arXiv:astro-ph/0011235v1 12 Nov 2000

Gravitational Lensing and Elliptical Galaxies

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1. Introduction

The probability that high-redshift quasars are gravitationally-lensed by intervening galaxies increases rapidly with the cosmological constant, Ω_{Λ_0} (whilst being only weakly dependent on the density parameter, Ω_{m_0}), and the low number of lenses observed implies that $\Omega_{\Lambda_0} \lesssim 0.7$ (e.g. Kochanek 1996). One of many uncertainties has been the (small) core radii of elliptical galaxies, which, at least naively, reduce their lensing cross-section. However, if ellipticals are normalised relative to their observed line-of-sight velocity dispersion, $\sigma_{||}$, then increasing the core radius must result in an increased mass normalisation (specified by the assymptotic velocity dispersion, σ_{∞}).

2. Elliptical galaxies

Elliptical galaxies are modelled as having de Vaucouleurs (1948) surface brightness profiles with (non-singular) isothermal mass distributions – constant mass-to-light ratio models cannot fit both lensing observations and dynamics (Kochanek 1996). With a few other non-pathological assumptions about the dynamics, solution of the Jeans equation is sufficient to calculate the line-of-sight dispersion as a function of projected radius, which can then be integrated over the central regions of the galaxy, to link $\sigma_{||}$, σ_{∞}, and the core radius, r_{c}. Whilst there are some model uncertainties, this approach shows that $\sigma_{\infty} \simeq 1.1\sigma_{||}$ for singular models, and that σ_{∞} increases roughly linearly with r_{c} (Mortlock & Webster 2000).

3. Lensing probability

With the choice of standard models for the galaxy population and the (optical) quasar luminosity function, the expected fraction of lenses in a magnitude-limited quasar sample, p_{q}, can be calculated. Under the incorrect assumption that $\sigma_{\infty} = \sigma_{||}$, p_{q} decreases with the scale core radius of the galaxies,
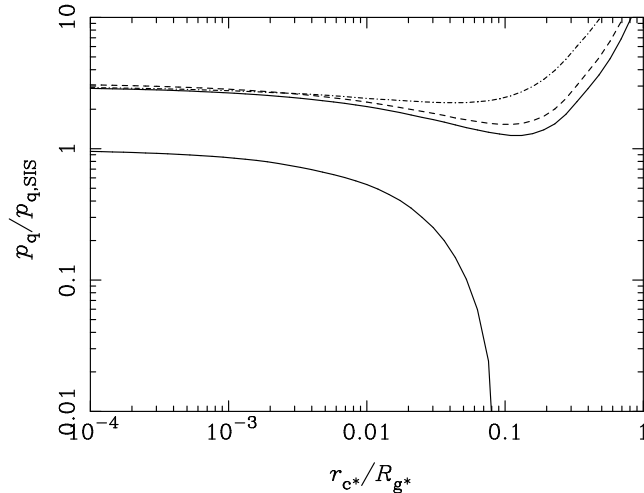
Figure 1.   The dependence of the lensing probability (relative to the naive singular model) on the canonical core radius of elliptical galaxies. With the identification $\sigma_\infty = \sigma_{||}$ the lower solid line is obtained; using a self-consistent dynamical normalisation results in the upper trio of lines, which show how the results depend on the cosmological model: $\Omega_{m0} = 1$ and $\Omega_{\Lambda_0} = 0$ (solid line); $\Omega_{m0} = 0$ and $\Omega_{\Lambda_0} = 0$ (dashed line); and $\Omega_{m0} = 0$ and $\Omega_{\Lambda_0} = 1$ (dot-dashed line).

r_{c*}, because, despite the increased magnification bias, the reduction in cross-section dominates. However the use of a self-consistent dynamical normalisation changes this dependence markedly, as shown in Fig. 1. Most importantly, the self-consistent lensing probability never drops below the maximum probability for the incorrect models.

4.   Conclusions

The use of self-consistent dynamical models for elliptical galaxies shows that, independent of their core radius, they are effective lenses. The results imply that the current upper limits placed on Ω_{Λ_0} due to the low observed frequency of quasar lenses are not weakened by any uncertainty in the core structure of ellipticals – in fact the existing limits are probably more robust than previously believed.

References

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