NGC 4258: A BENT JET IN A SPIRAL GALAXY

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The remarkable continuum arms in the spiral galaxy NGC 4258 are suggestive of some form of ejection from the nucleus of this galaxy (Van der Kruit, Oort and Mathewson, 1972). To summarize the observations (see Oort, Figure 2, this volume), the "anomalous spiral arms" are clearly distinct from the normal spiral arms, although wound in the same sense; there is a sharp gradient of the continuum emission on the leading edge of the arms, and an indication that the arms split on the western side; the arms go directly into the nucleus and coincide with Hα emitting filaments (Courtes, Viton and Veron, 1965).

The only model which has been suggested for the anomalous arms involves highly directional ejection of 10^7 to 10^8 $M_\odot$ of gas at velocities from 800 km/s to 1600 km/s. Interaction of the clouds with the differentially rotating gaseous disk of the galaxy accounts for the observed shape of the arms. We may obtain an alternative model by assuming that the anomalous arms are more or less steady-state jets which are bent both by a pressure gradient in the interstellar medium and by the ram pressure of rotating extended atmosphere. From the balance of centrifugal force wthin the bent jet against ram pressure and pressure gradient forces, one may derive a differential equation for the shape of the jet (Begelman, Rees and Blandford, 1979). I have assumed a rotating isothermal atmosphere (or gaseous halo) in a Hubble low potential with constant angular velocity on cylindrical shells. In this model there are five free physical parameters:

(1) $f = V_{mx}^2/(\sigma^2 + V_{mx}^2)$.
Here V_{mx} and σ are respectively the maximum rotational velocity and the velocity dispersion of the gas in the halo.

(2) θ_e = the initial angle of the jet with respect to the rotation axis of the galaxy.

(3) $\lambda = \rho_a/V_a^2/\rho_j V_j^2$.
This is the initial ram pressure in terms of the momentum flux in the jet.

(4) S_o = the distance of the sonic point in the jet from the galactic nucleus.

(5) R_o = the nozzle radius.

D. S. Heeschen and C. M. Wade (eds.), Extragalactic Radio Sources, 145–147.

https://doi.org/10.1017/S0074180900027571 Published online by Cambridge University Press

In addition there are two projection angles θ_1 and θ_2, but one of these is the known inclination of the galaxy.

There is one very necessary constraint on such a model. Ram pressure bends a jet into a spiral, but it is a leading spiral. However, the anomalous spiral ams have the same sense of winding as the normal spiral arms, and, presumably, the normal spiral arms are trailing. This means that, in the context of this model, the anomalous arms cannot lie in the plane of the galaxy. If our line of sight is between the plane of the galaxy and the plane of the anomalous arms then both the trailing normal arms and the leading anomalous arms will project into spirals with the same sense of winding.

Figure 1 shows the optimum bent jet model compared to recent VLA 20-cm observations of NGC 4258.

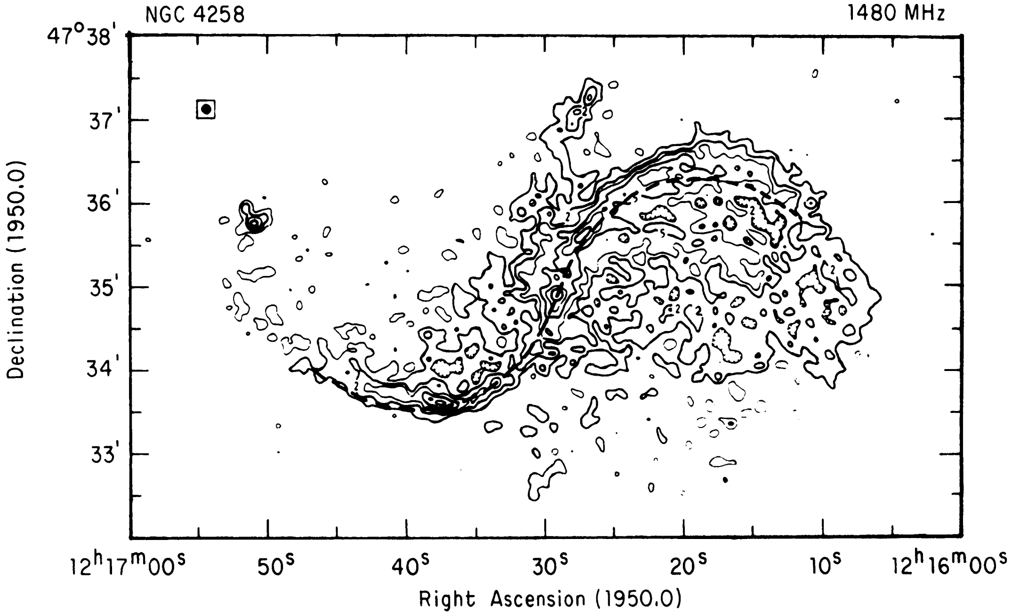

Figure 1. The bent jet projected on to the plane of the sky (dashed line) compared with the VLA 20-cm continuum map of Van Albada and Van der Hulst.

The parameters of this model are f = 0.8, θ^e = 80°, λ = 1.0, S_o = 250 pc, R_o = 100 pc with projection angles of 198° and 72° inclination). We see that the fit to the shape of the anomalous arms is reasonable. Moreover, assuming a jet velocity of 1000 km s^{-1}, the mass loss rate is fairly mild (10^{-3} $M_\odot$/year).

https://doi.org/10.1017/S0074180900027571 Published online by Cambridge University Press

This model has a very explicit observational consequence. To get the proper projection of the anomalous arms, the northwestern arm must lie behind the galactic plane. Therefore, we should see 21-cm absorption against the continuum arm.

NGC 4258 is an example of a normal spiral galaxy which may contain a jet. If jets do exist in normal spirals, perhaps the nuclei of most normal galaxies contain the same engines that are found in the powerful radio galaxies.

I am very grateful to G. D. van Albada and J. M. van der Hulst for kindly allowing me to use their 20-cm VLA map of NGC 4258 in advance of publication.

REFERENCES

Begelman, M. C., Rees, M. J., Blandford, R. D.: 1979, Nature, 279, 770.
Courtes, G., Viton, M., Veron, P.: 1965, Quasi Stellar Sources and Gravitational Collapse, eds. Robinson, Shild, Shucking, Univ. of Chicago Press, p. 307.
Van Albada, G. D.: 1978, Ph.D. Dissertation, University of Leiden.
Van Albada, G. D., van der Hulst, J. M.: 1981, in preparation.
Van der Kruit, P. C., Oort, J. H., Mathewson, D. S.: 1972, Astron. Astrophys., 21, 169.

DISCUSSION

OORT: I see several objections to your model. The first is that the normal arms of NGC 4258 show a pronounced weakening where according to the model of Van der Kruit, Oort and Mathewson the ejected gas would have swept them away. The second is that the inner parts of the anomalous arms, where they are seen in Hα emission, show that the general, presumably disk-emission in the region preceding the arms is much stronger than in the region behind, indicating that these parts of the arms, which reach out to at least 6 kpc from the centre, are likewise situated in the disk. This is further corroborated by the fact that they participate in the disk's rotation.

SANDERS: The outer spiral arms, at least the southern arms, do become less intense closer to the center of this galaxy. From visual inspection of photographs of this galaxy, the weakening seems to me to be entirely consistent with what is seen in other normal Sb systems (M81, for example). As you point out, the general Hα emission is certainly weaker in front at the southern anomalous arm; however, the region of this low intensity does coincide with a large dust patch. My impression from Van der Kruit's work on the Hα filaments associated with the anomalous arms is that the kinematic features differ rather conspicuously from that of the general disk