SHELLS AND DARK MATTER IN ELLIPTICAL GALAXIES

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ABSTRACT. A new method for probing the distribution of matter in elliptical galaxies surrounded by shell systems is described. As an illustration we have applied this technique to the giant elliptical galaxy NGC 3923. If the potential is modeled as the sum of an $r^{1/4}$ law and a non–singular isothermal halo, then the best fit to the shell number and shell distribution gives a halo mass (within the shell system $\sim 100h^{-1}$ kpc) ~ 40 times the mass of the elliptical and a halo core radius ~ 3 times the effective radius of the luminous material.

Shells around elliptical galaxies are formed as the result of interactions with less massive companions (Quinn 1984, Hernquist and Quinn 1986a). Highly ordered shell systems can be generated in nearly radial encounters if the companion is disrupted on the initial pass, through the process of "phase–wrapping" (Quinn 1984). In such cases, the shells are comprised of stars on nearly radial orbits with known turning points, and the shell distribution maps the radial period *vs.* radius which can be used to infer the potential.

At any given time the shell distribution will be comprised of stars with *commensurate* periods. Thus, if stars in the outermost shell have completed τ periods, then stars in the shells consecutively closer to the galaxy will have completed $\tau+1, \tau+2, \tau+3$ ... periods. If shells are labeled according to their distances from the galaxy ($n = 1$ is the outermost shell) then this requirement implies $t = (n+\tau-1-\Theta_n)P(d_n)$, where t is the time since the disruption of the companion, Θ_n is the initial phase of stars in the shell at distance d_n from the galaxy, and $P(d_n)$ is the radial period. It then follows that the expected number of shells between the outermost shell and an interior shell, n, is $N_{shells} = (\tau-.5)P(d_1)/P(d_n) - (\tau-1.5)$ for an initial phase $\Theta = .5$ (Hernquist and Quinn 1986b). For a power law potential $\varphi \propto r^{\nu}$, $P \propto r^{1-\nu/2}$ and the commensurability condition gives the expected shell distribution $\ln d_n/d_1 = (2/(\nu-2))\ln((n+\tau-1.5)/(\tau-.5))$.

A detailed analysis for the sum of an $r^{1/4}$–law plus non–singular isothermal halo yields a good fit to the observed shell system surrounding NGC 3923 if the halo mass (interior to the outermost shell) is $\approx 30-50$ times the luminous mass and the halo core radius is $\approx 2-4$ times the luminous effective radius (see Hernquist and Quinn 1986b).

T. de Zeeuw (ed.), Structure and Dynamics of Elliptical Galaxies, 467–468.

The results for NGC 3923 can be compared with observations of x–ray coronae around early–type galaxies (Forman, Jones, and Tucker 1985). A useful characterization of the halo properties is provided by the quantity $m_{dark}(r)/r$. For $r >> \gamma$, $m_{dark}(r) \sim r$ (for an isothermal distribution) and $m_{dark}(r)/r \sim$ constant $\equiv \Xi$. It is also instructive to compare these data with the Bahcall and Casertano (1985) rotation curve analyses of spiral galaxies. In this case, the halo properties can be characterized by $v_{max}^2/G =$ constant $\equiv \Xi$, where v_{max} is the maximum rotation velocity in the disk, since $v_{max}^2/G \sim m_{dark}(r)/r$. The comparison is shown in Figure 1, for a mass to light ratio $M/L = 6$ for the early type galaxies, and $M/L = 3$ for the spiral galaxies.

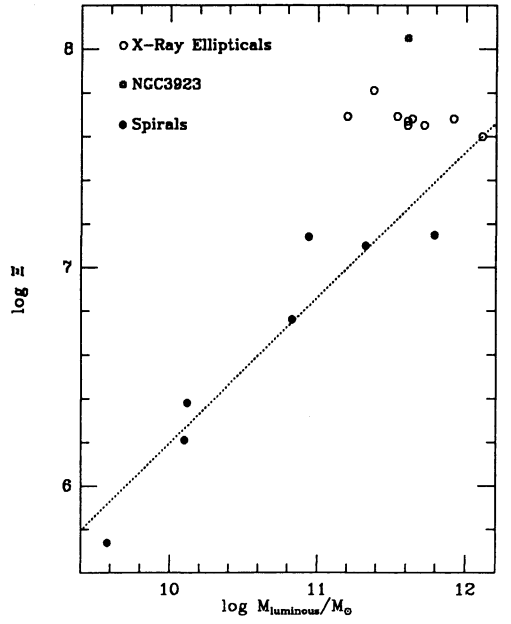

Figure 1. A comparison of the properties of the halo surrounding NGC 3923 with other observations.

The parameters of the halos surronding NGC 3923 and the x–ray galaxies are in good agreement, allowing for the uncertainty in the halo core radii for the x–ray sample (Hernquist and Quinn 1986b). An extrapolation of Ξ for the spirals (dotted line) suggests that the properties of halos surrounding ellipticals may differ from those surrounding spirals of the same luminous mass. However, the uncertainties are not negligible and a larger data–set is required. Future observations may help to determine if ellipticals formed as the result of mergers of spirals or if intrinsic differences in the local distribution of dark matter could have determined the Hubble type of the luminous material.

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