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Overview:

Using a newly developed Spatial Heterodyne Spectrometer (SWS), we have obtained the first radial velocity resolved emission-line profiles of diffuse [OII] (λ3726 and λ3729) and the [NII] (λ6548 and λ6583) lines in the intergalactic medium (ISM) of our Galaxy. The [OII] emission is from thermal excitation to the doublet D° 3, 3.3 eV above ground. Since this excitation energy is significantly larger than the ionization energy of the red [NII] and [SII] lines (1.9 eV), variations in electron temperature will result in a significant and (quantitatively) predictable variation in the [OII]/[NII] and [SII]/[NII] intensity ratios. This is the most direct observation of oxygen in the diffuse medium (with λ0/O near unity implied by both observations of [OII] and [SII]) as well as a primary forbidden line coolant. This means that the [OII] will be relatively bright, compared to the [SII], and that any variations in these ratios can be used to trace the temperature in the intergalactic medium (ISM) of our Galaxy.

The Crucial Test Provided by [OII] λ3727:

Because of the potentially profound consequences for understanding heating and ionization processes within the intergalactic halo, it is important to develop the ability to verify that variations in [NII]/[OII] and [SII]/[OII] within the intergalactic medium are in fact due to temperature variations, and not the result of peculiar ionization effects. A definitive method of discrimination would be to measure and compare the associated variations in [OII]/[NII] and [SII]/[NII]. The [OII] emission line results from thermal excitation to the doublet D° 3, 3.3 eV above ground. Since this excitation energy is significantly larger than that of the red [NII] and [SII] lines (1.9 eV), variations in electron temperature will result in a significant and (quantitatively) predictable variation in the [OII]/[NII] and [SII]/[NII] intensity ratios. This is the most direct test of the ionization state of oxygen in the diffuse medium (with λ0/O near unity implied by both observations of [OII] and [SII]) as well as a primary forbidden line coolant. This means that the [OII] will be relatively bright, compared to the [SII], and that any variations in the ratios (i.e., [OII] and [SII]) can be used to trace the temperature in the intergalactic medium (ISM) of our Galaxy.

Observations & Results:

We carried out velocity-resolved observations of the [OII] doublet emission over a region of the sky already mapped by WHAM in [NII] (λ0, 6583 and λ0, 6548). A series of 10 minutes exposures toward target galaxies are interpreted with exposures toward high Galactic latitude regions where only little interstellar [OII] emission is expected. This “on-off” technique is used to identify terrestrial emission, which can be included in the [OII] emission determination or used as an additional calibration line; refer to Figure 3. Our observations confirm the super-bright performance of the SWS technique for measurements of spatially extended faint emissions, including the first detection of [OII] emission extending outside of 20° from the Galactic equator in the longitude range of −10° to 150°. [OII] intensities range from tenths of Rayleighs near the Galactic plane to less than one Rayleigh at high Galactic latitude (Mierkiewicz et al., 2006). The [OII] line profiles clearly show structure indicating emission along the lines of sight from both local interstellar and more distant gas Doppler shifted by different Galactic rotation; refer to Figure 4.

This conclusion is borne out quantitatively. In Figure 5, observations of [NII] and [OII] (which are plotted versus [NII]/[OII] for the low velocity (local) gas) confirm our prediction of temperature variations within the diffuse ionized gas (DIG) by uniting two different observations of [OII] (46 and 64) and comparing those to predictions of the temperature structure of the DIG obtained with WHAM. The higher [OII] and [NII] line intensity ratios for the low velocity component (near LSIR) toward [OII] λ6548, λ6560, λ6576, λ6583 compared to that toward [OII] λ6548, λ6560, λ6576, λ6583 suggests the temperature of the former direction has a substantially higher temperature than that toward the latter direction. Not only are [OII] and [NII] line intensities higher in the higher temperature enhancement in [OII] than in that of [NII] just as predicted if the line ratio variations are due to variations in temperature (the excitation energy for [OII] is significantly higher than that for [NII]).

Line Ratios:

Line ratio comparisons of the SWS [OIII] spectra with WHAM spectra of [NII] and [OII] confirm the value of the [OII] observations as a diagnostics for variations in temperature within the diffuse ionized gas. This is illustrated in Figure 6, which shows spectra of [OII] toward two directions obtained with the SHS (4a and 4c) and compared to spectra of [NII] toward the same directions obtained with WHAM. The higher [OII] and [NII] line intensity ratios for the low velocity component near LSIR] toward [OII] λ6367, λ6370 compared to that toward [OII] λ6367, λ6370 suggests the component toward the former direction has a substantially higher temperature than that toward the latter direction. Not only are [OII] and [NII] line intensities higher in the higher temperature enhancement in [OII] than in that of [NII] just as predicted if the line ratio variations are due to variations in temperature (the excitation energy for [OII] is significantly higher than that for [NII]).

Conclusions:

The detection and study of diffuse intergalactic [OII] λ3726–9 emission has provided strong evidence that the large variations observed in [NII] and [OII] intensity ratios are the result of significant (100–3000 K) temperature variations within the diffuse ionized gas of the Milky Way. The reason for these temperature variations is not yet known.

References:


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