GIANT H II COMPLEXES OUTSIDE OUR GALAXY AT OPTICAL WAVELENGTHS

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I. THE OBJECTS

By definition giant H II complexes are luminous sources in the spectra of thermal photoionized interstellar gas. Therefore they are easily detected out to large distances. As a consequence the list of objects is vast and it is impossible to cover in detail all the results brought together by an increasing number of investigators. For more complete bibliography the reader is referred to the reference lists in the papers quoted. Let me line out here instead a number of aspects which have received considerable attention or which are still subject to major improvements.

The variety of nomenclatures for giant H II complexes one encounters in the literature often seems to hide the fact that the primary targets, H II regions, all obey the same astrophysical processes. It is therefore worthwhile to collect these names before going further on:
- classical extragalactic H II regions, usually resolved objects distributed in irregular galaxies and the arms of preferentially late type spirals,
- and large H II complexes which contribute considerable amounts of light to the total brightness of their parent galaxies or even outshine them, isolated or detached extragalactic H II regions, blue compact galaxies, H II region like galaxies, emission line dwarf galaxies (cf. Kinman and Davidson 1981 and references therein), clumpy irregular galaxies (Boesgaard et al. 1982), 'normal' species of active nuclei and hot spot galaxies (Meaburn and Terrett 1982) and even objects at higher redshift which have been previously catalogued as quasars (French and Miller 1981).

II. MORPHOLOGICAL ASPECTS

Optical observations, mainly spectrophotometry, are now available for objects covering about 4 orders of magnitude in distance (.05 to 350 Mpc) and luminosities at Hβ (10^{38} and 10^{42} ergs s^{-1}). A general trend exists for more distant objects to be more luminous, very likely the result of resolution effects. At the distance of M 101 a typical aperture of 5 arcsec diameter covers an area 170 pc across and data derived for H II complexes at

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larger distances necessarily refer to the integrated properties of objects at least as large as NGC 604. It is clear that M 33 does not contain H II regions comparable to the giant NGC objects in M 101. Furthermore relations exist between the type and luminosity class of galaxies and the typical size of the largest H II complex encountered (Van den Bergh 1981).

However, high resolution images show that for example NGC 5471 can be decomposed into a cluster, NGC 5461 into a chain (Israel et al. 1975) and the clumpy irregular galaxy Mkn 325 into a conglomerate (Coupinot et al. 1982) of NGC 604 size objects. Hence, the often claimed giantism of such H II complexes could just reflect the number of typical starformation cells (Hunter 1982) counted as one single object. The question of defining the boundaries of a given H II complex is however no longer of academic nature, if diameters or luminosities are to be used as distance indicators (cf. Kennicutt 1981), masses are to be determined or ionization structures are to be modelled.

Only very little is known on the differences in physical conditions across such chains or clusters of H II regions. A few remarks in literature (e.g. Sedwick and Aller 1981) point towards considerable changes in the emitted line spectra at different positions in the nebulae. A deeper understanding of such differences and correlations with the core-halo structures found at radio wavelengths is hampered by the fact that at present only 30 Dor has been studied in large detail. NGC 604 (Israel et al. 1981) is now receiving more attention and in principle the lot of spectrophotometric work on regions in M 33 and M 101 done so far could be used to mimic spatially resolved or multi-aperture observations. Unfortunately, out of a dozen investigations presenting spectrophotometry of M 101 objects only one shows the location of the measuring aperture on photographs. In NGC 604 the same is true for only two out of many spectra reported.

The rapid increase in sensitivity and spatial resolution at UV, IR and radio frequencies urgently calls for high spatial resolution work to be done at visual wavelengths. In particular absolute flux calibrated maps are required to derive maps of nebular extinction by comparison of Balmerline and radio continuum surface brightnesses. In addition it should be compulsory to report the exact position of small aperture observations on such inhomogeneous objects.

III. CHEMICAL ABUNDANCES AND ABUNDANCE GRADIENTS

An increasing amount of H II regions in a growing number of galaxies of different types has been covered by abundance determinations in the recent past (cf. Peimbert 1982 for extended lists of references, Talent 1981, McCall 1982). Weaker emission lines are included and measured with higher accuracies. The observational effort has been accompanied by extensive work on the theoretical side. Large numbers of model H II regions have been calculated to study the effects of geometry, internal dust, properties of the ionizing stars and chemical abundances onto the emerging emission line spectra (Stasińska 1982, Mathis 1982a). Semiempirical schemes to derive ionic and total abundances and effective temperatures of the ionizing sources have been improved and the reliability of such procedures has been discussed (French and Grandi 1981, Mathis 1982b, Stasińska et al. 1981).

The results continue to confirm the existence of abundance differences across and between galaxies and values derived for the pregalactic helium abundance seem to converge at Y = .225 (Rayo et al. 1982). Problems involved in deriving chemical abundances and the interpretation of the gradients found in terms of galactic evolution, chemical enrichment of the interstellar medium, nucleosynthesis in stars of different mass and bursts of starformation have been reviewed several times (cf. Edmunds and Pagel 1982, Pagel and Edmunds 1981, Peimbert 1982 and references therein).

One of the largest uncertainties present in abundance analyses of high metallicity H II regions is the lack of direct determined electron temperatures. The two solutions to this problem, either model fitting of the observed spectra or the use of semiempirical relations to derive an electron temperature may result in large errors for the final abundances determined (Stasińska 1980). Rayo et al. (1982) have recently carefully analysed 3 H II regions in M 101. For their innermost object, H 40 or S 3, they derive a logarithmic oxygen abundance of 8.81, based on directly determined electron temperatures. This is about 0.3 lower than the value found by model fitting for S 5, an object at almost the same galactocentric distance (Shields and Searle 1978). With the limited number of objects it is not possible to decide between the two possible explanations: Fluctuations in the abundance gradient on small galactic scales or too high abundances predicted by the model for S 5. Similarly, Dufour et al. (1980) discuss the possibility of abundance fluctuations in M 83, again based on model fitted abundances.

Such deviations from an idealized smooth gradient across galaxies is however expected, if properties of individual H II complexes are likely to depend not only on global properties of their parent galaxies alone but also on the detailed history and present conditions of their local environment. While the increasing sample of H II regions helps to proof the reality of abundance differences on galactic scales, it might simultaneously reveal the intrinsic scatter produced by the individuality of every single H II complex. Unfortunately it is not possible to merge results obtained by different investigations into a larger sample of objects for a given galaxy, due to the use of different atomic data and procedures to derive abundances. Clearly, M 33 and especially the chainlike H II regions in M 101 are favorable objects to study the reality of such fluctuations. In addition Stasińska (1980) points out that high spatial resolution observations of presumed metal-rich H II regions could be valuable to ascertain the high abundances quoted, by 'considering the variations of the emitted spectrum across the face of the nebula' (see end of section II!).

IV. PROPERTIES OF THE IONIZING STAR CLUSTERS - THE WR SOURCES

Integral properties of the ionizing stellar clusters of giant H II complexes, such as total luminosity in the lyman continuum, effective tem

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perature and total stellar mass involved are known, at least approximately, for most objects. However no direct observations of the possible ionizing stars were available, except for the central cluster in 30 Dor which is rich in Wolf-Rayet type stars. Although 30 Dor is an object comparable to many of the giant H II regions it was only recently that WR sources were detected in other giant H II complexes as well, due to two effects: Firstly, it has only now been realized that in particular the luminous WR stars of subtypes WN 6,7 and their possible descendants of type WC 6,5 can be identified with the evolutionary stages of the most massive stars (Maeder 1982). Secondly, almost all spectrophotometric work on giant H II regions has aimed at the nebular emission line spectra, thus taking the underlying stellar continua as an unwanted background.

The current list of giant H II complexes with identified WR star contribution contains about 25 objects, 16 of which are published (cf. D'Odorico and Rosa 1982). Remarkable examples are: 30 Dor (LMC), NGC 604 (M 33), NGC 5461 (M 101) and Tol 3. Experience with that sample shows that the strong WR bands around λ4650 Å scale in strength with the underlying blue continua, giving rise to an average EW of about 10 Å in the integrated spectra of the ionizing clusters. Since the bands are usually 30 to 50 Å broad, high signal-to-noise ratios are required in order to detect WR star contribution. It is therefore not surprising that the WR objects in NGC 604, though even spatially resolved, have been detected only after decades of frequent investigation (D'Odorico and Rosa 1981).

The absolute flux observed in the WR bands may be interpreted either by the presence of only a few very luminous objects (Conti and Massey 1981) or by a cluster of normal WR stars, comparable in number with the equivalent O5 stars needed to ionize the nebulae (D'Odorico and Rosa 1981, 1982). The data are at present not good enough to decide between the two possibilities. Furthermore, the identification of the ionizing sources is premature. If the stellar clusters are formed according to normal initial mass functions one expects the ionizing stars to be distributed in spectral type and in addition the ionizing properties of WR stars are unknown.

The only cluster to compare with in detail is the core of 30 Dor. However, its HR diagram is limited to M(BOL) brighter than -.7 for blue objects (McGregor and Hyland 1981). Hence it contains almost exclusively luminous WR sources, some of which are suspected to be multiple (Phillips 1982). Partly due to that apparent deficiency in O type stars the interest in identifying the ionizing source of 30 Dor has focussed on the most luminous WR object, R 136. It has been suggested by several investigators that R 136 must be a superluminous, supermassive (200 - 2500 $M_\odot$ are quoted), single object (Cassinelli et al. 1981, Schmidt-Kaler and Feitzinger 1982) in order to account for most of the ionizing flux needed in 30 Dor and several observed properties such as e.g. the small diameter, the luminosities in the optical and the UV and characteristics of the IUE line spectrum. However, the analysis of the data depends on very uncertain corrections for extinction towards R 136. Bolometric corrections as well as the properties of the dense envelope, expected by the strong mass loss claimed and evidenced by the WR characteristica observed, are unknown.

The ionizing flux inferred for R 136 could be lowered dramatically if besides the 14 additional WR stars present in the core of 30 Dor numerous less luminous O type stars could be detected in the yet unobserved lower part of the HR diagram. The interpretation of the WR sources found in other giant H II complexes strongly depends on the picture drawn for 30 Dor and in particular R 136. Emphasis must be laid therefore on the clarification of the situation there. Melnick (private communication), in working on a photometry of more than 100 stars brighter than 15th magnitude in the central area of 30 Dor, finds provisional evidence for a large number of O type stars.

V. SUPERSONIC MOTIONS - STELLAR WINDS

Fabry Perot measurements of the emission line profile widths of giant H II complexes imply the existence of supersonic motions in the gas (Terlevich and Melnick 1981). Although the spatially integrated profiles of more distant objects are gaussian in shape, resolved objects show multiple peaked profiles (Melnick 1978) and the high spatial resolution in 30 Dor offers a complex picture of line splitting (e.g. Meaburn 1981). Terlevich and Melnick (1981) have analysed correlations between Hβ luminosities and core radii on one side and the overall velocity dispersions on the other side for about 20 giant H II complexes. They find relations similar to those followed by elliptical galaxies and interpret the supersonic velocities observed as the motions of discrete gas clouds in the gravitational field of the H I, H II and stellar masses. Contrary to that view, stellar mass loss phenomena are invoked by many investigators to explain the line-splitting in 30 Dor and large shell nebulae in the LMC (Meaburn 1981, Dopita 1981) as well as other giant extragalactic H II regions (Dyson 1981). The mass loss connected with WR stars and their progenitors makes it likely that at least those giant H II complexes for which the presence of WR stars has been verified are strongly affected by stellar winds, as has been shown for NGC 604 (Rosa and D'Odorico 1982). Clearly, high spatial resolution observations are required to verify the importance of either mechanism, gravitational motions or stellar winds, on the broadening of the overall emission line profiles.

VI. FINAL REMARKS - SPACE TELESCOPE USE ?

The urgent need for high quality, high spatial resolution optical observations of giant H II complexes in nearby galaxies has been one of the main conclusions emerging from an overview of the present results available for such objects. Frequently one reads comments to use Space Telescope for more detailed observations. It must be emphasized that groundbased observations of giant H II regions in nearby galaxies (e.g. LMC, M 33, M 101) are incomplete and much can and has still to be done even with medium size telescopes (optical mapping, 'high' = 2 arcsec resolution). If any time on ST will be granted to H II region work it will be short. To make as much use of it as possible we have to know before what we are going to look at. Otherwise the ST view of e.g. NGC 604 might leave us with only the same complex picture we have already from ground based observations of 30 Dor.

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