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VI. DYNAMICS

A. *Stellar orbits – third integral*

Basic statistical and physical assumptions of stellar dynamics have been considered by Tsitsin (02.151.005). Other general aspects have been discussed and reviews of stellar dynamics given by Idlis (02.151.006), Contopoulos (05.151.034; 06.151.039), Rudnicki (02.151.058; 03.151.017), and Kuzmin (03.151.008).

The general problem of angular momentum and rotation and their origin has been treated by Peebles (01.151.004), Hunter (04.151.024 and .034), and Harrison (06.151.011). Brosche (05.158.098) has found a correlation between the maximum rotational velocity and the type of the Galaxy. Thus, the Hubble sequence at constant mass can be interpreted as an angular momentum sequence. Noonan (06.158.023), however, announces negative results of an attempt to find a correlation between the radius of maximum rotational velocity of spiral galaxies and other galaxian parameters.

No equipartition is possible in galactic nuclei according to Spitzer (02.151.038) and Saslaw and de Young (06.151.049).

Supposing that the phase density depends on three isolating integrals, Agekian (05.151.015) has derived the equations of motion in a self-gravitating non-spherical stellar system. He also (Agekian 06.151.022; 07.151.022; 1972) derived an analytical form of the third integral supposing that the density depends on the integral of energy and integral of areas only, and assuming that box-orbits appear. Stodókiewicz (1972) has considered potentials with the third integral quadratic in velocities and has found a class of potentials more general then that of Stäckel type, having such an integral for at least one family of orbits. The relation between the stability of circular orbits and the torus-like volumes accessible to stars in three-dimensional orbits was studied by Malasidze (1972) in steady-state systems with an axis and a plane of symmetry.

Deprit and Henrard (03.151.024) have stressed the fact that for practical purposes, stellar dynamics is justified in pretending that Contopoulos' model is structured by the third integral, even though it is likely that the model is not separable.

An initial perturbation as a cause of strong coupling of R- and z-motions in the outer parts of the Galaxy has been proposed by Innanen (02.151.016). Pomagaev (04.151.041) has solved the equations of motion of low-velocity stars taking into account unstable spiral perturbations. The series of papers on orbits in highly perturbed dynamical systems by Contopoulos (05.151.012) has been continued with a discussion of non-periodic orbits. In such cases there are many orbits asymptotic to two different periodic orbits. On the other hand, it was found that even with large perturbations small tubes of quasi-periodic orbits persist. It is doubtful whether real ergodicity is ever attained in dynamical systems, even locally.

Keplerian orbital parameters of O and B type stars have been computed by Ampel (04.155.043) and of galactic clusters by Syrovoj (03.151.066; 05.155.047). An expression for the potential which allows one to obtain plane galactic orbits in terms of elliptic functions has been discussed by Kuzmin and Malasidze (05.151.006). Malasidze (06.151.007) tackled the interesting question of dependence of the elements of plane galactic orbits on the structural parameters of the potential. Statistics of galactic orbits in terms of the history of the Galaxy has been presented by Woolley (06.155.046).

Orbits of gas clouds were calculated by van der Kruit (06.155.002) on the basis of a rough new model (see VI B). A systematic study of orbits in various models of barred spirals has been started by Mihalodimitrakis. Resonance phenomena seem to play an important role.

Martinet and Hayli (06.155.004) tried to find the limits of applicability of the third integral. They computed orbits of high-velocity stars in the non-separable Schmidt potential using the Ollongren interpolation formula and found that the quasi-isolating region is limited by an eccentricity of 0·6. Martinet and Mayer (1972) tried to see if slightly different potentials give the same results regarding the position of the periodic, tube, and quasi-isolating orbits. Perek (1972) has computed orbits of low-velocity stars in the exact form of the Schmidt potential in order to find an approximate form of the third integral. He has found that a third integral corresponding to a potential separable in eccentric elliptic coordinates gives a good approximation.

Innanen and his group (02.151.014; 04.151.012; 03.151.025 and .032; 05.151.046; 06.151.004) have made several orbital calculations and experiments based on his galactic model.

The very important problem of the places of origin of stars has been studied extensively. By supposing that young stars were formed in a spiral arm, Woolley (03.155.048) explained the deviation of the vertex. Hube (04.151.018) has found no support for a recent suggestion that stars tend to be formed in extreme portions of their orbits. The vertex deviation as a consequence of the places of origin has been discussed by Yuan (06.155.015) using the density-wave theory of galactic spirals. Janes and McClure (07.155.051) find that strong CN stars originate in regions close to the galactic center while moderately weak CN stars originate far from the center. Wielen (1972) has computed ages and orbits of classical cepheids. Most originated in the Sagittarius and Perseus arms. Only the youngest originated in the local arm.

The n-body problem, in particular the intricate questions connected with numerical integration, have received much attention. The *IAU Colloquium No. 10*, held in Cambridge, England, in 1970 (Lecar 07.012.004) dealt with that subject. A report on the Colloquium has been given by Contopoulos (05.151.049).

The detailed correspondence between the concepts, quantities and equations both in the n-body problem and in plasma physics has been given by Hénon (03.151.015; 04.151.044). Omarov (07.066.012) studied the n-body problem with a variable constant of gravity.

A modified Monte Carlo method has been applied by Spitzer and Hart (05.151.019) to study the influence of random gravitational encounters on the evolution of spherical systems. A rigorous method of treating close approaches has been designed by Peters (03.151.072) and a new treatment of encounters has been proposed by Janin and Bettis (07.151.073). The evolution of binaries in stellar systems has been studied by Agekian and Anosova (1968) and Agekian and Primak (1968), the dynamics of triple systems by Anosova (02.117.010), Harrington (04.117.004) and Szebehely (06.042.023; 07.117.009; 1972). Sanders (03.151.023; 04.151.042) has reported about a Monte Carlo simulation of a dense stellar system. He has found that stellar collisions lead rather to disruption than to coalescence. The effect of a galactic tidal field on clusters has been considered by Wielen (04.151.014), Dzigvashvili (06.151.006; 1972), and Keenan *et al.* (1972) and on binary clusters by Innanen *et al.* (1972). Marochnik and Babkov (03.151.068) report an increase of the stability of stellar systems by star-star collisions. Collisions between two H I clouds have been discussed by Stone (03.131.007 and .008) and the consequences of high-velocity extragalactic gas cloud colliding with galactic gases have been examined by Chow (06.131.148).

B. *Models of the Galaxy*

General principles of constructing galactic models have been discussed by Genkin (02.151.007) and Einasto (1972). Among the studies of the group of galactic models which are not concerned with velocity dispersion are those by Sizikov (04.151.010 and .039) who has presented new methods for obtaining the rotation curve from 21-cm profiles and for constructing galactic models; and by Basu and Saha (1973) who have included a logarithmic density law into their formulation of a potential. A thin exponential disk with a rather low velocity of escape has been proposed by Toomre

(07.151.103). Malasidze (04.155.030) studied an expression of the potential leading to galactic orbits expressed by elliptic integrals. A three-component model (population I, disk, population II) with an exponential density-law has been proposed by Einasto (04.155.020). Einasto and Einasto (07.151.099; 07.155.049) have given tables of descriptive functions giving the potential, attraction and other properties of these models. A three-component model with Gaussian distribution and a model for the spiral structure based on the density-wave hypothesis has been proposed for M 51 by Tully (1972). The importance of the rotation curve for the early dynamical history has been stressed by Saslaw (04.151.025). Other studies of models of this type by Genkina (06.158.121), Boulesteix (1971) and by Innanen (07.155.014) should be mentioned. Innanen and Ryman (1972) reviewed certain galactic density functions from the viewpoint of their suitability for numerical computations of the orbits.

Models for the galactic nucleus have been proposed by van der Kruit (06.155.002), by Oort (06.155.017) – a spherical model with density proportional to $R^{-1.8}$, and by Sanders and Lowinger (07.155.041) – a spheroidal model with density constant on similar spheroids and proportional to $R^{-1.8}$ in the plane of symmetry.

The second group of galactic models, involving distribution of mass as well as distribution of velocities, has received extended attention. Vandervoort (04.151.003) has solved Liouville's equation in an approximation based on the fact that the frequency of z-oscillations is large compared with the other frequencies and by solving the Poisson equation for a family of equilibrium configurations, he has constructed a dynamical model of the Galaxy. Later, Vandervoort (05.155.012) constructed a model of the Galaxy representing the local structure within observing errors. The model is a superposition of subsystems with the discrete set of subsystems replaced by a continuous spectrum.

Among the other stellar models we mention those by Hunter (05.151.050), by Miyamoto (05.151.017), by Janin (03.151.055 and .053), by Doremus *et al.* (03.151.033), by Infeld and Skorupski (06.151.001) and by Mihăilă (07.151.009). A model of the gaseous component has been proposed by Kellman (1972).

An application of the ergodic theory to stellar dynamics has been made by Agekian and Baranov (02.151.011), Baranov (04.151.031), and Agekian and Yakimov (06.151.010). They have determined the distribution of stellar density, potential, and velocity dispersion by taking a time-average in a system consisting of five bodies.

West (02.151.041) and Burdyugov (02.151.031) have studied axisymmetric gravitating systems with ellipsoidal velocity distributions. Rodionov (06.155.006) examined the behaviour of the density function outside the plane of symmetry of the dynamical model proposed earlier by Perek by means of orthogonal Chebyshev-Hermite polynomials.

Gomez studied the representation of the distribution function as a power series of the two integrals of motion. She has found that different developments give very similar results for the velocity distribution.

A special place is occupied by M 31 which is in many respects similar to the Galaxy and after the Galaxy is the first target of stellar dynamicists. Sizikov (01.158.042; 02.158.036) solved the integral equations connecting the rotation curve with the space distribution of mass and constructed a model of heterogeneous spheroids of varying ellipticity. A four component model has been proposed by Einasto (02.158.035) who later developed it into a hydrodynamical model (03.158.060; 04.158.063).

Einasto and Rümmel (03.158.074 and .075; 04.158.066; 07.158.169) have proposed a new model for M 31 and have given tables of descriptive functions of the gravitational field. The velocity field has been investigated and rotation curve derived from neutral hydrogen maps by Gottesman and Davies (03.158.099) and from surveys of emission regions by Rubin and Ford (03.158.026) who derived a mass model of the Andromeda nebula (03.158.076; 06.158.100) and compared it with the Galaxy.

The attraction perpendicular to the galactic plane and stellar motions in that direction are closely related. Innanen (04.112.003) attempted to determine the size of the Galaxy from perpendicular

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motions exceeding 100 km s^{-1}. Lohmann (05.155.036) has explained the galactic acceleration calculated earlier by Perry by the influence of a local galactic mass concentration. Turon-Lacarrieu (06.155.003) has found from stellar z-motions that the derived attraction is incompatible with Poisson's equation. This is explained either by non-steady state motion or by a mixture of different age groups among K giants. Gould and Vandervoort (07.155.069) have presented a new method for the determination of the z-attraction in terms of a set of virial equations. Another new method of determining the z-acceleration is due to Jõeveer (07.155.050) who has compared the z-distances and motions of young stars with their ages on the assumption that stars were formed near their maximum distances from the centre and from the galactic plane.

C. *Dynamics of galaxies-spiral structure*

Much recent work on the dynamics of galactic systems has been motivated by a desire to understand the spiral structure in disk-shaped galaxies. There are two principal aspects of this effort: (a) the theoretical investigation of the basic dynamical mechanisms that cause the spiral structure to be formed and to be maintained and (b) the study of the implications of the density wave theory and of the observable evidence for spiral structure. A review of the present situation in the theory of galactic spiral structure is contained in Contopoulos' Lecture Notes, published by the University of Maryland (07.151.080).

(a) *The question of origin and of permanence* of the spiral structure in disk-shaped galaxies continue to attract great attention. Several authors have suggested local instability mechanisms for the generation of spiral modes. Besides the suggestions by L. S. Marochnik and A. A. Suchkov reported to Commission 33 during the 1970 IAU General Assembly and (06.151.021), several other suggestions have appeared in the literature. Ptitsina (03.151.056), Marochnik and Ptitsina (03.151.051) and Niimi (03.151.007) considered the effect of gas and magnetic field. (See also 05.151.041). Harrison (04.151.027; 06.155.005) discussed the destabilizing effect of radial streaming motions from the galactic center, as did Kato (in preparation). M. N. Maksumov (04.151.019) discussed the possible role of the effects of stellar drift motions. Kato (07.151.007) considered the effect of the interaction of gas and stellar system via the processes of birth and dis-integration of stars. Other authors have attributed the long-term maintenance of spiral patterns to global effects over the whole galactic disk, with critical roles played by the Lindblad resonance regions. The necessary existence of these resonance regions for a neutral spiral mode has been established by Shu (03.151.027).

The simplest approach is to regard the spiral pattern as caused by an unstable normal mode of the stellar system according to the linear theory. Kalnajs (05.151.037) has shown that the total angular momentum of such a wave system must be zero, i.e. the local angular momentum density must have negative as well as positive values. However, it has been suggested by Lin (03.151.047; 06.151.060) that nonlinear processes may be essential. In this picture, the short trailing spiral waves are visualized to propagate inward from corotation ring to the center of the Galaxy or to inner Lindblad resonance where they are absorbed (Toomre 02.151.036; Mark 06.155.048). In either case this leads to an oval distortion in the central region of the galactic disk (a nonlinear effect) and the long-term maintenance of the spiral pattern is attributed to a feedback process from this distorted central region. Feldman and Lin (1973, have shown by using a gaseous disk model that short trailing waves are produced near corotation by a rotating bar located at the center of a galaxy.

To follow up the linear mode approach, Kato (06.151.012) and Lynden-Bell and Kalnajs (07.151.065) studied the mechanism for the transfer of angular momentum and energy at Lindblad resonances for the stellar disk. The propagation of short trailing waves from corotation to inner Lindblad resonance has been shown to conform to the principle of conservation of density of wave action (Toomre 02.151.036; Shu 03.151.028 and .038). The proof of this principle by the variational approach has been carried through by Dewar (07.062.033). A general study of patterns of density waves in a disk-shaped galaxy has been made by Hunter (07.151.072). A special case was studied by Simkin (03.151.011). Contopoulos (05.151.001) showed, by a linear analysis that the response of slightly growing spiral waves (leading or trailing) is trailing near the inner Lindblad resonance. Thus, trailing waves are preferred. Contopoulos and Georgala (1973) find that self-consistent trailing waves are possible.

When the amplitude of the wave becomes appreciable, nonlinear effects become important. The stars arrange themselves near two periodic orbits similar to two perpendicular ellipses. Thus one or two bar-like structures can be formed (Contopoulos 03.151.029 and .035; 04.151.136; 05.151.034). One of them is a continuation of the spiral arms and is called the main bar. It is natural to assume that the motion of gas takes place along the main bar. An application of this theory in the central region of our Galaxy has been made by Shane (07.155.002) and in more detail by Simonson and Mader (07.155.057). These authors found that most of the observed kinematic features near the galactic center can be attributed to a flow along dispersion orbits. Similar results were derived in M 51 by Tully (07.158.150) who found that a dispersion model is preferable to an expansion model.

Non-linear effects near the particle resonance have led Barbanis (03.151.044) to conclude that there is a trapping of orbits near two points situated 90° away from spiral arms (potential minima). Contopoulos (1973) showed that if the spiral force is 4% of the axisymmetric force about 30% of the mass in an annulus 2 kpc wide around particle resonance is trapped.

Another nonlinear effect of possible importance in galaxies is the non-linear interaction between various modes (Contopoulos 06.151.039). Other studies of nonlinear density waves have been made by H. Niimi (03.151.070) and by Vandervoort (05.151.032).

(b) *The predictions of and observational evidence* for the density-wave theory have been made during the triennium under review. In addition to efforts to correlate theory with observation along several lines previously initiated, two major new theoretical advances deserve special mention, viz. the inclusion of a galactic magnetic field (Roberts and Yuan, 04.156.001), and the introduction of the two-phase interstellar medium (Shu *et al.* 07.131.080).

Roberts and Yuan (04.156.001) calculated the sudden change, in both the magnitude and the direction of the magnetic field at the galactic shock, which is presumably marked out approximately by the location of the dust lane. This prediction is verified by the observation of continuum emission from M 51 by Mathewson *et al.* (07.158.039). Tosa (1973) has found that the effective thickness of a galactic gaseous disk may jump by about 30–40% at the shock front, and he suggested that the associated gaseous motion perpendicular to the galactic plane may lead to hydrogen gas high above the spiral arms. Preliminary indications of a sudden change of the magnetic field in the plane of the Milky Way has been reported by Rudkjøbing and his collaborators from measurements of the polarization of light from stars in the Perseus arm.

The behavior of interstellar gas, as it circulates around a spiral galaxy has been the subject of several recent studies. The introduction of the two-phase concept has supplied one of the principal dynamical processes. The increase in pressure across the galactic shock occurs in the 'hot' phase and is in turn transmitted to the cold clouds, leading to star formation. Detailed calculations based on this physical model have been made by Shu *et al.* (07.131.080). In their physical picture, gaseous clouds are visualized to exist both in the arms and in the interarm region. It is found that the critical mass for the gravitational collapse of a cloud is substantially reduced from that estimated earlier by Roberts (02.151.013). Other studies of these phenomena have been made by Biermann *et al.* (07.131.152), by Quirk (07.158.149) and by de Jong at Leiden.

Work is continuing on the application of the theory of density waves to explain the observed spiral structure in the Milky Way system. The principal theoretical spiral pattern adopted for these studies remains essentially the same as that proposed by Lin and Shu at *IAU Symp. No. 31* (1966), but secondary spiral features have been added. The major additions are a feature coinciding with the Carina arm and its counterpart, and the Orion arm with a possibility of its counterpart. Theoretical identification of the latter has been discussed by Lin (06.151.060). The dynamical basis for the former is now provided by the calculations of the nonlinear behavior of the gas by Roberts (07.155.056) and by Shu, Milione, and Roberts (1972). It is found, even without considering self-gravitation, that a secondary spiral arm tends to develop in the location of the Carina arm, which has been observationally established by Bok, Hine and Miller (03.155.043), by Humphreys

(03.155.054; 05.155.003 and .041) and their collaborators. In particular, the streaming motions of the stars in the Carina arm support the existence of a spiral gravitational field. [See Sections IV A and V B for further discussions.]

Shu *et al.* (05.151.039) have applied the density wave theory to the spiral structure of the galaxies M 33, M 51, and M 81. They obtained satisfactory results when the spiral pattern is assigned an angular velocity equal to that of the material objects in the outer parts of the galactic disk. In the case of M 51, a different picture has been proposed by Tully (07.158.150) who decided on a much higher velocity so that the corotation point is further inward. The outer part of the spiral structure is then attributed to the mechanism for producing intergalactic bridges, examined in detail by Toomre and Toomre (07.158.132). It should be noted that there is no clear observational distinction to indicate any change of character along the spiral arm. Also, the latter authors have not as yet examined the mechanism for the formation of dust lanes and young stars observed in the bridges. Neither has self-gravitation been included in their theory.

As mentioned above, the most impressive verification of the concept of density waves is provided by the observation of continuum emission by Mathewson *et al.* (07.158.039). Other evidence for density waves has been provided by the studies of the stellar population in M 33 by Courtés and Dubout Crillon (05.158.020) and by Dixon (05.151.020). Support of the density wave theory may also be derived from the studies of the distribution and motion of neutral hydrogen in several galaxies (Rogstad and Shostak, 05.158.086; 1972; Rogstad 05.158.087).

Piddington (private communication) has raised objections to the density wave theory. However, it appears that these are based on his own version of the interpretations of the observational data and of the implications of the theory. Detailed replies to his criticisms may be found in preprints distributed by Bok and by Lin and Shu, who reaffirmed their previous positions already published in the literature. In some cases, new evidence has also been offered in these articles.

D. *Computer simulations of stellar systems*

Many features of the development of stellar systems have been simulated by computer models. In the preceding parts of Section VI some of these have been mentioned. The gravitational N-body problem and direct integration of the equations of motion for large numbers of mass points have been reviewed by Contopoulos (05.151.049) and a report on *IAU Coll. No. 10* held in Cambridge England in 1970 (Lecar 07.012.004) contains many papers on this subject.

Galaxies

Numerical models for the development of spiral structure have continued to be investigated by Miller *et al.* (03.155.013; 03.151.045; 04.151.023), by Quirk (05.151.044; 06.151.074) and by Hohl (03.151.046; 05.151.013, .038, .051; 06.151.013, .056, .059; 07.151.102). Hohl found that Toomre's 1964 criterion for the velocity dispersion necessary to stabilize disk galaxies against small scale axisymmetric disturbances was not sufficient to prevent large scale bar-like instabilities. In most cases two to four times larger velocity dispersions were necessary to prevent the formation of a bar. These 'hot' galaxies, however, could not be made to develop spiral features. By removing the peculiar velocities of 10% of the 'stars' each revolution (artificially cooling the 'stars') spiral structure was initiated. Evidence to date indicates that Toomre's local criterion for local axisymmetric stability does not guarantee global stability.

It is important to look into methods that yield galactic models in exact stellar dynamical equilibrium. The construction of these is a challenging mathematical problem. Its importance is underlined by the need for an adequate initial condition of equilibrium for numerical simulation of spiral structure in disk shaped galaxies. Besides an earlier general asymptotic approach due to Frank H. Shu (02.151.027), Miyamoto (05.151.017) and Kalnajs (07.151.089) have now both obtained solutions for specific mass models. These solutions are exact, but they do not represent plausible realistic models. From the family of models obtained by Kalnajs, he was able to construct new models that can be either stable or unstable. Examples are given which show that nonaxisymmetric instabilities have been suppressed. The most troublesome mode appears to be the barlike oval deformation, as found earlier by Hunter to be the case for uniformly rotating disks in circular motion.

A slowly evolving equilibrium model with nonaxisymmetric kinematics but axisymmetric surface density has been developed by C. Berry (1973). This effort was motivated by the problem of vertex deviation of the velocity distribution of local stars.

A comprehensive survey of papers dealing with self-gravitating gaseous disks has been published by Hunter (1972).

Clusters

We mention briefly the work by Wielen (1972), by Spitzer and Chevalier (1972), by Bouvier (06.151.008) and by Bouvier and Janin (04.151.033) on the disintegration time of a typical *galactic cluster*, particularly under the encounters with H I clouds. The results are somewhat conflicting; the simulated cluster may be unaffected or its life may be too long by a factor or two or three. Aarseth and Woolf (1972) have studied the preferential escape of low mass stars in the Hyades due to encounters.

Simulated *globular cluster* systems have been studied by Spitzer and colleagues (05.151.019; 05.151.040; 07.151.068; 07.151.088) by Monte-Carlo techniques. A comparison between simulated clusters derived by Monte-Carlo techniques and those derived by direct numerical integration has been made by Wielen (1972).

E. *Magnetic fields, pulsars, X-ray and γ-ray sources*

The problem of the galactic magnetic field occupied several authors. Vainshtein and Ruzmaikin (06.156.004) and Parker (05.156.001 and .002) suggest that the combination of differential rotation and turbulence lead to dynamo action by processes similar to those in the Sun. Both large scale and small scale fields result, the latter having been investigated by Lerche and Parker (06.156.002) and Jones (06.156.005).

The role of the galactic magnetic field in the formation of spiral shocks was studied by Roberts and Yuan (04.156.001) while Fujimoto and Miyamoto (03.151.049) constructed dynamical models of helical magnetic fields in spiral arms. The nature of the galactic magnetic field and its possible effect on generating spiral structure was extensively studied by Piddington (04.156.004).

Our knowledge of the distribution of X-ray sources and pulsars was much improved. From the Uhuru satellite data a catalog of 125 X-ray sources (in the 2–10 keV energy range) was prepared by Giacconi *et al.* (1972). The source distribution suggests that about one third are galactic with a strong concentration toward the center. The identified galactic sources are mainly close binaries and supernova remnants. A rather weak source – of 2° extent in longitude – was found at the galactic center (Kellogg *et al.* 06.142.071). No strong emission ridge associated with the galactic plane has been seen and this puts important limits on the numbers of unresolved faint sources and hence on the X-ray luminosity function. Presumably many of the sources in the present catalogues are at distances comparable with 10 kpc and X-ray luminosities of 10^{36-38} erg s^{-1}. [Ryter (04.142.070); Setti and Woltjer (04.142.088); Gursky (1972)]. Few as yet undetected intrinsically bright sources should exist. Unless more numerous much fainter sources exist the usefulness of X-ray sources in general galactic structure studies may be limited because of their rarity.

At energies below 1 keV a strong background is observed, which because of the high opacity of interstellar matter for soft X-rays probably is of local origin. Experimentally the situation is still confused (e.g. Bunner *et al.*, 1973) and it is not yet known whether the emission is truly diffuse or the result of unresolved sources. Some of it appears to be related to supernova remnants and possibly to the galactic radio spurs [Shklovsky and Sheffer (05.142.077); Bunner *et al.* (07.155.010)].

A recent catalog of pulsars lists 61 objects (Manchester and Taylor 07.141.504). Analysis of the data shows that they are strongly concentrated toward the galactic plane and possibly in the galactic spiral arms and that the radio luminosities tend to decrease with increasing periods [Gold and Newman (03.141.198); Ryyänen (04.141.076); Cavallo (05.141.147); Venugopal (06.141.169)].

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Gamma ray astronomy is in its infancy. Observations of some possible sources have been reported, but even with regard to the galactic center area, where a rather strong source had been reported earlier, the situation is still very confused (Frye *et al.* 05.142.067).

Weber [(06.066.128) and references therein] has claimed the detection of gravitational radiation coming from the direction of the center of our Galaxy. Several authors have estimated the energy loss from the galactic center and found it to be in the range of $10^3\ M_\odot c^2$ to perhaps as much as $10^6\ M_\odot c^2$ per year if isotropic emission is assumed. Lawrence (06.066.115) and Misner (1972) have suggested that the radiation might be focused or beamed and that this could lower these estimates. The whole situation is currently in a state of flux and controversy, but since in several laboratories new experiments in this field are being started at the moment we should know in a year or two whether the events detected are actually due to gravitational waves. If so these results are of much importance for galactic dynamics. In fact Sciama *et al.* (02.151.054) have already noted that an energy loss of 70 $M_\odot\,\mathrm{yr}^{-1}$ for 10^9 yr would have significant effects on stellar orbits near the Sun. For a recent review of this field see Press and Thorne (1972).

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