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# ON THE ORIGIN OF TIGHTLY WOUND SPIRAL FEATURES IN GALACTIC NUCLEI

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A mechanism for the origin and development of spiral arms proposed earlier by one of the authors (P.P.) is recalled to show that spiral structure in the nucleus of a galaxy can be produced by matter ejected from a rotating nucleus. The mechanism can account for the observations of outward and/or inward motions in the nuclear regions of spirals. In particular our model applied to the tight nuclear spiral of NGC 4736 shows satisfactory agreement with observations.

1. Introduction. The morphology and motions in the nuclear regions of galaxies are known to exhibit complexities. High resolution imaging has shown that there exist high excitation emission clouds—hot spots—in a number of nuclei (see for example Sersic and Pastoriza [1]). Higher resolution observations may increase the sample, making possible a study of the frequency of the hot spots and their physical parameters such as mass, density, excitation degree, as a function of the type of galaxy—spirals in most cases.

Motions in the central region of some galaxies have shown that rotation along with radial motions are consistent with the observation; non circular motions—to use the loose term for the radial component of motions—do seem to exist. In the Seyfert-type galaxies motion of discrete clouds in the radial, as well as in the tangential direction is a plausible interpretation of the velocity data [2—4]. Such a phenomenon appears to be quite general in galactic nuclei. Moreover, the intensity of nuclear activity may show gradations: these may be much less important in some galaxies than in the Seyferts and still more violent in others which show optical and radio jets as evidenced from direct images and/or by spectroscopy. The jet in M87 is too well known a case in point. There is hardly any doubt that it is caused by ejection from the nucleus. A pair of symmetrical amorphous arms is observed to start from the nucleus of NGC 4258 [5] of which the radio continuum counter-part is detected by van der Kruit et al. [6].

The general belief — and ours as well — is that these features are the result of expulsion of gas from the nucleus of NGC 4258.

2. Tight nuclear spirals. In a number of galaxies the hot spots are arranged in a tight spiral form; NGC 1097 (SBb), NGC 4314 (SBa) and NGC 4736 (Sab) are good examples. These structures are usually referred to as "rings" but in no case do they delineate closed curves. These tight spirals are well defined and are usually associated with barred galaxies. An inner spiral appears to be of a category quite dilferent from the outer spiral as regards pitch angle or brightness suggesting that their origin may be different from the density wave phenomenon. In NGC 4736, to which our arguments to follow will be applied, the brightness diminishes abruptly outside the nuclear spiral, and the outer arms become multiple. Fig. 1 is a print of a direct H<sub>a</sub> imagetube photograph of NGC 4736 taken with the 2.1 meter reflector of the Observatorio Astronomico Nacional at San Pedro Martir, B. C. It shows clearly the inner arms and a circular nucleus. The outer multiple arms are too faint to appear on the reproduction (see Hubble Atlas for a detailed description of NGC 4736).

As regards the kinematics of central regions, radial motions as well as rotation are detected in a number of galaxies. The model for the nuclear kinematics which we shall present below accounts for radial motions *inwards* or *outwards* or *both* in the same galaxy. The overall trend in the radial motions reported so far in the literature are *expansion* in some cases and *contraction* in others. It is true that the sense of the motion will depend on the adopted orientation in space of the galaxy but we believe that at present there is a general agreement in the method of evaluating the orientation of a spiral so that no ambiguity is expected to exist as to the sense of the radial motions given in the literature. Table 1 lists the galaxies the nuclei of which exhibit radial motions.

3. The origin of nuclear spirals through ejection and rotation. In this paper we show that bi-polar outflow of matter from a rotating nucleus is able to produce *tight nuclear spirals*. At this point we wish to emphasize that our attempt is not intended to explain the "grand design" of spiral galaxies but only the spiral in a nucleus.

The idea of the origin of spiral forms by the hypothesis of ejection is not new. Over two decades earlier the discovery of the 3-kpc expanding arm by the Dutch radio astronomers and the probable ex-



Fig. 1. Enlargement of a direct image tube photograph through a 10A interforogram filter of the central spiral structure in NGC 4736 taken with a focal reducer attached to the 2.1 meter reflector of San Pedro Martir Observatory. The scale on the original plate is 49 arcsec  $mm^{-1}$ .

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pansion of the OB associations from the galactic center [16] prompted us to propose a simple model of ejection from a rotating nucleus, a mechanism which could produce spiral forms [17]; we became aware later that such an hypothesis was already proposed by Ambartsumian [18]. However, there were many questions left unanswered. Although the bipolar mode of ejection could be accounted for by invoking magnetic phenomena [19] the grand design was not explained as the resulting spiral would curl inwards contrary to observation.

Galaxy	Туре	Radial Motions	References	
M 31	Sb	Outward	[7]	
NGC 253	Sc	73	[8, 9]	
NGC 1068	Sb (Seyfert)	1.000	[2]	
NGC 4151	Sa (Seyfert)	1.1.1.1.1	[3, 4]	
NGC 4736	Sb	1	[10]	
NGC 2903	Sc	Inward	[11]	
NGC 3351	· SBb	Sec. 12.19.11	[12]	
NGC 3672	Se	13.5 M.	[13]	
NGC 5383	SBb		[14]	
NGC 6764	SBs3 (Seyfert)	n	[15]	

## RADIAL MOTIONS IN NUCLEAR REGIONS

A modified model was later proposed which could produce the grand design on the basis of a rotating and gradually contracting gaseous subsystem (without ejection), permeated by a magnetic field—say that of a *dipole*—centrally located the axis of which was perpendicular to that of rotation. This model applied to a concrete case, M 31, produced a double spiral in  $3 \cdot 10^9$  years with one and a half turns each from 20 to 5 kpc from the center of the galaxy [20]. A succinct account of the development of this approach to the spiral problem and the list of phenomena it can account for have appeared lately [21]. In that abstract references to the earlier work are also given.

Meanwhile the density wave theory was developed by Lin, Shu, Roberts and others (see the survey by Wielen, [22]). As of today it has been successful in explaining, in a general way, the existence of the spiral structure in galaxies, though it may be remarked that the cause of the onset of the density wave is not yet uniquely and satisfactorily explained.

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Table 1

The present paper treats specifically the central symmetrical double spirals in galactic nuclei. There appears to be ample evidence at present for the existence of radial motions in the central regions of galaxies attributed to a present or past nuclear activity. We have therefore deemed it of sufficient interest to renew our emphasis on the phenomenon of bi-polar ejection from a galactic nucleus and to look quantitatively into its consequences. The treatment in the paper by Huang and Pismis [16] we mentioned earlier was more of a phenomenological nature. In what follows, we actually compute the locus of the ejecta using the physical parameters of a sample spiral, the nuclear region of NGC 4736 for which van der Kruit has obtained a reliable velocity field by high dispersion spectroscopy [10, 23]. We obtain as a result a pair of intertwined spirals at time t which represent satisfactorily the morphology and the observed overall kinematics of the inner parts of NGC 4736.

a) Formulation. We consider the force acting on the distance to be only the attraction of a galactic nucleus taken as a mass point such that the dynamics can be treated as a two-body problem. The orbits of the ejecta will then be conic sections, and these are taken to be ellipses since the maximum distance reached by the ejecta will be finite. This simplified model of the force field should not alter the main trend of the locus of the ejecta.

Let M be the mass of the ejecting nucleus, R the distance of the ejected mass from the nuclear center,  $R_0$  the radius of the nucleus from where ejection takes place,  $R_{max}$  the maximum distance attained by the ejecta,  $\pi$  the velocity, radial from the center,  $\pi_0$  similar velocity at the moment of ejection,  $\theta$  the tangential velocity,  $\theta_0$  similar velocity on the nucleus (at  $R_0$ ).

We denote by  $\gamma$  the ratio  $R_{max}/R_0$ . From the two-body problem we have

$$\frac{\pi_0}{\theta_0} = \frac{\gamma - 1}{\gamma} \tag{1}$$

Assuming that the maximum distance of the tight spiral from the galaxy center is very close to the apogalacticon of the elliptical orbit described by the ejecta, we obtain a value for  $R_{\max}$  and this determines the value of  $\gamma$  when  $R_0$  is known. With  $\gamma$  and the mass M of the nucleus known, one can compute the locus of the ejected matter\* with given initial conditions which are  $\theta_0$ , the velocity of rotation and  $\pi_0$  the velocity at  $R_0$  radial from the nucleus, satisfying (1).

\* t years after the onset of ejection.

4. Application to the nuclear spiral of NGC 4736. The relevant physical parameters for NGC 4736 are  $M = 2.9 \cdot 10^{10} M_{\odot}$  and distance = = 10 Mpc (both data from [24]). The radii  $R_0$  and  $R_{me}$  estimated from the direct image of NGC 4736; at 10 Mpc these are 776 pc and 2424 pc respectively.  $\gamma$  is, then, very close to 3. We adopt the following rounded values for the parameters:  $M = 3 \cdot 10^{10} M_{\odot}$ ,  $R_0 = 800$  pc and  $\pi_0 =$ = 0.666  $\theta_0$  when  $\theta_0 = [GM/R_0]^{1/2}$ . Several simulations to the inner spiral of NGC 4736 were attempted with these values as initial conditions as well as by introducing small variations of these. We shall present here only the relevant cases.

a) Case 1. We assume all physical parameters such as ejection and rotation velocites, the mass and the radius of the nucleus, to be constant in time. Computation with these conditions has yielded a locus as given in Fig. 2. The  $\pi$  and  $\theta$  values at the computed points are marked on the locus as well as given in Table 2.



Fig. 2. The locus of the ejecta; assumptions  $M = 3 \cdot 10^{10} M_{\odot}$ ,  $\pi_0 = \text{constant}$ ,  $R_0 = 0.8$  kpc. (*Case 1*).

In this table as in Tables 3, 7 and 8, the coordinate R is the distance from the center of the galaxy where the mass point is assumed to be located. The coordinate  $\vartheta$  is measured counter-clockwise from

the line ox of Fig. 2. This definition accounts for the negative values for some of the angular coordinates.

Tuble 2 (Cose 1) LOCUS OF EJECTED MATTER FROM THE NUCLEUS OF NGC 4736 WITHIN ABOUT 10' YEARS FROM  $R_0 \Rightarrow \text{const}$ ;

Points	Coordi	nates	Velocity Components (km s <sup>-1</sup> )		
	R (kpc)	। श (rad)	π	0	
А	1.28	-1.42	220	251	
В	1.66	-0.73	165	189	
С	1.94	0.05	122	165	
· D	2.08	0.55	104	153	
Е	2.20	1.12	79	147	
F	2.25	1.52	61	141	
G	2.32	1.98	49	134	
Н	2.37	2.50	30	134	
I	2.40	3.14	6	134	

The model has to pass two tests: (a) It should reproduce the morphology and (b) the velocity field should be consistent with the observations. The observed velocity fields are not detailed enough for a point by point comparison therefore we compare only averages. Fig. 3 represents two spirals identical to that in Fig. 2 (from point C to I) starting from the ends of a diameter and projected onto the sky by 40°. The resemblance of this figure to the spiral image in Fig. 1 is satisfactory. We have left out the points inward of C since in the real image we wish to simulate there are no more bright condensations within the point C. The computed line of sight velocities, with the adopted inclination, as a function of position angle appear in Fig. 4. Plotted in the figure are also the average velocities given by van der Kruit [10]. Again the observations do not contradict the theoretical curve: as to the velocity averages we find that:

 $\bar{\pi} = 64 \text{ km s}^{-1}, \ \bar{\theta} = 144 \text{ km s}^{-1}, \text{ taking only points C through I}$  or

 $\overline{\pi} = 55 \text{ km s}^{-1} m \overline{\theta} = 141 \text{ km s}^{-1}$ , taking only points D through I. These are to be compared with van der Kruit's values [10]

 $\pi = 30 \text{ km s}^{-1}, \ \theta = 150 \text{ km s}^{-1}.$ 

We note that our average outward velocity is larger than the observed one.



Fig. 3. The double spiral, each as in Case 1 in the interval of  $\pi$  radians inclined by 40° to the plane of sky.



Fig. 4. Radial velocity with respect to the sun plotted against the position angle for NGC 4736. The observational data are taken from van der Kruit [10]; small dots indicate velocities from only one spectrum; crosses, velocities from two spectra and large dots, velocities from three spectra. Filled circles show the velocities computed from our model as described in *Case 1*. The P. A. of the line of nodes is assumed 123° and the systemic velocity, 300 km s<sup>-1</sup>.

So far we have considered a situation where the mass and the radius of the nucleus as well as the velocities of rotation and ejection are constant. It is reasonable to expect that all these parameters may vary on account of the mass outflow. The overall problem requires consideration of energy and angular momentum conservation which we do not carry out in the present study. Rather we explore the effect of the variation of the parameters one at a time, in particular the radius of the ejecting nucleus and/or the velocity of ejection.

b) Case 2. We now assume that the radius of the rotating nucleus varies from R = 0.9 kpc to R = 0.8 kpc, with  $\dot{R} = \text{const}$  in the course of  $7 \cdot 10^6$  years while the ejection velocity remains constant. We start with an ejection velocity of 242 km s<sup>-1</sup>. Table 3 gives the velocities along the locus of the ejecta for this case in an interval of  $\pi$  radians. In this as well as in the remaining Cases 3 and 4 the computed points of the locus evidently will not coincide with those of Case 1. Instead of designating the computed points by letters we prefer to identify them only with their polar coordinates where the angles have as origin the line ox marked in Fig. 2 (in this scheme point *I* in Fig. 2 is at polar angle  $\pi$ ).

Table 3 (Case 2)

(Same	as	in	Case	1	with	variable	R <sub>0</sub>	(Ŕ	_ =	const)	and	con-
		2	tant	π <sub>0</sub> ,	Tim	e interva	1~	107	ye	ars)		

Coord	linates	Velocity Com	ponents km s <sup>-1</sup>
R (kpc)	8 (rad)	π	0
1.76	0	85	180
1.89	0.53	70	170
2.02	1.09	54	161
2.14	1.59	41	154
2.25	2.11	31	148
2.37	2.64	22	142
2.48	3.14	15	138
2.25 2.37 2.48	2.11 2.64 3.14	31 22 15	144 142 133

The average velocities from the table give  $\pi \simeq 45$  km s<sup>-1</sup>,  $\overline{\theta} \simeq = 156$  km s<sup>-1</sup> and  $R_{max}/R_{min} \sim 1.41$ . The corresponding double spiral projected by 40° is similar to that in Fig. 3.

c) Case 3. Case 3 refers to the model in which the radius remains constant while the velocity of ejection diminishes at three different rates, nameley at  $d\pi_0/dt = -2.5$  km s<sup>-1</sup>, -5.1 km s<sup>-1</sup> and -7.7 km s<sup>-1</sup> per 10<sup>6</sup> years respectively. For each of these contraction rates the locus is given to three different distances reached by the initially ejected matter. These are 2.42, 2.46 and 2.49 kpc respectively. Table 4 lists

the  $\pi$  and  $\overline{b}$  and the  $R_{max}/R_{min}$  values (within  $\pi$  radians for all nine points).

$\frac{\Delta \tau_0 / \Delta \ell}{\text{km s}^{-1} / 10^6 \text{ y}}$	Present position	Velocity average	Velocity Components average over $\pi$ rad		
	of initial ojecta	ľπ	0		
-2.5	2.42 2.46 2.49	95 77 60	160 152 147	1.49 1.40 1.32	
-5.1	2.42 2.46 2.49	90 60 43	169 153 148	1.76 1.40 1.35	
-7.7	2.42 2.46 2.49	63 45 28	156 152 149	1.42 1.38 1.35	

Table 5 is the velocity field of the solution for  $d\pi_0/dt = -7.7$  km s<sup>-2</sup> per 10<sup>6</sup> years when the first ejected mass is at 2.49 kpc. The corresponding double spiral within  $\pi$  radians is similar to that in Fig. 3.

(Constant R.	(Constant $R_0$ , $\pi = -7.7$ km s ' per 10' years)						
Coordi	nates	Velocities	(km s <sup>-1</sup> )				
R (kpc)	8 (rad)	π	θ				
1.84	0.57	47 .	174				
1.96	1.05	37	163				
2.07	1.53	29	155				
2.18	1.99	23	147				
2.28	2.40	20	141				
2,38	2.78	19	135				
• 2.49	3.14	18	129				

Table 5

d) Case 4. Consider the situation where both the radius,  $R_0$  and the volocity of ejection  $\pi_0$  vary. The variation of  $R_0$  is approximately the same as in Case 2 and  $\pi \simeq -1.0$  km s<sup>-1</sup> per 10<sup>s</sup> years. The individual computed points of the locus are given in Table 6. The average values are:

$$\bar{\pi} \simeq 36 \text{ km s}^{-1}, \ \bar{\theta} \simeq 152 \text{ km s}^{-1}, \ \frac{R_{\text{max}}}{R_{\text{min}}} = 1.43.$$

The velocities show good agreement with observation and resemble the results of *Case 2*. However  $R_{max}$  is larger making thus the ratio of the maximum to minimum distance of the spiral larger than in *Case 2* and therefore larger than the observed value. The projected double spiral for this case is similar to that in Fig. 3.

Table	6 (	Case	4)
101		- 1	

(Variable	Ro	(0.9 - 0)	),8 kpc),	$\pi = -$	-1.0 km	3-1	per
	10ª	years	within	$\simeq 10^7$	years)		

Coord	inates	Velocities	$(\mathrm{km \ s}^{-1})$
R (kpc)	8 (rad)	74	U
1.81	0	70	177
1.92	0.39	56	167
2.03	0.86	44	159
2.14	1.33	36	153
2.25	1.80	28	147
2.36	2.24	23	142
2.47	2.70	19	136
2.59	3.14	16	13 <b>2</b>

Table 7

SUMMARY OF OVERALL VALUES OF PARAMETERS FOR THE FOUR CASES

	Case 1	Case 2	Case 3	Case 4	
	$R_0$ Constant	R <sub>0</sub> Variable	$R_0$ Constant	R <sub>0</sub> Variable	
	$\pi_0$ Constant	=0 Constant	$=_0$ Variable	= <sub>0</sub> Variable	
$\overline{\tau}; \overline{\upsilon} \; (\text{km s}^{-1})$	64; 144	45; 156	28; 149	36; 152	
Lifetime in 10 <sup>s</sup> years	~ 6	~7	~ 7	~ 7	
$R_{\text{max}}/R_{\text{min}}$	~ 1.24	~1.41	~ 1.35	~ 1.43	

The velocities are in the plane of the Galaxy.

5. Overall comparison of computed spirals with observations. In this paper we have presented an attempt towards a quantitative interpretation of the tight and bright spirals in the nuclei of galaxies, the so called "rings" through application to a concrete case. The basic assumption—a working hypothesis, advanced about two decades earlier is that these nuclear spirals are formed by matter ejected from diametrically opposite regions of a rotating nucleus [19].

Loci of the ejecta are computed for several values of the physical parameters of the nuclear region of NGC 4736 to simulate the morphology and the overall kinematics. The orbits described by the ejecta are taken to be ellipses for reasons given above. Table 7 summarizes the results for four different cases. The criteria for the choice of the best model are, in general, the average velocity of rotation and the agreement of the morphological features; the latter is expressed also as the ratio of maximum to minimum radius (the openness of the spiral). We have also considered the variation of some of the accepted parameters, namely the radius of the ejecting nucleus and the velocity of ejection for a given constant mass. It is seen that the results are not appreciably affected by the assumed small variations. Although the mass of the ejecting body may appear too large a lower mass value will again yield a tight spiral; a comparison with computed parameters of the spiral shows that there is satisfactory agreement between the computed and the observed parameters of the central spiral of NGC 4736 (Fig. 1) — within the uncertainties of the adopted values.

Case 1 and 3 seem to give the best fit to observation. In Case 1 although the computed average expansion velocity is rather high (64 km s<sup>-1</sup>) the rotation velocity (144 km s<sup>-1</sup>) and the  $R_{max}/R_{min}$  (1.24) are quite close to the observed values of 150 km s<sup>-1</sup> [10] and 1.25 estimated from the direct photographs, respectively. In Case 3 both rotation and expansion velocities are almost exactly as fobserved. However, the  $R_{max}/R_{min}$  is larger than that of the direct image of the spiral. Case 4 is acceptable as regards the kinematics but it fails somewhat in its morphology: its  $R_{max}/R_{min}$  is much larger than the observed one. As to Case 2, it provides the poorest match of all.

After reaching  $R_{max}$  the ejecta will be returning towards the nucleus on their way to their perigalacticon. The locus corresponding to the returning matter will again be a spiral but its motion in the radial direction will be one of approach. Thus radial motions outward in some galaxies and inward in others (Table 1) are a direct consequence of our model. Furthermore it is clear that both inward and outward motion may coexist in the same nuclear spiral.

Based on the present overall comparison we may state that a double tight "nuclear" spiral can be produced at least in NGC 4736, by a bi-polar outflow — probably in pulses — from a rotating nucleus of a galaxy.

6. Discussion of some simplifying assumptions. At present we have no information on the distribution of mass in the nucleus of NGC 4736 but the smoothly diminishing brightness with a striking circular symmetry of the image and the faintness of the  $H_x$  line between



2-1329

the nucleus and the tight spiral suggest strongly that a mass-point approximation for the potential of this nucleus is an acceptable one.

The magnetic field permeating the nucleus with parallel lines of force and all perpendicular to the rotation axis invoked to account for the symmetrical expulsion of the plasma in our model is approximated. by a dipole field. We do not discuss neither the origin and maintenance nor the strength of the postulated magnetic field. Such a field will be much weaker at present through loss of energy by the ejection and by decay. One might search for a vestige of the field in the presently observed nucleus, or in the condensations forming the spiral, by polarization measurements, particularly in the radio range. The lifetime of the magnetic field if primeval and without regeneration mechanisms could be estimated if one had information on the conductivity of the gas and the dimensions of the nucleus. We do not carry out such estimates at this stage for want of pertinent data. Furthermore, orbital computations do not take into account the resistence to bending of the magnetic lines of force nor the resistence of the interstellar medium around the nucleus; the orbits are strictly gravitational. If the ISM is not far from homogeneity, the orbits will still give a spiral form for the loci

7. Comparison with a detailed velocity field. In his 1976 paper, van der Kruit [23] has given a detailed velocity field of the inner part of NGC 4736 based on high dispersion spectra. Aside from confirming his earlier results that the inner "ring" is expanding at a velocity of around 30 km s<sup>-1</sup> he shows that the expansion is a function of position angle in the galaxy. Moreover, the outflow exhibits a marked bi-symmetry. His plot of the residual velocities—after eliminating the rotation component—shows maximum velocity of expansion ( $60-70 \text{ km s}^{-1}$ ) in the east-west direction. This direction is shifted by  $30^{\circ} \pm 10^{\circ}$  from the "major axis" and is coincident with the contours of the 1415 MHz emission, resembling bipolar lobes, observed by van der Kruit (also see Fig. 3 in [23]). These radio lobes are coincident with the open outer. ends of the bright spiral. According to our models these would corrospond to the matter first ejected and observed at present as the outer edge of the tight spiral.

Our computed outflow velocities also are functions of the position angle. They show a decrease as the spiral opens up but the detailed comparison with observation is not entirely satisfactory. Our values from all the four cases give expansion velocities of the order of  $30 \text{ km s}^{-1}$  for the outer region and around  $150 \text{ km s}^{-1}$  for the inner region as against  $40 \text{ km s}^{-1}$  and  $60 \text{ km s}^{-1}$  respectively of the observed values. It appears, therefore, that the assumptions of a constant velocity of outflow or a mild rate of decrease of that velocity assumed in our computations should be modified by taking into account a faster decrease of the ejection velocity with an explosive onset. It is quite reasonable to expect that ejection might have occurred in a violent fashion at the start. Computations based on an explosive model are under way.

It is suggested lately that the observed expansion velocities — non circular motions— in this and other galaxies are a consequence of the existence of a "fat bar" at the nucleus (see, for example Bosma [25]). Such a configuration of the nucleus will cause the orbits of stars and clouds to be elliptic. However, in the particular case of NGC 4736 the perfectly circular shape of its nucleus despite the inclination of the galaxy of about 40° makes the assumption of a "fat bar" untenable.

Another alternative interpretation is that the central spiral represents the inner corotation region in the frame of the density wave theory. Our mechanism of the origin and development or spiral features in the nuclei of galaxies does not contradict the density wave phenomenon rather it may help in trigging the density wave; once the spiral features are there the (smooth) gravitational potential will have acquired a spiral component, and a density wave will be expected to enter into operation. It is fair to state that the complexities in the morphology shown by the "grand design" in some galaxies, in the sense that there exist spiral features of different categories, particularly in barred spirals, defies a unique interpretation by the density wave theory.

Based on the above arguments we favor the interpretation that the observed radial motions represent the real motion of matter leaving the nucleus funneled through the magnetic lines of force. This outflowing matter describes elliptical orbits which as shown in this paper can generate a nuclear spiral. It is noteworthy that the ejection hypothesis is also supported by the observation of the symmetrical position of the two lobes, mentioned earlier, observed in 1415 MHz, oriented in the same direction as the initially ejected matter.

There is also the question of the lifetime of the condensations, the hot spots; they may be either ejected as such or they may result from the break-up of the plasma forming the locus. Any of the probable mechanisms for the origin of the nuclear spiral will have to face this question.

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# О ПРОИСХОЖДЕНИИ ТЕСНО ЗАКРУЧЕННЫХ СПИРАЛЬНЫХ ОСОБЕННОСТЕЙ В ЯДРАХ ГАЛАКТИК

#### П. ПИШМИШ, Э. МОРЕНО

Механизм происхождения и развития предложенной ранее одним из авторов (П. П.) использован для того, чтобы показать, что спиральная структура в ядре галактики может образоваться материей, выброшенной из вращающегося ядра. Механизм может объяснить наблюдения, направленные наружу или внутрь движений в ядерных областях спиралей. В частности наша модель, приложенная к тесной ядерной спирали NGC 4736, показывает удовлетворительное согласие с наблюдениями.

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