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Gravitational Lensing by 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,

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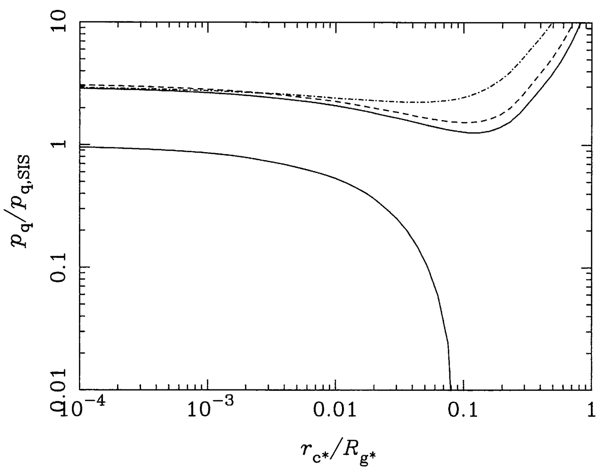

Figure 1. The dependence of the lensing probability (relative to the naive singular model) on the canonical core radius of elliptical galaxies. With the identification $\sigma_\infty = \sigma_{||}$ the lower solid line is obtained; using a self-consistent dynamical normalisation results in the upper trio of lines, which show how the results depend on the cosmological model: $\Omega_{m_0} = 1$ and $\Omega_{\Lambda_0} = 0$ (solid line); $\Omega_{m_0} = 0$ and $\Omega_{\Lambda_0} = 0$ (dashed line); and $\Omega_{m_0} = 0$ 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.

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References

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