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The Physics of galaxy evolution in situ with EAGLE

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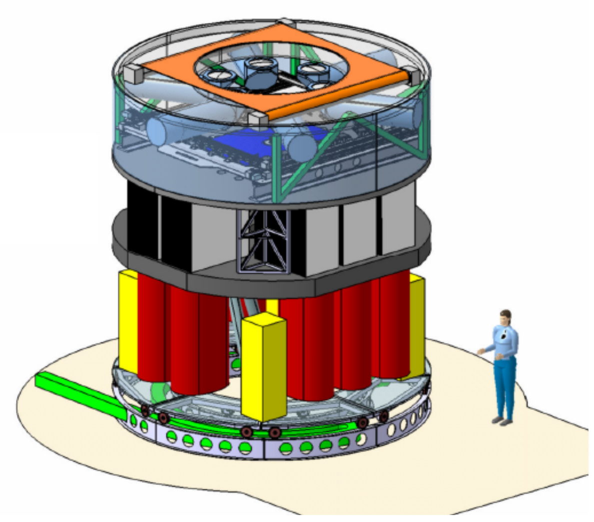
EAGLE

EAGLE is a NIR multi-integral field spectrograph assisted by MOAO dedicated to the E-ELT

Five Science Cases are driving the top-level requirements:

- Physics of high-redshift galaxies
- Resolved Stellar populations
- First light and the highest-redshift galaxies
- Black Holes and AGN
- Star-formation, stellar clusters,

and the IMF



EAGLE

EAGLE is a NIR multi-integral field spectrograph assisted by MOAO dedicated to the E-ELT

Five Science Cases are driving the top-level requirements:

- *Physics of high-redshift galaxies (this talk)*
- Resolved Stellar populations (see Chris' talk)
- First light and the highest-redshift galaxies (Jean-Gabriel's talk)
- Black Holes and AGN
- Star-formation, stellar clusters, and the IMF

Q: What is the main channel for mass assembly in galaxies (as a function of cosmic time)?

MareNostrum Cosmological Simulation (R. Teyssier et al.)

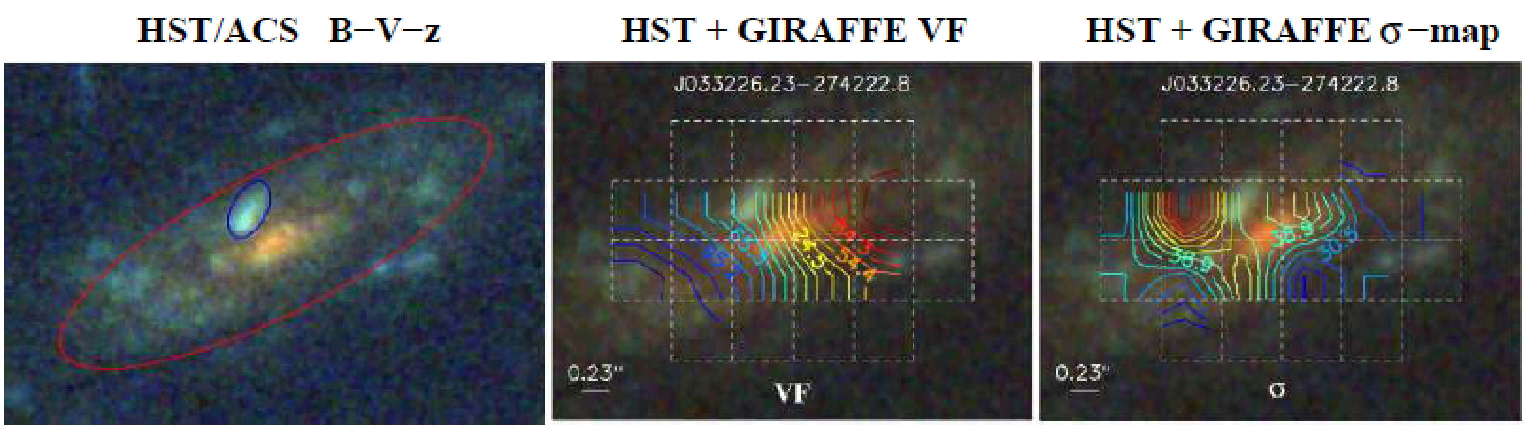
Galaxy Evolution

Q: What is the main channel for mass assembly in galaxies (as a function of cosmic time)?

A: *We don't know… But it is certainly one of these:*

- Cold gas accretion from filaments
- Minor mergers
- Major mergers

Violent process



We need to map the physical and chemical properties of galaxies

Scale-coupling

Galaxy evolution processes operate on different spatial scales

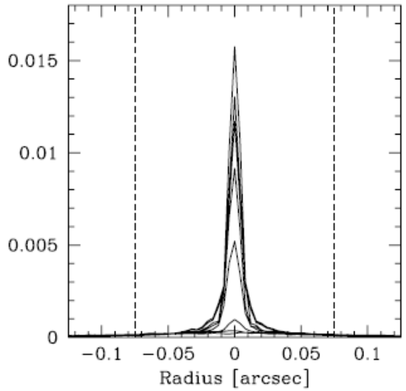
- Scale-coupling SC = scale to be resolved / size of the spatial element of resolution (Puech et al. 2008)
- Obviously: you need SC > 1, which simply means you need to adapt your IFS spatial resolution to the scale you need to probe…
- Examples: retrieving the whole shape of the rotation curve needs a higher SC than just deriving V_{rot} (Bosma78; Epinat+09 astro-ph/0904.3891)

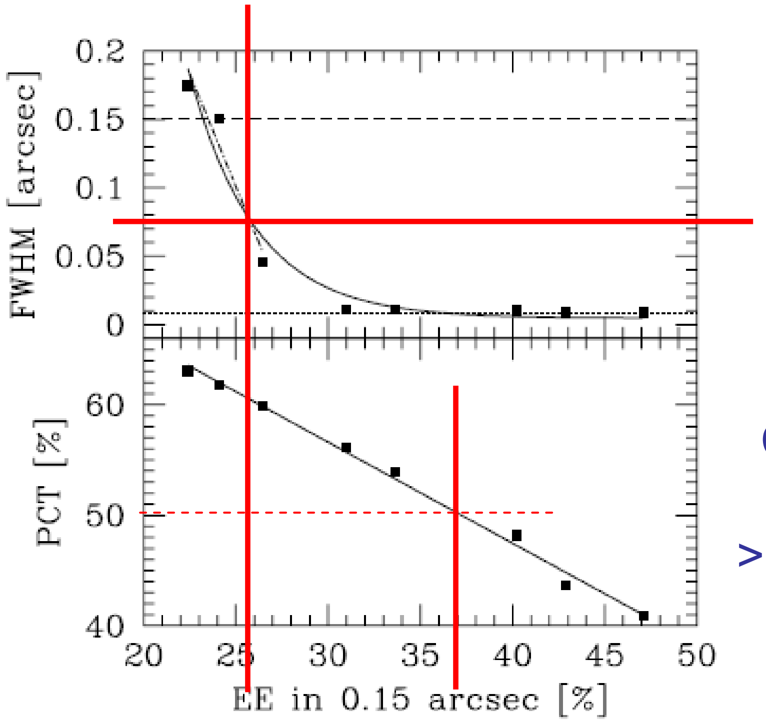
What is the right SC for studying galaxy evolution?

Contrast

- Contrast = how much of the light from the PSF lies within two spatial elements of resolution.
- The “contrast” sets how easy & accurate it is to distinguish discrete features over the sampling scale.

MOAO PSFs
From ONERA
(Neichel & Fusco)





Above EE ~25%,
s.e.r. = 2 pixels

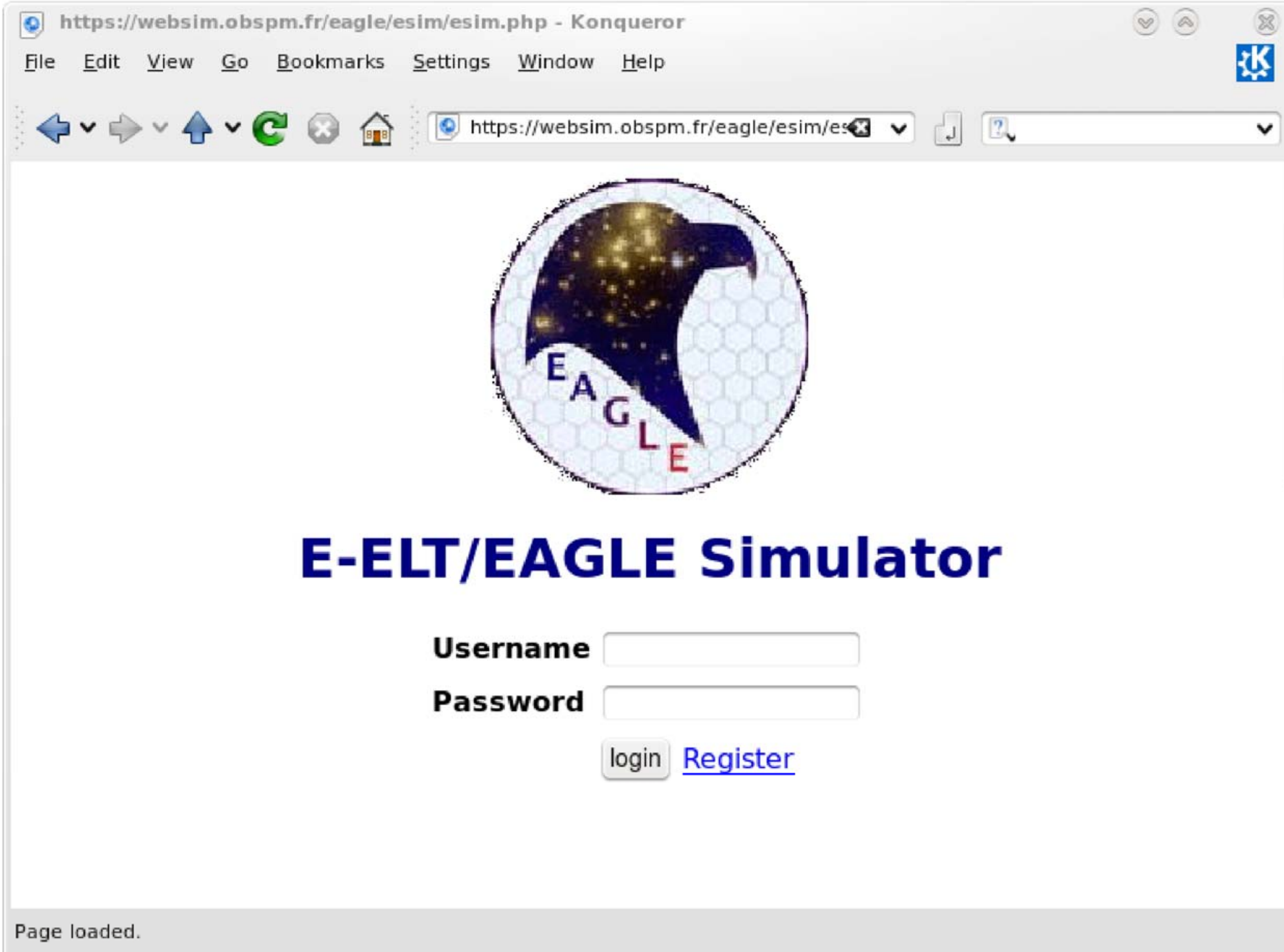
BUT

Significant
Cross-talk between
Adjacent spectra
> 50% up to EE~37%

Puech et al. 2008

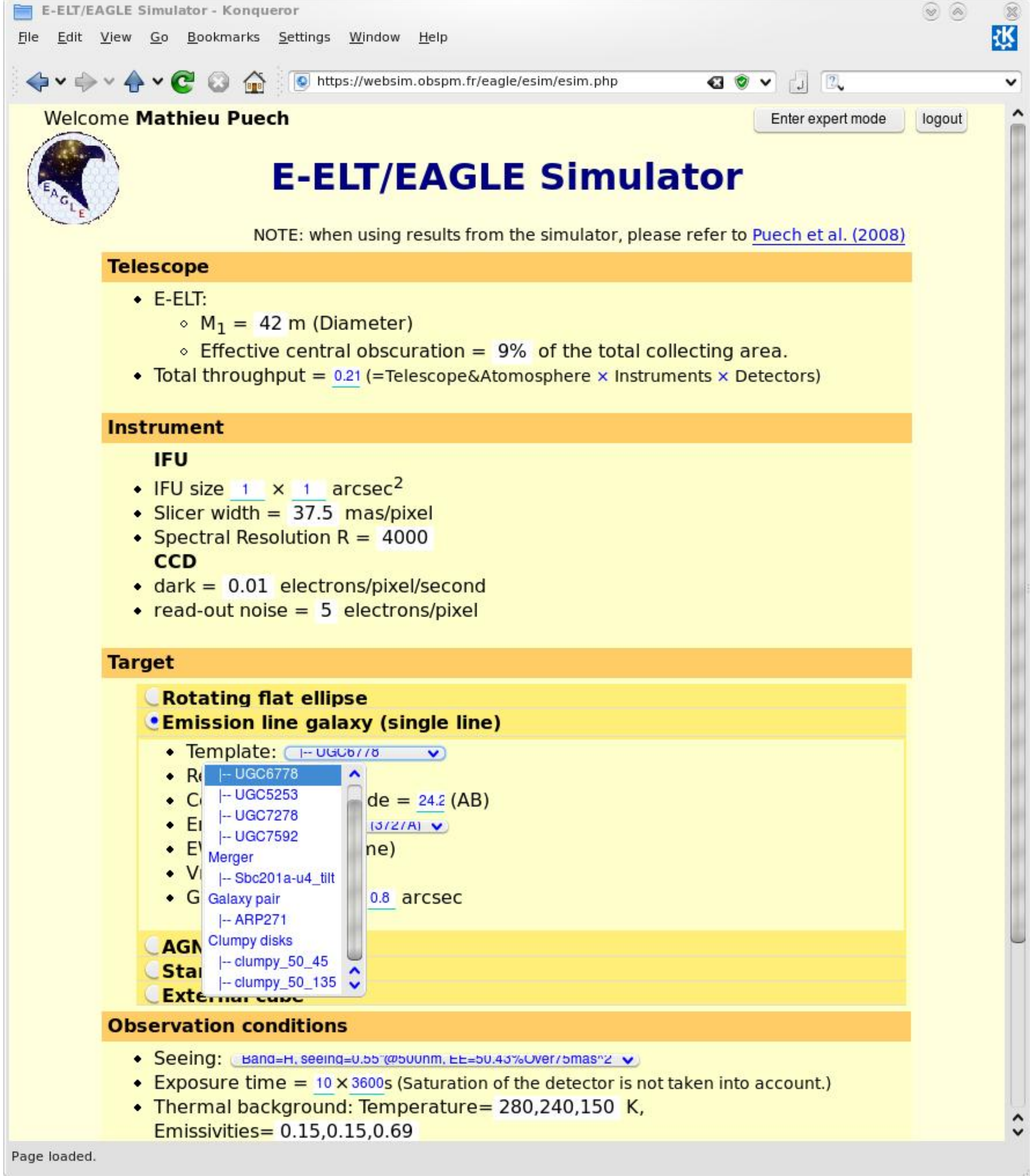
MOAO correction →

Simulations

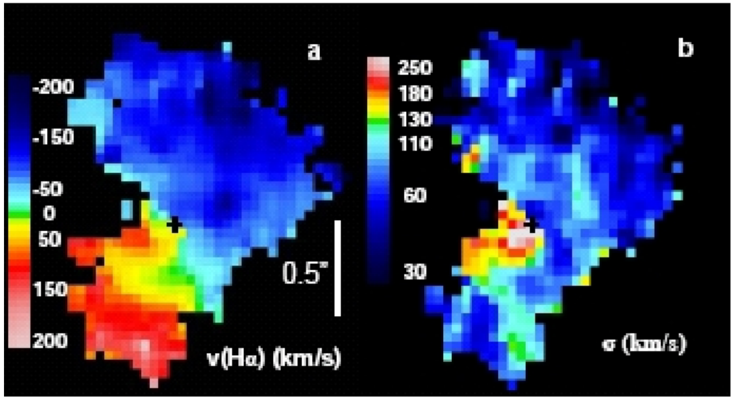


Behind the web interface:

The IDL code that was used for the DRM

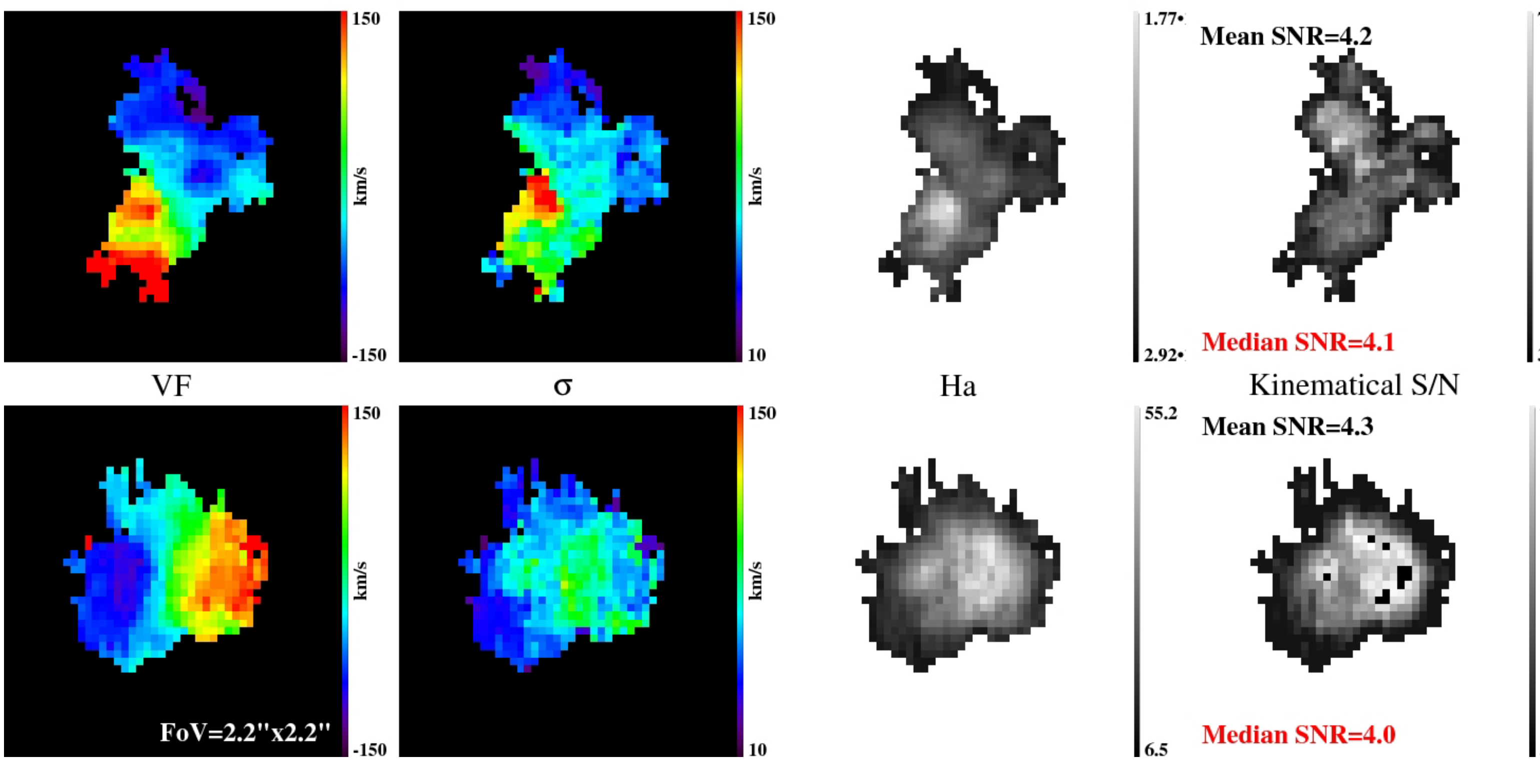


Testing the code (1): real observations at VLT/SINFONI

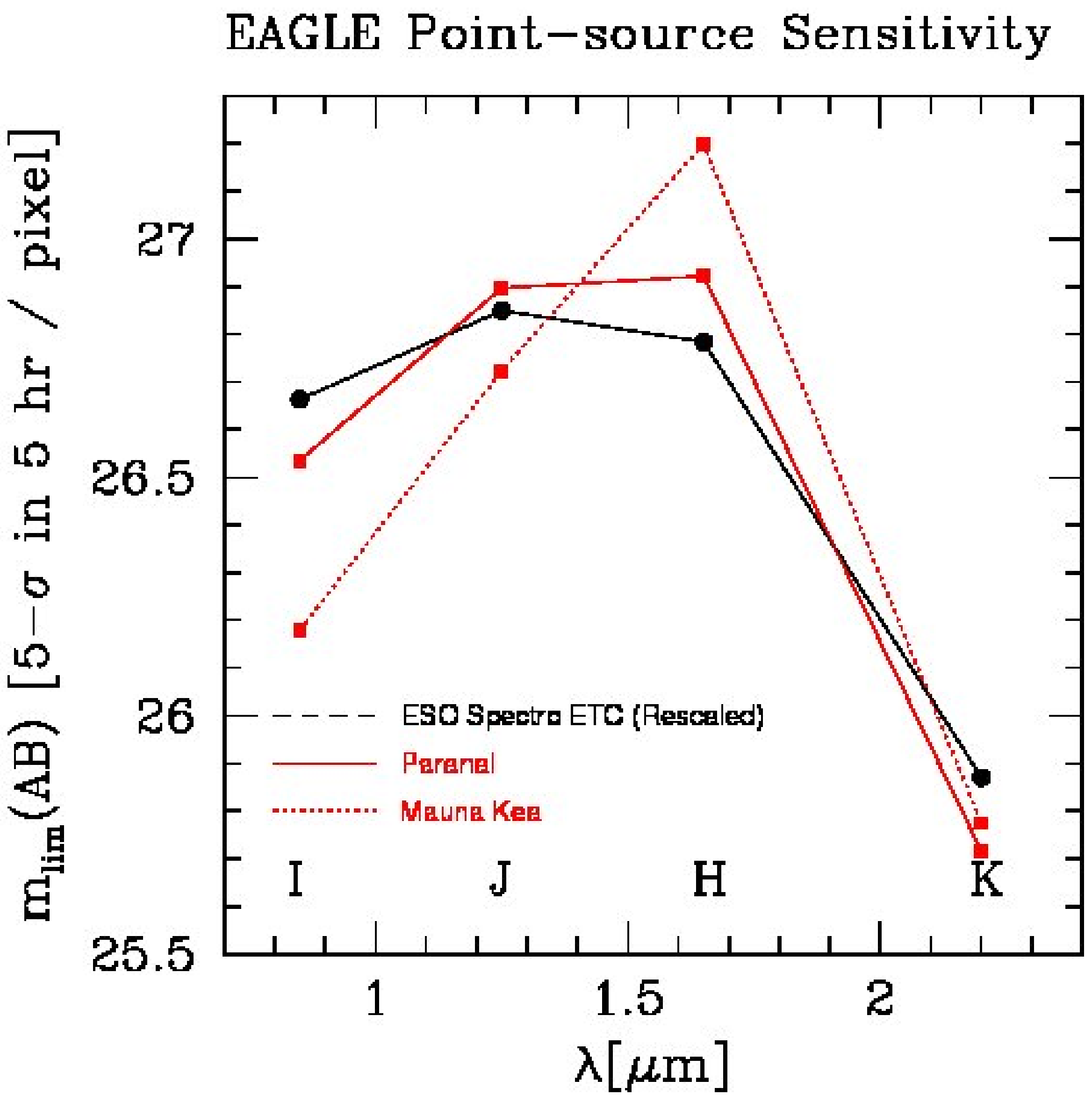


Genzel et al. (2006)
SINFONI data

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



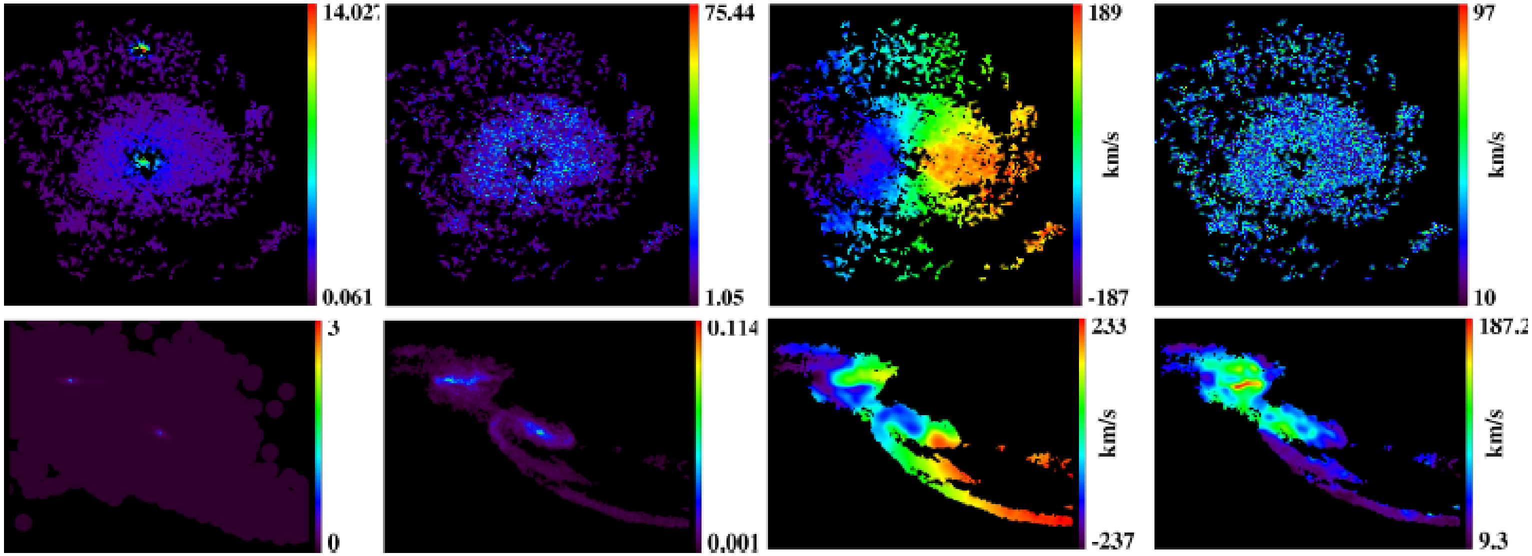
Testing the code (2): ESO E-ELT Point-Source Sensitivity



Large spatial scales

Test-case I : distinguishing between a grand-design spiral and a merging pair

UGC5253: Fabry-Perot Observations (Garrido et al. 2004)

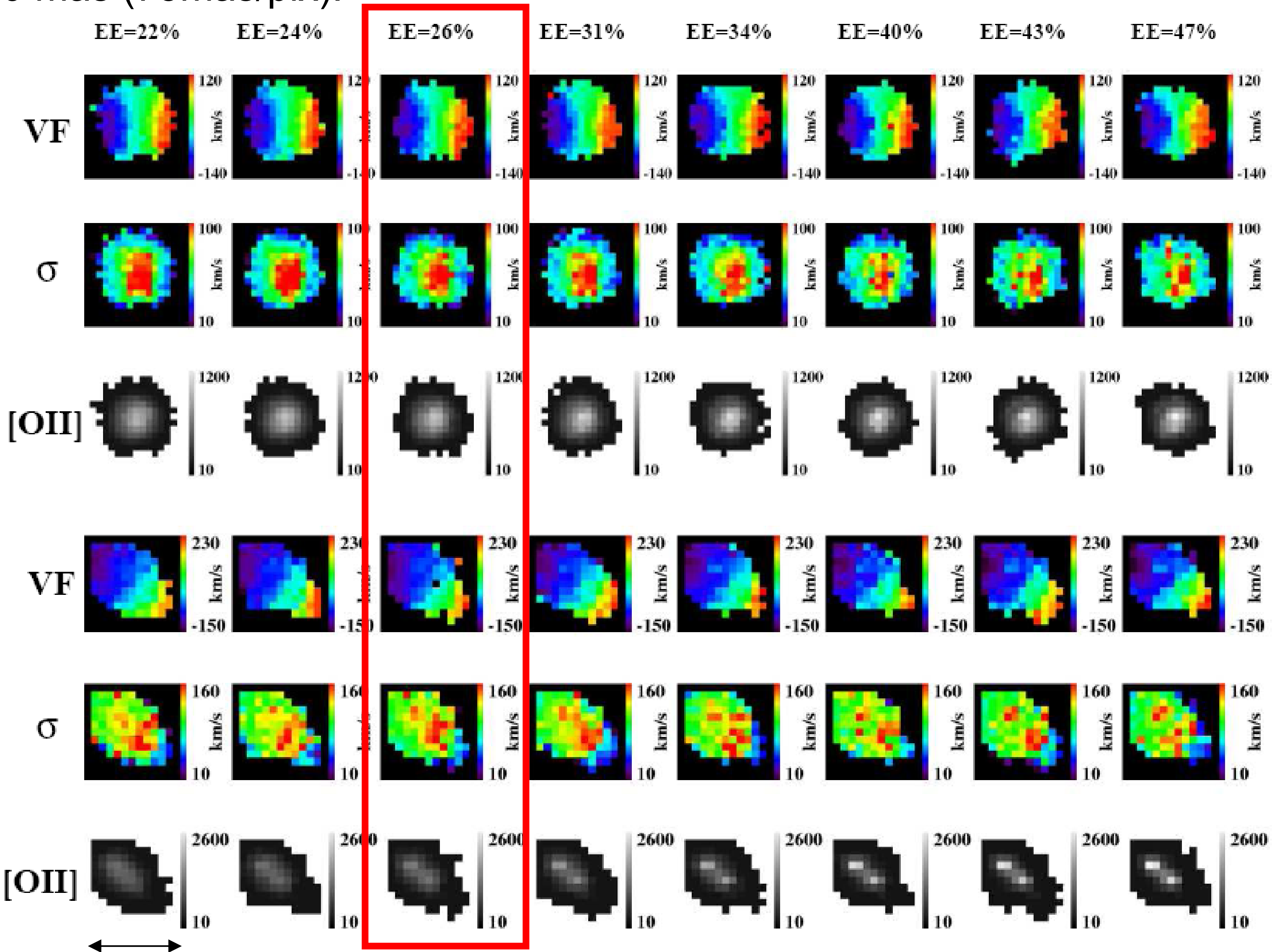


Sbc-Sbc Major Merger SPH Simulation (Cox et al. 2006)

What is the required scale-coupling & contrast to distinguish between them?

Mergers vs. Disks @ z=4

EE in 150 mas (75mas/pix):

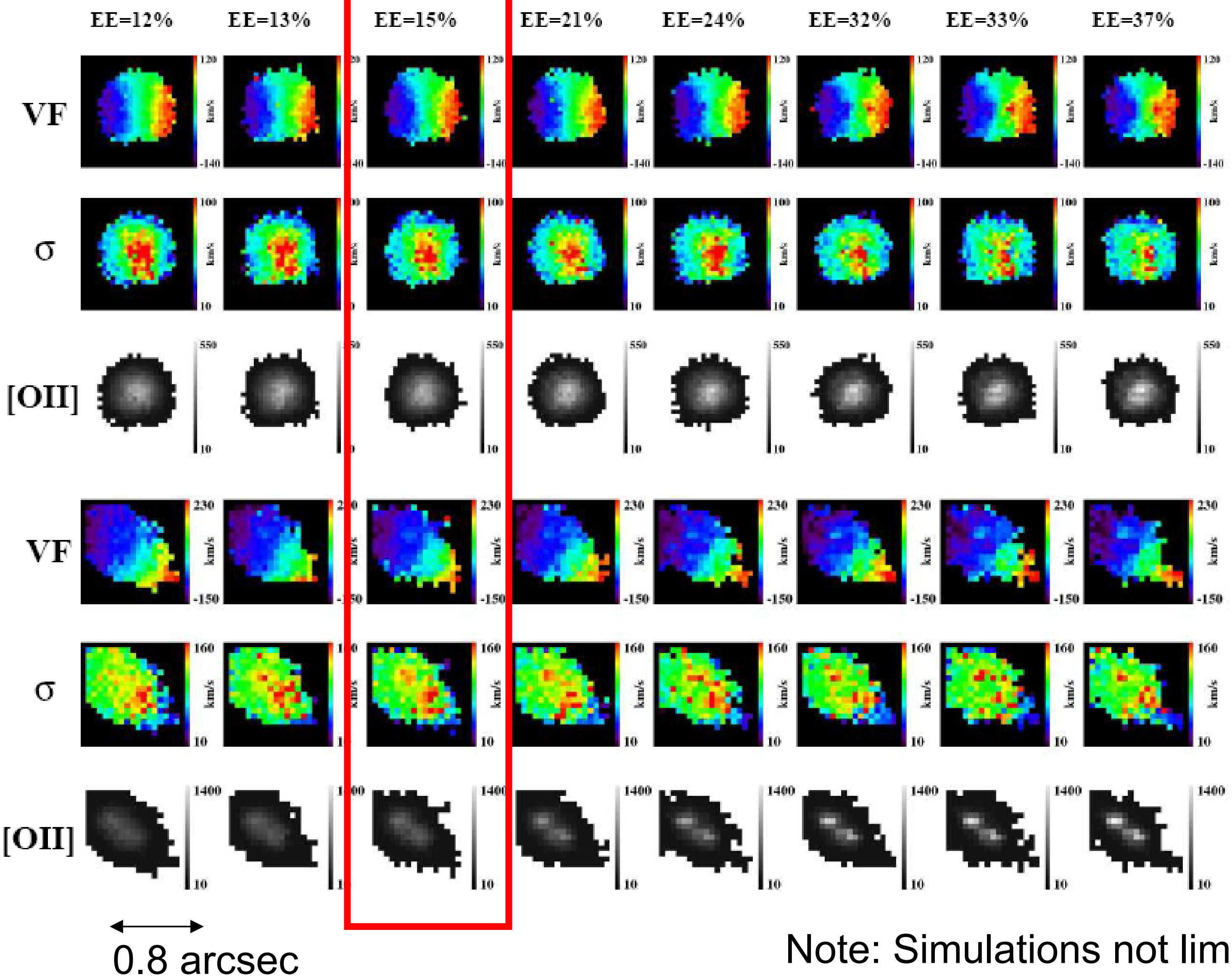


0.8 arcsec

Note: Simulations not limited by S/N

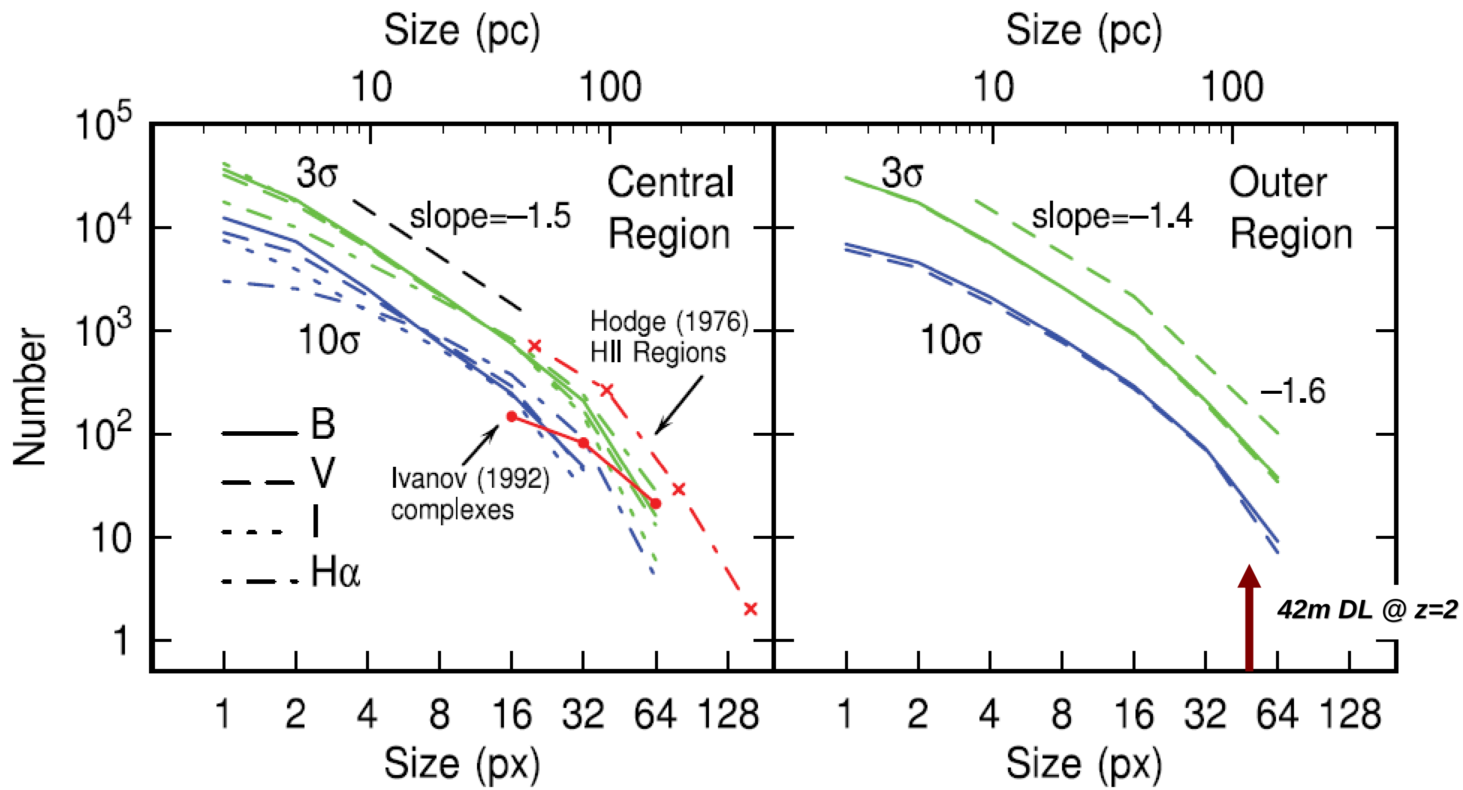
Mergers vs. Disks @ z=4

EE in 100 mas (50mas/pix): Smaller pixels ➔ smaller contrast required



Note: Simulations not limited by S/N

What about HII regions?

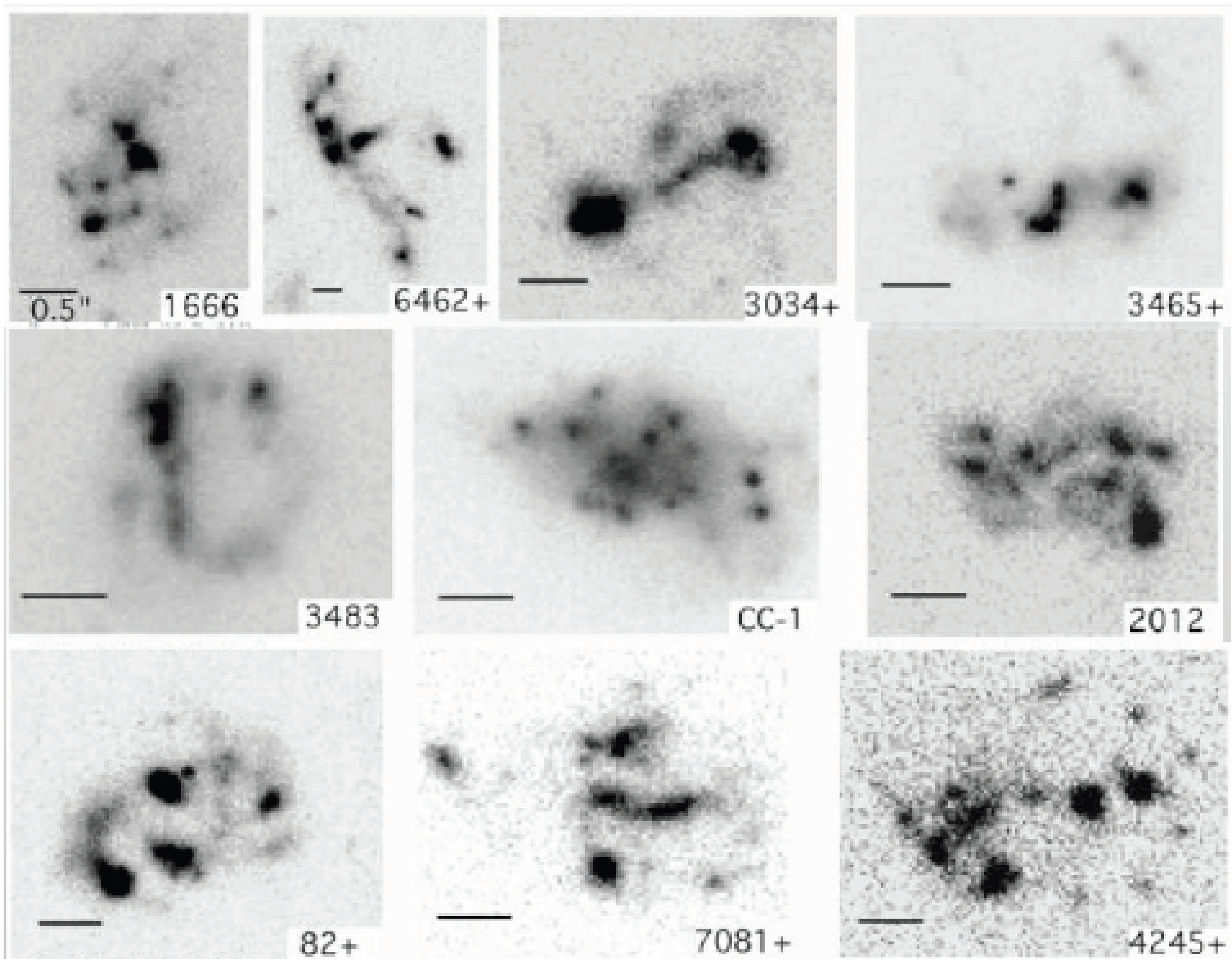


Elmegreen et al. 2006

The E-ELT will allow us to resolve only the largest HII complexes

Galactic scales

Kpc-sized clumps are ubiquitous in z>1 galaxies:

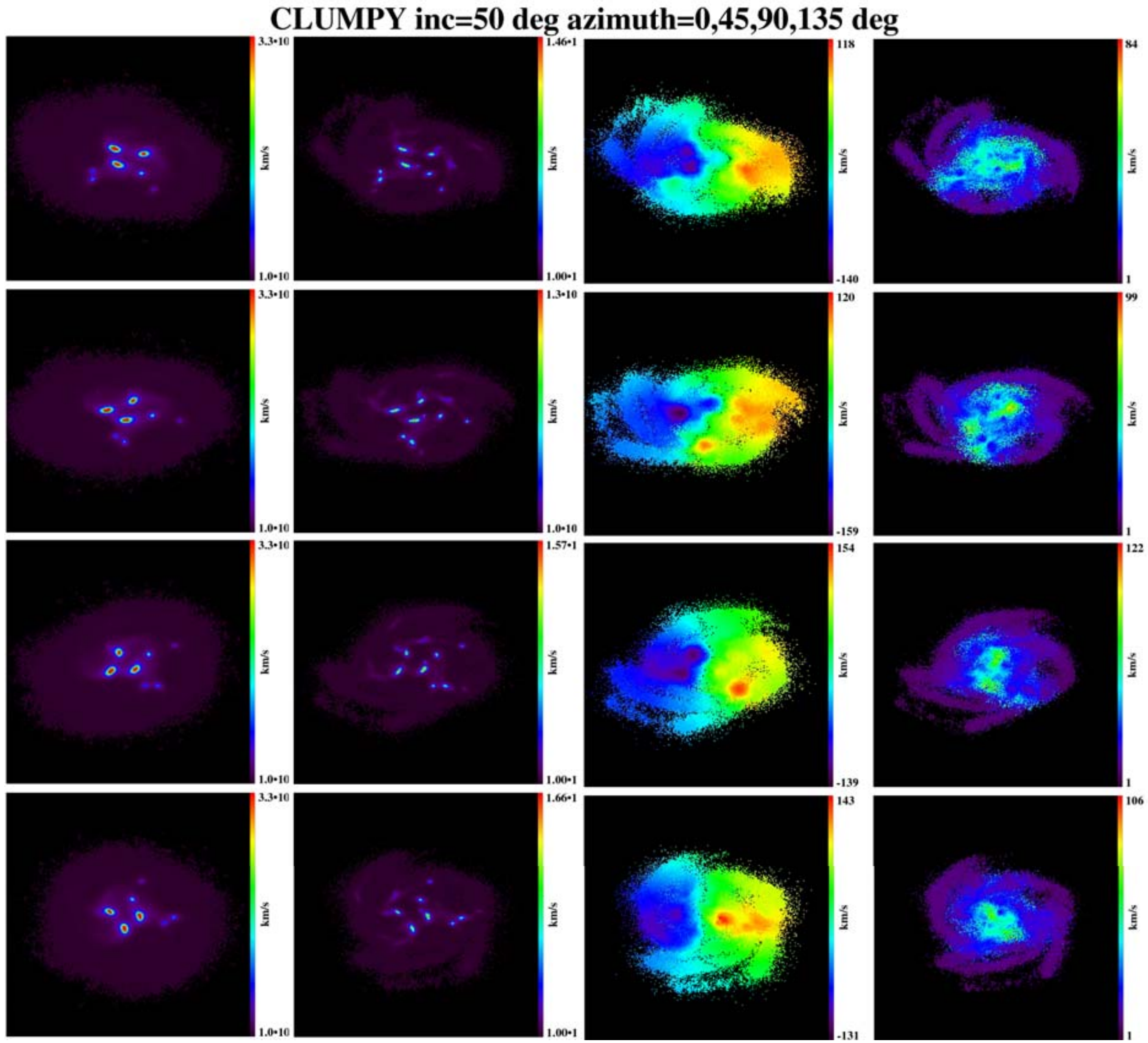


Clumps are thought to be resulting from Jeans-fragmentation in high-z, very gas-rich disks fed by cold streams

Elmegreen & Elmegreen 2005

Clumpy Disks

Test-case II : identifying clumps in high-z, Jeans-unstable disks

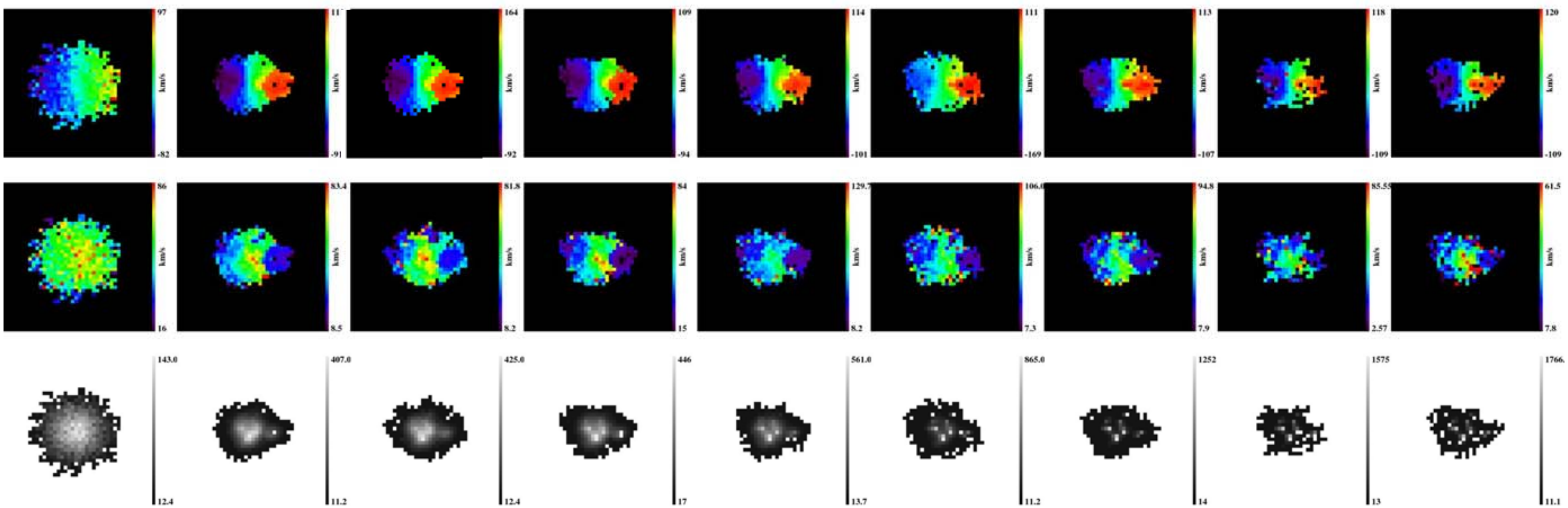


Bournaud et al. 2007

Clumpy Disks

Analogs with a range of EEs ... challenging since we consider a very small distant galaxy at z=4 with only 30A EQW (SINFONI data at z~2 show ~100A)

37.5mas/pix (EAGLE baseline) ➔ improved determination of the dynamics



seeing 15% 61%

At about 20% can start to see clumpy structure, 30% is more robust

EAGLE TLR (Galaxy Evolution)

Spatial scale	Minimal aperture/EE	Optimal aperture/EE	Comment
Large scale motions	30% in 150mas (~14% in 75mas)	30% in 100mas (~25% in 75mas)	Good confidence level
Clump detection	20% in 75mas	30% in 75mas	Structure of clumps uncertain at high z

	Minimal	Optimal	Goal
EE required in 75mas	15%	25%	30%

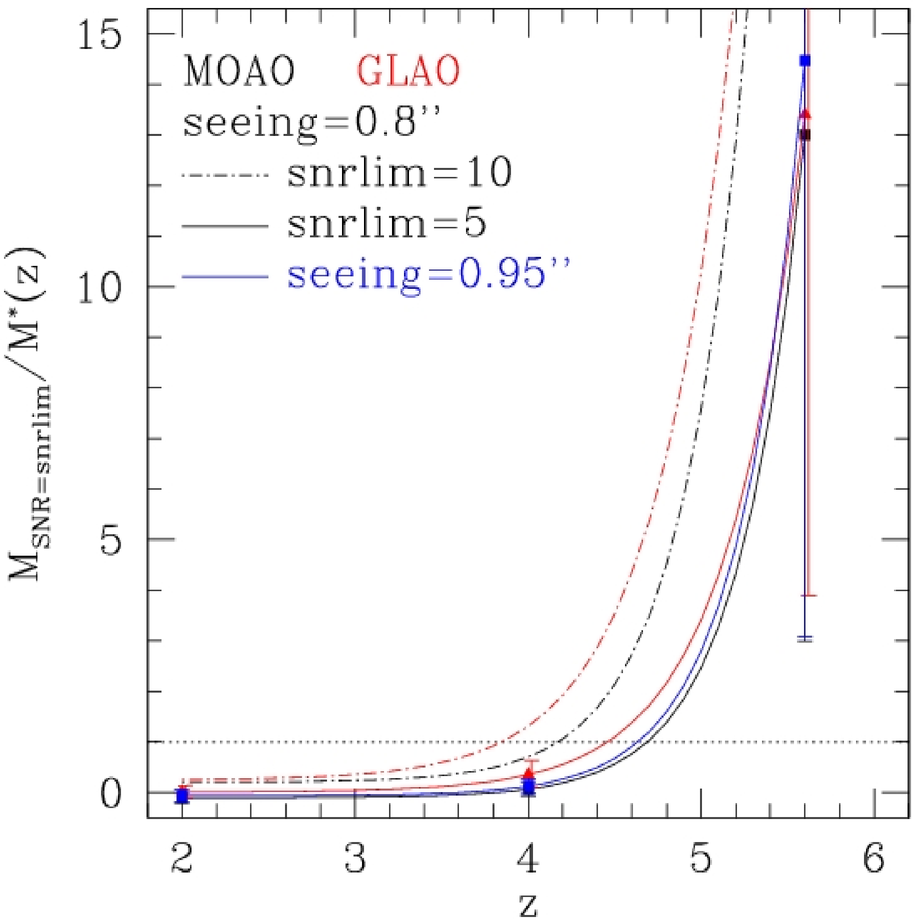
Current baseline: EE=30% in 75 mas (H-band) ⇔ $A_{E\text{-}ELT}\Omega_{EAGLE} \approx A_{VLT}\Omega_{KMOS}$

EAGLE Survey

DRM Results: mass-limited sample of z=2 to ~6 galaxies

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

T_{intg}	$0.5M_*$	M_*	$5M_*$	Total
z=2	1.2	0.8	0.3	2.3
z=4	2.3	1.4	0.6	4.3
z=5.6	—	66.9	16.39	83.2
Total	3.5	69.1	17.2	89.8

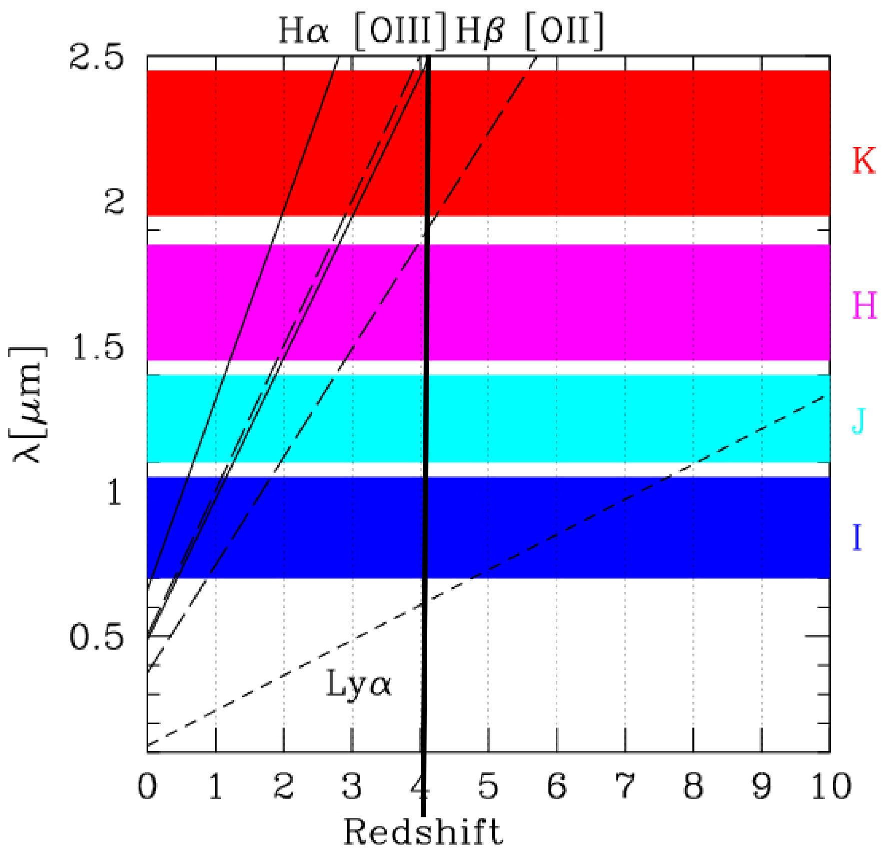


Actual high-z 3D samples are drawn from various selection criteria and constrains (ie, atm abs), which makes their representativeness relatively uncertain.

One would like to use the E-ELT power to observe *ALL* galaxies in a given volume and then draw secured representative samples

EAGLE Survey - Shallow

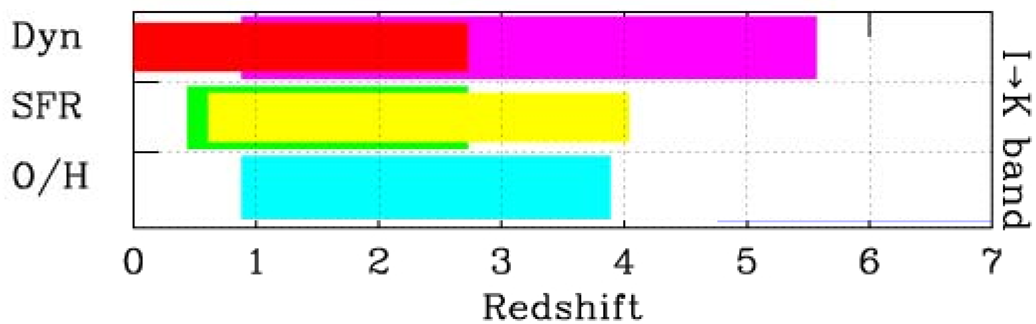
- A « Broad shallow survey » of galaxies in emission lines to study their dynamics
- z range = 1 to 4
- Hα up to z~2 and then switch to bluer lines to avoid the K-band
- Needs ~5-30 hr per field depending on mass, etc.
- Total integration time = ~100 hr for ~1000 gals (multiplex=20)
- Detection limit is ~ 10^{-19} erg/s/cm^2/A/pixel



EAGLE Survey – Deep

- A deeper survey in favorable windows to derive line ratios
- z range = [1.2-1.7, 2-2.6-3-3.6] to have emission lines available in 2 or 3 bands

- 20 gals / band



- Needs ~30 hr per band

- Total integration time ~270 hr for ~60 gals