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NEUTRON STAR STUDDED COMPACT GALAXIES

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From theory it follows that a contracting luminous stellar system gravitates toward a unique compact configuration G which satisfies the following two conditions. a) G is a limiting Schwarzschild body of zero effective mass and b) The surface brightness of G is equal to that of its constituting stars. Observations on hundreds of compact galaxies indicate that they represent transition stages from loose stellar systems to configurations of the type G. During the contraction the velosities of the stars and the number of collisions between them increase. As a result of direct collisions enormous amounts of energy are liberated and neutron stars are being formed. The resulting neutron star studded compact galaxies have all of the essential properties of quasistellar radio sources. Since to distances corresponding to cosmological redshifts $\Delta\lambda/\lambda > 2.0$ the sky is covered several times by clusters of galaxies and in part even by the galaxies themselves, we are forced to conclude that the quasistellar radio sources are closer than generally assumed. The great redshifts observed in their spectra are thus probably in large part due to the Einstein effect on light escaping from locations of low gravitational potential.

Numerous observational data on compact galaxies have now been secured and basic results deduced from theory the integration of which promises to lead to a satisfactory explanation of the characteristics of both quasistellar radio sources and radioquiescent ultracompact galaxies. The existence of an extended family of compact galaxies, blue, red and infrared in colour and exhibiting a rather astounding variety of spectral features has been firmly established. Among them the first two blue compact galaxies [at R. A. $11^h8^m5^s$ and Decl. $+29°2'$ (1950)], of stellar like appearance even when observed with the 200-inch telescope, were discovered by the author in 1956. Their spectra in the blue essentially show only λ3727 in emission indicating a symbolic velocity of recession of about $V_s = 8840$ *km/sec* [1, 2].

Some of the essential features of the most massive compact galaxies are masses greater than 10^{12} $M_\odot$, diameters less than 1000 *pc* and differential redshifts so far found between different parts greater than 10 000 *km/sec*, which are most likely due to the static Einstein effect. Many of the compact galaxies are nucleated, showing pointlike concentrations of very great surface brightness.

From the theory the existence of three unique types of ultracompact galaxies is deduced. These are

1. *Ultracompact luminous galaxies.* Of great interest is a hypothetical galaxy composed of luminous stars which has both reached the limiting Schwarzschild configuration and has a surface brightness equal to that of its constituent stars. If these are assumed to be uniformly distributed and of the type of the sun, the mass, radius, average density and absolute photographic magnitude of the ultimately dense configuration c_1 are [3].

$$M_1 = 1.85 \times 10^{13} M_\odot, \qquad R_1 = {}^1/_{12}\,\text{L.Y.} = 8.26 \times 10^{16}\ cm.$$

$$\bar{\rho}_1 = 1.6 \times 10^{-6}\ g/cm^3 \text{ and } M_{p_1} = -25.3.$$

If the constituent stars of our ultracompact stellar system were white dwarfs with the mass of the sun, 1/100 of its radius and a surface temperature of 25 000°K we should find

$$M_2 = 1.85 \times 10^8 M_\odot, \qquad R_2 = 8.26 \times 10^{14}\ cm \text{ (size of the solar system)},$$

$$\bar{\rho}_2 = 1.6 \times 10^3\ g/cm^3 \text{ and } M_{p_2} = -31.5.$$

As I have first shown in 1939 [4] the light escaping from the surface of a limiting Schwarzschild sphere of constant density throughout suffers an Einstein gravitational redshift $z = \Delta\lambda/\lambda = 2.0$ and its velocity on the surface is $c' = c/9$. Since such a sphere is not in dynamic equilibrium, releasing it from the strained state it will automatically assume a configuration of lower energy with the result that $z = \Delta\lambda/\lambda > 2.0$. Just what the value of z would be depends entirely on the nature of the material element constituting the sphere.

Long before the limiting configuration of luminous stellar system can be formed destructive effects set in, that is evaporation of the stars because of mutual irradiation, whittling down of the stars by the frictional effects of the interstellar gas clouds and the tidal actions of mutual encounters and finally direct collisions among the stars. These generate large fluctuations in the luminosity and, most important they result in the production of neutron stars.

2. *Neutron Star Studded Luminous Galaxies* [5, 6]. On approaching the ultimately dense configuration c_1 a compact galaxy of 10^{12} stars of the radius and mass of the sun may have shrunk to a radius of 100 light years. The constituent stars have velocities of the order of 5000 to 1000 *km/sec* and will make an average of one hundred collisions a year each of which releases the energy of a bright supernova outburst. At the same time, if there are any white dwarfs among them the stagnation pressure on stopping each other will be at least $p_s = 10^{25}$ *dynes/cm*$^2 = 10^{19}$ *atm* in their center. For a neutron to decompose into a proton and electron a space of at least $\Delta v = 10^{-30}$ *cm*^{3} must be made available, which requires an energy $p_s \Delta v = 10^{-5}$ *ergs*. Since the decay energy of the neutron is only 780 000 $eV = 1.25 \times 10^{-6}$ *ergs* it therefore becomes stabilized at the pressure p_s and a neutron core is being formed while the external shells of the stars are ejected with velocities up to 30 000 *km/sec* giving rise to extended plasmas, magnetic fields and emission of radio waves. Quasistellar radio sources may thus find their explanation through the above events resulting in the formation of neutron star studded compact galaxies regardless of whether we interpret the redshifts observed as almost entirely cosmological in nature or as caused in great part by the Einstein effect.

As I have suggested before [3, 6] I consider the latter case much more probable since to distances correspoding to a cosmological redshift $z = 2.0$ the sky will be covered five times by the central parts of the rich clusters of galaxies alone for each of which dimming of light by intergalactic obscuration amounts at least to about 0.3 magnitudes. A loss of 1.5 magnitudes for $z = 2.0$ must therefore be expected even if no increase of the space density of clusters with distance is assumed as we should expect it to exist. There seems to be no difficulty to explain all spectral features of quasistellar radio sources on the above theory, that is intensities, widths and relative positions of emission and absorption lines. The only fact which remains to be explained is that the observed increase in the number of radio sources with magnitude is faster than would be expected from objects distributed uniformly in space. As a hypothesis which is being tested presently the suggestion may be advanced that the weak radio sources among the compact galaxies are so numerous that their numbers N per steradian increase with flux density S as $N = AS^{-n}$ where $n > 1.5$ while for a uniform distribution in space it would be $n = 1.5$.

3. *Neutron Star Studded Dark Galaxies.* The ultimate stage of the developments indicated would be galaxies composed entirely of cold neutron stars. These could not be seen in their own light but only because of their effects on passing light.

Summarising, our observational and theoretical results suggest that the quasistellar radio sources and the ultra compact galaxies are much nearer than the interpretations of their redshifts by the cosmological effect would indicate and that, in fact, these redshifts are largely due to the Einstein effect on light emerging from points of low gravitational potential.

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КОМПАКТНЫЕ ГАЛАКТИКИ, УСЕЯННЫЕ НЕЙТРОННЫМИ ЗВЕЗДАМИ

Ф. ЦВИККИ

Из теории следует, что сжимающаяся излучающая звездная система гравитирует к единственной компактной конфигурации G, которая удовлетворяет следующим двум условиям: а) G является граничным телом Шварцшильда нулевой эффективной массы. б) Поверхностная яркость G равна яркости составляющих его звезд. Наблюдения сотен компактных галактик указывают, что они представляют собой переходные стадии от рассеянных звездных систем к конфигурациям типа G. Во время сжатия системы возрастают скорости звезд и число столкновений между ними. В результате прямых столкновений освобождается огромное количество энергии и образуются нейтронные звезды. Результирующие компактные галактики, усеянные нейтронными звездами, имеют все существенные свойства квазизвездных радиоисточников. Так как на расстояниях, соответствующих космологическим красным смещениям $\Delta\lambda/\lambda \geqslant 2.0$ небо перекрыто несколько раз скоплениями галактик и частично даже самими галактиками, следует заключить, что квазизвездные радиоисточники находятся ближе, чем обычно предполагалось. Таким образом, большие красные смещения, наблюдаемые в их спектрах, по-видимому, большей частью обусловлены гравитационным эйнштейновским эффектом.

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