GRAVITATIONAL LENSES AS PROBES OF THE DISTRIBUTION OF DARK MATTER IN THE UNIVERSE

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ABSTRACT. Studies of the characteristic properties of gravitational lensing by clusters of galaxies suggest that the dark matter in them is probably smoothly distributed on the scale of the cluster itself, rather than being clumped into halos around individual galaxies.

1. INTRODUCTION

Gravitational lensing by clusters of galaxies give information on the distribution of dark matter in the universe. Different properties are obtained from the lens depending on whether (1) dark matter is smoothly distributed on the scale of clusters and individual galaxies are embedded in it, or (2) dark matter clumps into halos around individual galaxies. We show here the difference between these properties, and suggest that observations favour scenario 1. Fig. 1 shows the calculated profiles of surface density (σ) of the galaxies (solid line) and the dark matter (dashed line) according to scenario 1 (Cowsik and Ghosh, submitted to Ap.J.); the data (dots) is also shown.

2. SMOOTHENED POTENTIALS

Lenses are studied through the scalar potential formalism (Schneider 1985, Astr. Ap. 143, 413, Nityananda 1985 private communication). The deflection $\bar{\alpha}$ is the gradient of the scalar potential

$$\psi(\underline{r}) = \int \rho(\underline{r}') \ln|\underline{r} - \underline{r}'| d^2r'$$

Potentials ψ_1, ψ_2 generated by smoothened distributions of galaxies and dark matter according to scenarios 1 and 2 are shown in Fig.2. A background potential, generated by a (critical) background density is subtracted in each case to avoid double counting. The deflection α_1, α_2 generated by ψ_1, ψ_2 are also shown. The radial scale $l_\nu = [\langle v_\nu^2\rangle/12\pi G\, \rho_\nu(o)]^{\frac{1}{2}}$ is the structural length of the cluster.

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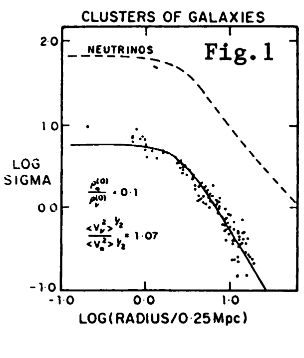
Here $\langle v_\nu^2 \rangle$ is the dispersion in the velocities of the neutrinos, m_ν is the neutrino mass and $\rho_\nu(o)$ is the density of dark matter at the centre of the cluster.

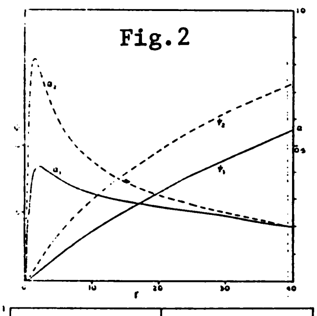
3. FLUCTUATIONS

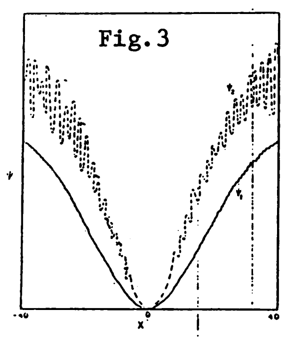
Individual galaxies cause fluctuations about the smoothened potentials. Fig.3 shows the fluctuations in ψ along the x-axis of a typical cluster. The length scale for the fluctuations if $l_* = [\langle v_*^2 \rangle / 12\pi G\rho_*(o)\ \ ]^{\frac{1}{2}}$, the structural length of a galaxy. Here, $\langle v_* \rangle^{\frac{1}{2}}$ is the r.m.s. velocity of the stars in the galaxy and $\rho_*(o)$ is the visible density at the centre of the galaxy. Deflection angles obtained from the potentials of Fig.3 are displayed in Fig.4.

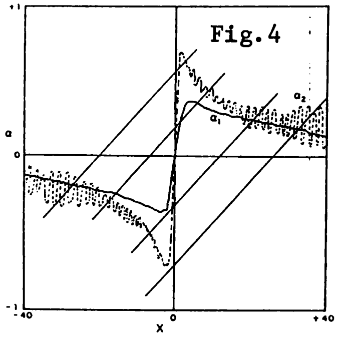
4. COMPARISON OF SCENARIOS

First, mass models for the gravitationally lensed quasar 0957 + 561 (Greenfield, Roberts and Burke 1985, Ap. J., 293, 370) have shown that scenario 1 is preferred over scenario 2. Second, the straight lines in Fig.4 correspond to various values of the left-hand side of the lens equation $\underline{r} - \underline{x} = \underline{\alpha}(\underline{r})$; their intersections with α-curves give the positions of the images. Scenario 1 give well-separated images which are sharp and undistorted. In scenario 2, several of these images are actually multiple images with small splitting; at low resolution these appear as diffuse, distorted images. The observed lack of distorted images (Tyson et al, 1984, Ap.J. (Letters), 281, L59) favours scenario 1.









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