Astronomy

Gas in elliptical galaxies

from A.C. Fabian

IT HAS generally been held that early-type galaxies — lenticulars and ellipticals — are devoid of gas[1]. The gas lost by stars, both as the winds from red giants and as planetary nebulae, has been presumed to be blown out of the galaxies by the cumulative effect of supernova explosions. A galactic wind thus scours a galaxy clean of gas, explaining why only relatively minute quantities (and little star formation) have been detected at radio, optical or ultraviolet wavelengths. This picture, itself, is now being blown away by evidence from the *Einstein Observatory* satellite: a considerable number, and perhaps all, early-type galaxies contain large quanities of gas that are only detectable by their X-ray emission. A new compilation of the data[2] shows that the mass of gas in a large elliptical galaxy can be about the same as that in our own spiral Galaxy.

One of the first results[3] reported from the *Einstein Observatory* was that the Virgo cluster of galaxies appeared 'spotty' in X rays. Individual normal and early-type galaxies appeared as diffuse sources of X rays. Further work[4-6] showed that many other normal galaxies were also X-ray sources, and attention seems to have drifted away from the early-type galaxies to more exotic objects such as active galactic nuclei.

Spiral galaxies, such as our own and Andromeda (M31), are X-ray luminous because they contain populations of X-ray emitting binary star systems. Large elliptical galaxies, however, are about one hundred times more X-ray luminous than spirals, such that over 1,000 very bright X-ray binary sources would be required. That interstellar gas is a more likely candidate for the observed X-ray emission is demonstrated by the X-ray emitting 'plume' of NGC4406 (M86; ref. 3). This large elliptical galaxy is falling through the Virgo cluster at about 1500 km s^{-1} and much of its gas is being stripped out by interaction with the extended halo around M87, to form a tail or plume in its wake. The nearby active galaxy Centaurus A also shows diffuse X-ray emission[7] (apart from the nucleus, jet and so on) which is most likely due to a hot interstellar medium, and not binary X-ray sources. The gas in elliptical galaxies should be at X-ray temperatures, for gas lost from stars moving at speeds σ, relative to the galaxy, of a few hundred km s^{-1} should themalize to a temperature of between 10^6-10^7 K such that its sound speed is about σ.

W. Forman, C. Jones and W. Tucker have compiled[2] the *Einstein Observatory* X-ray data on 55 early-type galaxies, most of which show X-ray coronae, and have obtained results that are of considerable significance to studies of early-type galaxies. Crude spectral analysis shows that the emission is consistent with that from hot gas and not with that of known classes of X-ray binaries. Thus, most optically luminous lenticular and elliptical galaxies contain hot gas; they cannot blow winds. Supernova heating, which could have ejected the gas, must be much less than previously assumed.

An important application of these hot gaseous coronae is the measurement of the masses of early-type galaxies. If the gas is observed, then its bulk motion must be highly subsonic, otherwise impossibly large sources of mass are required to maintain a detectable density. Consequently the coronae must be close to hydrostatic equilibrium and

$$\frac{dP_{gas}}{dr} = -\varrho_{gas}\frac{GM(r)}{r^2}$$

Measurements of the X-ray surface brightness and temperature profiles yield the gas pressure, P_{gas}, and density, ϱ_{gas}, and thus the mass as a function of radius $M(r)$. The compiled data yield total masses of about $1-5\times10^{12}\,M_\odot$ out to 100 kpc for the best studied cases. Some of these galaxies are in the Virgo cluster but most are in the weak groups and some are relatively isolated. The X-ray data imply massive dark haloes around most elliptical galaxies. Their mass-to-light ratio is around 100 in solar units.

For detectable amounts of hot gas to accumulate in galaxies the gas must be cooling at a significant rate, already discussed in the context of a small subset of the present sample[8]. Gas must be cooling and objects condensing out of the resultant cooling flow at a rate of about one solar mass per year, so that the formation of stars in large elliptical galaxies take place at a rate not much less than it does in our own Galaxy. Their optical appearance, however, provides no indication for this. The conditions must be such that the high-mass stars that we normally associate with regions of star formation in our Galaxy are absent. The new stars in eliptical galaxies must be of very low mass, perhaps even below that for nuclear burning. We conclude that elliptical galaxies are not quite so full of old stars as previously thought, although one solar mass per year for a Hubble time does not yield a $10^{12}\,M_\odot$ galaxy. Nevertheless there are intriguing implications for the formation of galaxies and of the so-called dark matter associated with them.

We thus have an extremely powerful tool for measuring the mass profiles out to distances of 10 - 100 kpc and for studying the gas and energy flows in early-type galaxies. When are we going to see more data? Unfortunately, the *Einstein Observatory* re-entered the atmosphere three years ago and the telescope on the EXOSAT satellite is not sensitive enough to help out. ROSAT, to be launched in 2 - 3 years time, should detect many elliptical galaxies out to 100 Mpc or more and, in the 1990s, high-quality imaging X-ray spectroscopy should become routinely available for any elliptical galaxy. □

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Congenital diseases

Complementary genes for an adrenal enzyme deficiency

from Ian R. Phillips and Elizabeth A. Shephard

ONE of the most common inborn errors of metabolism, congenital adrenal hyperplasia, results from a deficiency in the adrenal cortex of the enzyme 21-hydroxylase[1], which is involved in the biosynthesis of cortisol, the principle glucocorticoid hormone of the adrenal. The disease is inherited as a recessive trait and is closely, but enigmatically, linked to the major histocompatibility complex of humans, *HLA*. Two separate reports now help explain the linkage. First White *et al.*[2] show that the disease is due to a defect in a gene coding for cytochrome P- 450_{C21}, a protein that is specifically catalytic for the 21-hydroxylation of steroids. Second, Carroll *et al.*[3] have shown that the P- 450_{C21} genes lie within the HLA region of human chromosome 6.

Although the biochemical basis of the 21-hydroxylase deficiency has never been definitively established, steroid 21-hydroxylation can be catalysed *in vitro* by a combination of two microsomal membrane proteins of the adrenal cortex: P-450_{C21} and a NADPH-dependent cytochrome P-450 reductase[4]. Since only the P-450_{C21} is specific for the reaction, White *et al.*