Neutral ISM surrounding starburst regions

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We present the far-UV spectroscopic study of NGC604, a giant HII region in the spiral galaxy M33. Numerous atomic hydrogen and metals lines are observed in absorption against the continuum of the young, massive stars embedded in the ionized gas. Profile fitting of absorption lines allowed us to determine the chemical composition of the diffuse neutral gas in front of the stellar cluster. We find that nitrogen, oxygen, argon and iron are underabundant by a factor ~6 in the neutral phase in comparison with the ionized phase, suggesting the presence of very low metallicity gas in the line of sight.

1. OBSERVATIONS

1. NGC604 is an ideal object to study abundances in the extraplanar ISM and in particular the influence of a starburst on its environment. Furthermore, NGC604, as a single HII region, is able to provide useful indications to analyze galaxies absorption spectra.

2. In order to correct for the effects of the source’s spatial extension on absorption lines profiles, we have obtained FUSE spectra with two different slits (see fig. 1).

2. METHOD AND DATA ANALYSIS

1. Sightlines toward the youngest stars intersect specie from the diffuse neutral gas.

2. From the resulting absorption spectra (fig. 2), it is possible to determine the neutral chemical composition.

3. MOLECULAR HYDROGEN

1. Profiles of absorption lines are adjusted by a $g^2$ minimization with the Owens procedure. This program returns the most likely values of free parameters such as gas velocity, column densities, turbulent velocities, shape and intensity of the continuum, line broadening and zero level.

2. Errors are estimated by the same program and include uncertainties on all the free parameters.

3. The spatial distribution of the stars within the slit (see fig. 3) degenerates lines resolution.

4. We avoid systematic errors by including an additional broadening of all the lines. Column densities (Table 3) determinations account for the spatial extension in the far-UV.

4. ATOMIC HYDROGEN

1. with FUSE, HI column density is mainly constrained by the damping wings of Lyman-β. Because of stellar contamination by OVI Pcygni component, we have analyzed the profile of the “blue” wing only (see fig. 9).

2. with STIS: the Lyman-β profile of the star field (in $S^2$) cannot be adjusted considering only the instrumental broadening. It is necessary to include an additional broadening in order to account for the multiple lines of sight (see fig. 10).

3. with STIS: it is also possible to measure H column density toward each star in the slit. We measure variations up to 0.4 dex (see fig. 5), suggesting inhomogeneities of the diffuse neutral gas. Column densities toward the brightest stars are close to the global HI column density.

5. IONIZATION CORRECTIONS

1. Abundances are derived from column densities and must take into account the ionization of the medium. A priori, in the neutral gas (where hydrogen is in H0, one expects that oxygen is in OIII). Simultaneously, H, O, Fe, and P should be also the dominant stages.

2. We have modeled the HII region with the photoionization code CLOUDY in order to check these assumptions.

3. H and O are well coupled with HI in the neutral gas and these species do not show significant amount of HI (see fig. 2).

4. HII is also coupled, but only deep in the neutral cloud, suggesting that a little ionization correction is necessary since argon could exist in this phase.

5. Finally, FeII, PII and FeII are coupled with HI in the neutral gas but can be found in the HII gas, but this is significant only for FeII.

6. DISCUSSION

1. With FUSE, we measure absorption of the diffuse neutral gas in front of the cluster NGC604.

2. Column densities account for the spatial extension of the source. We assume that the neutral gas is homogeneous.

3. Stellar populations models have been used to constrain the continuum and identify possible contamination by the absorption of stellar atmospheres.

4. The combination structure has been investigated. HI, PII, FeII and FeII reveal to be g0 tidal traces of the neutral gas. Argon is mainly in H0.

5. Argon, oxygen, nitrogen, and iron are underabundant in the neutral gas by a factor ~6.

6. Kunth & Sargent (1986) proposed that the HII region of the dwarf star-forming galaxy ULaB has enriched itself with metals produced during the current burst and expelled by supernovae and stellar winds. However, the metallicity differences observed in NGC604 cannot be due only to such a self-enrichment. Indeed, only 1% of elements (in particular O and Ar) but not FeII, mainly produced by massive stars, are likely to enrich the HII gas.

7. In NGC604, we also observe that iron is underabundant, suggesting that all abundances of neutral specie are actually lower because of the presence of less processed regions in the line of sight.

8. These results could suffer from observational systematic errors that await to be checked (for instance the presence of hidden saturation). If metals are indeed underabundant in the diffuse neutral gas, this opens the question of mixing at large scales and would bring a new perspective on the chemical evolution of elements in the ISM.

References:

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Additional broadening is brought by the multiple lines of sight. 

$N(HI) = 210$ km s$^{-1}$

$N(HI) = 20.96$ km s$^{-1}$

$N(HI) = 21.0$ km s$^{-1}$

$N(HI) = 20.96$ km s$^{-1}$