FURTHER CANDIDATES OF SUPERMASSIVE STARS IN OTHER GALAXIES

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To look for other supermassive stars in other galaxies means to answer the question: what is the spectroscopic and morphological signature of such objects? The interpretation of WR sources found in other supergiant HII complexes depends basically on our picture of 30 Dor and in particular of R136a.
Guided by the experience with 30 Dor we look for supergiant HII complexes with WR features in the spectrum, esp. near 4650 Å. Supergiant HII regions are defined by $S_5D^2 \gtrsim 5000$ Jy kpc^2 (emission measure exceeding 50 times that of the Orion Nebula; Smith et al., 1978) with D the distance in kpc and S_5 the flux at 5 GHz. The characteristic morphology of the 30 Dor nebula (and of NGC 604 as a similar object) serves as a guideline to find prospective objects.

Supergiant HII regions can often be decomposed into a cluster or a chain or a conglomerate of smaller HII complexes, which may themselves be of complex structure i.e. into cells typical of star formation. Typical examples are Mkn 325 (Coupinot et al., 1982) and NGC 5461 (Israel et al., 1975). The maximum sphere of influence of star formation is $\sim$300 pc, if mechanical energies on the order of 10^{50} - 10^{51} ergs per HII region are being returned to the ISM from massive stars (Hunter 1982).

16 supergiant HII complexes with WR contributions have been published (D'Odorico, Rosa, 1982). Experience with that sample shows that the strong NIII bands around 4650 Å scale in strength with the underlying blue continuum, giving rise to an average equivalent width of 10 Å. Since the bands are usually 30 - 50 Å broad, excellent spectra with high signal-to-noise ratios are required.
A comparison of IUE spectra of those regions with galactic and LMC OB and WR stars, as well as R136a shows:
1) All spectra bear great resemblance to R136a.
2) Broad, PCyg like profiles of CIV, SiIV, NIV are observed.
3) The spectra do not resemble the average O or WR spectra (Massey, Hutchings, 1983, D'Odorico, Benvenuti, 1983).

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Why do we expect WR features? The luminous WR stars of subtypes WN 6,7 (and their possible descendants of type WC 5,6) can be identified with late evolutionary stages of the most massive O stars (Maeder, 1982). The absolute flux observed in the WR bands can be interpreted by the presence of a single (or only a few) very luminous objects or by a cluster of normal WR stars, comparable in number with the equivalent of 10^3 - 10^4 O5 stars needed to ionize the whole nebula (Conti, Massey, 1981; D'Odorico, Rosa 1981). If the ionizing stellar cluster is formed with the normal initial mass function, the great excess in the number of O stars compressed into small volumes, must be explained. One severe problem arises at this point: The WR stars are most probably the descendants of main sequence O stars and therefore considerably older. The observation of the earliest O types O3-O5 in the same small volume where the WR stars are located means that a continuing star formation process must be postulated. This contradicts the fact that the region is extremely heated up by the first O (plus WR) star generation, effectively inhibiting the ensuing star formation.

Two interpretations of the physics of supergiant HII regions appear possible:

1) Burstlike star formation in small volumes. To explain the Hβ luminosity of NGC 6764 requires 1.5 10^{40} erg/s^{-1} or 3.3 10^{53} ionizing photons. This is equivalent to 6.6 10^2 O5 or 4.5 10^3 O7 or 1.8 10^4 O8 stars in an volume of less than 1 kpc.
   For Mrk 309 with Hβ = 1.6 10^{41} erg s^{-1} the number of ionizing photons per sec is 3.5 10^{54}. This requires the presence of 7.1 10^3 O5 stars (Osterbrock and Cohen, 1982). The star burst model works very well in the case of dwarf galaxies (NGC 5204, 5474, 5585) and their HII regions which are less extreme than typical supergiant HII regions (Fabbiano and Panagia, 1983).
   The alternative is:
2) Supermassive objects, responsible for 50 - 90 % of the ionization power. The best known example is R136a (cf. Feitzinger, Schmidt-Kaler, 1983, Table 1 this volume). It can be shown that this object must be responsible for the major fraction of the ionization of the 30 Dor nebula, irrespective whether it is a single star or an extremely compact cluster of most massive O stars. This is so because its temperature is certainly exceeding 45000 K and its (de-reddened) UV flux implies $M_{Bol} < -14.0$, consequently producing the larger part of the ionization.

We have undertaken a search of possible sites of such supermassive stars on the basis of the morphology of 30 Dor and NGC 604. Four subtypes were used:

Subtype	Prototype	Characteristics
1	NGC 604	spiral galaxy shows a compact knot in the outer parts comparable to central region of galaxy
2	30 Doradus	galaxy shows dominating Hα region near end of bar or spiral arm

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Subtype	Prototype	Characteristics
3	NGC 5430	one or more large knots in or near edge of central region of spiral galaxy
4	IC 3576	several large bright knots similar to the galaxy nucleus

The survey was conducted on the POSS and ESO-Blue & SRC films. The following lists of galaxies were searched:

a) Elmegreen and Elmegreen, 1980: 44 Sm, Im, with diameters $\gtrsim$4'

b) Wray, de Vaucouleurs, 1980: 78 galaxies with identified super-associations

c) Revised Shapley-Ames-Catalogue (Sandage and Tammann, 1981) 113 galaxies of types S, SB, I with radial velocities $\leq$ 820 km/s ($\lesssim$15 Mpc)

d) Heidmann, 1983: 8 clumpy Irregulars

e) Vorontsov-Veljaminov, 1977: ~50 large HII regions

The survey is almost completed. Preliminary statistics shows that supergiant HII regions do not occur in systems of luminosity class IV and V, and show up preferentially in systems of type Sc, Sd, Sm II, III. High-luminosity early spirals do not apparently occur because of selective effects. The percentage of barred spirals seems quite normal. Some of the more interesting cases are being studied by high resolution direct photographs in UBVR Hα.

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