Intermediate
Mass
Galaxy
Evolution
Sequence

Mathieu PUECH

ESO/GEPI
& the IMAGES Coll.
(P.I.: F. Hammer)

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IMAGES Survey

Sample selection

$M_J < -20.3$ & $0.4 < z < 0.9$

$M_{stellar} > 1.5\ 10^{10} M_\odot$ (~M*)

Integrated properties

FORS2 (600RI+600z)

Spitzer

Chandra

Morphology

ACS imagery

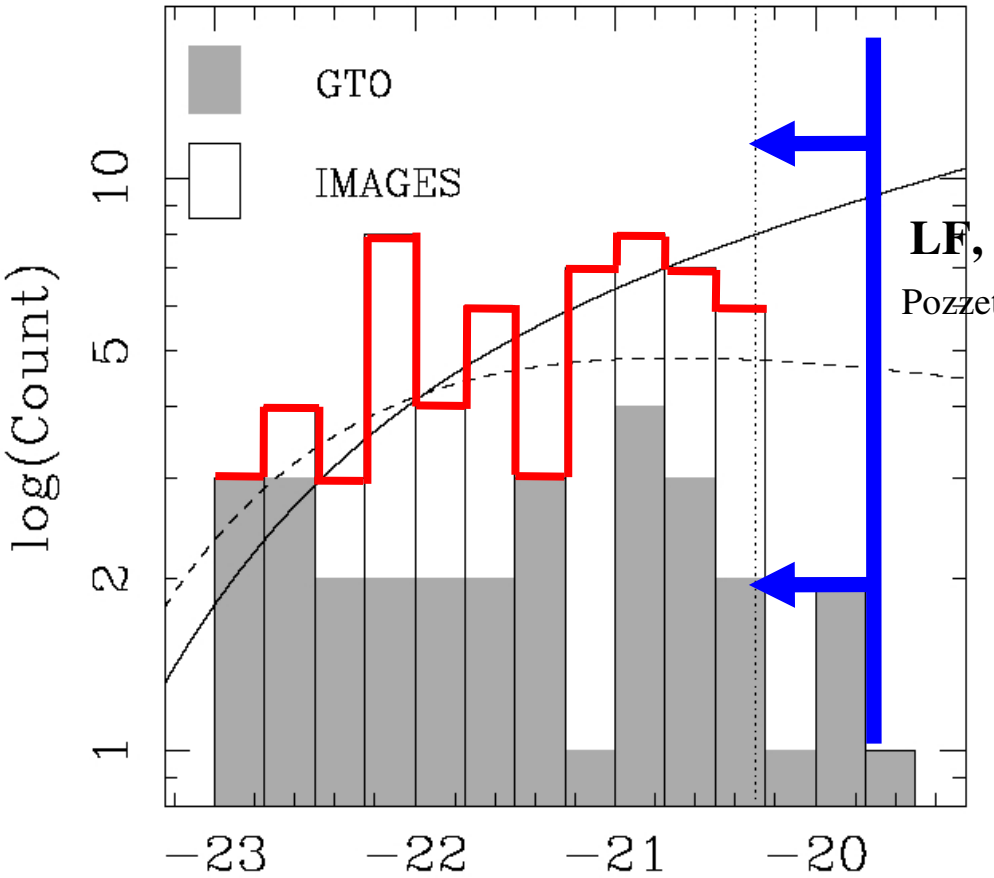
Kinematics

VLT/FLAMES-GIRAFFE

This talk:

Sub-sample with $EW_0([OII])>15$ Å and $0.4 < z < 0.75$

+ GTO



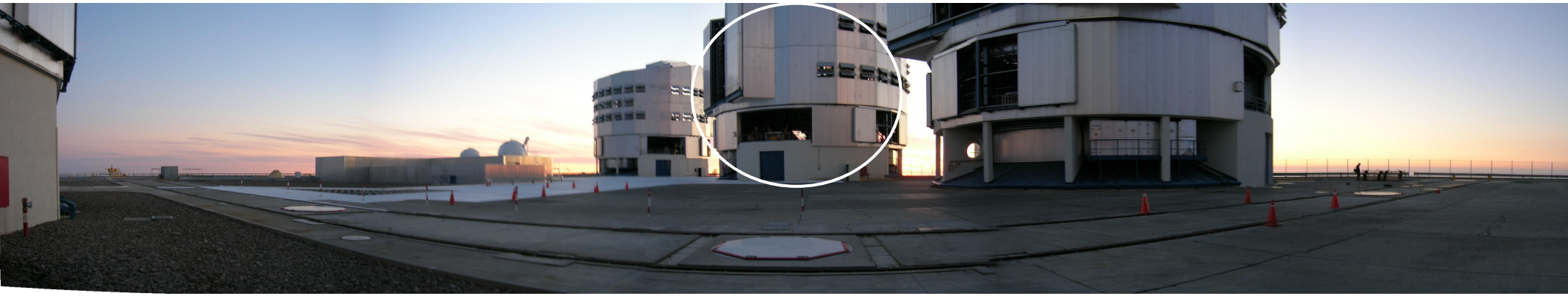
LF, z=0.5,1

Pozzetti et al 2003

Yang et al (2007)

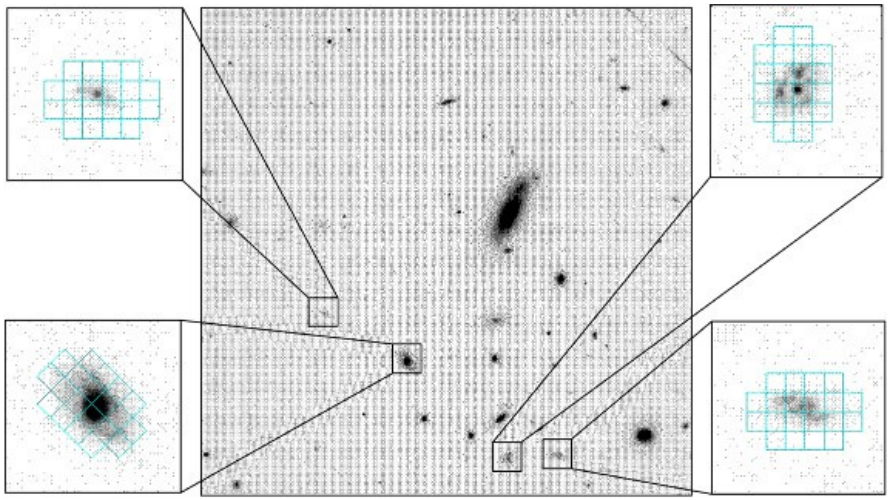
IMAGES+GTO = a representative sample of 63 M* galaxies selected in 4 different fields of view

FLAMES/GIRAFFE on the VLT

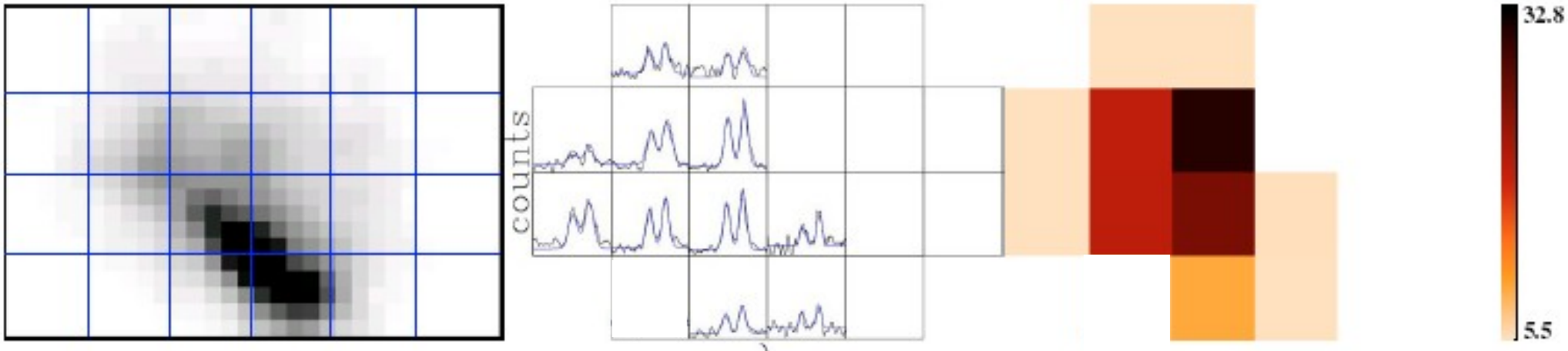


IFU Mode: 15 x 3''x2''arrays
(20 sq. µlenses, 0''.52)

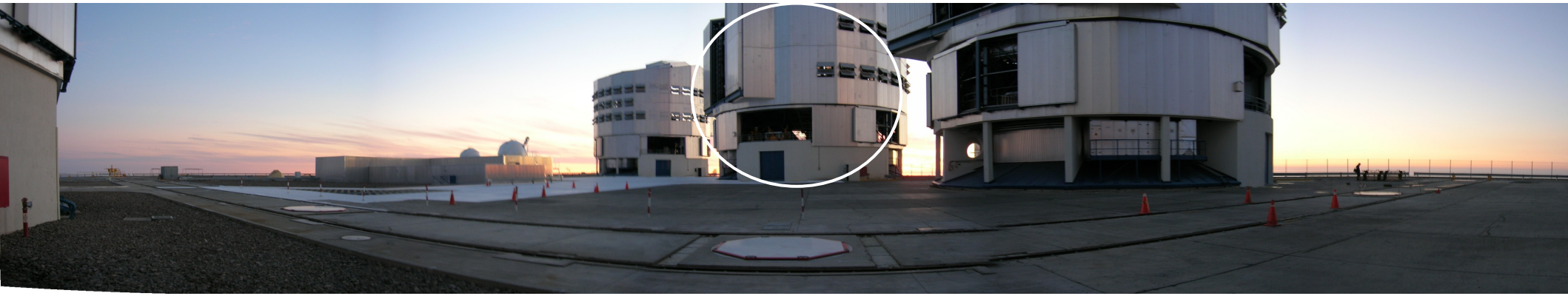
15 IFUs deployable over a 20 arcmin FoV with $R_{effective}$>13000 ➔ the [OII] doublet can be resolved



CFRS03.0488, z=0.46, (3''x2'')



FLAMES/GIRAFFE on the VLT



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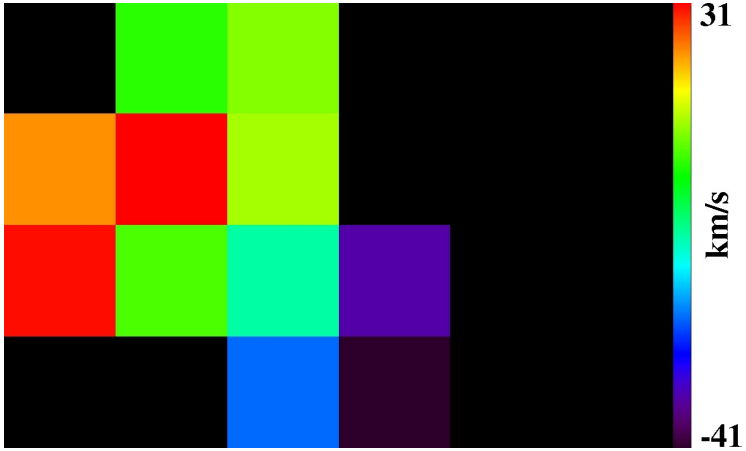
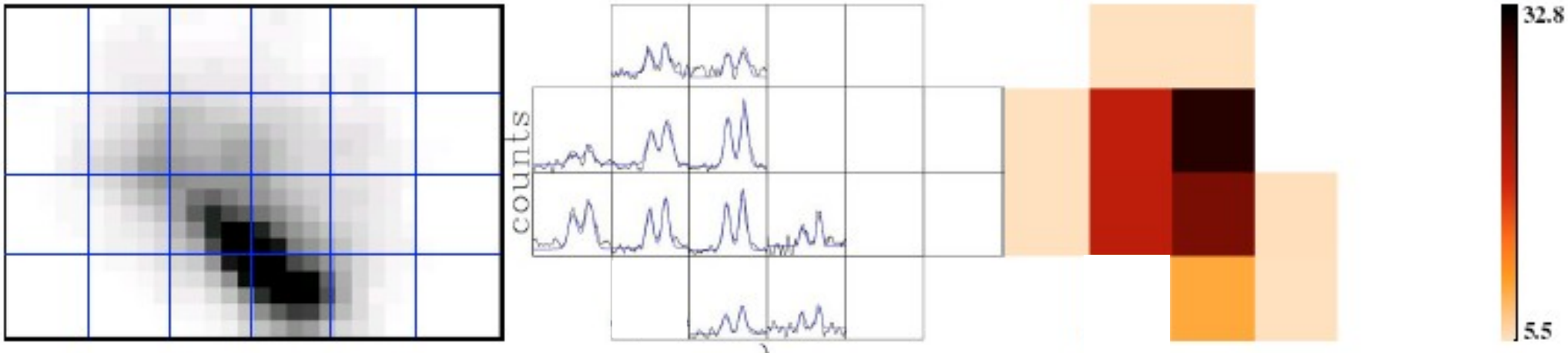
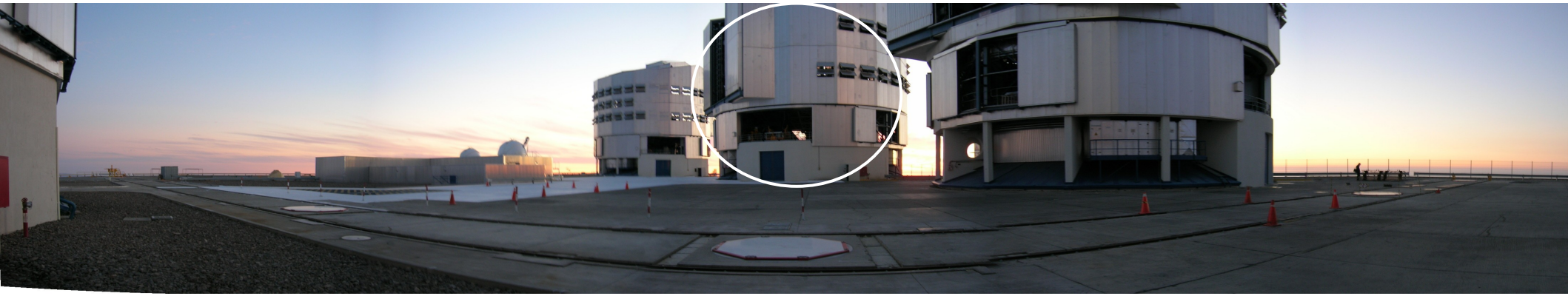


CFRS03.0488, z=0.46, (3''x2'')

VF using pixels with S/N > 3



FLAMES/GIRAFFE on the VLT



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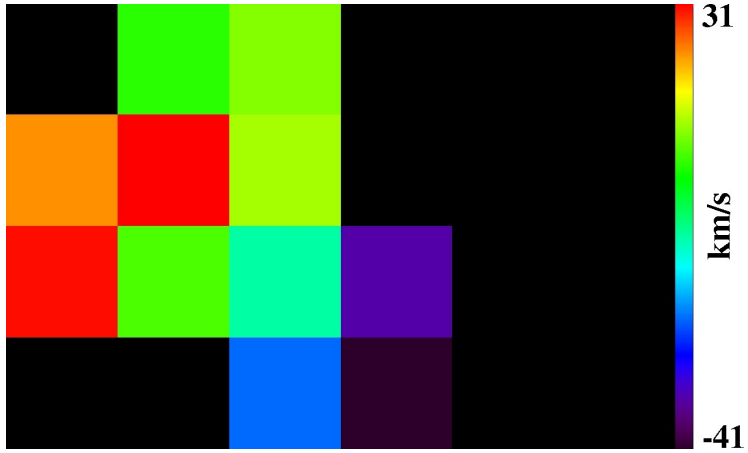
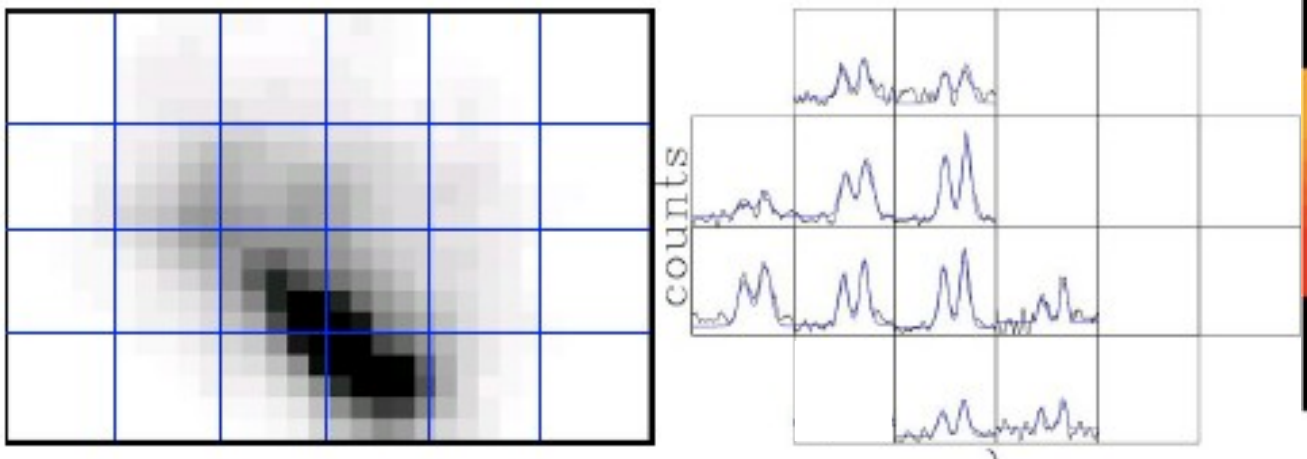
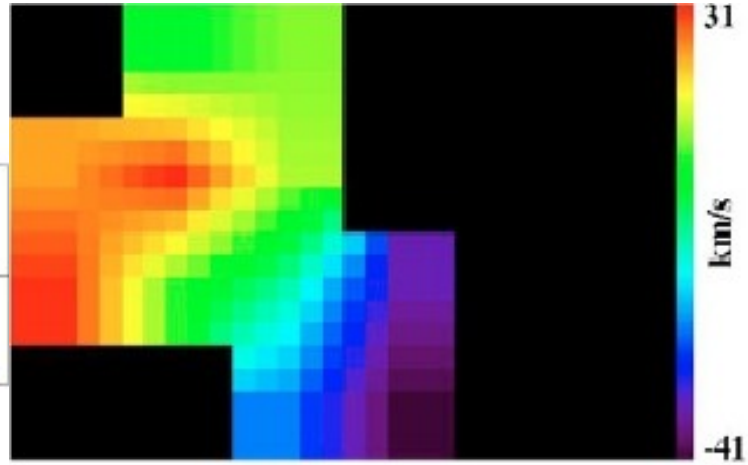


CFRS03.0488, z=0.46, (3’’x2’’)

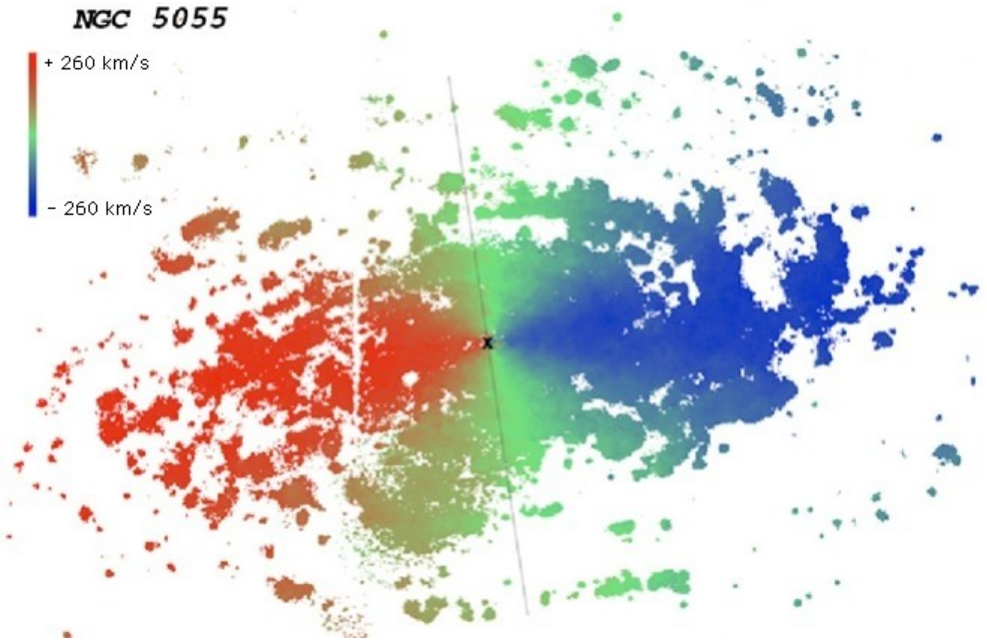


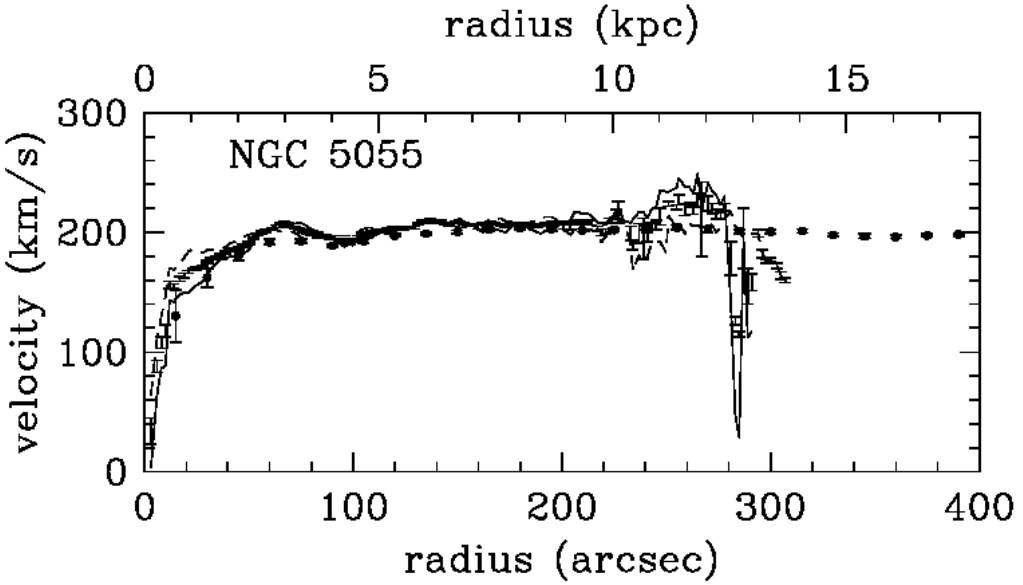


5x5 linear interpolation

Velocity dispersion maps

<u>Provided by</u>: the absence of cross-talk between individual spectra.



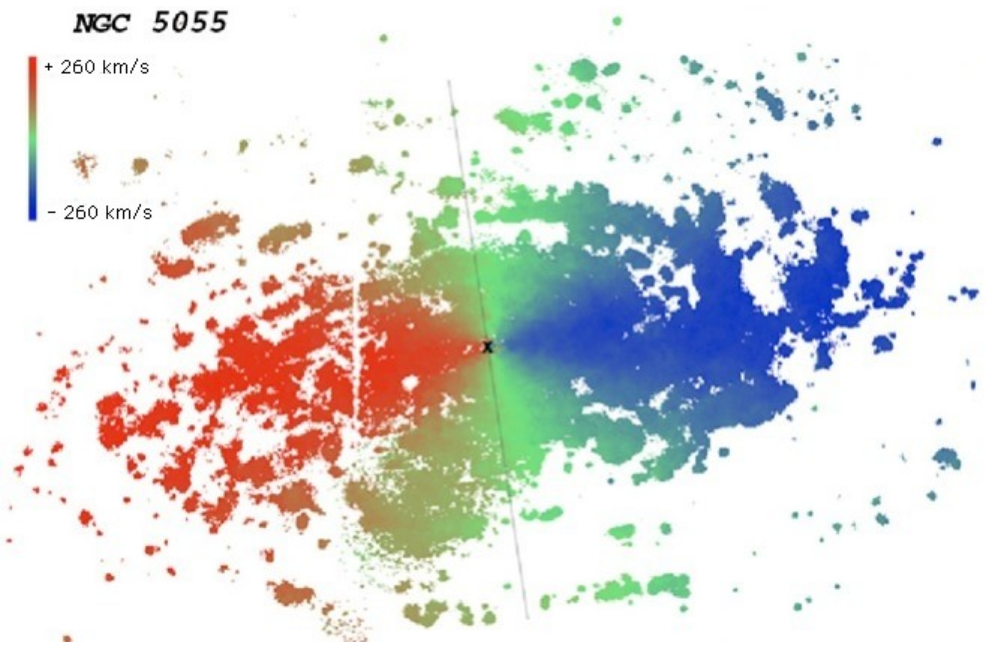


from Blais-Ouellette, Amram et al, 2002 (Fabry-Perot/Halpha)

VFs but also σ-maps

<u>Provided by</u>: the absence of cross-talk between individual spectra.

$$\sigma_{pixel} = \sigma_{random\_motions} \otimes \Delta V_{large\_scale\_motions}$$



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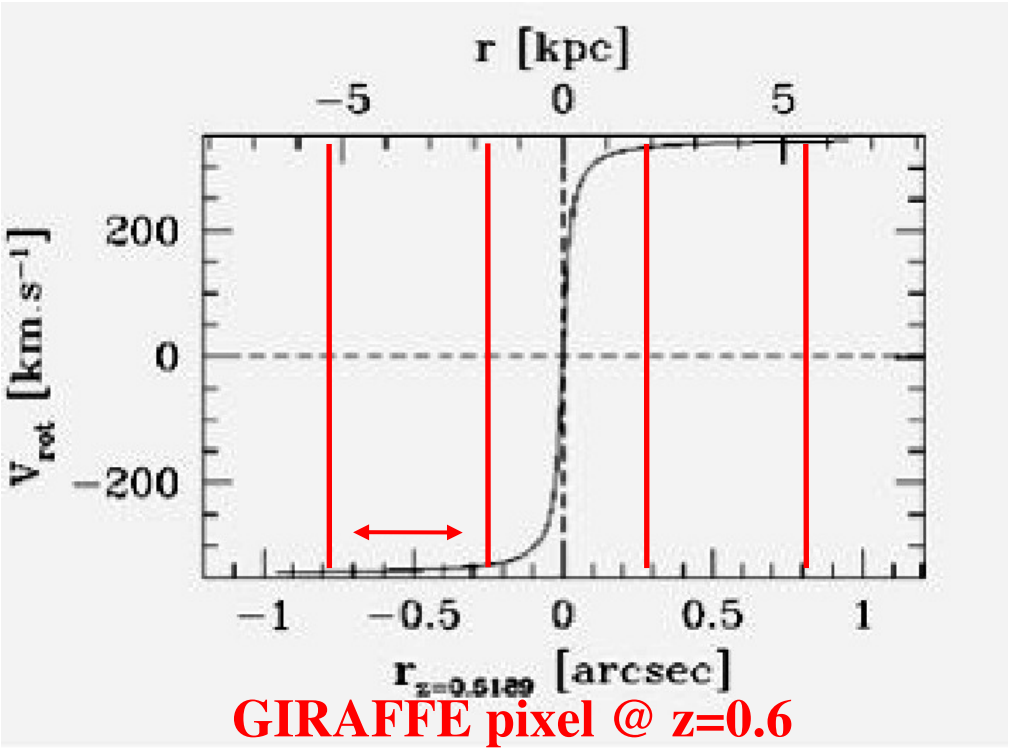

GIRAFFE pixel @ z=0.6

VFs but also σ-maps

Provided by: the absence of cross-talk between individual spectra.

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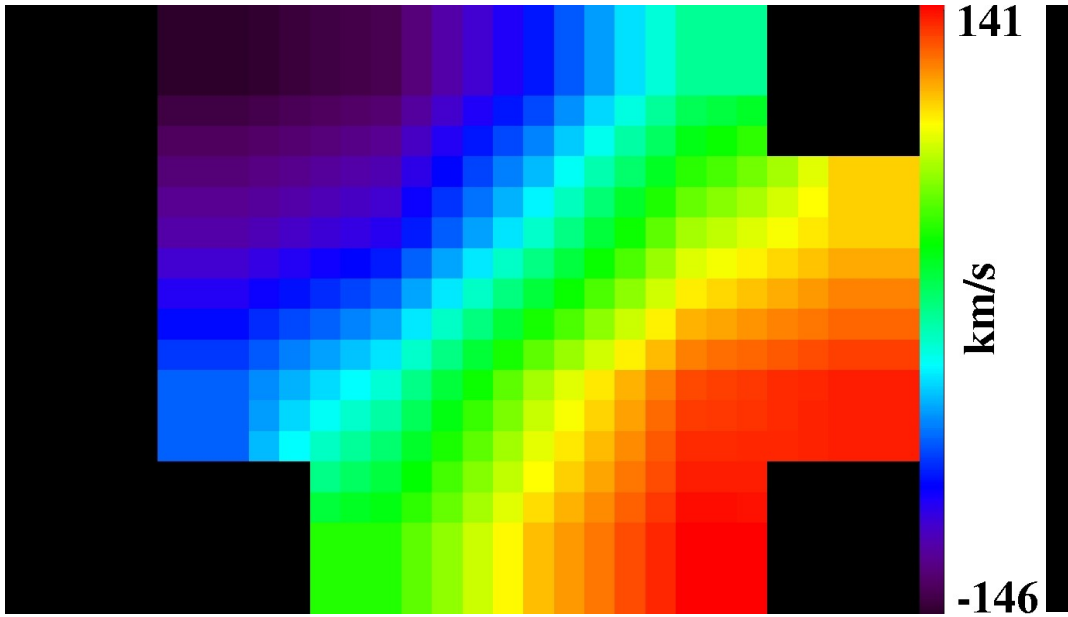
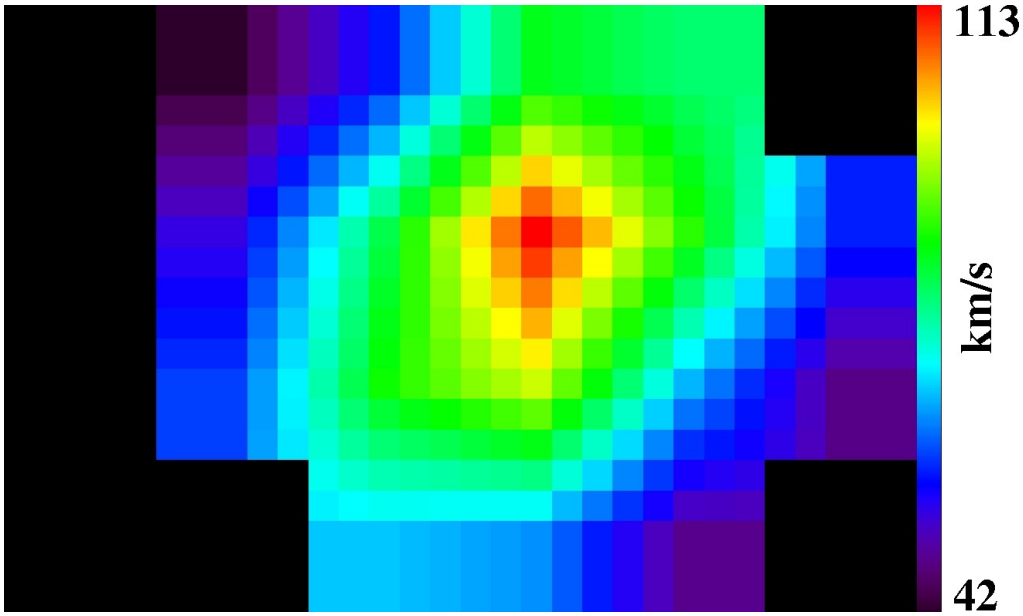
At low spatial resolution, dispersion maps of rotating disks do show a peak in their dynamical center



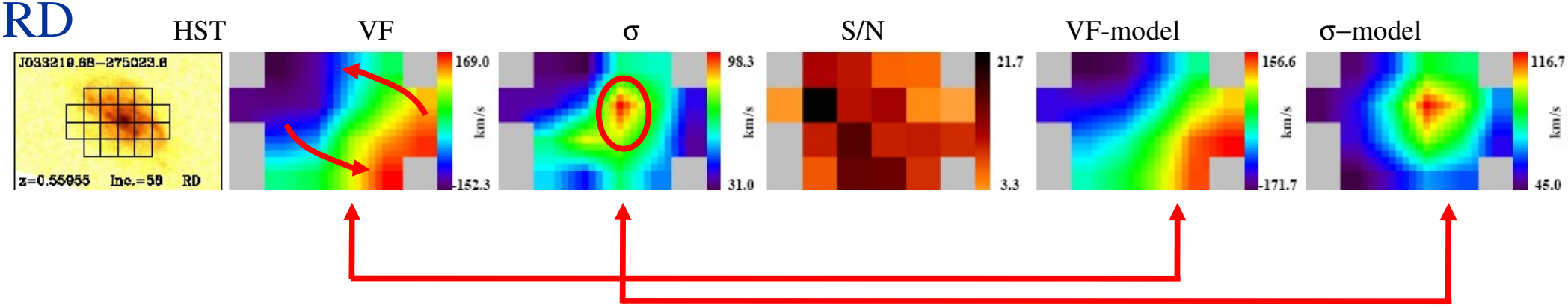
Velocity map



Dispersion or σ map

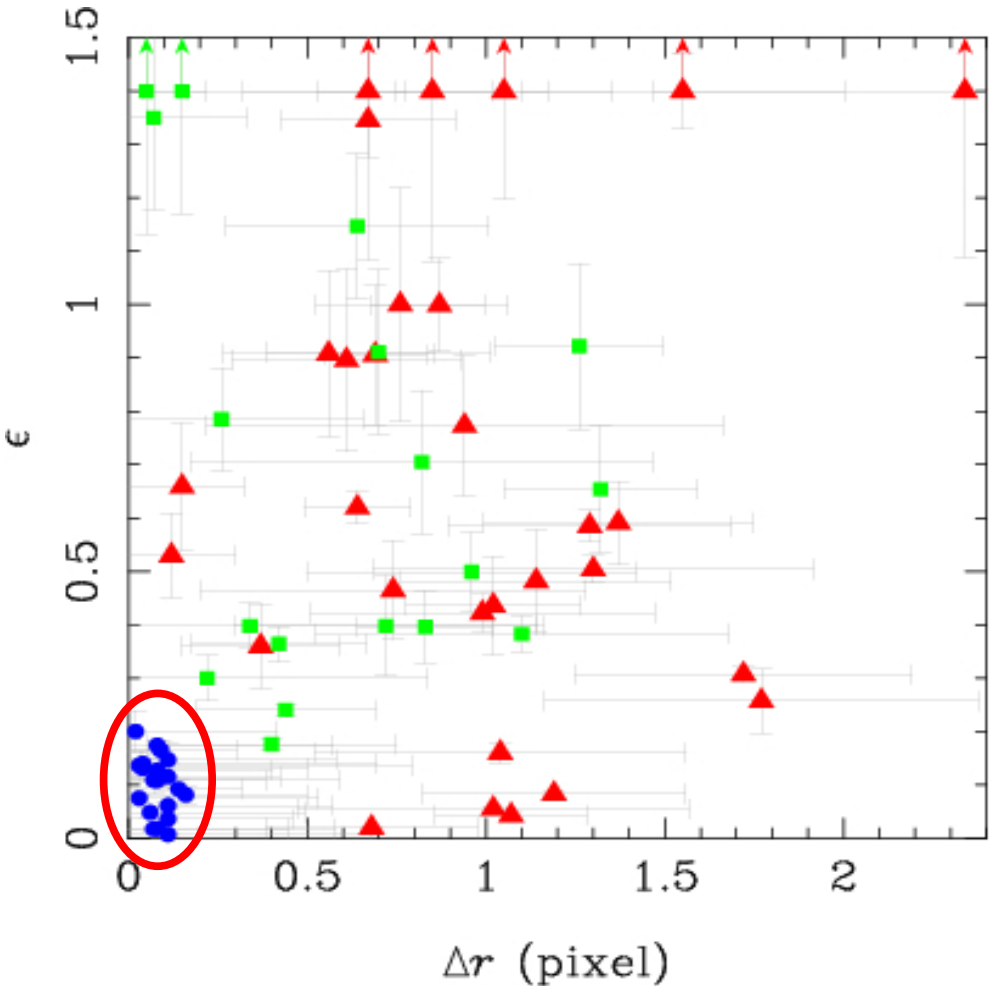
Resolved Kinematics

RD

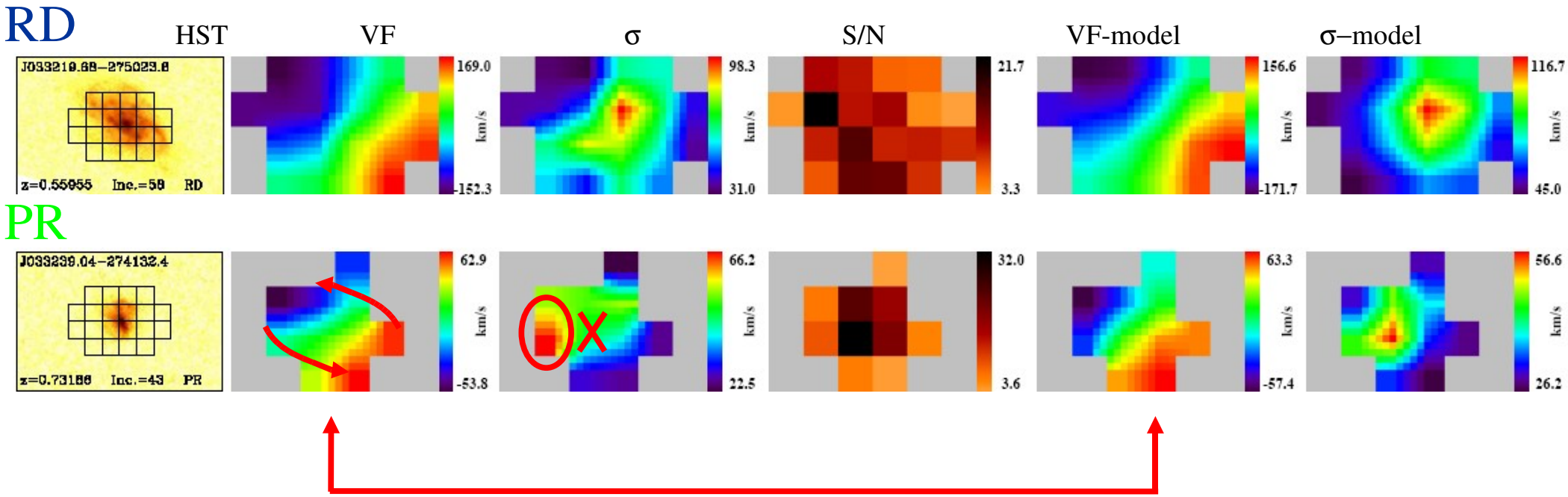


All galaxies are assumed to be rotating disks:

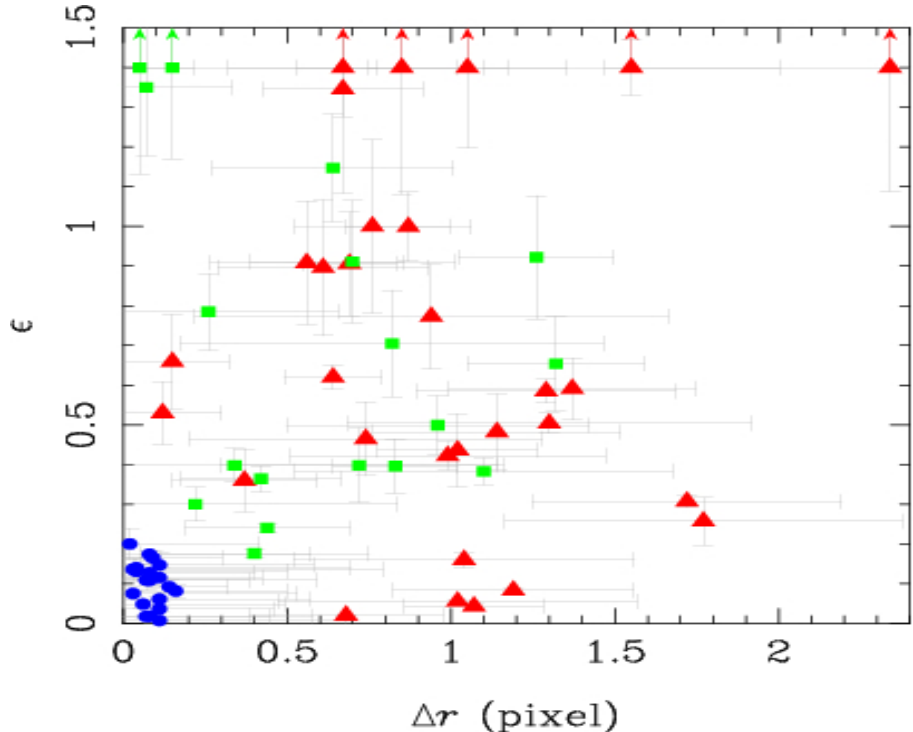
- **their large scale motions are due to rotation**
- **simulation of corresponding VF and σ-map**
- **comparison of the derived σ-maps to the observed ones (relative difference of amplitude ε vs. σ peak distance Δr)**



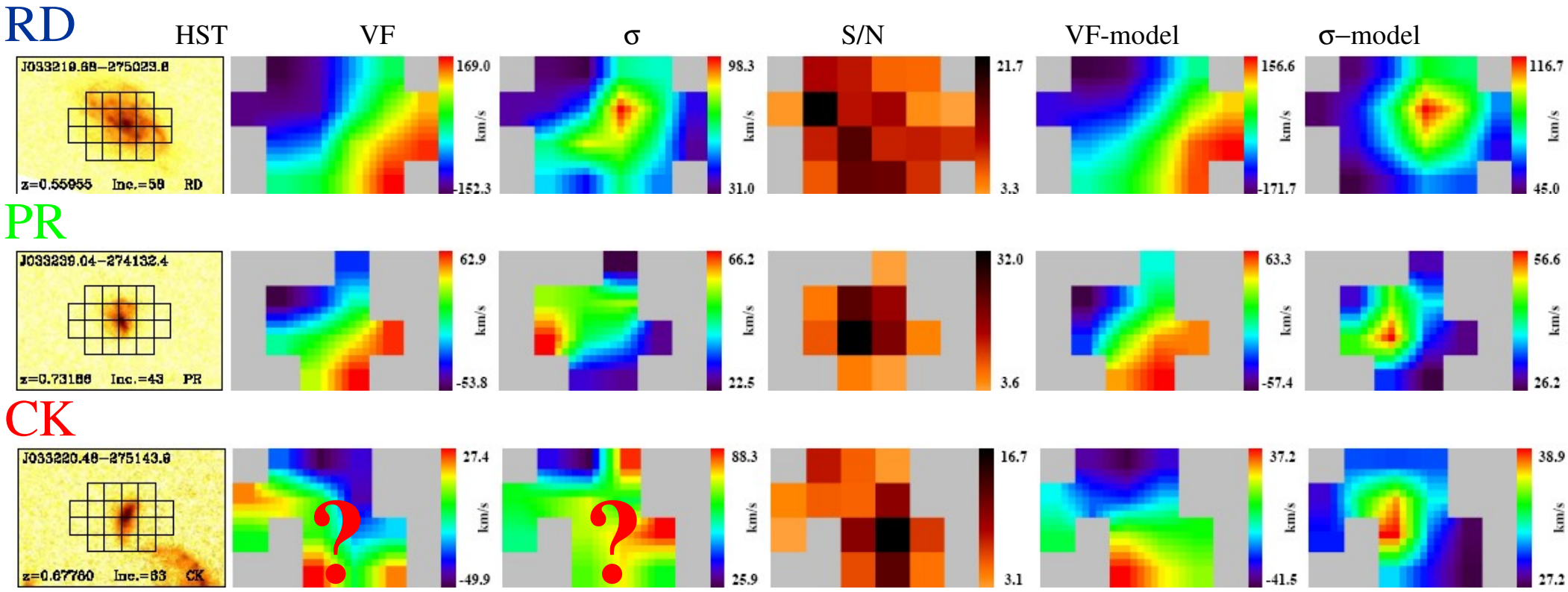
Resolved Kinematics



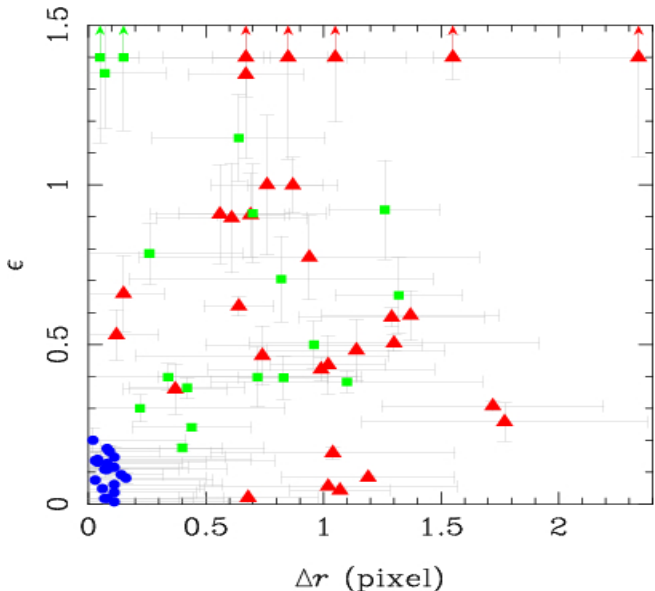
- **Rotation seen in the VF**
- **Off-centered σ peak**



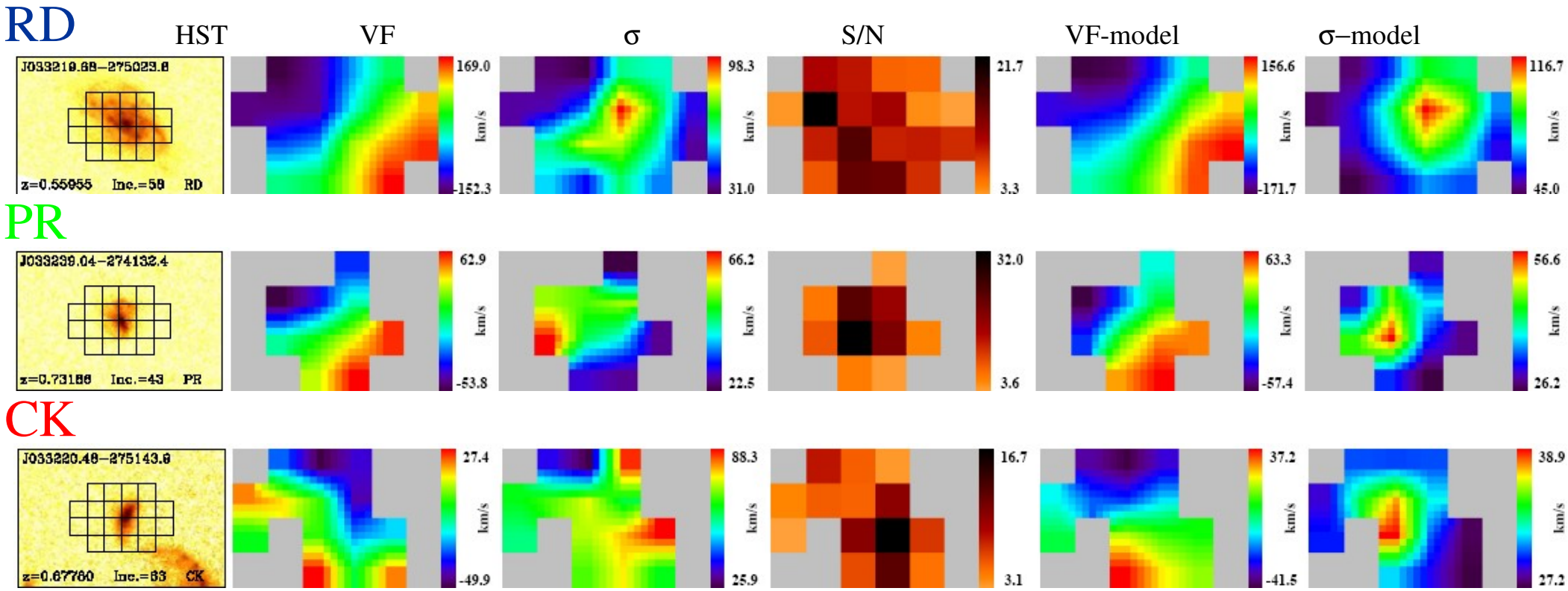
Resolved Kinematics



- **No obvious structure in the VF/σ-map**



Resolved Kinematics



Flores et al (2006)
Puech et al (2006a)
Yang et al (2007)

Coming soon:

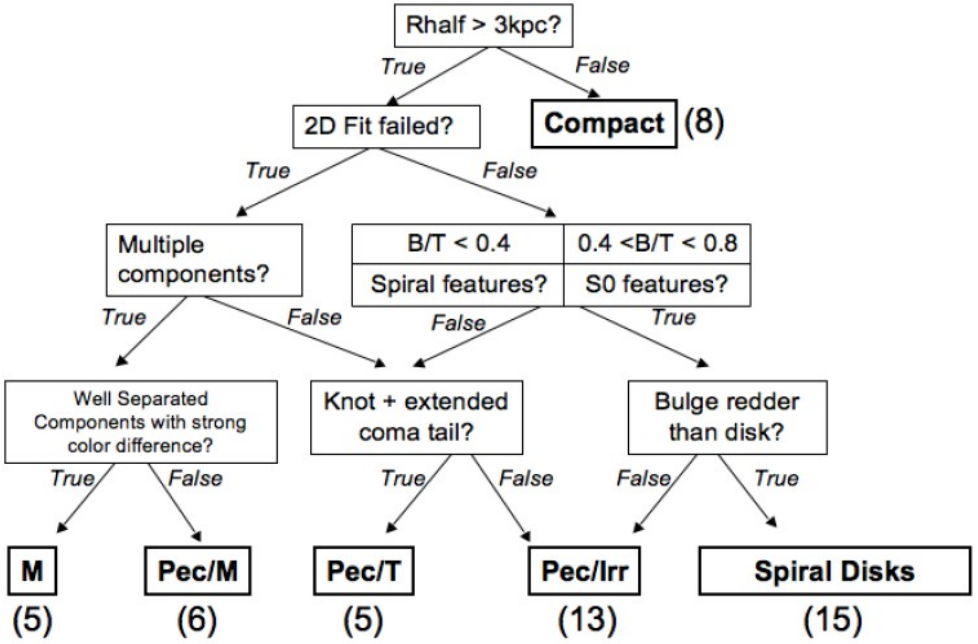
~30 more gals @ z~0.7-0.9

Statistics in the sample

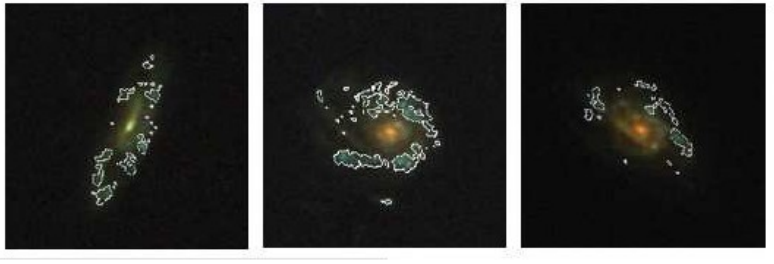
Type	#	fraction
RD	20	(32%)
PR	16	(25%)
CK	27	(43%)
UC	6	(9%)

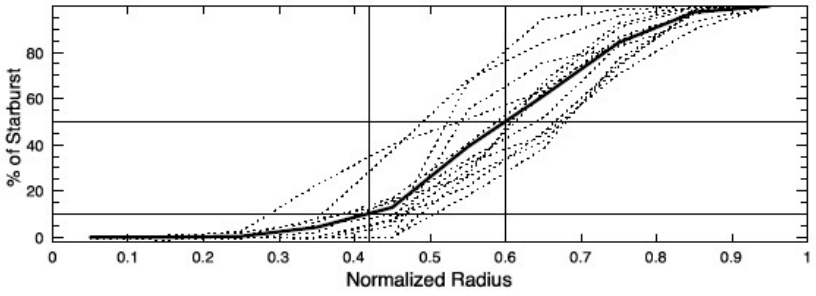
Morphology

Neichel et al (2008)

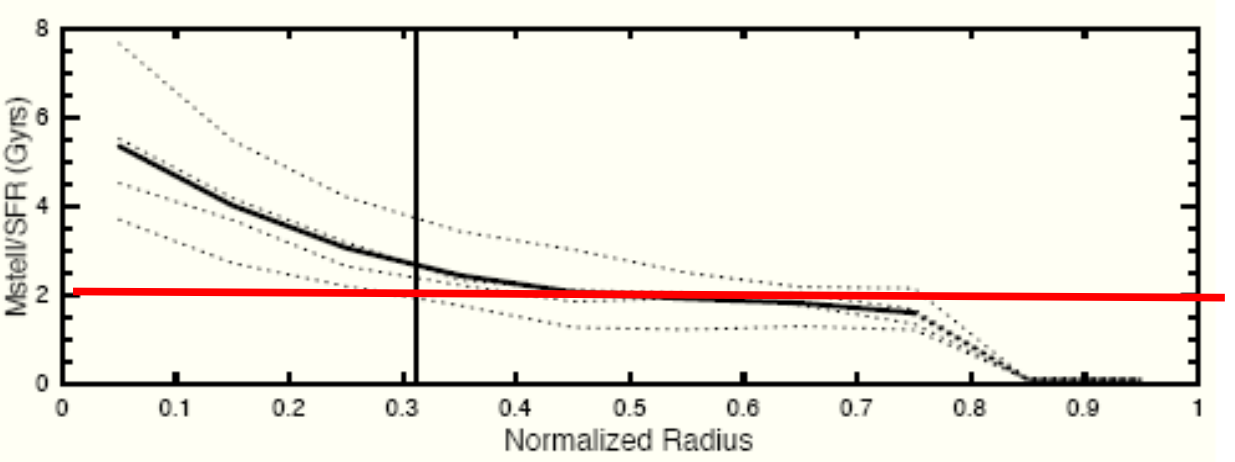


Semi-automatic decision tree: GALFIT + Color maps + Visual inspection





Evidence for an inside-out growth of disks



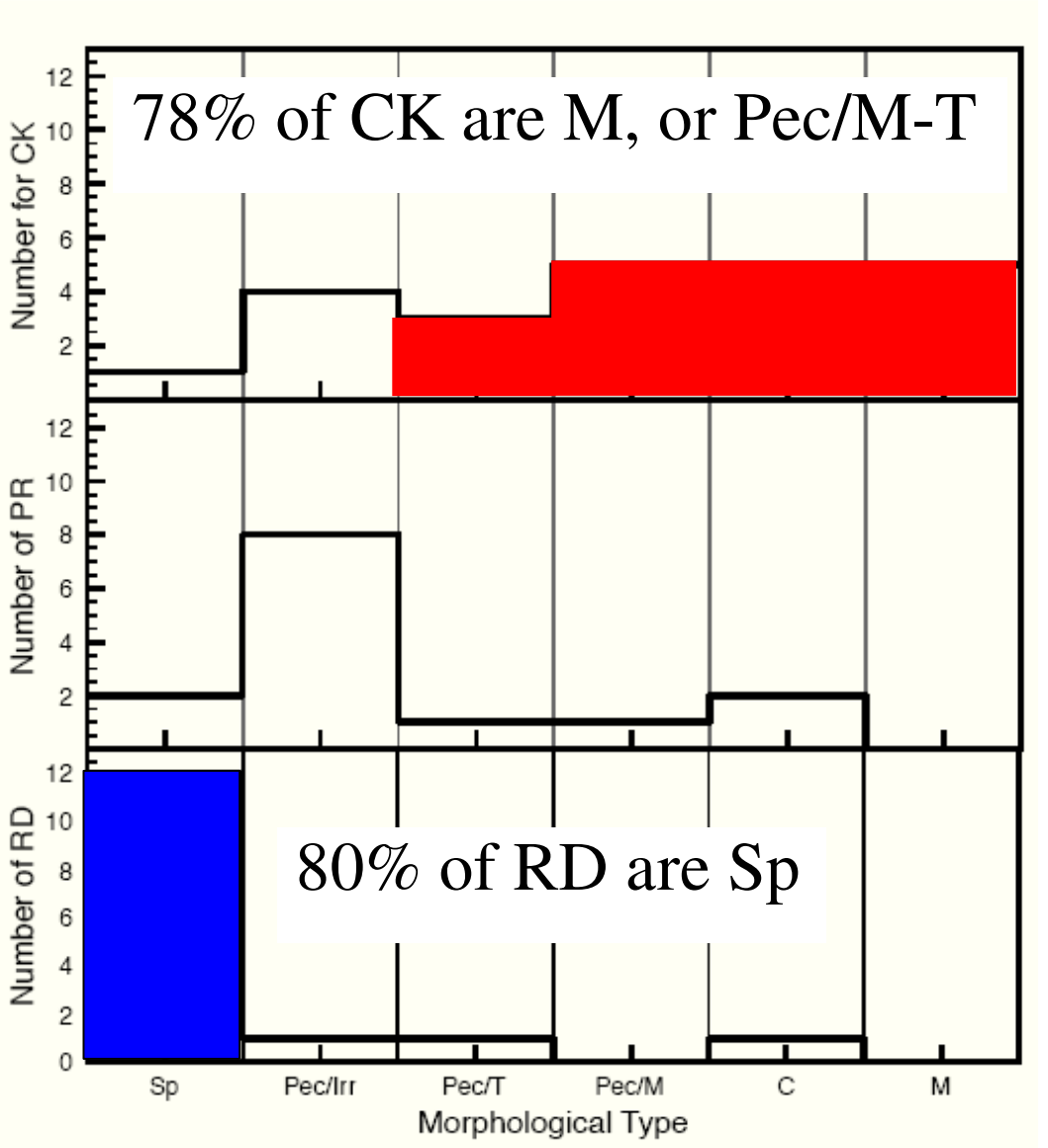
Morpho-kinematics

Agreement between kinematic and morphological classifications

16% of the sample is classified as Sp+RD

33% of interm.-mass galaxies are Sp+RD

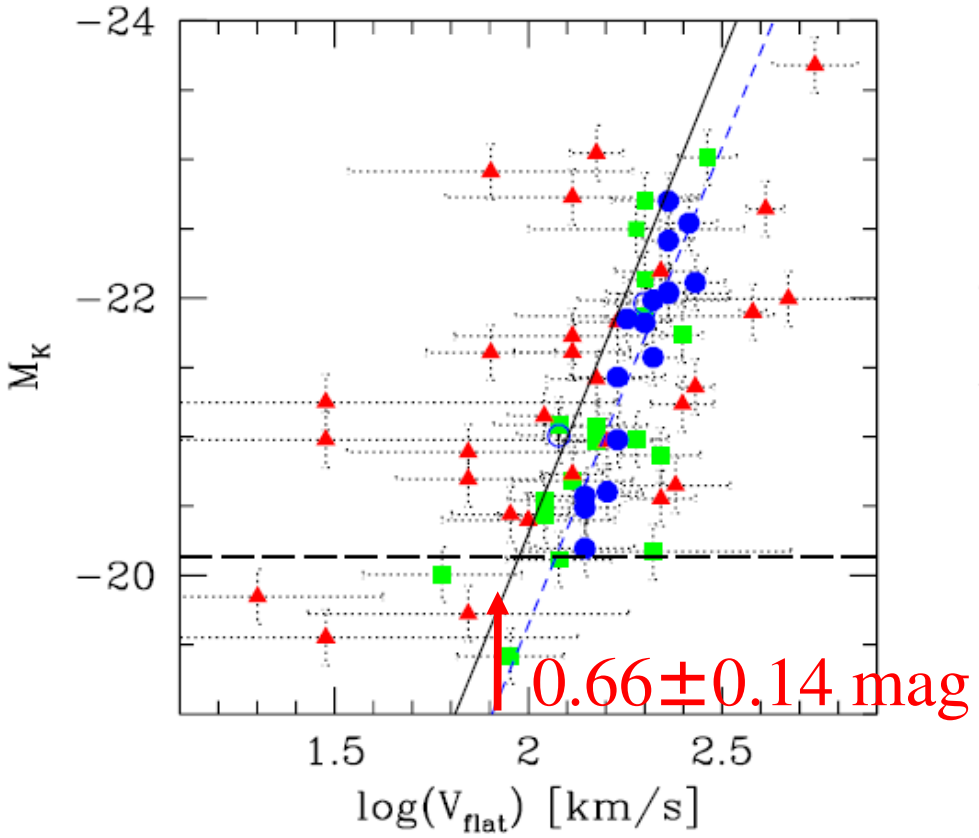
2 times less SpRD than today

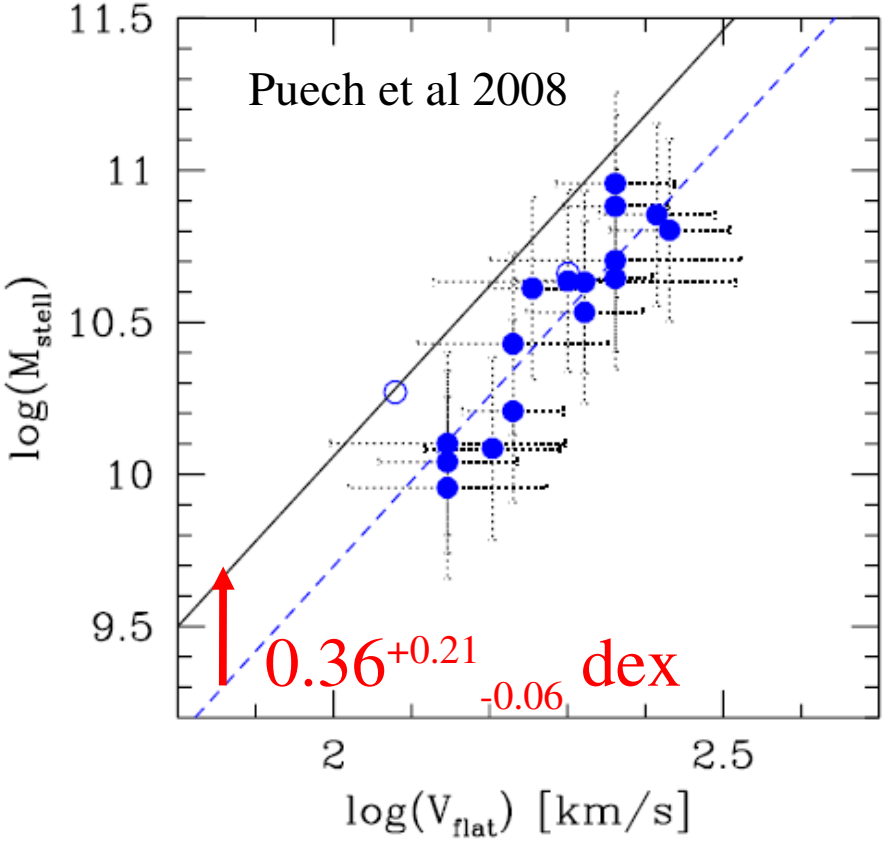


with EW([OII])<15Å		with EW([OII])>15Å			
E/S0	RSpD	RSpD	Pec	C	M
23%	17%	16%	28%	10%	6%

Neichel et al (2008)

K-band and Stellar mass TFR





Complex Kinematics
Perturbed Rotators
Rotating Disks

Local relation (SDSS galaxies; Hammer et al. 2007)

✓ Dispersion of TF explained by non-relaxed galaxies

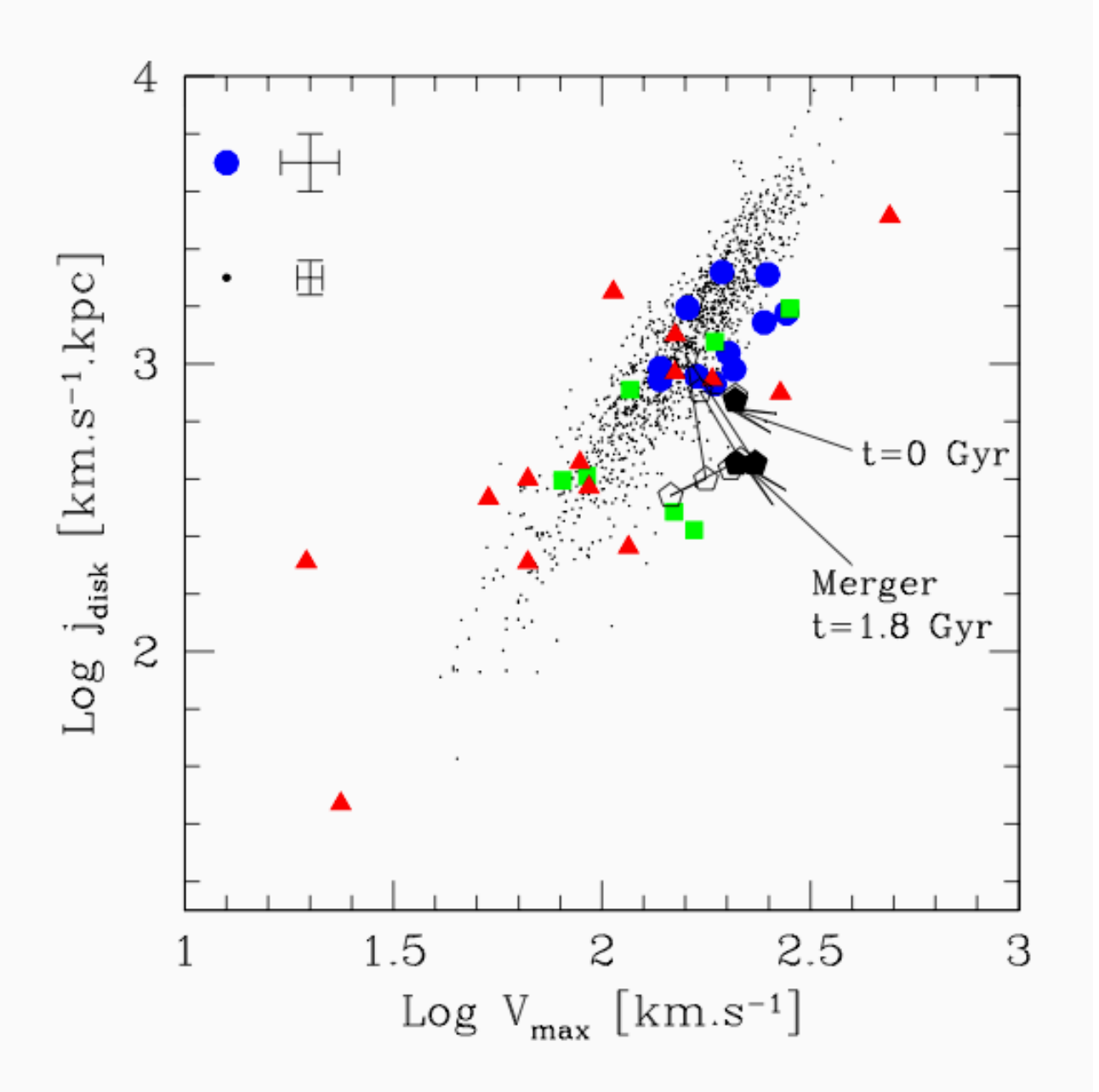
✓ First detection of a significant evolution of the K/sm-TF relation

RDs grew up by a factor ~ 2 in stellar-mass since z~0.6

Specific Angular Momentum

$j_{disk}=2R_dV_{max}$

- A random-walk evolution of j_{disk}
- Dispersion of CKs consistent with major mergers

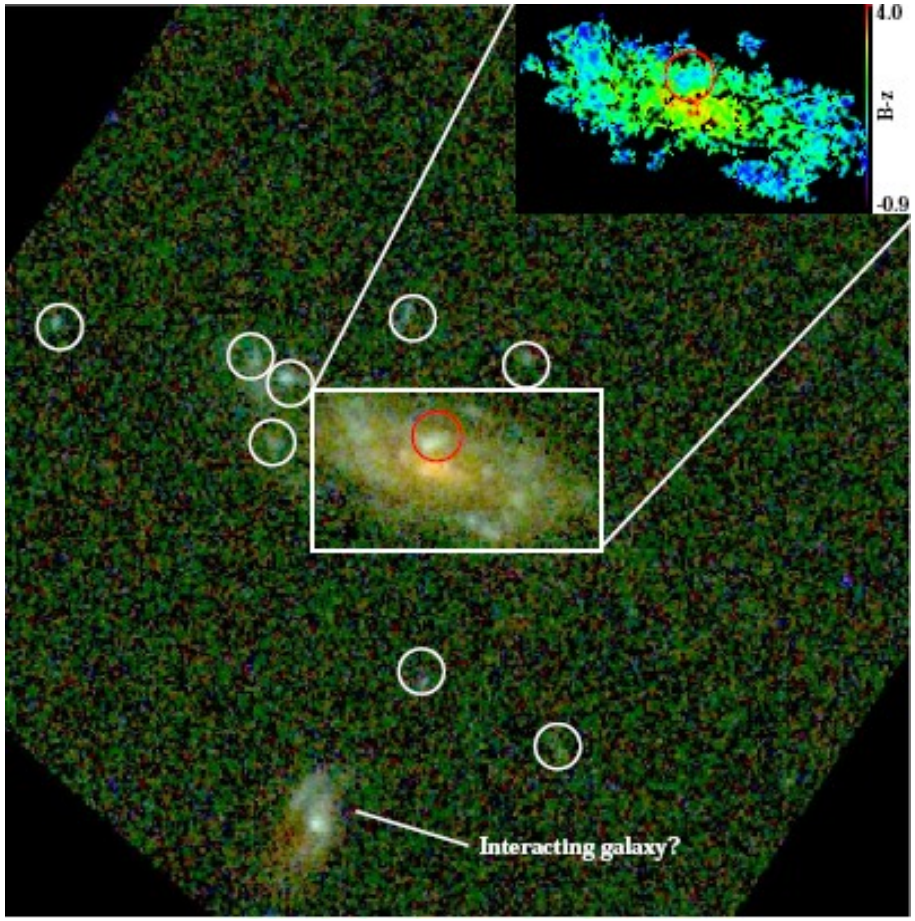


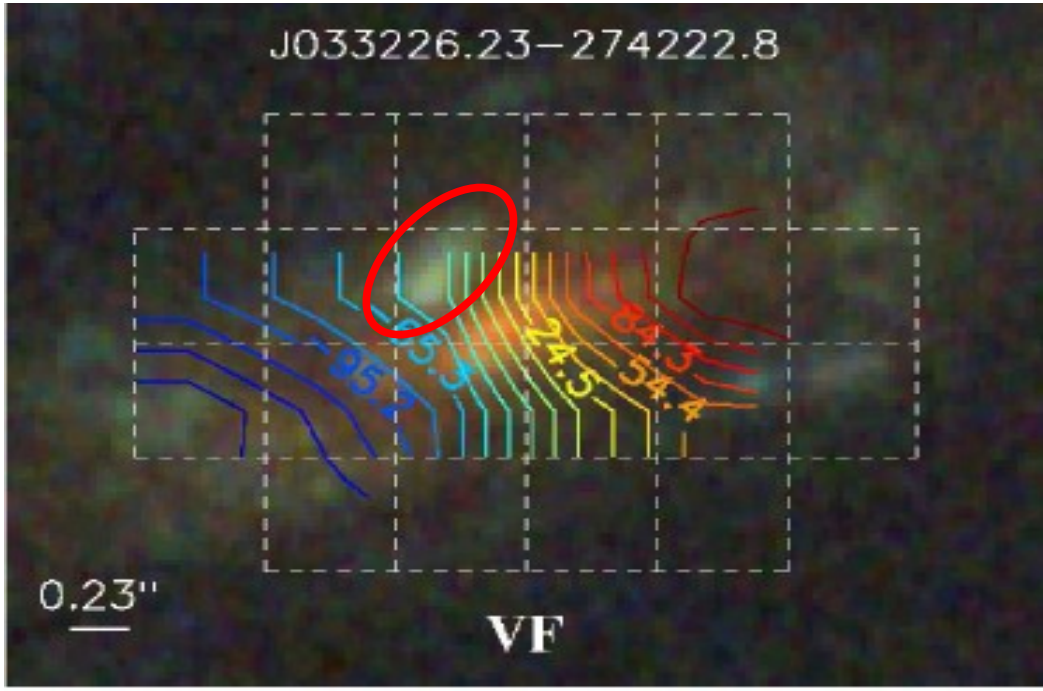
Puech et al. 2007

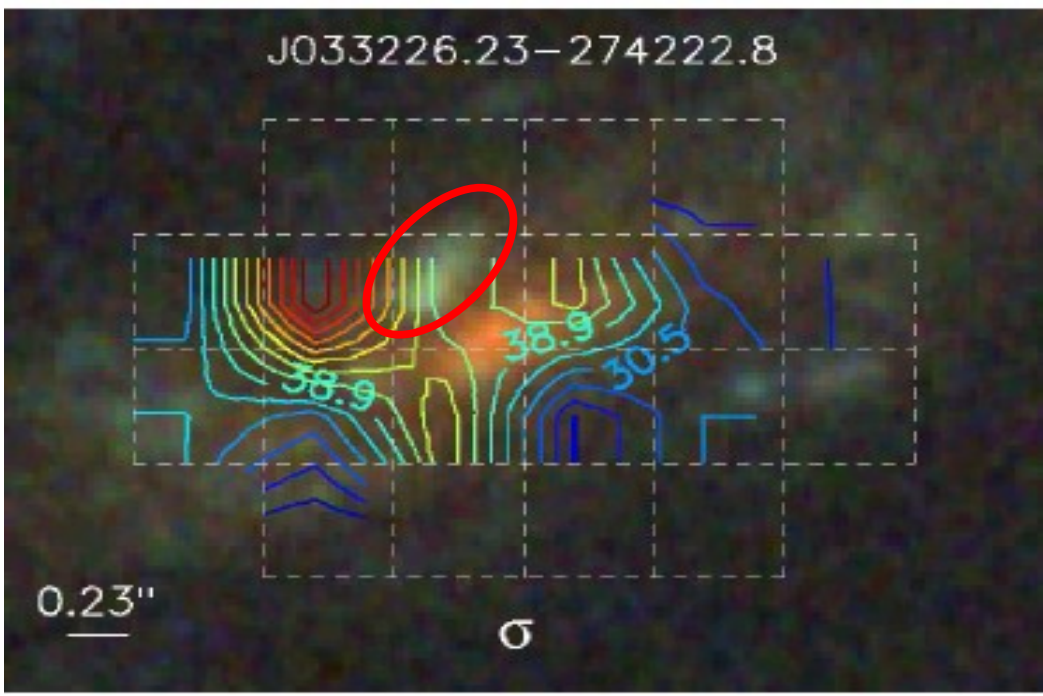
First detection of a minor merger at z~0.6

- Perturbed Rotator at z~0.6
- Stellar Mass ratio 1:18
  $Log(M_{stellar}/M_{\odot})=9.5:10.7$
- SFR_{IR+UV} ~ $21M_{\odot}$/yr, enhancement ~ $3\ M_{\odot}$/yr

A very plausible physical process for PRs

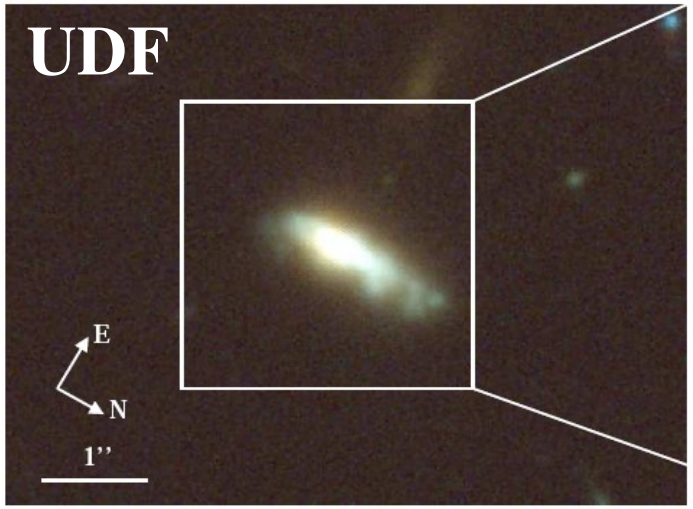


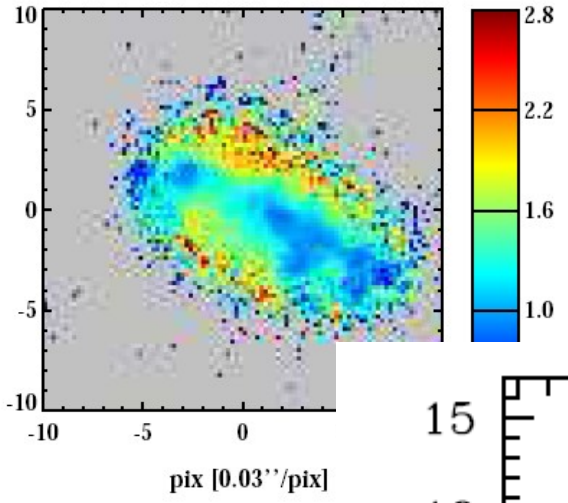




Puech et al 2007

A forming disk at z~0.6?



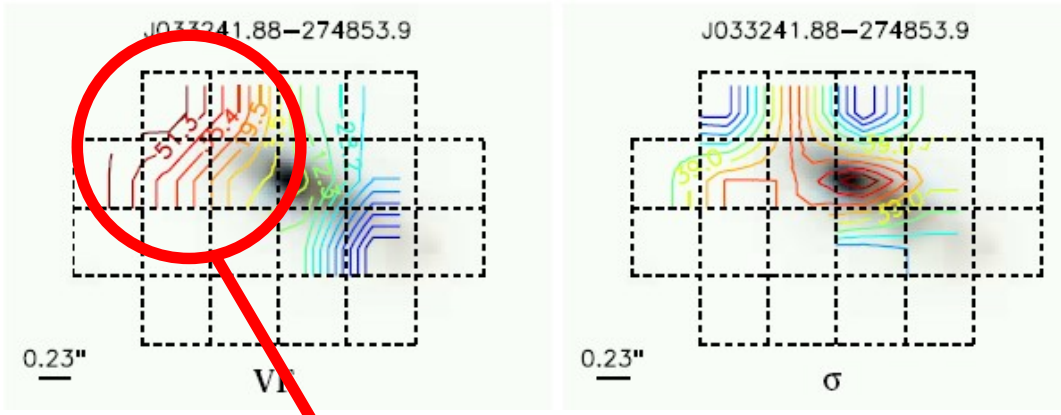


$Z=Z_{\odot}$ age~300 Myr

τ=100 Myr

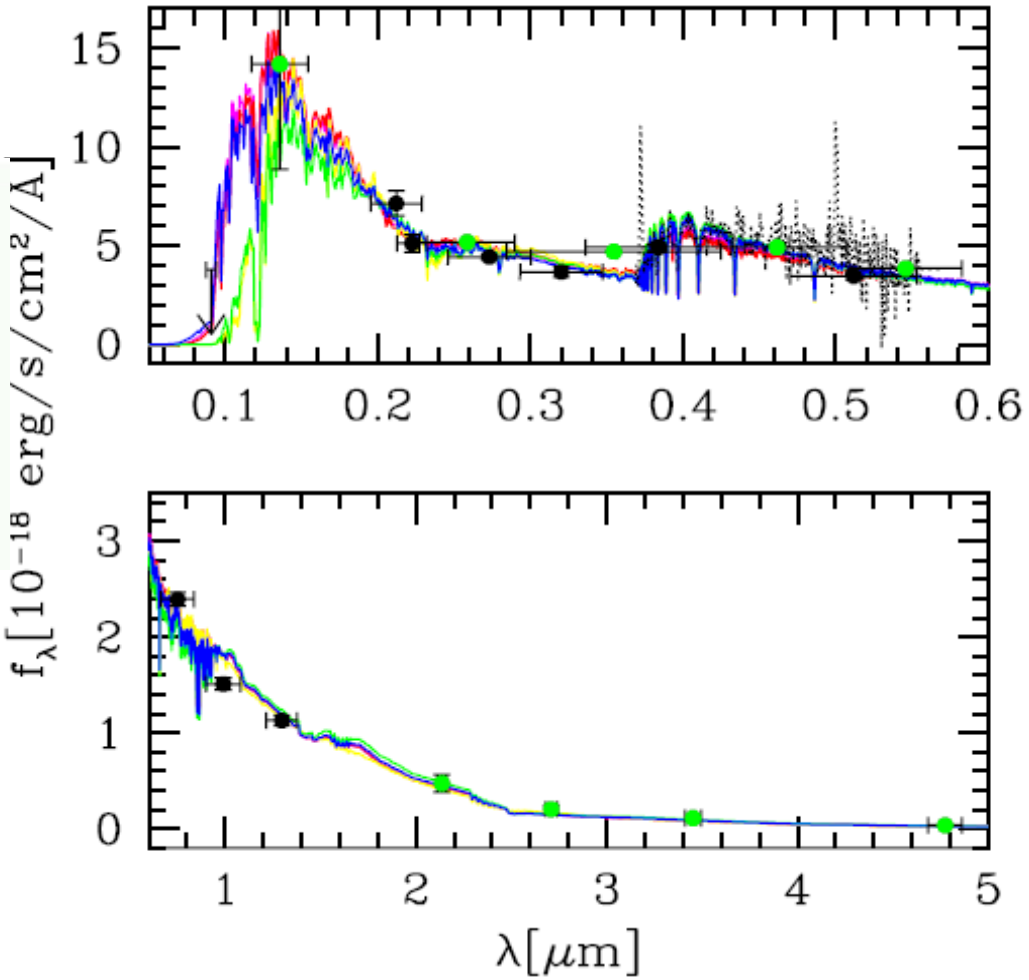
$\mathrm{Log}(M_{stellar}/M_{\odot})$=9.45

$\langle SFR\rangle_{100Myr}=2.8M_{\odot}/yr$



Puech et al in prep.

Gas but no stars



- Merger remnant?
- Rotating disk with f_{gas}~90%?

Conclusions

GTO+IMAGES: representative sample of 63 M* emission line galaxies at z~0.6

- Large fraction of dynamically non-relaxed galaxies: 40% (accounting for all $M_J(AB) < -20.3$ including quiescent E/S0/…), in agreement with morphology
  - ✓ explains the huge dispersion of the distant TF
- Important evolution of rotating disks since z~0.6:
  - ⇨ z=1to 0.6 (~2Gyr): inside-out growth of disks
  - ⇨ z=0.6 to 0 (~6 Gyr): doubling of stellar mass (cf. TFR) and number
- Cause of disturbed kinematics?
  - PR = minor mergers + other local mechanisms (e.g., clumps) ?
  - CK = major mergers (cf. AM)?

Combination of 3D spectro. + morphology reveals that violent dynamical processes are at work in z~0.6 progenitors of today's spirals

Consistent with major mergers but what about other scenarios, e.g., cold gas accretion (Dekel+2006; Birnboim+2007) ?

3D predictions needed!

Advertisement slide: IMAGES Papers

New spectroscopic redshifts from the CDFS and a test of the cosmological relevance of the GOODS-South field⋆

("IMAGES 0") Ravikumar et al. 2007, 465,1099

IMAGES⋆ I. Strong evolution of galaxy kinematics since $z = 1$

Yang et al. 2008, A&A, 477, 789

IMAGES⋆ II. A surprisingly low fraction of undisturbed rotating spiral disks at $z \sim 0.6$.
The morpho-kinematical relation 6 Gyrs ago

Neichel et al. 2008, A&A, 484, 159

IMAGES⋆-III: The evolution of the Near-Infrared Tully-Fisher relation over the last 6 Gyr

Puech et al. 2008, A&A, 484, 173

IMAGES-IV: Strong evolution of the Oxygen abundance in gaseous phases of massive galaxies since $z \sim 0.8$

Rodrigues et al., To be submitted