FORMATION OF BI-POLAR SPIRAL FEATURES IN GALACTIC NUCLEI

Paris Pişmiş and Edmundo Moreno
Instituto de Astronomía, Universidad Nal. Autónoma de México
Apdo. Postal 70-264, México 04510, D.F.

1. Introduction

In earlier communications we have called attention to the existence of very tight spiral formations in the nuclei of some galaxies, particularly of the early type barred spirals, proposing a mechanism for their formation (Pişmiş and Moreno 1984). These kiloparsec-scale structures are loosely termed "rings" but their overall morphology suggests strongly that the image is a tightly wound double spiral usually delineated by knots of emitting material, "hot-spots". A striking characteristic of these spirals is their very high luminosity compared to the outer regions of the galaxy. 26 galaxies with "nuclear" spirals are listed by Buta,thesis. A systematic search with short exposure high resolution imagery may reveal many more nuclear spirals. NGC 4736 (Sb) though not a barred spiral has a well defined inner spiral delineated by very luminous H II regions.

We have shown earlier that nuclear spirals can be engendered by collimated outflow of matter in a bi-polar fashion from the equator of a rotating massive nucleus. Turning the argument around we had stated that a tight nuclear spiral is evidence of activity in a galactic nucleus (Pişmiş 1987). We now give the general analytic expression for the locus of the ejecta in the gravitation field of a nucleus assumed to be a mass point. In this picture the ejecta describe conic sections.

2. Formalism

Let V_{rot} be the rotation velocity at radius R_o from the central mass point with mass M, V_{ej} the radially outward velocity, R and β the polar coordinates; further, $\xi = R/R_o$ and the eccentricity, $e = V_{ej}/V_{rot}$. Two cases will be presented; the equation of their respective loci are:

Case 1. Elliptical $e < 1$

$$\beta = \arccos \frac{1}{e}\left(1-\frac{1}{\xi}\right)-\left(1-e^2\right)^{-3/2}\left\{e\left[|\cos\alpha|-\sqrt{1-e^2}\right]+\alpha-\arcsin\right\}-\frac{\pi}{2}$$

$$\alpha = \arcsin \frac{1}{e}\left\{1-\xi\left(1-e^2\right)\right\}$$

Case 2. Hyperbolic $(e > 1)$

$$\beta = -\arcsin \frac{1}{e}\left(1-\frac{1}{\xi}\right)+\left(e^2-1\right)^{-3/2}\left\{\sqrt{e^2-1}\left[\sqrt{\xi^2 e^2-(\xi-1)^2}-e\right]+ \right.$$

$$\left. + \ln \frac{e\left(e\sqrt{e^2-1}\right)}{\xi\left(e^2-1\right)+1+\sqrt{e^2-1}\sqrt{\xi^2 e^2-(\xi-1)^2}}\right\}$$

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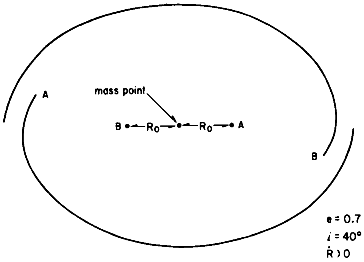
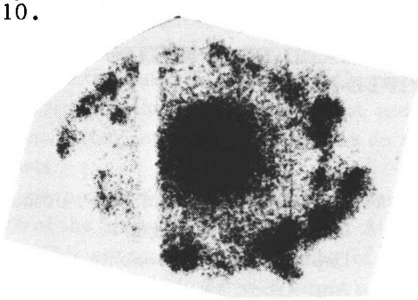
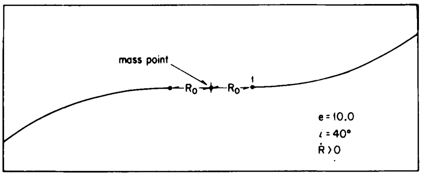
The double locus computed for Case 1 (e = 0.7) is shown below at left. Note that this double locus resembles the image of the nuclear spiral of NGC 4736 (at right). Case 2 reproduces the open S-shaped appendages -low thrust jets- of the nuclei of Seyfert galaxies (Wilson and Ulvestad 1982), also given below for e = 10.







3. Discussion

a) It follows from our model that: radial motions of the outflow (and inflow, after the ejecta have crossed the apogalacticum) will vary with the central angle β. This is indeed observed in NGC 4736 (van der Kruit 1976) and in NGC 1512 (Lindblad and Jörsäter 1981). b) We believe that the outflowing plasma is entrained by magnetic lines of force (of a dipole field -see Pişmiş 1963). In fact, observations with the VLA of the nuclear spiral of NGC 4314, at 6 and 20-cm have shown the radiation to be non-thermal and plane polarized (García-Barreto and Pişmiş 1985).

We have neglected in the present treatment the commonly accepted ram pressure caused by the outlying matter and the consequences thereof. In defense of our purely gravitational approach we point out that the contrast in luminosity, and hence of mass, of the ring-like spirals with respect to the outlying matter is very high; therefore to a fair first approximation ram pressure effects may be neglected. Ram pressure, if present, will tend to diminish the eccentricity of the orbits of the ejecta while frozen in magnetic lines will resist to bending. These two phenomena work in opposite sense and may partly cancel one another.

In concluding, we wish to emphasize that gravitational forces may be important in the shaping of nuclear appendages such as tight spirals and S-shaped "low thrust" jets in Seyferts.

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