30 Years of Photodissociation Regions:

A symposium to honor David Hollenbach's lifetime in science

Asilomar, CA, USA - June 28th to July 3rd, 2015

Probing the Cold Neutral Medium with Carbon Radio Recombination Lines

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The interstellar medium (ISM) plays a central role in the evolution of galaxies. The interplay of stars and their surrounding gas leads to the presence of distinct phases. Diffuse atomic clouds (the Cold Neutral Medium, CNM) where atomic hydrogen is largely neutral but carbon is singly ionized by photons with energy less than 13.6 eV, but larger than the ionization potential of carbon (11.2 eV). Watson, Western & Christensen (1980) and Walmsley & Watson (1982) showed that at low temperatures (~ 100 K) electrons can recombine via dielectronic recombination to high quantum levels ($n \approx 1000$, Stepkin et al. 2007). Transitions between high quantum levels produce Carbon Radio Recombination Lines (CRRLs). These CRRLs have been observed in the interstellar medium of our Galaxy towards two types of clouds: diffuse clouds (e.g.: Roshi et al. 2002, Oonk et al. 2014) and photodissociation regions (PDRs), the boundaries of HII regions and their parent molecular clouds (e.g.: Natta et al. 1994, Quireza et al. 2006).

Here, we present new theoretical models of low frequency CRRLs ($<$350 MHz) under the physical conditions of cold diffuse clouds (Salgado et al. 2015a). We show that detailed modeling of the level population of carbon atoms (Salgado et al. 2015b) together with radiative transfer allow us to determine the temperature and density of the diffuse clouds from observations. Furthermore, combined observations of CRRLs with HI 21 cm can be used to constrain the carbon abundance and the cosmic ray ionization rate (Oonk et al. 2015).

In the coming years, we will use the Low Frequency Array (LOFAR) to carry out a full northern hemisphere survey of CRRL emitting clouds in the Milky Way. Observations and models will allow us to study the thermal balance, chemical enrichment and ionization rate of the cold neutral medium from degree-scales down to scales corresponding to individual clouds and filaments in our Galaxy. Furthermore, following the first detection of low-frequency CRRLs in an extragalactic source (i.e. M82; Morabito et al. 2014) we will also use LOFAR to perform the first flux limited survey of CRRLs in extragalactic sources. As new observations are performed, detailed modeling is necessary to determine the physical properties of the clouds. Low frequency CRRLs provide a unique window on the ISM and allow us to study diffuse clouds with new tools.

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