DISTRIBUTION OF DUST AND H II REGIONS IN SPIRAL GALAXIES

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Abstract. The bright H II regions of a galaxy are always found near or in regions of high obscuration. It is also generally true that the dust lanes of a galaxy better define a spiral pattern than do H II regions. There appears to be a correlation between the size of the central region and the number of H II regions in a galaxy.

This is the second progress report on the study of the distribution of dark nebulae in galaxies. The ultimate goal of this investigation is to try to answer the questions "Which constituents of a spiral galaxy best define the basic pattern of its structure; and do the different constituents delineate the same design?". In the present study, I have concentrated on a comparison of the distribution of interstellar dust, as detected by its occultation of luminous regions of a galaxy, with the positions of the bright H II regions, as detected on Hα interference filter photographs of the spirals. The observational data of the paper consist of direct photographs, both in blue light and in the light of the Balmer alpha line, of 33 galaxies. For twelve of these objects, I used the Hα material obtained by Sandage at the 200-in.; the remaining 21 galaxies were photographed with the University of Arizona's 90-in. telescope equipped with a Carnegie image tube. The blue photographs used were gathered from the Hale Observatories' files, from Mrs Burbidge's collection, and from the 90-in. observations. The conclusions presented in this report are based on a sample of 3 S0, 2Sa, 11 Sb, and 16 Sc galaxies.

The general conclusions presented in my first progress report (Lynds, 1970) which was based on studies of 16 Sc galaxies (eight of which had Hα photographs available), are confirmed and extended to earlier type spirals. The bright H II regions of a galaxy are always found either next to or embedded in regions of high obscuration. It is also generally true that the dust lanes of a galaxy better define a spiral pattern than do the H II regions.

Figure 1 is an example of the technique now used in studying the 90-in. data. A series of interference filters, each with almost the same transmission curve of half-width of about 75 Å and centered at the wavelengths of 6563, 6607, 6650, and 6782, are used. Each galaxy is photographed through the appropriate filter so that the Balmer alpha line is recorded and then the galaxy is also photographed in the red through a filter which does not transmit this emission line. The two top photographs of the figure show NGC 5194 (M51) as photographed through the 6563 filter (left, which transmits the emission line) and the 6650 (right, which does not transmit the line). The lower left-hand photograph is the same galaxy photographed through a broad-band blue filter. The lower right-hand picture is a scale drawing of the location of the darkest dust lanes of the galaxy. The drawing itself was made from the superb

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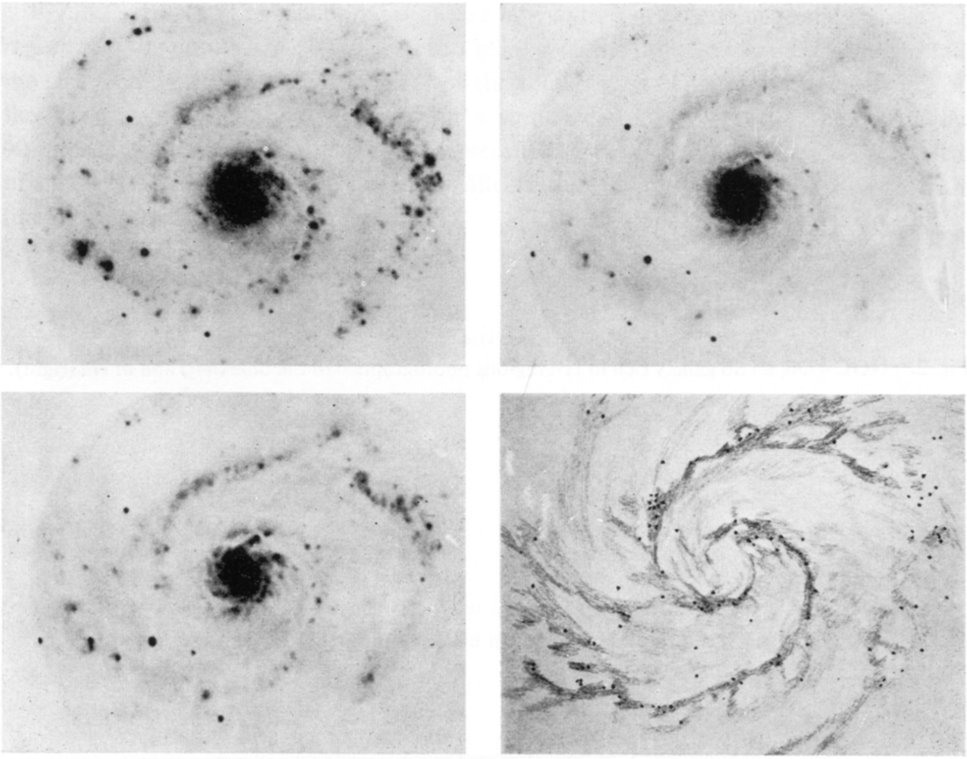
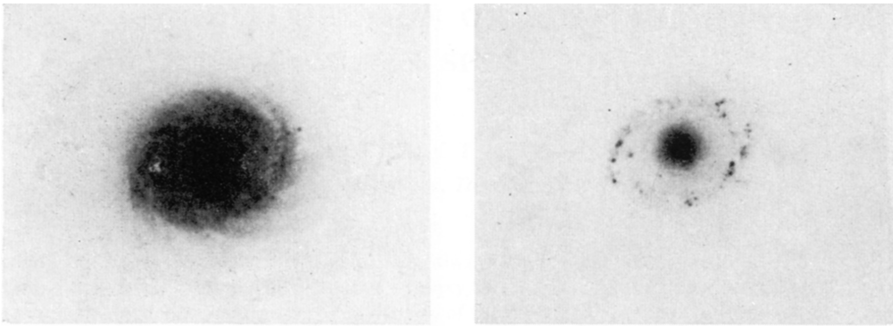


NGC 5194

Fig. 1. NGC 5194 (M51) photographed (top left) through a 6563 Å filter which transmits the Balmer alpha emission line and (top right) through a 6650 Å filter which does not transmit this line, and through a broad-band blue filter (lower left). The lower right-hand picture is a scale drawing of the location of the darkest dust lanes of the galaxy.

blue photograph taken by Humason with the 200-in. A careful comparison of the two top photographs enables one to identify the H II regions of NGC 5194, and these regions are marked as black dots in the drawing. NGC 5195 would lie just to the right of the photographs, and one could easily imagine that there is some evidence for a disturbance on the right-hand side of the drawing. The characteristics of the distribution of dust in an Sc galaxy are well illustrated in this case. The H II regions are invariably found in obvious dark lanes. Very often, they are found on the edge of the primary dust lane which lies on the inside edge of a luminous arm, but they are also found in feathers of dust which cross the lanes and in the more diffuse outer wisps of dark nebulosity. Frequently, H II regions occur at a branching of a dark lane.

The search for bright H II regions in spirals of earlier type is not so fruitful. NGC 4736, seen in Figure 2, is an Sb galaxy rather rich in H II regions (as seen on the Hα photograph on the right of Figure 2); but it is quite evident that the complex spiral structure of this galaxy is defined by the dust in the regions interior to the zone of bright H II regions as well as in the outermost parts of the galaxy (as seen on the blue photograph



NGC 4736

Fig. 2. NGC 4736, an Sb galaxy rich in H II regions photographed in the blue (left) and in Hα (right).

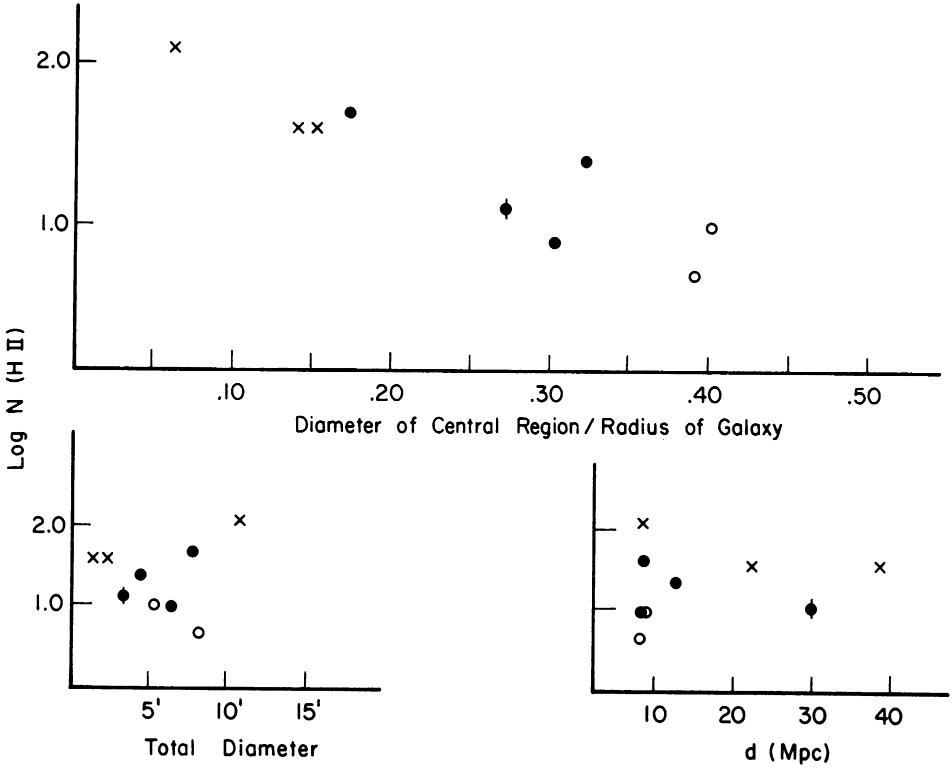
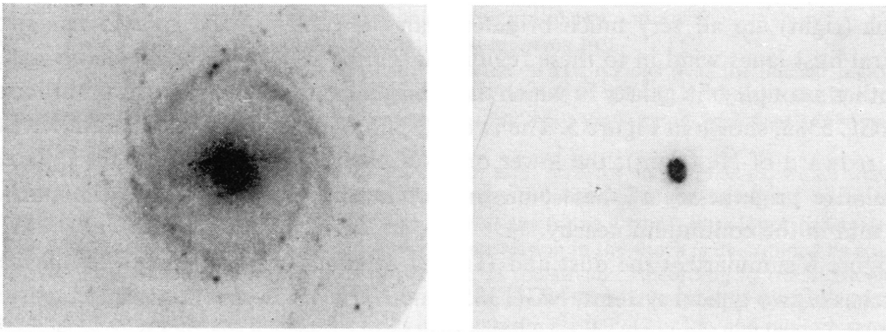


Fig. 3. (upper diagram) The size of the central region (in units of the total radius of the galaxy) vs the log of the number of H II regions detected on a standardized photograph taken with the 90-in. telescope. The log of the number of H II regions detected vs total diameter (lower left) and vs linear diameter of the central region (lower right).

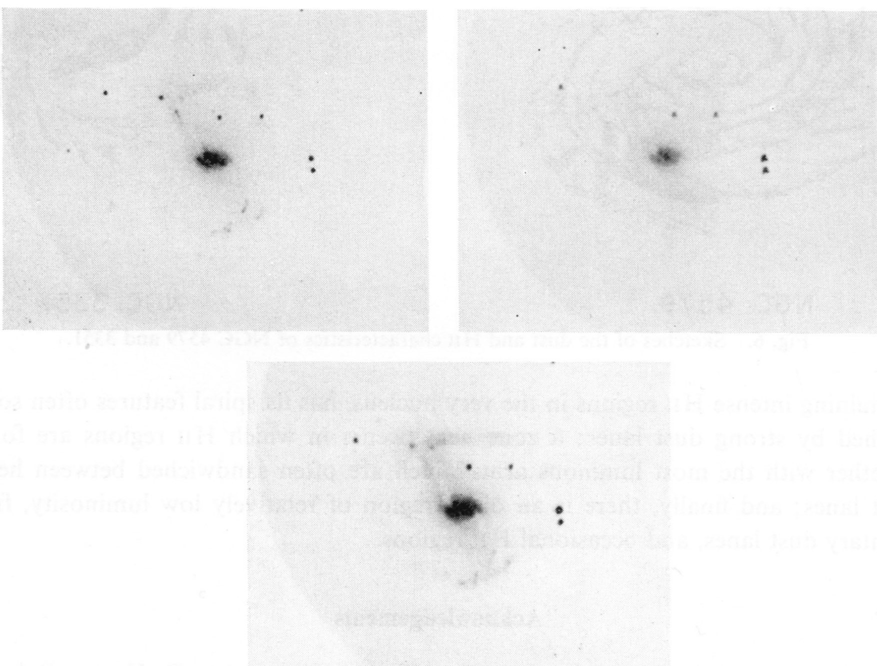
on the left of Figure 2). It is possible to divide each of the Sa and Sb galaxies into three distinct regions: a central zone in which no H II regions exist (the exception to this is a group of galaxies in which very intense H II regions are found in the nucleus itself), an intermediate belt in which the brightest of the H II regions are located, and an extended low-luminosity region. In all regions, spiraling dust patterns are detected.

Figure 3 shows that there appears to be a correlation between the size of the central region and the number of H II regions in a galaxy. In the upper diagram, I have plotted the size of the central region (in units of the total radius of the galaxy) vs the log of the number of H II regions detected on a standardized photograph taken with the 90-in. telescope. These nine galaxies represent the best data available; they consist of three Sc galaxies (crosses), three Sb (filled circles) and one SBb (filled circle with line), and two Sa galaxies (open circles).



NGC 3351

Fig. 4. NGC 3351 photographed in the blue (left) and in Hα (right).



NGC 5383

Fig. 5. NGC 5383 photographed in the light of Hα (top left), redward of Hα (top right) and in blue light (lower photograph).

The fact that the Sc, Sb, and Sa galaxies are arranged in the diagram in the sense of increasing diameter of the nuclear region is a reflection of the manner in which Hubble set up his morphological classification. The figure itself illustrates that the smaller the central amorphous region, the more H II regions are found exterior to it. The two lower diagrams demonstrate that there appears to be no selection effect in the H II counts as far as the angular size of the galaxy and its distance are concerned.

Six of the galaxies studied have several very bright H II regions in their nuclei. One example, NGC 3351, is shown in Figure 4; the six knots seen in the Hα photograph (right) are all very much brighter than the center of the galaxy. The strong central dust lanes wind in to these regions as will be seen on a sketch of this galaxy. Another example of a galaxy in which these bright central emission regions are found is NGC 5383, shown in Figure 5. The two top photographs are in the light of Hα (left) and redward of Hα (right); the lower one is a blue photograph. Note the difference in relative brightnesses of these emission patches as photographed in the emission line and in the continuum nearby.

Figure 6 summarizes the dust and H II characteristics of Sb galaxies by means of sketches of two typical systems, NGC 3351 and NGC 4579 – a central region, possibly

NGC 4579 NGC 3351

Fig. 6. Sketches of the dust and H II characteristics of NGC 4579 and 3351.

containing intense H II regions in the very nucleus, has its spiral features often solely defined by strong dust lanes; a zone next occurs in which H II regions are found together with the most luminous arms which are often sandwiched between heavy dust lanes; and finally, there is an outer region of relatively low luminosity, fragmentary dust lanes, and occasional H II regions.

Acknowledgements

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Lynds, Beverly T.: 1970, in W. Becker and G. Contopoulos (eds.), 'The Spiral Structure of our Galaxy', *IAU Symp.* **38**, 36.

Discussion

Salpeter: Is the dust density higher in the inner regions, devoid of H II, than further out in the galaxy?

Mrs Lynds: The central dust lanes are certainly more *regular* and appear more dense, but that may be because the outer ones are diffuse and fragmentary.

King: With what 'arms' do you compare the distribution of H II and dust?

Mrs Lynds: The bright blue arms were what I was referring to.

Mrs Rubin: Can you say anything about the presence of H II regions near the nuclear regions of galaxies? Are the regions absent, or are they just not visible in the light from the nuclear bulge?

Mrs Lynds: The bright H II regions are exterior to this zone. We see only occasionally H II regions in the nucleus.

Ozernoy: Dr Pikelner explains both the dark lanes and 'feathers' in Sc galaxies, which were observed by Mrs Lynds, as the result of the compression of interstellar gas by shock waves in the framework of Lin's theory of spiral arms. The rarefied gas forms a front, but clouds penetrate into the arm without great deceleration. The degree of compression in the shock is determined by equality of internal pressure (mainly magnetic) and pressure of the stream. According to observations, the density of the material in the dark lanes is 10 cm^{-3} or more. From this Pikelner predicts that such high compression is possible, if magnetic fields in Sc galaxies are 0.9 μG or less and random velocities 2 km s^{-1} or less, i.e. field and velocities in Sc are considerably less than those in Sb and, in particular, in our Galaxy.