PART V

DISTRIBUTION OF DUST AND GAS

DUST NEAR THE NUCLEUS OF M 31

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Abstract. Special photographic observations reveal silhouetted dust patterns as close as 6″ from the nucleus. The spatial distribution and kinematics of the dust are discussed.

1. Introduction

Johnson and Hanna (1972) have copied a plate of the central region of M 31 (Johnson, 1961) with a technique which especially well depicts the abundant dust features in the radii $r = 6''$ to several arc min. We wish to make a series of conclusions about the distribution and motions of the interstellar gas and dust, partly with reference to the kinematics now well known in most of the range within $r = 2' = 400$ pc of center (Rubin and Ford, 1971). The major semi-axis X of the rotationally approaching side of the main body of M 31 is at the position angle $PA = 218°$, and the principal plane of the main body of M 31 is inclined to the line of sight at $i = 13°$ (Rubin and Ford, 1971). Thus the far side of the principal plane of M 31 lies in the range of position angles which increase from $PA = 38°$ by 180°.

2. Discussion and Conclusions

(1) If light and dust were confined to the principal plane of M 31, the dust should be equally silhouetted at all position angles. However, the light of M 31 near center is not at all confined to the principal plane, as is shown by the isophotal ratio of minor axis to major axis, 0.7 at $r = 1'$ with a slow decrease beyond $r = 1'$ (Kinman, 1965), compared with sin $i = 0.225$ for the principal plane. Nonthermal radio sources centered on the nucleus of M 31 are also nearly spherical to the radius of 3′5 (Pooley and Kenderdine, 1967). Clouds of dust which intercept lines of sight through luminous spheroids will be much better silhouetted in the near hemisphere because of the smaller ratio of foreground to background light. Therefore we interpret the strongest images to be clouds in the near hemisphere. Of course, a given optical depth in the near-hemisphere clouds can mimic the effect of larger optical depth in clouds farther along the same line of sight, so the interpretation if statistical.

(2) Cloud structure becomes more mottled with increasing r. Mottling is fairly equally prevalent in all position angles at $r \geqslant 2'$. We think that this argues against confinement of clouds to the principal plane because of the unequal silhouetting effect in near and far hemispheres as discussed in paragraph 1. We think that the more diffuse clouds are broken into wavy clumps with a typical size of 20″ and they cover about 50% of the area inside $r = 3'$.

Greenberg and Van de Hulst (eds.), Interstellar Dust and Related Topics, 215–217.

(3) An arm-shaped cloud originates (or terminates) very faintly near $r = 6''$, $PA = 120°$, thrusts northeastward, becomes quite strong by $r = 15''$ just before it crosses the major axis at $r = 1'1 - 1'7$ in $PA = 38°$, and continues northward to $r = 2'0$, $PA = 10°$, at least in one branch of several possible branches. Is this a 'spiral arm'? We know of no test in this case to prove spiral structure or, on the contrary, to prove accidental contiguities. If the proposed arm is rectified onto the principal plane, it appears to be overly stretched parallel to the Y-axis, and it cannot then be well approximated by a logarithmic spiral or an Archimedes spiral. We believe that the feature does not lie in the principal plane.

(4) If the feature discussed in paragraph 3 were a spiral arm, we might expect a symmetrically opposite arm. A very faint counterpart indeed appears to exist, and to be identical with Baade's (1958, 1963) S1 arm where it crosses the X-axis at $PA = 218°$. If it is axi-symmetric with part of the paragraph-3 arm, the axis of symmetry may not be close to the rotation axis of the principal plane of M 31 because the arms should then be equally visible where they cross the respective $\pm X$ semi-axes.

(5) We conclude that the dust near the nucleus of M 31 is probably not restricted to the 25-pc-thick disk of gas in the principal plane to which the model of Rubin and Ford (1971) confine the gas. We think that the dust is not even confined to the 100-pc-thick co-planar disk of clouds which Rubin and Ford (1971) postulate. Spatial decoupling implies kinematical decoupling, so we anticipate the radial-velocity jumps which Rubin and Ford (1971) report at the intersections of the spectrographic slit with cloud images. The most pronounced discontinuity on their spectra occurs where the slit crosses the image of a large and dark cloud complex marked 'f' on their Figure 8, at about $r = 70''$ in $PA = 338°$

(6) We conclude from both form and relative contrast of various dust features which are silhouetted on the central bulge of M 31 that their distribution falls into four domains: (i) apparent absence within $r = 6''$, (ii) two arm-like features out of the principal plane within $r = 1'$, (iii) branching and break-up into wavy structure in a nearly isotropic transition zone around $r = 2'$, and (iv) formation into major spiral arms nearer the principal plane and beyond $r = 2'5$ on the minor axis and certainly by $r = 8'$–$10'$ on the major axis (Baade's N2 and S2 arms). Rubin and Ford (1971) observe velocities of gas in dust to be prevalently redshifted relative to velocities of disk gas. This suggests net infall of dust towards center, possibly with tide-like effects on clouds captured from domain (iii) into domain (ii). The dust clouds contain gas which emits brighter lines than the disk does (Rubin and Ford, 1971). Volume-emissivity must be higher in the clouds than it is in the disk since the cross-sections of the clouds are generally smaller than 100 pc, which is the line-of-sight depth of the gas confined to the disk models of Rubin and Ford.

(7) We take note that the position angle of the major axis of the ellipsoidal nucleus of M 31 is at $PA = 52° \pm 2°$ or 14° greater than the position angle of the major axis of the principal plane of the main body of M 31, as discovered by Johnson (1961). This has important dynamical implications. If the angular-momentum vector of the nucleus is not parallel to the angular-momentum vector of the bulk of the mass of

M 31, the decoupling may be the result of inflow of matter from outside the principal plane of M 31. If 'the nucleus of M 31 is really quite young', as Spinrad (1971) asserts, the input of fresh matter may be required by way of stellar evolution.

(8) Finally we note that S And, the 1885 supernova, appeared at $r = 17''$, $PA = 254°$ (Copeland, 1886), which is in or near a small knot of dust in the counter-arm described in paragraph 4.

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