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Studies of Compact H II Regions with ISO

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Abstract. We summarize results of a study of combined ISO SWS-LWS grating spectra of compact H II regions in our Galaxy.

Compact H II regions, which are the result of the ionizing radiation of newly formed massive stars, are either completely embedded in their natal molecular clouds or in the process of breaking out. These regions consist of ionized material from the local interstellar medium (ISM) and therefore, are excellent probes of the ISM and can be used to trace the spatial distribution of chemical elements in galaxies. Abundance determination methods based on infrared observations present clear advantages over optical studies as the infrared fine-structure lines are not very sensitive to large changes in the electron temperature and do not suffer from high extinction.

Using the Infrared Space Observatory (ISO), we observed with the SWS and LWS in the grating mode 45 compact H II regions sampling the galactic plane from the center to the outer regions. The spectra cover a range from 2.5 to 196 μm with resolving powers $\lambda/\Delta\lambda$ between 150 and 1500. The complete spectral coverage gives access to nearly all the atomic fine-structure lines in the infrared range. For some elements, different ionization stages are measured, which alleviates the problem of applying ionization correction factors for unseen ions. In addition to the atomic emission lines, the spectra are dominated by strong dust continua and a series of dust bands, as well as absorption bands from molecular ice species (see Fig. 1).

The data have been reduced using up-to-date SWS and LWS reduction software. A description of the reduction techniques as well as a catalogue of the line intensities will be given in Peeters et al. (in preparation) and the first results of this study will be presented in Martín-Hernández et al. (in preparation) - see also a preliminary report in Martín-Hernández et al. (2000). This report will summarize the problems related to the determination of the N/O abundance ratio and give some results obtained on the dust properties.

The abundance ratio N/O has a special significance for galactic nucleosynthesis models because the main stellar source of N is still unclear. Simple chemical evolution models predicts that its dominant isotope (^{14}N) originates principally from primary nucleosynthesis (through H-burning of carbon newly-generated within the star), but, how much ^{14}N is produced from secondary nucleosyntheis (i.e. through the CNO cycle where the carbon is already present in the star) is still an open question.

Fig. 2a shows the ionic abundance ratio N^{++}/O^{++} versus the galactocentric distance D_{gal} (the ratio is derived from the measured strengths of the nearby [OIII] 51.8 μm and [NIII] 57.3 μm lines, adopting the electron density from the

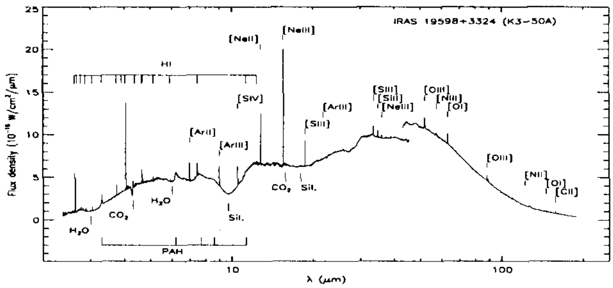

Figure 1. Combined SWS and LWS spectrum of K3-50A. The positions of the atomic fine-structure lines and H I recombination lines are labeled, as well as the main dust bands.

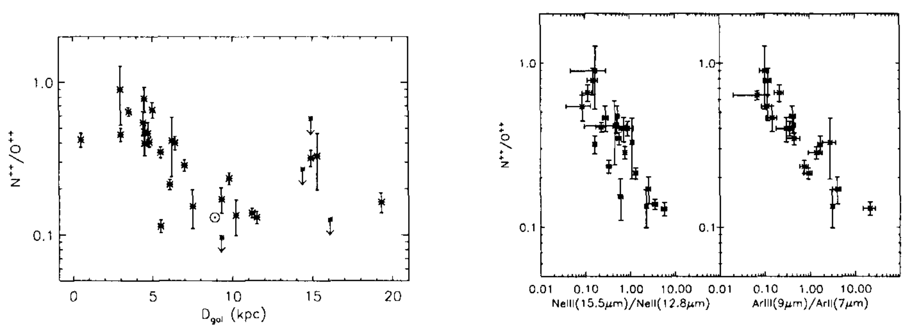

Figure 2. (a) Plot of the ionic abundance ratio N^{++}/O^{++} versus D_{gal}. The arrows indicate upper limits. The solar abundance ratio N/O is indicated by ⊙. (b) Plot of the ionic abundance N^{++}/O^{++} versus the intensity ratio between lines of different ionization stages of neon and argon.

O^{++} region). A clear trend is observed between 3 and 12 kpc, in agreement with previous results based on Kuiper Airborne Observatory (KAO) observations of galactic H II regions (e.g., Afflerbach et al. 1997). Beyond 14 kpc, the scatter of the data is too large to make yet a firm statement. In order to derive the abundance ratio N/O, ionization correction factors must be applied. Assuming that most of the nitrogen and oxygen is found in the form of N^{++} and O^{++}, this ionic abundance ratio can be interpreted as a measure of the N/O in the nebulae. However, this assumption depends on the degree of ionization of the central star(s). Fig 2b shows N^{++}/O^{++} against the intensity ratio between lines of different ionization stages of Ne and Ar, which are very sensitive to the stellar effective temperature. The clear trends which are observed indicate that the dependence of N^{++}/O^{++} on galactocentric distance also includes an ionization

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dependence. As mentioned by Stasinska & Schaerer (1997), who presented photoionization models combined with CoStar stellar models (Schaerer & de Koter 1997), the determination of N/O using N^{++}/O^{++} gives rise to important biases. At high stellar effective temperatures, $T_{eff} \geq 4.5 \times 10^4$ K), N^{++} partly transforms into N^{3+}, and at low effective temperatures N^{+} and O^{+} are the dominant ionic species. First estimates using these models suggest that we are in the latter case, i.e. $N/O \leq N^{++}/O^{++}$ - see Martín-Hernández et al. (in preparation) and Morisset et al. (in preparation) for detailed discussions.

In addition to the study of the ionized gas and the derivation of the abundance gradient, the ISO data also provide a wealth of information on the dust around massive young stars. There are indications that the dust properties change in the surroundings of compact H II regions. For instance, the large number of H I recombination lines in K3-50A has been used to derive the extinction towards this object which has been found to deviate from the 'standard' extinction curve (Martín-Hernández et al. 2000). The attenuation is higher than expected and clearly lacks the deep minimum near 7 μm, indicating that, either the properties of the dust surrounding K3-50A are very different from those of the typical interstellar dust, or that there are geometrical effects. All the spectra of the H II regions show strong emission bands and dust continuum. The spectral appearance of the dust spectrum varies from source to source and are in some cases different from the spectra observed in less excited regions of the ISM (Roelfsema et al. 1996). The changes are thought to be the result of variations in the physical conditions of the emitting region such as the radiation field or the density (Cox & Roelfsema 1999; Peeters et al. in preparation). A study of these spectra and of the properties of the sources, together with detailed laboratory measurements, will provide constraints on the models of the dust (PAHs) which emit this family of emission bands.

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