MOND
Modified Newtonian dynamics

Milgrom 1983

Bekenstein and Milgrom 1984

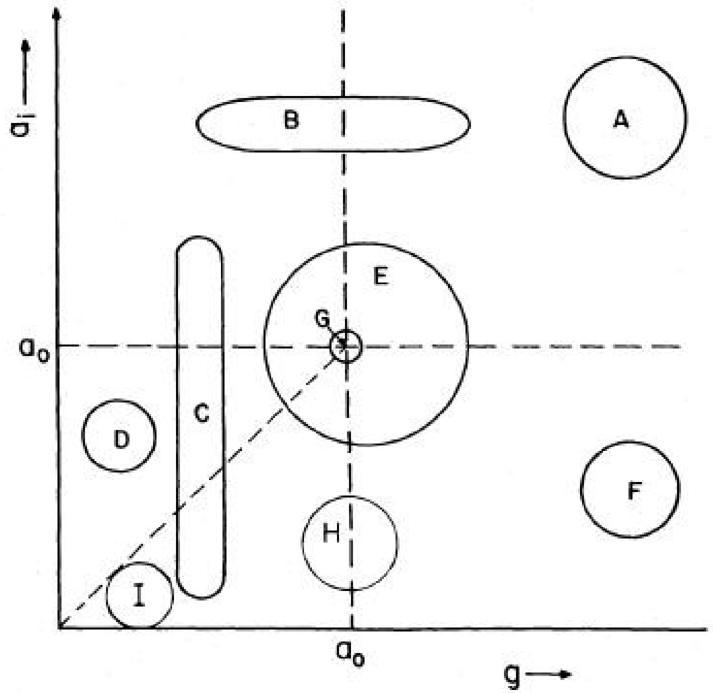

FIG. 1.—A schematic classification of some composite systems according to their typical internal (a_i) and c.m. (g) accelerations. A: Atomic, nuclear, everyday systems, solar system, etc. B: Atoms, stars, binaries, etc. in the field of a galaxy. C: A galaxy in the field of a neighbor galaxy, of a group or of a cluster. D: The Local Group in the field of the Local Supercluster. E: Globular clusters in the field of a galaxy. F: Laboratory low acceleration experiments freely falling in the field of the Earth + Sun. G: Long-period comets-Sun system in the field of the galaxy. H: Open clusters in the solar neighborhood. I: Dwarf elliptical galaxies in the field of the Milky Way.

(Milgrom 1983)

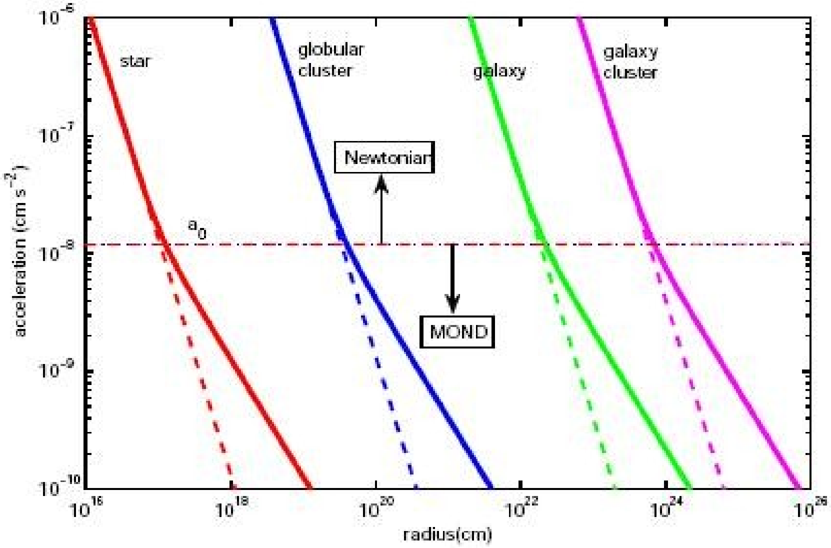

Fig. 1.— The MOND centrifugal acceleration of a particle on a circular orbit around a mass M, as a function of orbital radius (in heavy lines), for a star of one solar mass $(1M_\odot)$(red), globular cluster of mass $10^5 M_\odot$ (blue), a galaxy of mass $3 \times 10^{10} M_\odot$ (green), and a galaxy cluster of mass $3 \times 10^{13} M_\odot$ (magenta). The Newtonian accelerations are shown as dashed lines. Departure of MOND from Newtonian dynamics occurs at different radii for different central masses, but always at the same value of the acceleration, a_0, below which we are in the MOND regime, and above which we are in the Newtonian regime.

(Milgrom 2009)

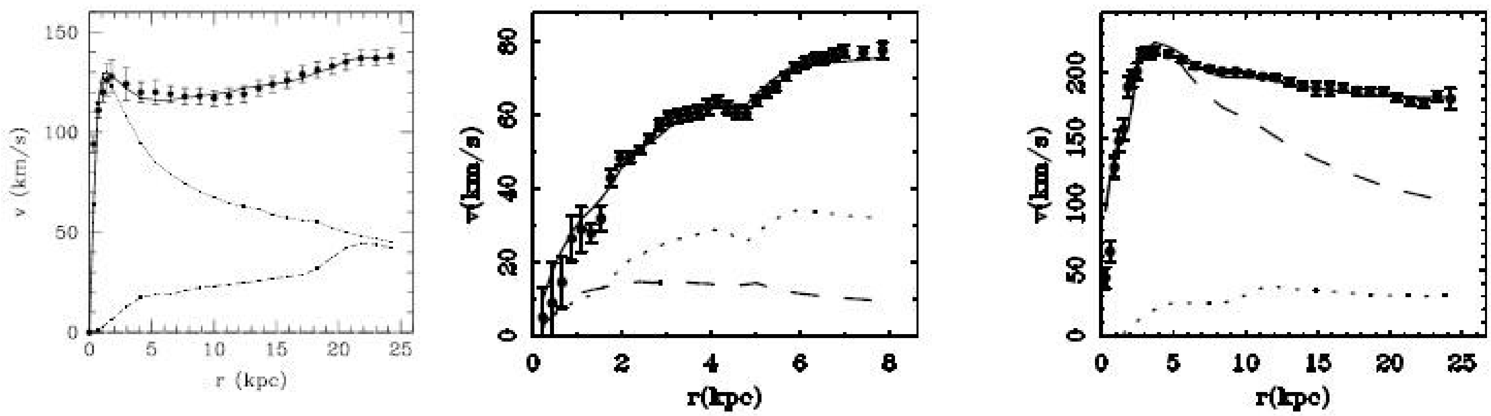

Fig. 2. The observed and MOND rotation curves (in solid lines) for NGC 3657 (left), NGC 1560 (cnter), and NGC 2903 (right). The first from Sanders (2006), the last two from Sanders and McGaugh (2002). Points are data, dashed and dotted lines for the last two galaxies are the Newtonian curves calculated for the stars and gas alone; the reverse for the first (they add in quadrature to give the full Newtonian curve).

Milgrom 2008

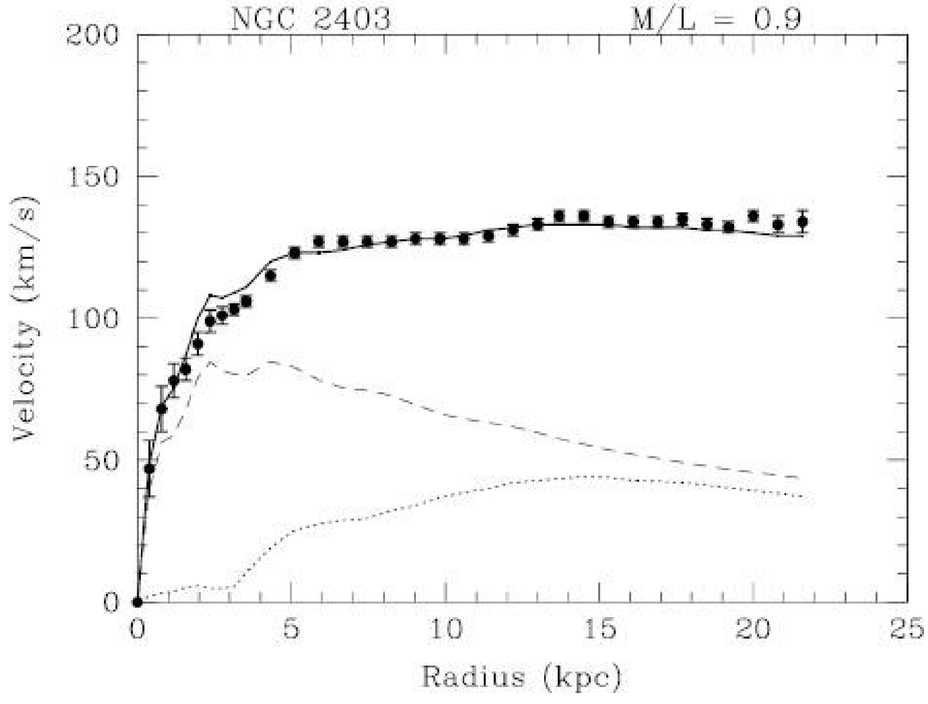

Figure 1: The points show the rotation curve of NGC 2403 as deduced from 21 cm line observations [6]. The dashed curve is the Newtonian rotation curve of the stellar component as deduced from the observed surface brightness distribution with M/L=0.9, and the dotted curve is the Newtonian rotation curve deduced from the observed HI surface density distribution. The solid curve is that calculated from Milgrom's formula. Here $a_0 = 10^{-8}$ cms^{-2}.

Sanders 2008

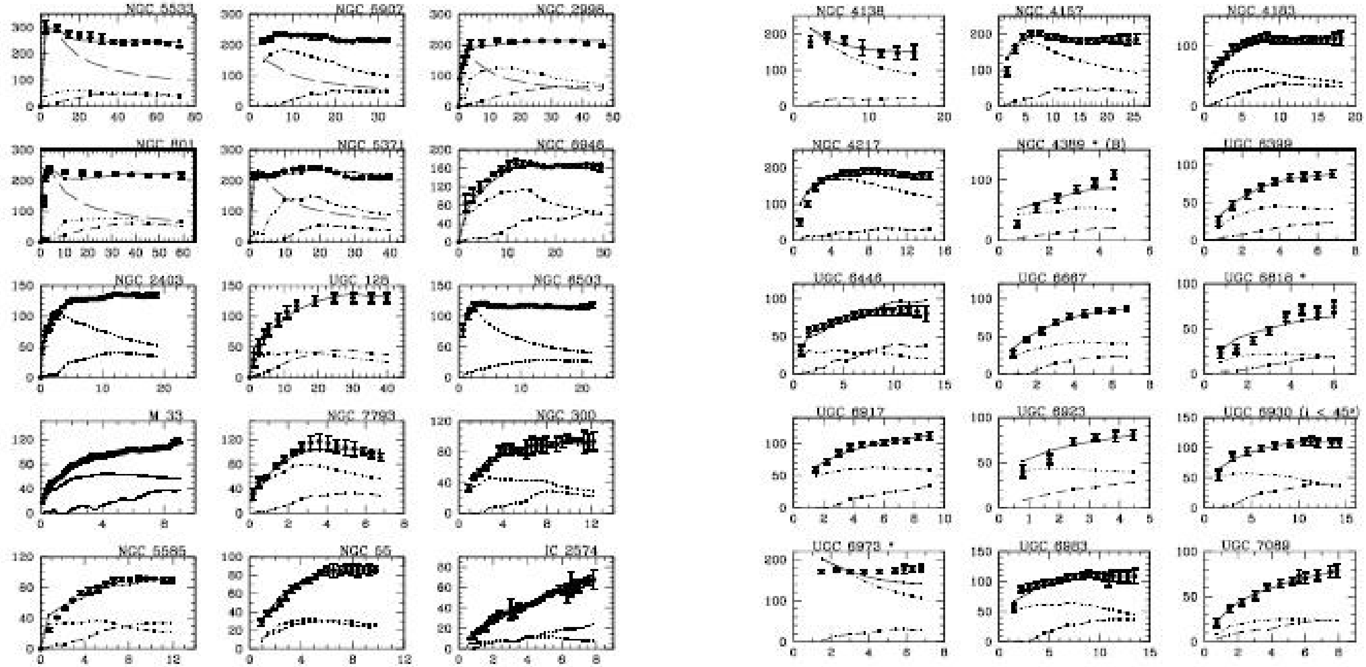

Fig. 3. Additional MOND rotation curves from Sanders (1996) and de Blok & McGaugh (1998) (left) and from Sanders & Verheijen (1998) (right). (MOND curves in solid; stellar disc Newtonian curves in dotted; gas in dot-dash; and stellar bulge in long dashed.)

Milgrom 2008

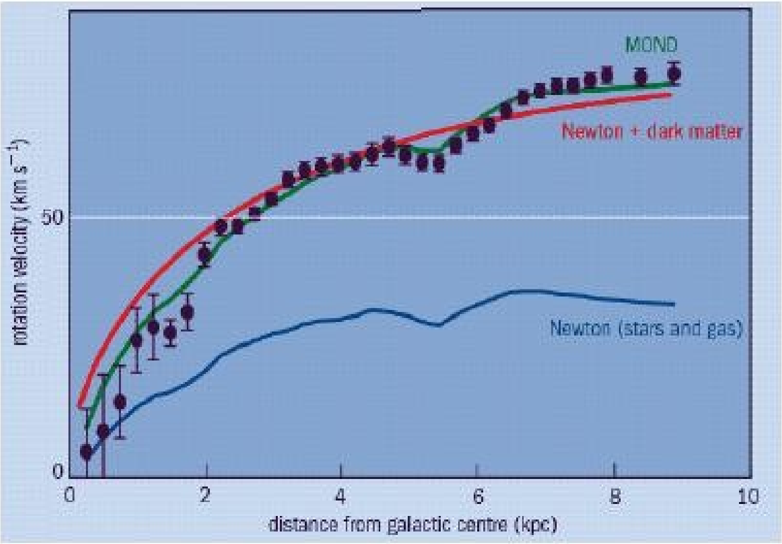

Fig. 3.— The measured rotation curve of the galaxy NGC1560 shown by the data points. The predicted Newtonian curve based on the measured mass distribution is shown in blue. It shows a velocity disparity of a factor 2.25 at the last measured point, which corresponds to a factor-of-five mass discrepancy. The MOND prediction is shown in green. The best fit with a dark matter hallo of the type predicted by CDM simulations is shown in red. I has two free parameters over which the fit is optimized: the mass and scale of the halo (no such freedom exists for MOND). Courtesy of Stacy McGaugh.

Milgrom 2009

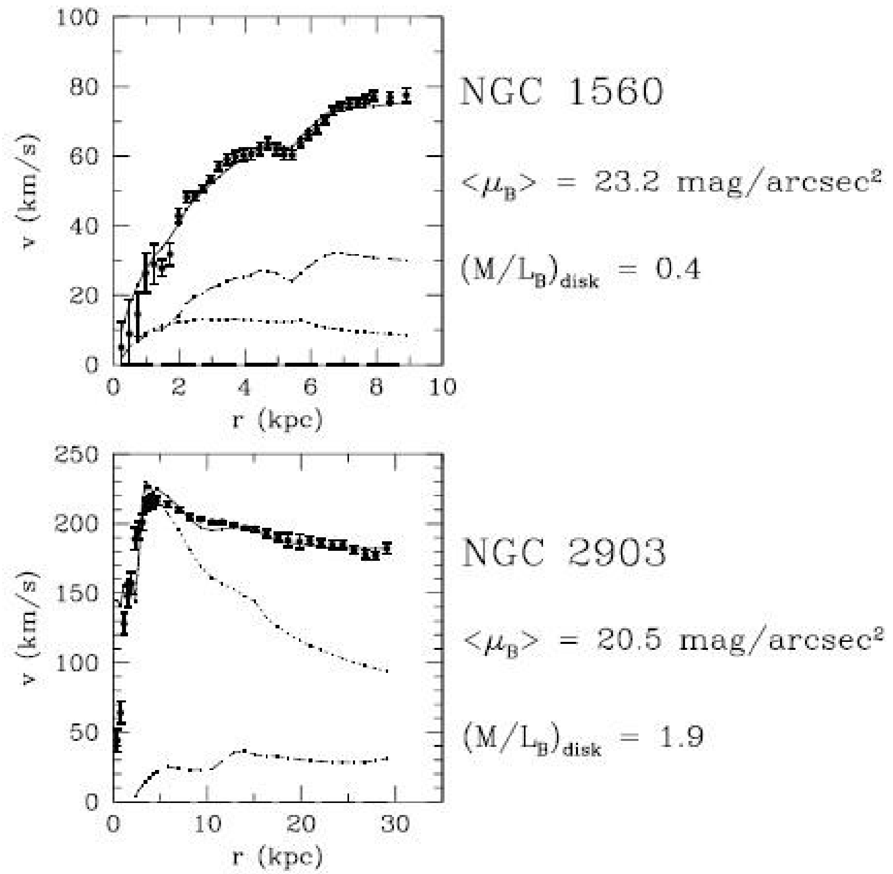

Figure 3: Observed rotation curves of a low surface brightness (Broeils [15])and a high surface brightness galaxy (Begeman [6]). Here the dotted curve is the Newtonian rotation curve of the stellar component and the dashed curve for the gas. The solid curve is the MOND rotation curve. The mean surface brightness and the implied mass-to-light ratios are indicated.

Sanders 2008

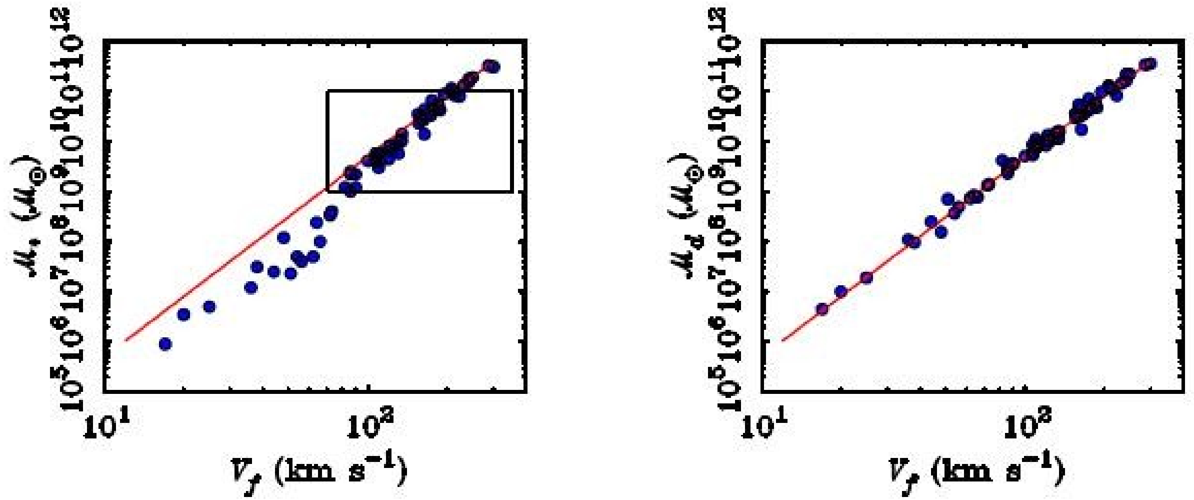

Fig. 1. Galaxy mass vs. asymptotic velocity. Left: analog to the traditional Tully-Fisher plot involving stellar mass alone. Right: gas mass is included. The solid line has the log-log slope of 4, predicted by MOND and is not a fit (McGaugh 2005b).

Milgrom 2008

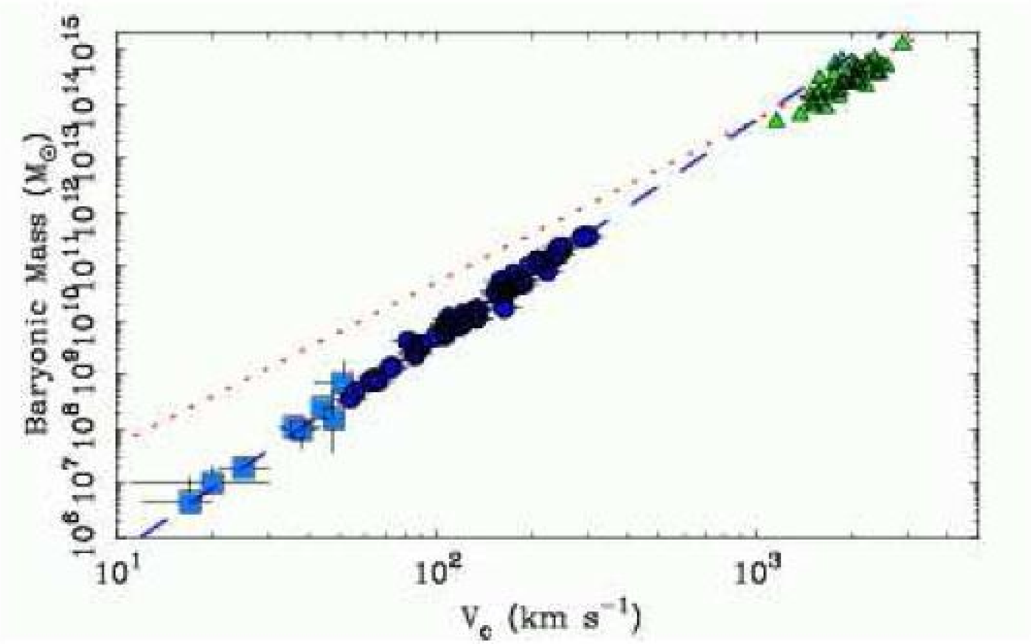

Figure 2: The baryonic Tully-Fisher relation derived by McGaugh [7]. This is the the baryonic mass plotted against the rotation velocity for a sample of spiral galaxies. The squares are dwarf galaxies where gas makes a dominant contribution to the baryonic mass. The triangular points are the deduced circular velocity for clusters of galaxies. The solid line is the MOND relation and the dotted line is that predicted from CDM simulations.

Sanders 2008

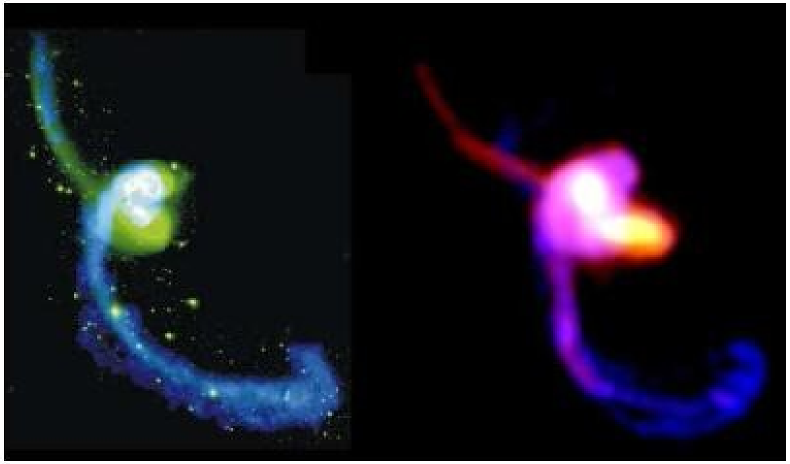

Fig. 4.— Simulation of closely interacting galaxy pair known as The Antennae with MOND (right) compared to the observations from Hibbard et al. 2001 (left). In the observations, the gas is represented in blue and the stars in green. In the simulation the gas is in blue and the stars are in yellow/red. Considering that many of the details of the history of the collision are not known and cannot be incorporated in the simulation, the agreement is quite remarkable. From Tiret and Combes 2008.

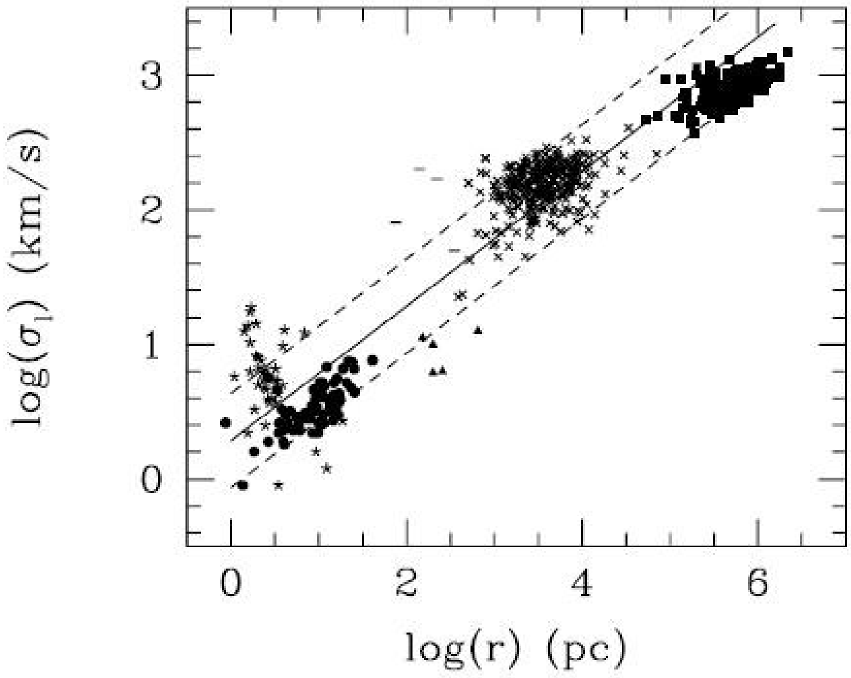

Figure 4: A log-log plot of the velocity dispersion in hot stellar systems against the characteristic size for different classes of objects. The star points are globular clusters, the solid round points are massive molecular clouds in the Galaxy, the crosses are luminous elliptical galaxies, the triangles are dwarf spheroidal galaxies, the squares are X-ray emitting clusters of galaxies. The solid line corresponds to $\sigma^2/r = a_0$ and the dashed lines show a factor of 2.2 variation on each side. The references to the relevant observational papers may be found in [2].