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Metallicity Structure across the Galactic Disk: Radio Observations of H II Regions

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Abstract. H II regions are the sites of massive star formation and are the archetypal tracers of spiral arms. Because of their short lifetimes (< 10 Myr) their abundances provide a measure of the nuclear processing of many stellar generations. Here we review our ongoing efforts to explore the metallicity structure of the Galactic disk by observing radio recombination line (RRL) and thermal radio continuum emission toward H II regions. The RRL-to-continuum ratio provides an accurate measure of the electron temperature which is used as a proxy for metallicity. Since collisionally excited lines from metals (e.g., O, C) are the main coolant in H II regions, the thermal electron temperature is well correlated with metallicity (e.g., [O/H]). We determine H II region distances from maser parallax measurements when possible; otherwise we use kinematic distances. Such radio diagnostics of H II regions yield an extinction free tracer to map the metallicity distribution across the entire Galactic disk.

Keywords. Galaxy: structure, ISM: H II regions, radio lines: ISM

1. Background

We use infrared and radio surveys of the Milky Way to identify potential H II regions (Anderson *et al.* 2014). Infrared images from the Wide-field Infrared Survey Explorer (*WISE*) reveal emission from stochastically heated small dust grains within the ionized gas at 22μm, coincident with radio continuum, surrounded by polycyclic aromatic hydrocarbon (PAH) emission at 12μm. We measure the RRL and thermal (free-free) continuum emission toward H II region candidates using the Green Bank Telescope (GBT). Detection of a RRL confirms that the source is an H II region and provides a velocity which, together with a model of Galactic rotation, yields a kinematic distance (Bania et al. 2010). Parallax distances are used if available (e.g., Reid *et al.* 2014). The RRL-to-continuum ratio is proportional to the electron temperature which can be used as a proxy for metallicity. We detect both radial and azimuthal metallicity structure in the Galactic disk (Figure 1). The flatter radial gradients along the axis of the bar may be due to radial mixing from the Galactic bar (e.g., see Kubryk *et al.* 2013).

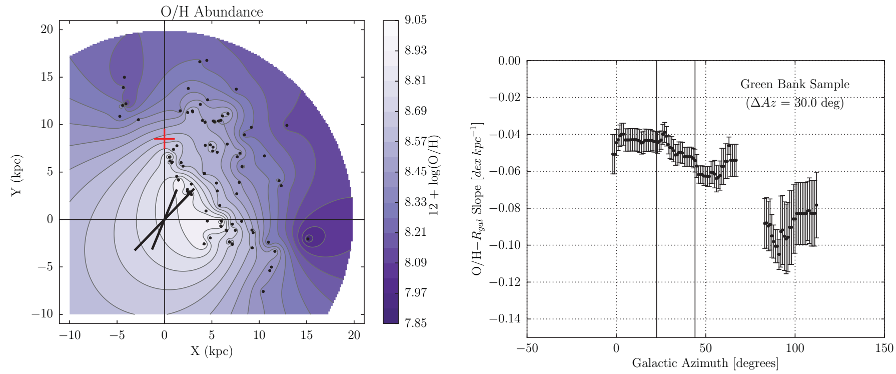

Figure 1. *Left:* Face-on Galactic [O/H] abundance ratio image using Kriging to interpolate between the discrete H II region values from the GBT (Balser *et al.* 2015). The points indicate the location of the discrete H II regions. The solid lines intersect at the Galactic Center. The red lines mark the location of the Sun. The thick lines correspond to the central locii of the putative "short" and "long" bars. *Right:* [O/H]-$R_{\rm gal}$ slope as a function of Galactic azimuth. Azimuth bin sizes of $\Delta Az = 30°$ are centered at the indicated azimuth. The vertical solid lines mark the orientation of the bars.

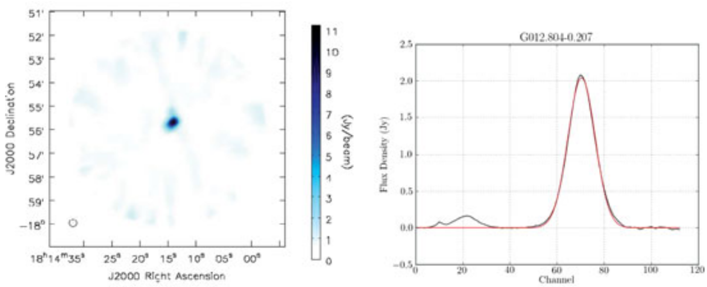

Figure 2. JVLA free-free continuum image at 9 GHz (left) and RRL spectrum from the averaged H87α-H93α RRLs (right). The H, He, and C RRLs are visible from right-to-left.

2. Current and Future Work

We use the Jansky Very Large Array (JVLA) to accurately measure the RRL and continuum emission toward a sample of 140 H II regions distributed throughout the Galaxy. Figure 2 shows a JVLA image of the RRL and continuum emission of G012.804−0.207. More accurate electron temperatures, and therefore metallicities, can be derived using the JVLA because of the superior continuum measurements. A data reduction and analysis pipeline has been written and is currently undergoing testing. Future work includes: (1) an H II region discovery survey using the Australia Telescope Compact Array (ATCA) to significantly increase the number H II regions in the Southern sky; (2) investigate kinematic distance uncertainties using parallax-determined distances; and (3) reanalyze the [O/H]-$T_{\rm e}$ relationship with modern optical/infrared and radio data.

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