QSO host galaxies at z~3:
Image reconstruction techniques

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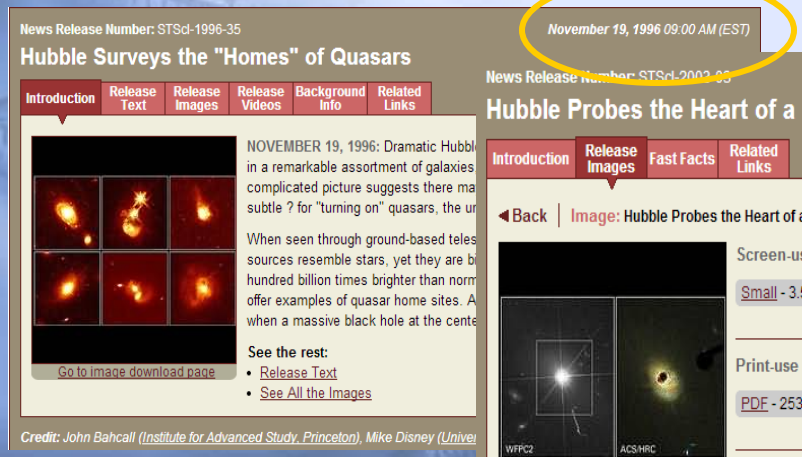
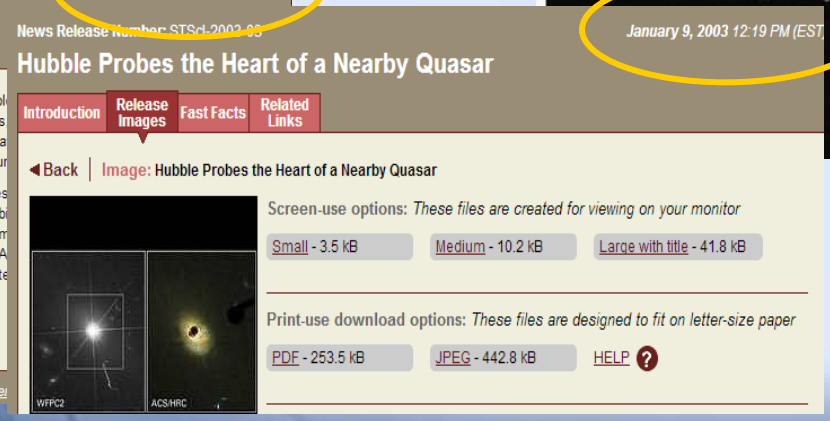
Motivation

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 ?

z=7.1, most distant known qso



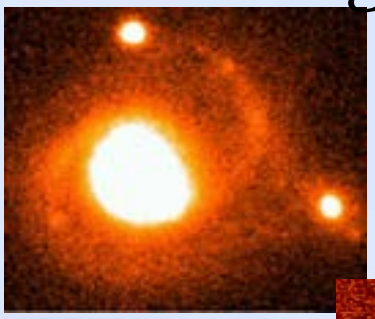


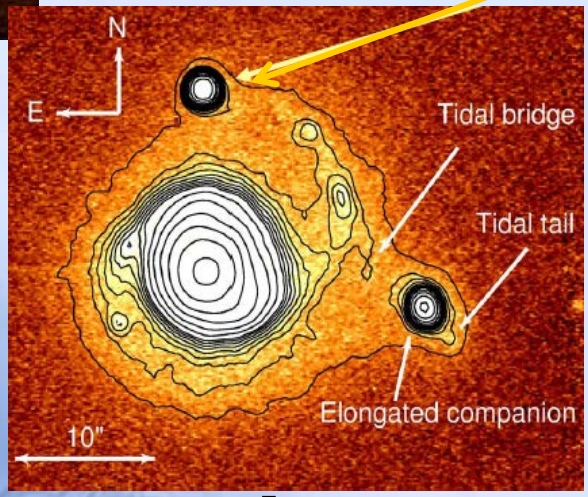
Discovered by UKIDSS; Reported in June, 2011

Motivation

The I Zw 1 System

J-band image (ISAAC+VLT)





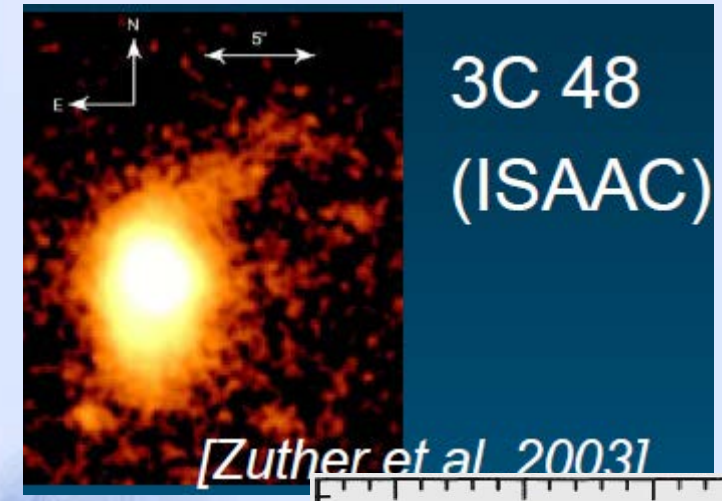
Scharwachter et al. 2003;

Courtesy: Julia Scharwacher's ppt

@20 April 2007-Huatulco

1. **z=0.06**
2. **Palomar Green QSO with a spiral host**
3. **Possily 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?**

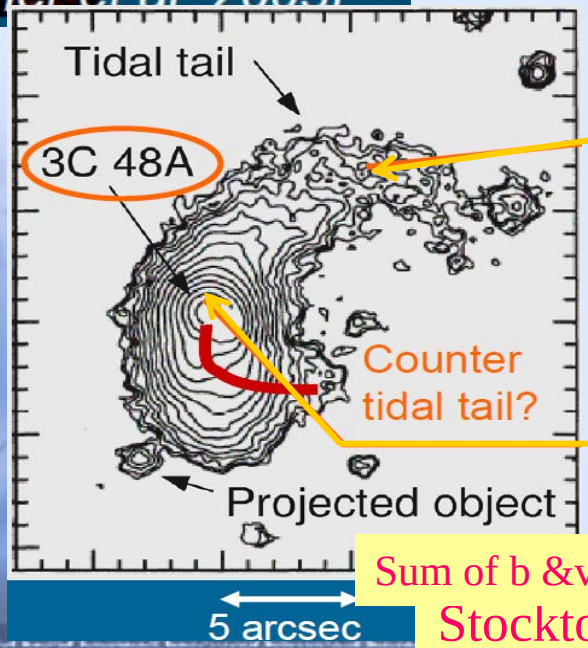
Motivation



1. z=0.367
2. radio source
3. Mv ~ -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

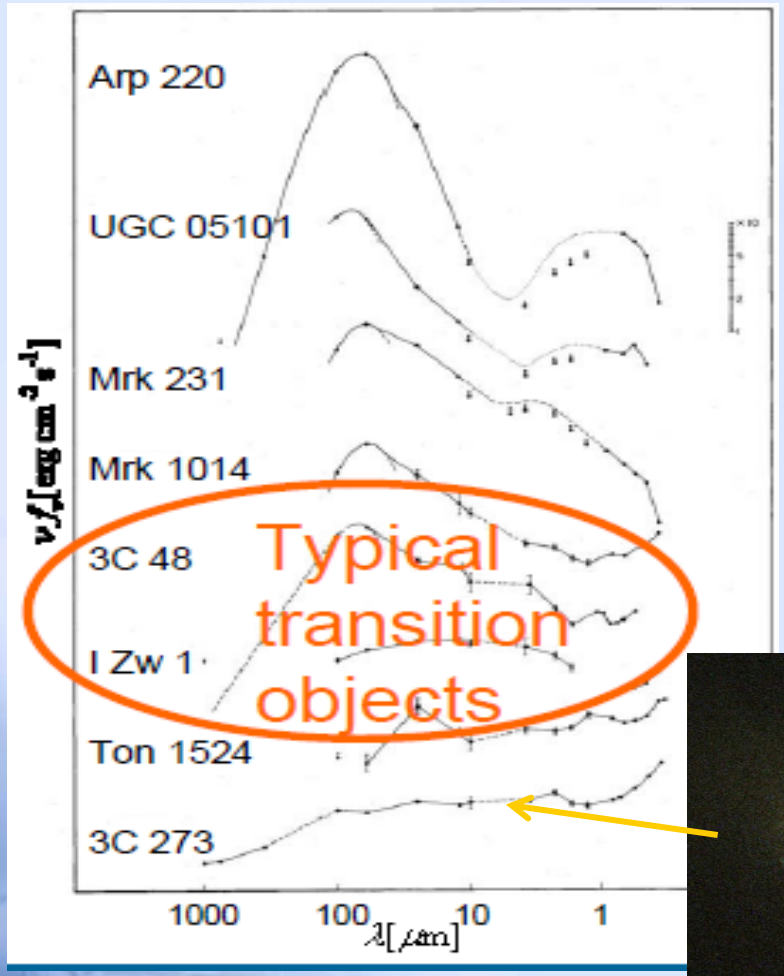
Motivation

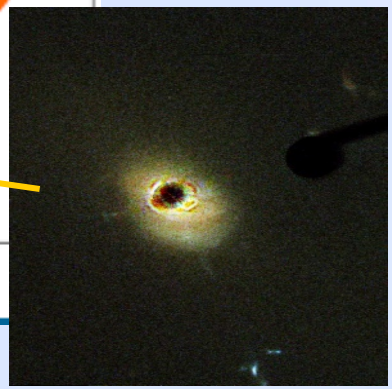
Sanders et al. 1998

Merger-driven Evolutionary sequence from ULIGs to QSO

Signs of two galaxy centers, as a major meger

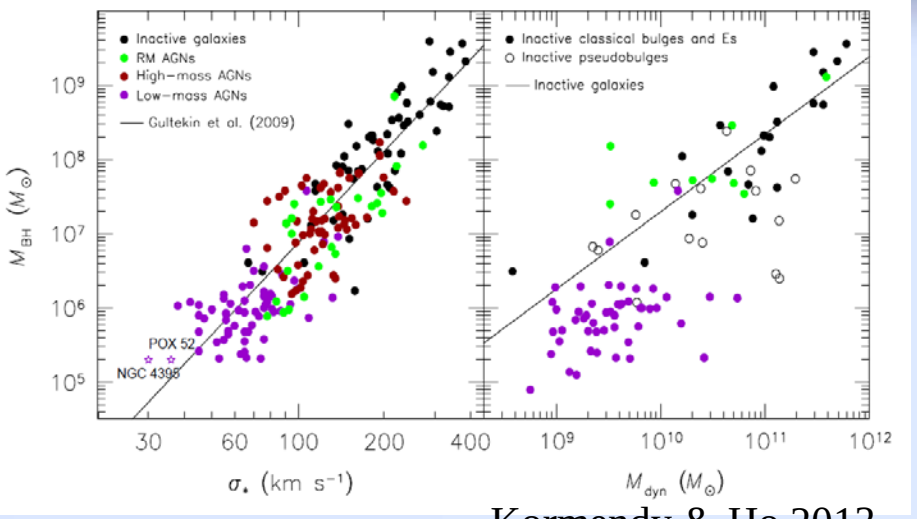
Signs of SF enhanced by tidal interaction, possibly a minor meger





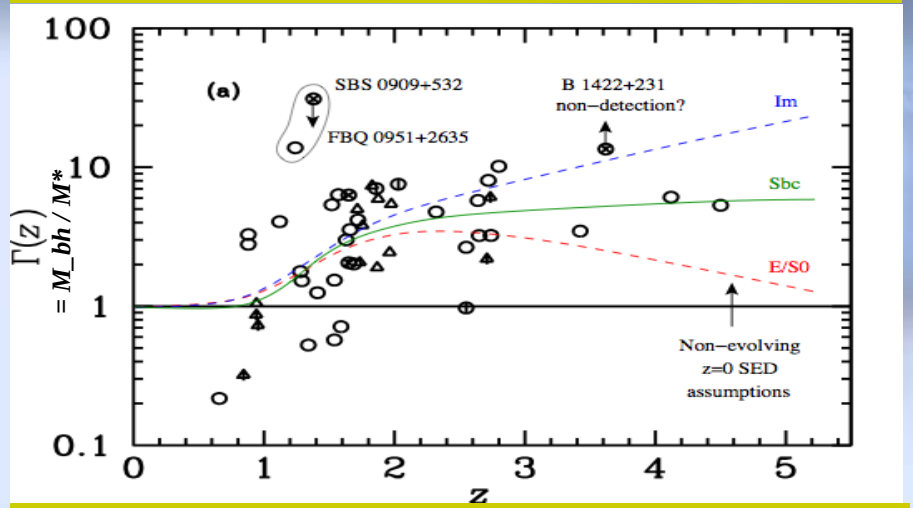
ACS's coronagraph reveals a spiral plume wound around the QSO, a red dust lane, a blue arc and clump in the path of the jet blasted from the QSO.

Scaling relation in BH mass domain



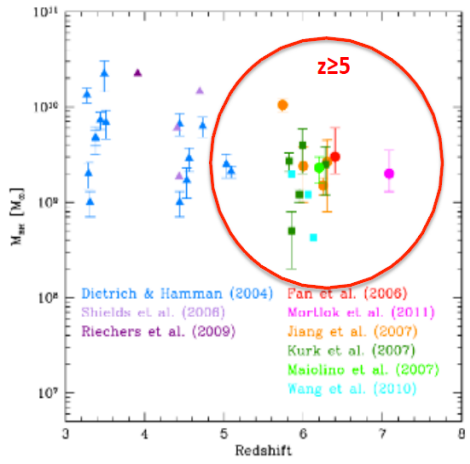
Kormendy & Ho 2013

Scaling relation over cosmic time



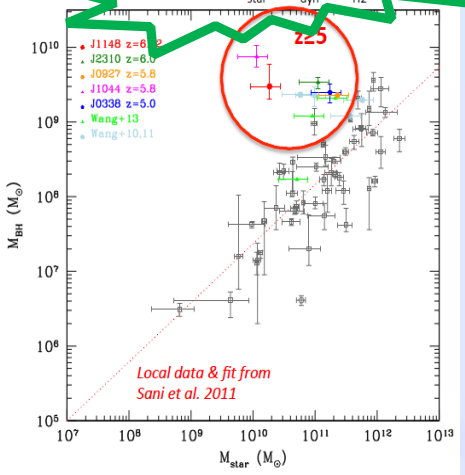
The circles are the lensed hosts and the triangles are the directly imaged hosts from Ridgway et al 2001 and Kukula et al. 2001. Points with a vertical line may represent the low limits (Peng et al. 2006).

The growth of super massive black holes

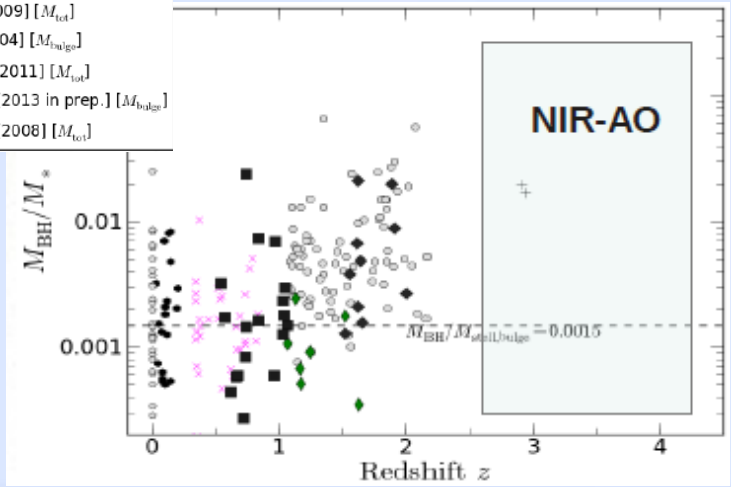


Link to the host galaxies

NB: at z>5 $M_{star} = M_{dyn} - M_{H2}$



Host galaxies of QSOs at z~3

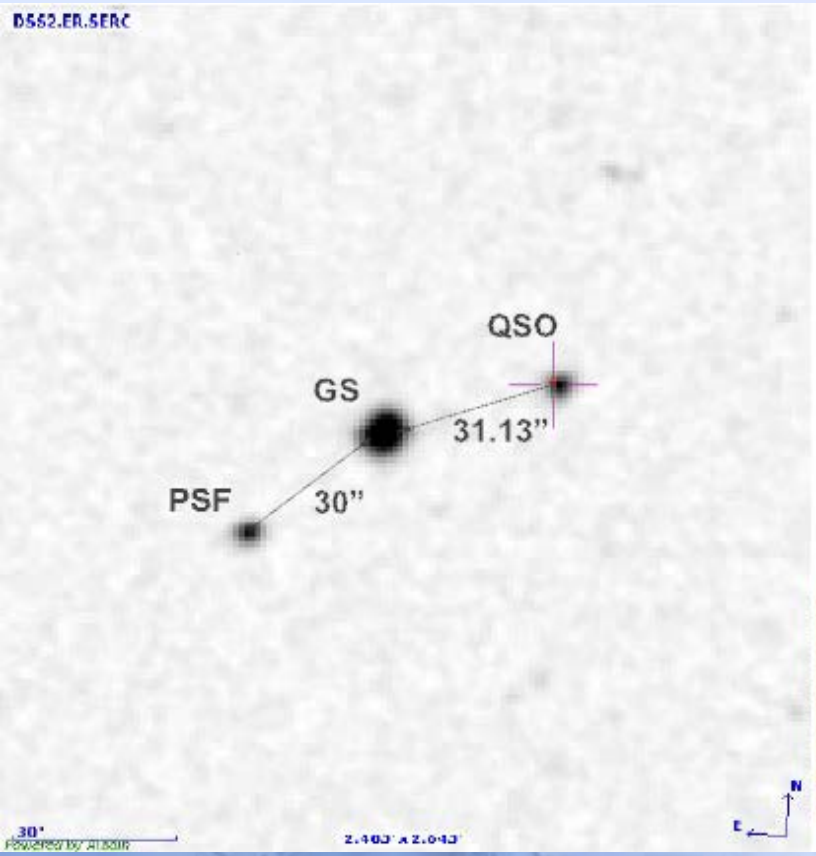


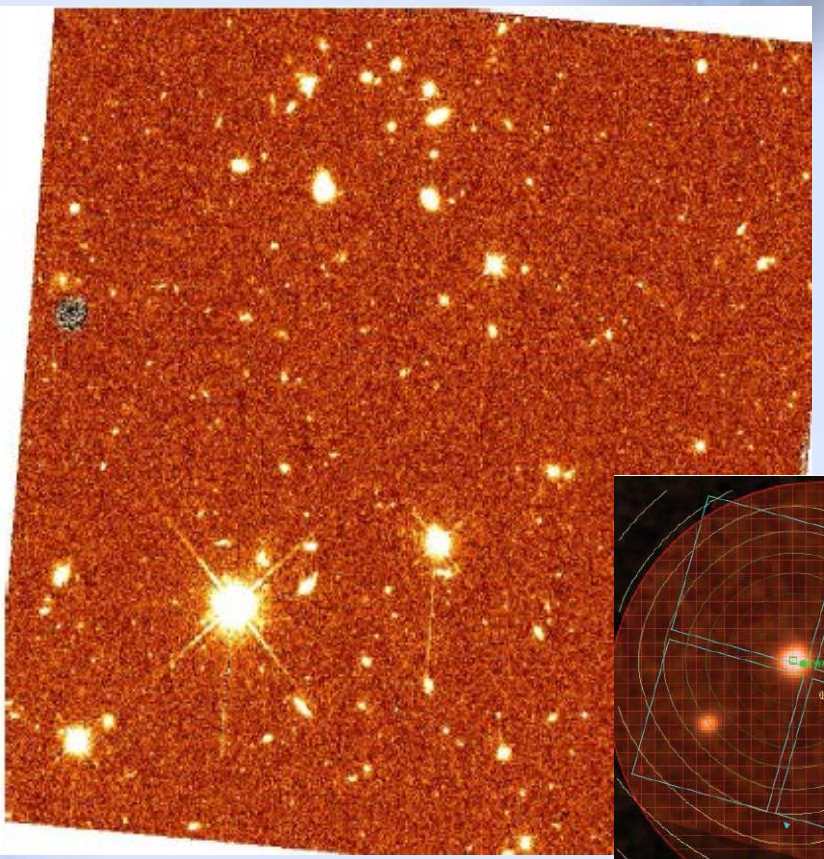
Courtesy: Rosa Valiante's presentation

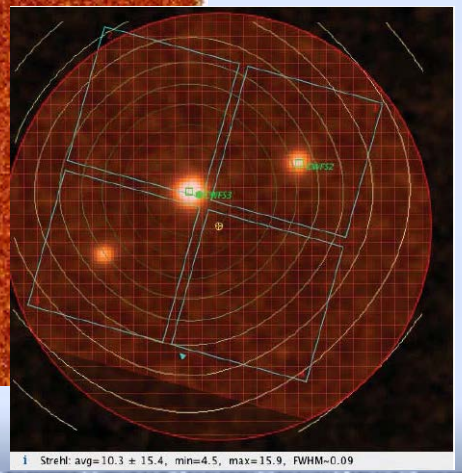
Walter et al.2004;Peng et al. 2006;McLure et al. 2006;Riechers et al. 2008;Merloni et al. 2010;Wang et al. 2010,2012

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

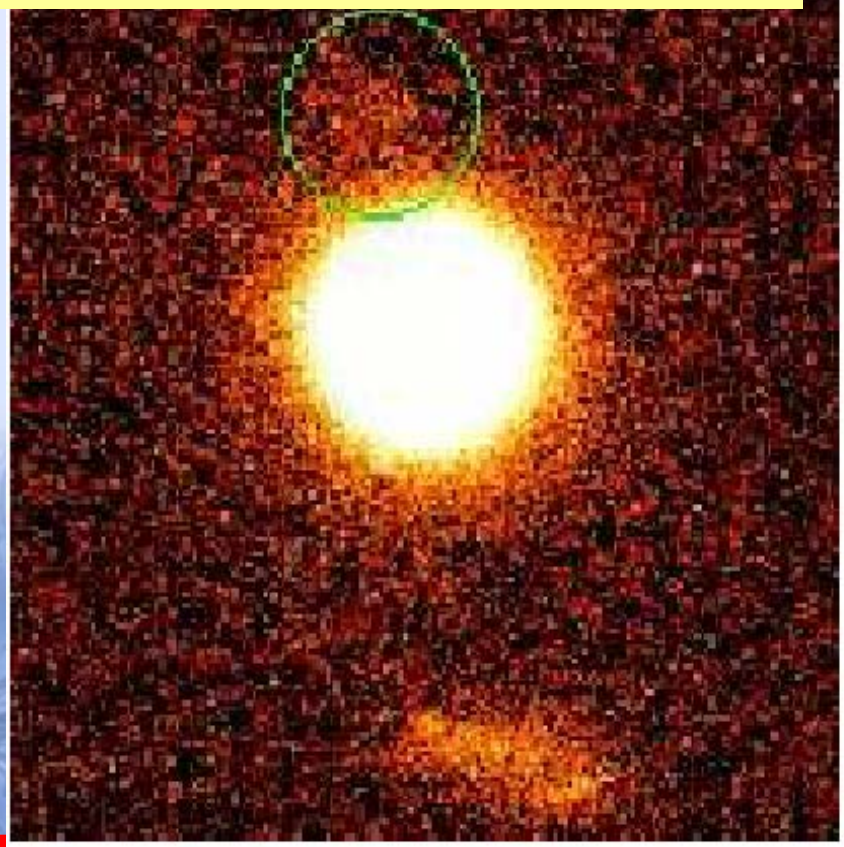


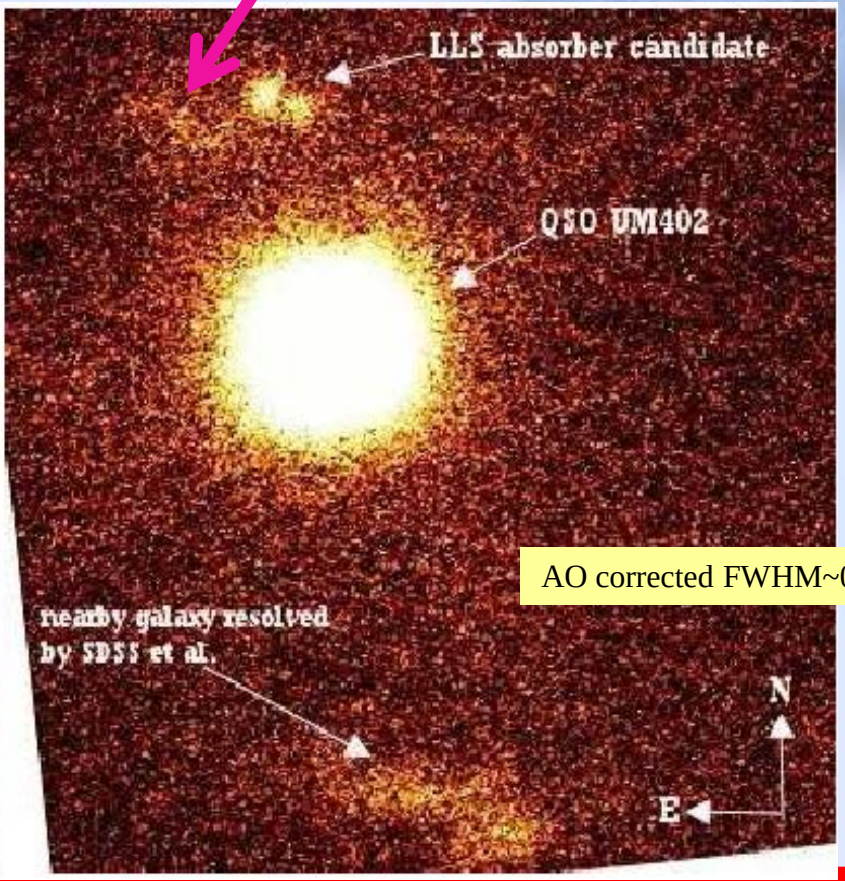




IRCS+AO observation of UM402 at z~3

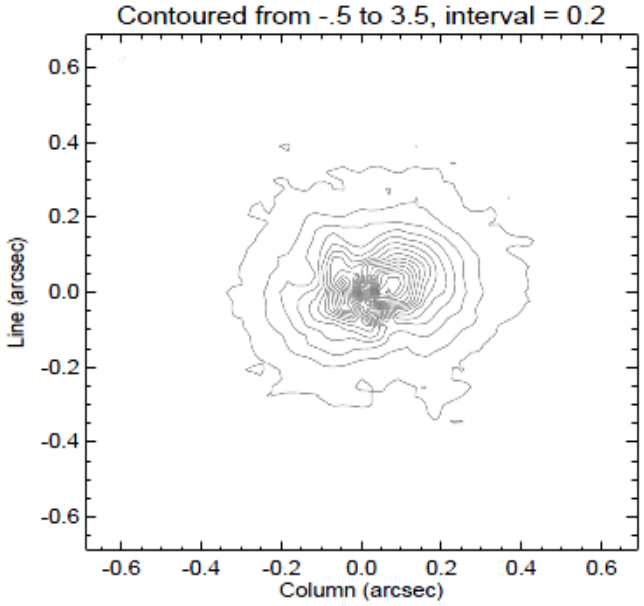
5” x 5”, AO corrected FWHM~0.”2

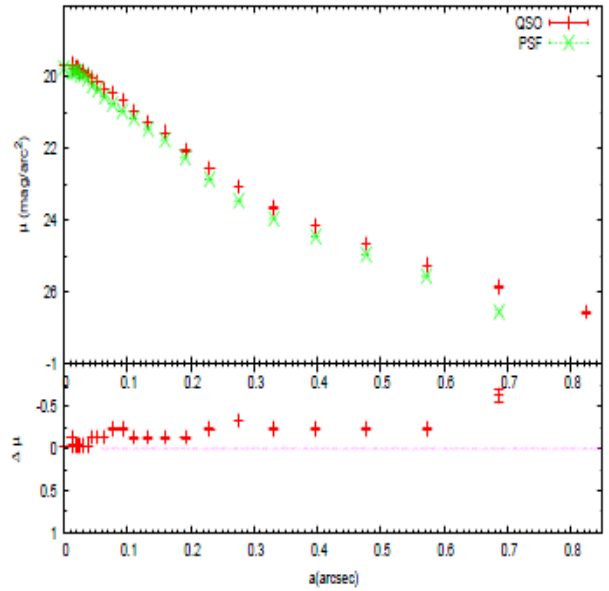


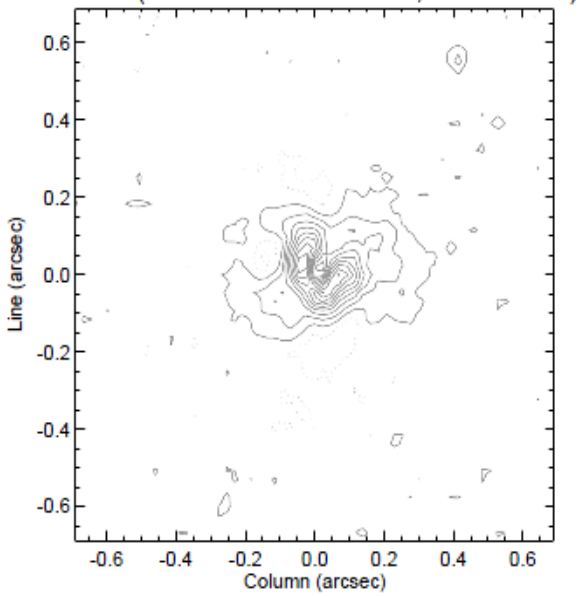


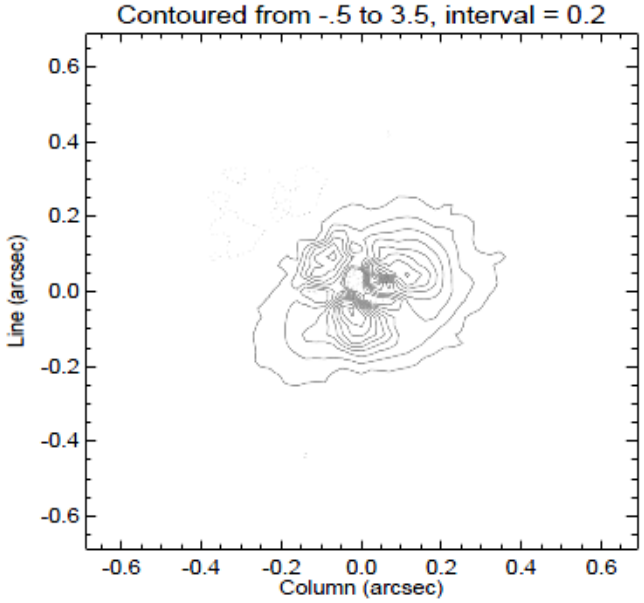
1) 2”.4 north of the QSO sightline. The candidate is indicated in the image.
2) impact parameter of ~ 19.6 kpc, if at z~2.53.
3) apparent K-magnitude m=21.91+/-0.26, as well as a red color J-K~1.6

Wang et al. 2013, 2015


Contoured from -.5 to 3.5, interval = 0.2
Line (arcsec)
Column (arcsec)


QSO
PSF
μ (mag/arc²)
Δ μ
a(arcsec)


UM402 (Contoured from -.5 to 3.7, interval = 0.2)
Line (arcsec)
Column (arcsec)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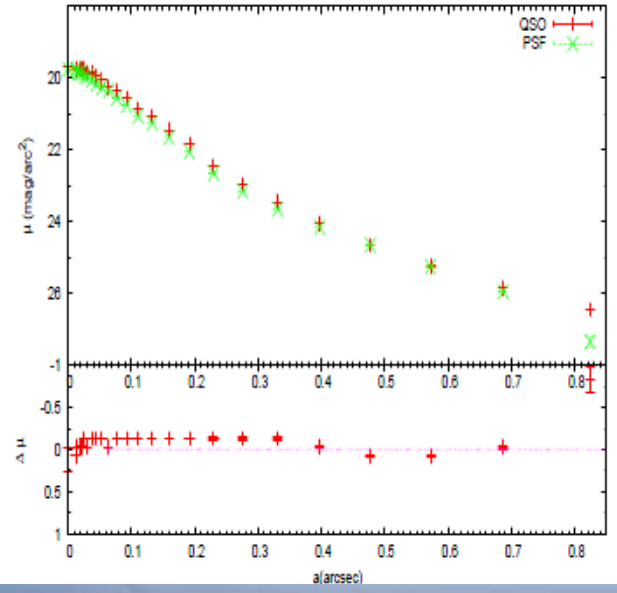
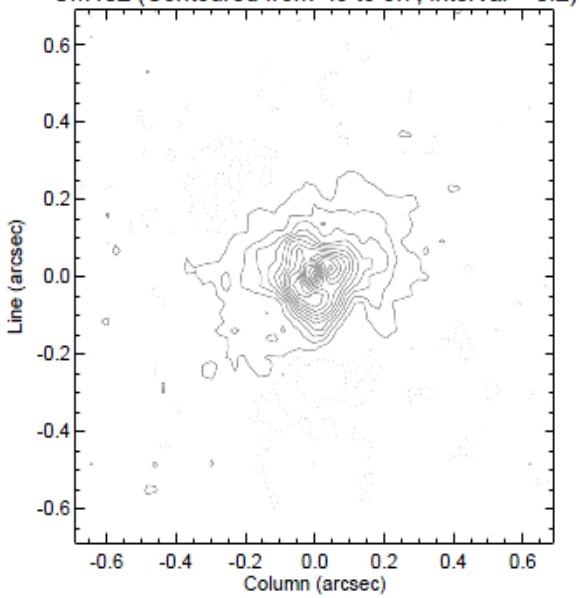
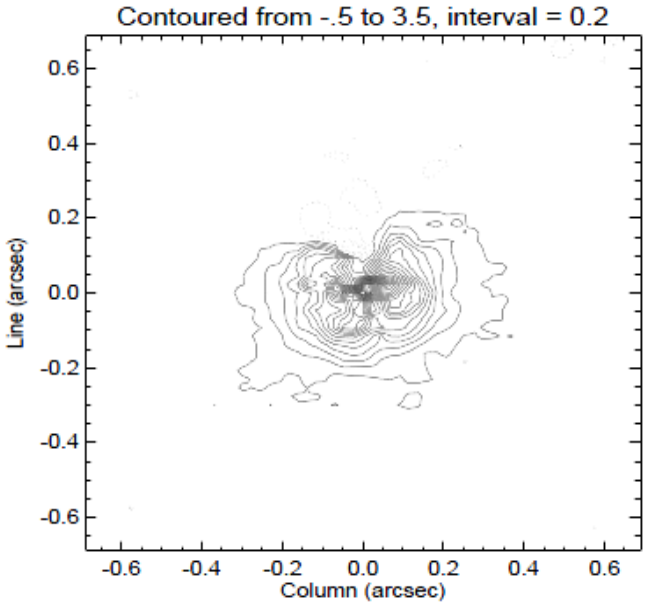
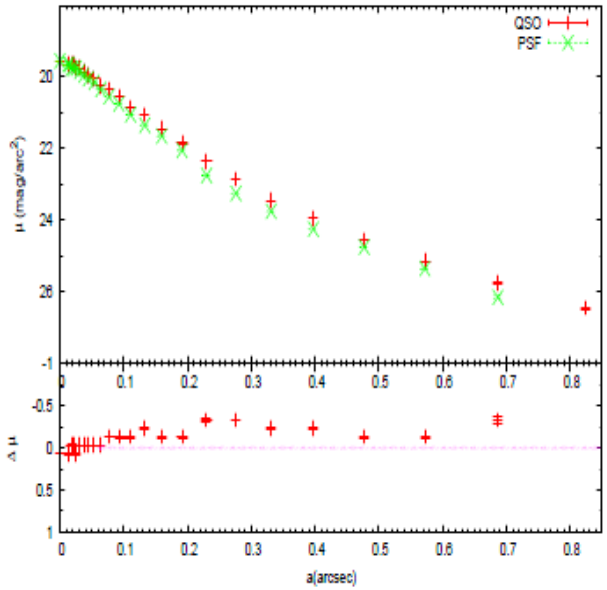
Column (arcsec)


QSO
PSF
μ (mag/arc²)
Δ μ
a(arcsec)


UM402 (Contoured from -.5 to 3.7, interval = 0.2)
Line (arcsec)
Column (arcsec)


Contoured from -.5 to 3.5, interval = 0.2
Line (arcsec)
Column (arcsec)


QSO
PSF
μ (mag/arc²)
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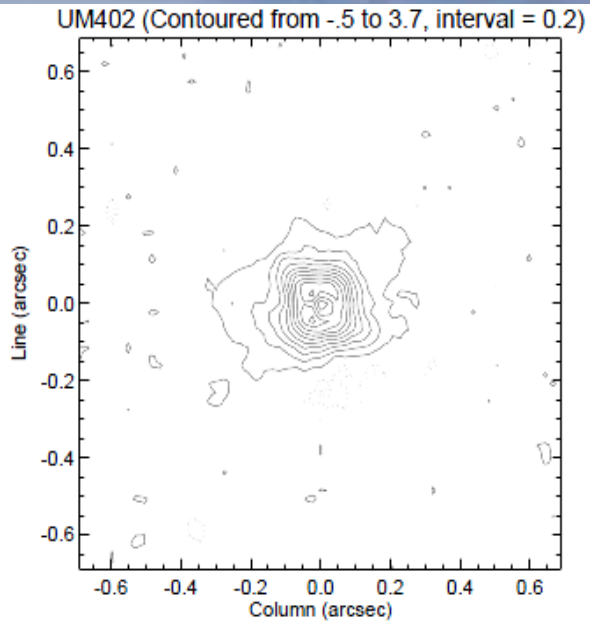
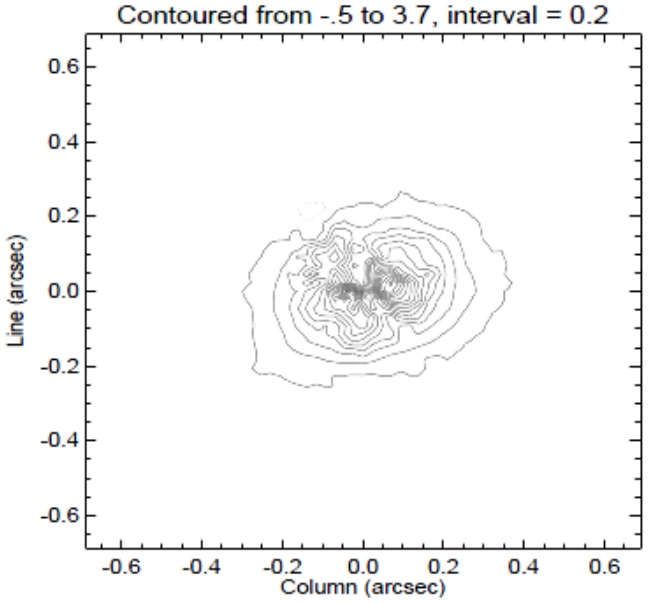
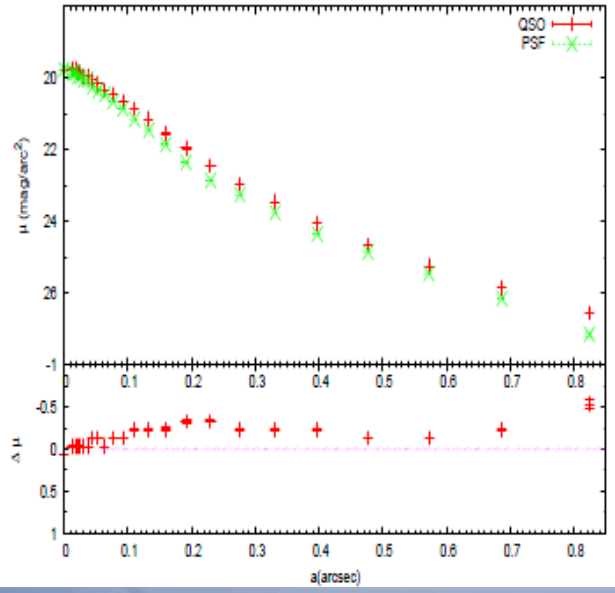
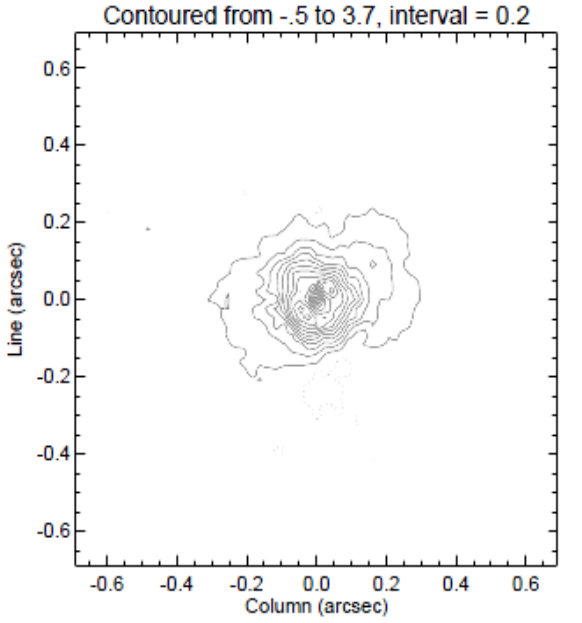

UM402 (Contoured from -.5 to 3.7, interval = 0.2)
Line (arcsec)
Column (arcsec)


Contoured from -.5 to 3.7, interval = 0.2
Line (arcsec)
Column (arcsec)


QSO
PSF
μ (mag/arc²)
Δ μ
a(arcsec)


Contoured from -.5 to 3.7, interval = 0.2
Line (arcsec)
Column (arcsec)

QSO host galaxy decomposition and analysis

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

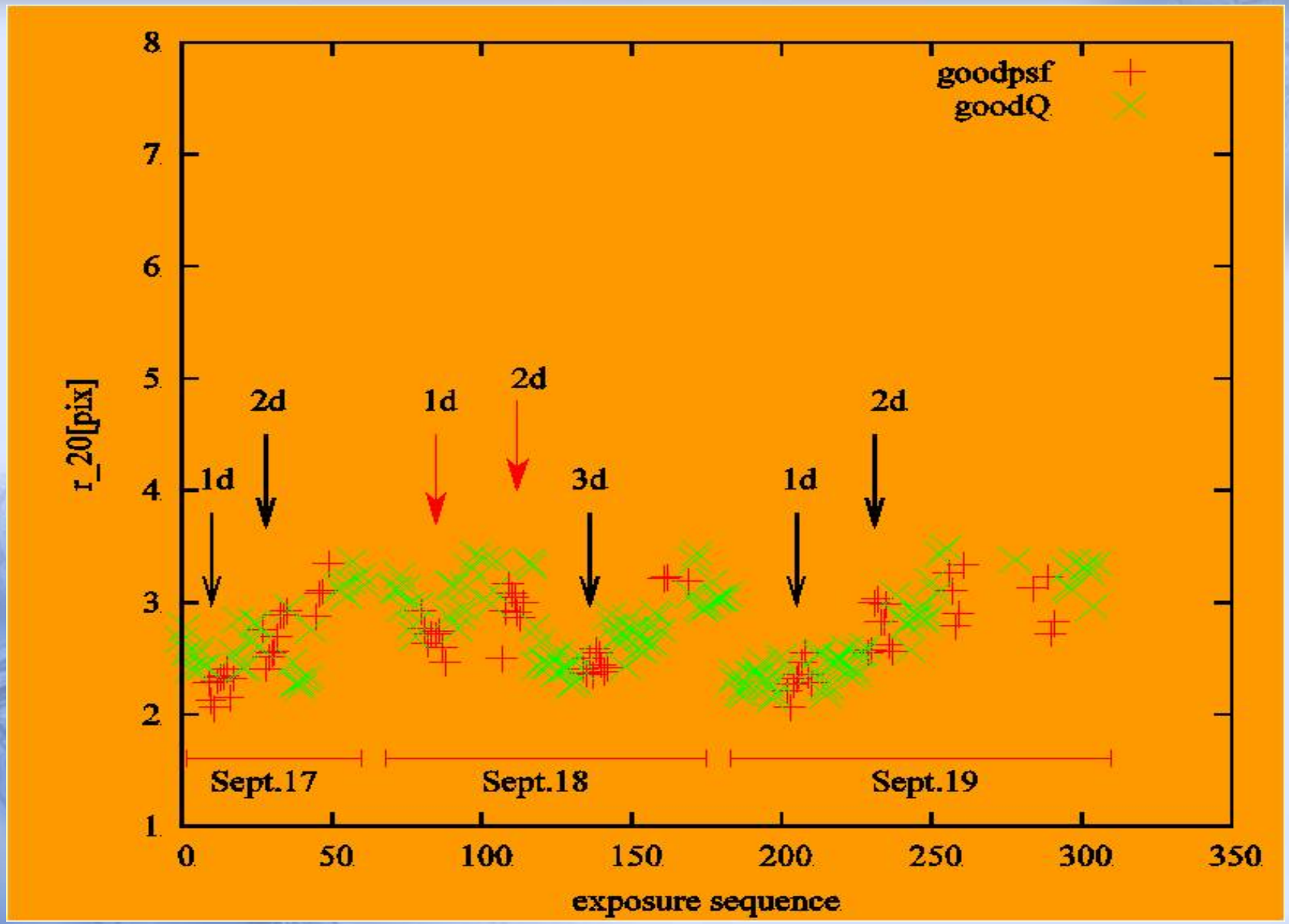
$Q(x,y)$ =nucleus +host galaxy

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)


goodpsf
goodQ
r_20[pix]
exposure sequence
1d
2d
1d
2d
3d
1d
2d
Sept.17
Sept.18
Sept.19
0
50
100
150
200
250
300
350
1
2
3
4
5
6
7
8

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:

$$\hat{I} = \sum_{k=1}^{K_{klip}} < T, Z_k^{KL} > Z_k^{KL} \qquad (3)$$

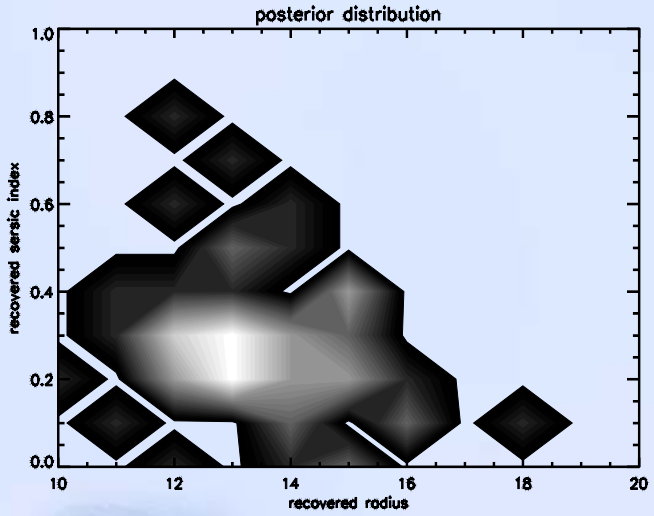
Then the final reduction image

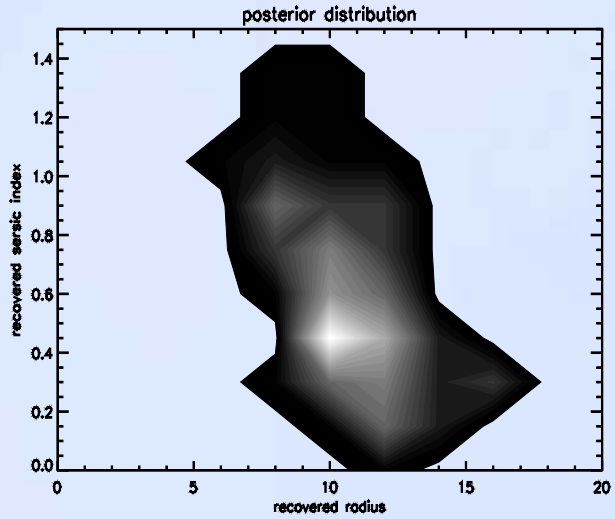
$$F = (I - \hat{I}) + (A - \sum_{k=1}^{K_{klip}} < A, Z_k^{KL} > Z_k^{KL}) \qquad (4)$$

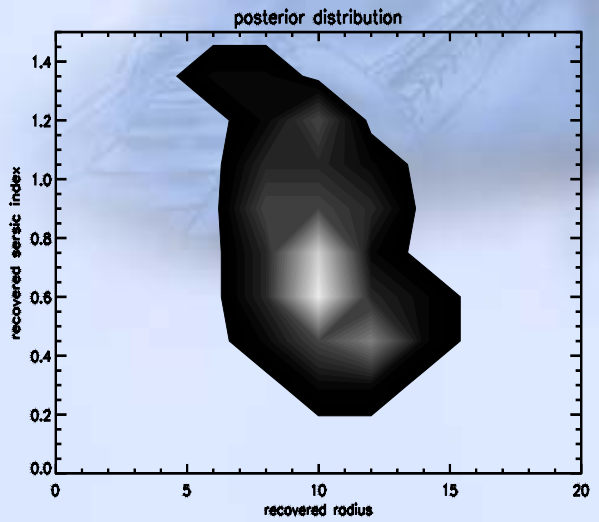
2) Further modeling using MCMC

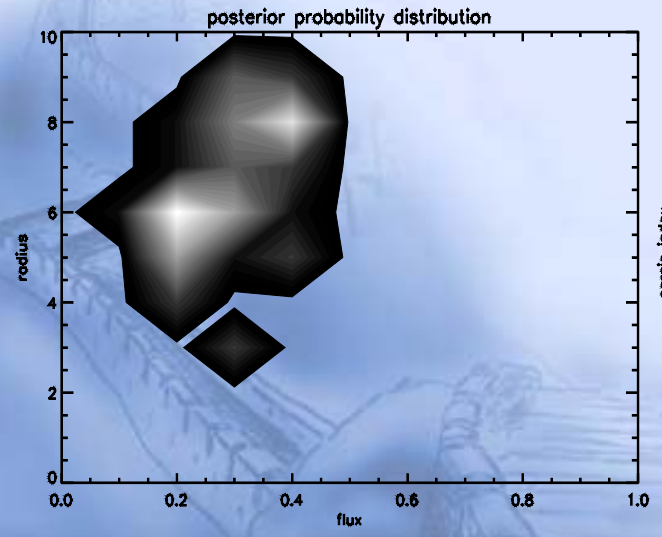
$$\sum_{n=1}^{N_s} (F - A_\theta + \sum_{k=1}^{K_{klip}} < A_\theta, Z_k^{KL} > Z_k^{KL})^2$$

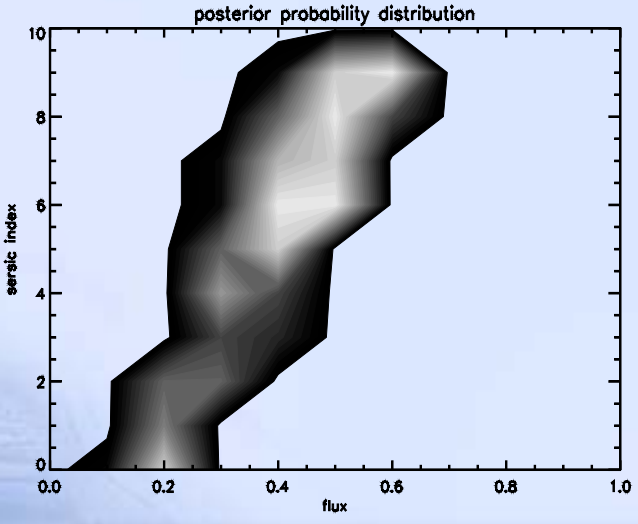
(He et al. in preparation)

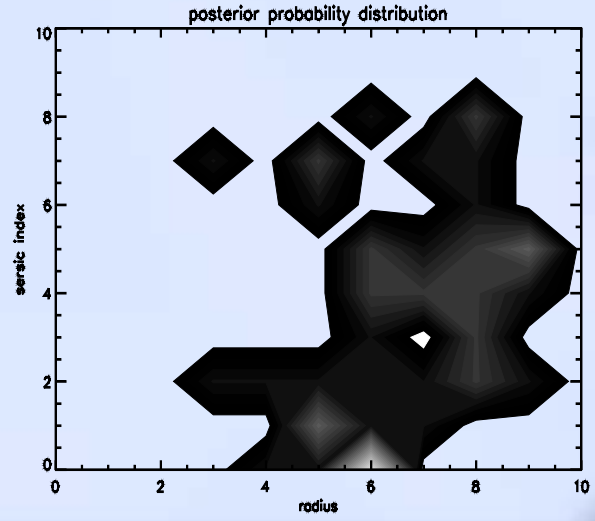












Discussion notes: