Things to do with 1000 lensed quasars:

Anomalous flux ratios

(Microlensing with Euclid)

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faculty of science and engineering
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My main goal in Groningen:

build an automated lens modelling code,
to be applied in *“mass production mode”*, i.e. Euclid lenses

- state of the art features, e.g.:
  adaptive source grid,
  various source regularization schemes,
  multiwavelength data,
  etc…

- Minimum human interaction:
  guessing initial parameters,
  fine tuning,
  etc…

- Able to work both with data and simulations:
  see talks by Dorota and Sampath

- Public, complemented by series of tools
  and database of mock observations

v0.99 ready, stay tuned for Aosta V !

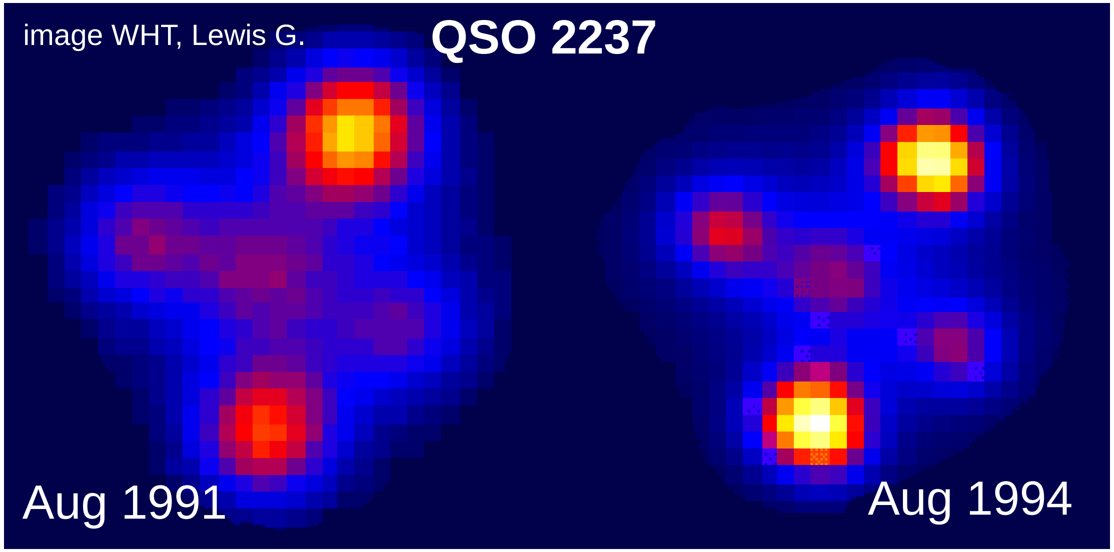


image WHT, Lewis G.
QSO 2237
Aug 1991
Aug 1994

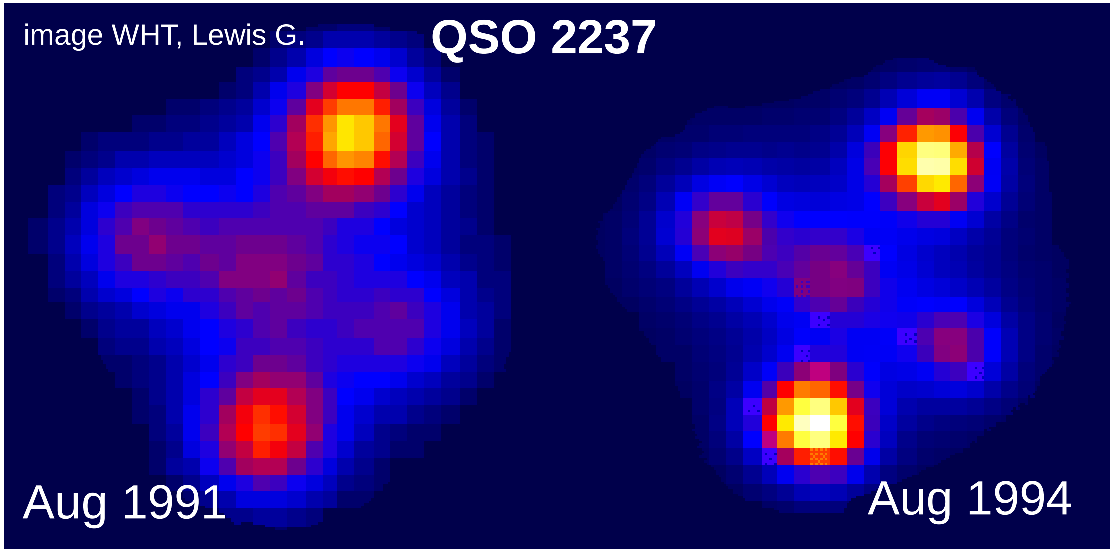
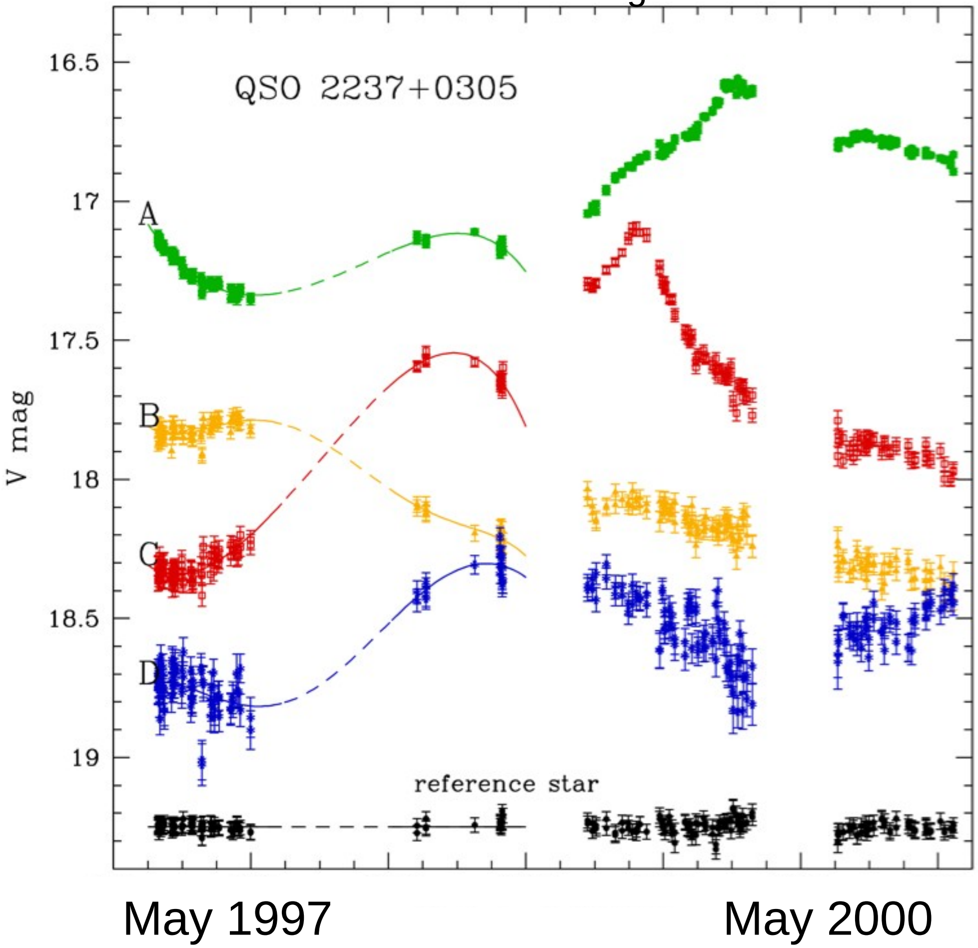
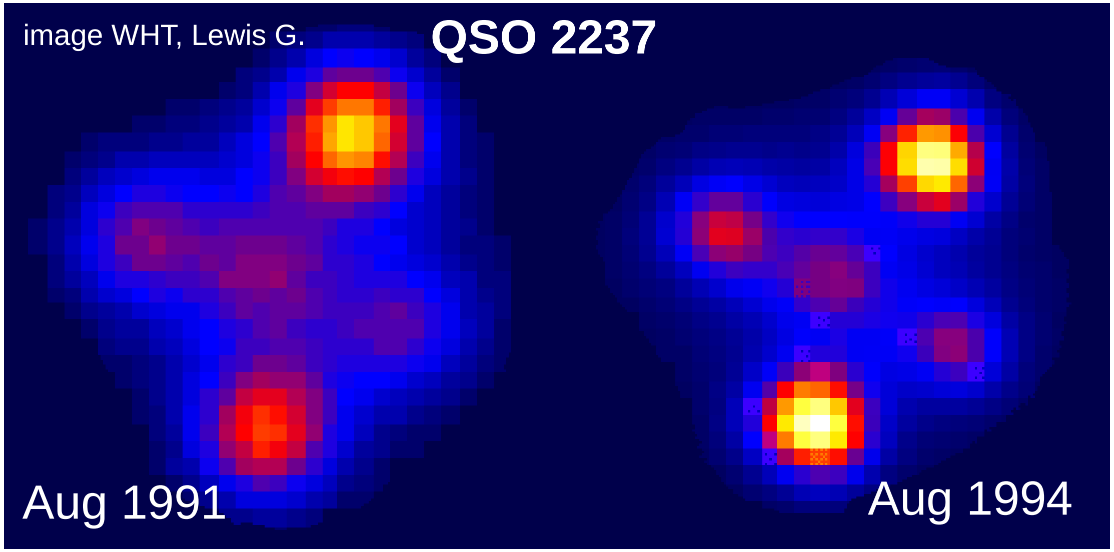


Figure: OGLE database





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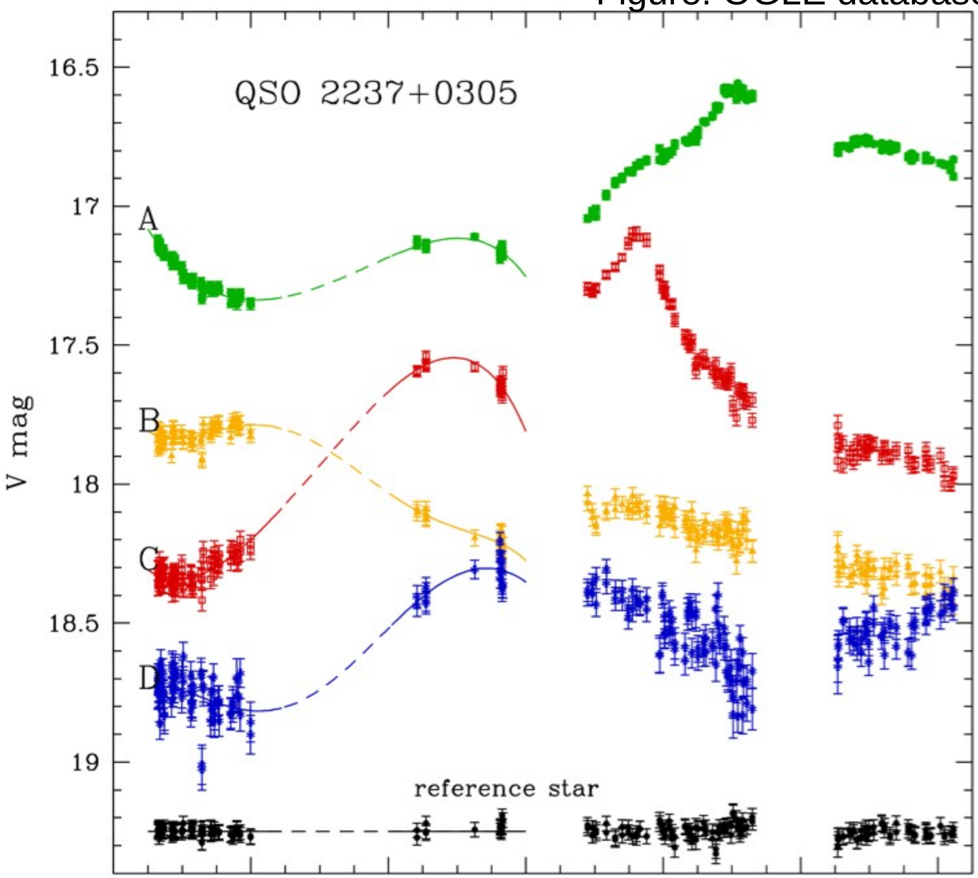
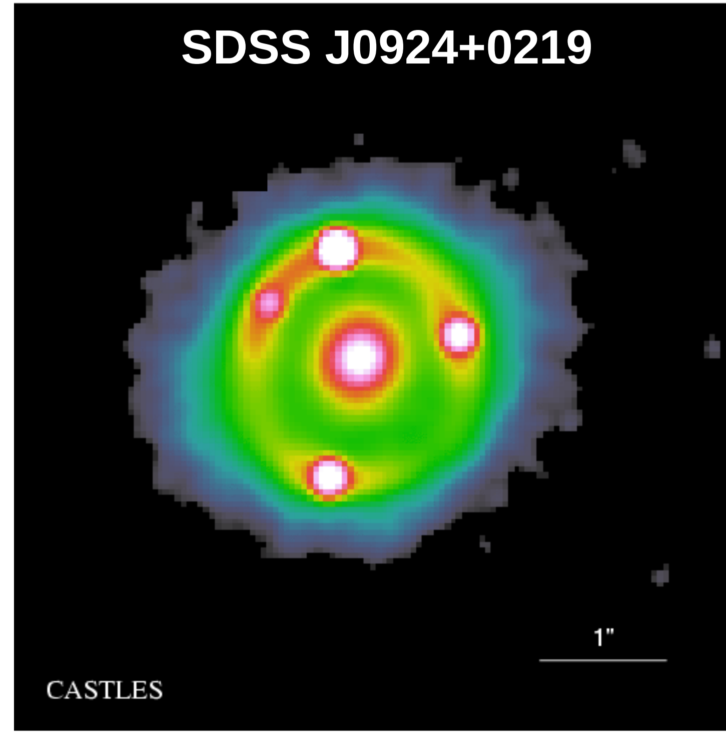
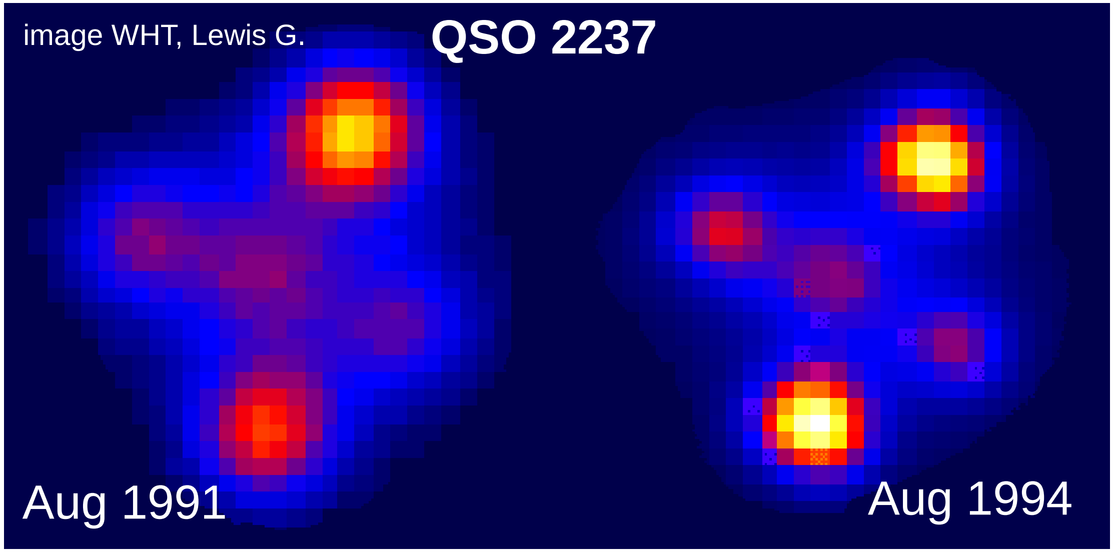
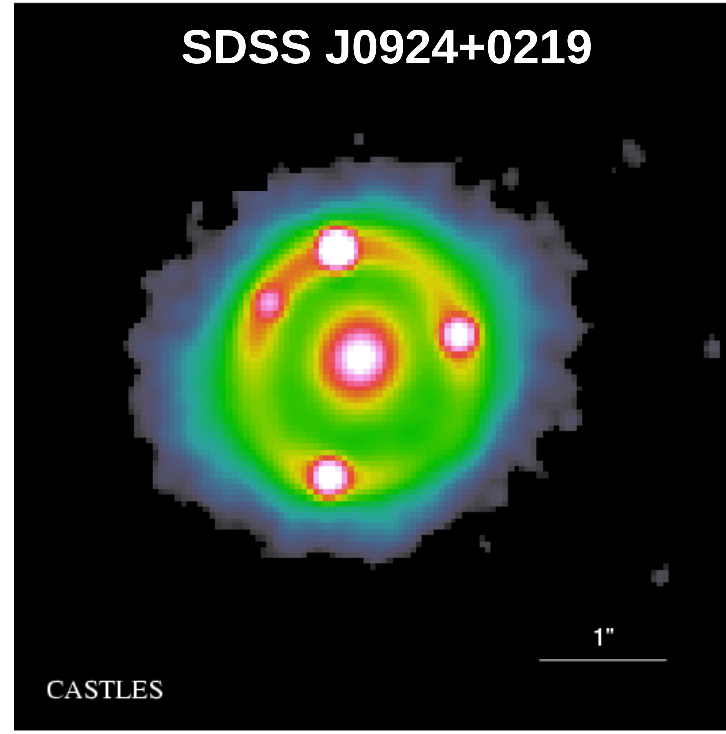


May 1997 May 2000







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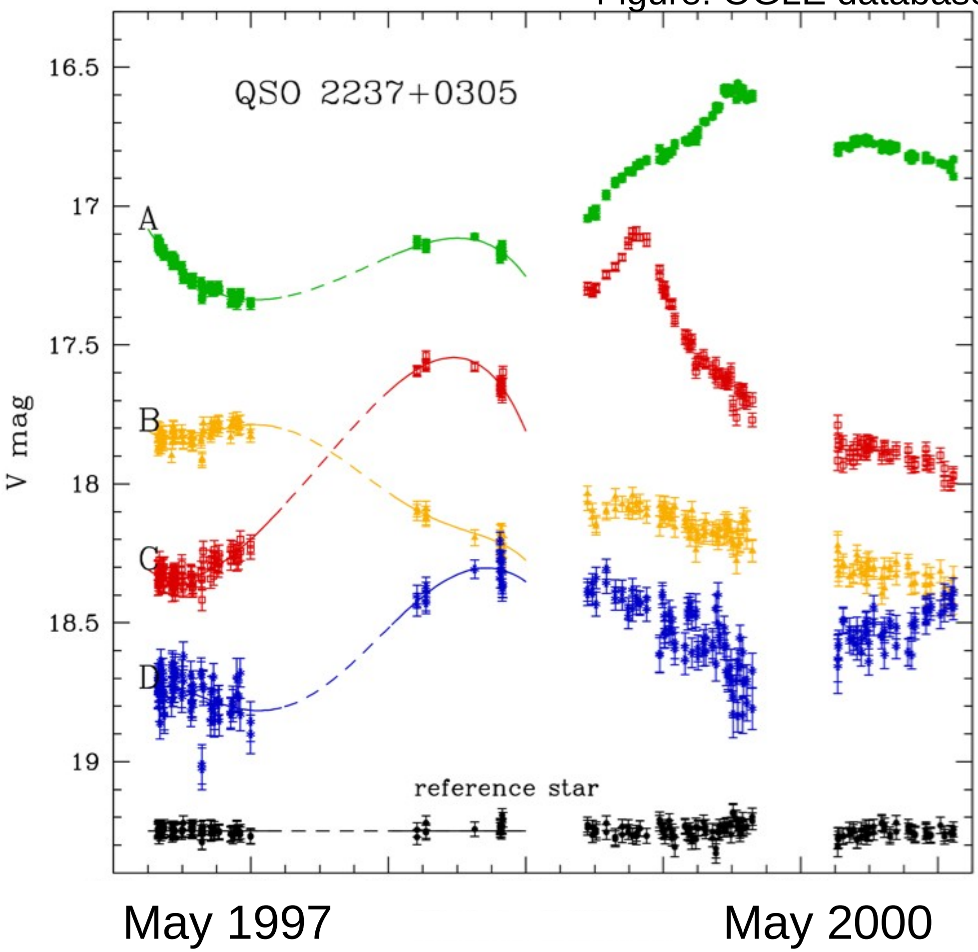
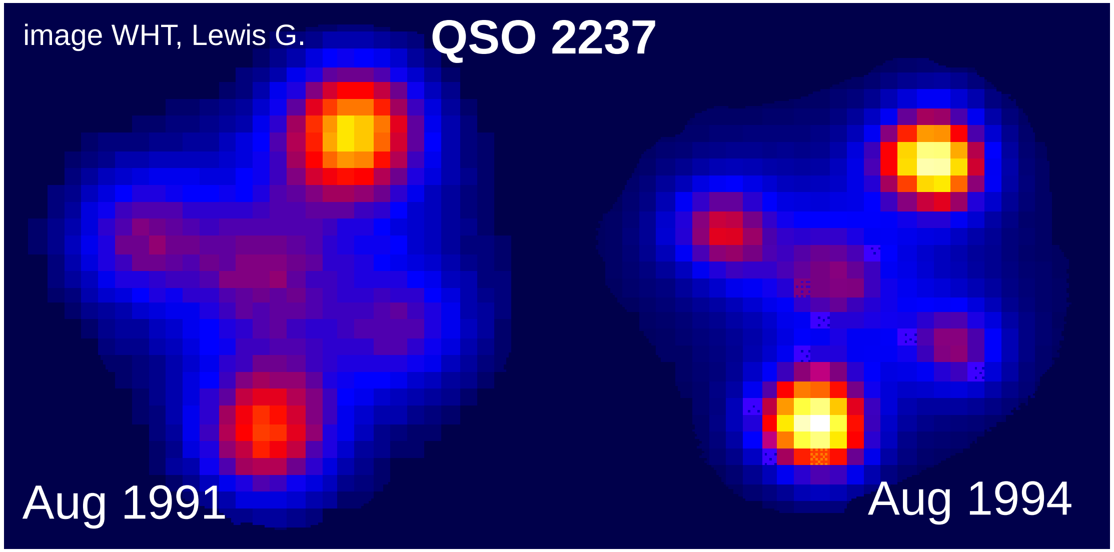
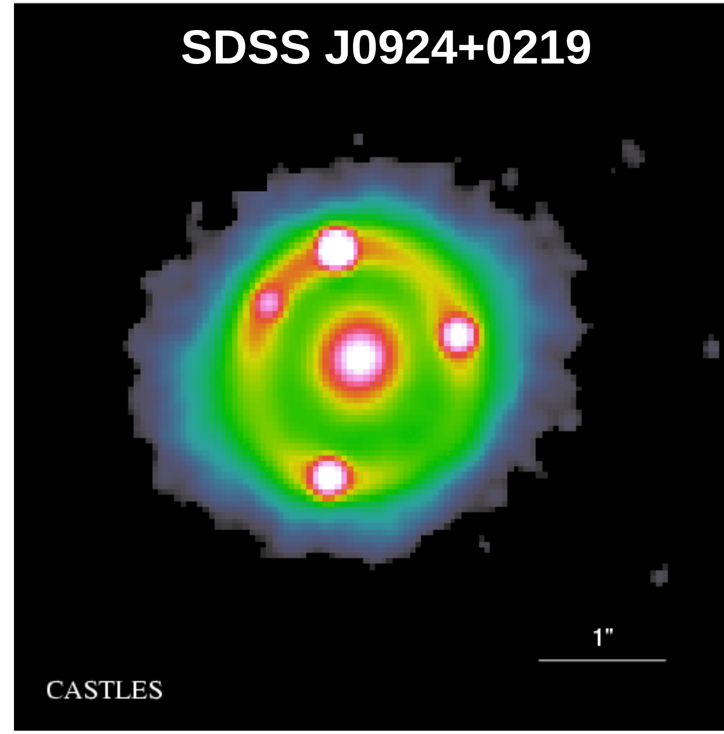


- ▶ *uncorrelated variability due to the lens*
- ▶ *models predict constant magnification*
- ▶ *we assumed smooth matter only...*





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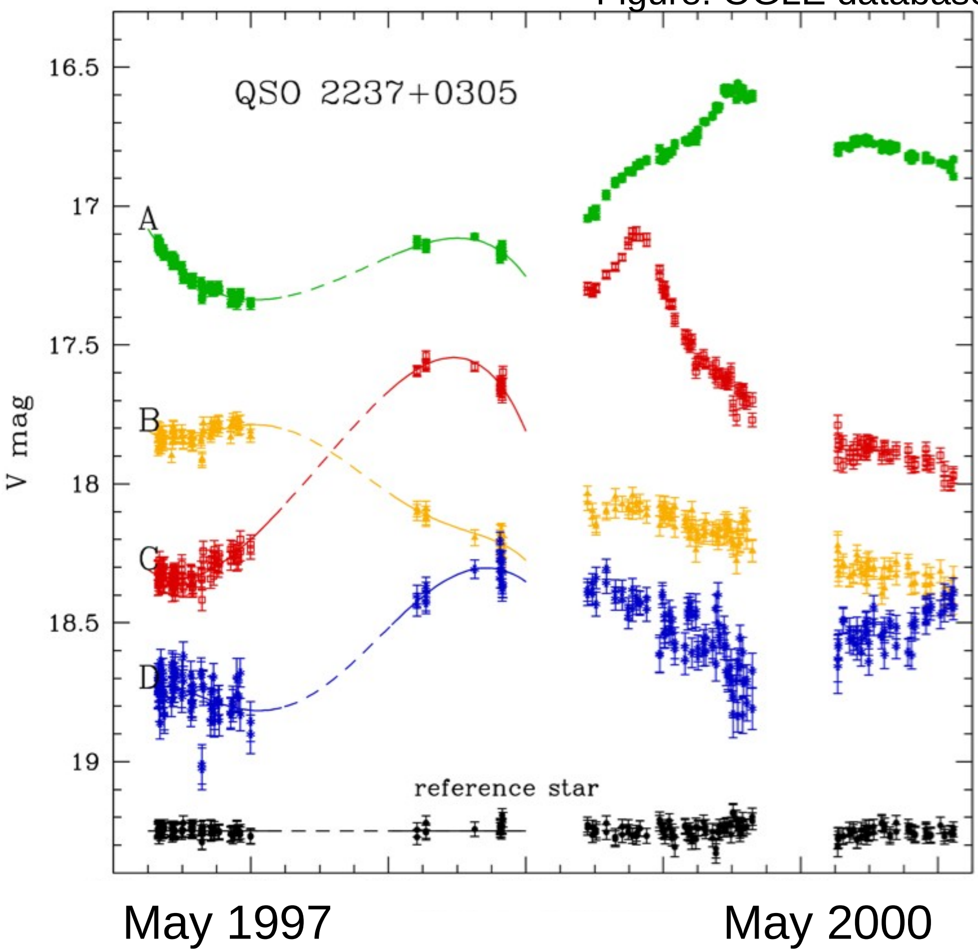


- *uncorrelated variability due to the lens*
- *models predict constant magnification*
- *we assumed smooth matter only...*

compact objects near the line of sight

+

relative motion

+

accretion disc size

=

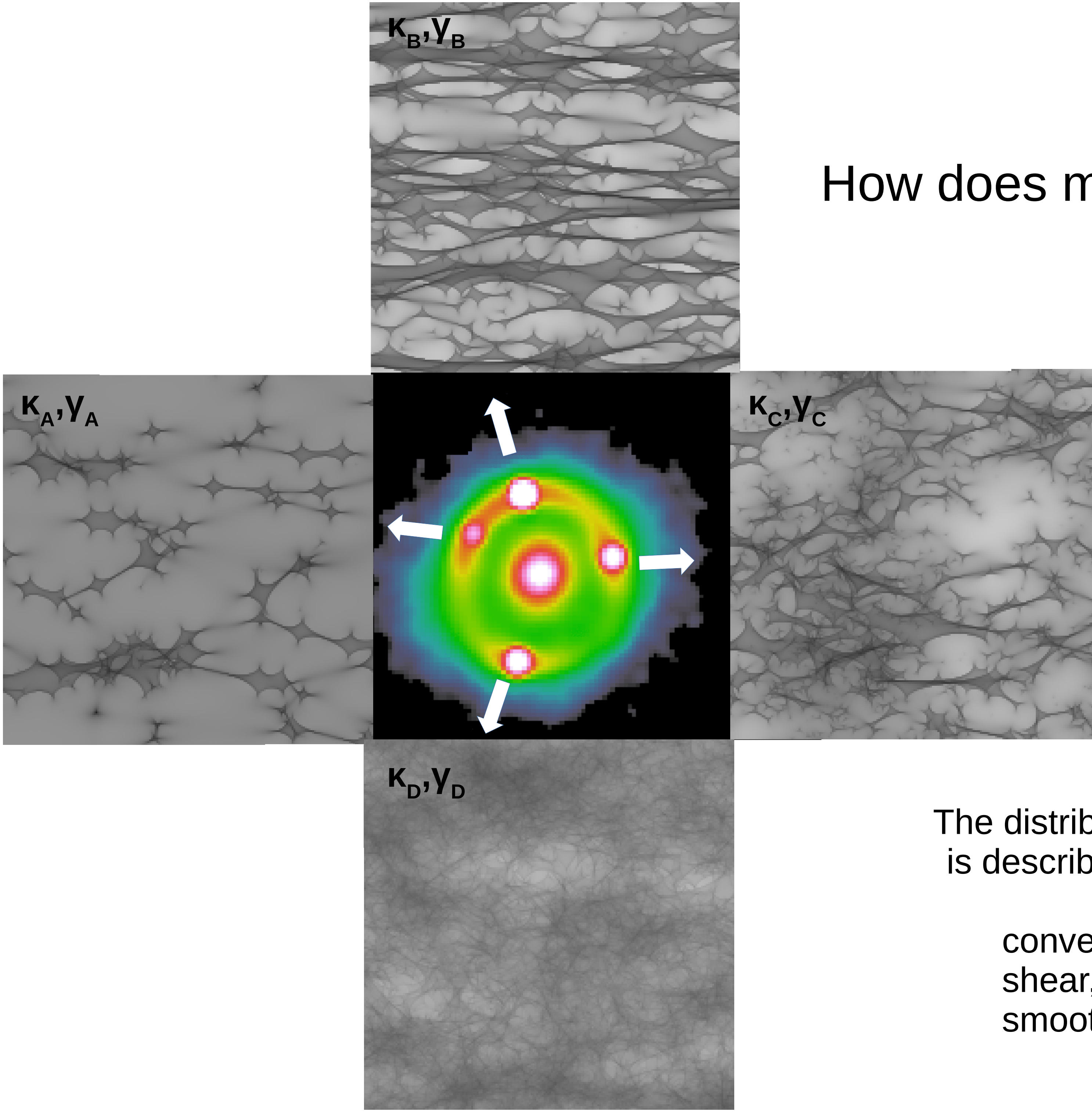
Quasar microlensing

How does microlensing work?

The distribution of the microlenses
is described by three parameters:

convergence, **κ**
shear, **γ**,
smooth matter fraction, **s**

How does microlensing work?



The distribution of the microlenses is described by three parameters:

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- Microlensing and substructure can both produce similar flux ratios between multiple images
- Microlensing depends on the ratio between stellar and dark matter (s)

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Microlensing flux ratios
between the closest pair of images

Can we probe the stellar vs dark matter ratio?

Can we find "global" microlensing flux ratio properties?

Can we identify accretion disc types?

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- Microlensing depends on the ratio between stellar and dark matter (s)

Using only Euclid data !

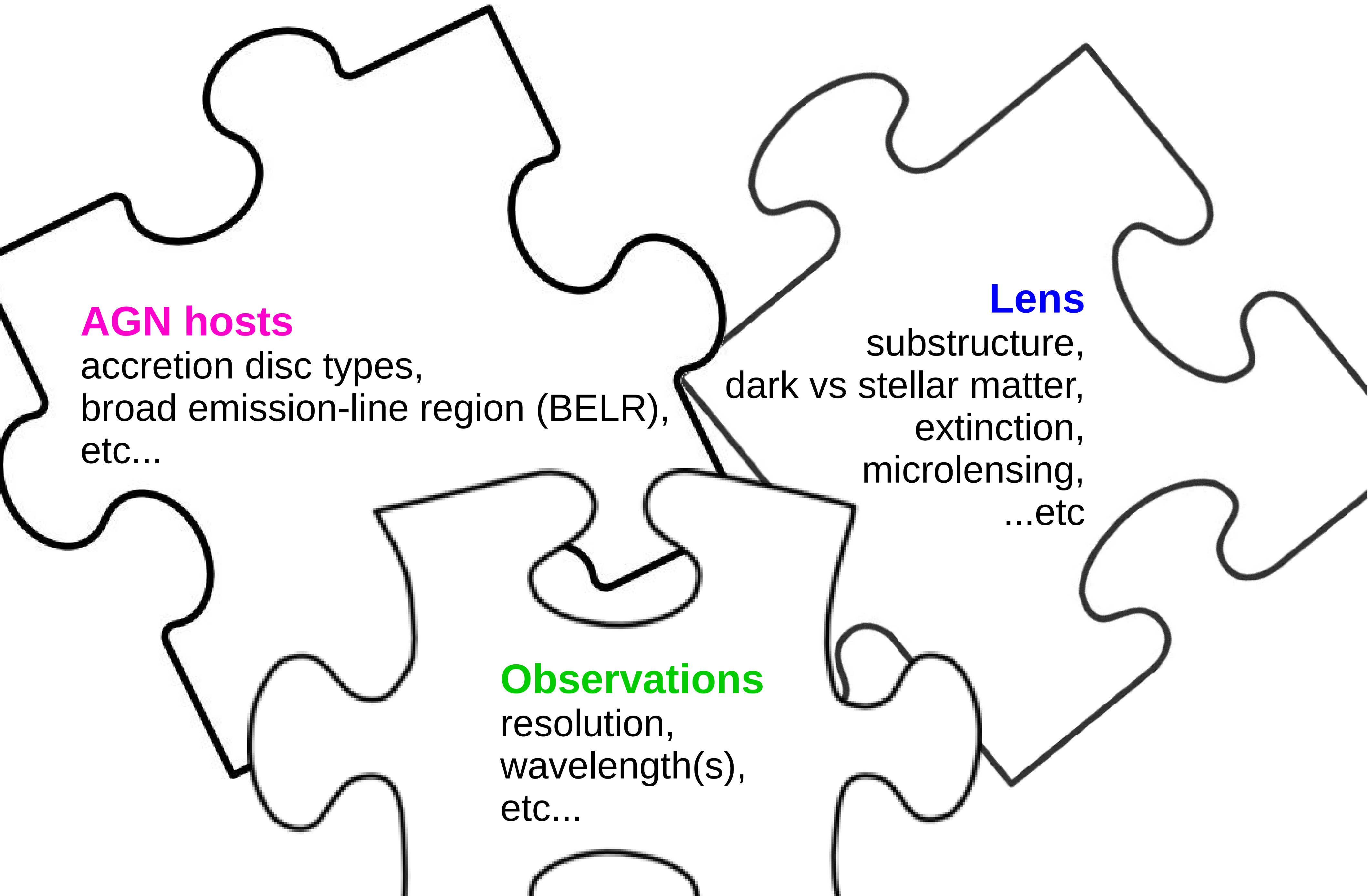
Microlensing flux ratios
between the closest pair of images

Can we probe the stellar vs dark matter ratio?

Can we find “global” microlensing flux ratio properties?

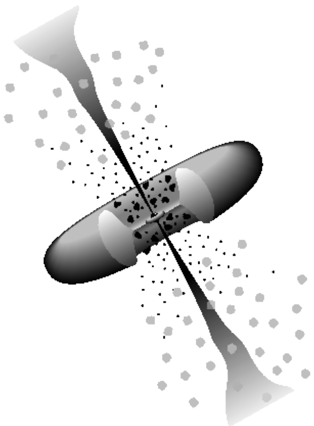
Can we identify accretion disc types?

Creating a mock population of lensed quasars



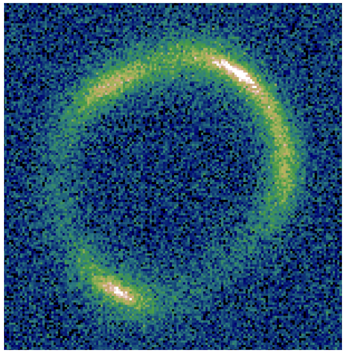
Creating a mock population of lensed quasars

Assumptions



Source:

represented by a SS disc
no complex structure (e.g. BELR)



Lens:

represented by a SIE+γ
no extinction
stellar density profile (see next)

Oguri & Marshall, 2010, public catalog

Observations:

Euclid: ~20,000^2 deg of sky,
resolution: 0.1 arcsec at 600nm

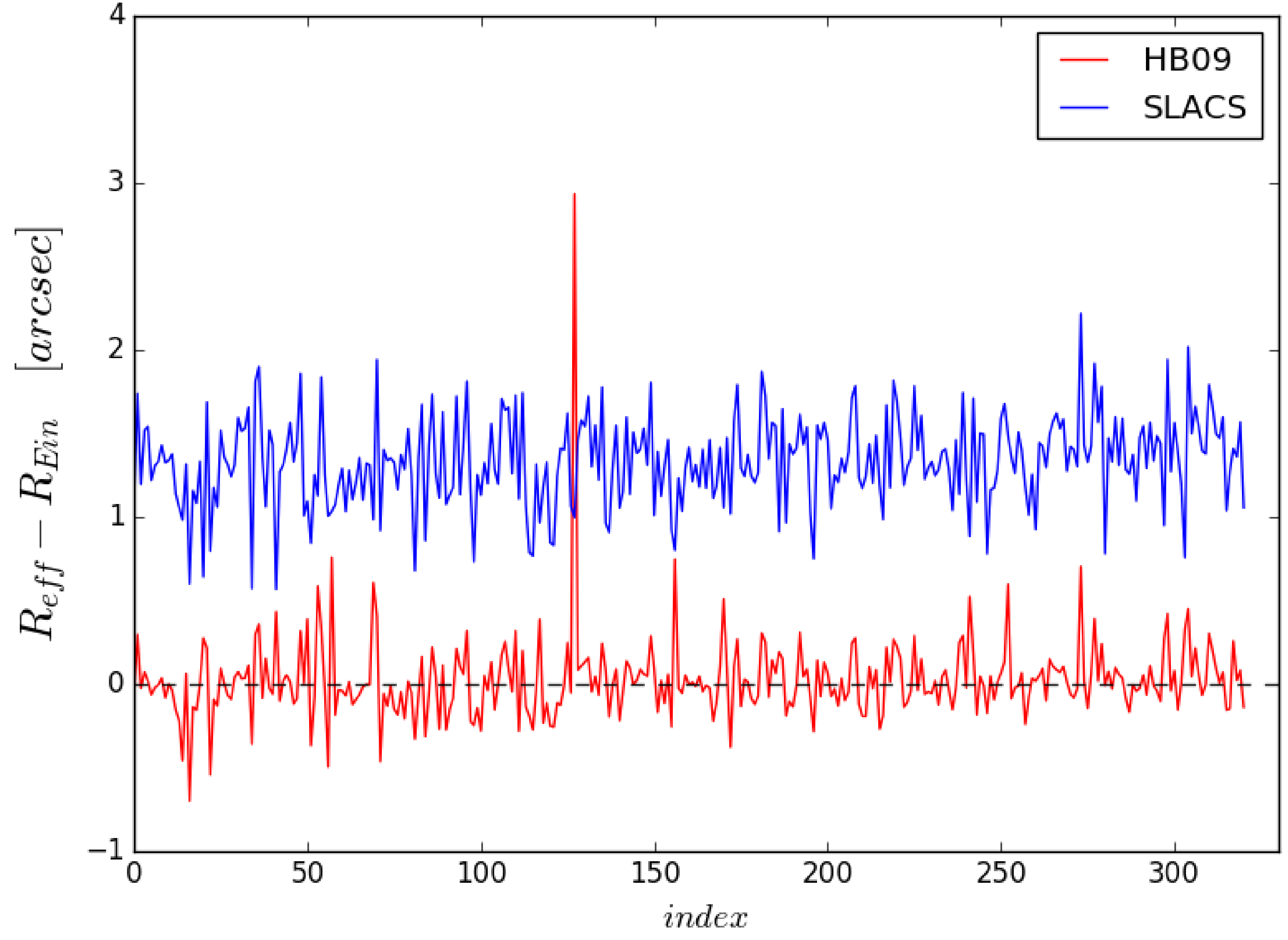
(perfectly deblended images)
(NIR filters available too)

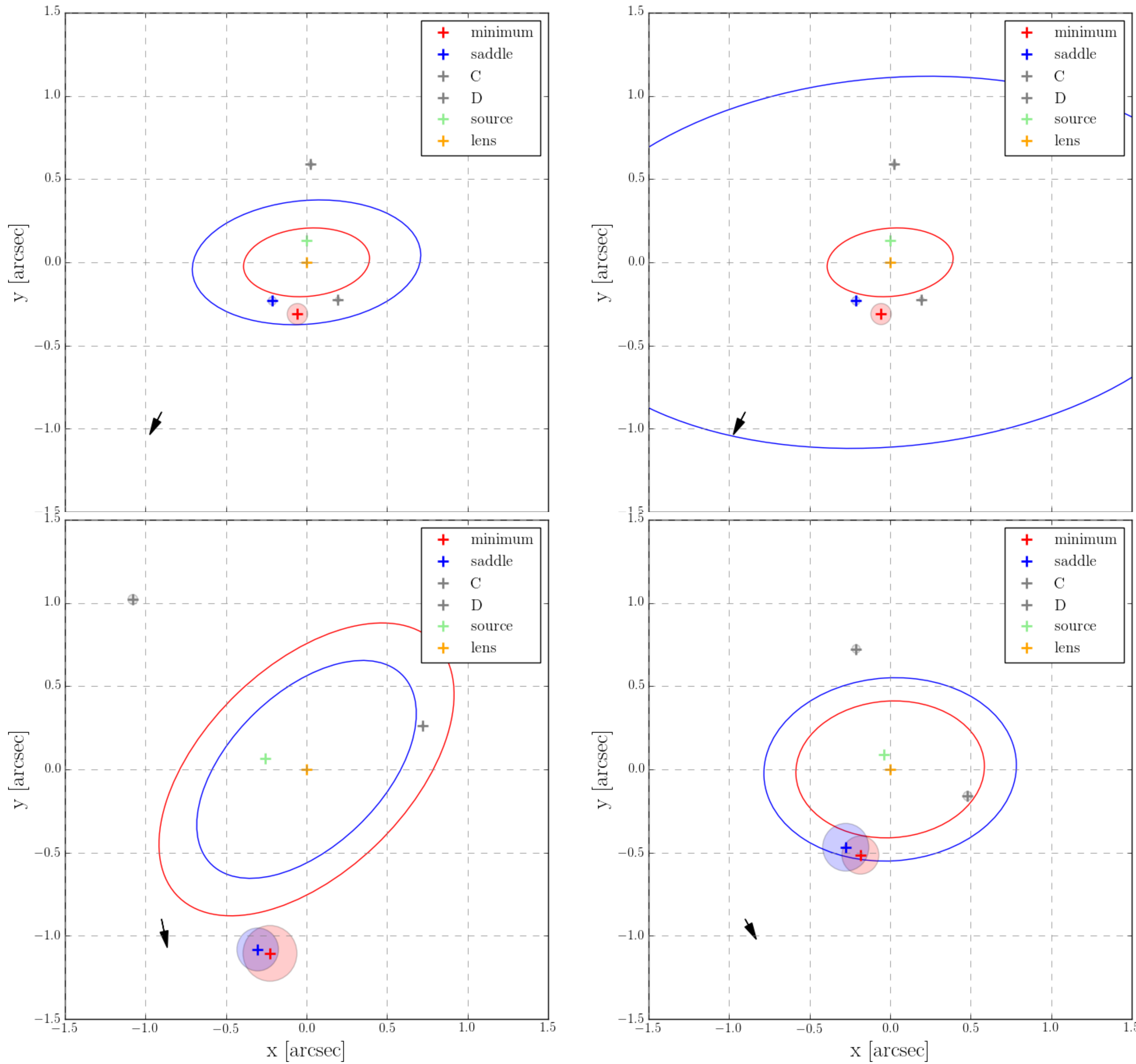
~1000 mock lensed quasars

Sersic profile: m, $\mathbf{R}_{\text{eff}}$ and $\boldsymbol{\kappa}_{\text{eff}}$ free

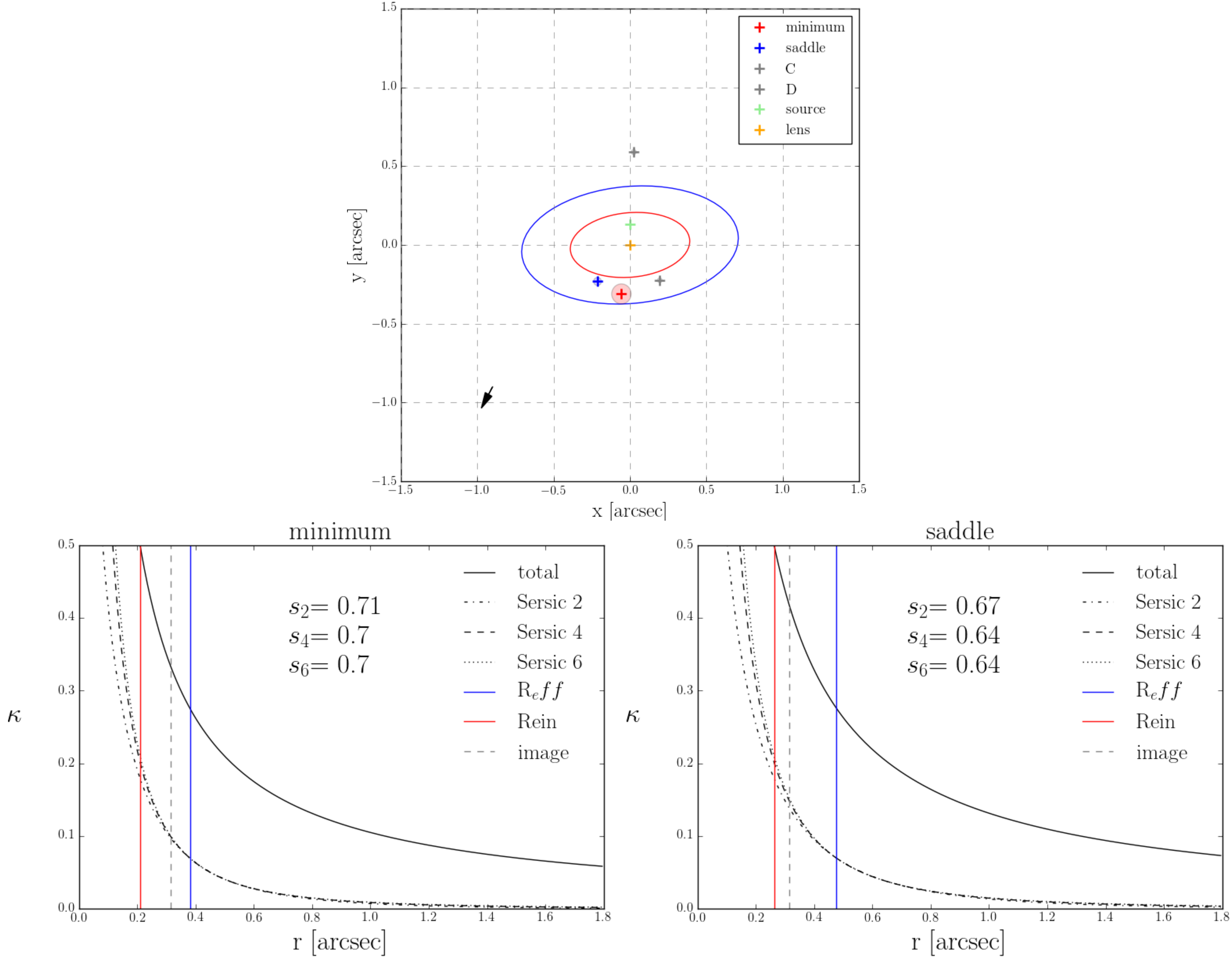
Stellar density profile:

SLACS: Bolton et al., 2008
HB09: Hyde & Bernardi, 2009b

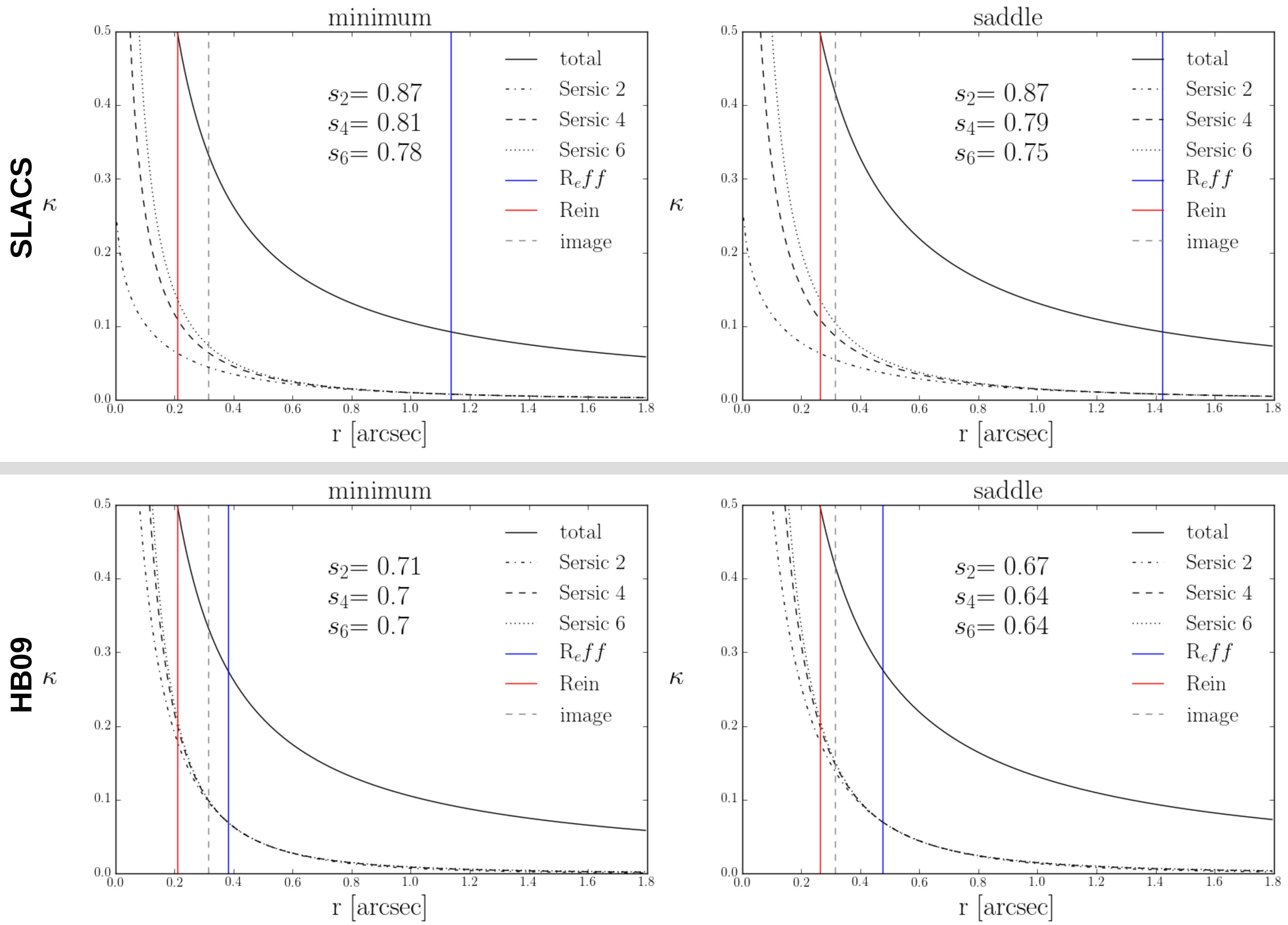




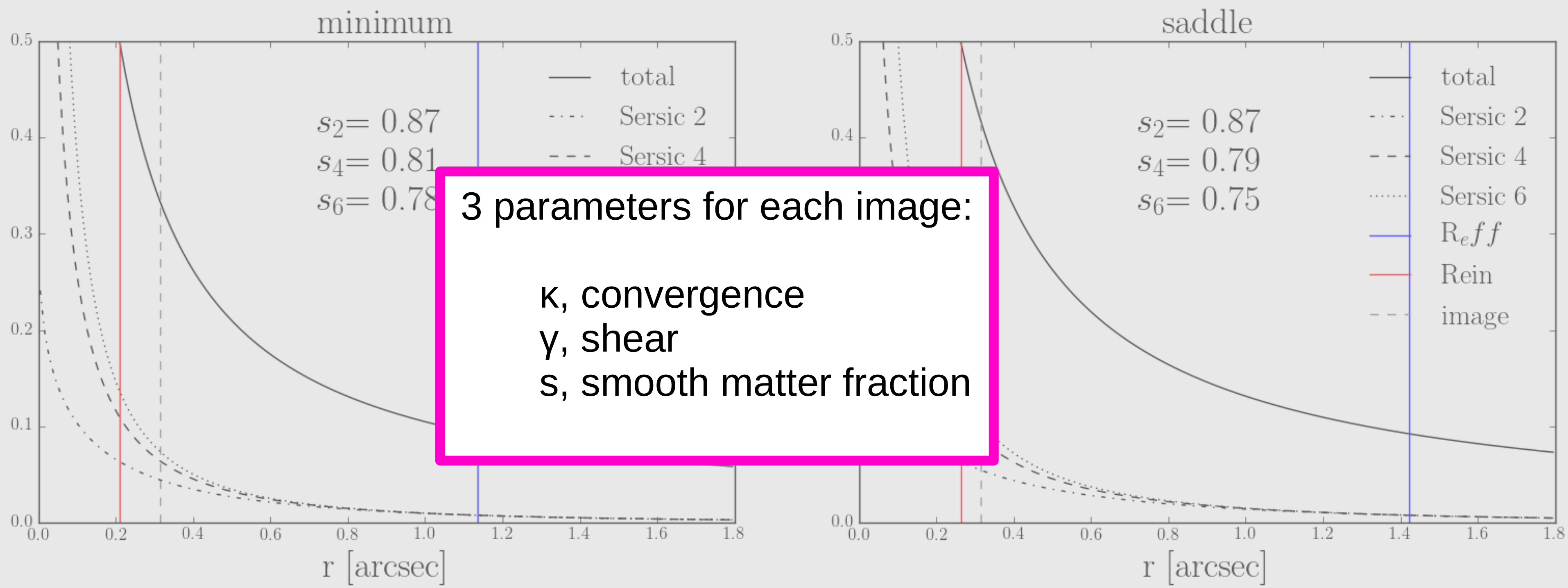
minimum
saddle
C
D
source
lens
x [arcsec]
y [arcsec]



minimum
saddle
C
D
source
lens
x [arcsec]
y [arcsec]
minimum
saddle
s_2= 0.71
s_4= 0.7
s_6= 0.7
s_2= 0.67
s_4= 0.64
s_6= 0.64
total
Sersic 2
Sersic 4
Sersic 6
R_{eff}
Rein
image
κ
r [arcsec]


SLACS
HB09
minimum
saddle
κ
r [arcsec]
total
Sersic 2
Sersic 4
Sersic 6
R$_{eff}$
Rein
image
s_2= 0.87
s_4= 0.81
s_6= 0.78
s_2= 0.87
s_4= 0.79
s_6= 0.75
s_2= 0.71
s_4= 0.7
s_6= 0.7
s_2= 0.67
s_4= 0.64
s_6= 0.64

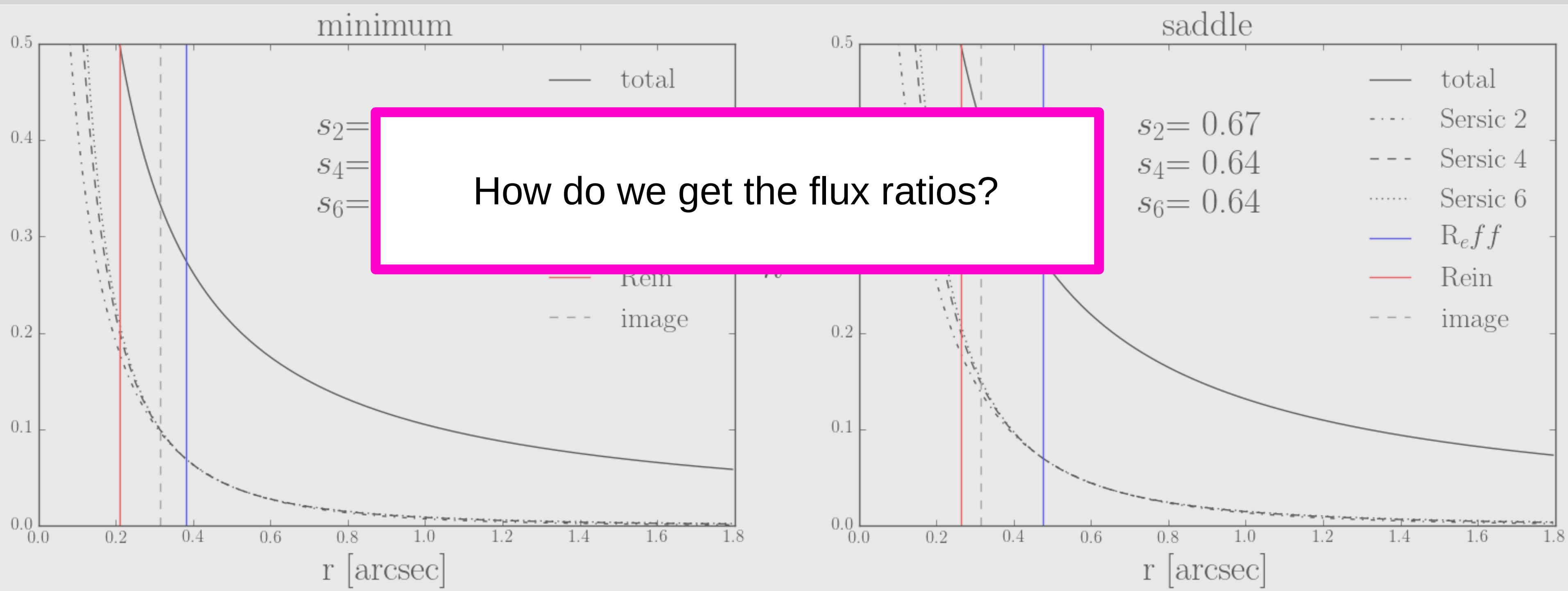
SLACS



3 parameters for each image:

κ, convergence
γ, shear
s, smooth matter fraction

HB09



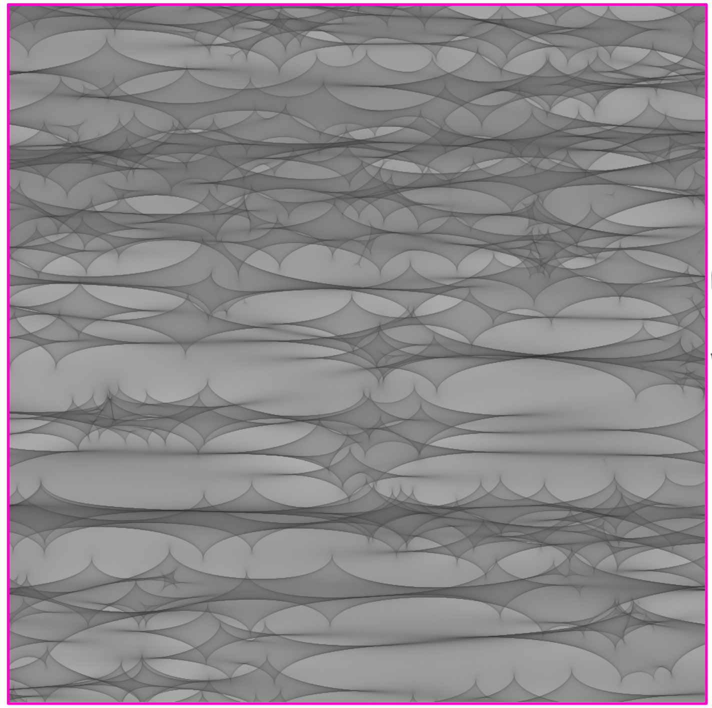
How do we get the flux ratios?

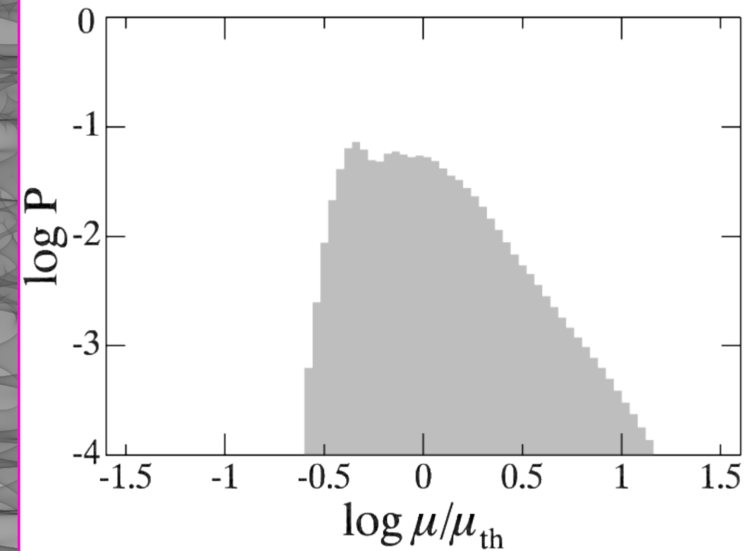
Minimum

κ = 0.33

γ = 0.59

s = 0.7



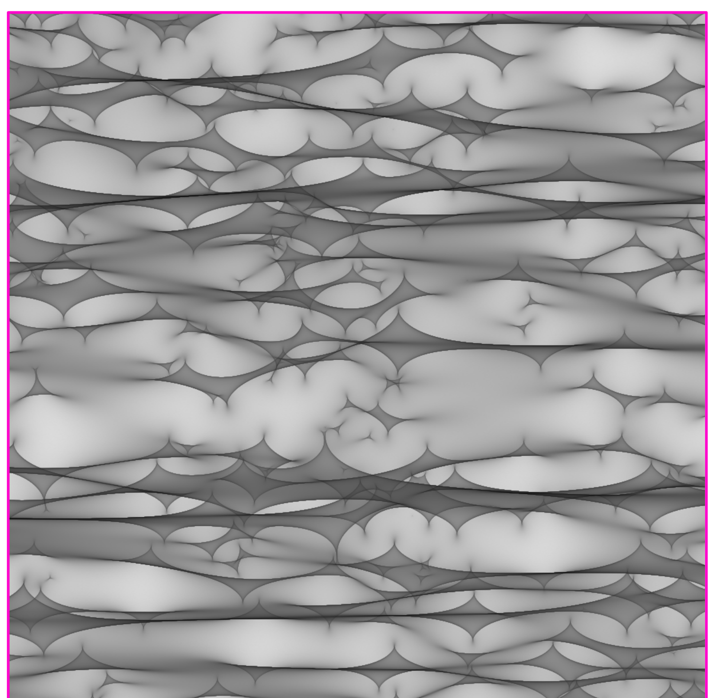


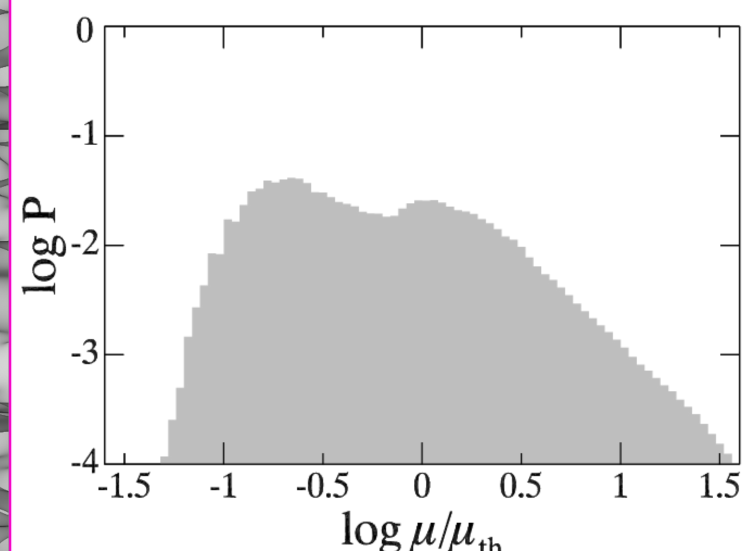
Saddle

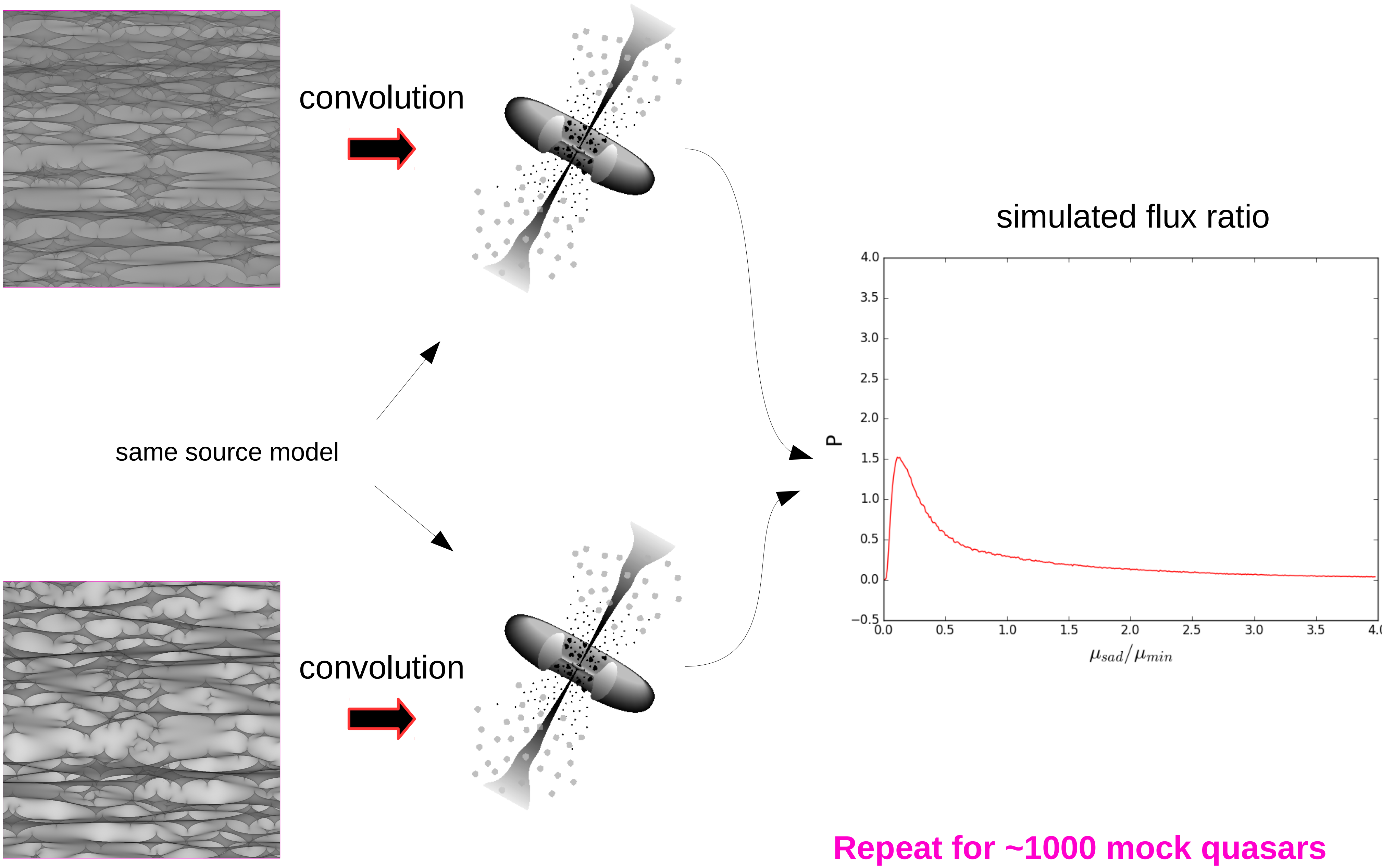
κ = 0.42

γ = 0.75

s = 0.6

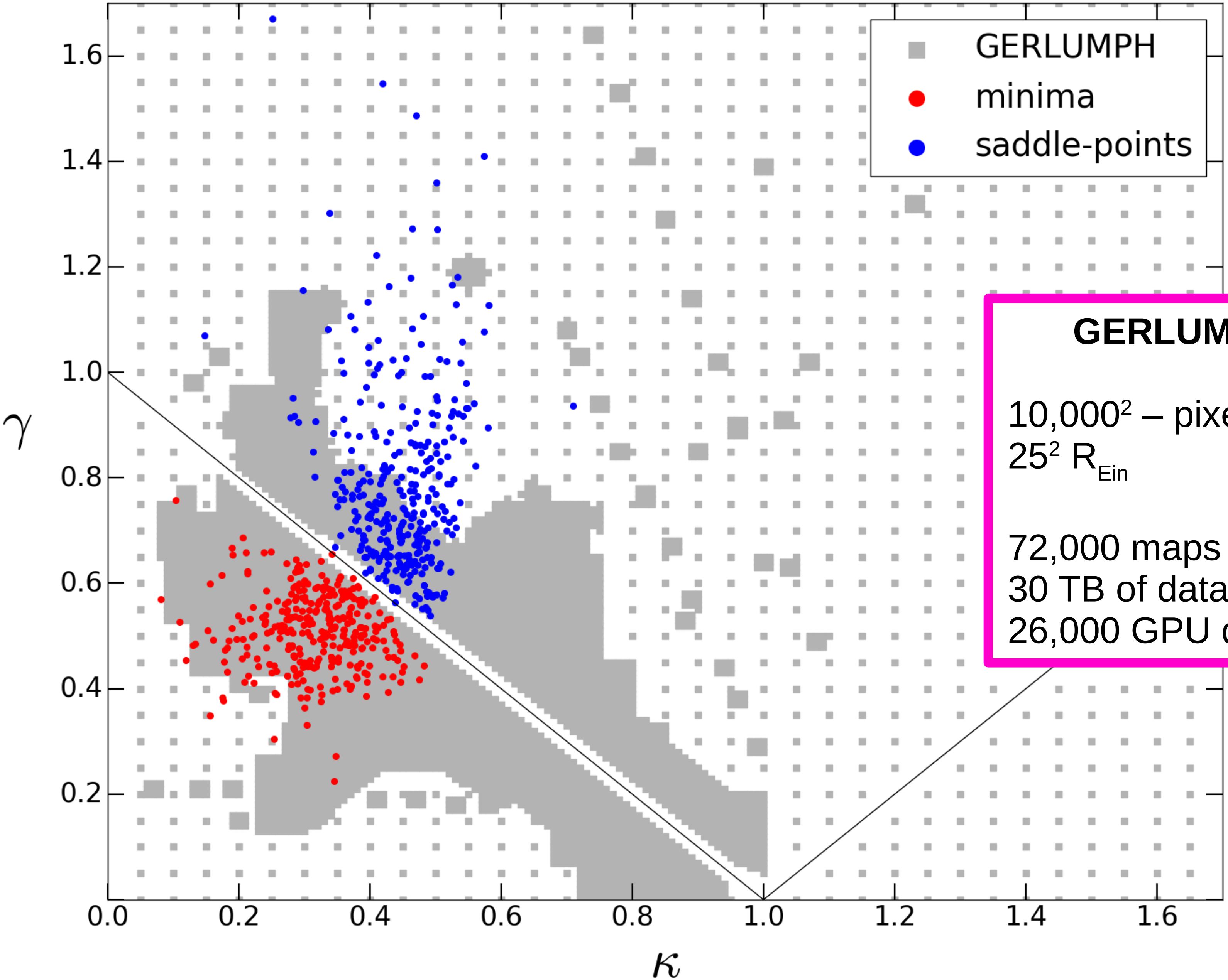






convolution
convolution
same source model
simulated flux ratio
P
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0
μ_{sad}/μ_{min}
Repeat for ~1000 mock quasars

http://gerlumph.swin.edu.au



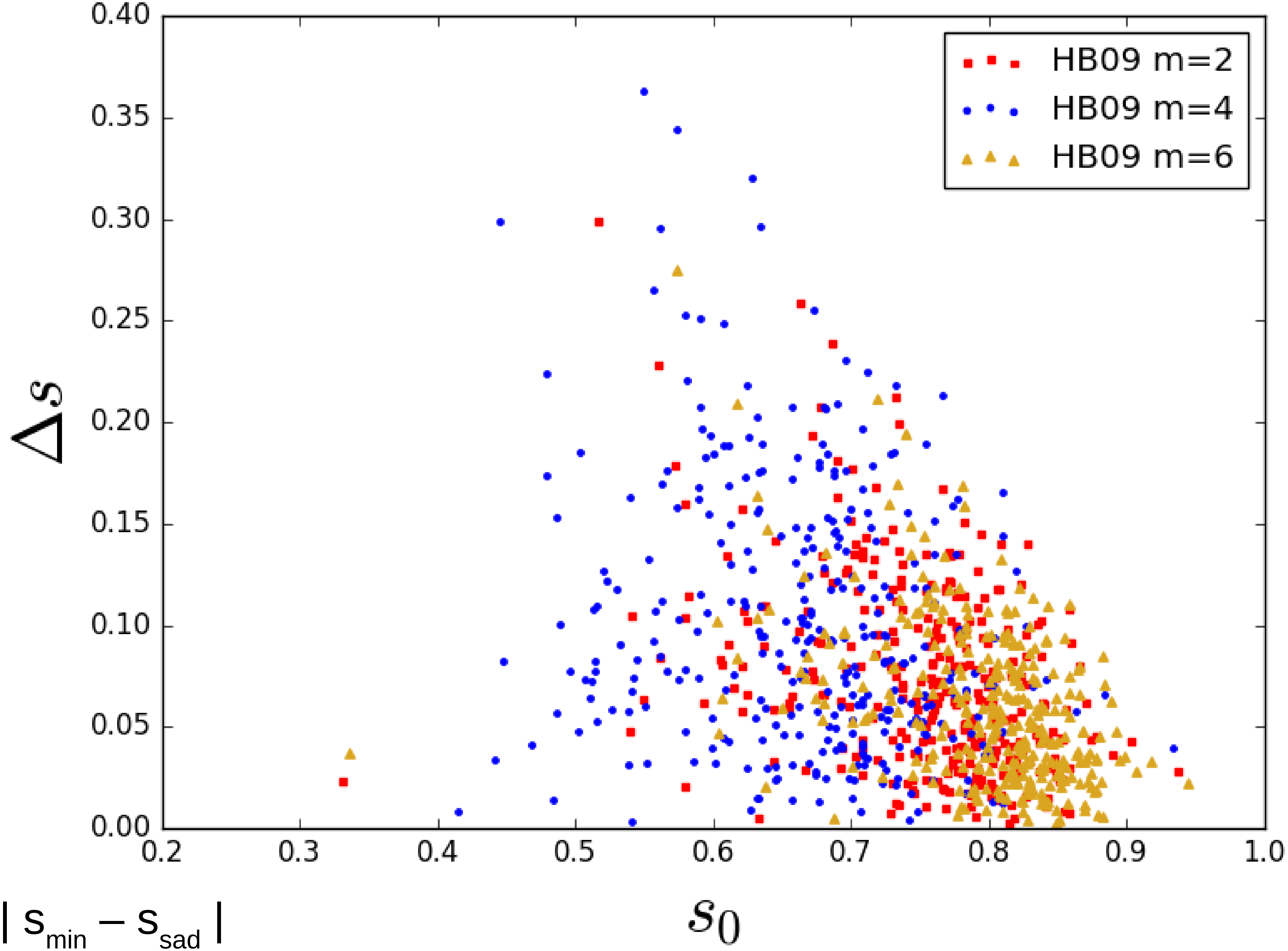
GERLUMPH

$10{,}000^2$ – pixel maps
25^2 R_{Ein}

72,000 maps
30 TB of data
26,000 GPU days

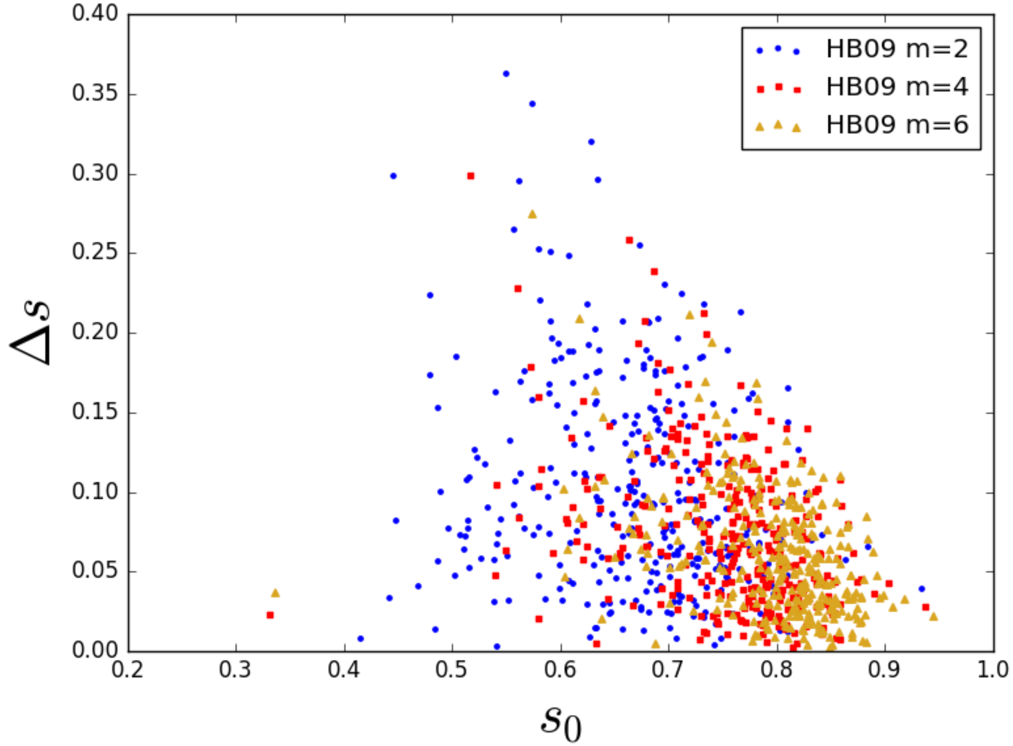
http://gerlumph.swin.edu.au

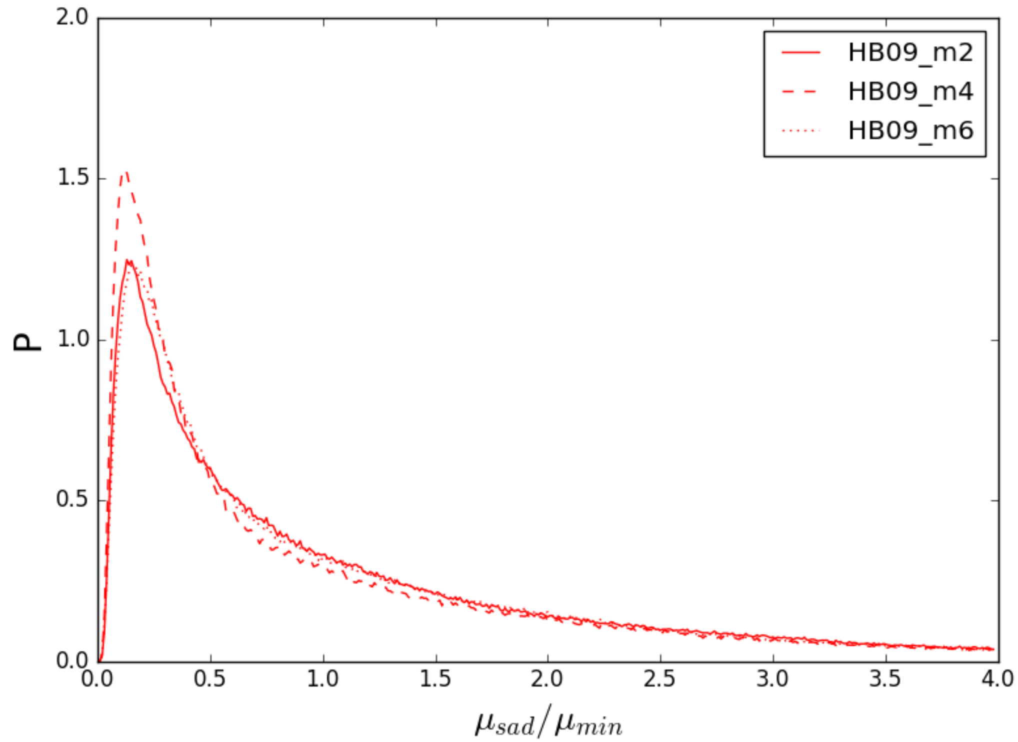
Dark vs stellar matter content



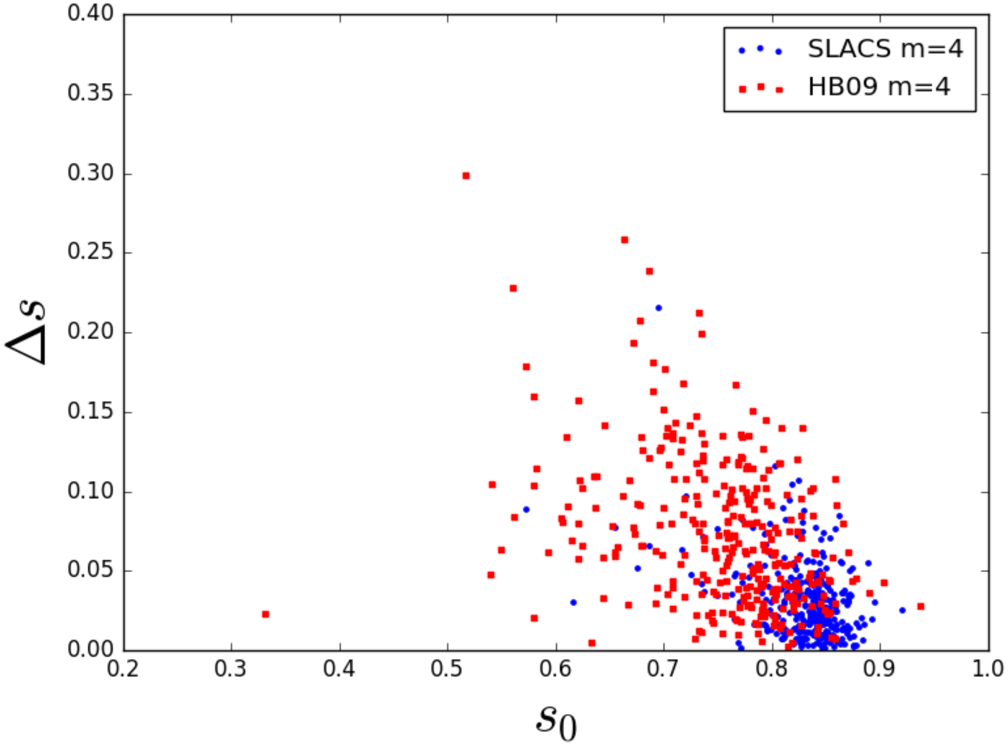
$\Delta s = | s_{min} - s_{sad} |$

$S_0 = \min(s_{min}, s_{sad})$

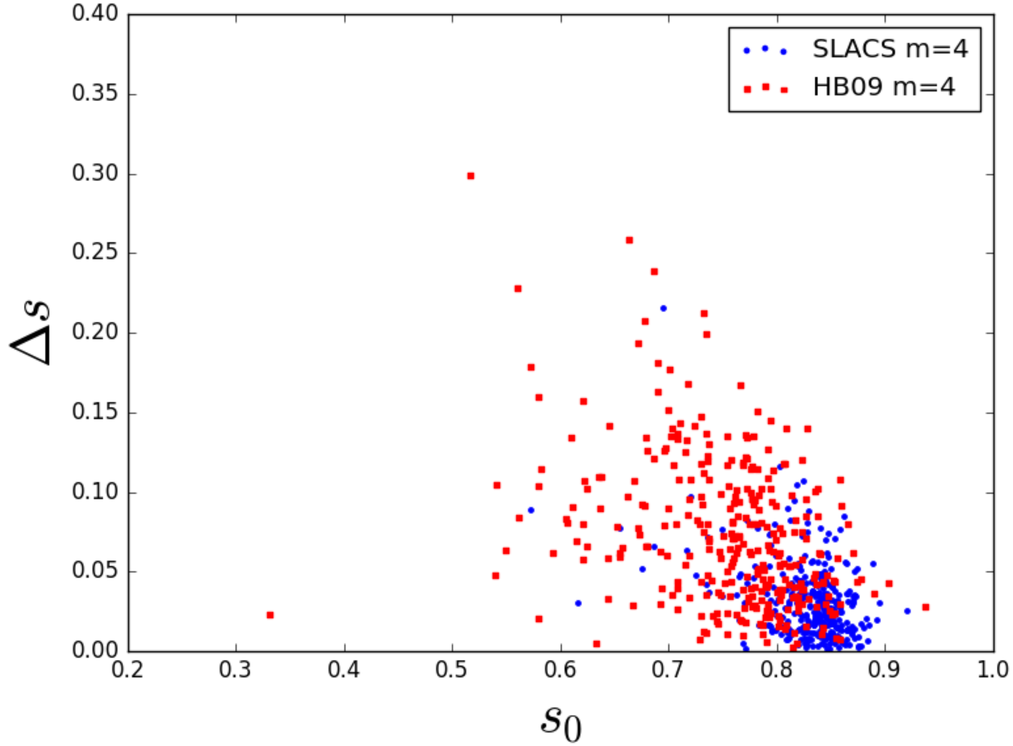


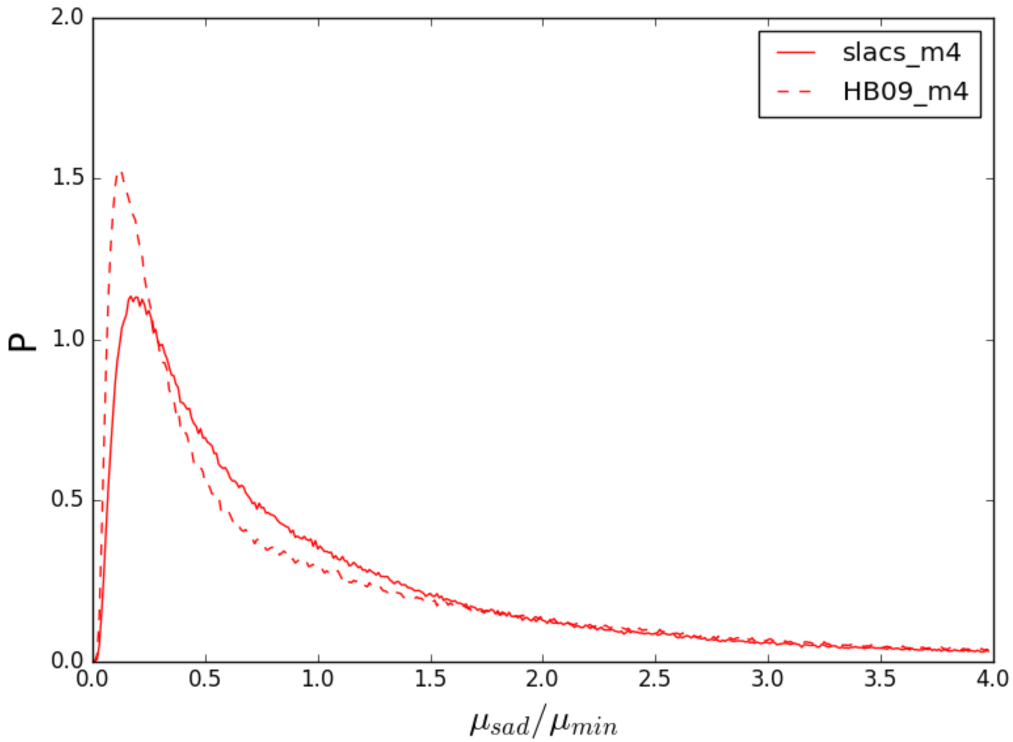


Preliminary

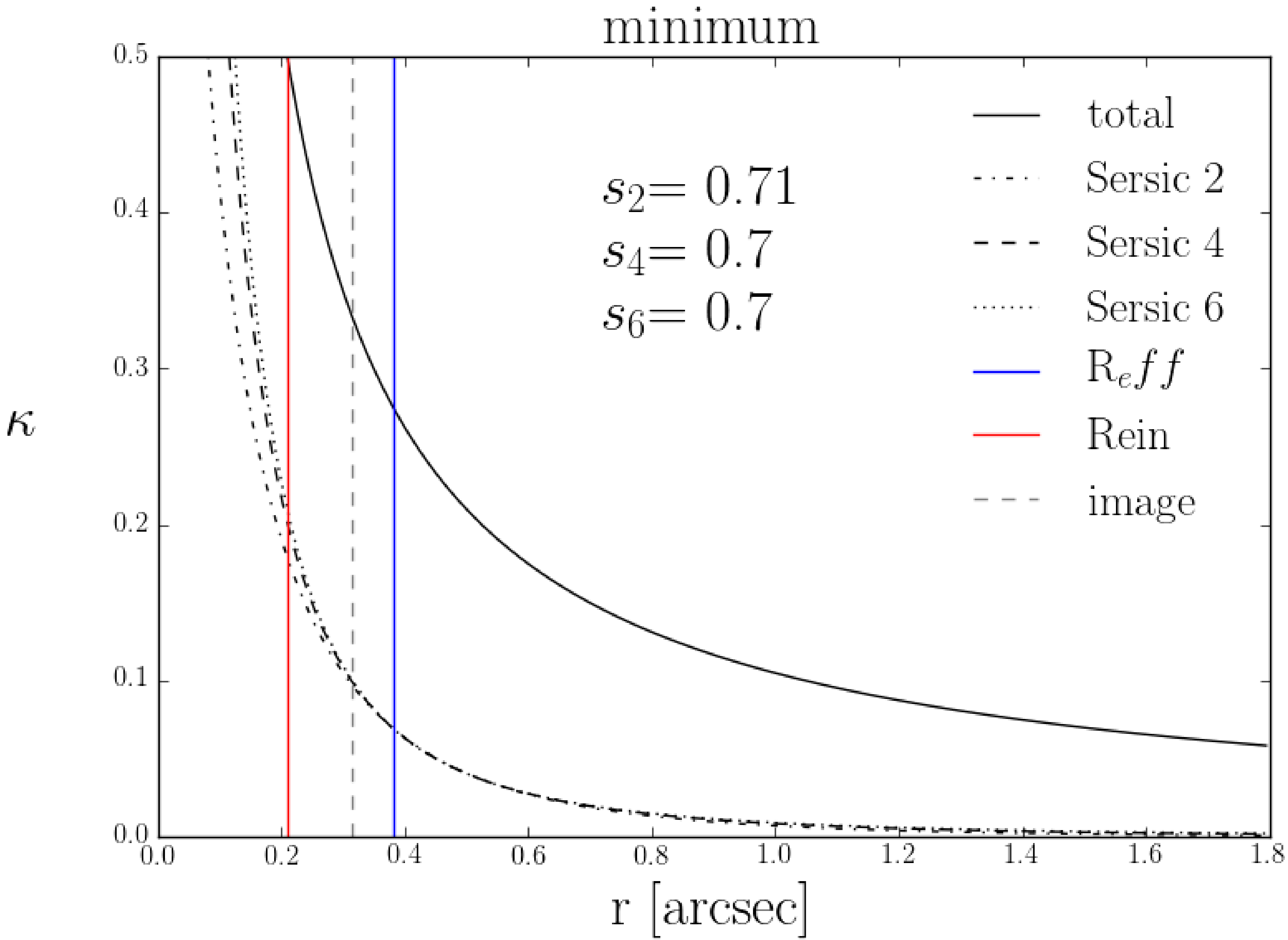


Preliminary

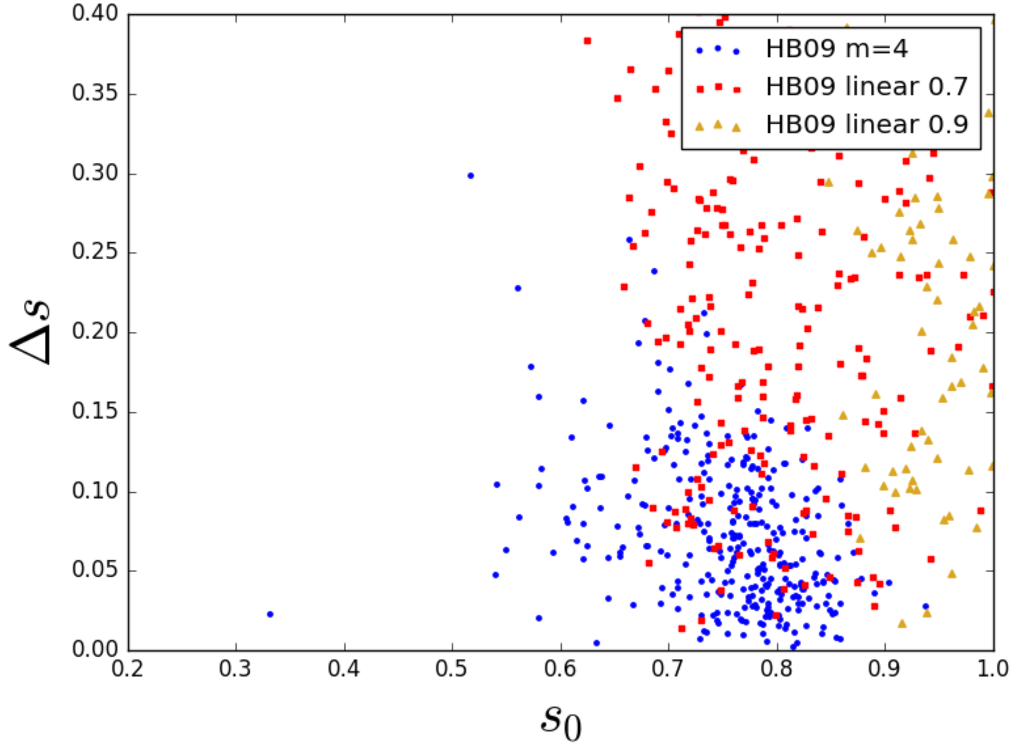




Preliminary

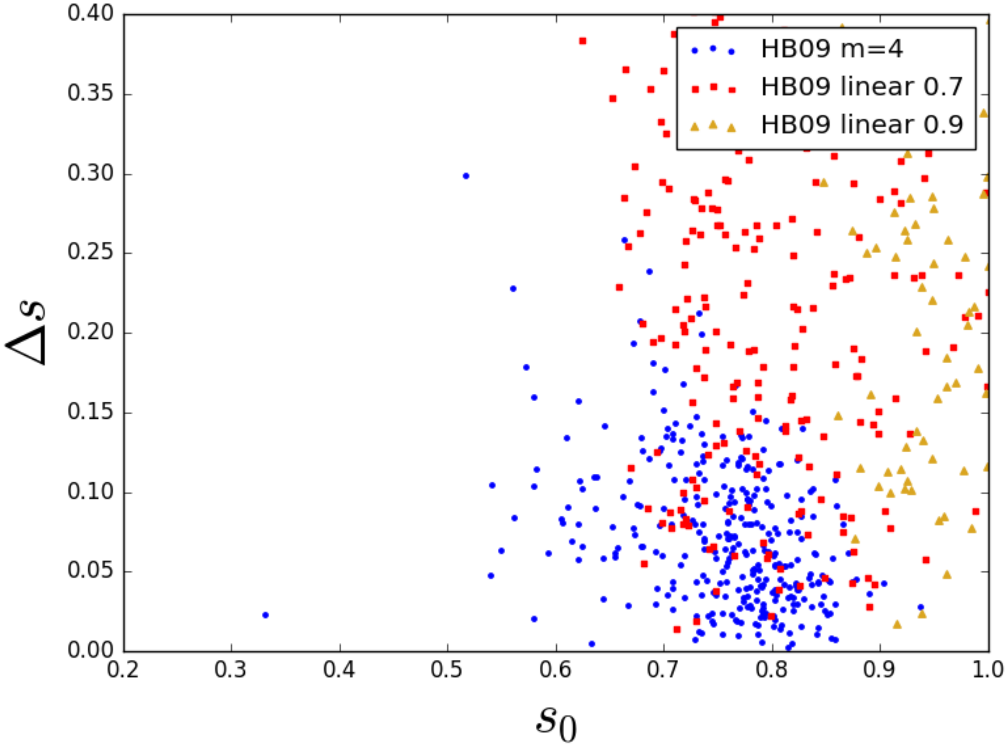


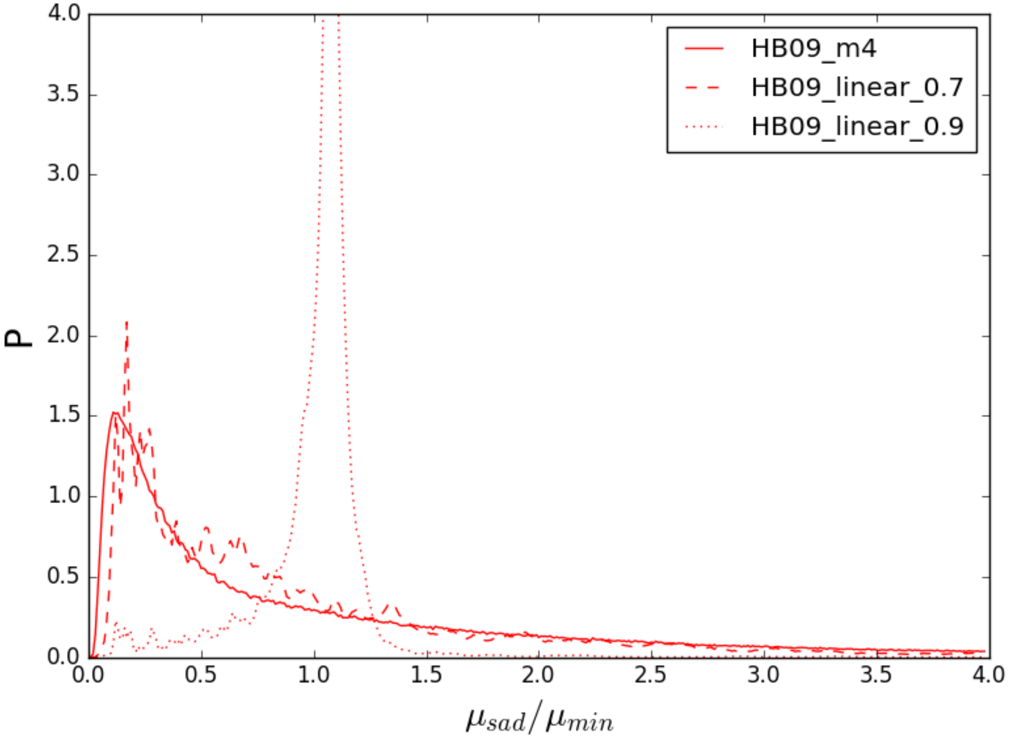
minimum
0.5
0.4
0.3
0.2
0.1
0.0
κ
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
r [arcsec]
s_2= 0.71
s_4= 0.7
s_6= 0.7
total
Sersic 2
Sersic 4
Sersic 6
$\mathrm{R}_{e}ff$
Rein
image



Preliminary

Preliminary



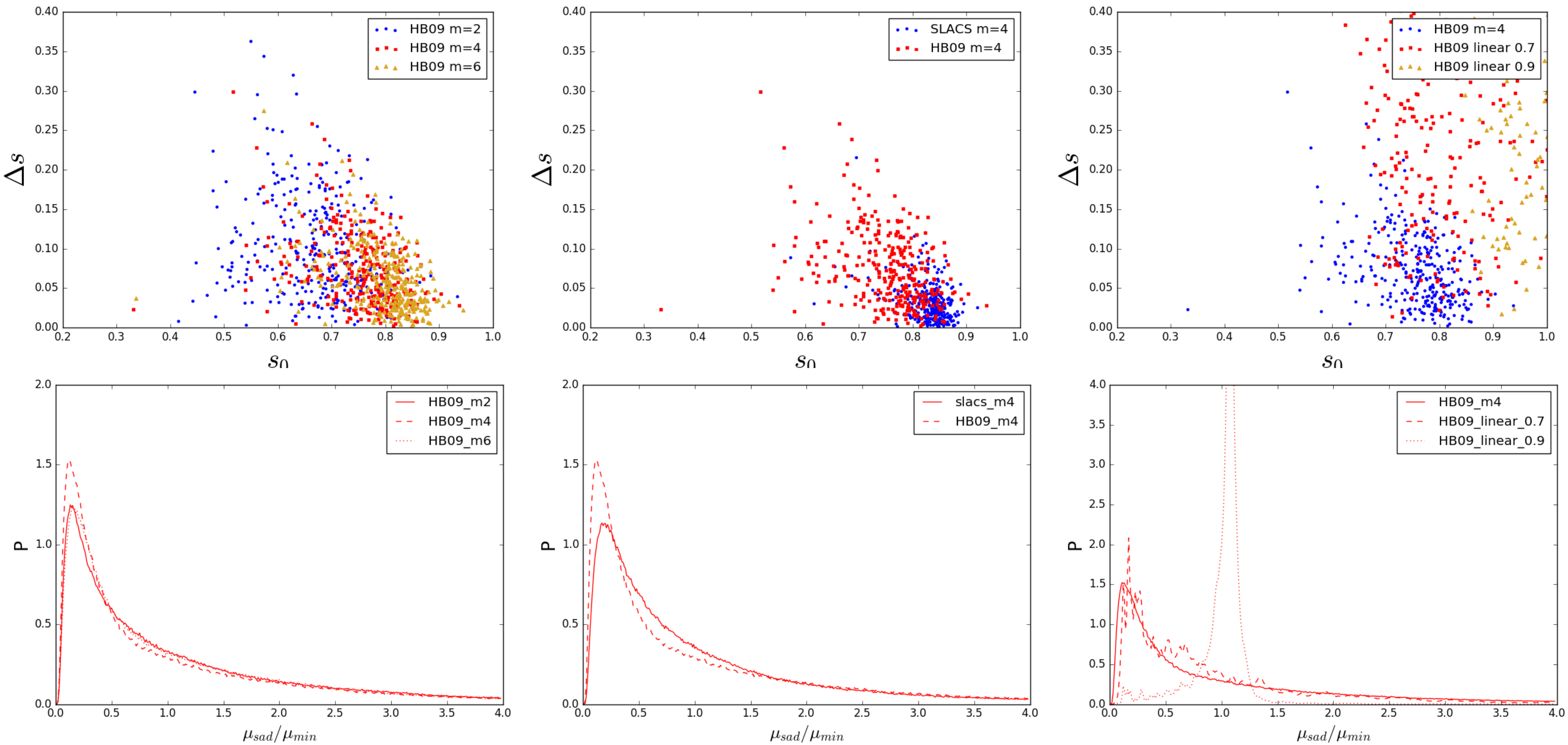


Preliminary

Sersic index

R_{eff}

High s



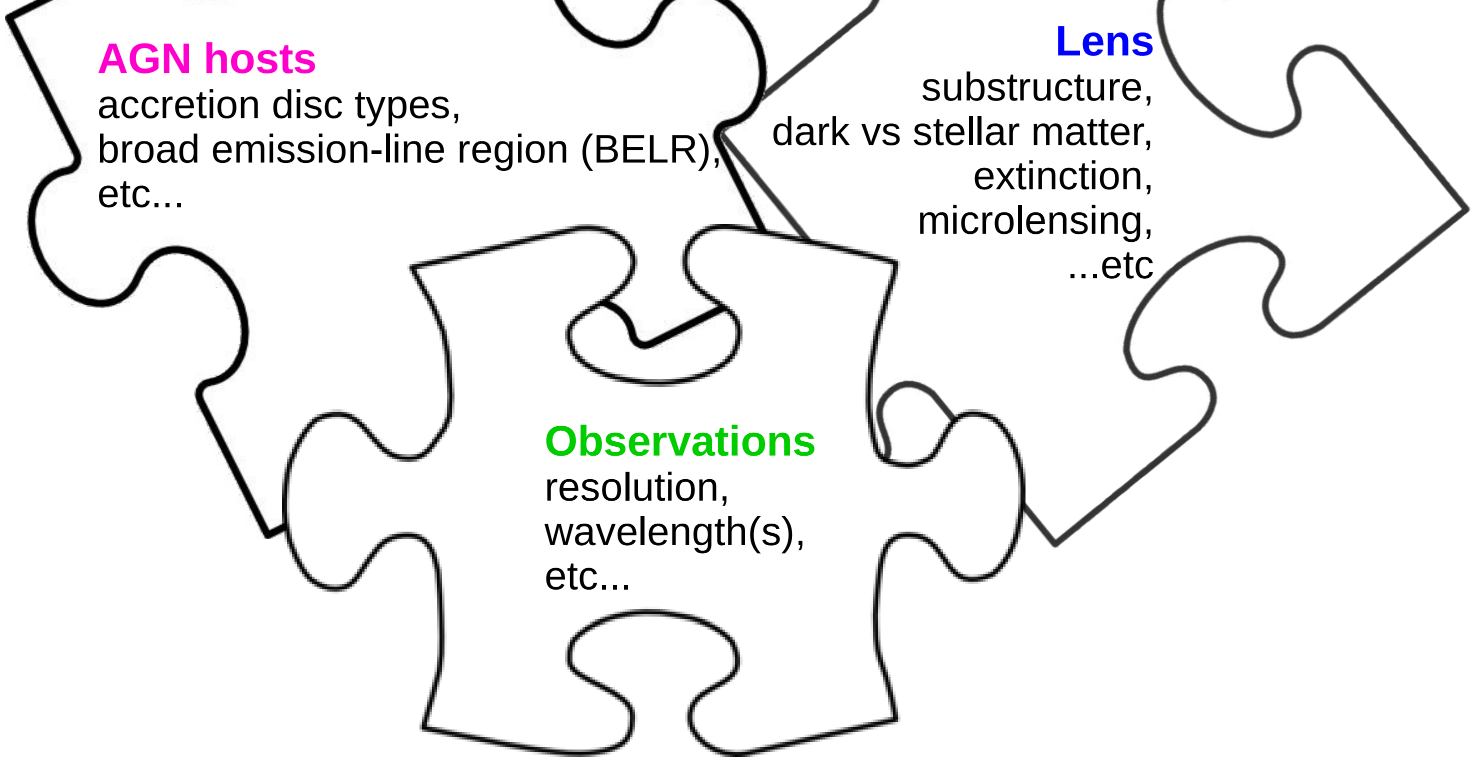
Can we probe the stellar vs dark matter ratio?

Can we find "global" microlensing flux ratio properties?

Can we identify accretion disc types?

Conclusions

- We can calculate the microlensing flux ratios for a lensed quasar population with any stellar density distribution.
- Different stellar profiles seem to give very similar ratio distributions (dependence on λ!).
- Extreme s leads to no microlensing.



Future

- Introduce dependence on λ (longer $\lambda \rightarrow$ less microlensing).
- Use different accretion disc parameters/types.
- Light curves/time delay challenges:

  "one man's noise is another man's signal"
- Bayesian approach to infer models for lens/source from data.