Theoretical incidence of gravitational lensing effects (AGN) in the XXL field

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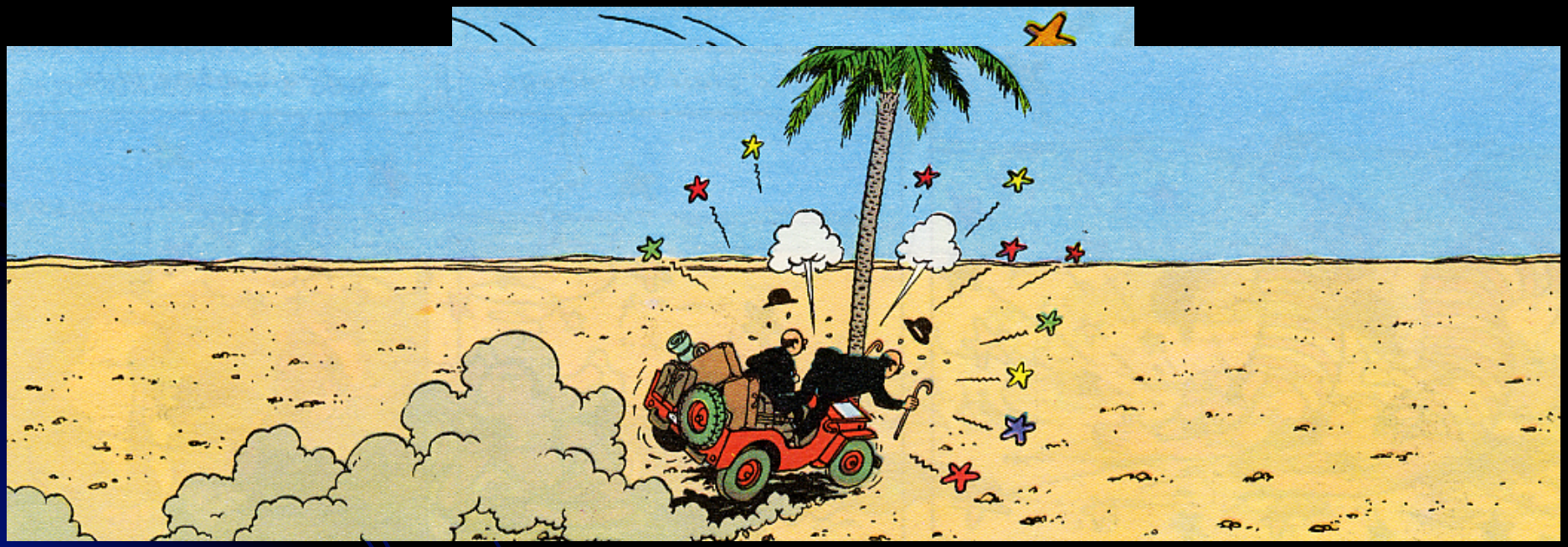
XXL Consortium meeting (Meudon 9-13 July 2012)

ULg
UNIVERSITÉ de Liège

An atmospheric mirage is an optical illusion …

… whose cause is real!



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Layout

1. Why searching for GLS?
2. Incidence of GL in the XXL field

1. Why searching for GLS?

- Determination of the Hubble parameter H_0

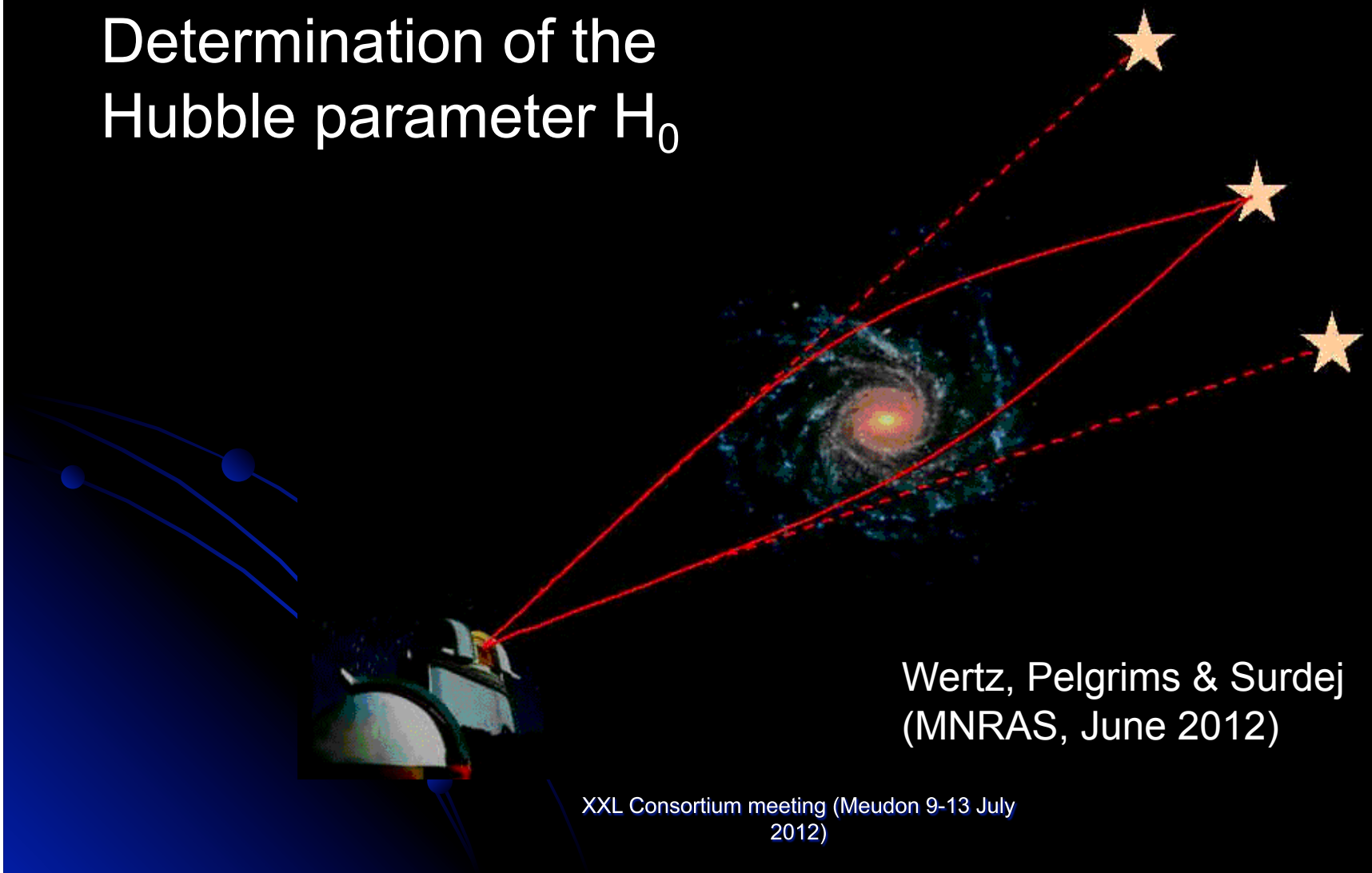
- Gravitational lens inversion

- Micro-lensing effects to study the AGN structure

- etc.

1. Why searching for GLS?

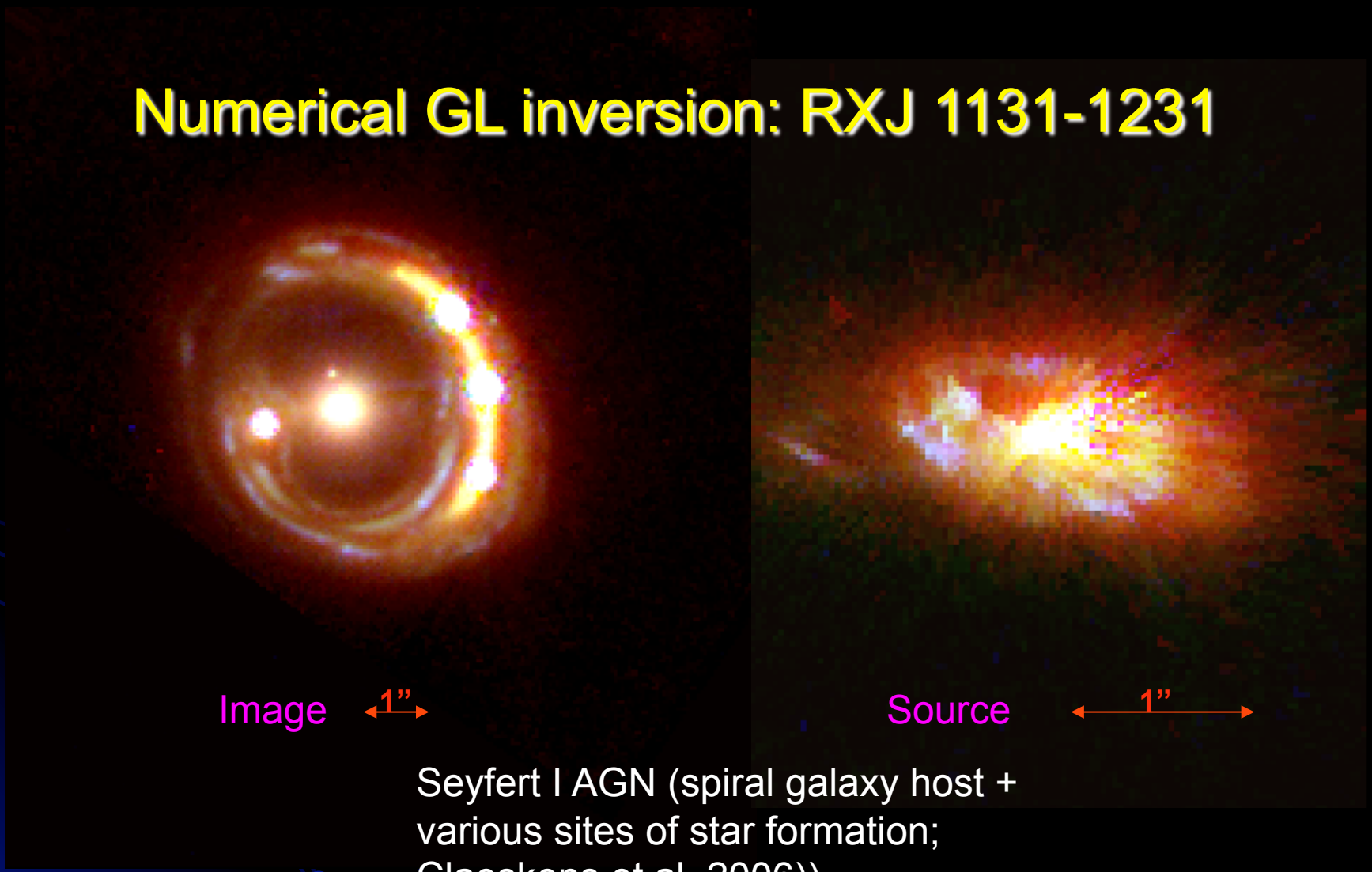
Determination of the Hubble parameter H_0



Wertz, Pelgrims & Surdej (MNRAS, June 2012)

1. Why searching for GLS?

Numerical GL inversion: RXJ 1131-1231



Seyfert I AGN (spiral galaxy host + various sites of star formation; Claeskens et al. 2006))

1. Why searching for GLS?

Numerical GL inversion: RXJ 1131-1231

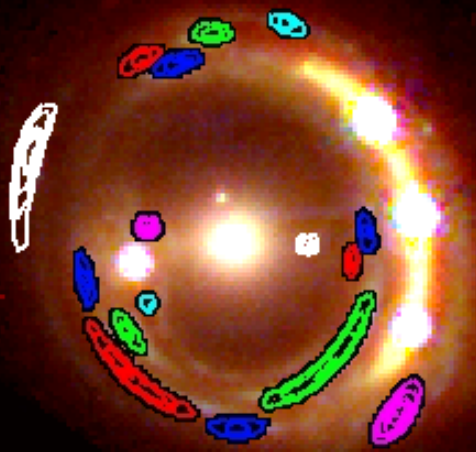
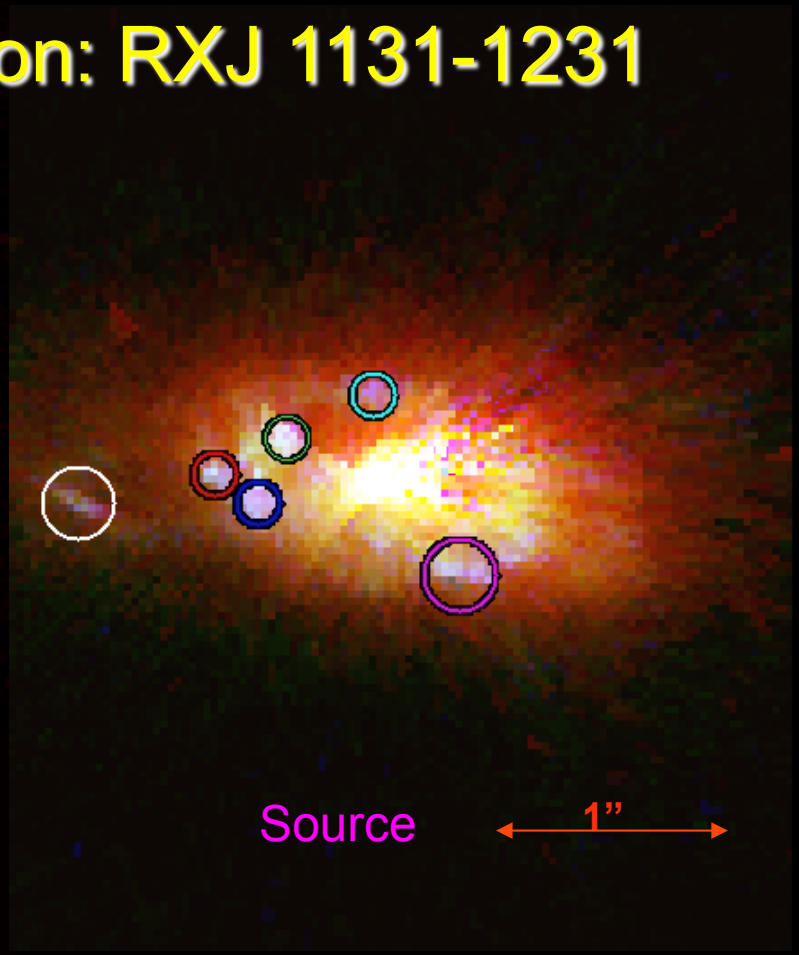


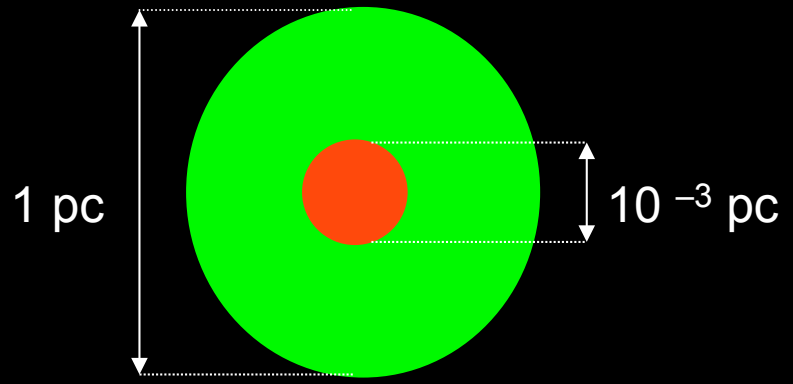
Image 1”

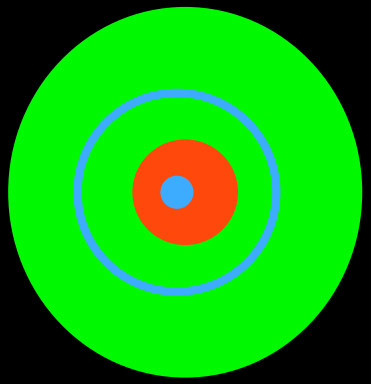


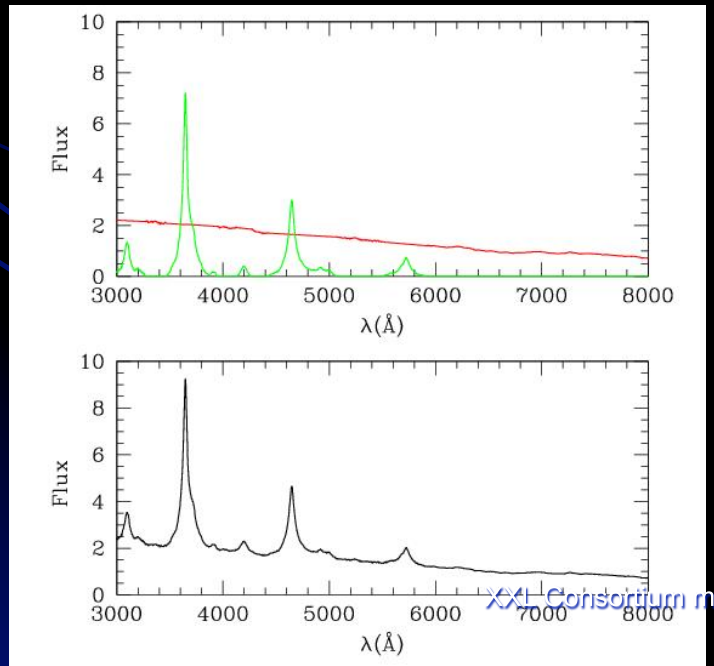
Source 1”

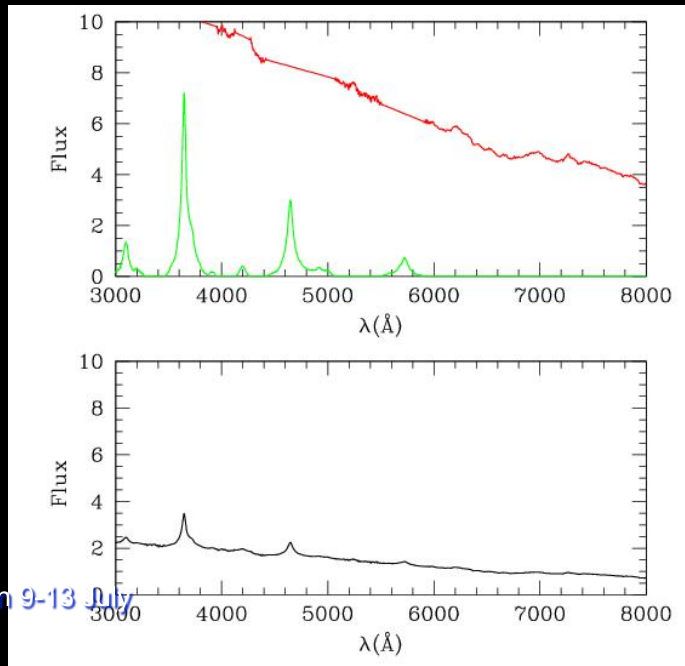
Microlensing: study of AGN structure

For $0.01M_{sol} < M_L < 10^4 M_{sol}$ scan the spatial structure of AGN:









2. Incidence of GL in the XXL field

- The angular Einstein ring of a point mass lens (PML) is:

$$\theta_E = \sqrt{4GMD_{DS} / (c^2 D_{OD} D_{OS})}$$

- The angular separation between the lensed images is (z_l=0.5; z_s=2):

$$\Delta\theta \approx 2\theta_E \approx 4.10^{-6} \sqrt{M / M_{sol}} \quad arc\,\mathrm{sec}$$

- The typical time for crossing the Einstein ring is (v=1000 km/s):

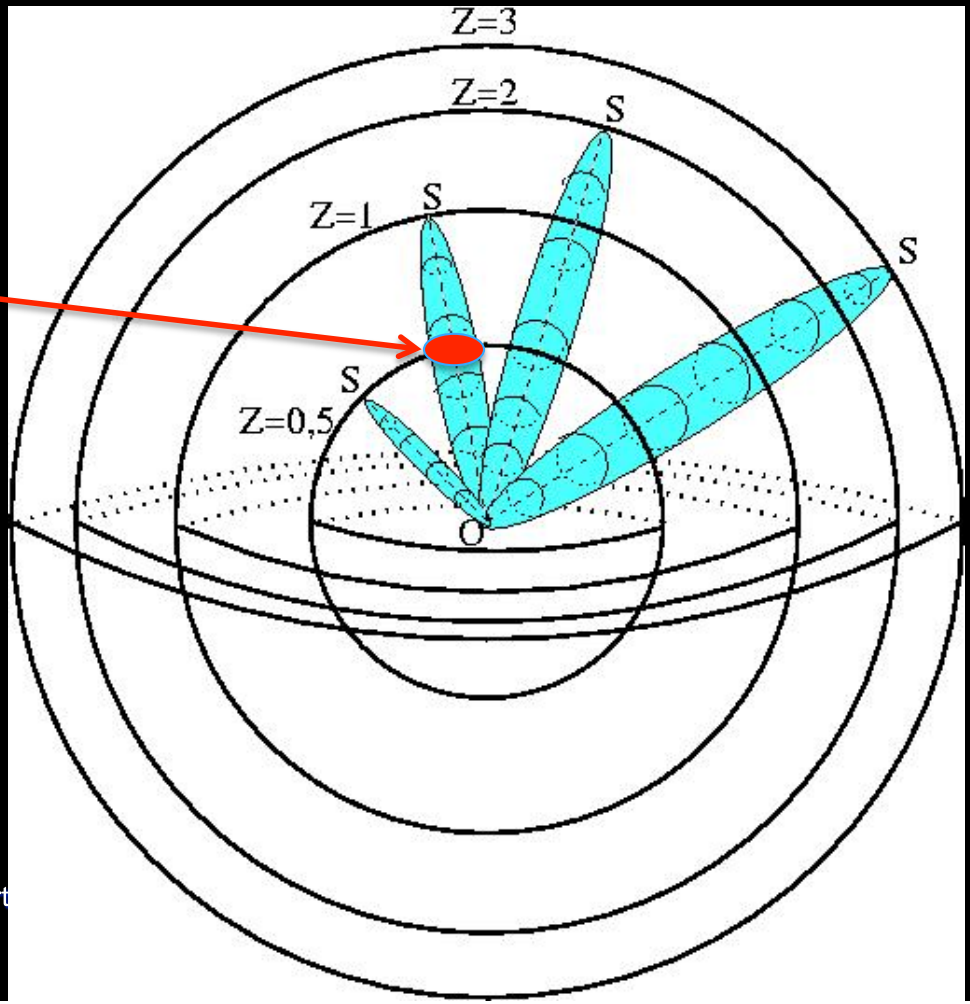
$$t_E \approx 20\sqrt{M / M_{sol}} \quad years$$

2. Incidence of GL in the XXL field

In order to produce multiple image of a background source, a PML must reside within an effective volume between the source and the observer

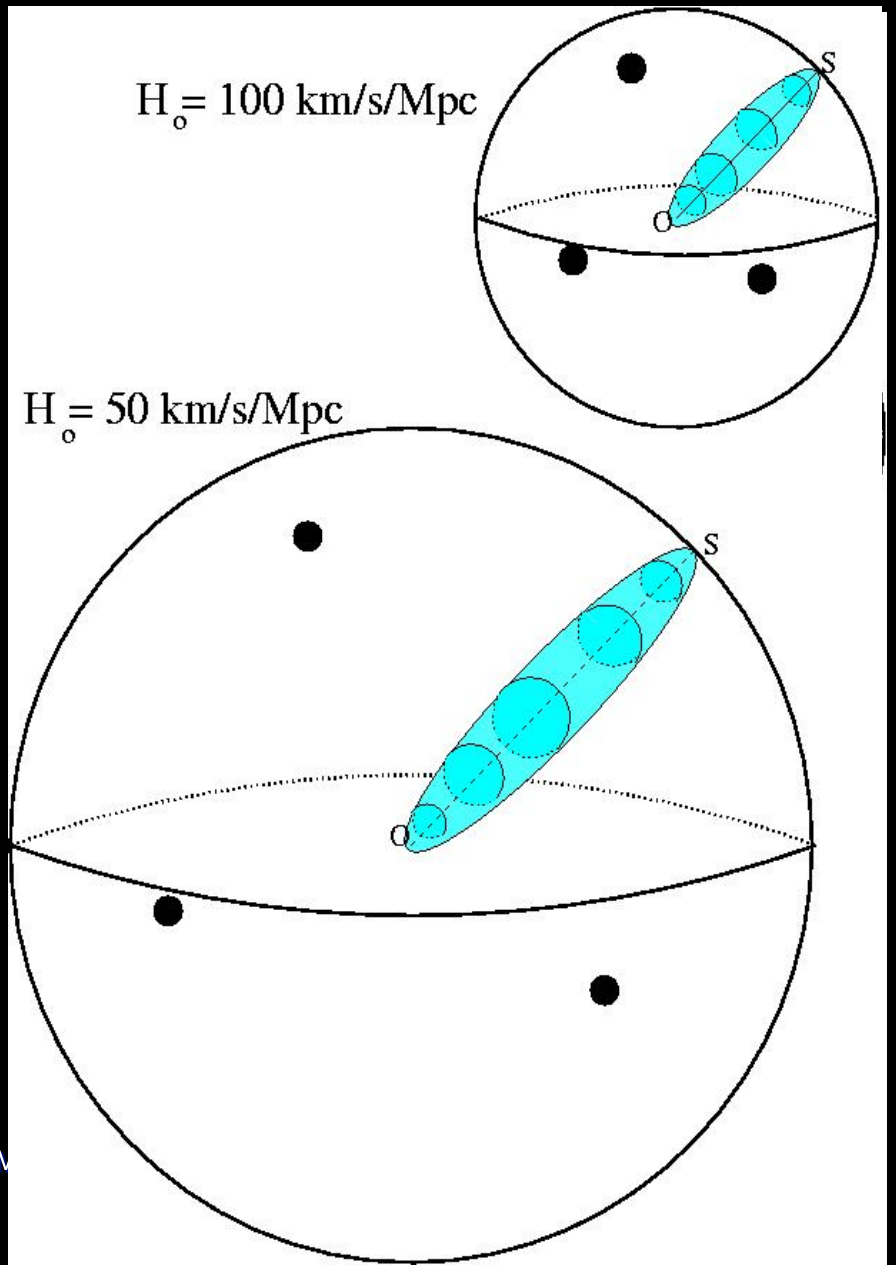
$$\Sigma_{geom} = \pi \, \theta_E^2 \, D_{OD}^2$$

$$P_{GL} \; \alpha \; V_{eff}(z,\ldots)$$

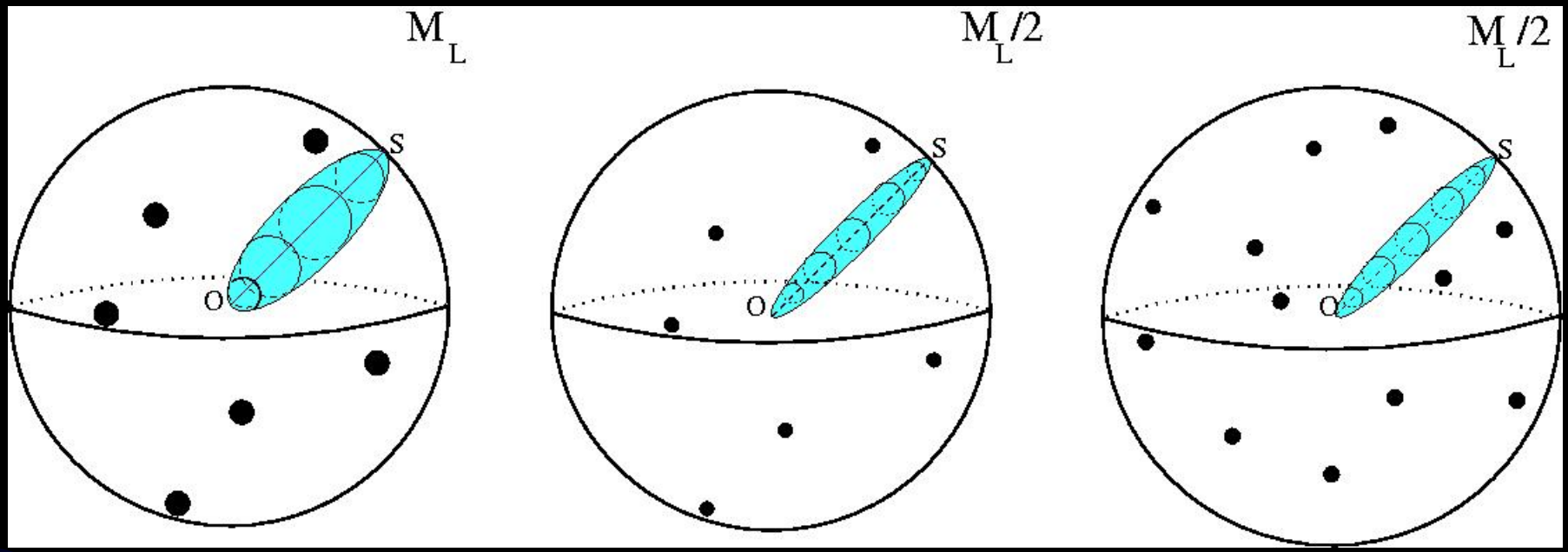


2. Incidence of GL in the XXL field

$P_{GL} \propto V_{eff}(z, \Omega_o, \lambda_o, \ldots)$



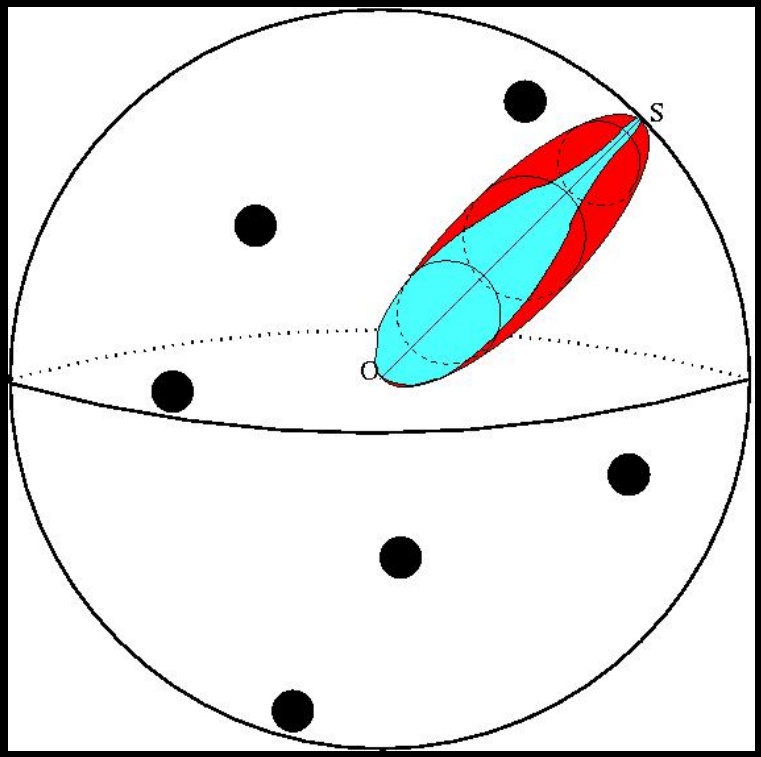
2. Incidence of GL in the XXL field



$P_{GL} \alpha n_L V_{eff}(z, \Omega_o, \lambda_o, M_L, ...)$

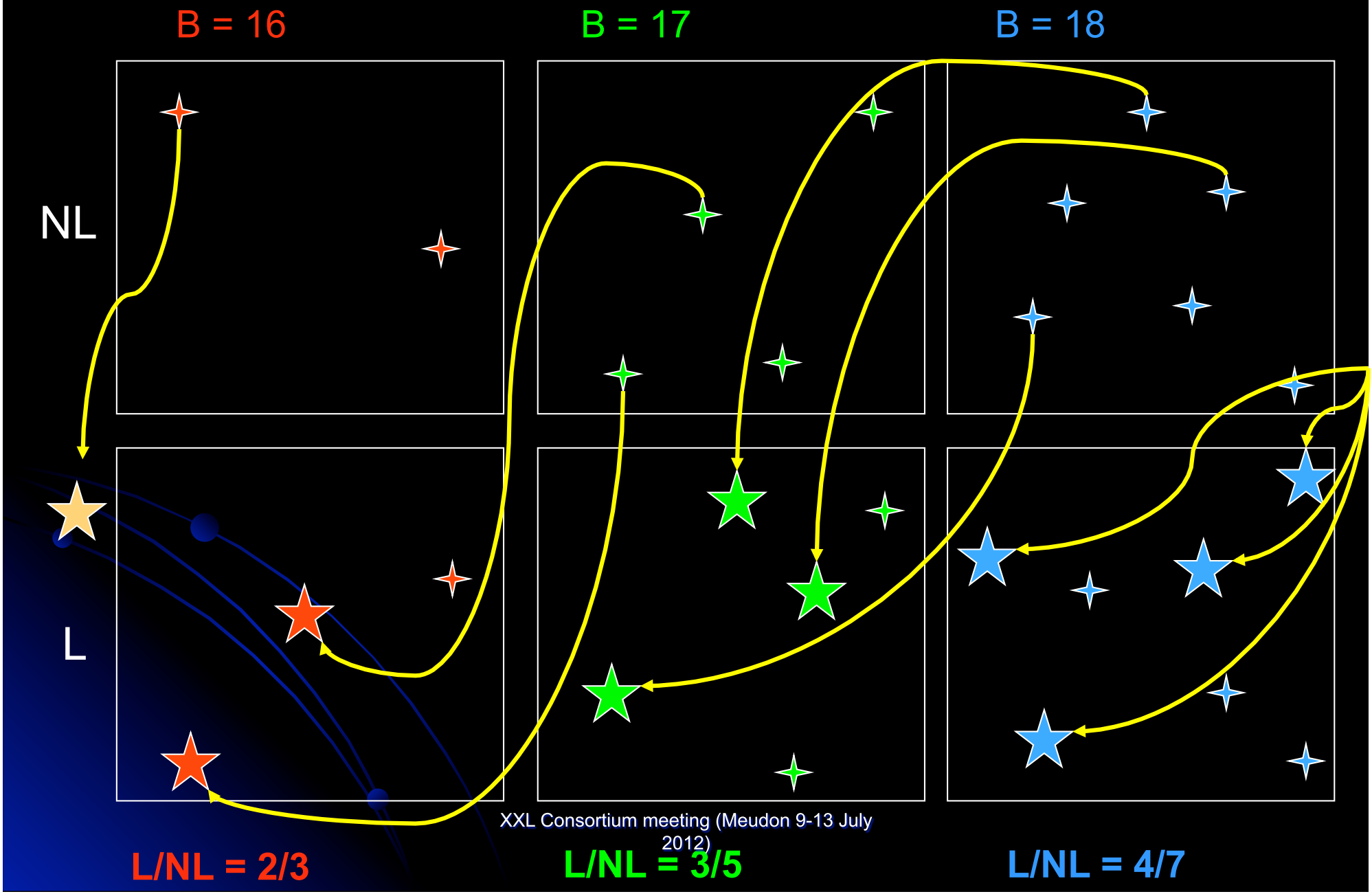
and: $n_L \alpha \Omega_L/M_L$ ➡ $P_{GL} \alpha \Omega_L/M_L V_{eff}(z, \Omega_o, \lambda_o, M_L, ...)$

2. Incidence of GL in the XXL field

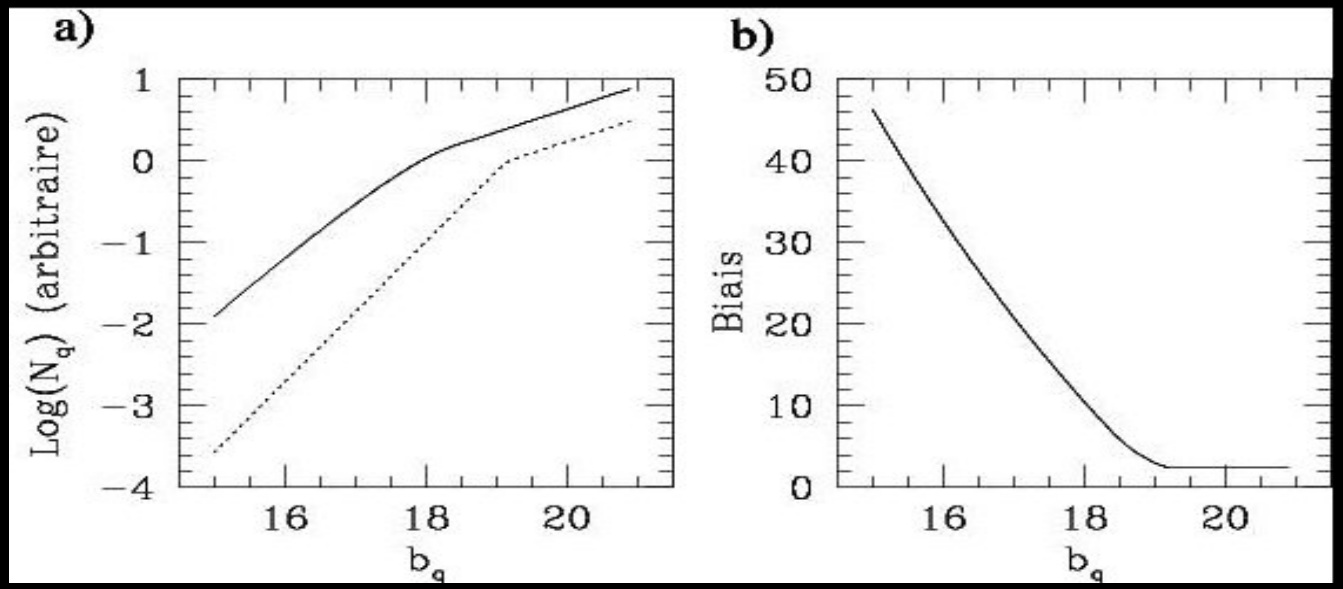


$$P_{GL} \ \alpha \ \Omega_L / M_L V_{eff}(z, \Omega_o, \lambda_o, M_L, \mathrm{ASF})$$

2. Incidence of GL in the XXL field: M-B



2. Incidence of GL in the XXL field: M-B



$P_{GL} \alpha \Omega_L / M_L V_{eff}(z, \Omega_o, \lambda_o, M_L, ASF)\ Bias(b_q, LF)$

P_{GL} maximum (~1%) for *distant* and *bright* AGN:

➡ Observe Highly Luminous QSOs (HLQs)

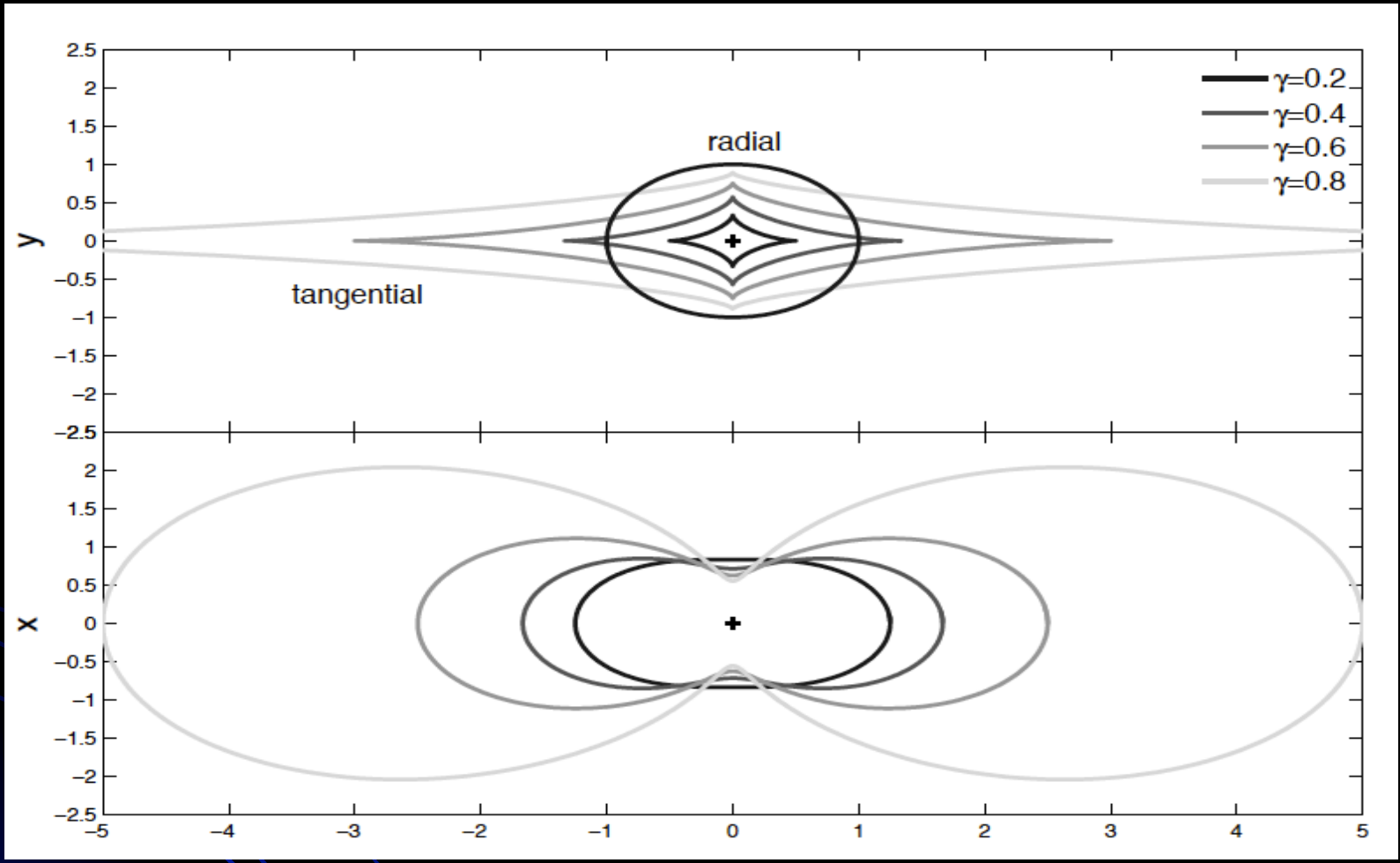
2. Incidence of GL in the XXL field

$$\alpha = \alpha_{iso} + \alpha_{aniso}$$

$$\alpha_{iso} = -x^{\epsilon-2}\mathbf{x}$$

$$\alpha_{aniso} = \gamma \begin{pmatrix} \cos 2\omega & \sin 2\omega \\ \sin 2\omega & -\cos 2\omega \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \end{pmatrix}$$

2. Incidence of GL in the XXL field



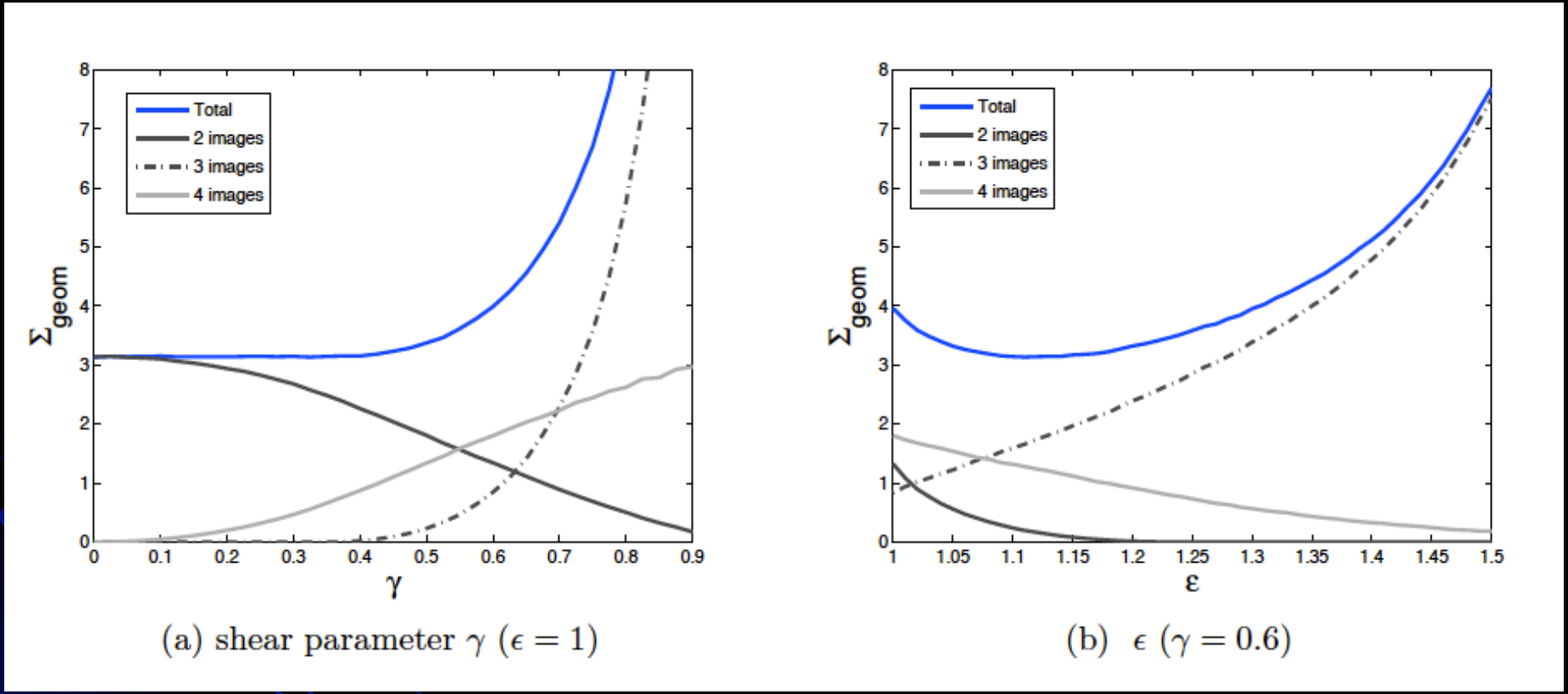
Caustics and critical curves for the SIS case with γ = 0.2, 0.4, 0.6, 0.8. The radial critical curve is degenerated to the origin point in the deflector plane and the radial caustic is independent of the shear value

2. Incidence of GL in the XXL field

$$\Sigma_{geom} = b_0^2(z) \int_{S_y} d\mathbf{y}$$

$$\begin{aligned}
\Sigma_{eff} &= b_0^2(z) \int_{S_y} \frac{N_q(b_q + 2.5 \log A_{tot})}{N_q(b_q)} d\mathbf{y} \\
&= b_0^2(z) \int_{S_x} \frac{N_q(b_q + 2.5 \log A_{tot})}{N_q(b_q)} \frac{d\mathbf{x}}{A(\mathbf{x})}
\end{aligned}$$

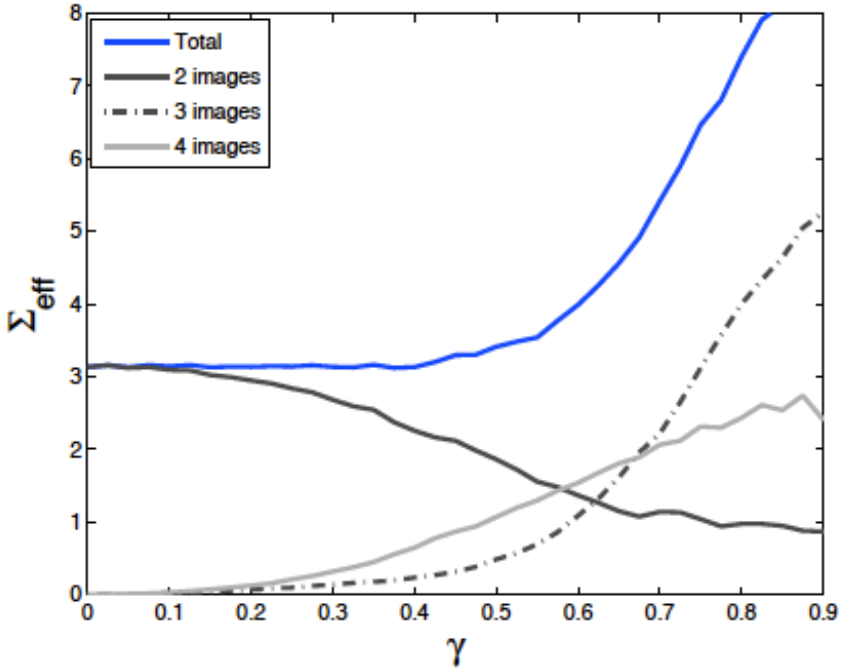
2. Incidence of GL in the XXL field

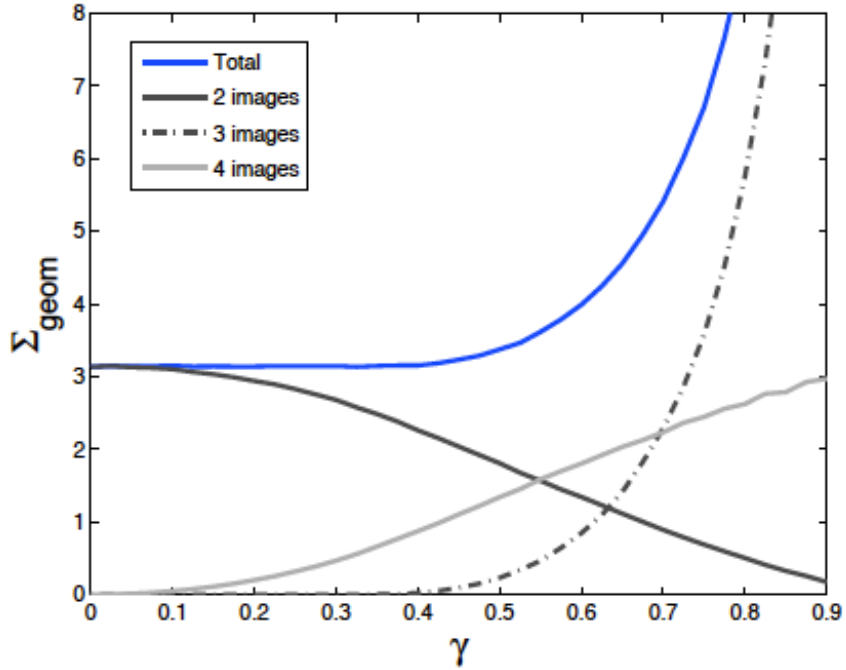


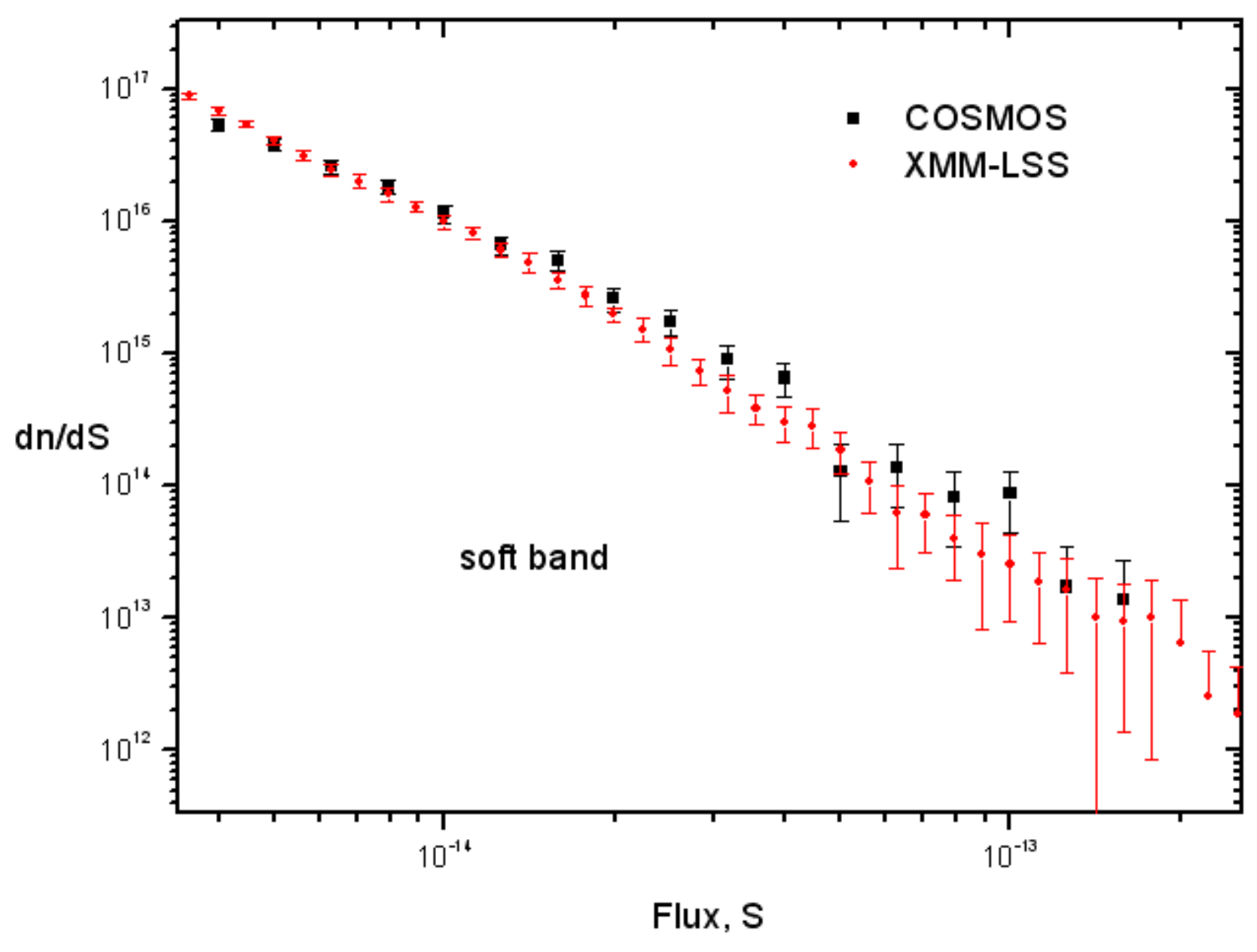
(a) shear parameter γ ($\epsilon = 1$)

(b) ϵ ($\gamma = 0.6$)

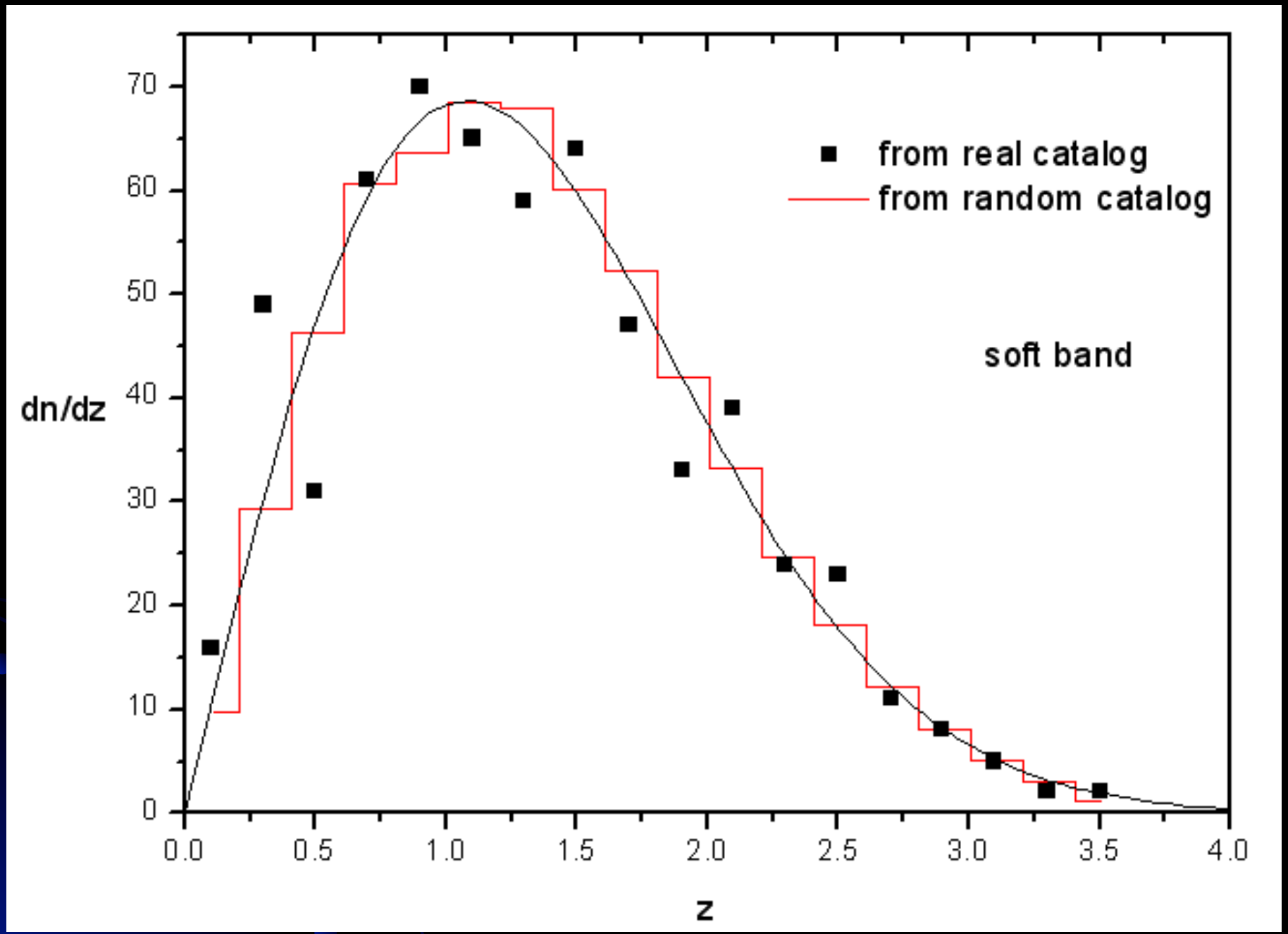
2. Incidence of GL in the XXL field

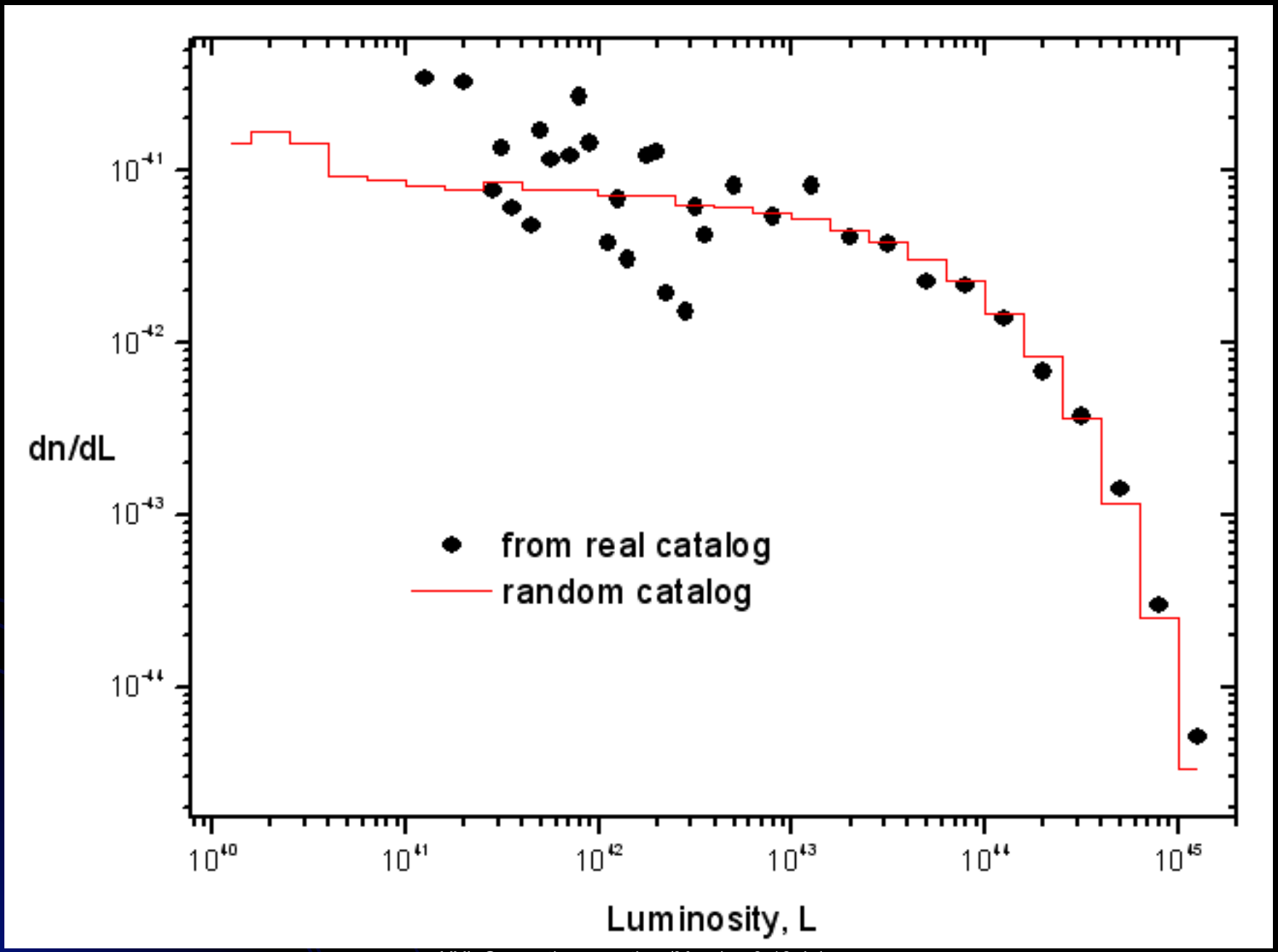




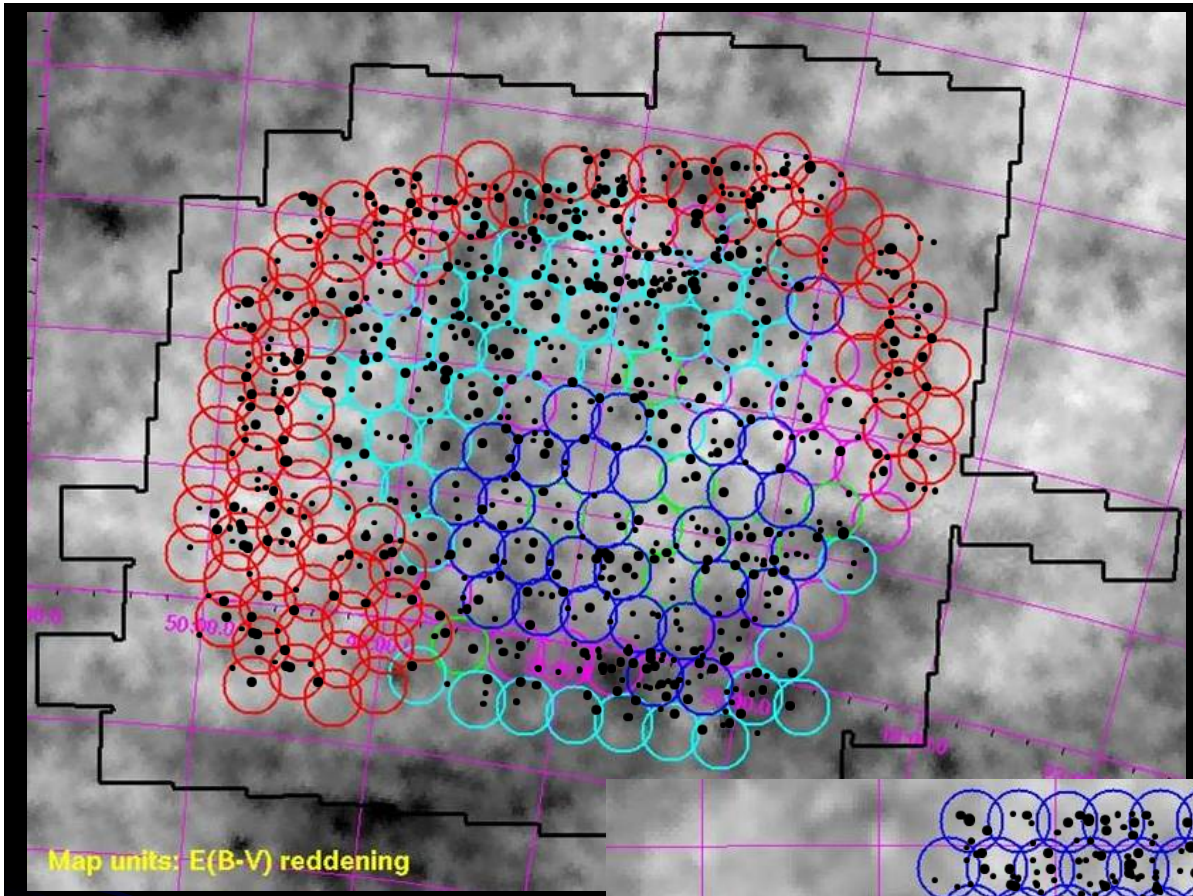


Differential source counts from the COSMOS and XMM-LSS fields in the soft band


from real catalog
from random catalog
soft band
dn/dz
z
0
10
20
30
40
50
60
70
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0

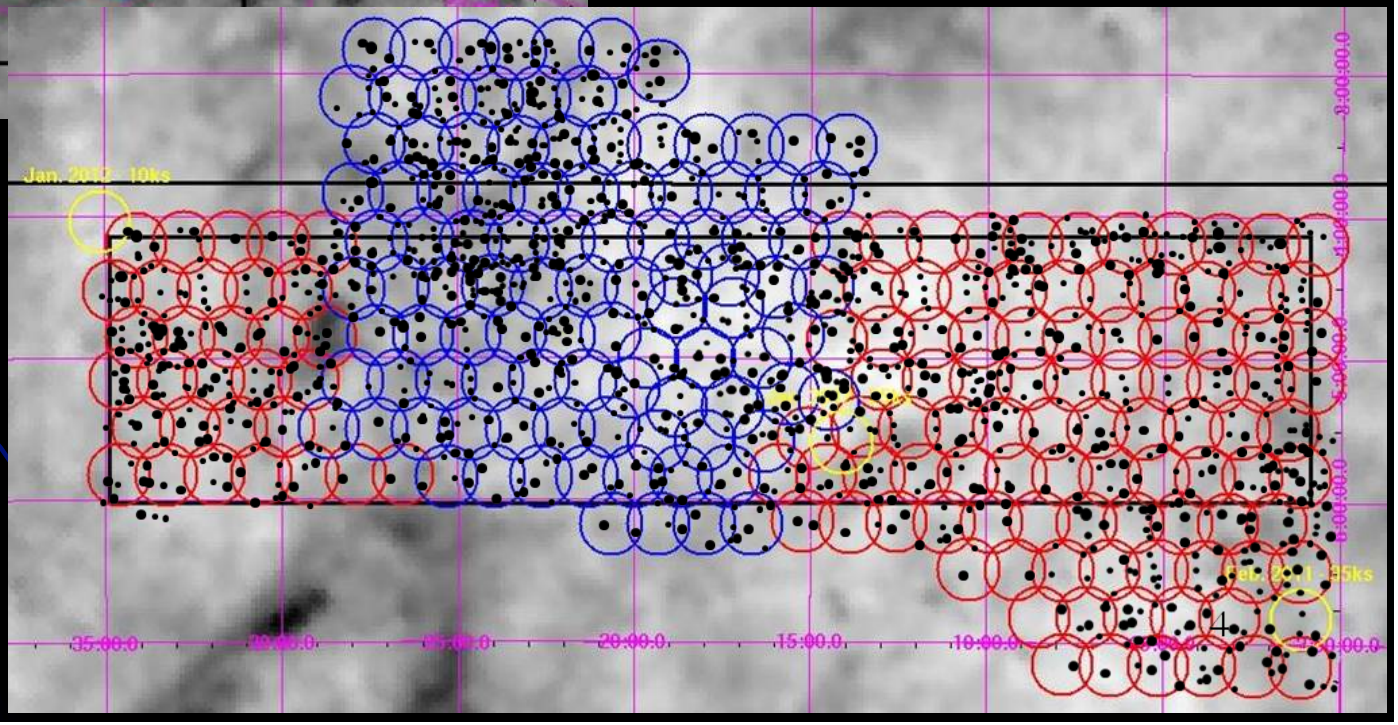


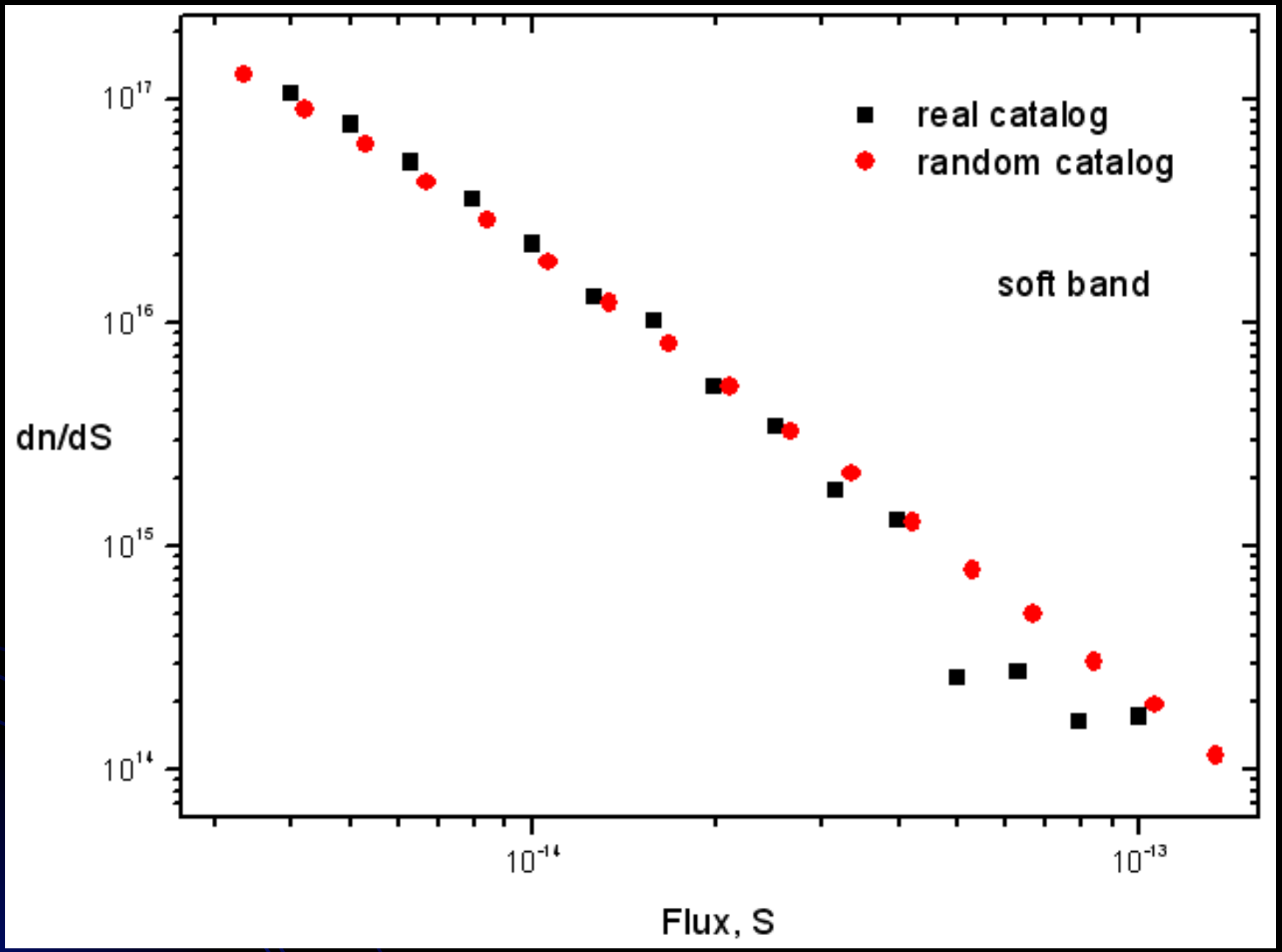
Luminosity function in the soft band



- S > 3 10^{-15} erg cm^{-2} s^{-1} (soft band, 10 Ksec.)
- 606 sources over 2 deg^2 (COSMOS)

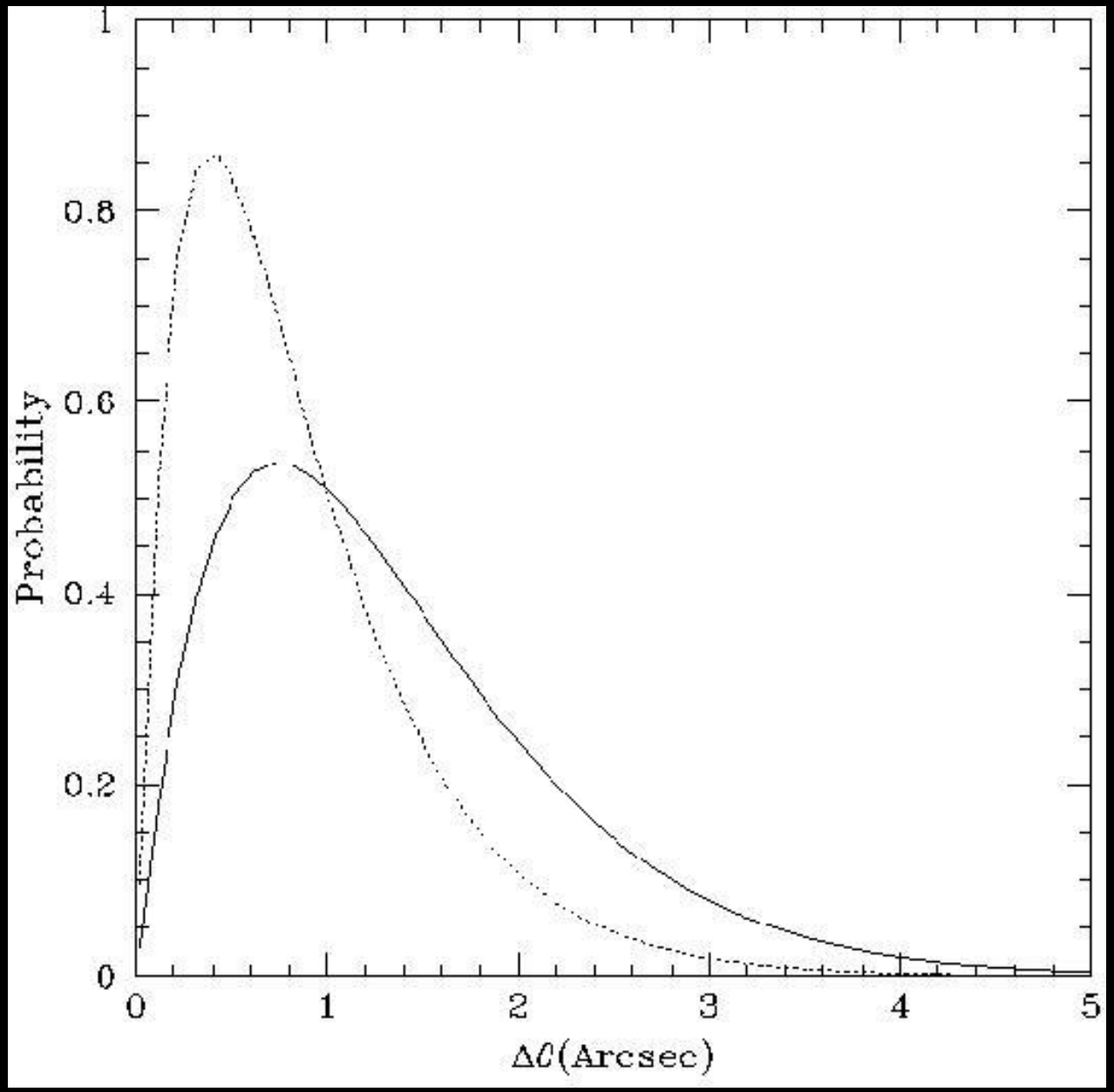
- H_0=72, Ω_m=0.27, Ω_λ=0.73
- 50 deg^2
- 15 000 X-ray sources

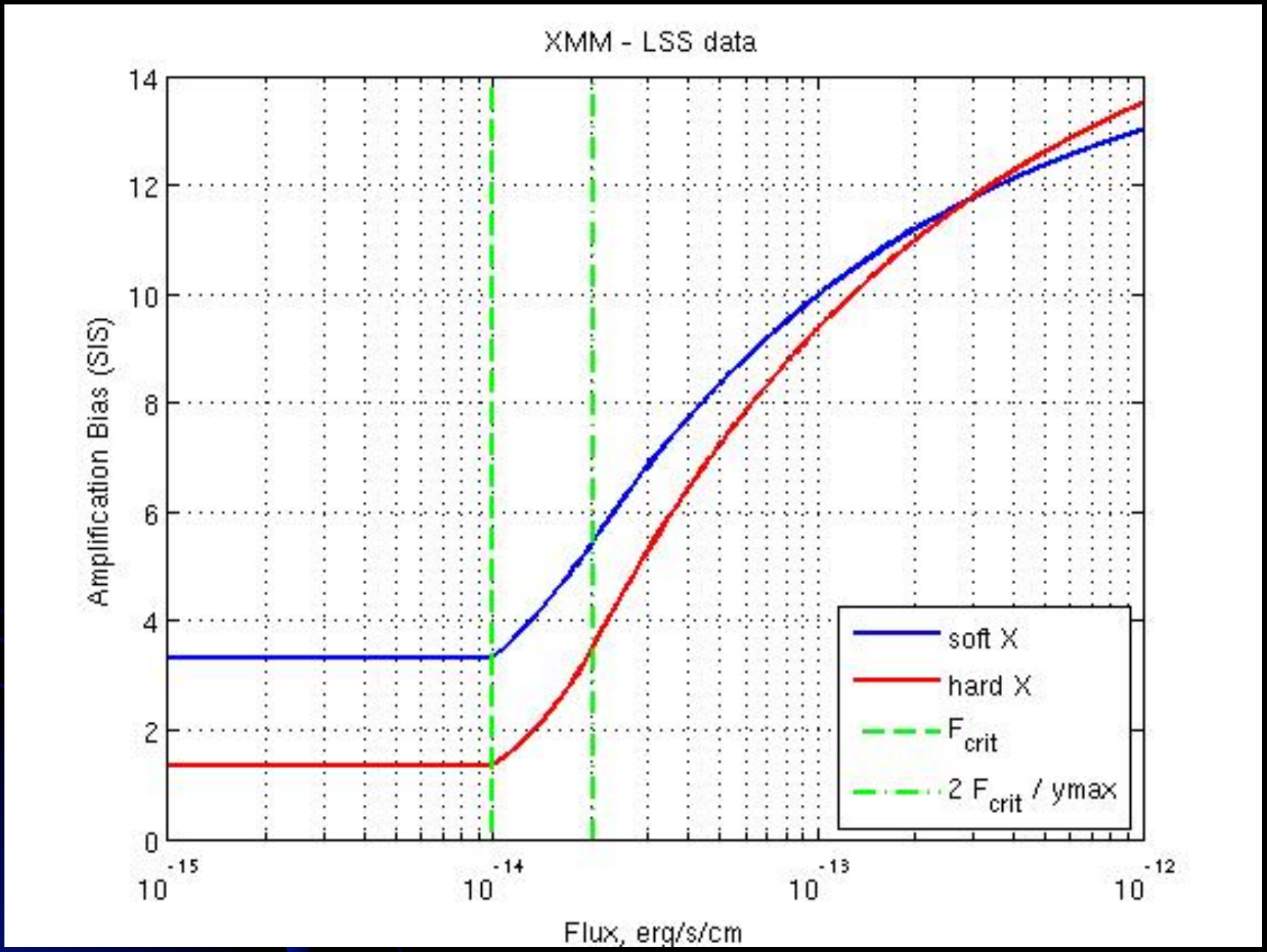


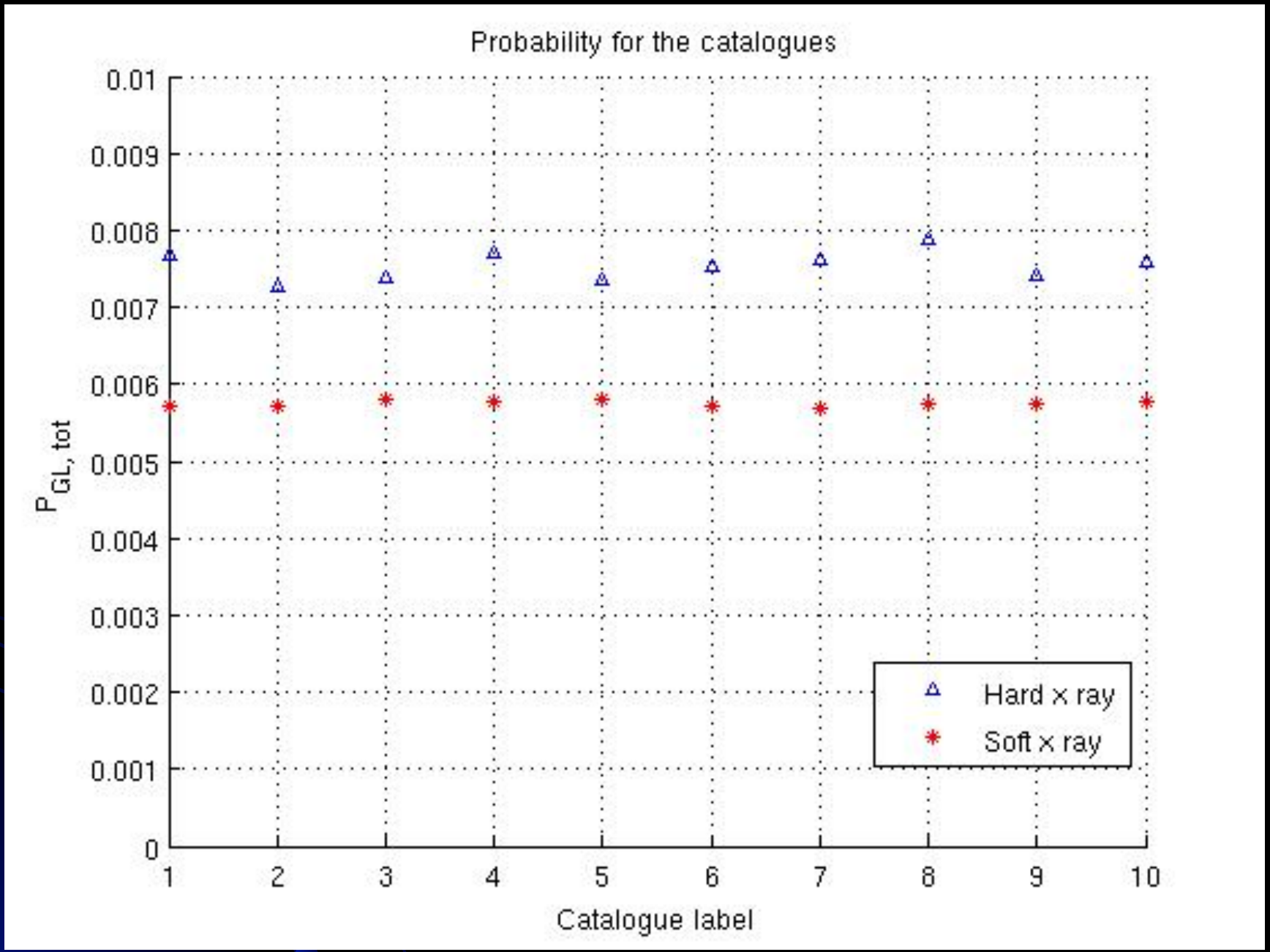


Comparison between the differential source counts from the real and simulated catalogs

Probability distributions P(Δθ) for the angular separations Δθ expected between the multiple images of an AGN at z = 2, lensed by a cosmological population of SIS galaxies (dots = spiral ones, continuous line = elliptical + S0 ones)




XMM - LSS data
Amplification Bias (SIS)
Flux, erg/s/cm
soft X
hard X
F crit
2 F crit / ymax
0
2
4
6
8
10
12
14
10 -15
10 -14
10 -13
10 -12


Probability for the catalogues
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
P GL, tot
1
2
3
4
5
6
7
8
9
10
Catalogue label
Hard x ray
Soft x ray

2. Incidence of GL in the XXL field

PGLens = 0.0058 x 0.7 x 0.7 = 0.0028 (soft)
PGLens = 0.0075 x 0.7 x 0.7 = 0.0037 (hard)

Expected number of multiply imaged AGN in XXL:

NGLens = 15 000 x 0.0028 = 43 (soft)
NGLens = 2600 x 0.0037 = 10 (hard)

Gravitational lensing statistics of multiply imaged X-ray selected AGN may help in constraining the cosmological parameters Ω_λ, Ω_m . Furthermore, micro-lensing effects provide a unique tool to study the AGN source structure at micro-arcsec in the X-rays and other wavelengths.
These systems could also turn out to be useful for an independent determination of H_0 ... and to retrieve the real shape of the lensed AGN based upon GL inversion.

SIS + γ