E-ELT DRM

The Physics and Mass Assembly of Galaxies

Final Update

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ELT SWG meeting – Apr 2, 2008

ToDo List
From last SWG meeting (Oct07)

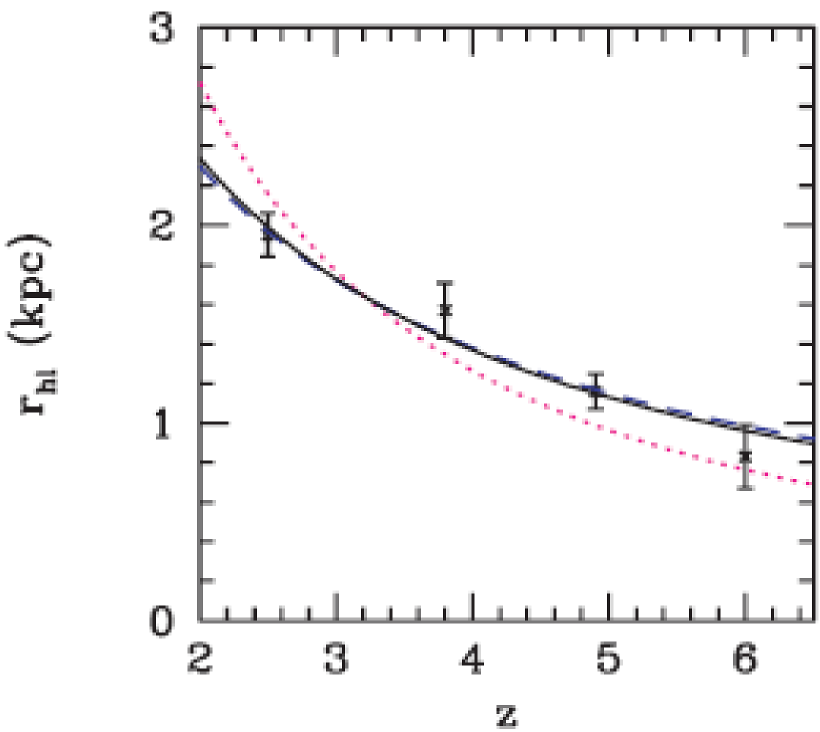
- **Size vs. Mass**
- **Size morphological k-correction**
- **Thermal background & validation with SINFONI**
- **Detection of clumps in disks (extension of kinematical/morphological templates)**

Pipeline updates

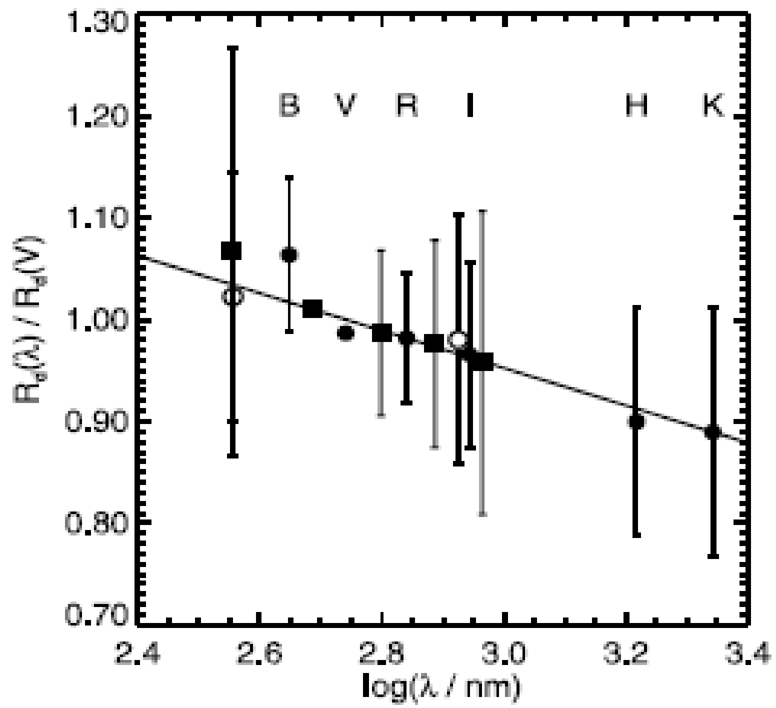
Size vs. Redshift and stellar mass:

✓ **Redshift: Bouwens+04 Ferguson+04 Dahlen+07=> R_{half} vs. z in the UV**

Barden+05 => conversion @ $\lambda_{[OII]}$=3727Å or $\lambda_{H\alpha}$=6563Å



-6% -11%



✓ **Size vs. Stellar mass:**

Courteau+07: $R_{half}(K) \propto L_K^{0.35}$ => $R_{half} \propto M_{stellar}^{0.35}$

Effect on $R_{0.1M*}$: -55 % w.r.t. R_{1M*}

Effect on R_{10M*}: +124 % w.r.t. R_{1M*}

Pipeline updates

- **AO modes: now includes**

MOAO – GLAO – MCAO – LTAO

=> From Analytical code: MOAO & MCAO
(ONERA; B. Neichel & T. Fusco)

No Speckle noise - No central obscuration

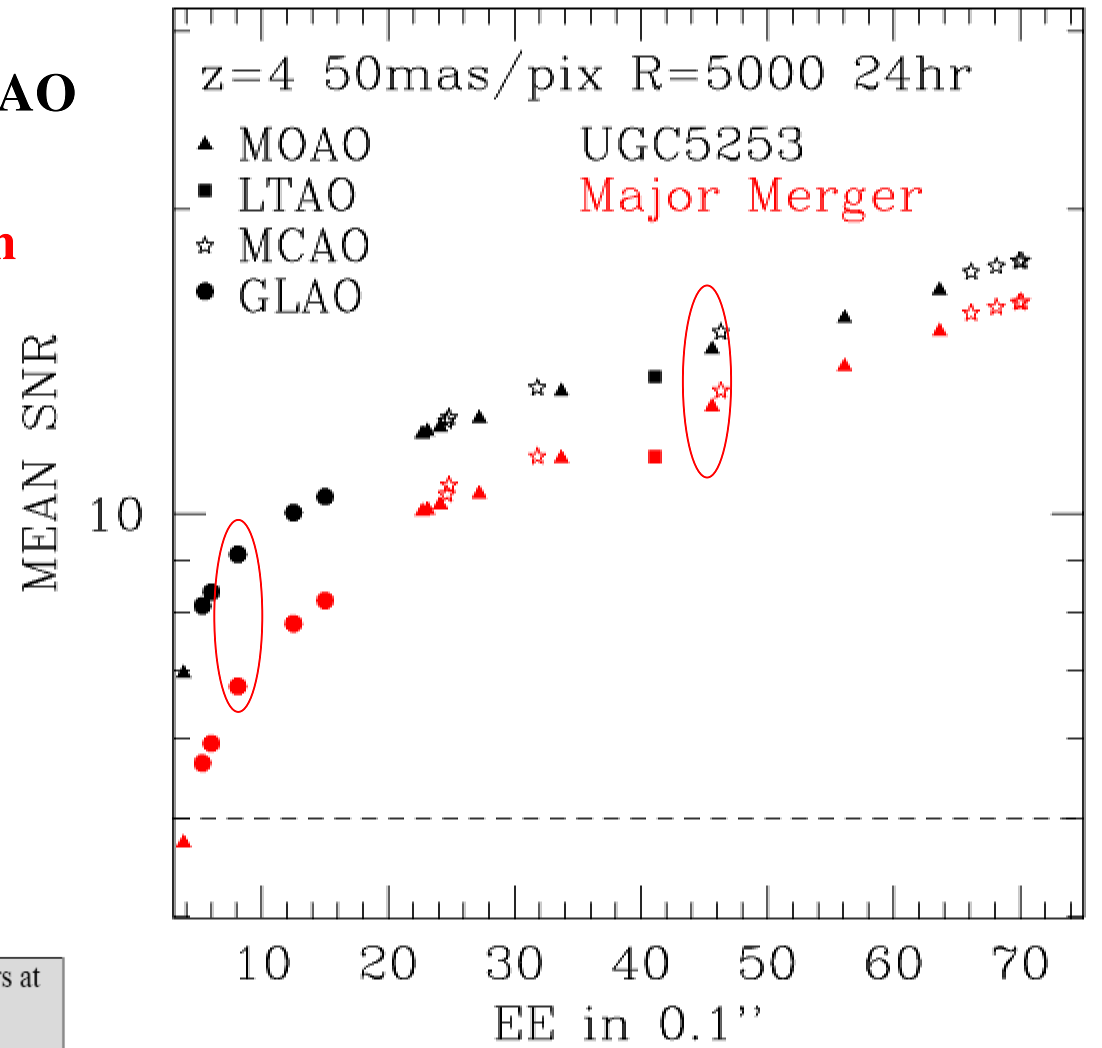
=> From E2E code: GLAO & LTAO
(ESO; M. Le Louarn)

- **Turbulence model: seeing=0.8'' same turbulence profile & L0**
same DM pitch (~ 0.5 m)

- **Multiplex => MOAO or GLAO**

Down to I_{AB}=25 (WFSPEC report):

FoV size (arcmin x arcmin)	Expected numbers at 1.4< z < 2.5	Expected numbers at 2.7< z < 3.4	Expected numbers at 3.5 < z < 4.5	Expected numbers at 4.8 < z < 5.8
0.5 x 0.5	2.25	0.45	0.2	~0.01
1 x 1	9	1.8	0.8	~0.1
5 x 5 (JWST)	225	45	20	~1
10 x 10	900	180	80	~6

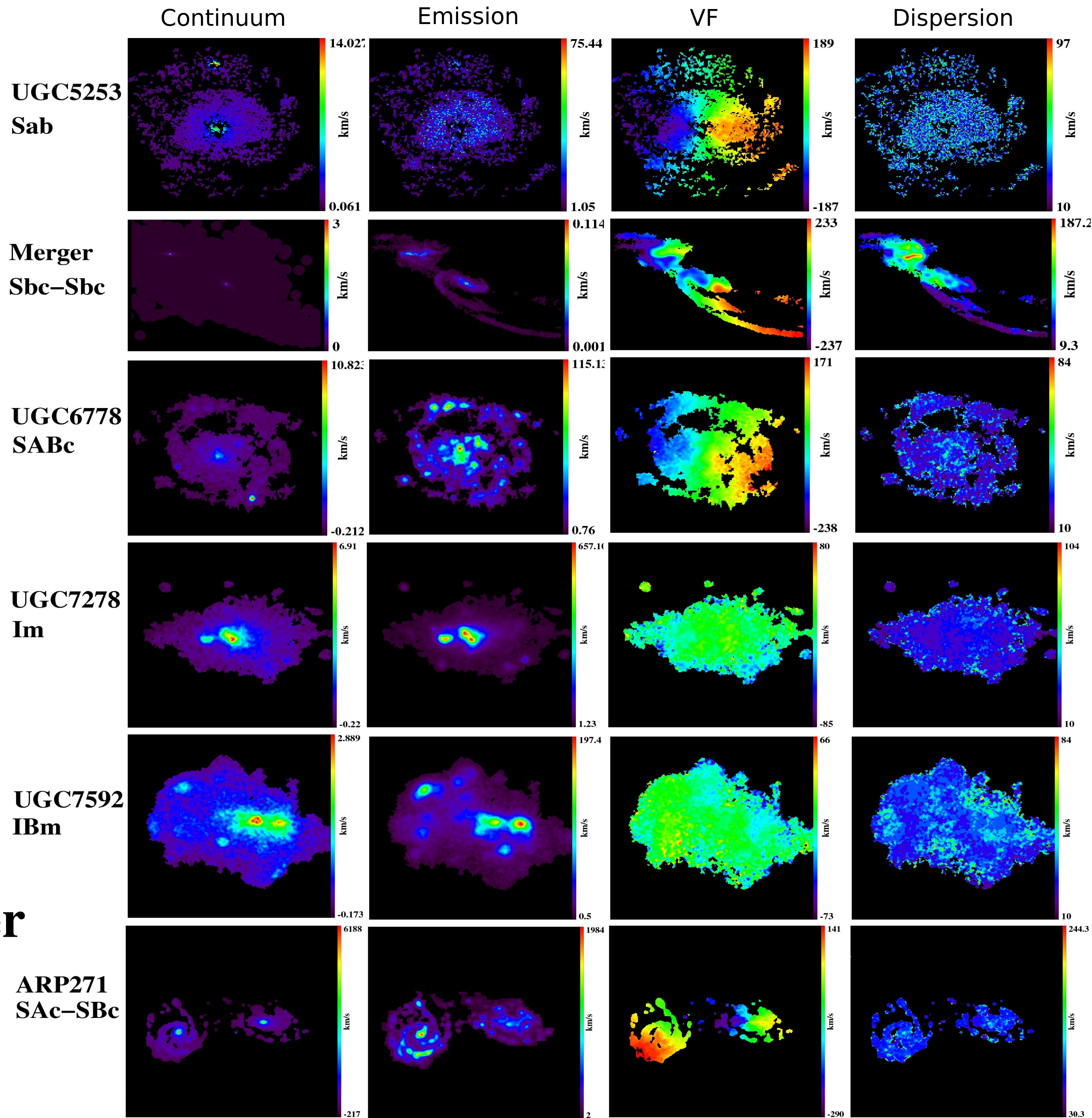


LTAO FoV=45'' on axis
MCAO Fov=0.5' or 5', Dir=0,0.5,2,2.5' 3DMs
GLAO FoV=1,2,5,10,15' on axis
MOAO FoV=0,0.25,0.5,1,2,3,4,5' on axis

Pipeline updates

- Local obs:
UGC5253
UGC6778
ARP271
UGC7278
UGC7592
From GHASP
Amram+02

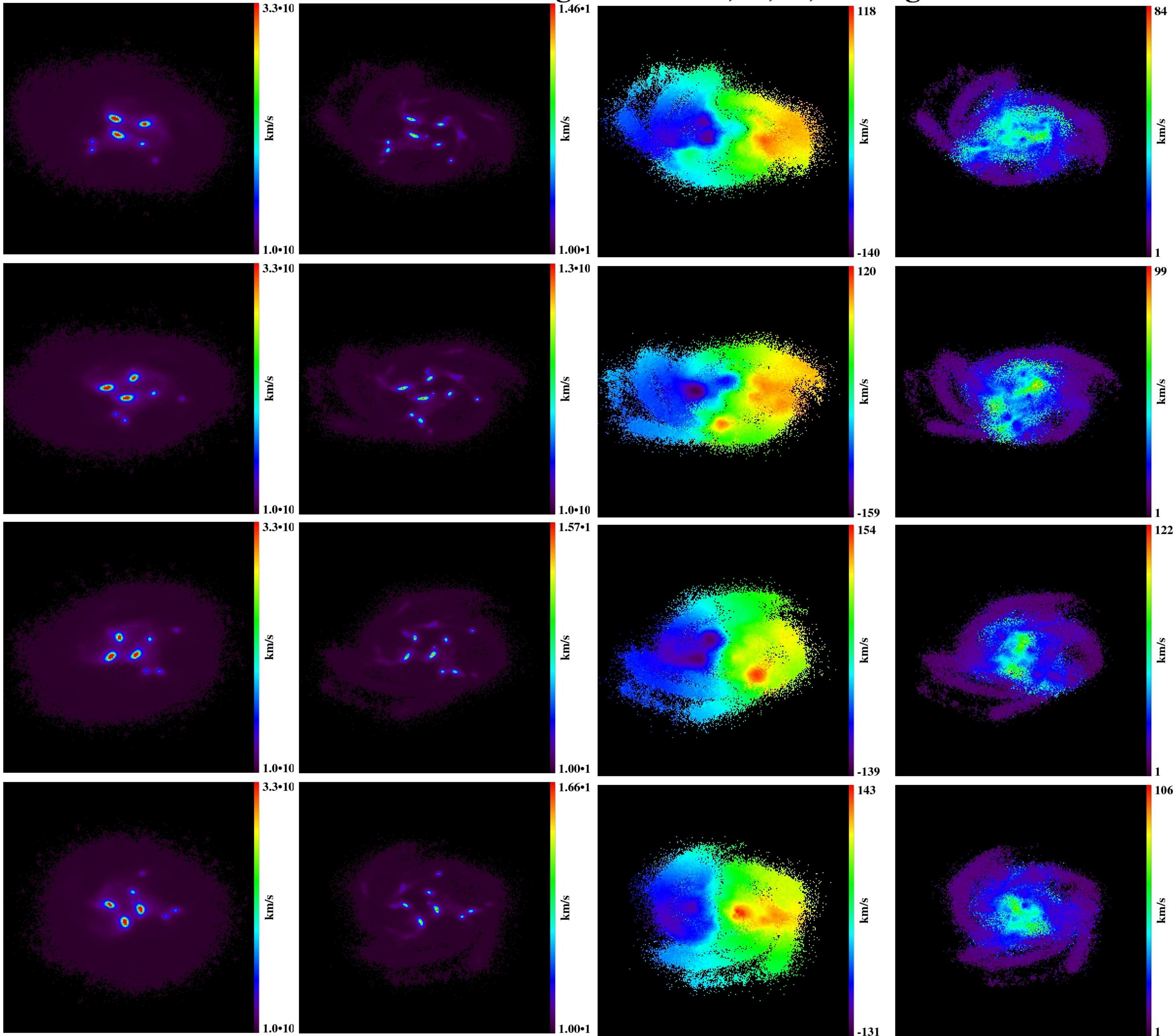
- Hydro-sims:
Sbc major merger
Cox+06



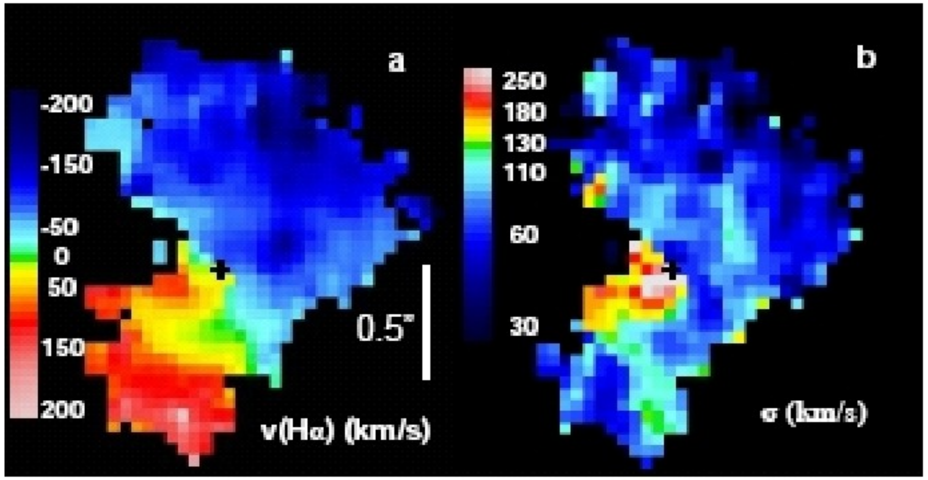
CLUMPY inc=50 deg azimuth=0,45,90,135 deg

Bournaud et al. 2007

Hydro-simulations



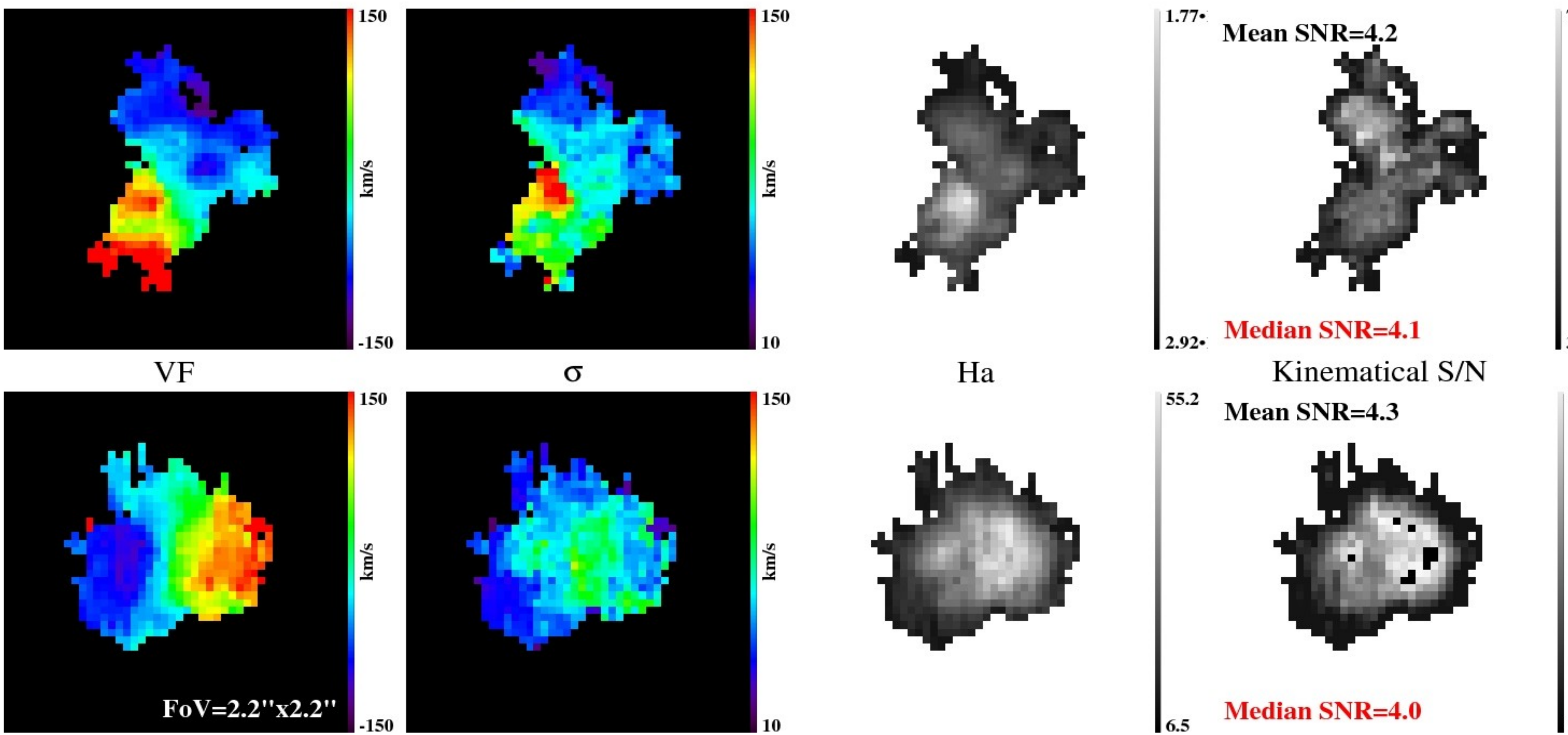
Pipeline validation



Genzel et al. (2006)
SINFONI data

T_{VLT}=287 K
ε_{VLT}=6% (Cassegrain focus)
$\varepsilon_{SINFONI}$=15% (5 optical surfaces)

z=2.3834 Rgal~0.8"
K=21.47 EWo(Ha)=140A
Tintg=6hr
50x100mas FWHM=150" (smoothed to 190)"



Incremental Goals for this DRM

Kinematics is the most demanding analysis in terms of SNR: enough SNR for kinematics => enough SNR for flux ratio maps (e.g., SFR or metallicity maps)

- **STEP 1: 3D detection of emission line galaxies: what mass can we reach with a minimal (emission line spatially integrated) SNR=5?**

- **STEP 2: Dynamical state of distant galaxies: major mergers vs. Rotation disk. Can we recover large scale motions?**

- **STEP 3: Rotation Curves: can we recover V_{rot} (eg, Dynamical masses, Tully-Fisher)? Shape of the RC (mass profiles/decomposition)?**

- **STEP 4: Detailed kinematics: detection of, e.g., clumps in disks?**

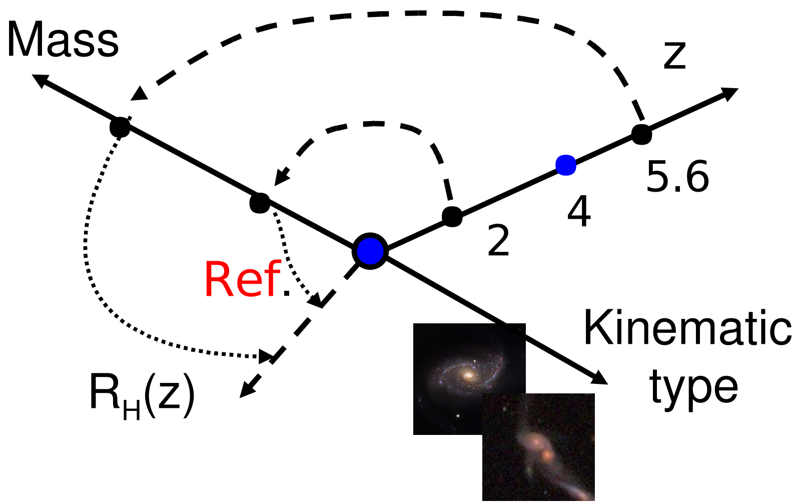
3D detection of emission line galaxies

- **SNR=SNR(SB,z,EE,D,EW$_0$,T$_{exp}$,R,Δpix,…) ➔ M$_{lim=}$M$_{lim}$(SB,z,EE,D,EW$_0$,T$_{exp}$,R,Δpix)**
- **We define M$_{lim}$ = M$_{stellar}$ @ SNR=5 (spatial mean in the [OII] emission line), set up from kinematical studies**

Reference case (z=4, M* galaxy)

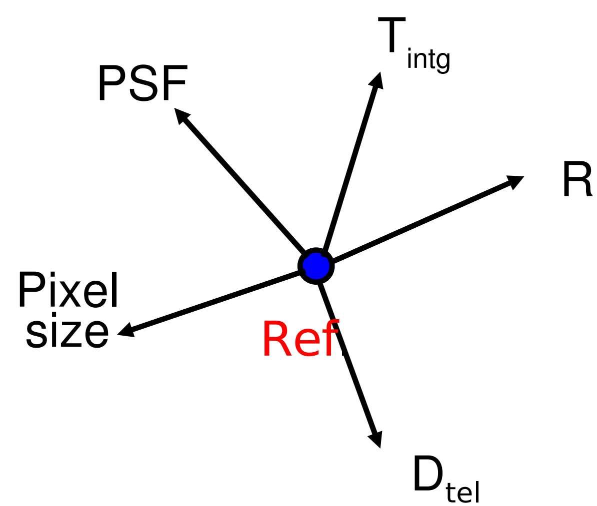
Physical params

z=4, H_{AB}=24.3 (M* @z=4)
V_{max}≈ 230 km/s Log(M*)=10.7 $M_\odot$
EW_0=30A ([OII] in H band)
R_{gal}= 4R_{half}=0.75”(5.2 kpc)

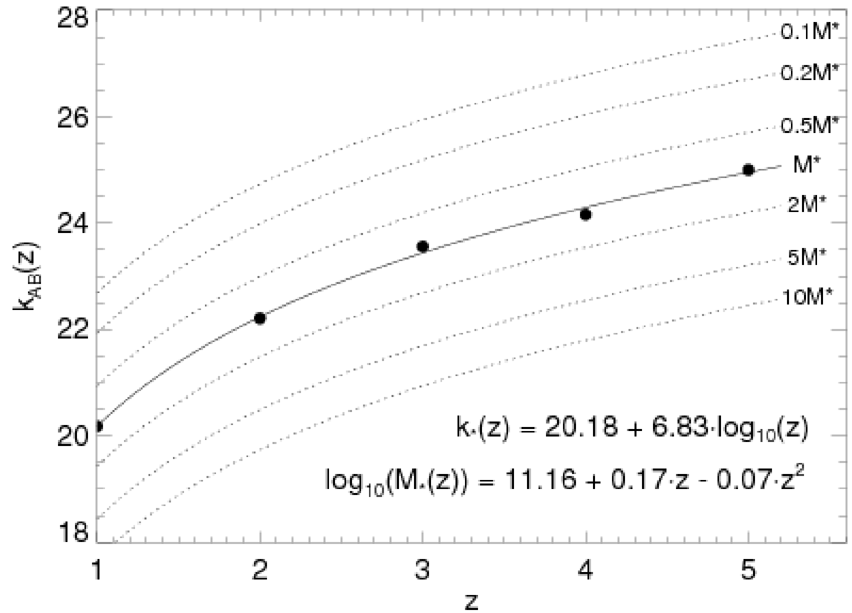


Instrument params

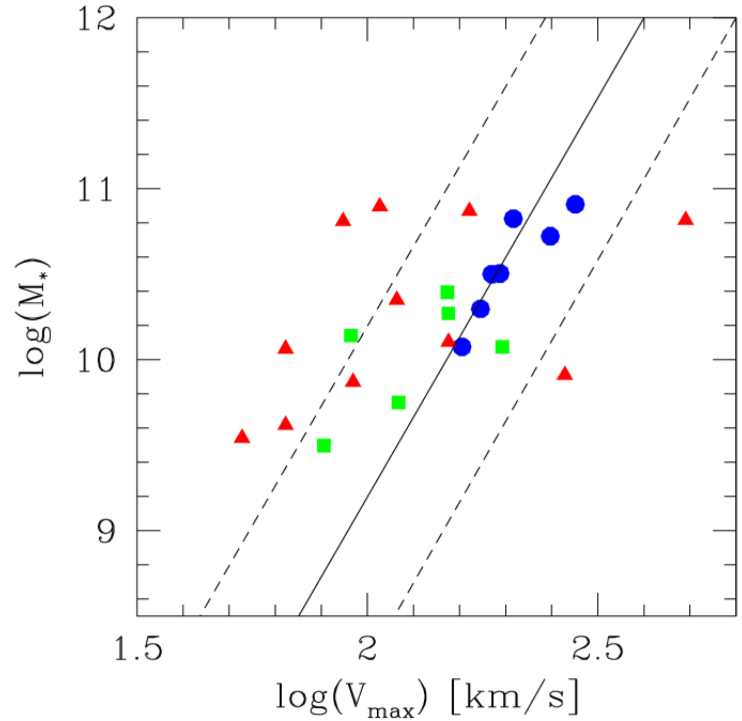
D=42m ExpTime=24h
R=5000 Δ_{pix}=50 mas



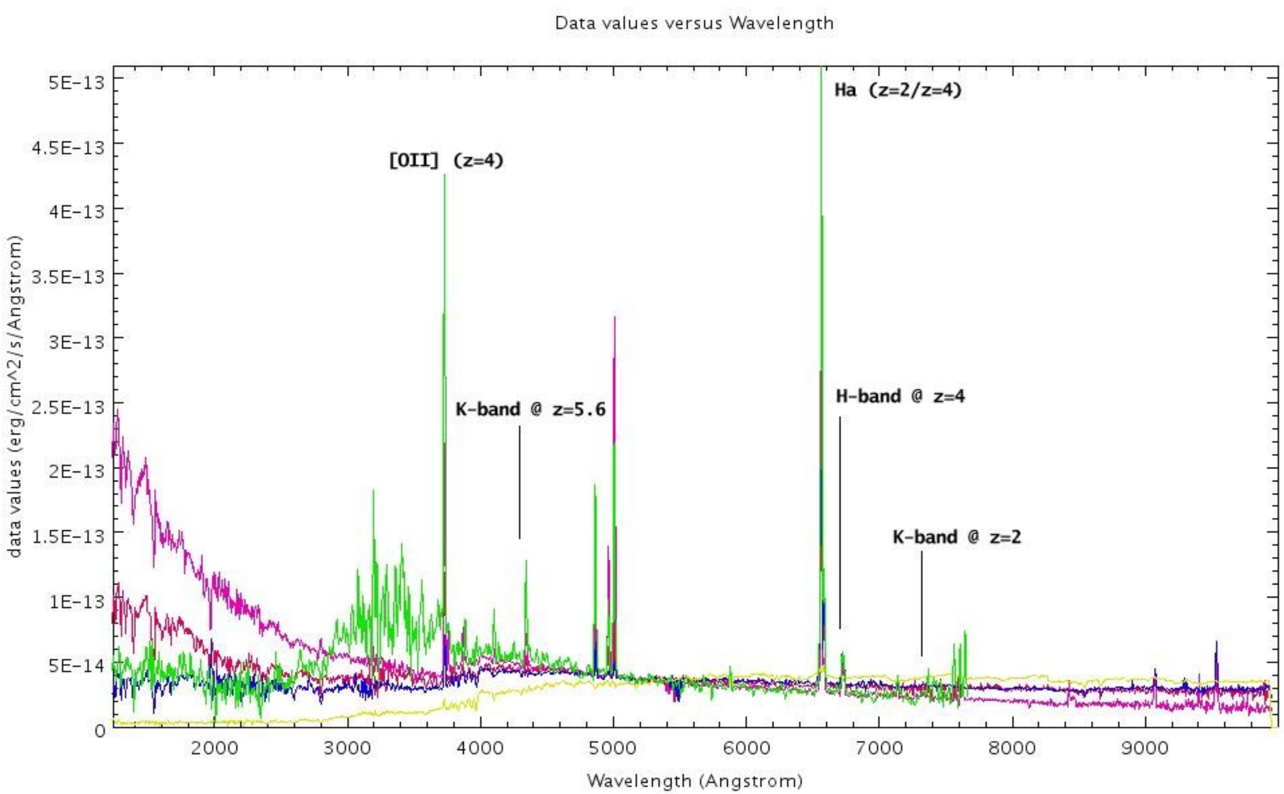
$$< S/N >_{min}= 5 \left(\frac{T}{24h}\right)^{0.5} \left(\frac{D}{42\,m}\right) \left(\frac{EW}{30\text{Å}}\right) \left(\frac{R}{5000}\right)^{-0.5} \left(\frac{\Delta pix}{50\,mas}\right)$$



GSMFs from MUSYC survey (S. Toft)



smTFR Flores et al. 06



Uncertainties:

$M_{stellar}(z) \sim 0.3$ dex
$K_{AB}(z) \sim 0.75$ mag
from GSMFs & LMFs

$V_{max}(M_{stellar}) > 0.1$ dex
from smTFR slope

Continuum Flux(K_{AB}) ~ 2
from SEDs

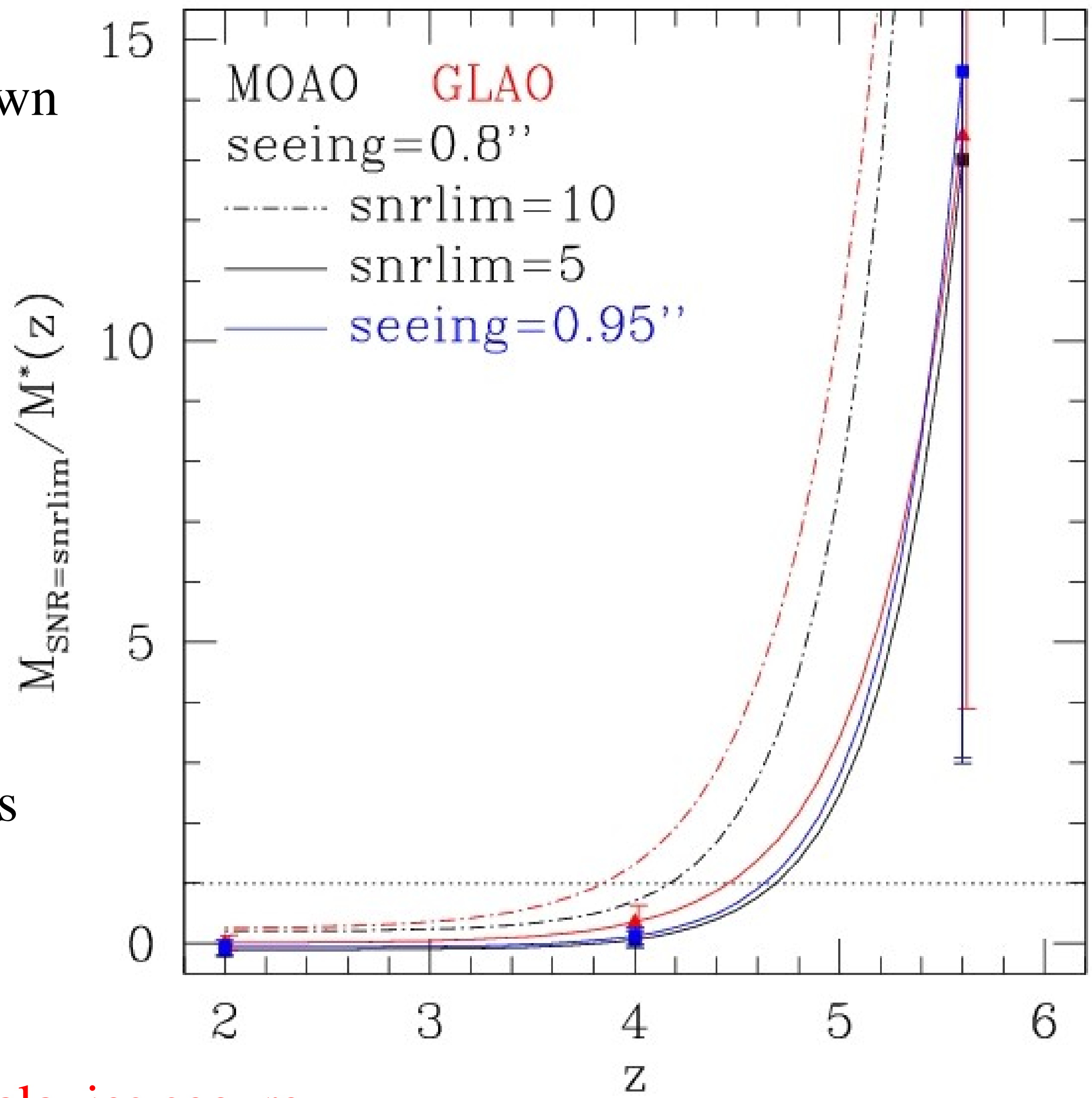
3D detection of emission line galaxies

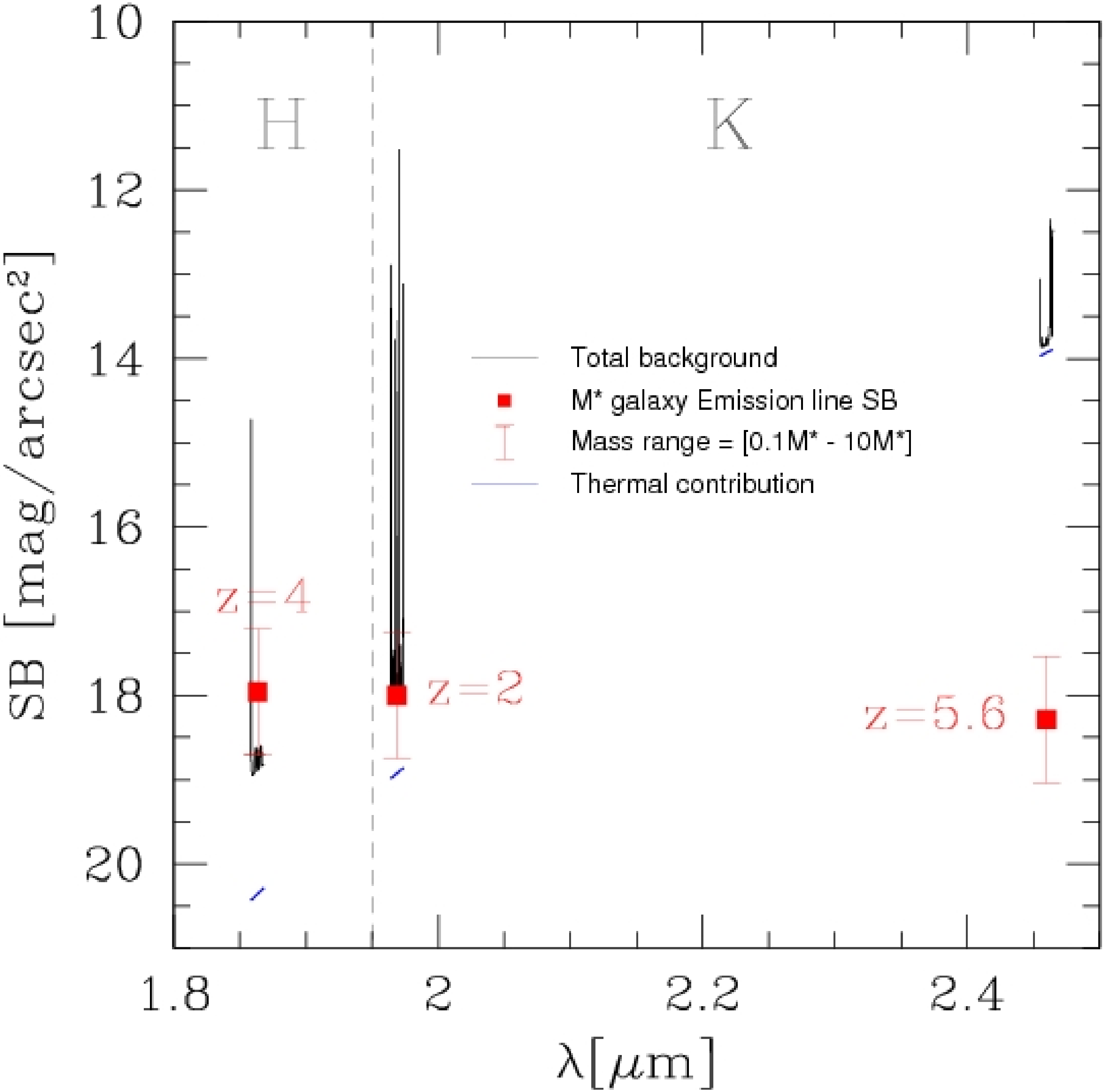
The GSMF can be probed down to M* up to a redshift of:

- with MOAO: z~4.7
- with GLAO: z~4.4

Flat curve below z~4.5: no strong sensitivity to variations in, eg, seeing, AO mode, SNR limit,...

=> 3D spectroscopy of z<4 galaxies secure

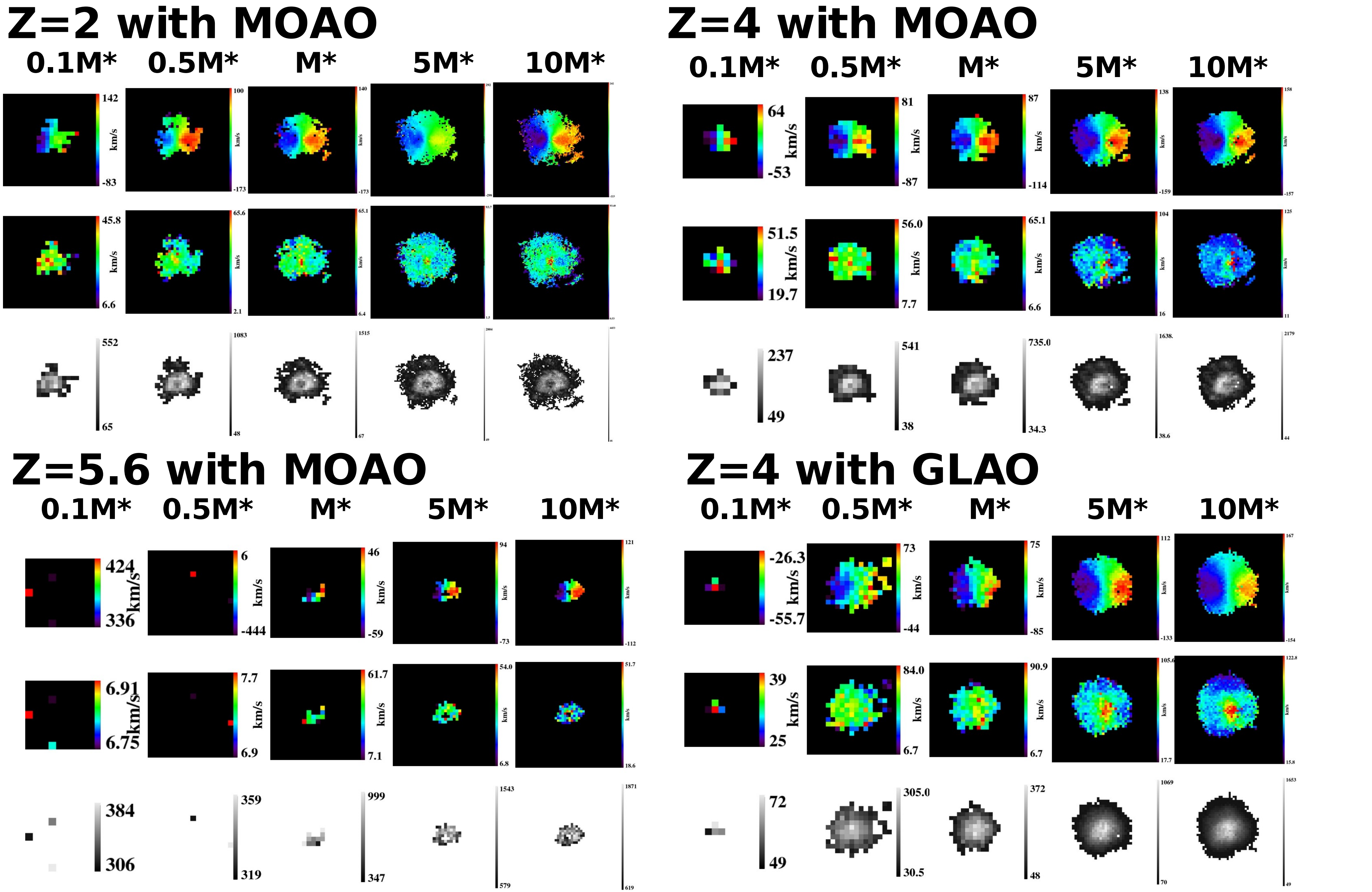




Exponential tail in M_{lim} vs z plot

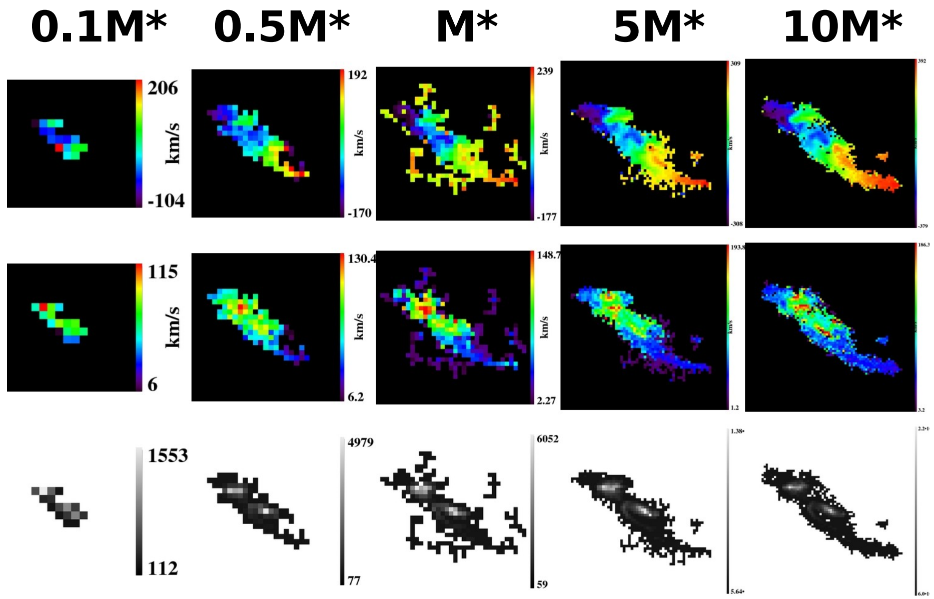
Thermal Background: significant impact only above z>5

Dynamical state: relaxed rotating disk

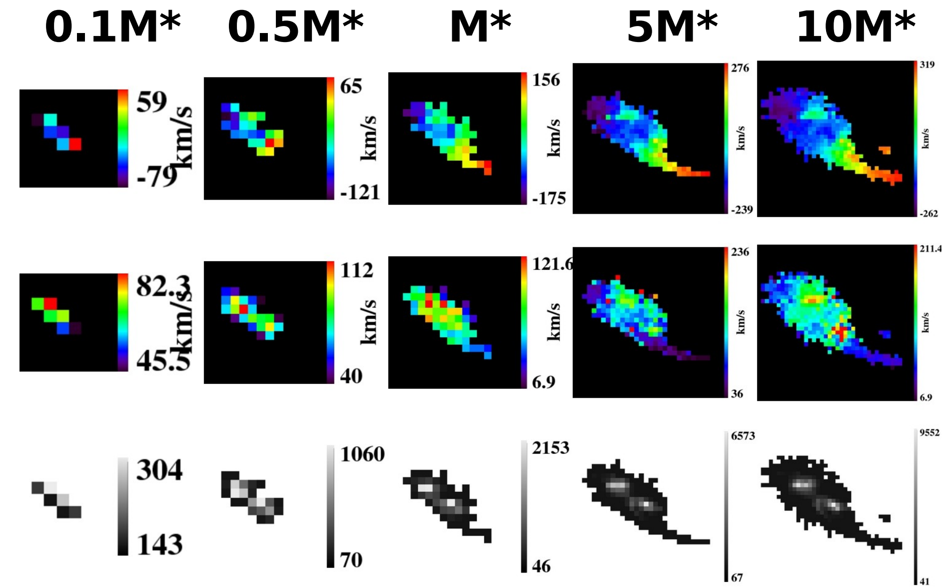


Dynamical state: major merger

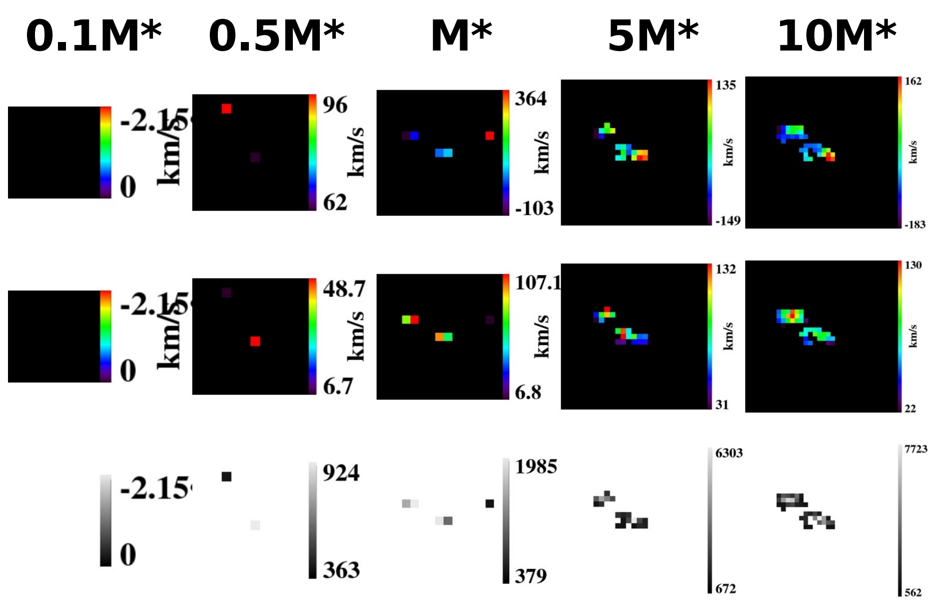
Z=2 with MOAO



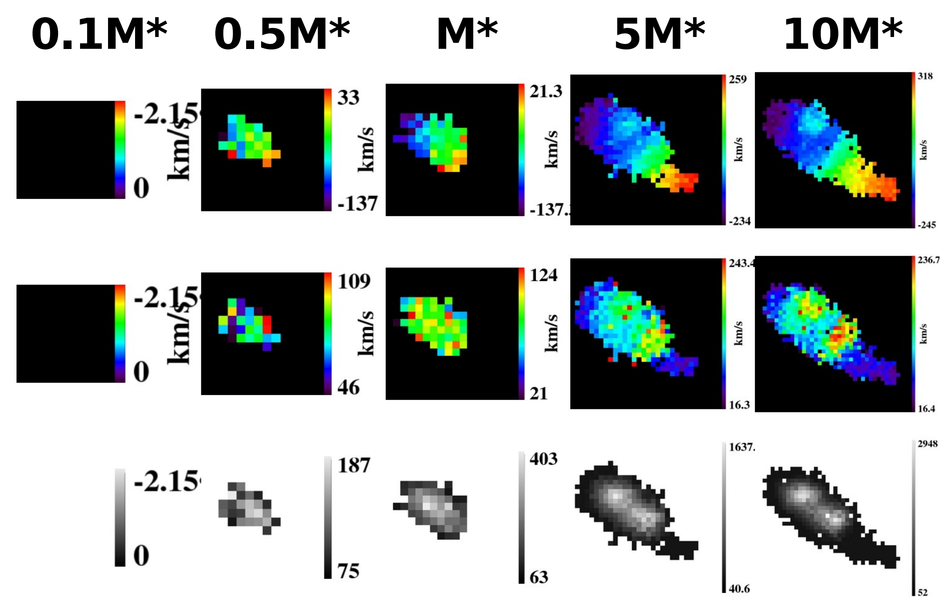
Z=4 with MOAO



Z=5.6 with MOAO



Z=4 with GLAO

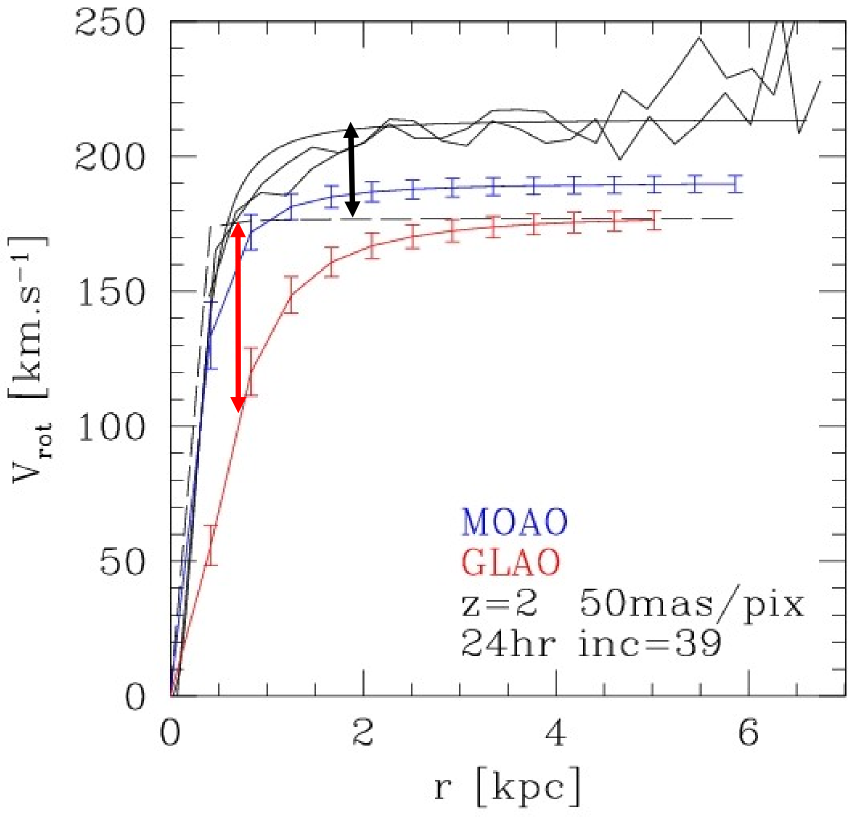


Needs SNR=5-10 depending on redshift

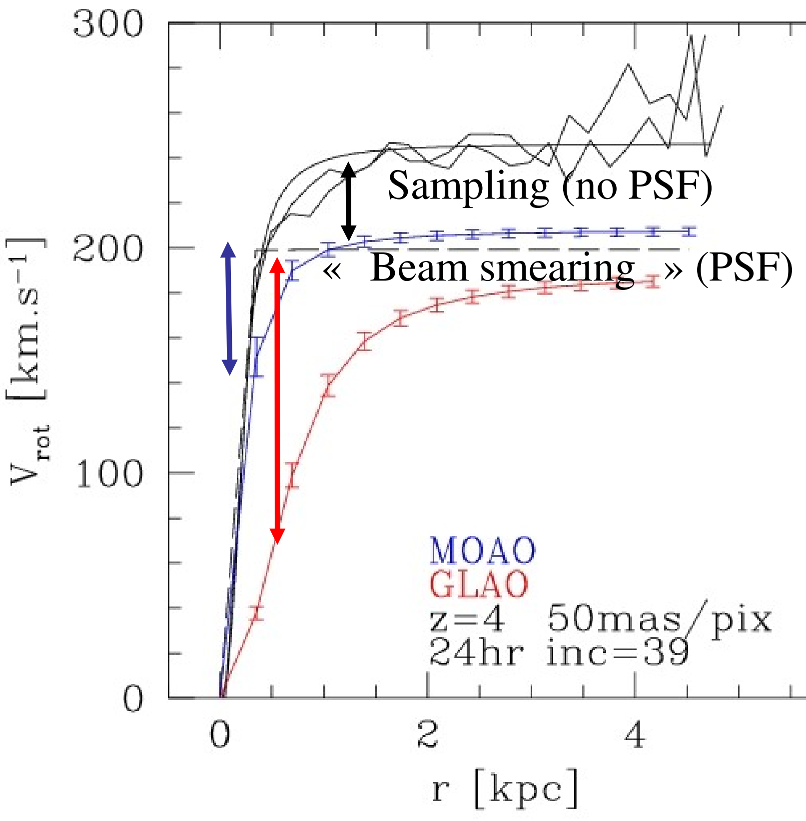
Rotation Curves (UGC5253)

- ✓ Accuracy on the RC limited by the spatial resolution and sampling
- ✓ z=2: $M_{stellar}$=M* FWHM$_{MOAO}$~11mas FWHM$_{GLAO}$~161mas $D_{gal}/2\Delta pix=15$
- ✓ z=4: $M_{stellar}$=5M* FWHM$_{MOAO}$ ~ 8mas FWHM$_{GLAO}$~235mas $D_{gal}/2\Delta pix=6$

Z=2



Z=4

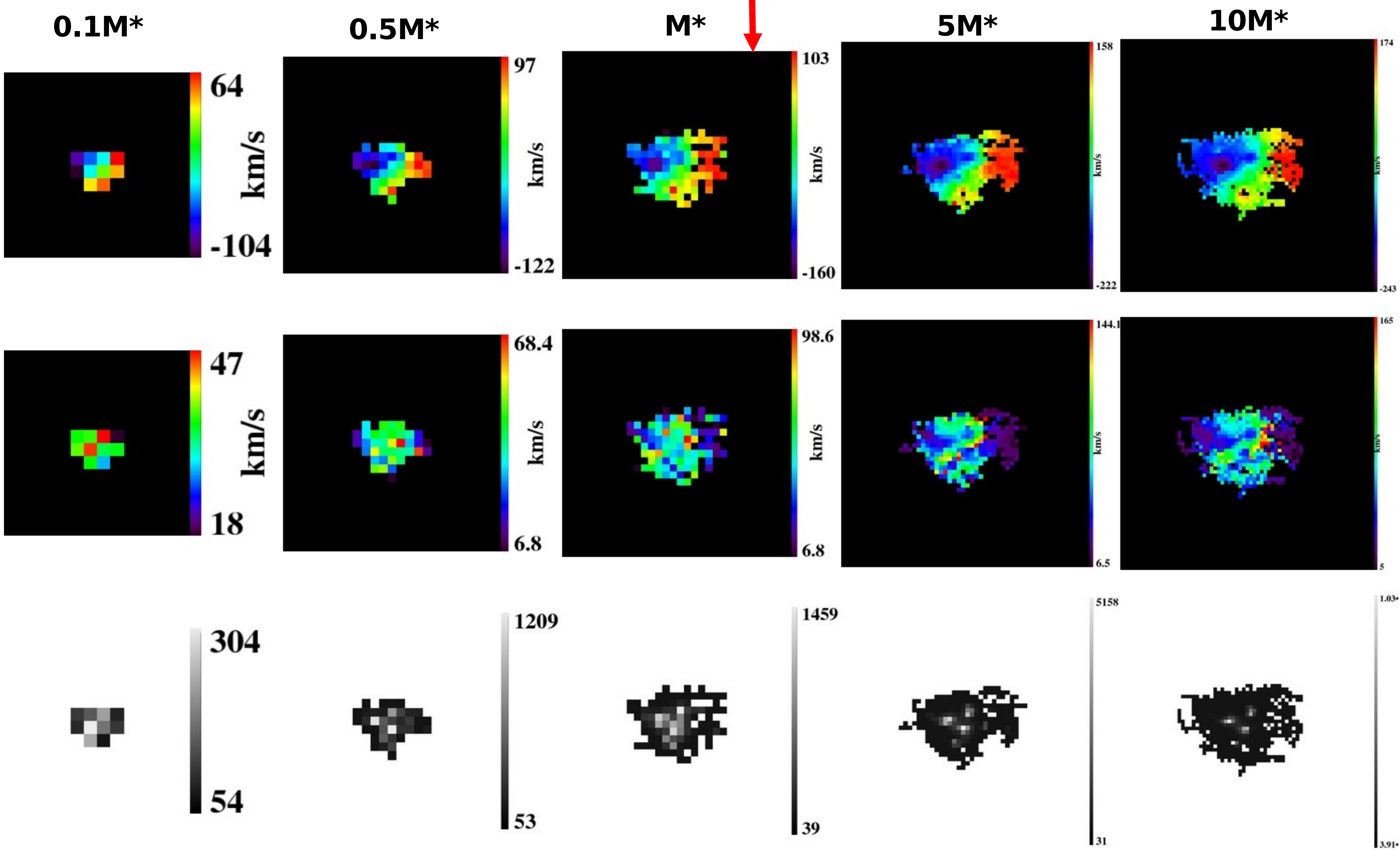


Bosma78's rule of thumb : $D_{gal}/2\Delta pix > 14$

Detailed kinematics: clumpy disks

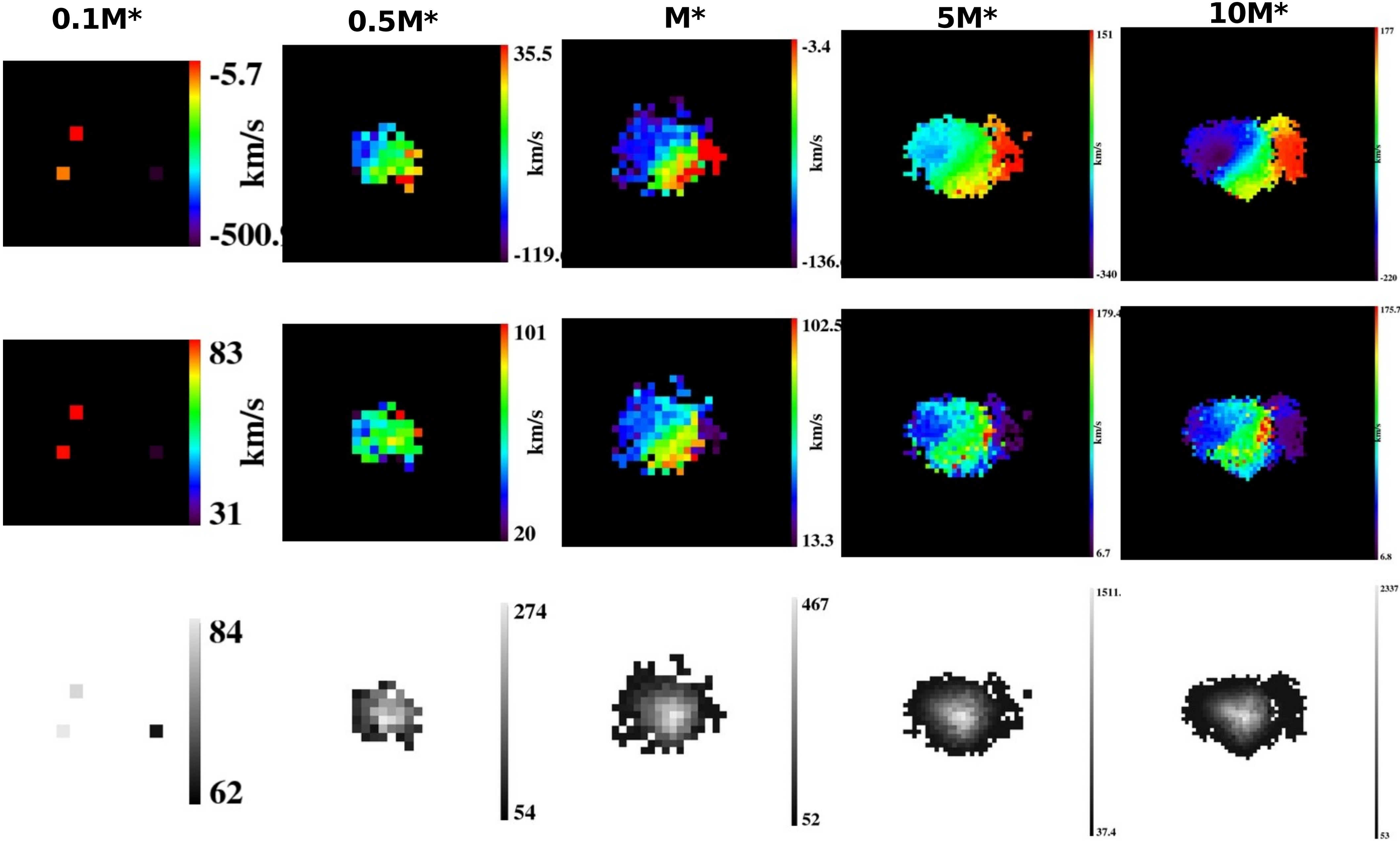
MOAO z=4

Detection of clumps down to M*



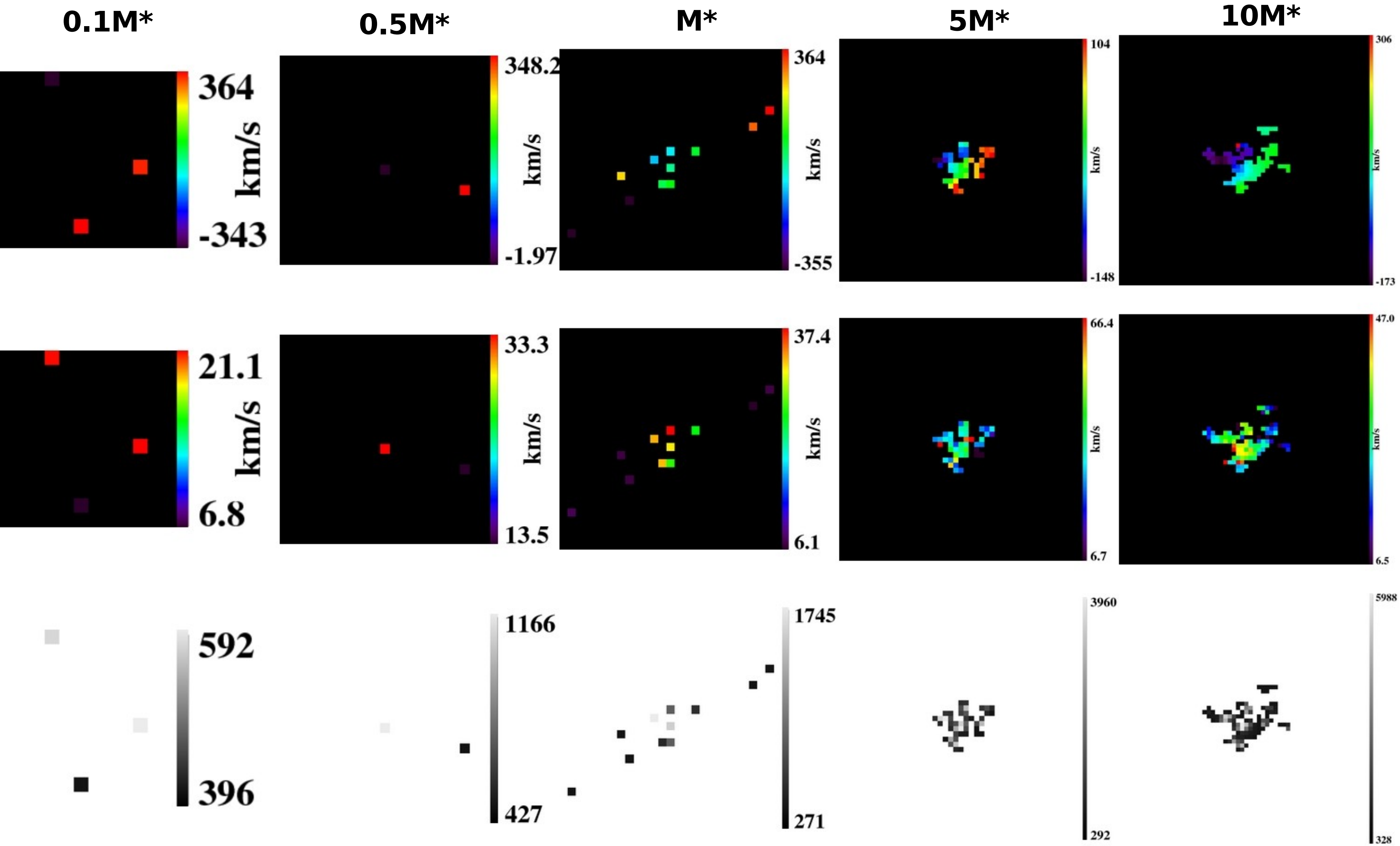
Detailed kinematics: clumpy disks

GLAO z=4



Detailed kinematics: clumpy disks

MOAO z=5.6



Summary - Science

- Simulation pipeline complete and successfully compared to SINFONI observations @ z=2.38. Internal consistency reached (typical uncertainty factor ~ 2 on physical quantities used).
- DRM STEP 1: 3D detection: The Galaxy Mass Function can be sampled down to M* up to z~4.9 (4.2) using MOAO and z~4.4 (3.8) using GLAO with SNR_{lim}=5 (10). At z>5: kinematics of super-M* galaxies possible. 3D kinematics of M* galaxies secured up to z~4.
- DRM STEP 2: Dynamical state of galaxies (large scale motions): SNR_{min}=5-10. No need for very high spatial resolution (GLAO enough) nor sampling (75mas/pix enough).
- DRM STEP 3: Rotation Curves: Bosma's rule of thumb requires D_{gal}/2Dpix > 14. z=2: V_{rot} (MOAO/GLAO) and shape of RC (MOAO) recovered for M* galaxies. z=4: V_{rot} only with MOAO, beam smearing affecting RC shapes. In any case: deconvolution will be needed as it is already the case at at z=0.5-2.5 with GIRAFFE & SINFONI.
- DRM STEP 4: Detailed kinematics: recovery of clumps using MOAO for M* galaxies up to z=4. GLAO does not provide enough spatial resolution.

Summary - Technical

<S/N> vs. phys. parameters, instr. parameters, telescope parameters

➡ Scaling relations compared to and validated by simulations

- Impact of telescope:
  - Dominant source of background in K-band; SNR in background-limited regime for the z=5.6 case: limits detectability a very high z.
  - No breaking point in telescope diameter. $\text{SNR} \propto D$: reducing the diameter from 42 to 30m would require longer exposures by a factor 2. No impact on spatial resolution (partial AO correction regime).
- Impact of site:
  - Sky background: dominant source of background only in H-band (z=4 case) but the SNR is not in a background limited regime in this band.
  - Seeing: limited impact on (integrated) SNR (loss of ~5-15% from 0.8'' to 0.95''). Strongest seeing conditions will limit ability in recovering Rotation Curves and detailed kinematics.

Proposal

Goal: ~ 1000 galaxies at 2<z<6 with $0.1 < M_{stellar} < 5.10^{11}\ M_{\odot}$

Assumptions:

- MOAO, Mauna Kea-like Background
- R=5000, 50mas/pix
- SNR_{min}=10
- 3 redshift bins: z=2 (~10 Gyr ago), z=4 (~12 Gyr ago), z=5.6 (~12.6 Gyr ago)
- 3 mass bins per z bin : 0.5 – 1 – 5.0 $M^*(z)/M_{\odot}$
- 3 morphological/kinematical types per z/mass bin
- Multiplex=37 = minimal # of targets per elementary bin => 1000 galaxies
- Overheads = 30 %

Conclusion

Texp (hr)	0.5M*	M*	5M*	Total
Z=2	28	20	8	56
Z=4	56	34	13	103
Z=5.6	3220	1605	391	5215
Total	3304	1658	412	5373

Texp (n)	0.5M*	M*	5M*	Total
Z=2	4	2	1	7
Z=4	7	4	2	13
Z=5.6	402	201	49	652
Total	413	207	51	672

- Need to optimize the instrument for the highest-z bin: bigger pixels, better transmission, more multiplex, improved AO, ...
- Program feasible in ~ 100 nights, selecting galaxies with $M_{stellar}>10^{10}\,M_{\odot}$ ($M^*(z=5.6)=0.8\ 10^{10}\,M_{\odot}$)
- The "Physics of high-z galaxies" DRM is now completed
- Published proposal updated with results from simulations

  Science goals ⟺ requirements

- DRM report to be written soon