Comparing Fe Abundances in Neutral and Ionized Gas in the Magellanic Clouds

Fe/H is *lower* in some H II regions than in adjacent neutral gas

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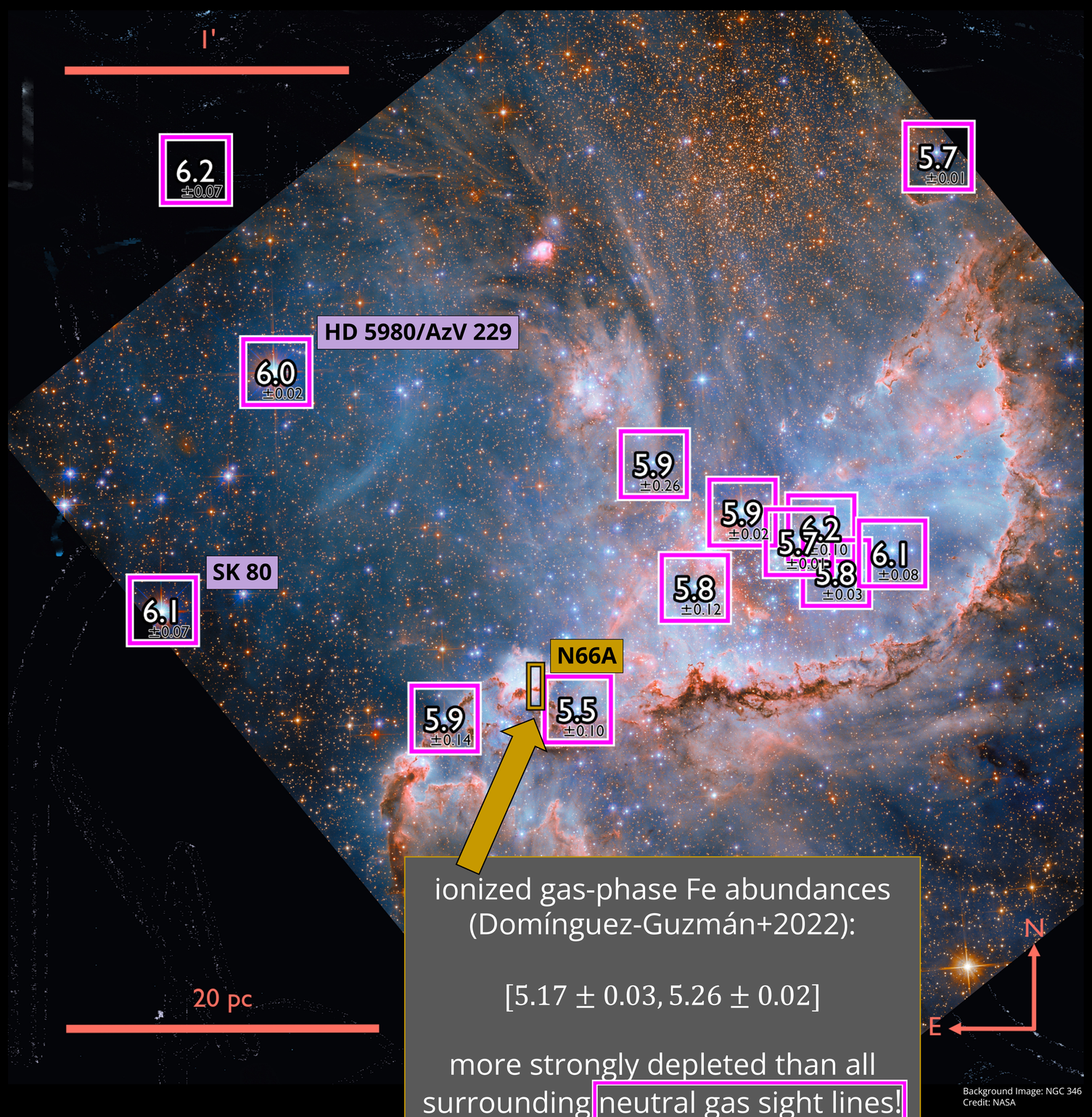
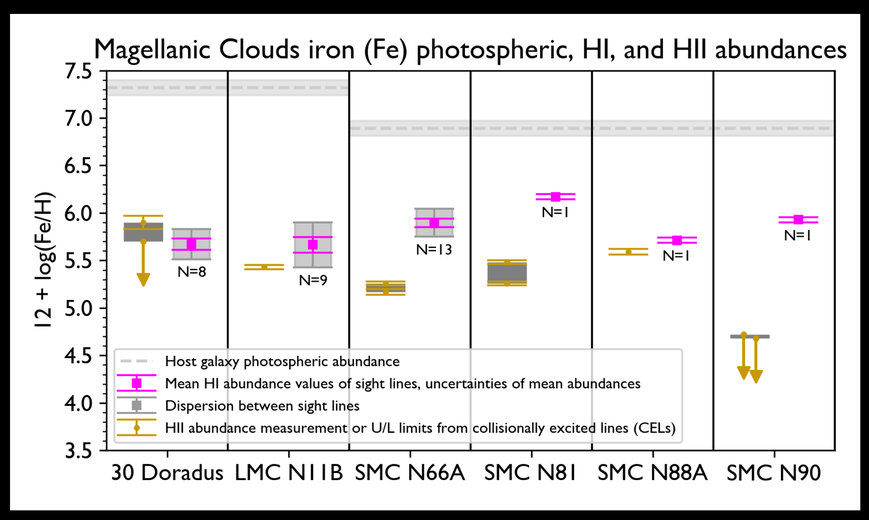


We compared the neutral gas-phase elemental abundances in the Magellanic Clouds, measured from UV absorption lines or adopted from previous studies [4, 11], to H II region abundances accumulated from the literature [1, 8, 14]. For sightlines that are within 3' from H II regions in the Large and Small Magellanic Clouds (LMC, SMC), we measured the sulfur (S) and iron (Fe) abundances using multiple S II and Fe II transitions. We found that S abundances are consistent over stars, neutral gas, and ionized gas – indicating no significant depletion onto dust. Fe is more strongly depleted for H II regions N66A, N81, and N90 in the SMC than surrounding neutral gas. Fe incorporation onto dust is possibly completed in the cold, dense molecular clouds preceding the H II regions. Physical and chemical properties of the pre-H II clouds may constrain the Fe grain species; variation of depletion across environments can be resulting from the grain growth mechanism; and the properties of the subsequent H II regions can inform grain processes.

Figure 1. Neutral gas-phase Fe abundances along sightlines, shown in the squares as 12 + log(Fe/H) compared to the ionized gas-phase Fe abundance in the compact SMC H II region N66A. We measured the neutral gas-phase abundances from HST/COS and HST/STIS UV absorption spectra with stars as background continua. The Fe abundance of N66A is adopted from a VLT/UVES study by Domínguez-Guzmán et al. (2022); the ocher arrow points at the position of the slit.



The neutral ISM abundances are consistent with established studies [4, 10, 11, 12]; the ionized ISM abundances generally match correlations with large local and extragalactic samples [1, 5]. We speculate Fe depleted onto dust in dense clouds and survived the subsequent onset of H II ionization: dust has previously been observed in H II regions [2, 6, 13]. Other possible scenarios: alternative ionization mechanisms [5]; multi-component ISM along sightline [6]; recent cold gas-infall [3].

Figure 2. Fe abundance/depletion comparisons for six H II regions and neutral gas sightlines in their vicinity. The number of available neutral gas sightlines are labelled with N. The Fe abundance of SMC N88A (5th column) is the ionic sum of Fe III and Fe IV, while the other H II Fe abundances are ionization corrected from only Fe III measurements [1]. The upper and lower limits represent two different ionization correction schemes [9].

Contact

Data and notebooks:

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1. Domínguez-Guzmán, G., Rodríguez, M., García-Rojas, J., Esteban, C. & Toribio San Cipriano, L. The homogeneity of chemical abundances in H ii regions of the Magellanic Clouds. Monthly Notices of the Royal Astronomical Society 517, 4497–4514 (2022).
2. Faison, M. et al. Infrared Spectroscopy of Ultracompact H II Regions. The Astrophysical Journal 500, 280–290 (1998).
3. Hernandez, S. et al. First Cospatial Comparison of Stellar, Neutral-gas, and Ionized-gas Metallicities in a Metal-rich Galaxy: M83. The Astrophysical Journal 908, 226 (2021).
4. Jenkins, E. B. & Wallerstein, G. Interstellar Gas-phase Element Depletions in the Small Magellanic Cloud: A Guide to Correcting for Dust in QSO Absorption Line Systems∗. ApJ 838, 85 (2017).
5. Méndez-Delgado, J. E. et al. Gas-phase Fe/O and Fe/N abundances in star-forming regions: Relations between nucleosynthesis, metallicity, and dust. Astronomy and Astrophysics 690, A248 (2024).
6. Murray, C. E. et al. A Galactic Eclipse: The Small Magellanic Cloud Is Forming Stars in Two Superimposed Systems. The Astrophysical Journal 962, 120 (2024).
7. Paladini, R. et al. Spitzer and Herschel Multiwavelength Characterization of the Dust Content of Evolved H II Regions. The Astrophysical Journal 760, 149 (2012).
8. Peimbert, A. The Chemical Composition of the 30 Doradus Nebula Derived from Very Large Telescope Echelle Spectrophotometry*. ApJ 584, 735 (2003).
9. Rodríguez, M. & Rubin, R. H. The [Fe IV] Discrepancy: Constraining the Iron Abundances in Nebulae. The Astrophysical Journal 626, 900–908 (2005).
10. Roman-Duval, J. et al. METAL: The Metal Evolution, Transport, and Abundance in the Large Magellanic Cloud Hubble Program. II. Variations of Interstellar Depletions and Dust-to-gas Ratio within the LMC. ApJ 910, 95 (2021).
11. Roman-Duval, J. et al. METAL: The Metal Evolution, Transport, and Abundance in the Large Magellanic Cloud Hubble Program. III. Interstellar Depletions, Dust-to-Metal, and Dust-to-Gas Ratios versus Metallicity. ApJ 928, 90 (2022).
12. Roman-Duval, J. et al. METAL: The Metal Evolution, Transport, and Abundance in the Large Magellanic Cloud Hubble Program. I. Overview and Initial Results. ApJ 871, 151 (2019).
13. Stephens, I. W. et al. Spitzer Observations of Dust Emission from H II Regions in the Large Magellanic Cloud. The Astrophysical Journal 784, 147 (2014).
14. Toribio San Cipriano, L. et al. Carbon and oxygen in H ii regions of the Magellanic Clouds: abundance discrepancy and chemical evolution. Monthly Notices of the Royal Astronomical Society 467, 3759–3774 (2017).

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