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IMAGING RESOURCES FOR THE GTC: THE LOCAL GROUP CENSUS

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RESUMEN

El Censo del Grupo Local es un cartografiado con filtros estrechos para estudiar las poblaciones que presentan líneas de emisión en las galaxias del Grupo Local. Se usa la cámara de gran campo del telescopio de 2.5m Isaac Newton. Los datos están a disposición de toda la comunidad astrónomica y representan una valiosa base de imágenes para posteriores estudios espectroscópicos con el Gran Telescopio Canarias.

ABSTRACT

The Local Group Census is a narrowband imaging survey aimed at cataloguing the emission-line populations in the galaxies of the Local Group. Data, which were obtained using the Wide Field Camera of the 2.5m Isaac Newton Telescope, are available to the whole astronomical community, resulting in a valuable imaging resource for follow-up spectroscopy with the GTC.

Key Words: **H II REGIONS — ISM — LOCAL GROUP — PLANETARY NEBULAE**

1. THE LOCAL GROUP CENSUS

The Local Group Census (LGC) is a narrowband survey of all the galaxies of the Local Group (LG) with Dec$\geq -30°$, being carried out as part of the Isaac Newton Group's Wide Field Survey programme. Observations have been obtained with the Wide Field Camera (WFC) at the 2.5m Isaac Newton telescope, equipped with a mosaic of four 2k×4k EEV CCDs covering a field of view of $34' \times 34'$.

The main aim of the survey is to find, catalogue and study old and young emission-line populations (e.g. HII regions, planetary nebulae, supernova remnants, luminous blue variables, Wolf-Rayet stars, symbiotic binaries, etc.) to unprecedented levels. The value of narrowband images is enhanced with complementary broad band data. This enable the linkages between stellar populations in the range of LG galaxies to be probed. Analysis of the population samples across the wide range of galaxy types and metallicities seen in the LG will aid to understand the LG evolutionary processes, and the role of the stellar populations in e.g. chemical enrichment of the LG.

The observations of the LGC have almost been completed during some 45 clear nights of observations in different runs from 2001 to 2003. All data are available to the astronomical community.

The galaxies observed are (in brackets are the number of WFC fields when larger than one): Sextans A, Sextans B, Leo A, Leo II, GR 8, Leo I, NGC 147, NGC 185, NGC 205 (2), NGC 6822 (4), Ursa Minor (4), Draco (4), EGB 0427+63, IC 10, M 33 (7), WLM, IC 1613, Pegasus, and DD210. This list includes most luminous galaxies in the LG, the most notable exception being M 31, for which no time was allotted as similar observations were already been obtained by other ING programmes.

Most galaxies were observed in four narrow filters which select the nebular emission lines [OIII]5007 Å, Hα+[NII], [SII]6717,.6731 Å, and HeII4686 Å, respectively. In addition, the same fields were also observed in the broadband Sloan g', r', i' and the *Strömgren Y* filters, this latter one particularly suited to be used as a 'continuum' filter for [OIII]. Exposure times were 1 hour for the narrowband filters, 30 min for *Strömgren Y*, and 20 min for the Sloan filters. This allowed us to reach a detection limit, during photometric dark nights with good seeing conditions, of an equivalent V magnitude of 25.5 with S/N=10 in all narrowband filters. Note that, for instance, the equivalent V magnitude for the [OIII] filters is defined as $\mathrm{m}_{5007} = -2.5 \log \mathrm{F}_{5007} - 13.74$, where F_{5007} is given in erg cm^{-2} s^{-1} (Jacoby 1989).

An example of an Hα LGC image is shown in Fig. 1. More details about the survey and a complete list of the data obtained can be found at

http://www.ing.iac.es/~rcorradi/LGC/.

2. AN ILLUSTRATIVE EXAMPLE: PLANETARY NEBULAE

In the last years, the study of extragalactic planetary nebulae (PNe) has received a big impulse thanks

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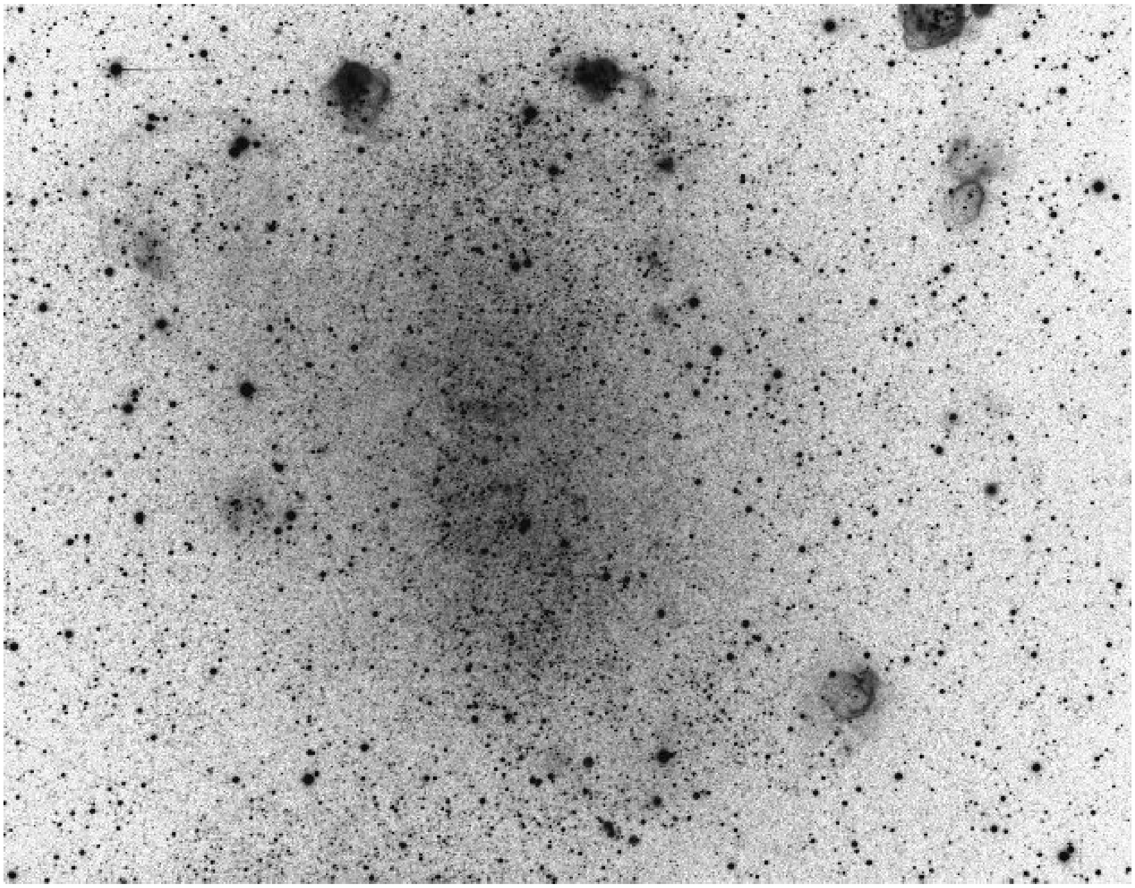

Fig. 1. The Hα+[NII] LGC image of the central region of the irregular galaxy NGC 6822. Note the number of large HII complexes in this galaxy.

to the improvement of the observing techniques, like for instance the availability of high quality narrow-band filters coupled to sensitive detectors[3], of large size telescopes which allow deep spectroscopic studies, and of specific instrumentation (e.g. the Planetary Nebula Spectrograph, specifically built to detect PNe in galaxies and determine their radial velocities,(see e.g. Douglas et al. 2002).

The technique used for searching PNe in external galaxies is almost invariably that of obtaining a narrowband, continuum-subtracted image in a filter isolating the [OIII]5007 Å line. A large fraction of the total luminosity of the star is in fact concentrated in this line, and this is the unique property that makes individual stars in the planetary nebula phase visible to very large distances: up to several hundred solar luminosities can be emitted in this (narrow) spectral line. Observation of the hydrogen Hα line, also very bright, is sometimes added to discriminate against the detection of highly redshifted galaxies, or to estimate the ionization class and discuss possible misclassification with compact HII regions. An additional criterium to select extragalactic PNe is that they are not spatially resolved by ground based imaging, their sizes being usually a fraction of a parsec which translates into a couple of hundredth of an arcsec at a distance of 1 Mpc, approximately the outer edge of the Local Group.

Extragalaxtic PNe are important objects to discuss a number of astrophysical topics. First of all, PNe are bright representative of any intermediate mass stellar population. Their number can be related to the total luminosity of the underlying stellar population from which they derive (Renzini & Buzzoni 1986). In particular, PNe have proven to be excellent tracers of stellar populations in large volumes with a low density of stars, whose integrated stellar light is low and hardly detectable, like the in-

[3] The tunable filters of GTC+Osiris will cause a further step forward in reaching significantly lower detection limits.

tergalactic and intracluster space and in the haloes of elliptical galaxies (Arnaboldi, Aguerri, Napolitano et al. 2002).

Extragalactic PNe also provide important information on the chemical evolution of the host galaxies, as the nebular abundances of elements like oxygen, neon, sulphur, or argon, do not vary significantly during the evolution of low and intermediate mass stars. Therefore the abundances of these elements probe the initial metallicity of their environment at the time when their progenitors were born. This includes a range in ages that cannot be covered using other classes of stars. In addition, the study of the abundances of elements like helium, nitrogen and carbon, provides insight into the nucleosythesis processes in the stellar interiors, the dredge-ups to the stellar envelopes, and the enrichment of the interstellar medium in the different environments associated to the variety of the LG galaxies.

Moreover, PNe can be used as reliable extragalactic distance indicators, through the invariance of their luminosity function with galaxian type and metallicity (Jacoby 1989). Finally, as they are also detected in stellar systems of low-surface brightness, they are extremely valuable test particles to map the dynamics of stars in galaxies up to very large galactocentric distances.

In this framework, the LGC has provided a much more complete view of the population of PNe in the LG than previously known. A significant number of new PNe have been discovered in the galaxies analysed so far (Magrini, Corradi, Mampaso & Perinotto 2000; Magrini, Corradi, Walton et al. 2002; Magrini, Corradi, Greimel et al. 2003; Magrini, Corradi, Greimel et al. in preparation, Corradi, Magrini, Greimel et al. submitted; Leisy, Corradi, Magrini et al. in preparation), which include irregular, spheroidal, and spiral systems. The LGC data appear to be generally consistent with the predictions of the stellar evolution theories, as the number of observed PNe in each galaxy scales reasonably well with the luminosity of the galaxy (Magrini et al. 2003). In spite of this agreement, there are also some interesting peculiarities, which could be related to the different metallicites of the host galaxies or their different star formation history. For instance, we have found a possible lack of PNe when the metallicity of the galaxies is $[Fe/H] << -1.0$, which might indicate that below this point the formation rate of PNe is much lower than for stellar populations of near-solar abundances. This might, in turn, be related to the mass loss mechanism in red giants, that is governed by radiation pressure on dust grains and is therefore sensitive to a significant deficiency of heavy elements in the stellar envelopes. Another result of our survey is the discovery of candidate planetary nebulae at large galactocentric distances, like in the case of IC 10 and NGC 6822 where PNe cover areas much larger than the optical diameters of the galaxies. These faraway PNe are likely to be related to the enormous neutral hydrogen envelopes surrounding these galaxies (cf. van den Bergh 2000).

3. PERSPECTIVE WITH THE GTC

The photometric data from the LGC survey are clearly a starting point for future spectroscopical studies of individual objects, aimed at confirming their nature and, more important, at determining their physical and chemical properties.

In the case of PNe and HII regions, deep spectra which detect faint diagnostic emission lines are needed in order to determine their physico-chemical properties with a good accuracy (0.1 to 0.3 dex for He, O, Ne, N, Ar, and S). A general problem of many previous studies, in fact, is that the gas electron temperature and densities are not directly determined (but somewhat arbitrarily assumed), nor is the emission of an element available in several of its ionization stages (thus introducing a large correction factor for the unseen ions).

To avoid these problems and measure all relevant emission lines, at the typical distances of the LG galaxies a 8-10m telescope is needed if one wants to limit exposure times to a practical value. Preliminary analysis of some spectra recently obtained by our group using the VLT 8m from ESO and the MOS facility at the FORS2 spectrograph shows that the required level of accuracy is indeed reached with exposure times of about 3 hours per field (1.5 h to cover the 3500-6600 Å range of the optical domain, and another 1.5 h for the 6300-9600 Å red end of the spectrum). In Fig. 2, we show the VLT spectrum of a PN in the dwarf irregular LG galaxy Sextans A: all faint lines needed for a direct determination of electron temperature and density are detected with good S/N, and thus, a proper physico-chemical analysis is allowed.

For its location in the Northern hemisphere, and its large collecting area, GTC and its MOS spectrograph OSIRIS are clearly the natural choice for a future, extensive follow-up spectroscopy of the PNe and HII regions catalogued by the LGC. This would allow us to gain an overall and complete view of the chemical content of the local Universe through its emission-line populations. With this objective, an active scientific collaboration between the ING

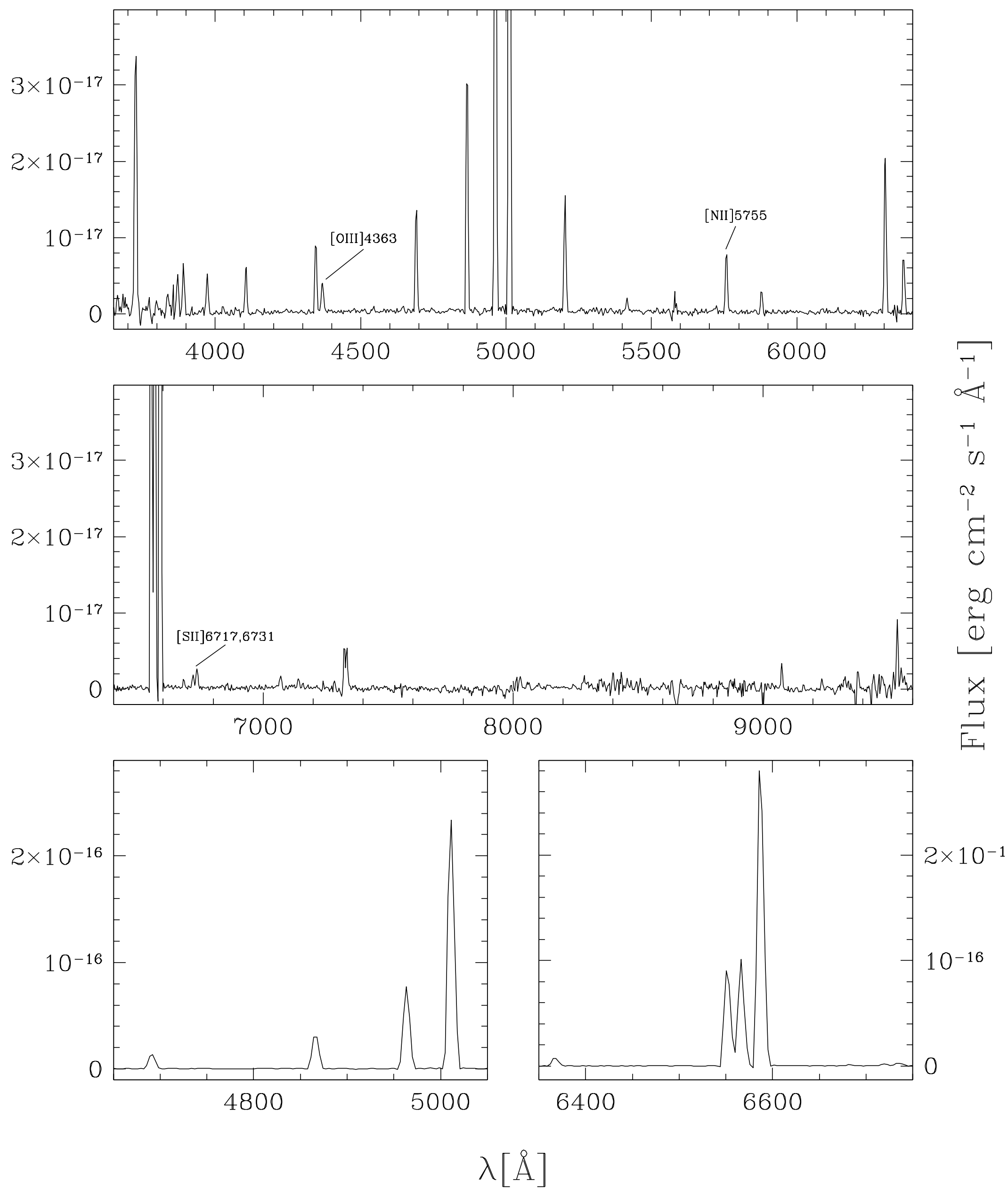

Fig. 2. VLT spectrum of a PN in Sex A. The [OIII], [NII], and [SII] lines needed for direct determination of the electron temperatures and densities are labelled. On the bottom panels, enlargements of the [OIII] and Hα spectral regions.

(La Palma), IAC (Tenerife), IAA (Granada) and the University of Florence has been set up and is producing some first results using VLT data, while waiting for the start of operation of GTC.

But there is a number of other fields can be further explored using the LGC data, and that can be fully exploited by follow-up observations with the GTC, like for instance the study of supernova remnants, bright interacting binaries like symbiotic stars, young massive stars and their nebulae, etc. Concluding, the LGC survey is a good example of the ability of a 2.5 m telescope in providing valuable resources for a large telescope as the GTC: the selection, photometry and morphological study of targets to be observed spectroscopically with a 10m telescope can be easily done with a relatively small telescope like the INT. Any interested astronomer is encouraged to make use of the LGC data with this (or other) purposes.

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