

# QSO host galaxies at $z \sim 3$ : Image reconstruction techniques

Yiping Wang

National Astronomical Observatories of China

[ypwang@bao.ac.cn](mailto:ypwang@bao.ac.cn)

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*@ Washington D. C.*

# Motivation

3C 273

<http://en.wikipedia.org>



Quasar 3C 273 taken by Hubble Space Telescope. [1]

Constellation: Virgo : Redshift: 0.158  
Type: Blazar, Sy1, Radio source ; Mv: ~ -26  
Notable features: optically-brightest quasar; first spectrum of a quasar

Host galaxy: a giant elliptical galaxy

## What TMT will bring to us ?

ULAS J1120+0641

<http://en.wikipedia.org>



$z=7.1$ ,  
most  
distant  
known  
qso

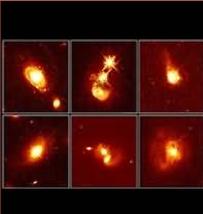


Artist's rendering

News Release Number: STScI-1996-35

### Hubble Surveys the "Homes" of Quasars

Introduction | Release Text | Release Images | Release Videos | Background Info | Related Links



NOVEMBER 19, 1996: Dramatic Hubble in a remarkable assortment of galaxies complicated picture suggests there may be subtle ? for "turning on" quasars, the universe's most powerful energy source. When seen through ground-based telescope sources resemble stars, yet they are hundreds of billions of times brighter than normal stars. These images offer examples of quasar home sites. At the center of each is a massive black hole at the center of a galaxy.

See the rest:

- Release Text
- See All the Images

Go to image download page

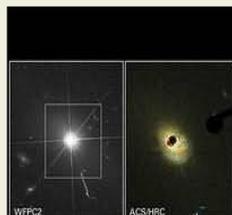
Credit: John Bahcall (Institute for Advanced Study, Princeton), Mike Disney (University of California, Berkeley)

News Release Number: STScI-2003-05

### Hubble Probes the Heart of a Nearby Quasar

Introduction | Release Images | Fast Facts | Related Links

◀ Back | Image: Hubble Probes the Heart of a Nearby Quasar



Screen-use options: These files are created for viewing on your monitor

Small - 3.5 kB | Medium - 10.2 kB | Large with title - 41.8 kB

Print-use download options: These files are designed to fit on letter-size paper

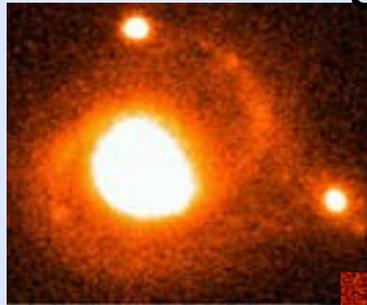
PDF - 253.5 kB | JPEG - 442.8 kB | HELP ?

Discovered by UKIDSS;  
Reported in June, 2011

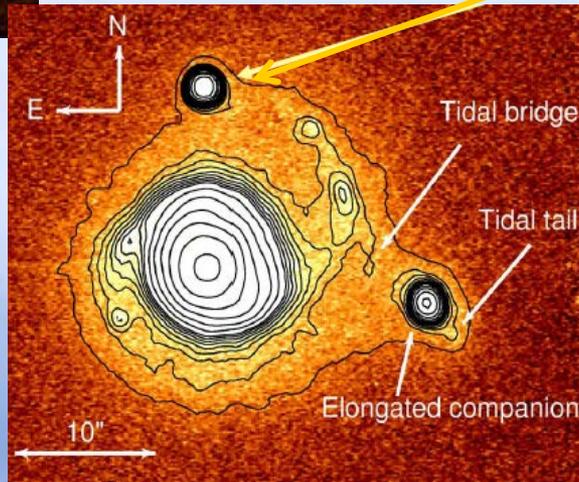
# Motivation

## The I Zw 1 System

J-band image (ISAAC+VLT)



Foreground star



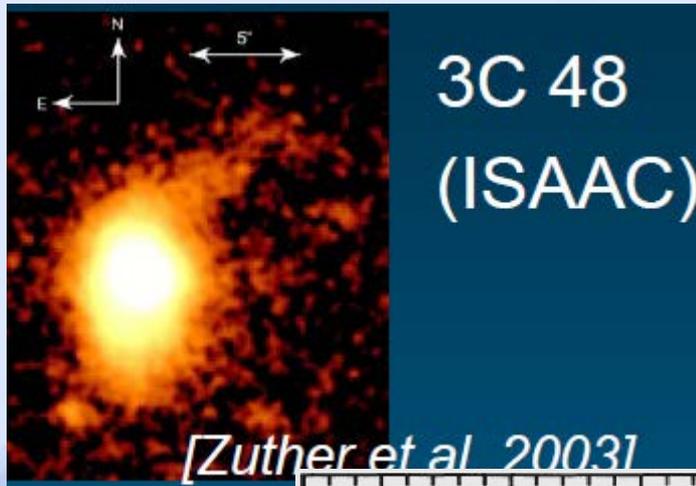
1.  $z=0.06$
2. Palomar Green QSO with a spiral host
3. **Possibly minor merger**
4. Possibly transition stage
5. Narrow-line Seyfert I, probably young stage of nuclear activity (Mathur et al. 2000)
6. Black hole mass, small BH, QSO in formation?

Scharwachter et al. 2003;

Courtesy: Julia Scharwacher's ppt

@20 April 2007-Huatulco

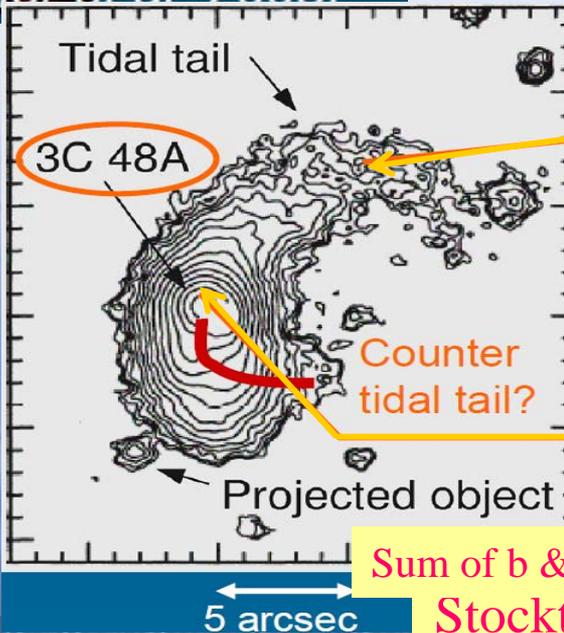
# Motivation



1.  $z=0.367$
2. radio source
3.  $M_V \sim -25$
4. first solid identification of a quasar host galaxy
5. possibly two interacting galaxy centers,

as a major merger

“Antennae”-like merger?



~ 1" to the NE of the QSO nucleus,  
possibly two merging nuclei?

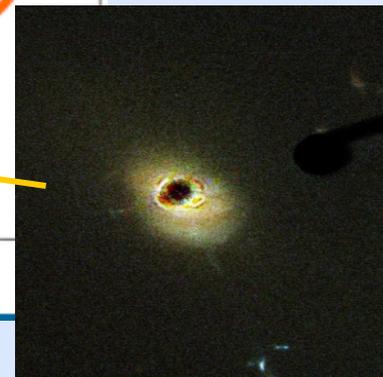
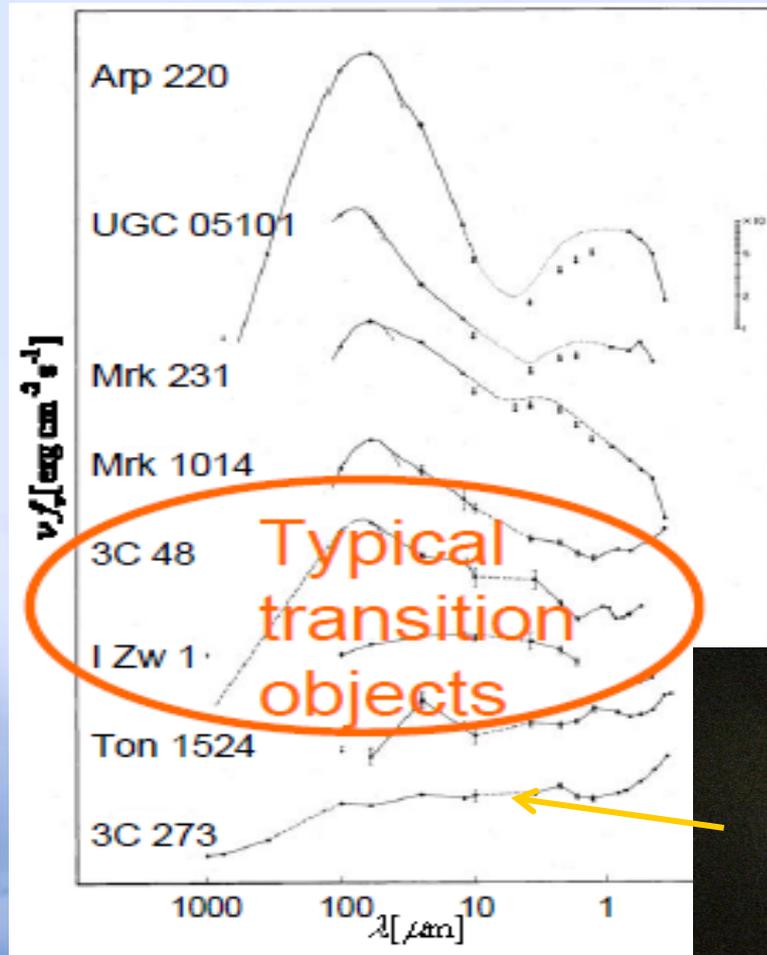
Sum of b & v images taken by UH2.2m  
Stockton & Ridgway 1991

Courtesy: Julia Scharwacher's presentation @20 April 2007-Huatulco

# Motivation

Sanders et al. 1998

## Merger-driven Evolutionary sequence from ULIGs to QSO

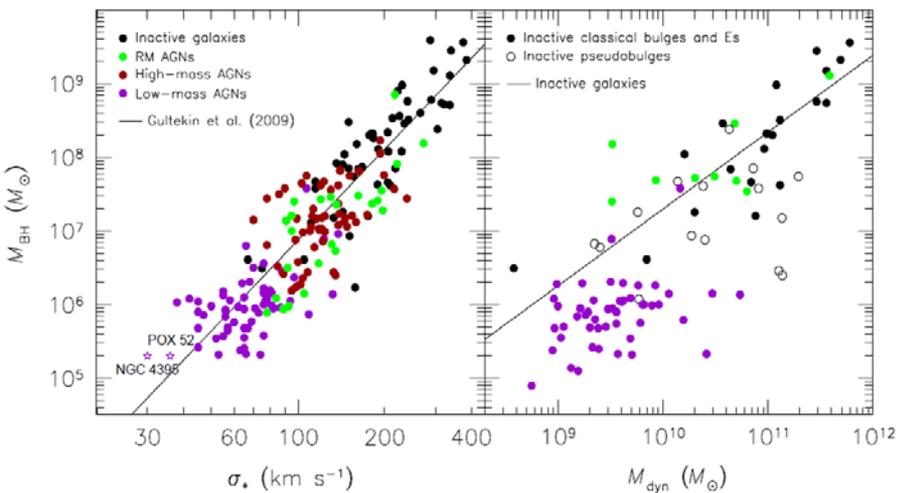


ACS's coronagraph reveals a spiral plume wound around the QSO, a red dust lane, a blue arc and clump in the path of the jet blasted from the QSO.

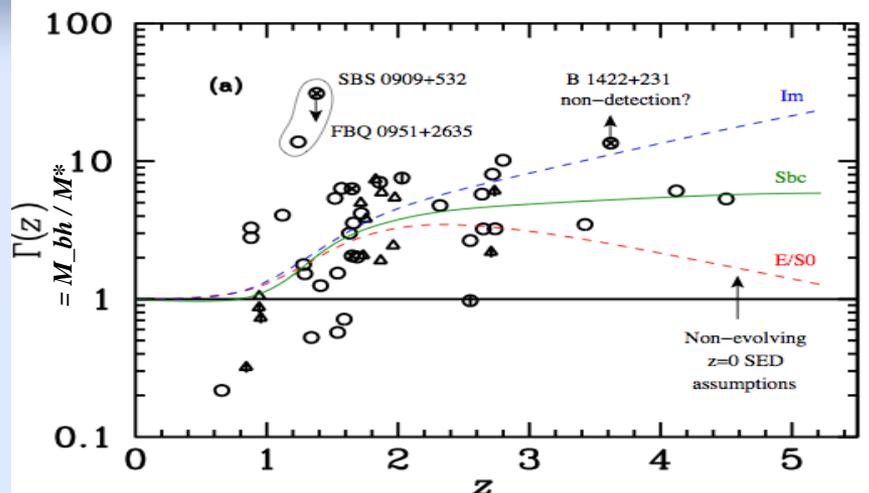
Signs of two galaxy centers, as a major merger

Signs of SF enhanced by tidal interaction, possibly a minor merger

# Scaling relation in BH mass domain



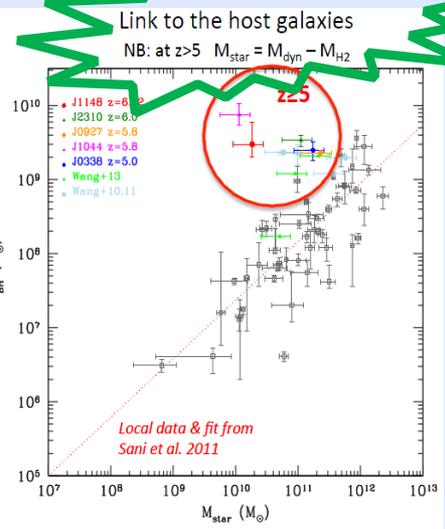
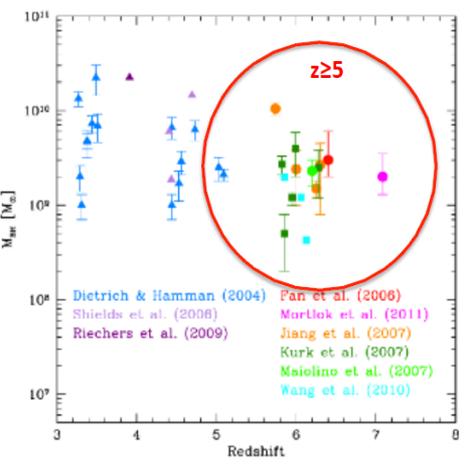
# Scaling relation over cosmic time



The circles are the lensed hosts and the triangles are the directly imaged hosts from Ridgway et al 2001 and Kukula et al. 2001. Points with a vertical line may represent the low limits (Peng et al. 2006).

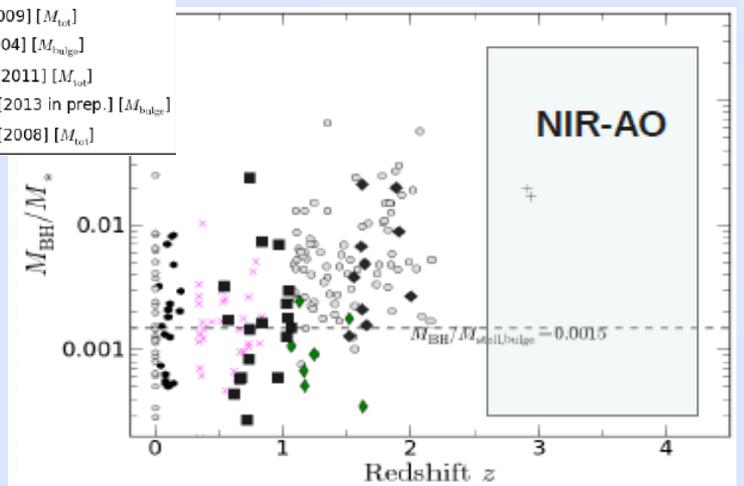
## Kormendy & Ho 2013

The growth of super massive black holes



## Host galaxies of QSOs at z~3

- Schramm[2012] [M\_bulge]
- Haering&Rix[2004] [M\_dyn]
- ◆ Jahnke[2009] [M\_tot]
- ◇ Bennert[2011] [M\_bulge]
- Merloni[2009] [M\_tot]
- Jahnke[2004] [M\_bulge]
- × Cisternas[2011] [M\_tot]
- ◆ Schramm[2013 in prep.] [M\_bulge]
- + Schramm[2008] [M\_tot]

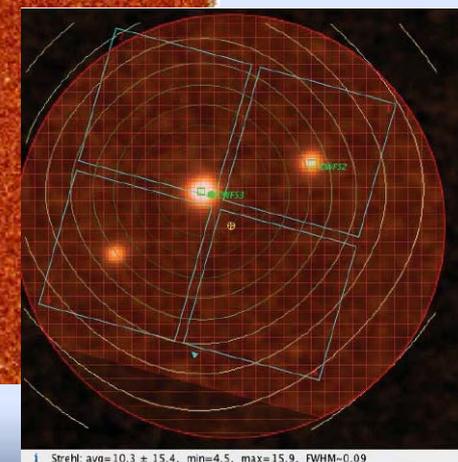
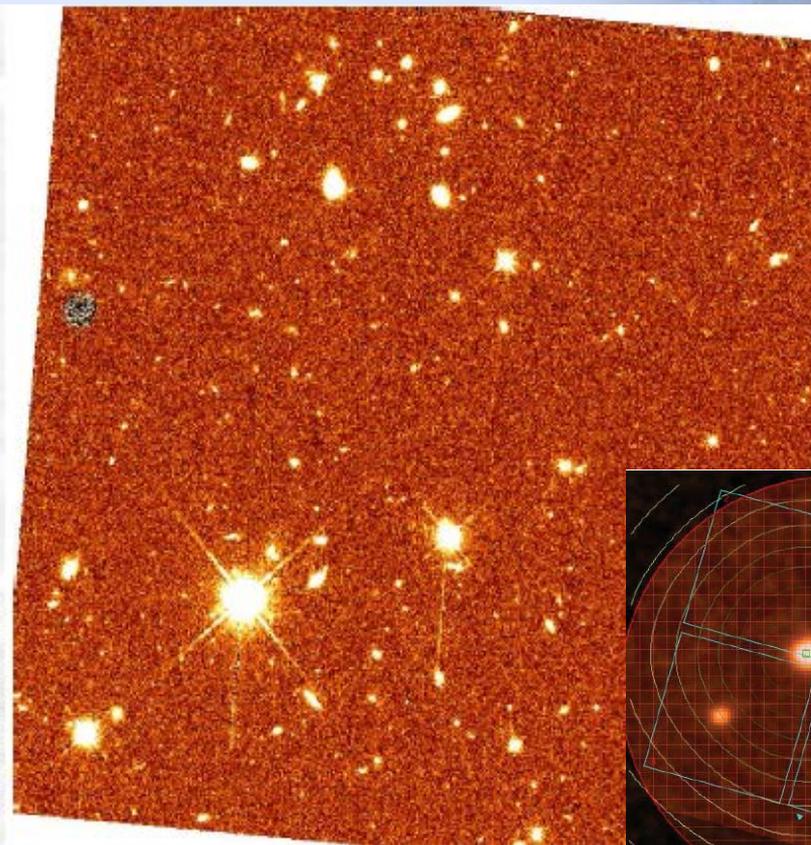
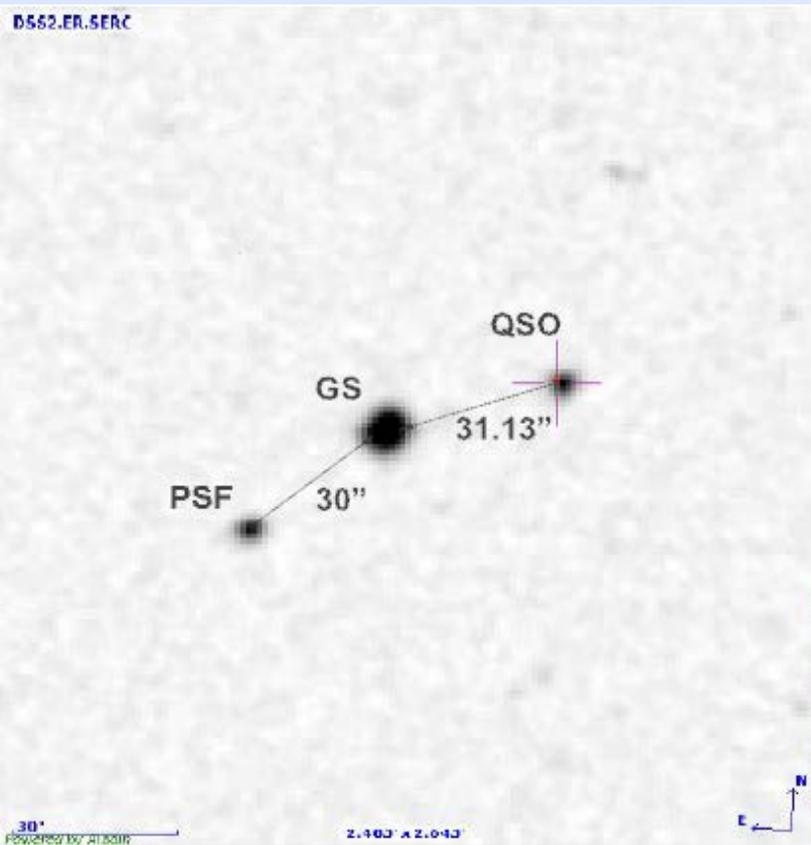


Courtesy: Rosa Valiante's presentation

Walter et al.2004;Peng et al. 2006;McLure et al. 2006;Riechers et al. 2008;Merloni et al. 2010;Wang et al. 2010,2012

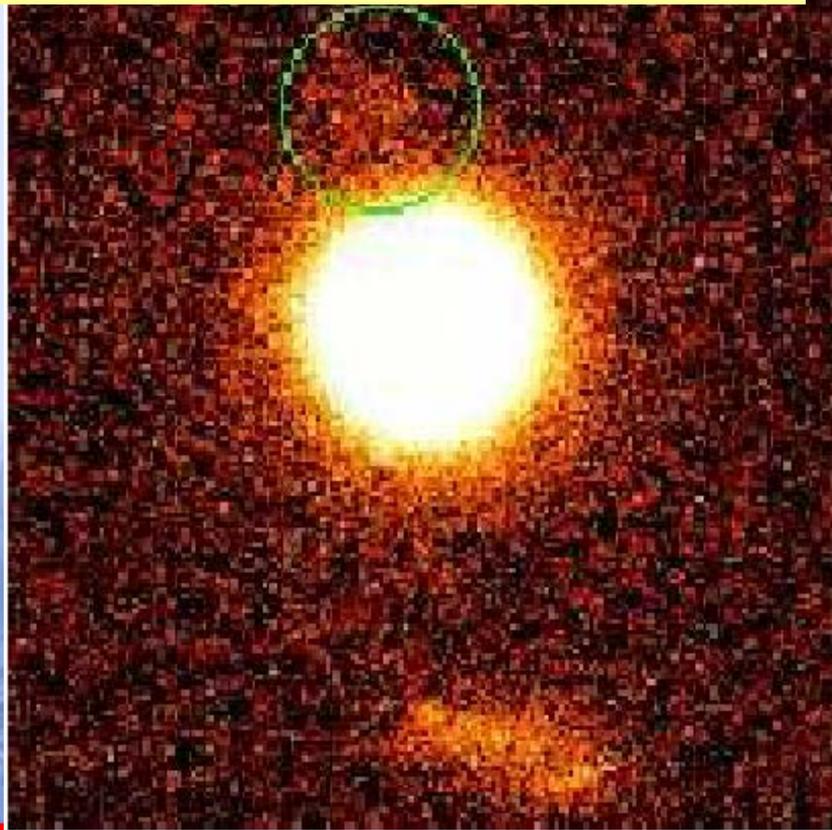
Schramm et al. 2013

Obj.	Type	RA(J2000)	DEC(J2000)	$z$	$R_{mag}$
UM 402	RQQ	02 09 50.71	-00 05 06.6	2.855	15.8
PSF star		02 09 54.51	-00 05 34.0		16.6
Guide star		02 09 52.84	-00 05 15.2		13.8

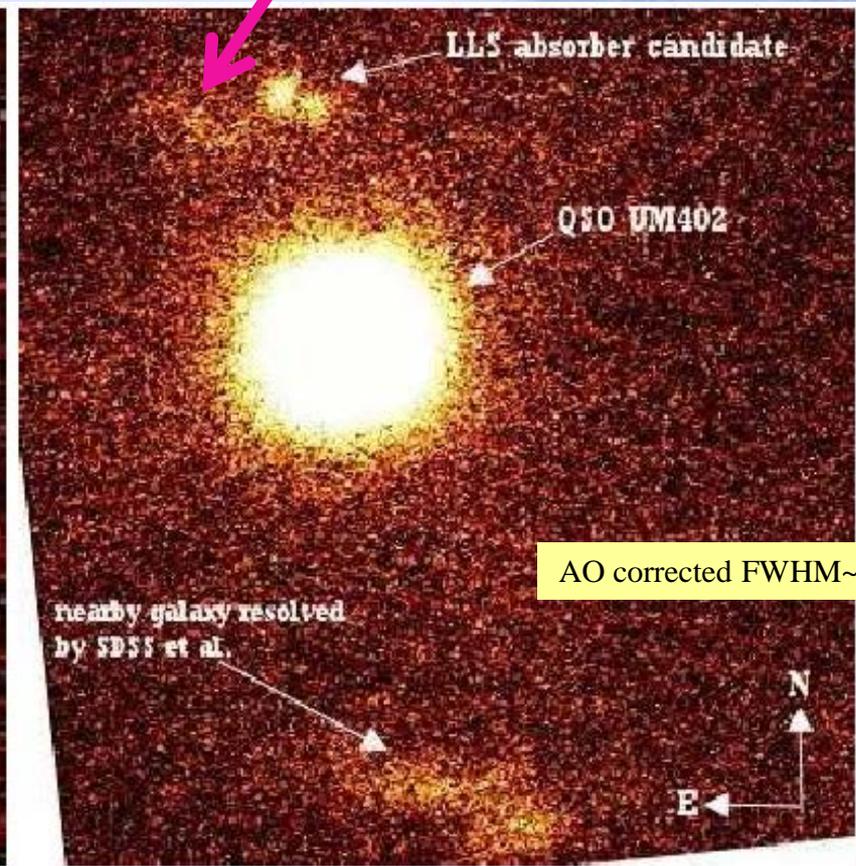


# IRCS+AO observation of UM402 at $z \sim 3$

5" x 5", AO corrected FWHM  $\sim 0.2''$



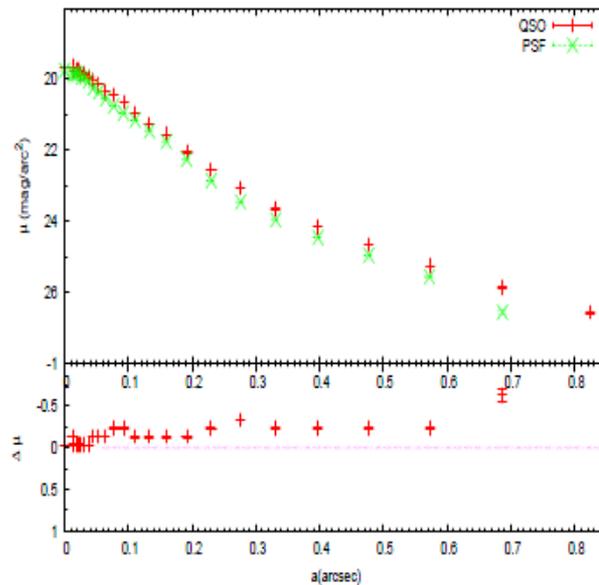
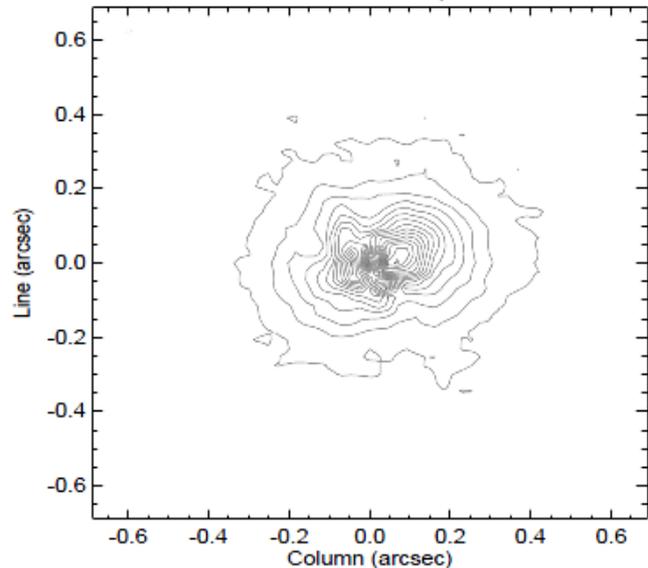
A faint tidal tail?



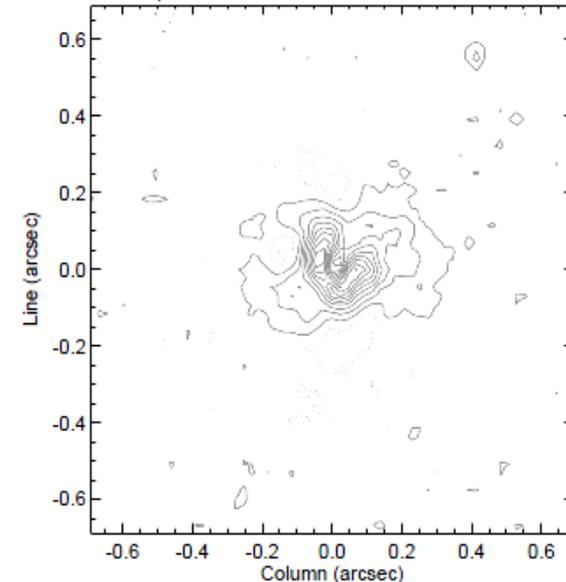
AO corrected FWHM  $\sim 0.13''$

- 1)  $2''.4$  north of the QSO sightline. The candidate is indicated in the image.
- 2) impact parameter of  $\sim 19.6$  kpc, if at  $z \sim 2.53$ .
- 3) apparent K-magnitude  $m = 21.91 \pm 0.26$ , as well as a red color  $J-K \sim 1.6$

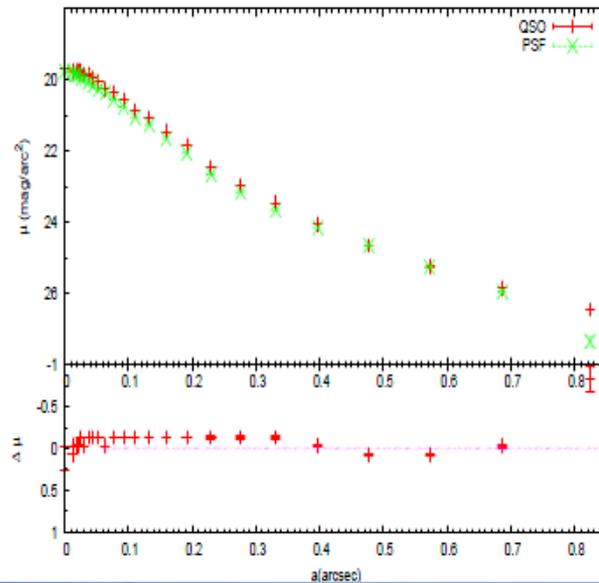
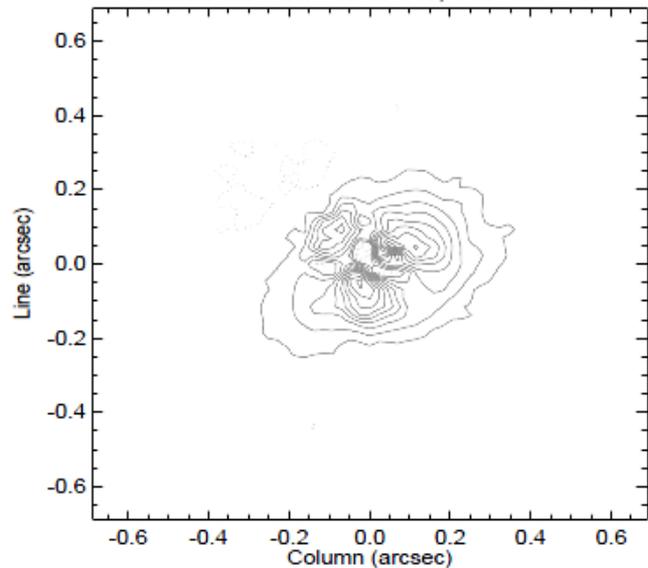
Contoured from -0.5 to 3.5, interval = 0.2



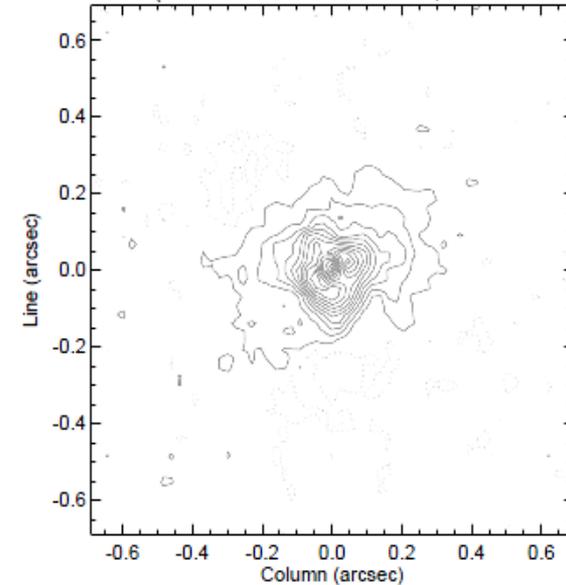
UM402 (Contoured from -0.5 to 3.7, interval = 0.2)



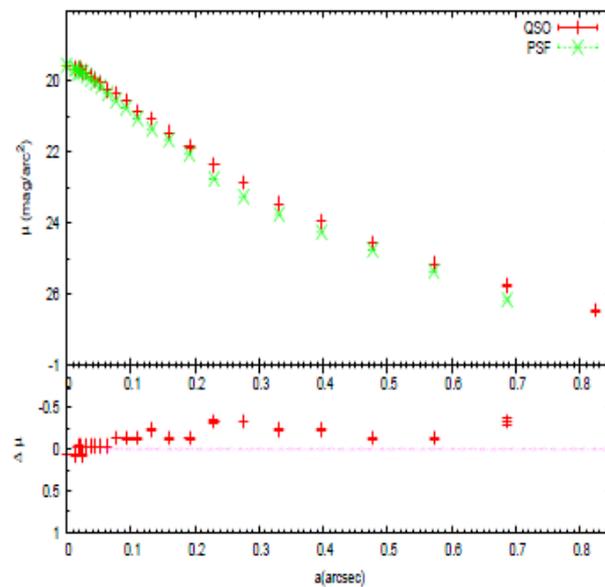
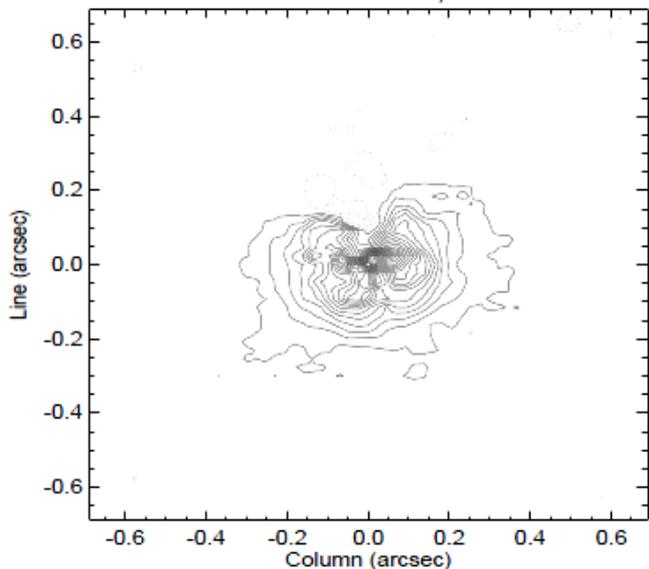
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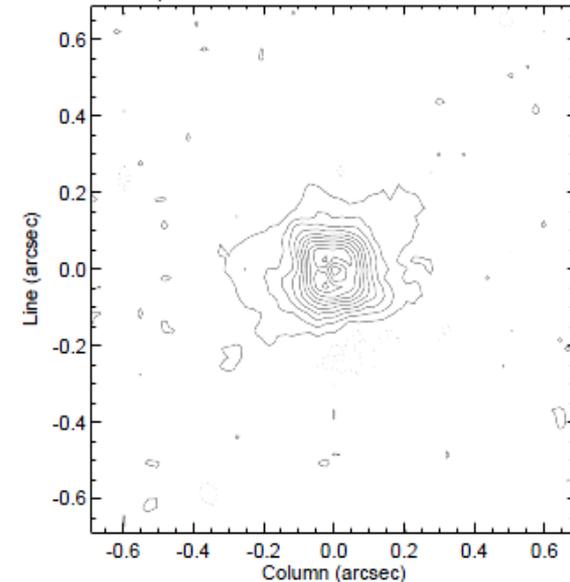
UM402 (Contoured from -0.5 to 3.7, interval = 0.2)



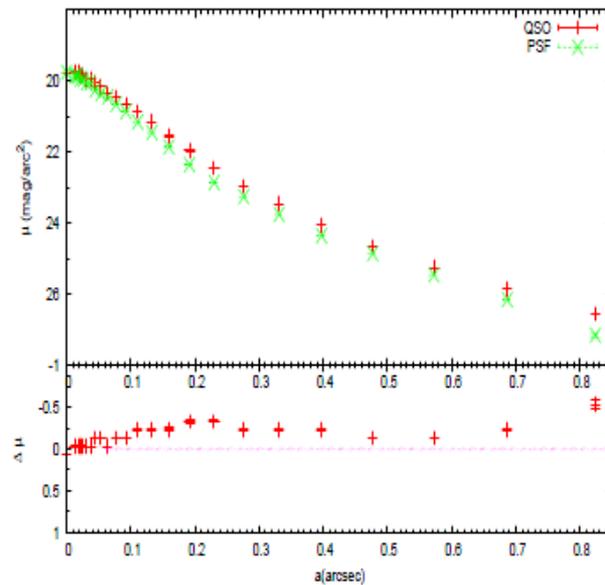
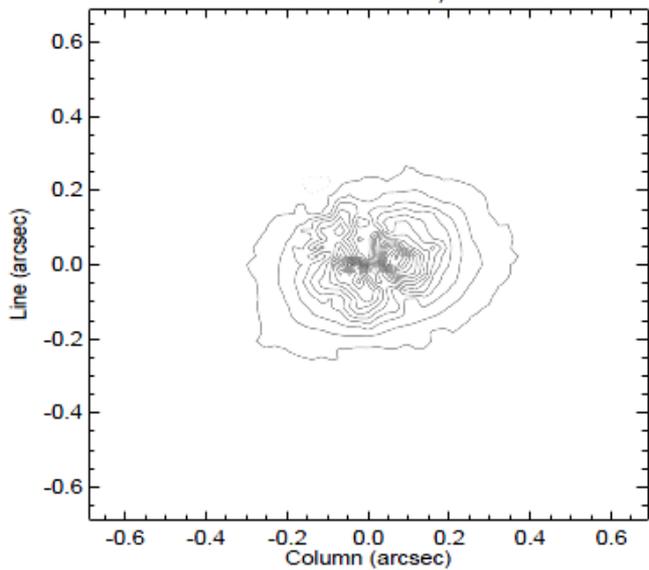
Contoured from -0.5 to 3.5, interval = 0.2



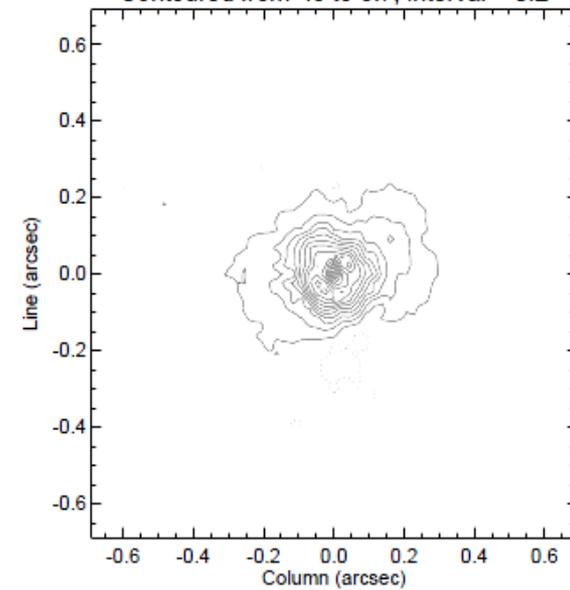
UM402 (Contoured from -0.5 to 3.7, interval = 0.2)



Contoured from -0.5 to 3.7, interval = 0.2



Contoured from -0.5 to 3.7, interval = 0.2



# QSO host galaxy decomposition and analysis

QSO images:  $I(x,y) = Q(x,y) * P(x,y) + c(x,y)$

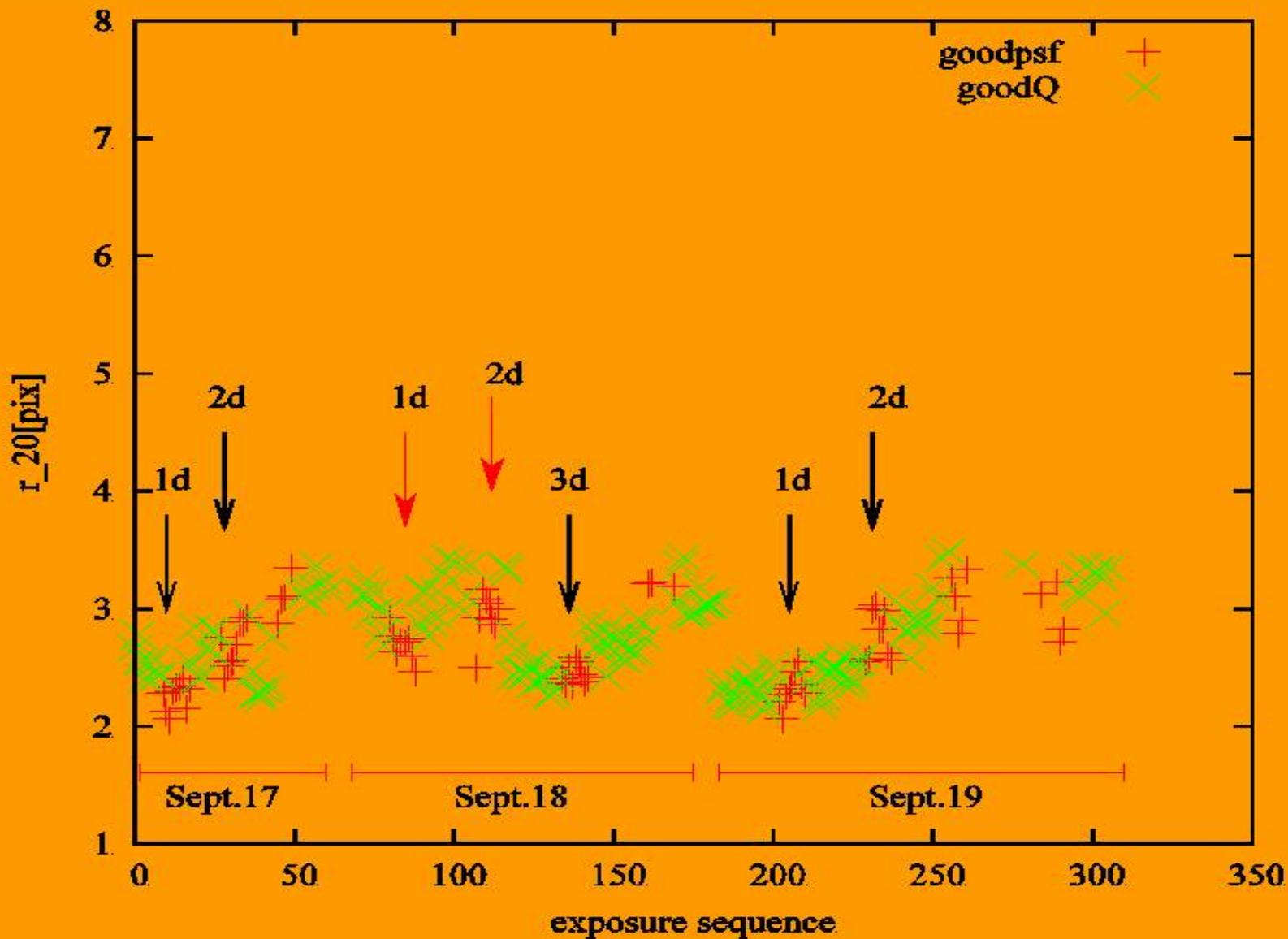
$Q(x,y) = \text{nucleus} + \text{host galaxy}$

2D modeling for PSF subtraction problems :

1) GALFIT (Peng et al. 2002)

2) AIDA (Uslenghi & Falomo, 2007)

3) GALPHAT (Yoon et al. 2011) (assuming error-free PSF)



# PSF variability: time & spatial variability

## The Karhunen-Loeve Image Projection approach (KLIP):

(assuming a library of reference PSFs, a K-L transform of these references is used to create an orthogonal basis of eigenimages on which the science target is projected (Soummer et al. 2012). )

### 1) Optimal PSF subtraction

3. Compute the estimation of the actual PSF from the projection of the target image on the truncated KL basis:

$$\hat{I} = \sum_{k=1}^{K_{klip}} \langle T, Z_k^{KL} \rangle Z_k^{KL} \quad (3)$$

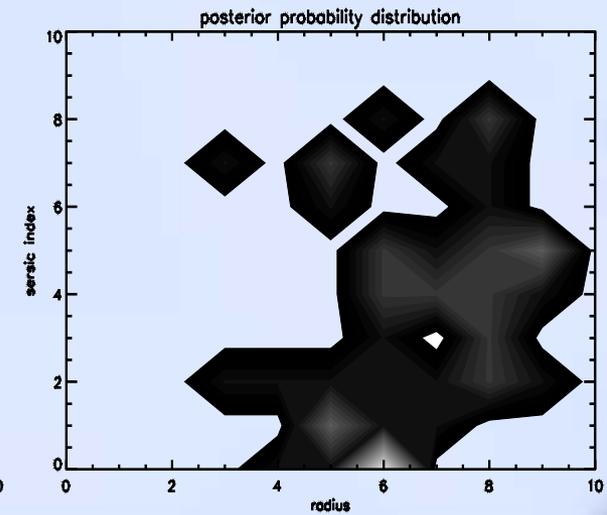
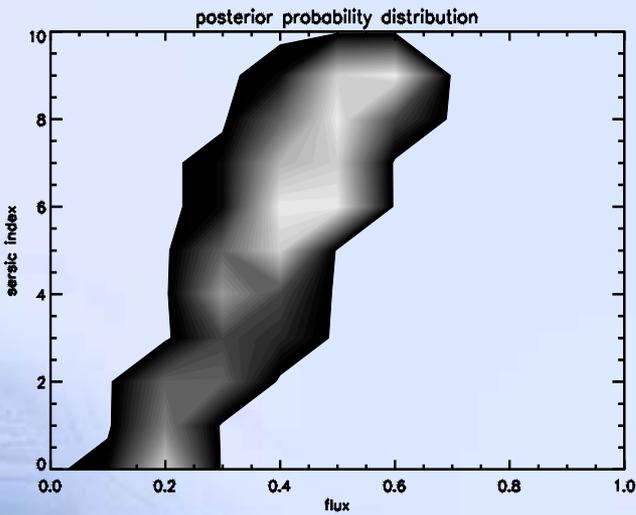
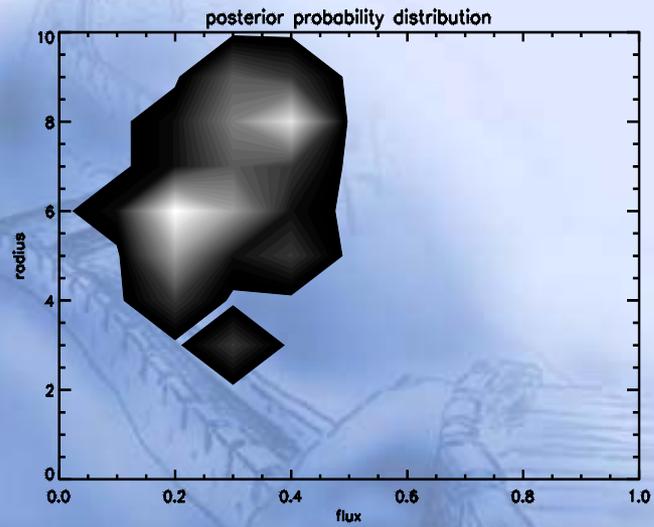
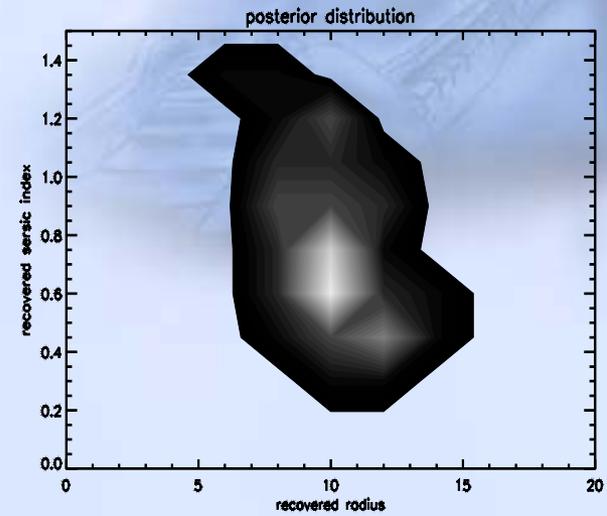
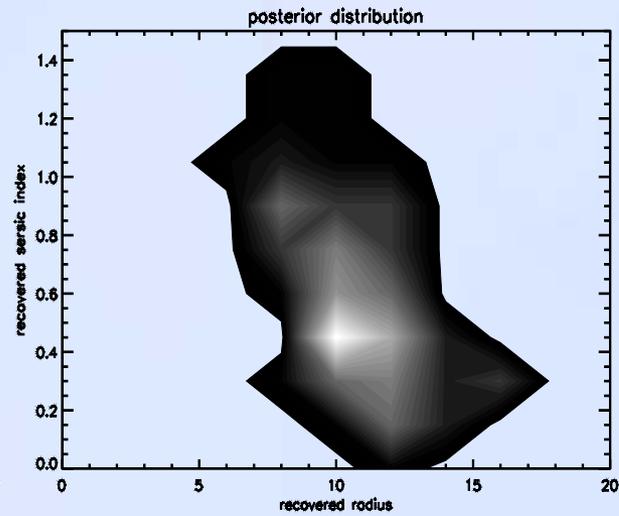
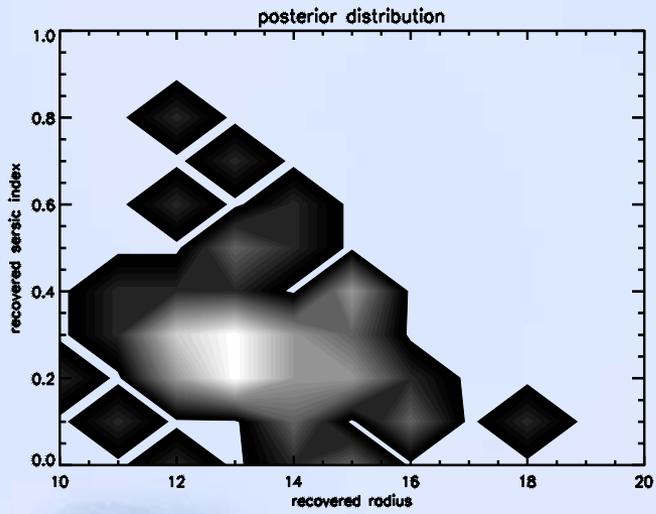
Then the final reduction image

$$F = (I - \hat{I}) + (A - \sum_{k=1}^{K_{klip}} \langle A, Z_k^{KL} \rangle Z_k^{KL}) \quad (4)$$

### 2) Further modeling using MCMC

$$\sum_{n=1}^{N_s} (F - A_{\theta} + \sum_{k=1}^{K_{klip}} \langle A_{\theta}, Z_k^{KL} \rangle Z_k^{KL})^2$$

(He et al. in preparation)



Discussion notes:

