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High-Mass Star Formation in Southern Disk Galaxies

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I. Introduction

Accurately calibrated images in the light of Hα provide a reliable measure of the star formation rate in galaxies. This is because the Hα flux effectively counts the total number of Lyman continuum photons produced by young, massive stars. The absolute flux in the continuum adjacent to Ha may be used to measure the mass of intermediate and low mass stars. The gas content in the galaxy is most accurately obtained from radio observations in the 21 cm line of neutral hydrogen. Radio continuum observations also provide a measure of the star formation rate, since the radio flux density can be related to the number of Lyman continuum photons. Radio continuum data can be used to correct the optical observations for extinction.

Using high-resolution optical and radio images of external galaxies, the rate and distribution of star formation in the disk and nuclear regions can be derived. The distributions can be used to provide fundamental data on star formation processes in galaxies, and to test existing theories. For example, Dopita (1985) has shown that a general law of star formation in disk galaxies can be derived on the assumption that energetic processes, themselves associated with star formation, pressurize the interstellar medium and maintain the z-velocity dispersion of the gas. These ideas have since been developed, (Dopita, this conference) and this has led to a model in which star formation rates can be predicted as a function of gas content, metallicity and past star formation history. If σ_g, σ_*, and σ_t are the surface densities of gas, stars and of the matter, respectively, and if z_g and z_* are the scale heights of the gas and stars, respectively, then the rate of star formation of massive stars per unit area is given by a relation of the form:

$$\mathrm{SFR} = \mathrm{const.}\ [z_* /(z_* + z_g)]^{1/3}.\ \sigma_t^{1/3}.\ \sigma_g^{4/3}$$

This relationship agrees well with the observational data gathered by Kennicutt (1989) in other disk galaxies.

As part of a major study of the physical processes of star formation and the evolution of galactic discs, the detailed distribution of high-mass star formation within southern late-type spirals and Magellanic-type galaxies is being measured by means of narrow-band imaging in Ha and the continuum, spectroscopic studies of prominent HII regions identified in the Ha images, and by radio mapping in neutral hydrogen and the continuum. The radio mapping will be undertaken with the southern hemisphere's first large, multi-frequency synthesis array, the Australia Telescope. Some optical imaging and spectroscopic data has already been acquired; the optical data and some preliminary results are described below.

II. Observations

Optical images in Hα and the adjacent continuum at λ6626Å have been obtained for six galaxies using the 3.9 m Anglo-Australian Telescope (AAT) located at Siding Spring, NSW, Australia, and for four nearby galaxies using the 2.3 m new-technology telescope of the Mount Stromlo and Siding Spring Observatories. The filters used for the Hα work are 16Å wide (FWHM), and so exclude contamination from the nearby [NII] lines. After calibration to absolute flux using the Magellanic Cloud PN as flux standards, these data can be used to derive the radial distributions of the massive young stars, and of the older stellar population.

Spectra of prominent HII regions are taken with AAT in the $\lambda\lambda 3600$ -7500 Å region. These will be used to provide data on variations in chemical abundance using the methodology developed by Evans and Dopita.

III. Results

Radial distributions of the $\lambda 6626$Å continuum (proportional to the number of older disk stars) and the Ha flux (proportional to the number of young, massive stars) are shown in Fig. 1 for four galaxies mapped with the AAT. In these and all other galaxies studied so far, the scale length for star formation is greater, and in some cases much greater, than the scale length of the underlying exponential disk of stars already formed. If a relation of the form given above applies to the star forming disk, then the implication of these observations is that the radial distribution of the gas is flatter than that of the stars. We hope to confirm this supposition, and to define the exact form of the star formation law, using AT observations in both the HI and in the CO lines.

The star-forming activity as defined by the Hα distribution shows a fairly sharp outer cutoff at a particular radial distance. This in agreement with the results of Kennicutt (1989), who suggests that this is caused by the onset of global instabilities in the gaseous layer (Quirk, 1972).

The radial distribution of the oxygen/hydrogen abundance ratio derived from spectroscopic observations of HII regions in NGC 3423 is shown below. The oxygen abundance gradient has a scale length which is two times greater than the star formation gradient, and four times greater than the scale length of the stellar disk. Since the O/H ratio is set directly by the total amount of star forming activity that has occurred in the disk gas, data of this type will put very strong limits on the history of star formation, and quantify the importance of infall or radial flows.

References

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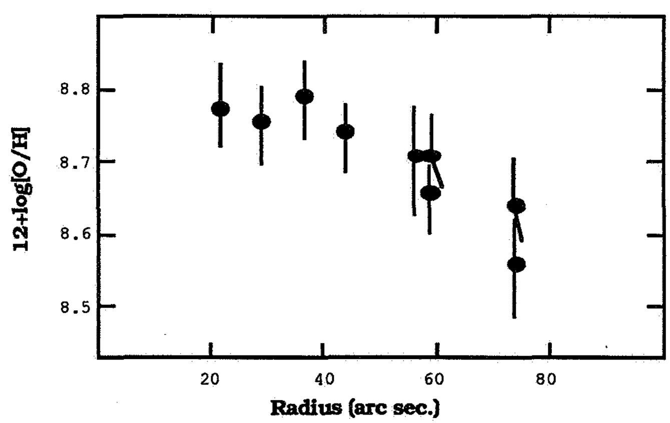
Figure 2: The radial abundance gradient in NGC 3423. The scale length for the abundance gradient is about twice that of the star formation rate gradient, and four times that of the stars already formed.



Continuum and H-alpha Radial Variation