Statistical Demagnification of Hi-Z Object due to Weak Lensing

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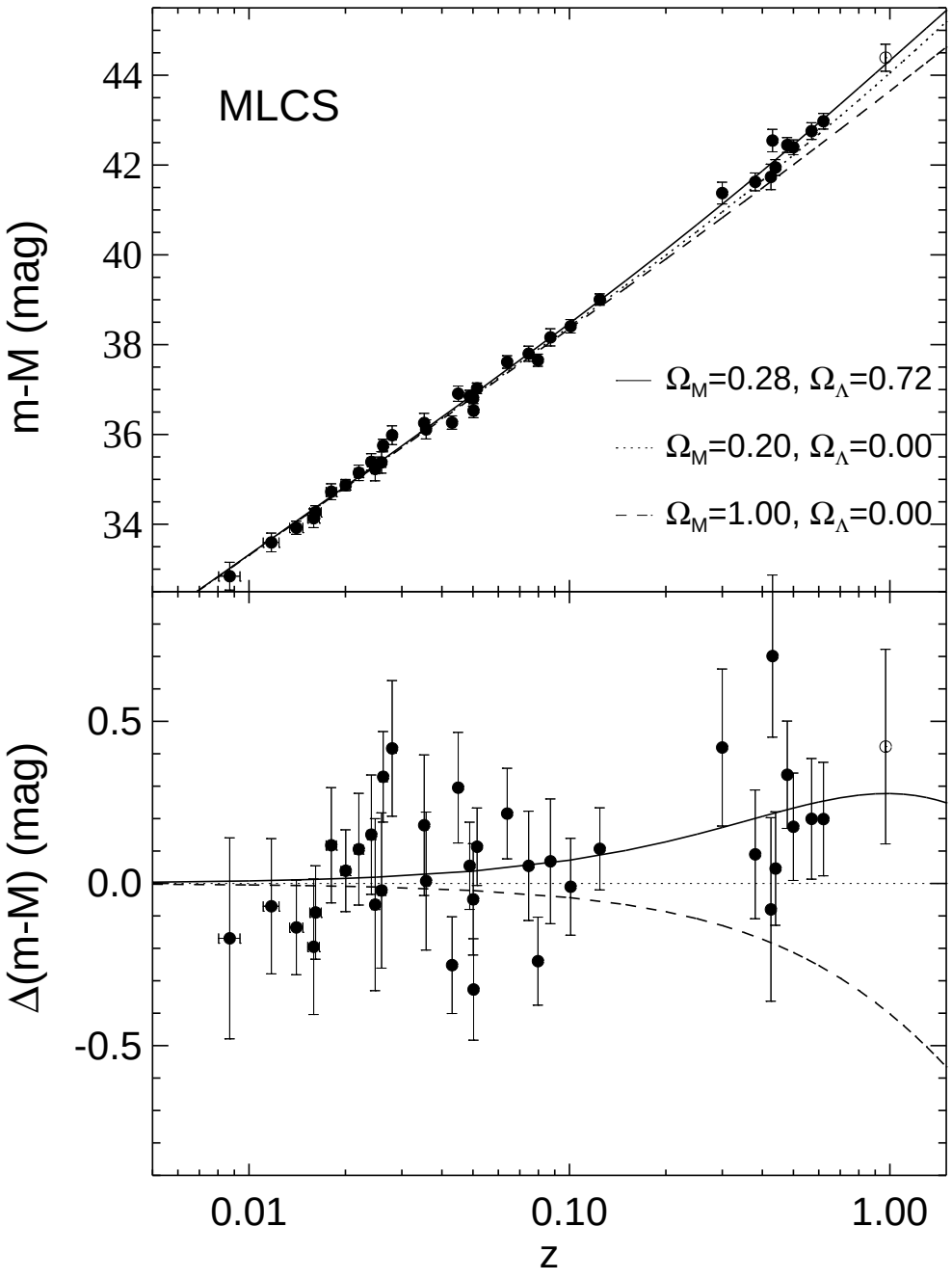
Introduction

Resent results from High-z Supernova Search (astro-ph/9905049 9805201, 9805200) and Supernova Cosmology Project (astro-ph/9812133) "proved":

NON-ZERO Λ is necessary

to explain the observed luminosity of High-z SNe



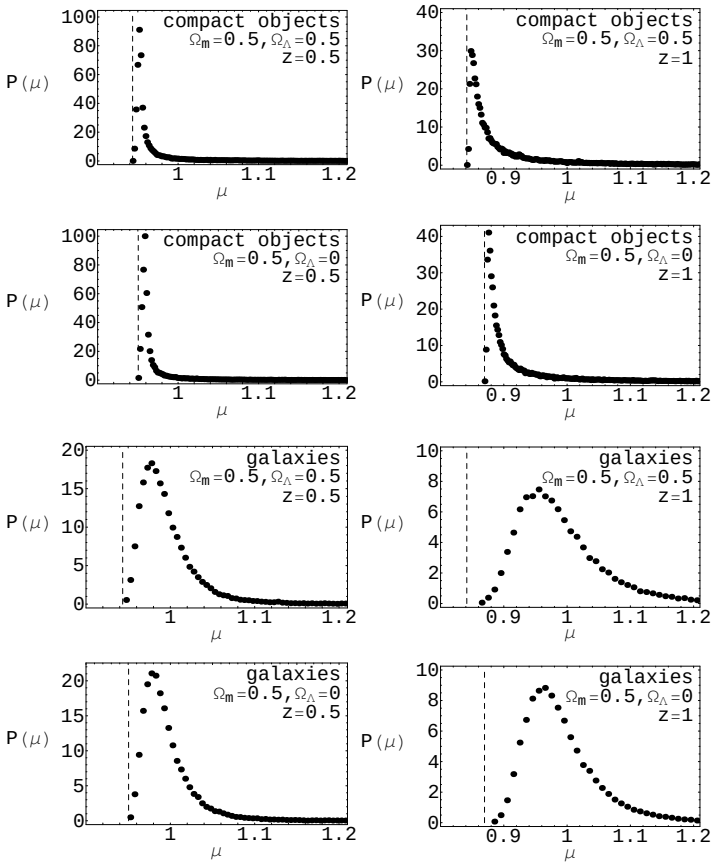
Possible sources of bias

- Evolution (*e.g.*, Riess *et al.*, 1999)
- Extinction (*e.g.*, Aguirre and Haiman 1999)
- Weak gravitational lensing (*e.g.*, Holz 1998)
- ...

Here we discuss the weak lensing.

Holz (1998)

- Effect of point-mass particles is LARGE.
- Galaxies of REALISTIC SIZE have much smaller effect.



Galaxy model in Holz (1998)

- mass $8.5 \times 10^{12} M_{\odot}$
- truncation radius 380kpc (for $\Omega_m = 0.5$)

One might ask...

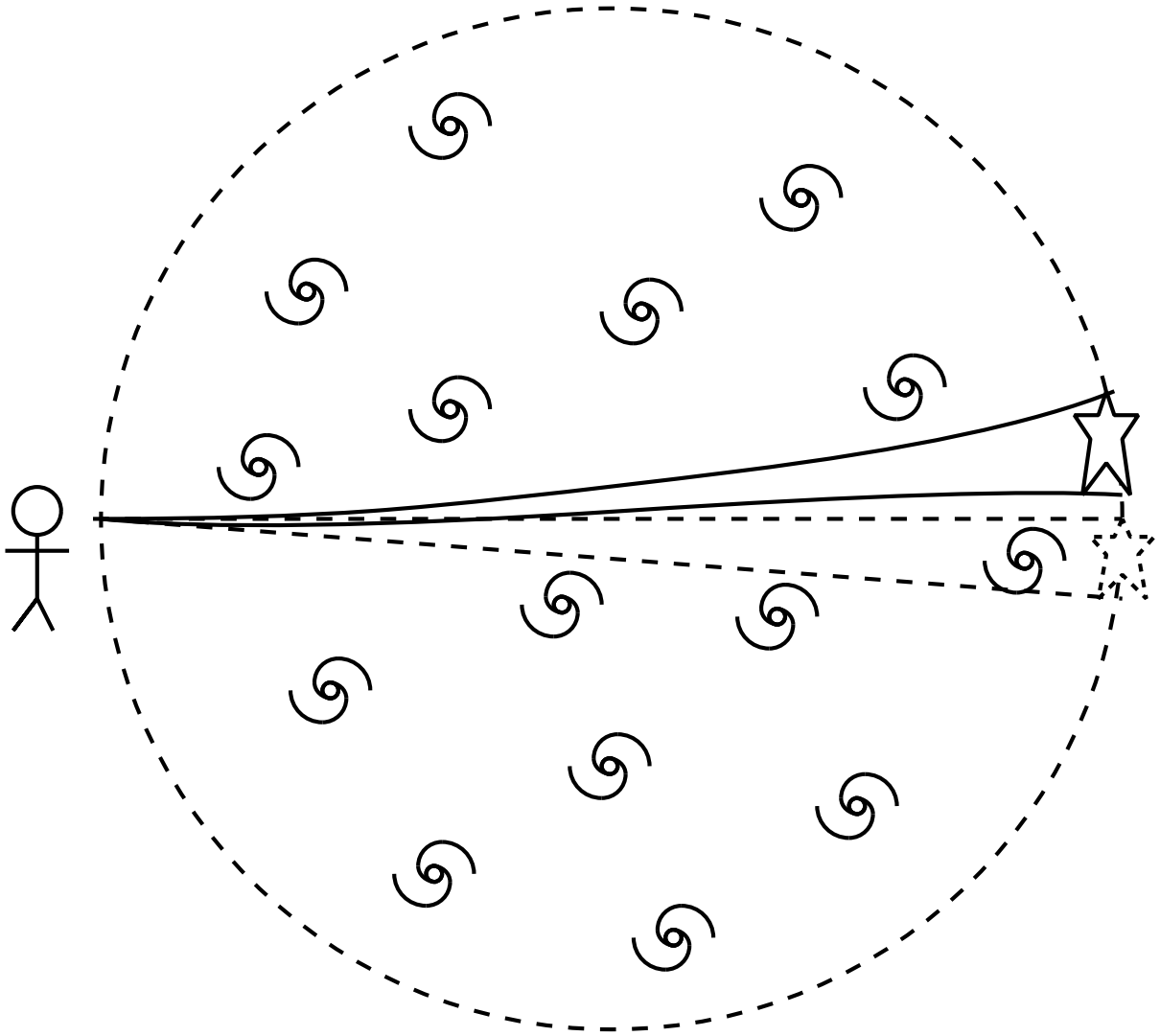
— Aren't they, well, a little bit *too large?*

— What is the effect of changing the size and mass of galaxies?

We investigated the effect of the size of the lenses.

New calculation

- In order to study the pure effect of the size, we considered an idealized universe
  - Stationary Universe (Λ cancels gravity)
  - Lenses are all spherically symmetric and do not evolve



Calculation details

System of Units:

- Gravitational constant $G = 1$,
- Radius of Sphere $R = 1$,
- Light velocity $c = 1$,
- Total Lens mass $Nm = 1/2$

Model used:

- N lenses are randomly distributed
- Mass distribution within each lens: truncated singular isothermal sphere

Calculation method:

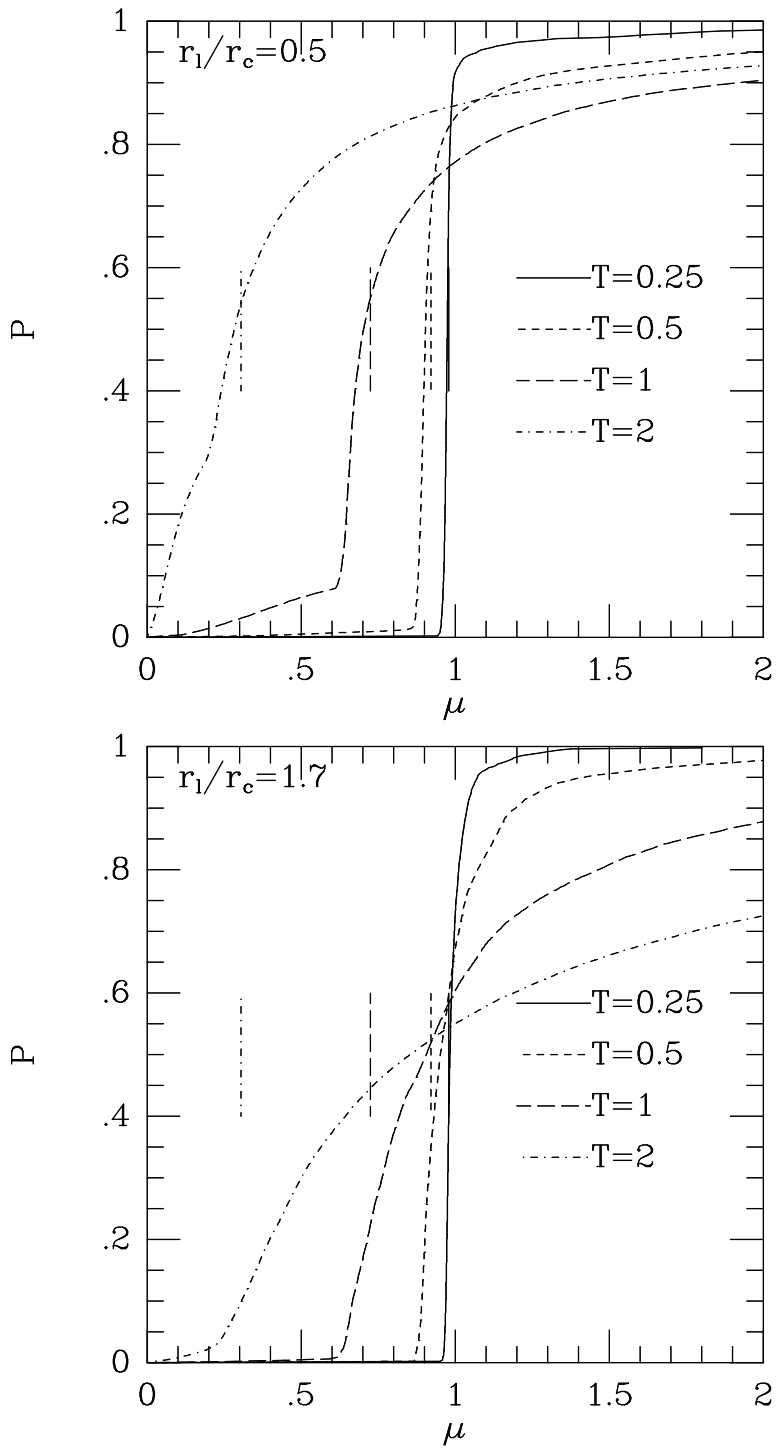
- "Weak gravity" approximation
  - effectively same as classical equation of motion except that deflection is $2\times$
  - see Funato *et al.* 1994, ApJL 411, 53 for technical details

Demagnification distribution

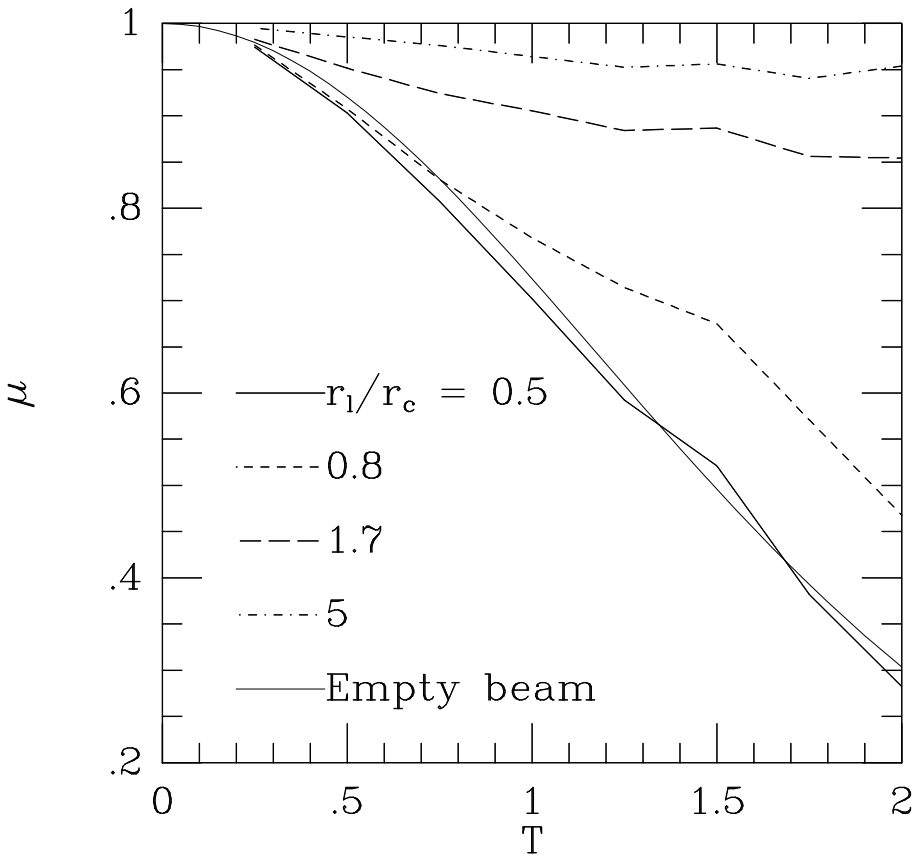
Cumulative provability distribution of (de)magnification for different epochs and size of lenses

The size of the lenses is relative to "Critical radius"

$$r_c = \left(\frac{Gm}{c^2 n}\right)^{1/4} = 40\mathrm{kpc}\left(\frac{\Omega}{0.2}\right)^{1/4}\left(\frac{M_l}{10^{12}M_\odot}\right)^{1/2}\left(\frac{H_0}{65\mathrm{km/s}}\right)^{-1/2}$$



Median demagnification



- If $r_l < r_c$, median demagnification is well approximated by empty beam
- Even if $r_l > r_c$, agreement with empty beam is good if $T << 1$

(in the limit of $z \to 0$, $T = \Omega z$)

Comparison with Holz(1998)

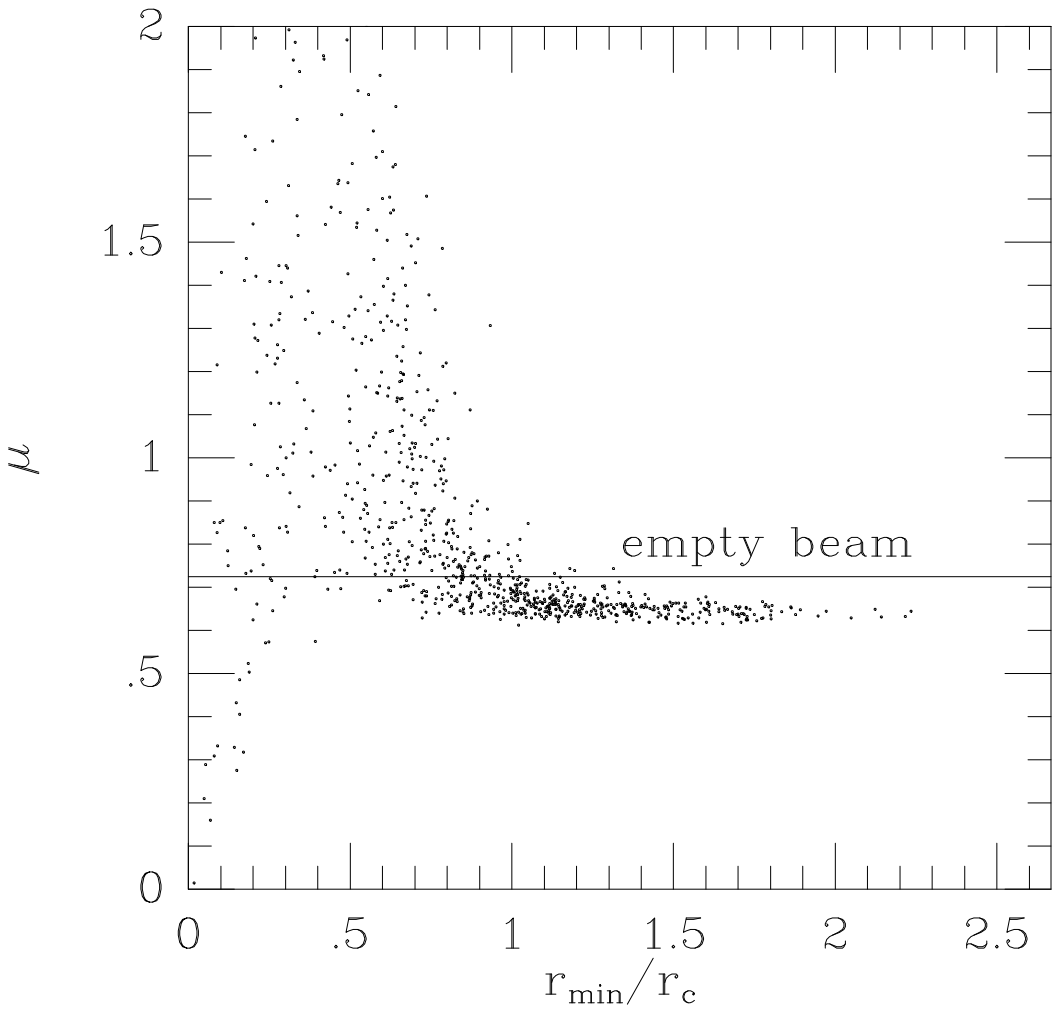
"Galaxy" in Holz (1998): $10^{13} M_\odot$, $r_l = 380\mathrm{kpc}$
$r_c = 90\mathrm{kpc}$
$\longrightarrow$ Lens effect negligible

A more realistic galaxy model: $10^{12} M_\odot$, $r_l = 40\mathrm{kpc}$
$r_c = 40\mathrm{kpc}$

$\downarrow$

The lens effect is comparable to that of point mass lenses, at least for low z ($z \leq 1$).

Relation between demagnification and minimum distance to lenses



- r_{min}: minimum distance (impact parameter) to the lenses
- If $r_{min} > r_c$, the demagnification is almost same as that of empty beam

If there is no galaxy (beside the host galaxy) in the distance of r_c from the light path, the magnitude-redshift relation of empty-beam must be used.

Summary

- We investigated the relation between the size of the lens and the demagnification effect.
- For point-mass lens, median demagnification is well expressed by empty beam.
- If $r_l < r_c =$, lenses can be regarded as point-mass lenses.
- For low z, lenses can be regarded as point-mass lenses even if $r_l \sim r_c$.
- Typical galaxies are slightly smaller than r_c.
- Weak lensing by Galaxies may have significant effect on the brightness of High-z SNe, similar to the "compact object" case of Holz (1998)