A NOTE ON THE POST-EXPLOSION GAS DEPLETION IN THE CENTRAL REGION OF NORMAL SPIRAL GALAXIES

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Abstract. The problem of post-explosive gas depletion in the central region of normal spiral galaxies like our own has been investigated. It has been calculated that with a plausible density law and with some restriction on gas temperature, a sufficient quantity of gas will be depleted from the central region over a time-scale ranging from a few times \(10^7\) to a few times \(10^8\) years, the exact time depending on the particular density law. Such a time-scale has been suggested by many authors as the period for one phase of activity in the nuclei of these galaxies. A similar time-scale has also been proposed by several authors as that for the formation and destruction of the spiral patterns of these galaxies.

1. Introduction

Gigantic explosions in the nuclei of many disk galaxies are assumed to occur periodically, leading to an instantaneous release of energy and outflow of matter, terminating the quieter phase of the nucleus. In the subsequent state the nucleus continues to eject mass and radiate energy, the intensity of ejection depending upon the scale of the catastrophe that has occurred. Tremendously violent explosions in the deep core of some galaxies force the nuclei to be blown up, as observed in M82 (Sandage and Lynds, 1963; Solinger, 1969). Sometimes streams of ionized gas in the form of jets may be ejected as in M87. In some galaxies, such as NGC 1068 (Walker, 1968) and NGC 3227 (Rubin and Ford, 1968), high-velocity gas clouds have been observed to run away from the nuclear region. The nuclei of many Seyfert and radio galaxies are highly active, causing ejection of matter with speeds as high as 3000 km s\(^{-1}\). These activities are also associated with radiation of strong infrared, radio waves and cosmic rays. When the characteristics of the explosion inside the nuclei are rather moderate, a slow but continuous ejection of gas has been observed from their cores. Most of the normal spirals, including our own, may belong to this class. The ejection of mass from an active nucleus continues until it is almost devoid of gas, when its activity may temporarily stop. Ambartsumian (1965), Arp (1969), van der Kruit (1970, 1971), Burbidge and Hoyle (1963), Unsöld (1969) and many other authors believe that the outer structure of a galaxy – including the disk, spiral arms and even halo – are mainly constituted by the gas supplied from the active nucleus, and hence they are expected to weaken as soon as the nuclear activity fades. According to the estimations of these authors, one particular phase of the galactic activity may continue for a time-scale of
the order of $10^8$ years. Since radial outflow of mass from the nucleus is one of the characteristics of spiral galaxies, and as the larger fraction of detectable galaxies are of spiral type, there must exist several mechanisms by which the depleted mass may be replenished into the nucleus. Many authors have proposed that most of the outgoing mass loses its angular momentum before going far from the nucleus, and should therefore fall back into the nucleus. Moreover, a continuous infall of mass from the halo to the nucleus has been reported (Wentzel, 1961). Also, a considerable portion of the mass shed by evolved stars in the central bulge of the nucleus is assumed to be accreted onto the nucleus (Sanders and Lowing, 1972; Sanders and Prendergast, 1974). As depletion and accretion processes are going on side by side, it is likely that either a nucleus never becomes totally devoid of gas to stop its activity or that the activity of a nucleus may stop temporarily but, being aided by the process of mass replenishment, again becomes massive enough to explode and to regain its activity. Evidence of repeated explosions in our Galaxy and in others have been reported by many authors (cf. Sanders and Prendergast, 1974; Scoville, 1972; van der Kruit, 1970, 1971). Also, the spiral structure of a galaxy has been assumed to decline and reappear repeatedly. (P. O. Lindblad, 1962; B. Lindblad, 1962).

In this paper an attempt has been made to investigate the motion of gas which emerges radially out of a moderately excited nucleus and enriches the galactic disk. The galaxy in its pre-explosive stage has been considered here as an infinitely extended, very rarefied, thin disk with a superdense gaseous core at its centre. Since the massive central region of a rotating gaseous system rotates more rapidly than its rarefied outer zone (Suckmann and Anand, 1970), the superdense core is supposed to possess a sufficiently high angular velocity $\Omega$ relative to the entire system. After the explosion, a strong impulsive force is generated and a bulk of gas rushes out from the nucleus instantaneously. The emerging gas possesses the same rotational velocity of the core it begins to rotate around the core like a rigid body. At a certain distance from the nucleus, which we may call the boundary of the envelope, the rigid body rotation law fails and an outflow of gas takes place (Rayleigh, 1917). Considering two-dimensional motion (confined in the galactic plane) with circular symmetry, the radial and cross-radial components of equations of motion have been written whose solutions lead us to determine the time-scale during which one phase of activity of a galaxy may continue. It has been derived that the radial outflow of gas from the boundary of the envelope occurs subject to the condition that the centrifugal force exerted by gas in this region is greater than twice the gravitational pull of the nucleus. The greater the centrifugal force of gas in the position where the outflow of gas starts, the higher the rate of mass depletion from the nucleus, and the shorter the period of one phase of nuclear activity. As the nucleus rotates more rapidly than the disk, and as the gas emerges from such a highly rotating nucleus as the result of the explosion, the centrifugal force of the gas just outside the nucleus increases – and when this centrifugal force exceeds twice the gravitational pull of the