9th 东亚天文学会议
2013/10/14–18 @台湾

Studies on galaxy formation using high-z QSO absorption line systems

Yiping Wang 王益萍
National Astronomical Observatories of China

Collaborators: T. Yamada, I. Tanaka, M. Iye, T. Ji, H. J. Tian, T. Misawa , Y. Minowa , K. Okoshi, Y. Yao et al.

Outline

1) Galaxy formation overview
2) Current status on QAL system studies
3) Subaru deep imaging of high-z QSO fields

Galaxy formation: puzzles

(I) Massive galaxy formation: when and how?

(II) High-z galaxies are compact? no big disks at high-z?

(III) Late type galaxy evolution, "closed" box?

Galaxy formation studies: methods

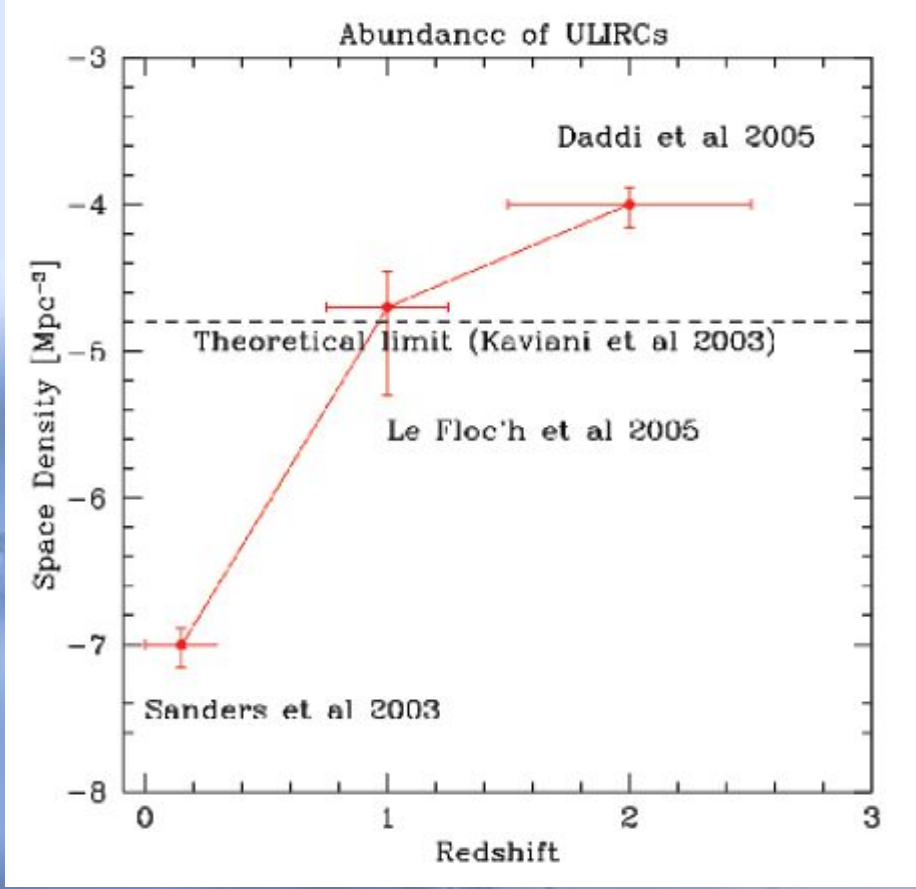
(I) sample selection by luminosity, mass, morphology et al. (galaxy surveys, flux-limited sample)

(II) sample selection by cross section (QAL)

Massive galaxy formation: ------when and how?

ULIRGs: Lir~10^12 Lsun, SFR~200Msun/yr
stellar mass~10^11 Msun

Daddi et al. ApJ 670, 156, 2007



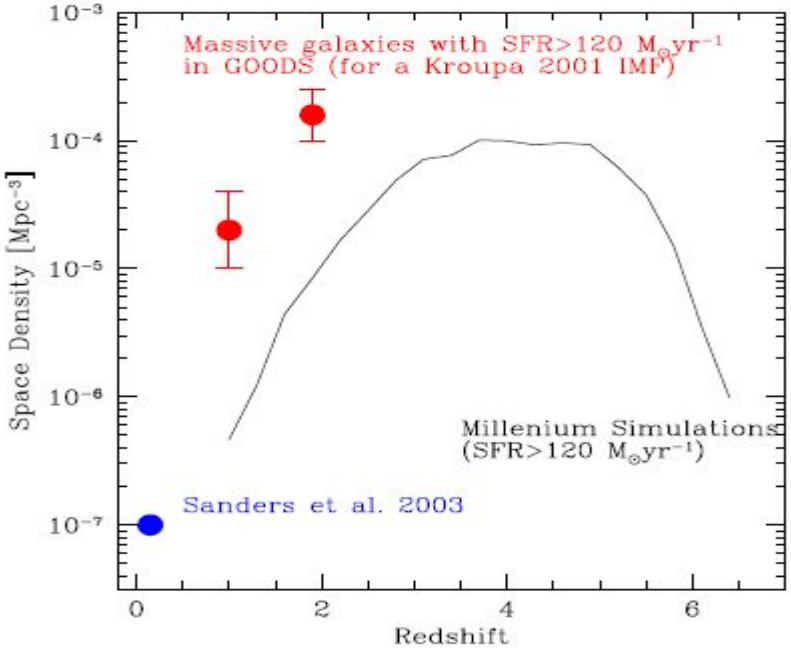
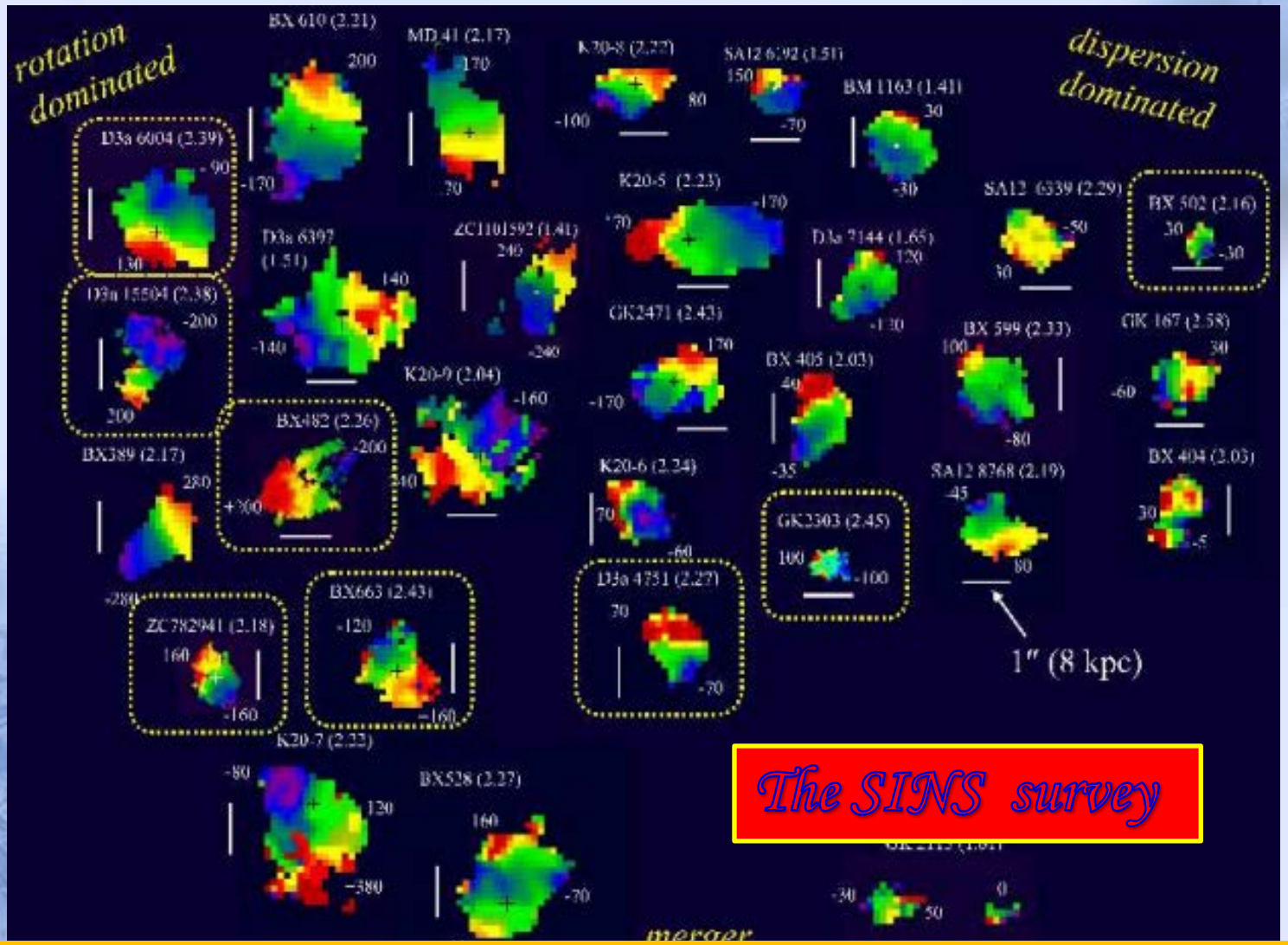


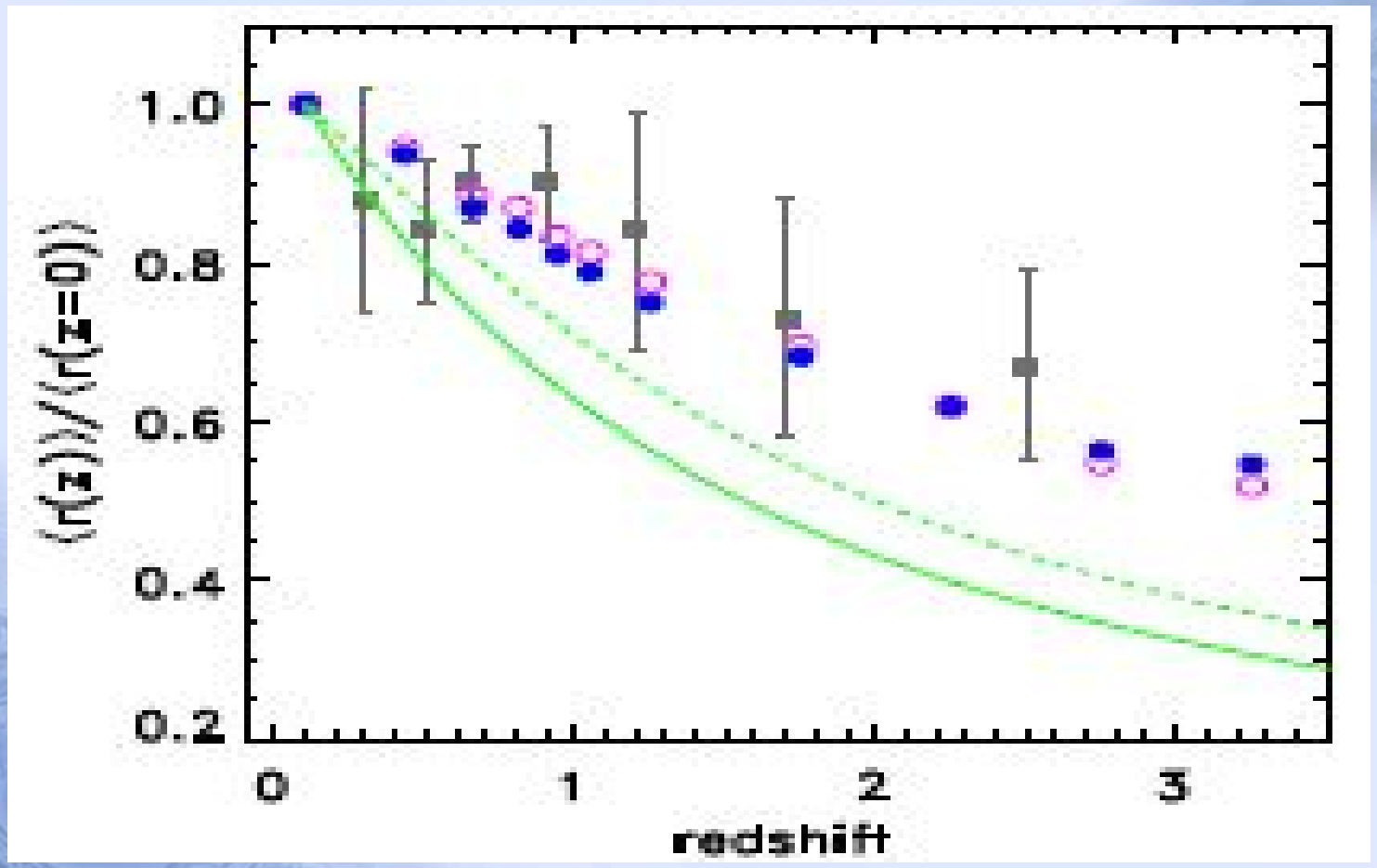
FIG. 15.— The space density of ULIRGs (excluding individually detected AGNs) at $z = 2$ and $z = 1$ inferred from GOODS (red filled circles) is compared to the local density from Sanders et al. (2003; filled green circle) and to predictions of star-forming galaxy density from the mock lightcones based on the Millennium simulation (Kitzbichler & White 2007). The rate of $120\,M_\odot$ yr^{-1} corresponds to a ULIRG in the case of a Kroupa (2001) or Chabrier (2002) IMF.

Large, rotating disks are important at high-z



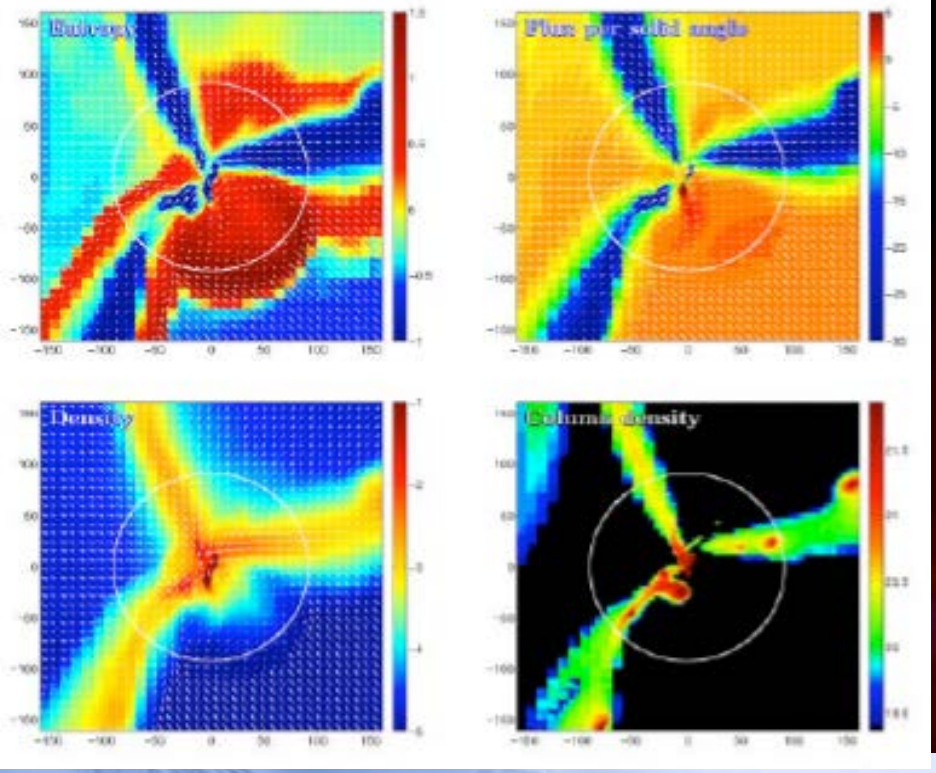
SINFONI Integral field spectroscopy of z~2 star forming galaxies, Forster Schreiber et al. 2009, ApJ 706, 1364

Size evolution of disks

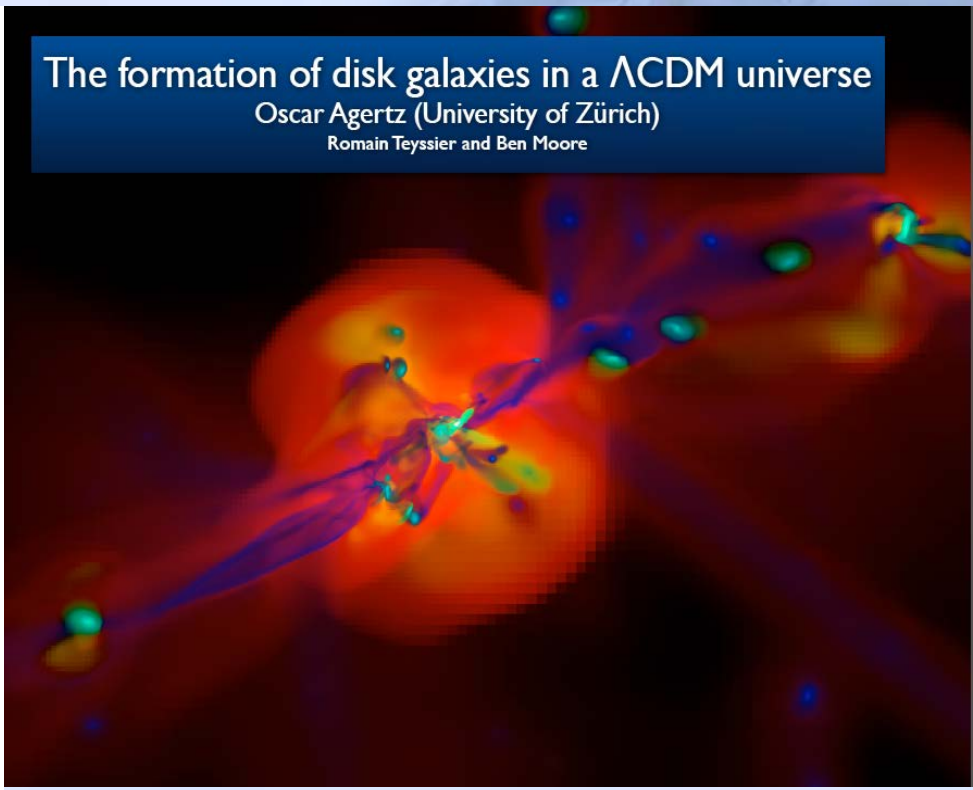


Size evolution of disks with stellar mass>3X10^10 Msun. Filled squares with error bars are the data from Trujillo et al. 2006. Circles and lines show the revised model prediction by Somerville et al. 2008 and that of Mo et al. 1998.

High-z disks formed mainly by cold flows?

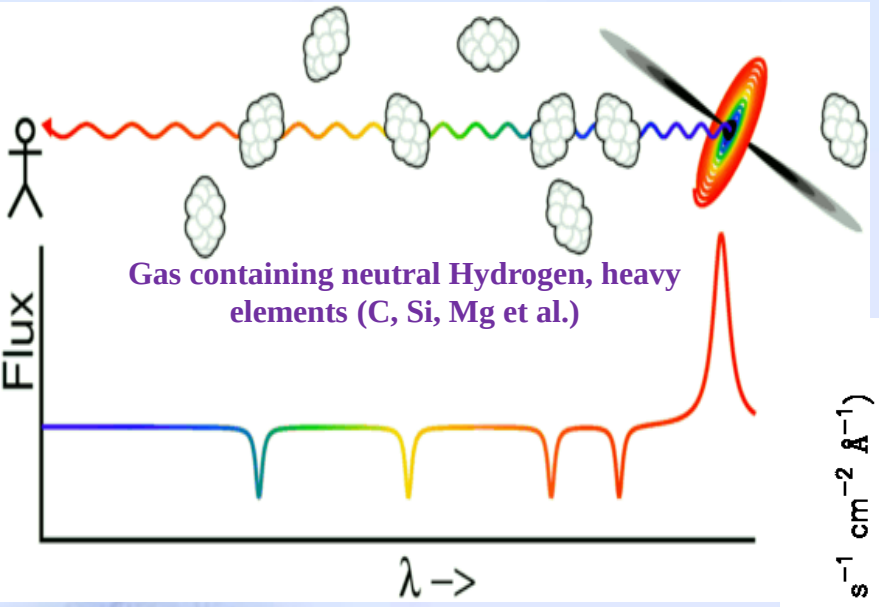


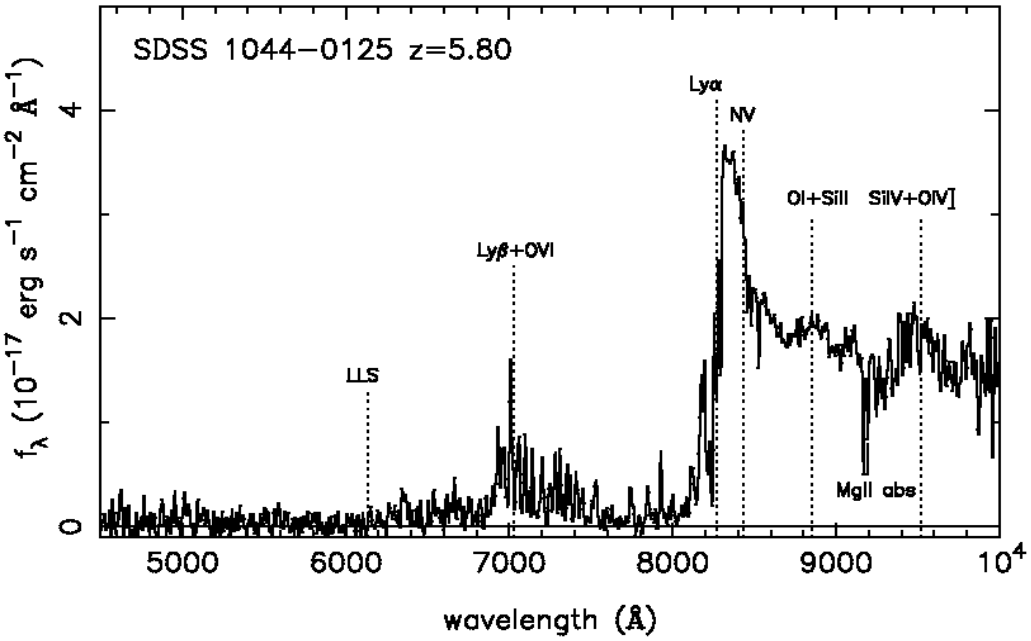
Dekel et al. Nature 457, 451, 2009



Agertz et al. MNRAS 397,L64, 2009

1. QSO aborption line systems





LL Systems are a class of QAL system. They are defined to be optically thick at the Lyman Limit, which generally implies N(HI)> 10^17 cm^-2. They all show metals.

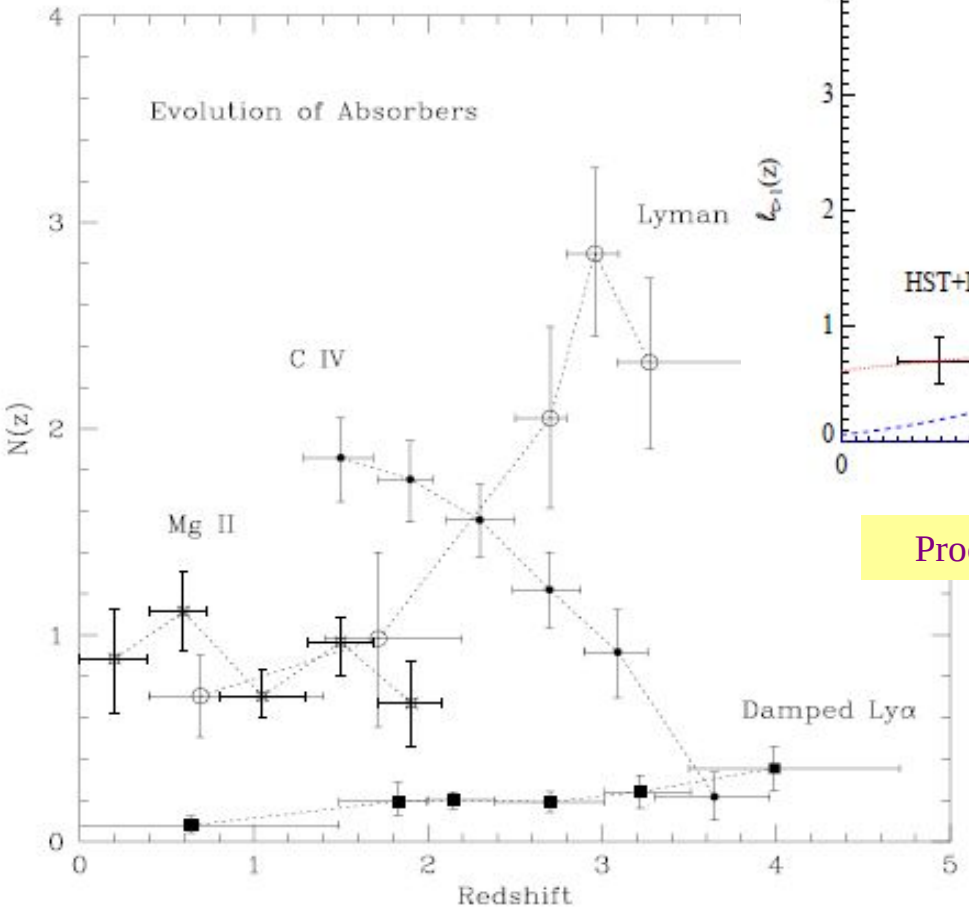
2. Main QSO absorption line systems

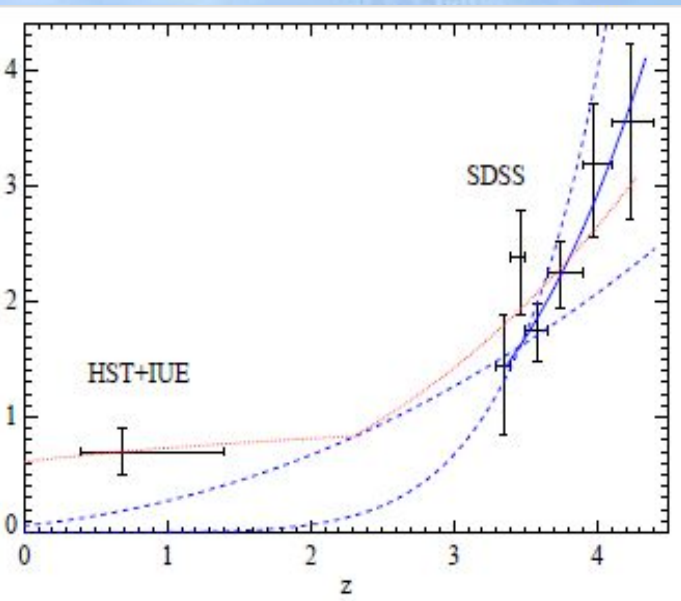
1) Lyman alpha forest (N_HI < ~ 1.6 x 10^17 cm^2):

2) Lyman Limit system (**1.6 x 10^17 ~ < N_HI < ~ 10^20 cm^2**)

3) Damped Lyman alpha system (N_HI > ~ 10^20 cm^2)

4) Metal absorption lines (e.g. C, Si, Mg..)



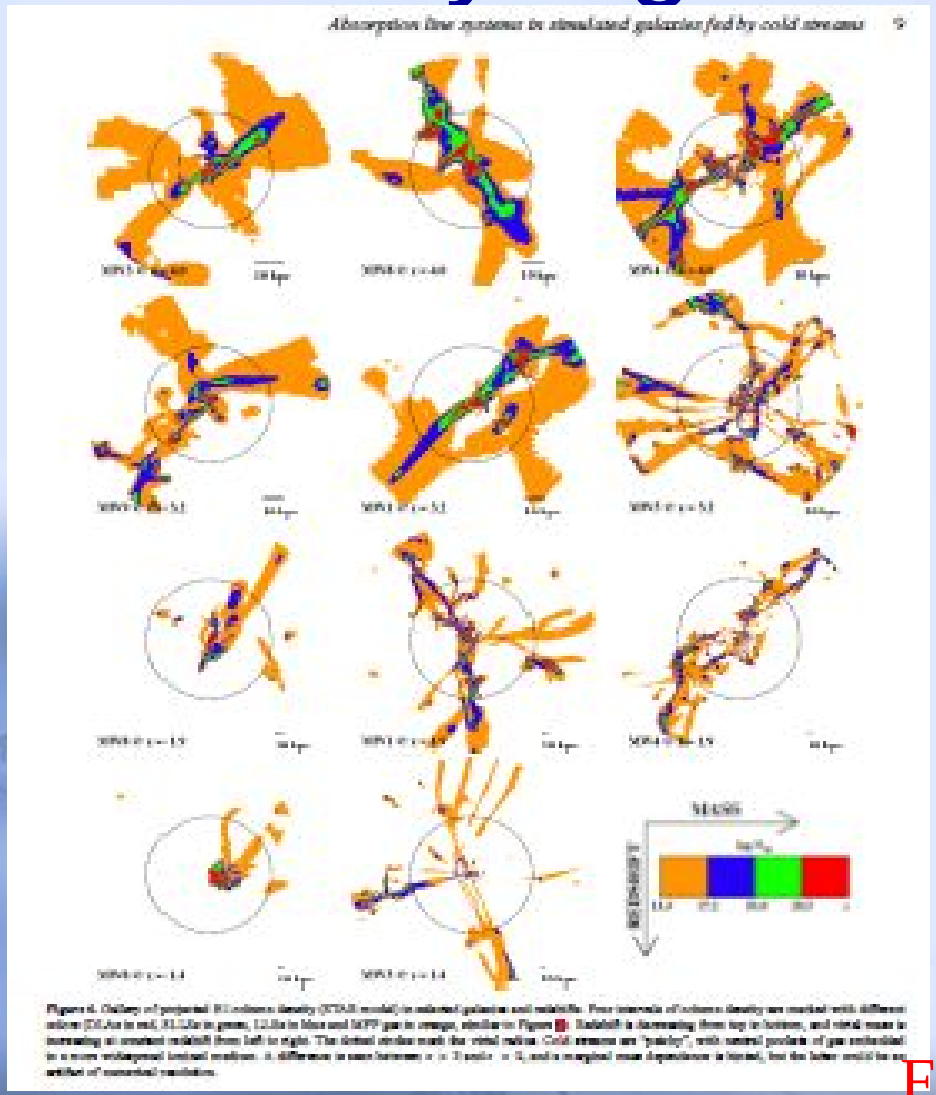


Prochaska et al. ApJ 718, 392, 2010

FIGURE 16. Number of absorbers per unit redshift, N(z), as a function of redshift, for damped Lyα systems (filled square), Mg II absorbers (cross), C IV absorbers (filled circles) and Lyman limits (open circles). Data from Storrie-Lombardi & Wolfe (2001), Stengler-Larrea et al. (1995), and the compilation of York et al. (1991).

Courtesy: Dr. S. G. Djorgovski's lecture Ay21

Why high-z LLS sample ?



1. Massive disk galaxy at high-z, Collapse? Merger? Cold stream?

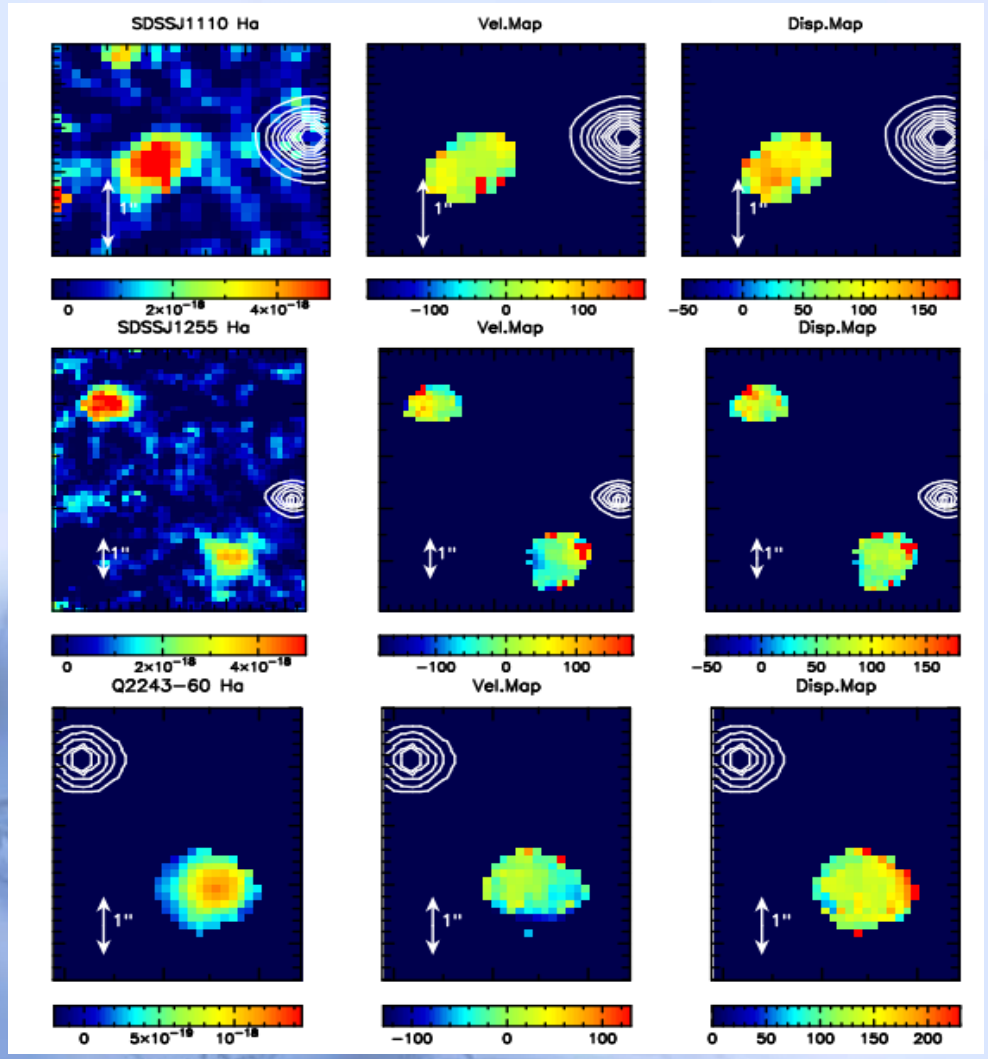
2. Good place to study gas cycling during intensive galaxy formation epoch (z~3)

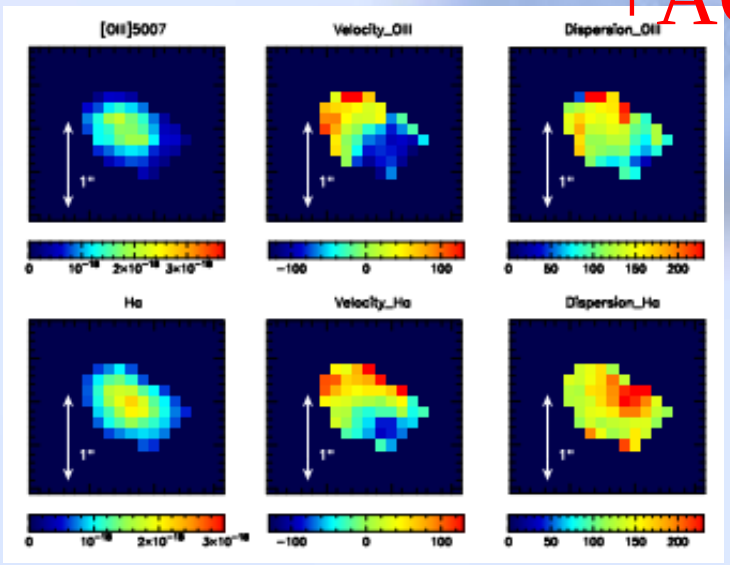
3. Feasible with current high spatial resolution large facilities

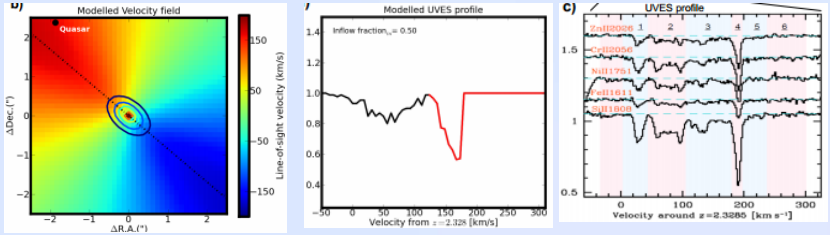
Fumagalli et al. 2012

High-z examples resolved by SINFONI/VLT

+AO



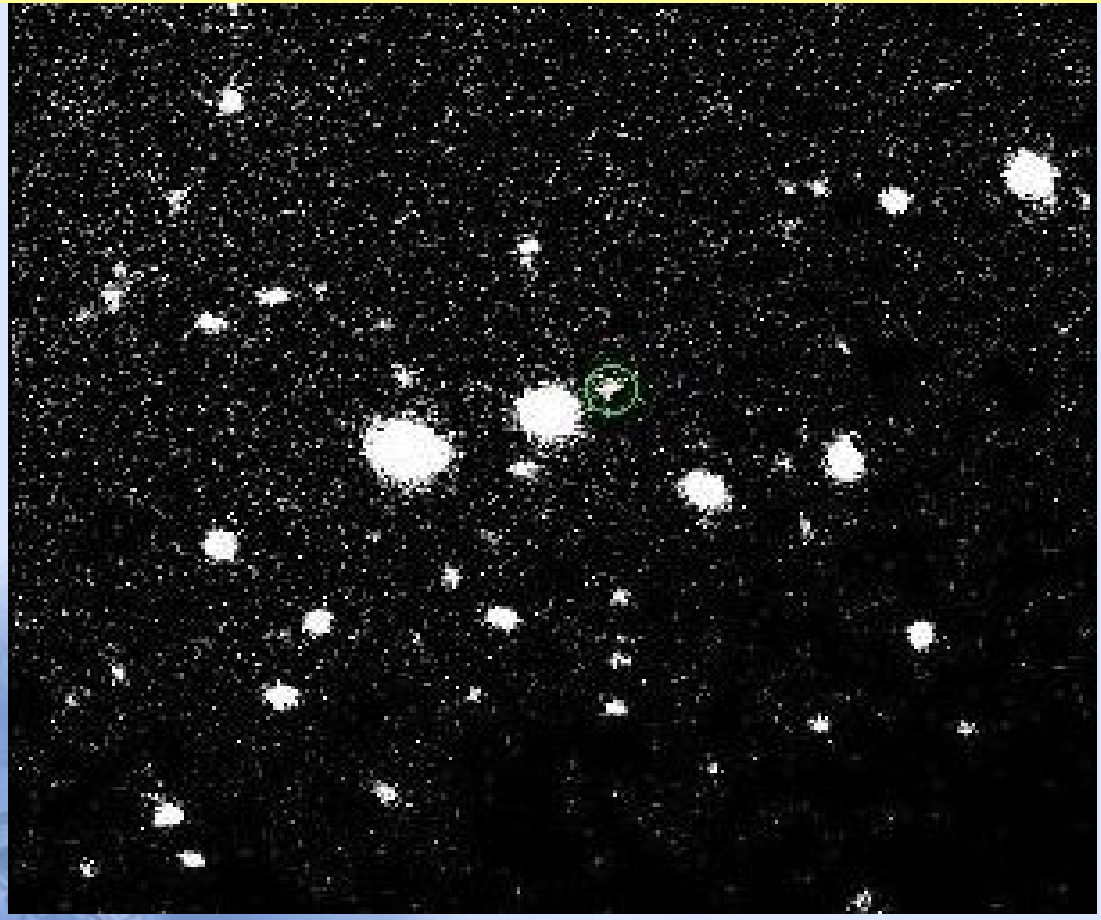




Bouche et al. MNRAS 419, 2, 2012

Signatures of cool gas fueling a star-forming galaxy at z~2.3 (Bouche et al. science 2013)

FOCAS, SupCam, MOIRCS and IRCS/SUBARU + AO

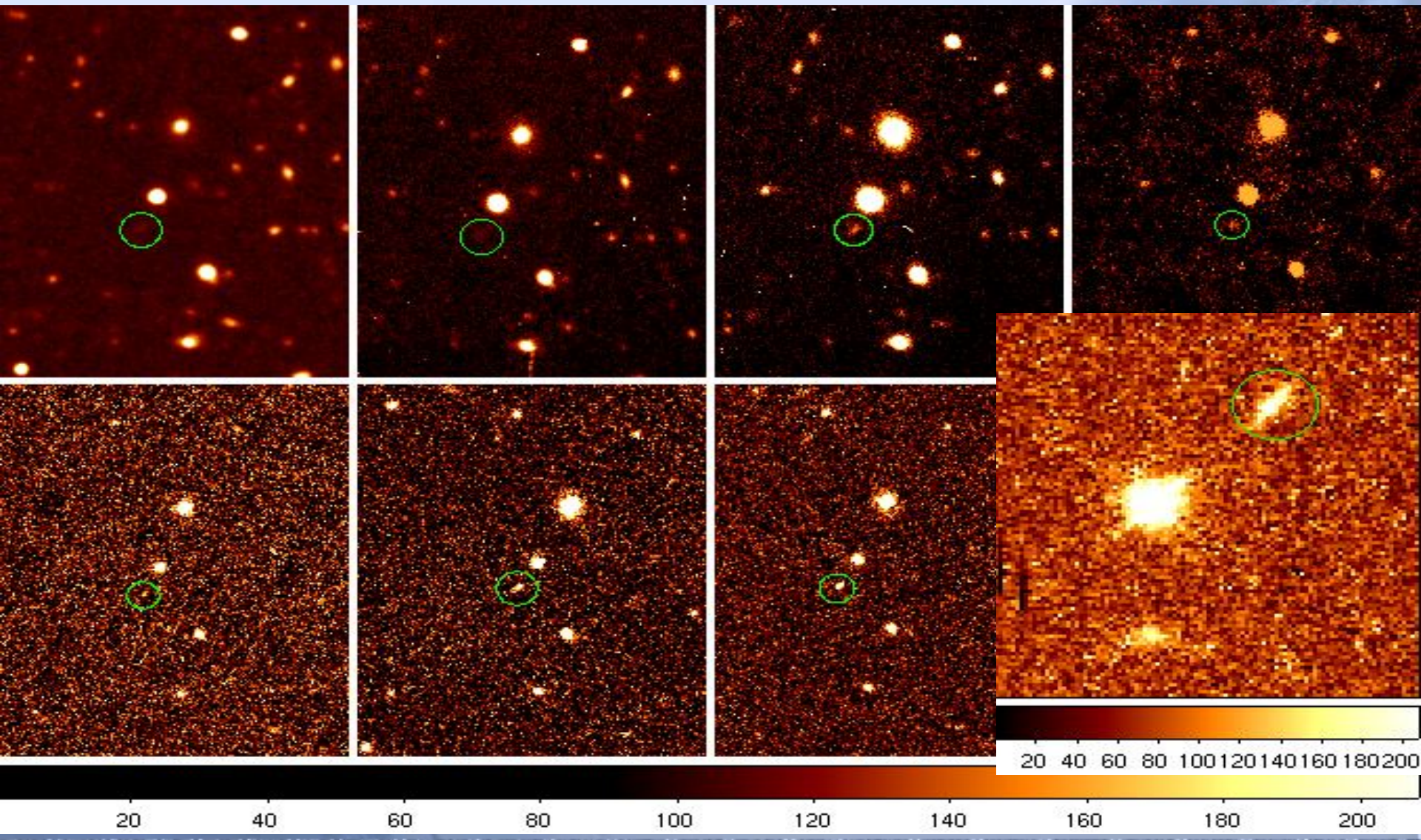


G1, B-dropout, a possible galaxy resposible for a previous known LLS (z~3.88) seen in the QSO spectrum.

1) 3".5 NW of the QSO sightline;
2) impact parameter of ~ 24kpc, if at z~3.88

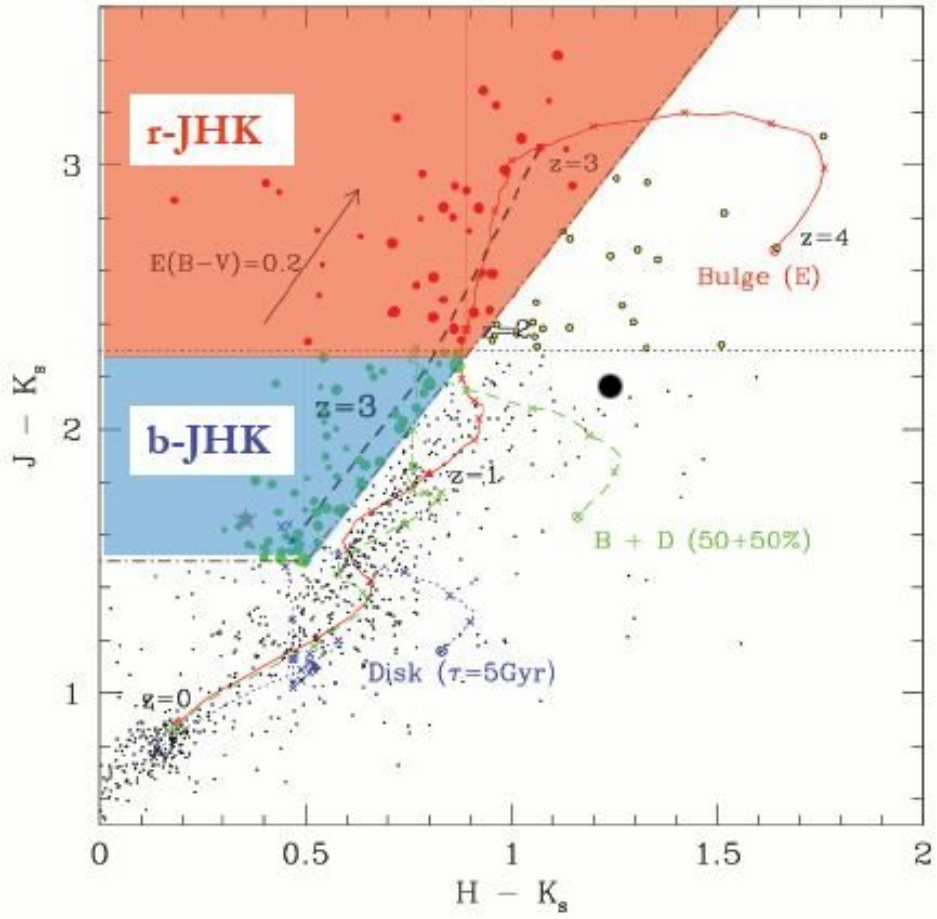
A combined R-band image of a region of 30x30 arcsec^2 centered on the QSO, which has an image quality of FWHM ~0".7. Galaxy "G1" is indicated by a circle in the image.

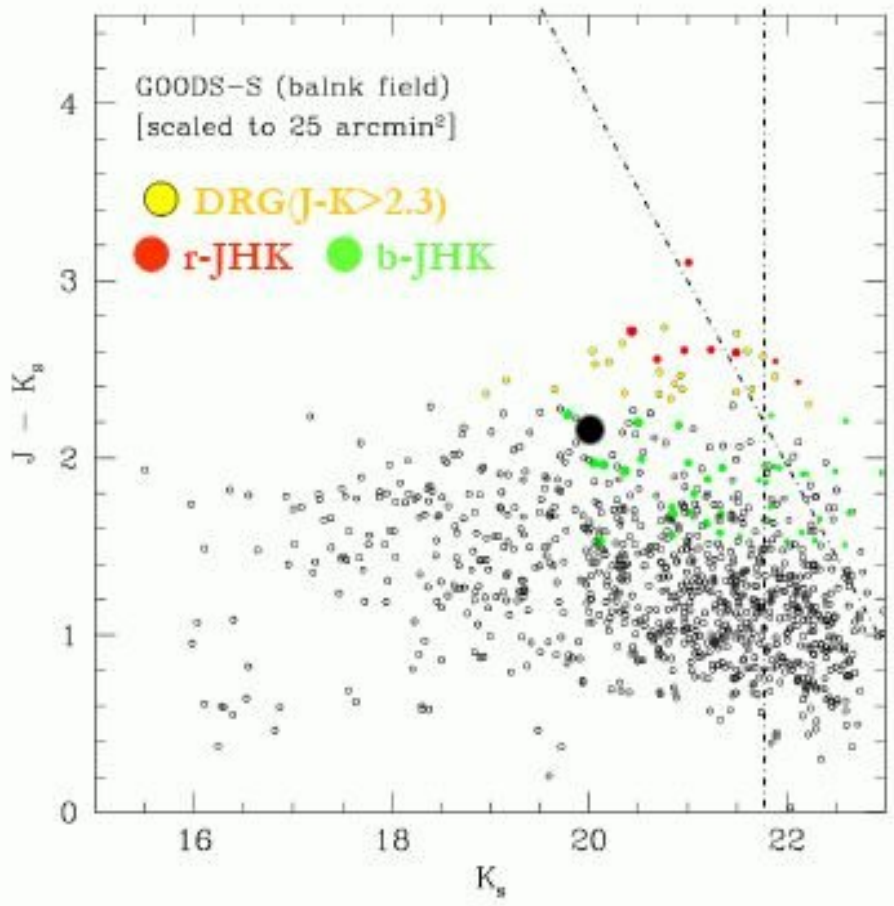
BVRIJHKs deep imaging using Subaru and HST :



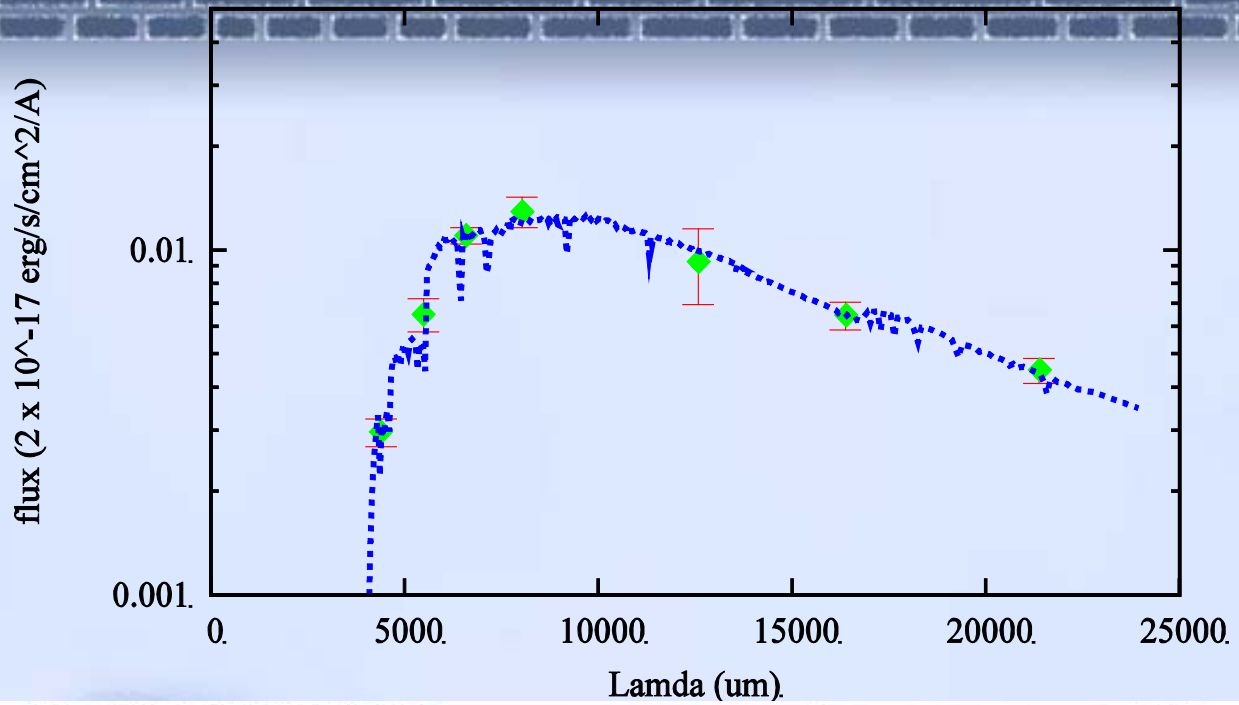
NIR properties and stellar mass estimation

- J-Ks=2.07±0.28; H-Ks=1.21±0.13; Ks=20.01±0.08; Ms~8.9x10^10 Msun

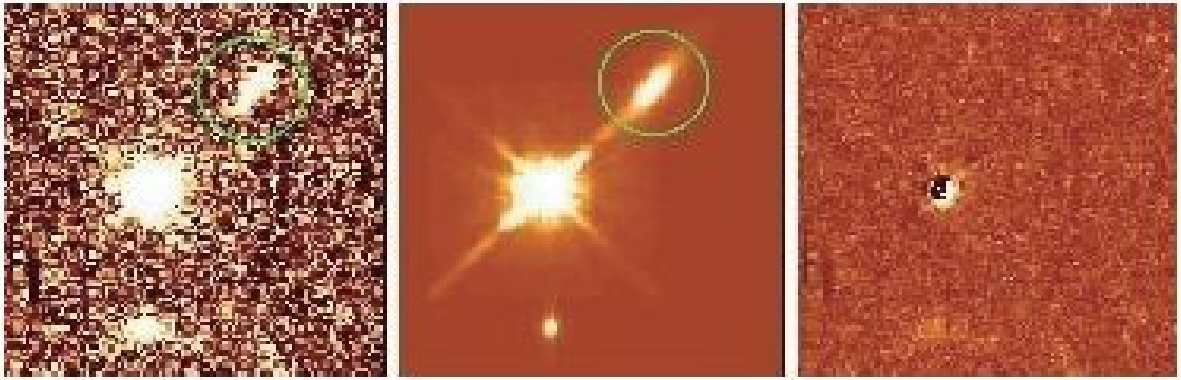




JHK selection criteria for 2<z<3 galaxies, Kodama et al. 2007



Broad-band photometry in the BVRIJHKs. The best fit evolutionary synthesis model indicates a young starburst of age ~2Myr at z~3.5 with extinction of Av~2. The stellar mass M*~9X10^10 M_sun.



HST WFPC2 + F814W:

Sersic index n=0.7(0.2)

Re=0".57(0.23),

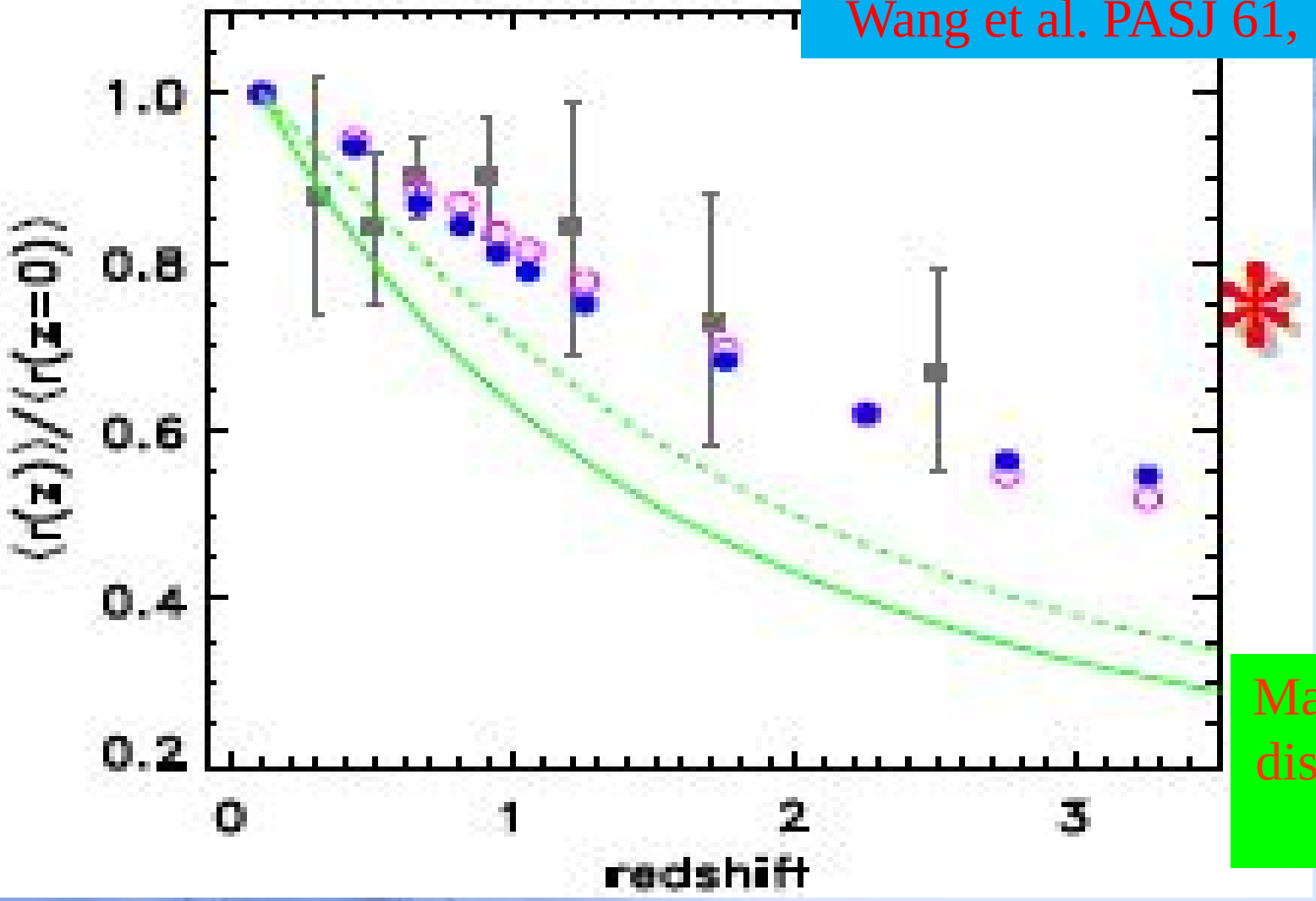
Chi^2/nu=1.58

If z~3.88, Re~3kpc

Fig. 4. 2-D image decomposition on the HST WFPC2+*F814W* data of the QSO field ($\sim 10'' \times 10''$), centered on QSO 1508+5714. From left to right, they are the original image, the final model of the objects, and the residuals from GALFIT. North is 20°.77 left of upper and east is left of it.

Size evolution of disks --models

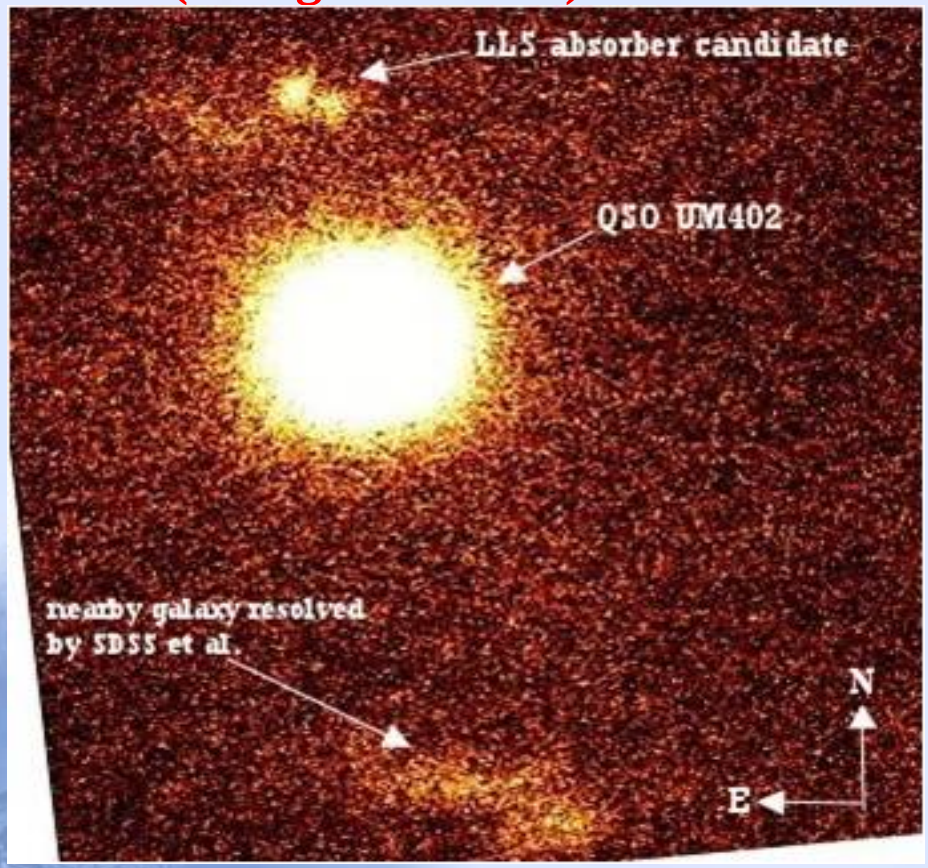
Wang et al. PASJ 61, 1179, 2009



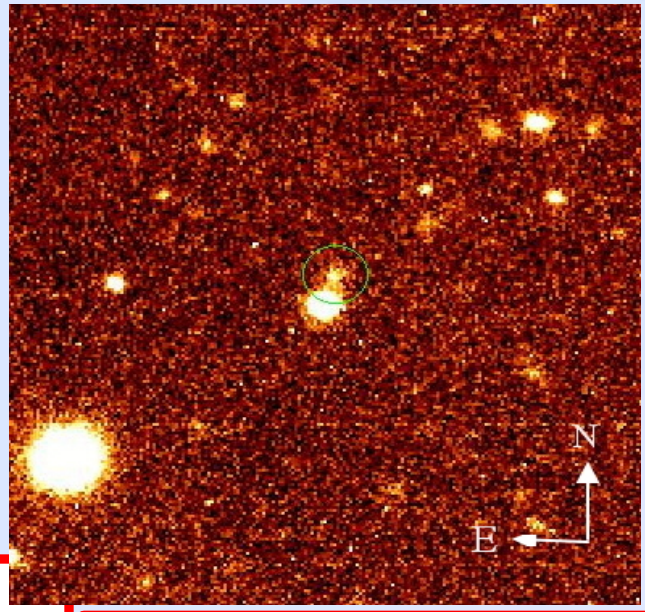
Massive distant disk galaxies at z~4 ?

IRCS+AO observation of UM402 at z~3

(Wang et al. 2013)



We are trying to construct a small sample at z~3 !!



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
in preparation

Thank you very much !!