Can Microlensing Explain the Optical Long−Term Variability of Quasars?

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Introduction

Although controversial, the idea of microlensing as the dominant mechanism for the optical variability of quasars on timescales of a few years does provide a natural explanation for both the statistical symmetry, achromaticity and the lack of cosmological time dilation in observed quasar light curves (e.g. Hawkins 1996, 2001).

Here, we investigate to what extent microlensing by populations of compact objects allowed in the currently favoured Ω_M=0.3, Ω_Λ=0.7 cosmology really can reproduce the average first−order structure function (representing a curve of growth of variability with time lag), the high degree of variability and the amplitude−redshift relation of quasars.

Microlensing Simulations

For every combination of the discrete parameter values listed in Table 1, around 35000 microlensing light curves spanning 25 years have been generated for quasars in the redshift interval z_{QSO}=0.13−3.6. Both magnification and Malmquist bias have been taken into account when assembling the light curves into synthetic quasar samples used for comparison with observations.

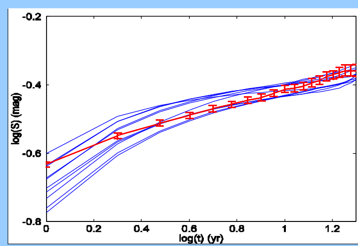
Table 1

$\Omega_{compact}$ = 0.05, 0.1, 0.15, 0.2, 0.25, 0.3
$M_{compact}$ = 10^{-5}, 10^{-4}, 10^{-3}, 10^{-2}, 10^{-1}, 1 solar masses
$\sigma_{v,compact}$ = 200, 400, 600 km/s
R_{QSO} = 10^{12}, $3{\cdot}10^{12}$, 10^{13}, $3{\cdot}10^{13}$ m

Here, R_{QSO} represents the typical radius of the optical continuum−emitting region (accretion disk) of quasars.

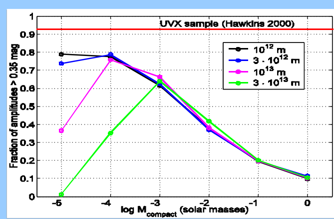
Average Structure Function

Figure 1: The average structure function of a sample of quasars (Hawkins 2002, private communication) selected on basis of ultraviolet excess (red line) compared to the ten best fitting average structure functions derived from simulations (blue lines). The best fits are produced from lens parameters in the range $M_{compact}=10^{-3}$−10^{-4} solar masses, $\Omega_{compact}$=0.3−0.25, $R_{QSO}=10^{12}$−$3{\cdot}10^{12}$ m, $\sigma_{compact}$=200−600 km/s. Even though no single parameter configuration completely reproduces both the shape and scaling of the observed structure function, the agreement is reasonable given the limited resolution of the explored microlensing parameter space.



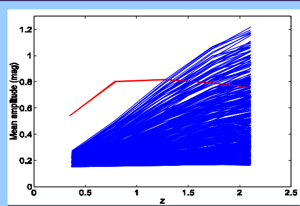
Variability

Figure 2: The red line indicates the observed fraction of quasars selected on basis of ultraviolet excess (Hawkins 2000) which varies with an amplitude higher than 0.35 magnitudes during 20 years of monitoring. The remaining lines represent the corresponding fractions derived from microlensing simulations for different $M_{compact}$ and R_{QSO} in the case where $\Omega_{compact}$=0.3 (the most variable scenario) and $\sigma_{v,compact}$=400 km/s. In no case is microlensing able to completely reproduce the high degree of observed variability.



The Amplitude−Redshift Relation

Figure 3: The observed mean quasar amplitude attained during 20 years of monitoring (Hawkins 2000) as a function of redshift (red line) and the corresponding relation predicted from the 432 different microlensing scenarios of Table 1 (blue lines). In no case is microlensing able to reproduce the high mean amplitude of quasars at redshift z < 1.25.



Conclusions

Even though microlensing may reasonably well reproduce the observed average structure function of quasars, it fails to reproduce both the high fraction of objects with amplitudes higher than 0.35 magnitudes and the observed amplitude−redshift relation. Microlensing may still contribute to the optical long−term variability of quasars at some level, but another significant mechanism (giving symmetric and achromatic variations) must also be involved.

References

Hawkins, M.R.S. 1996, MNRAS, 278, 787
Hawkins, M.R.S. 2000, A&AS, 143, 465
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