Determination of the redshift of an invisible lens

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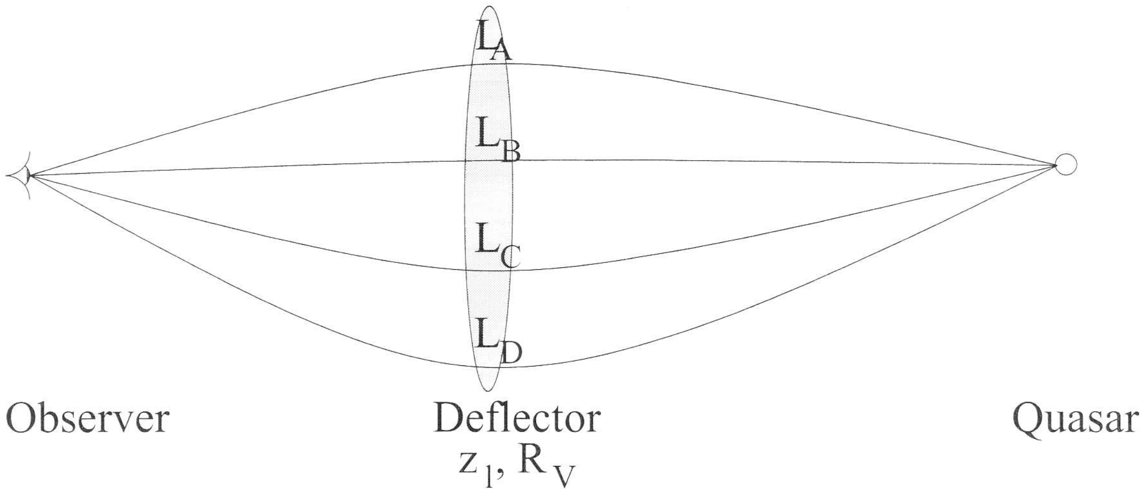
Introduction



Flux received by the observer from component i at the wavelength λ:

$$\boxed{F_{\lambda,i} = F_\lambda^0 \, A_i \, e^{-\mathrm{Ext}(\lambda',R_V)L_i}}$$

with F_λ^0 the flux emitted by the quasar;

A_i the magnification of component i;

$\mathrm{Ext}(\lambda', R_V)$ the extinction ($\lambda' = \dfrac{\lambda}{1+z_l}$, R_V is a parameter);

and L_i the path length of component i through the deflector.

We assume no contamination, no intrinsic colour variations between the components, no micro-lensing effects and that the extinction is taking place in a single lensing plane.

Colour difference between component i and a reference component is then:

$$(M_{\lambda_1,i} - M_{\lambda_2,i}) - (M_{\lambda_1,\mathrm{ref}} - M_{\lambda_2,\mathrm{ref}}) = \frac{2.5}{\ln(10)} \mathcal{L}_i \left[\mathrm{Ext}(\lambda_1', R_V) - \mathrm{Ext}(\lambda_2', R_V)\right]$$

with $M_{\lambda_1} - M_{\lambda_2} = -2.5 \log\left(\dfrac{F_{\lambda_1}}{F_{\lambda_2}}\right)$

and $\mathcal{L}_i = L_i - L_{\mathrm{ref}}$.

Fitting

$$\underbrace{(M_{\lambda_1,i} - M_{\lambda_2,i}) - (M_{\lambda_1,\mathrm{ref}} - M_{\lambda_2,\mathrm{ref}})}_{\text{Experimental colour}} =$$

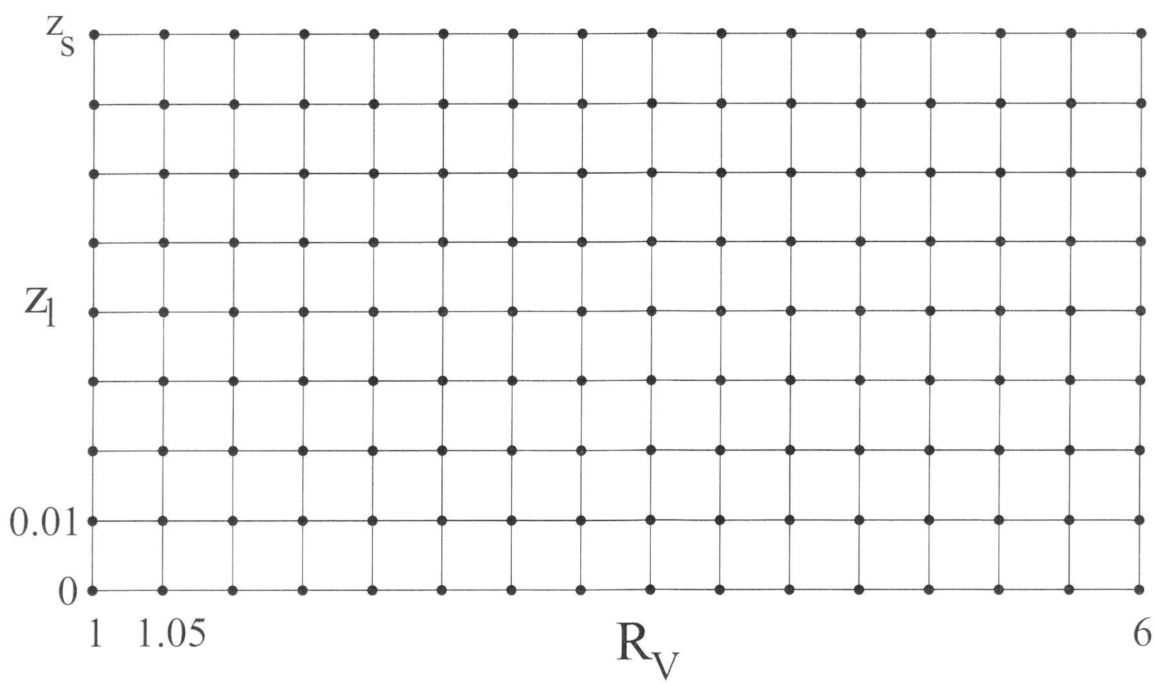
$$\underbrace{\frac{2.5}{\ln(10)}\,\mathcal{L}_i\,[\mathrm{Ext}(\lambda'_1, R_V) - \mathrm{Ext}(\lambda'_2, R_V)]}_{\text{Fitted colour}}$$

For the fitted colour:

- $\mathrm{Ext}(\lambda'_1, R_V) - \mathrm{Ext}(\lambda'_2, R_V)$ is computed for different contiguous values of R_V and z_l;
- $\mathcal{L}_i$ is fitted by a routine for each selected (R_V,z_l) point in order to minimize:

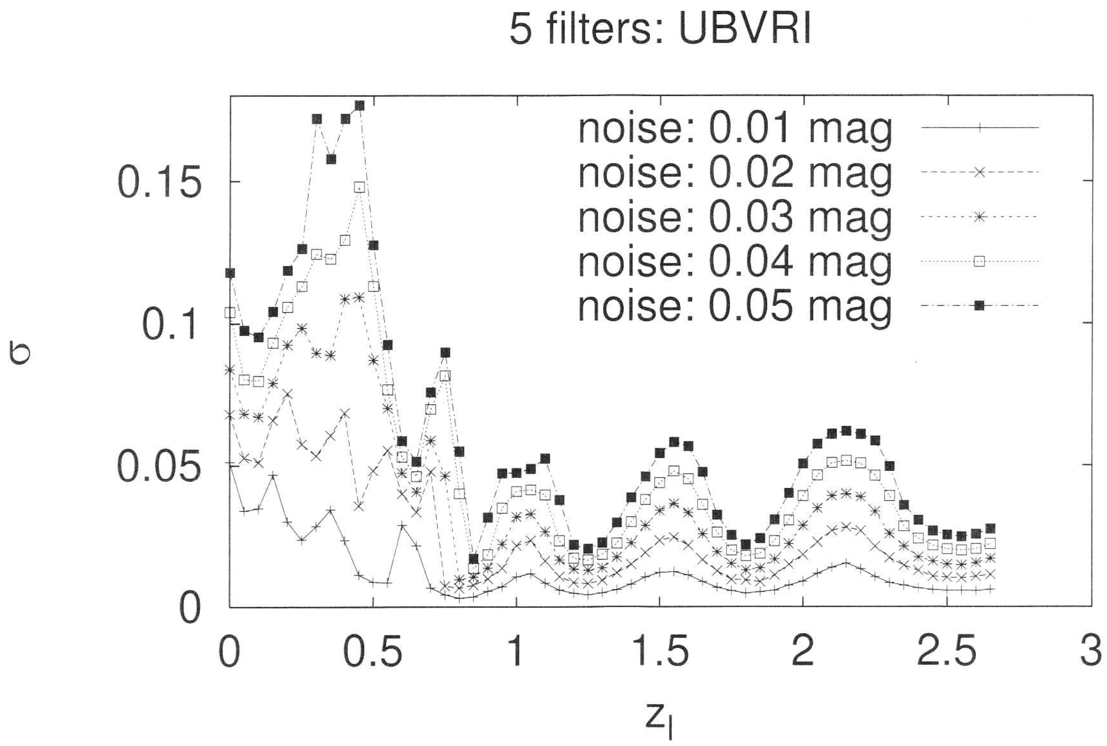
$$\boxed{\chi^2 = \sum \frac{(\text{Experimental colour} - \text{Fitted colour})^2}{\sigma^2_{\text{Experimental colour}}}}$$

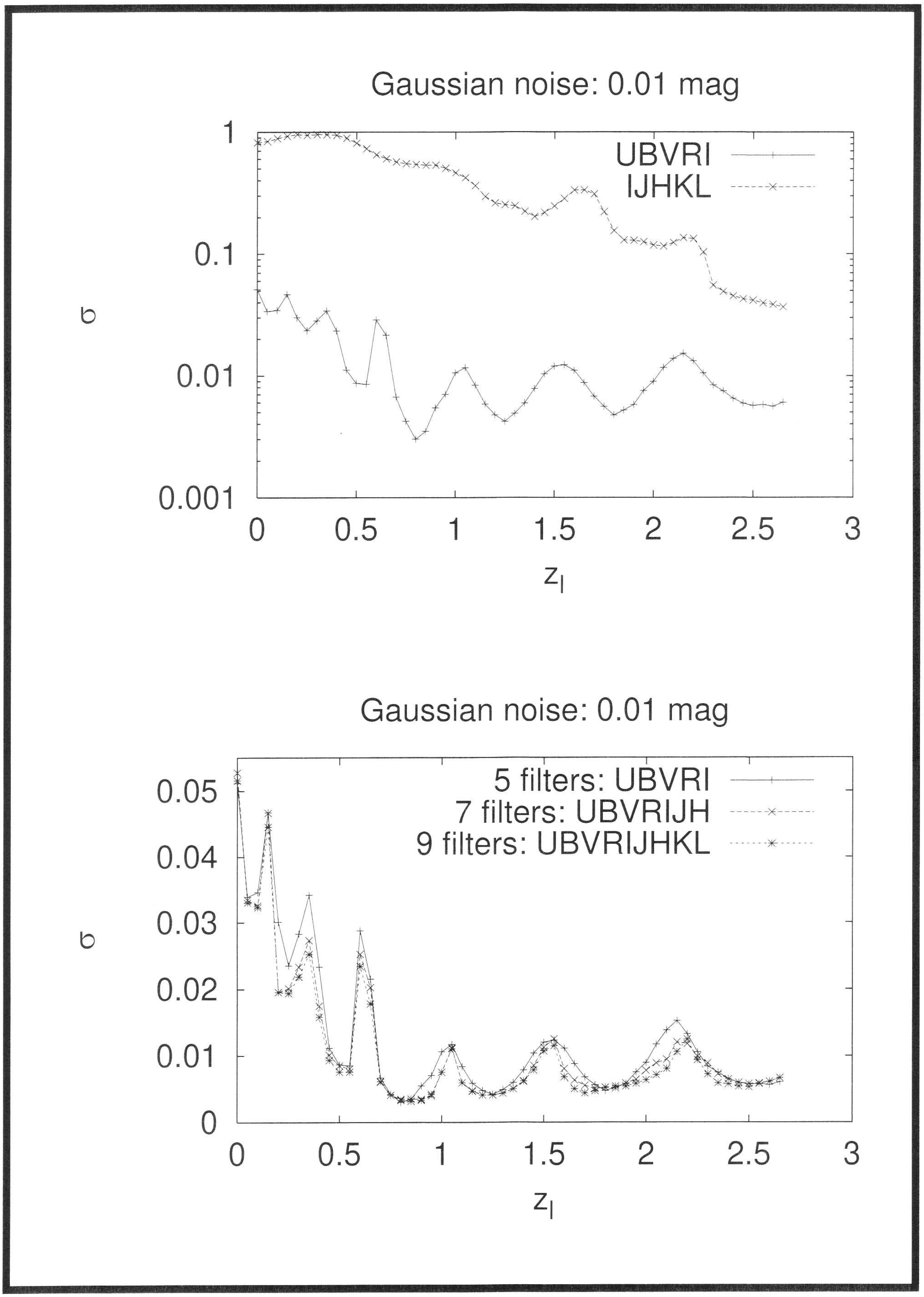
A χ^2 map is thus obtained:



Monte Carlo Simulations

Study of the errors affecting the determination of the lens redshift from a set of 100 simulations. Gaussian noise was added to the simulated magnitudes of the 4 selected components.




Gaussian noise: 0.01 mag
1
0.1
0.01
0.001
σ
UBVRI
IJHKL
0
0.5
1
1.5
2
2.5
3
z_l
Gaussian noise: 0.01 mag
0.05
0.04
0.03
0.02
0.01
0
σ
5 filters: UBVRI
7 filters: UBVRIJH
9 filters: UBVRIJHKL
0
0.5
1
1.5
2
2.5
3
z_l

Conclusions

Monte Carlo simulations indicate that the redshift of an invisible lens can be retrieved with this method provided that we have accurate photometric observations of the macro-lensed images.

This method is particularly sensitive to the redshift of the deflector and thus offers an original way of determining the redshift of an invisible lens.

High quality photometric data ($\sigma \simeq 0.01$ mag) are badly needed.

Photometry for at least 5 broad band filters is necessary.