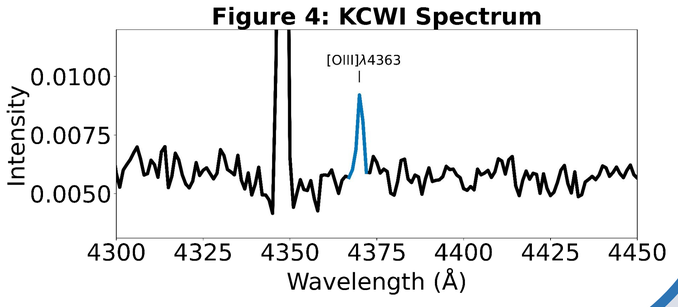
- In **Fig. 2** we present a CMD of the 194 stars recovered from the HST observations of Leonessa using DOLPHOT. A well-defined main sequence and red giant branch are found at a F606W-F814W color of ~-0.3 and ~1.0, respectively.
- From the measured tip of the red giant branch (TRGB) magnitude (blue horizontal line in **Fig. 2**) we determine a distance to Leonessa of 15.92±0.66.
- Using the TRGB distance we calculate a stellar mass of $\log(M_*/M_\odot)$=6.12±0.08, using SDSS *r*- and *i*-band magnitudes [1,4].
- The refined distance finds the system located within the Cnr-CMi-Hyd void [5], with the nearest neighboring galaxy at a proximity of ~1.9 Mpc.

Figure 3: HI 21cm Spectrum



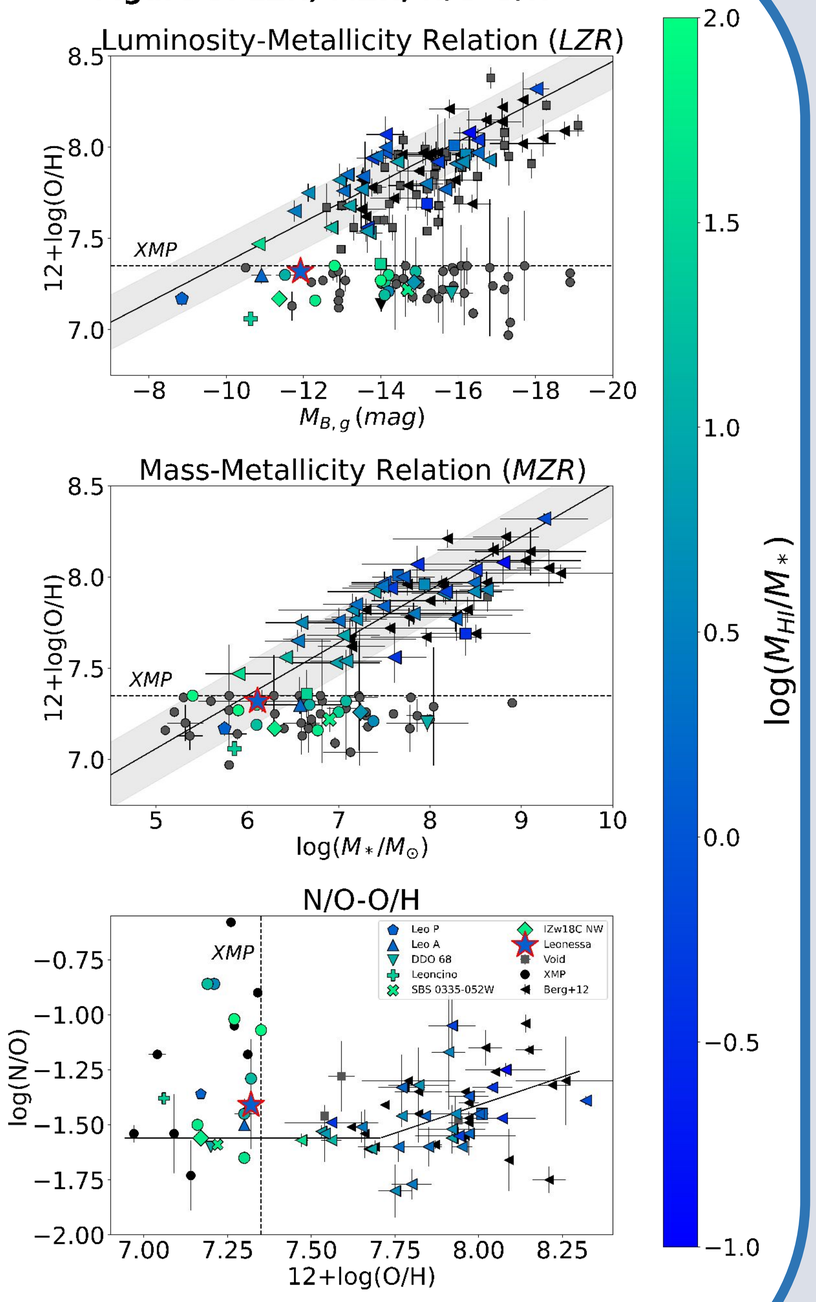
- **Fig. 3** presents the GBT 21cm radio spectrum for Leonessa. The line displays a thin Gaussian profile, indicative of a quiescent gas disk, with a low velocity dispersion.
- Using HI 21cm flux and TRGB distance we calculate a gas-mass of $\log(M_{HI}/M_\odot)$=6.25±0.11 [3].
- **Fig. 4** presents the [OIII]λ4363 line, from which a gas-phase oxygen abundance of 12+log(O/H)=7.32±0.04 was measured using the `direct' method.
- The N/O (see Fig. 5, bottom panel) ratio was determined from the [NII]λ6548 line in the HET spectrum.

Figure 4: KCWI Spectrum



Conclusions

Figure 5: LZR, MZR, N/O-O/H



- **Fig. 5** compares Leonessa, along with a sample of dwarf galaxies, to well-established LZR, MZR, and N/O-O/H trends (solid black lines) for nearby galaxies.
- XMP galaxies show a significant scatter away from the trends on all three planes, with the LZR having the greatest dispersion.
- When gas-to-stellar mass ratios (**Fig. 5;** colobar) are added to the planes they show a clear anti-correlation with metallicity.
- Leonessa disagrees with the LZR trend, is consistent with the MZR trend, and is slightly offset from the N/O-O/H trend.
- Leonessa is a gas-rich system though it is considerably less gas-rich than a majority of XMP systems.
- We conclude that Leonessa has followed a chemical evolution path to be expected for low-mass galaxies; its divergence from the LZR trend is likely the result of recent star formation skewing its luminosity brighter.

References

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