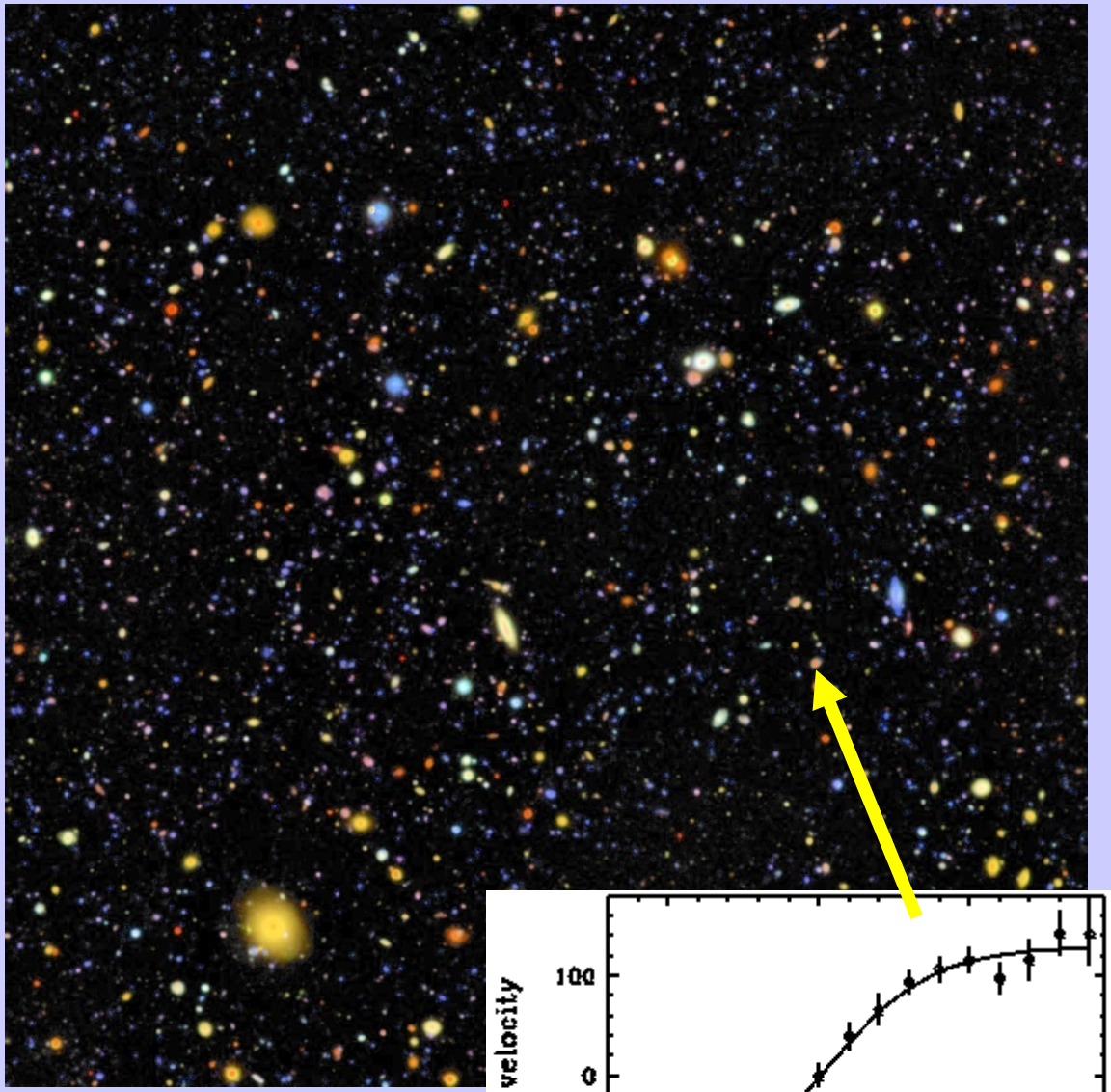
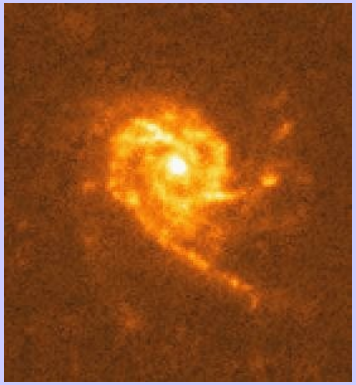
Kinematic & Structural Evolution of Field & Cluster Spirals

Bodo Ziegler

European Southern Observatory

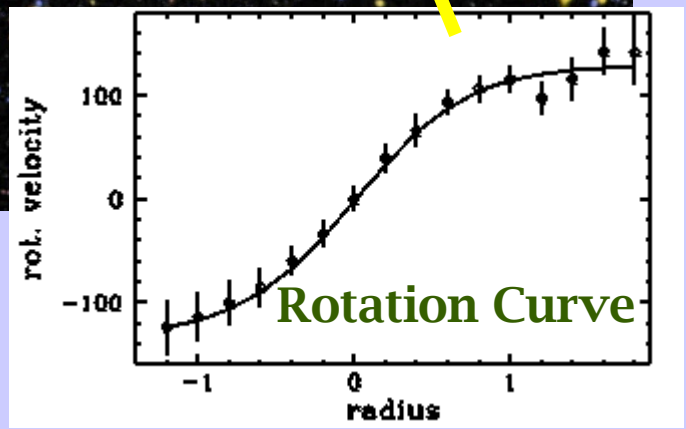


FORS Deep Field

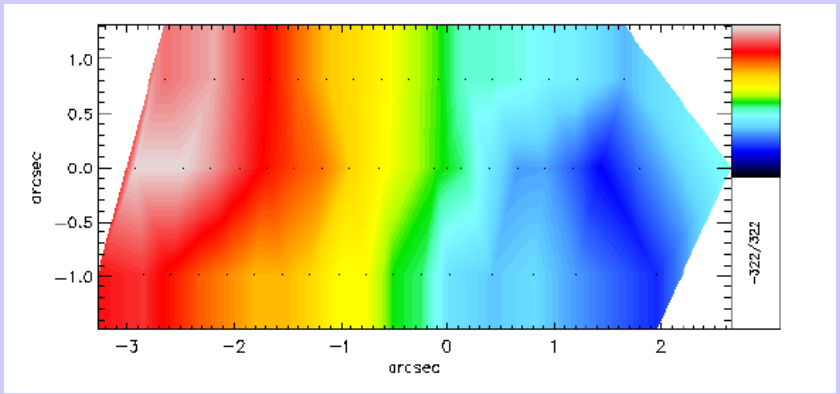


Morphology

Cluster z=0.5



Rotation Curve



Velocity Field

Galaxy Evolution with Deep Fields

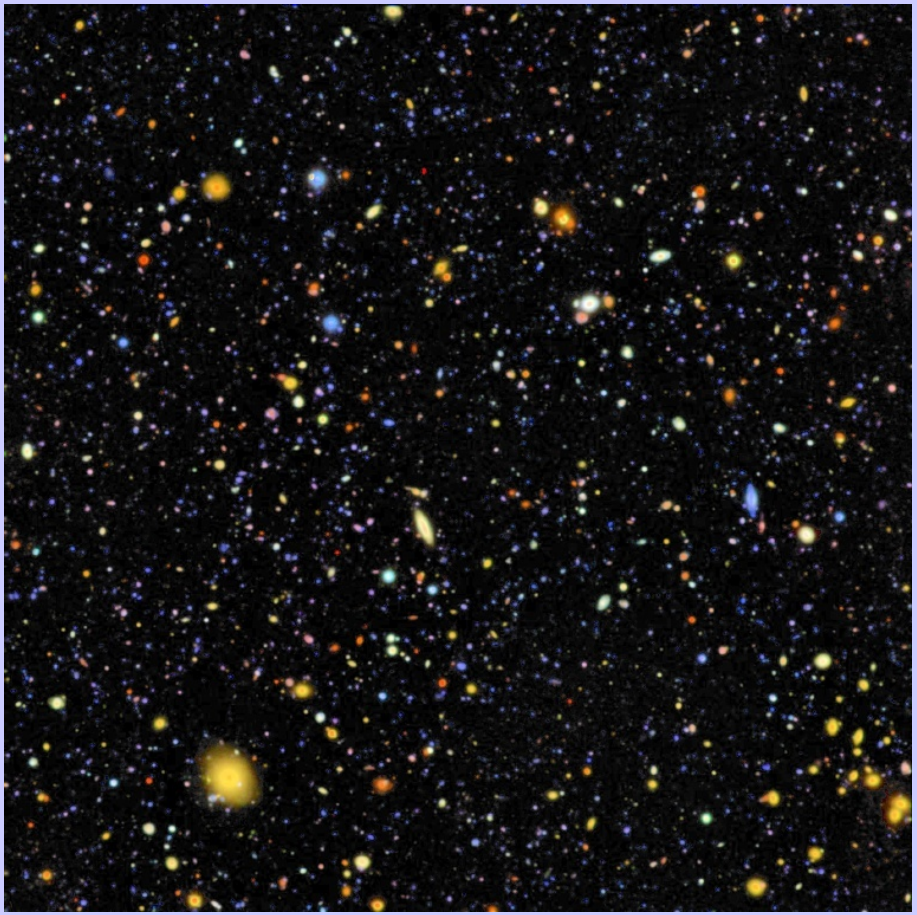
Deep photometry
+template fitting

↓↓

luminosity evolution

- number counts
- clustering
- luminosity functions
- etc.

FORS Deep Field

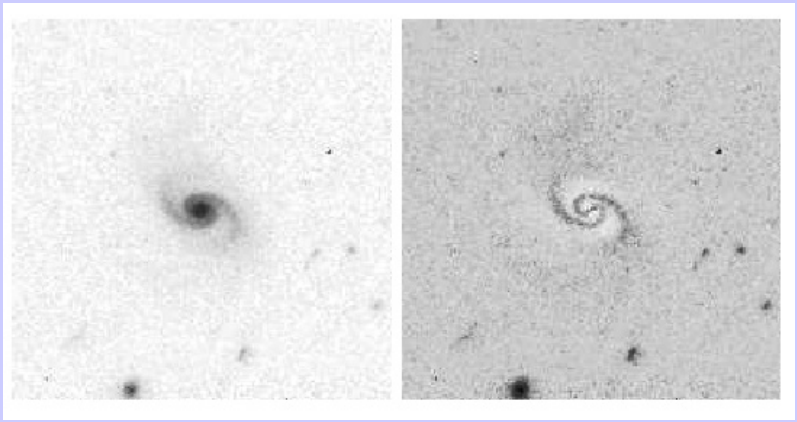


Appenzeller et al. 2000

Heidt et al. 2003

- What about environment?
- Current (past) star formation, starbursts, post–SBs, AGNs?

Morphologies of distant galaxies



z=0.5 spiral
GALFIT
disk+bulge

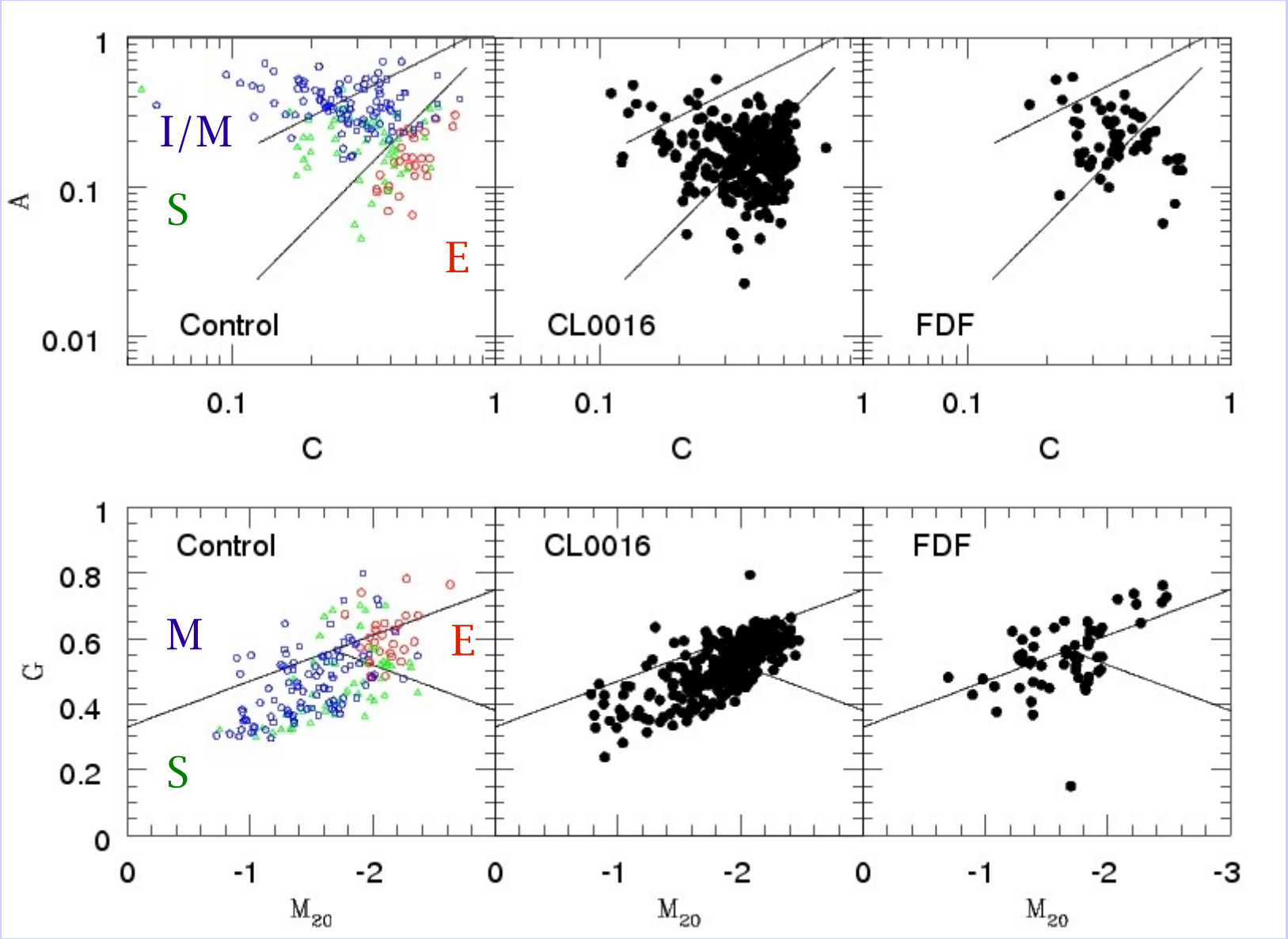
Fit 2dim surface brightness with your favorite
- law (exponential, Sersic etc) for disk & bulge
- model package (GALFIT, GIM2D, BUDDA)

or use your favorite non–parametric approach
- CAS: concentration, asymmetry, clumpiness
- Gini & M_{20}

⇒ **structure evolution**

- What defines the morphology of a galaxy?

Morphologies of distant galaxies



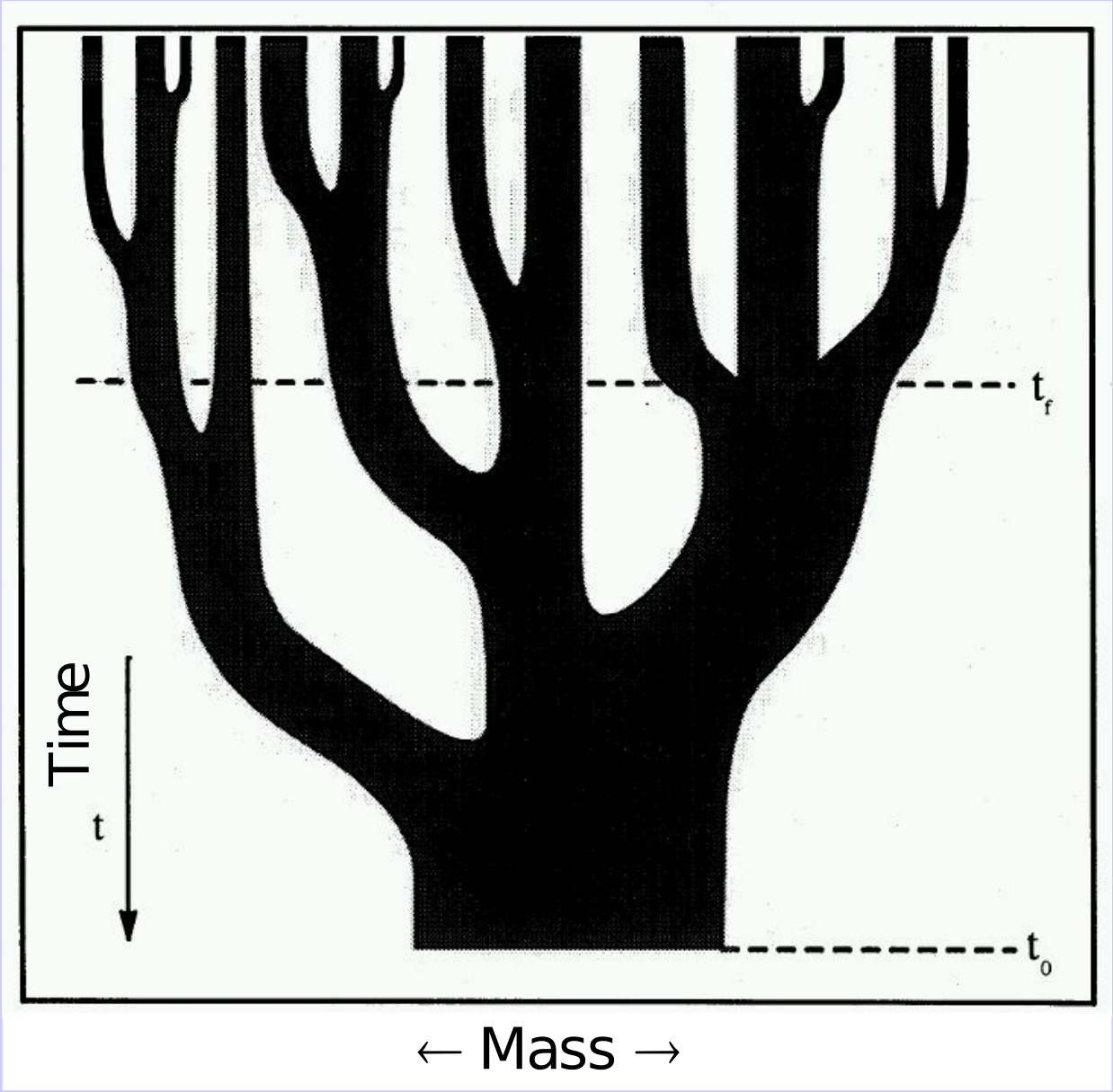
CL0016:
z=0.54±.05

FDF only for:
0.45<z<0.65

Da Rocha & Ziegler 2009

Control sample: Böhm et al. 2009
STAGES project: visual clas.

Cold Dark Matter models: hierarchical growth of cosmic structures

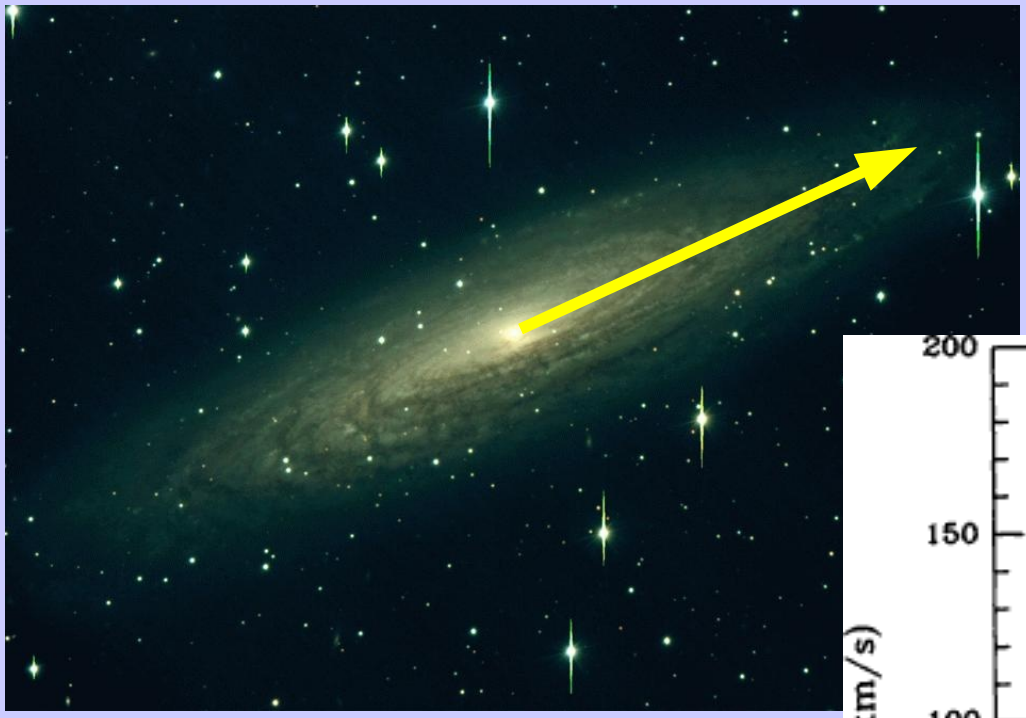


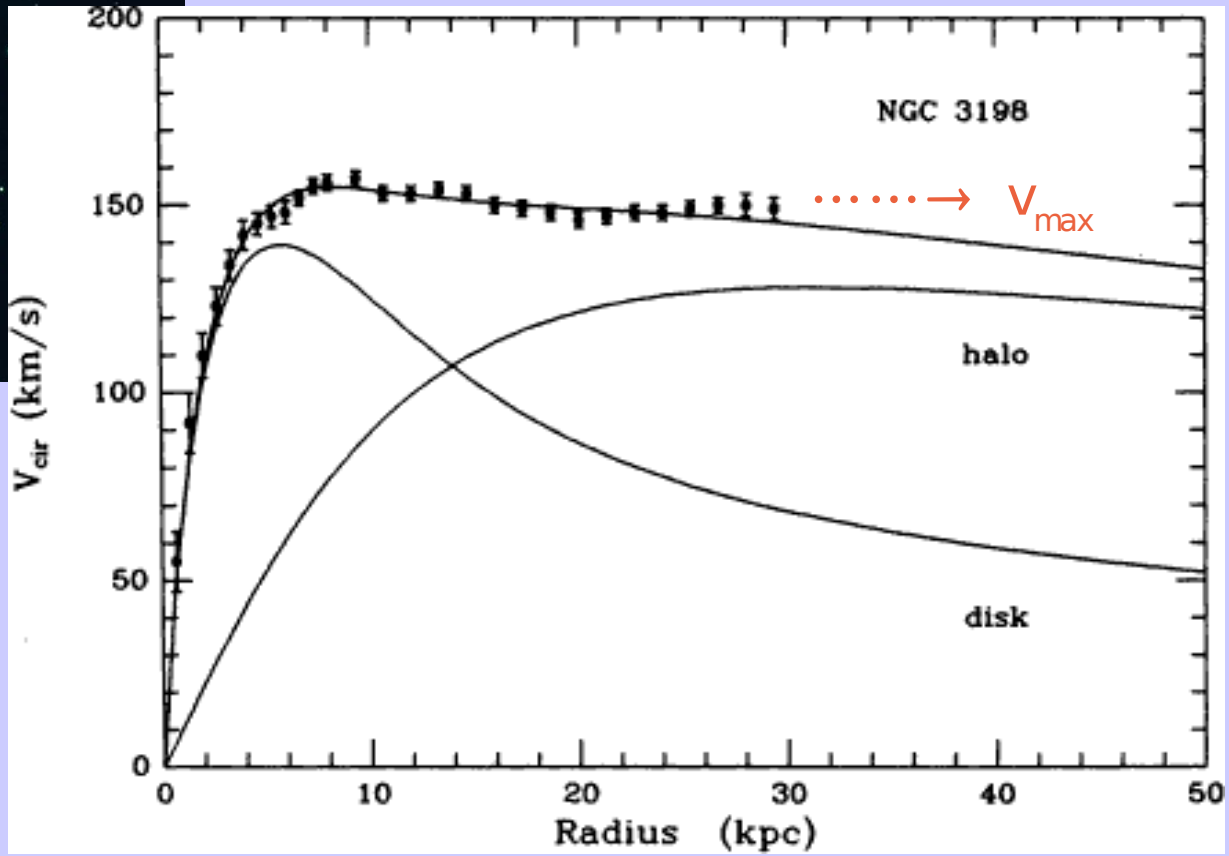
Lacey & Cole 1993

⇒ **Mass evolution**

↪We need total dynamical masses!

Rotation Curve of a Spiral Galaxy

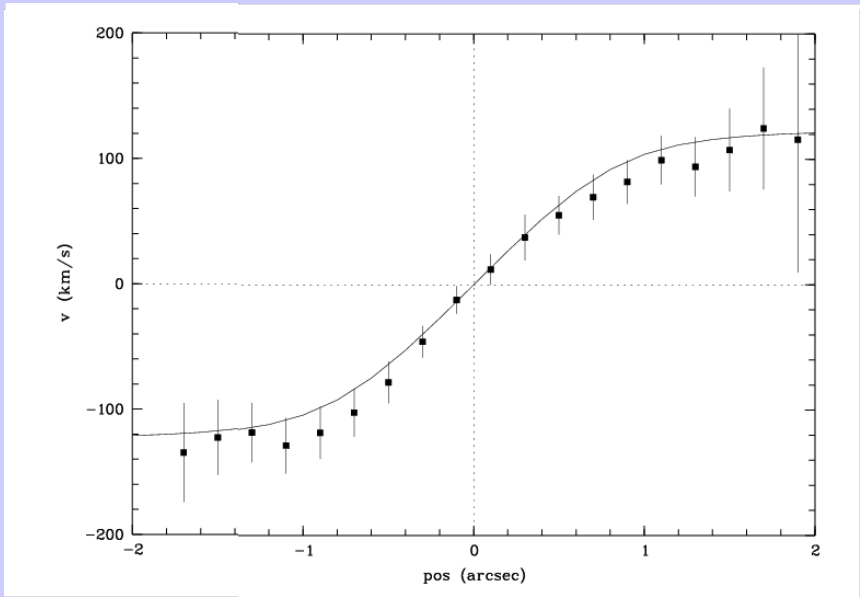


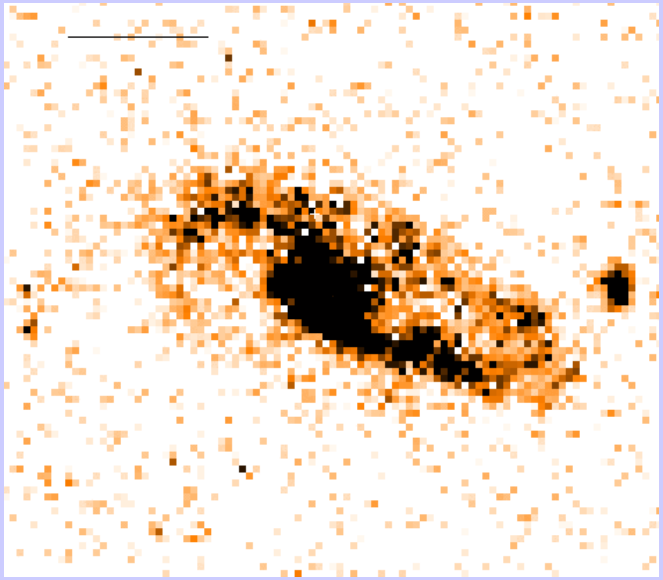


Measurement of stellar (baryonic) and dark mass

adopted from van Albada et al. 1985

Mass evolution of field spirals up to z = 1





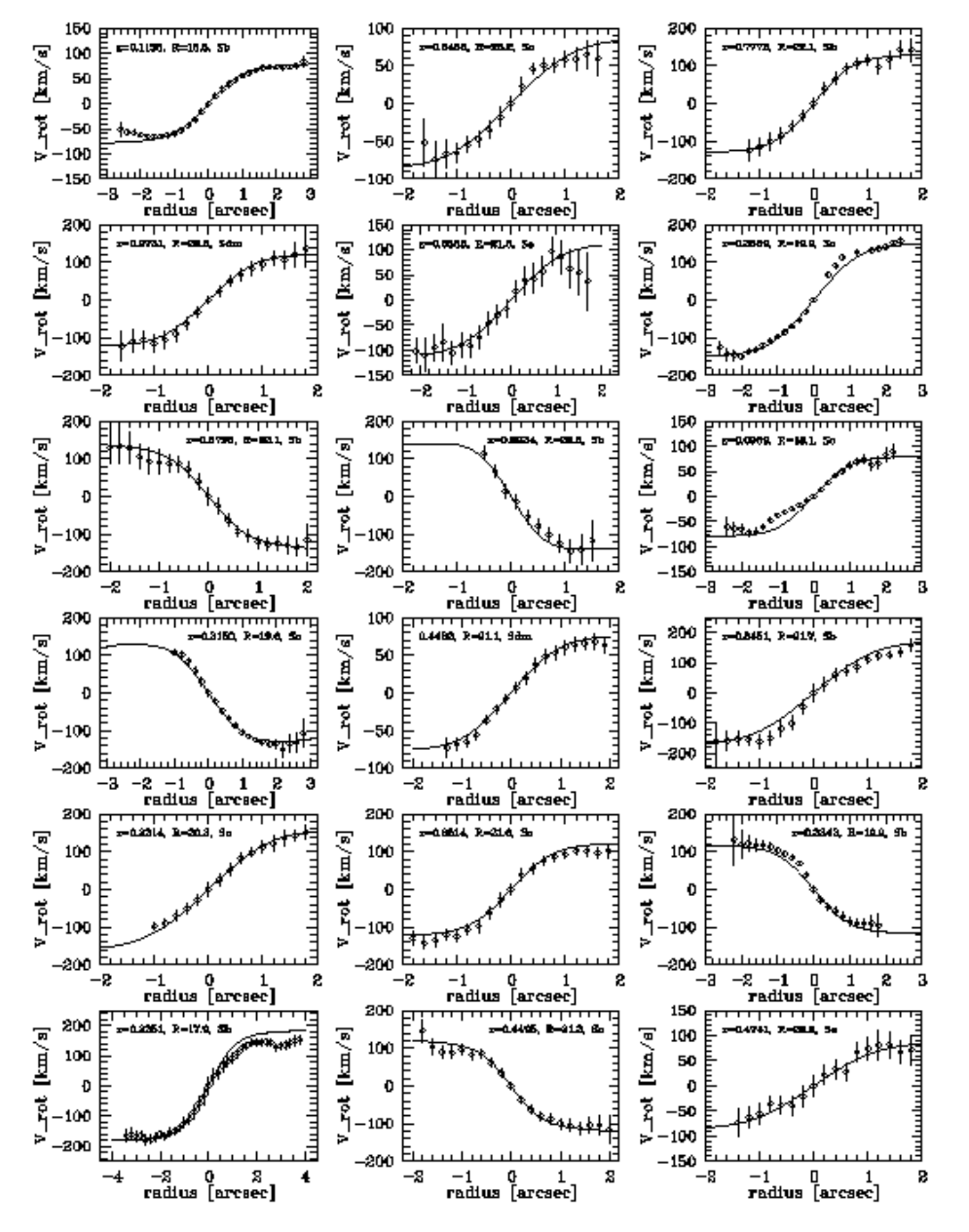
VLT/FORS2 spectrum:
sym. rotation curve
V_{max} = *170* km/s
I brightness: *21.8* mag

HST/ACS image:
z=1 galaxy
m=2 spiral mode
disk length: 4.4 kpc

Virial mass: $5 \times 10^{11} M_{\odot}$

Rotation curves of field spirals with z=0.1 to z=1

VLT/FORS
spectroscopy
FDF & WHDF
249 galaxies
→ **130 RCs**

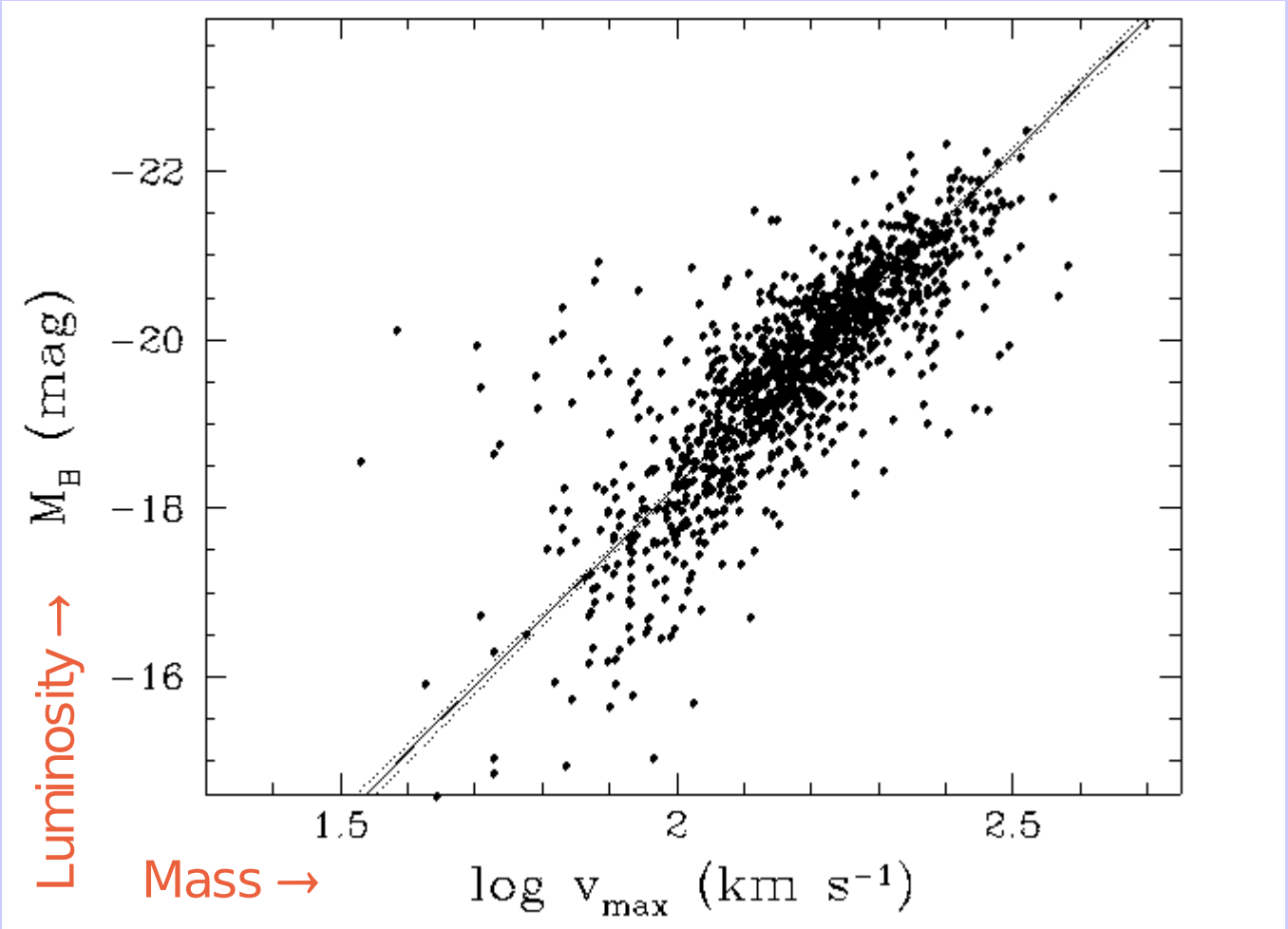


Ziegler et al. 2002

Böhm et al. 2004

Böhm & Ziegler 2007

Local Tully-Fisher Relation

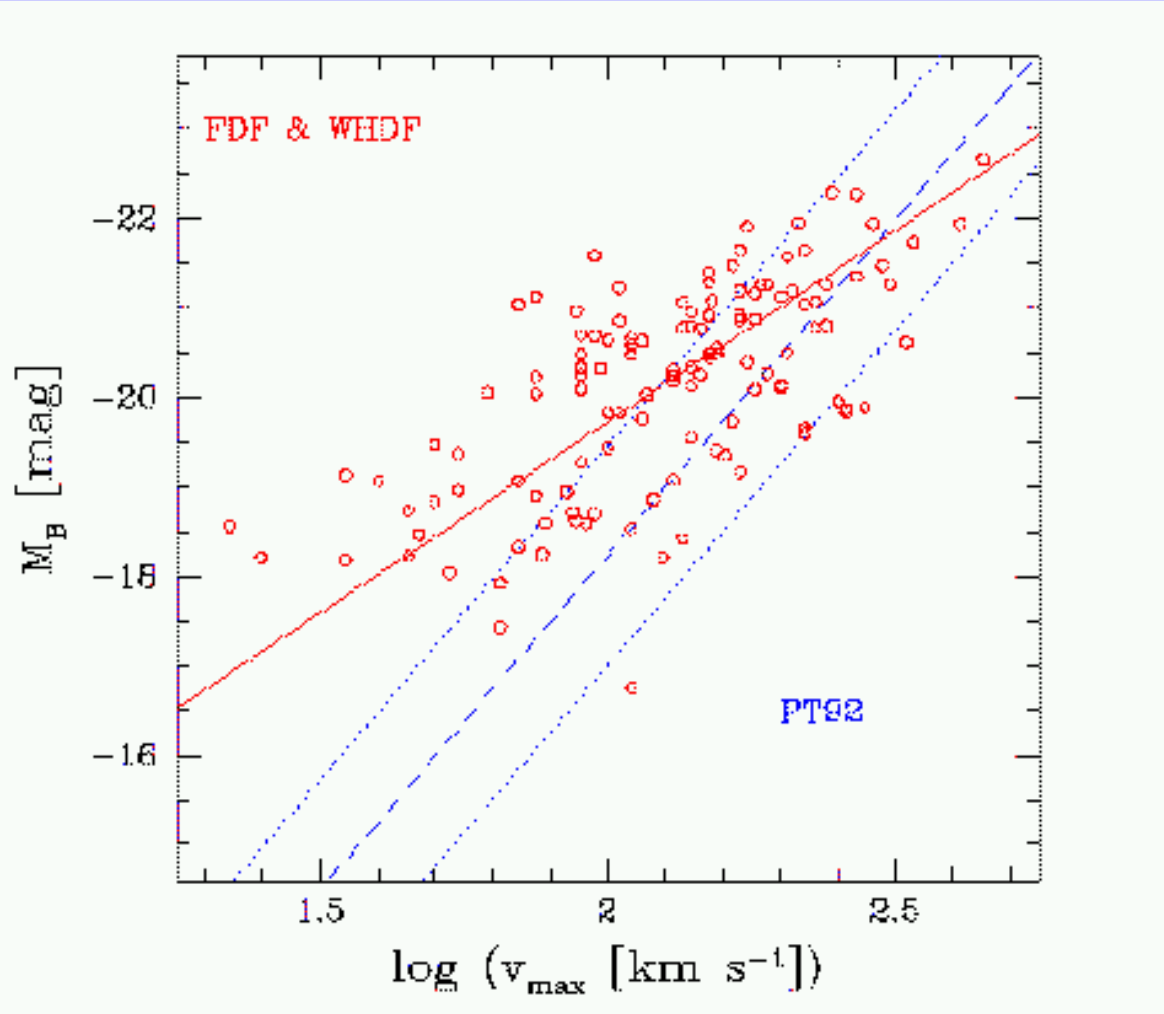


Haynes et al. 1999

1200 spiral galaxies with *cz*<12.000km/s

v_{max} ≙ mass scale: "normalization" for luminosity

Tully-Fisher Relation at half the Hubble time



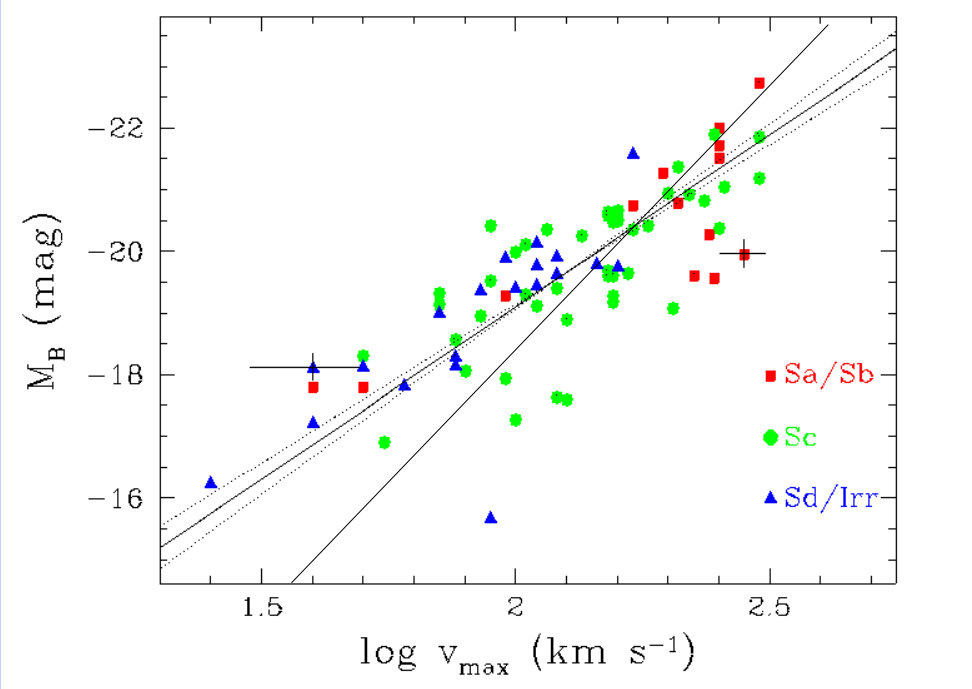
bisector fit to
63 HQ-RCs

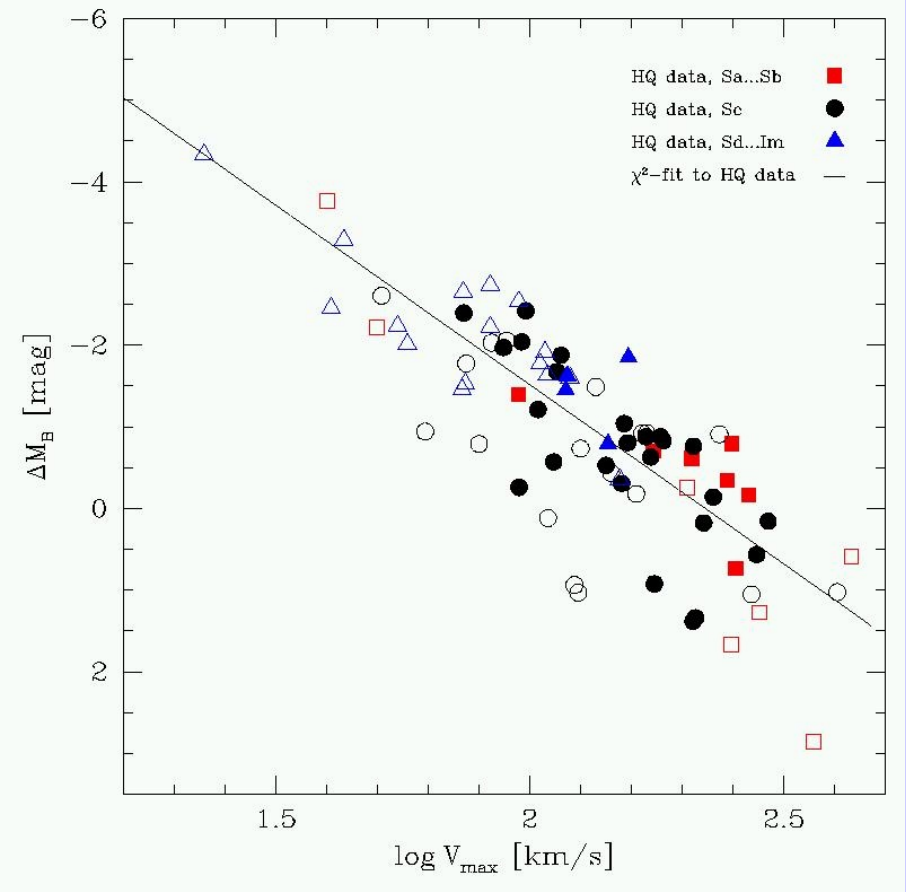
Pierce & Tully 1992

Böhm & Ziegler 2007

⇒ change of slope:
from -4.3 @ $z \simeq 0.5$ to -7.5 @ $z=0$ ($>3\sigma$)

Tully-Fisher Relation at half the Hubble time

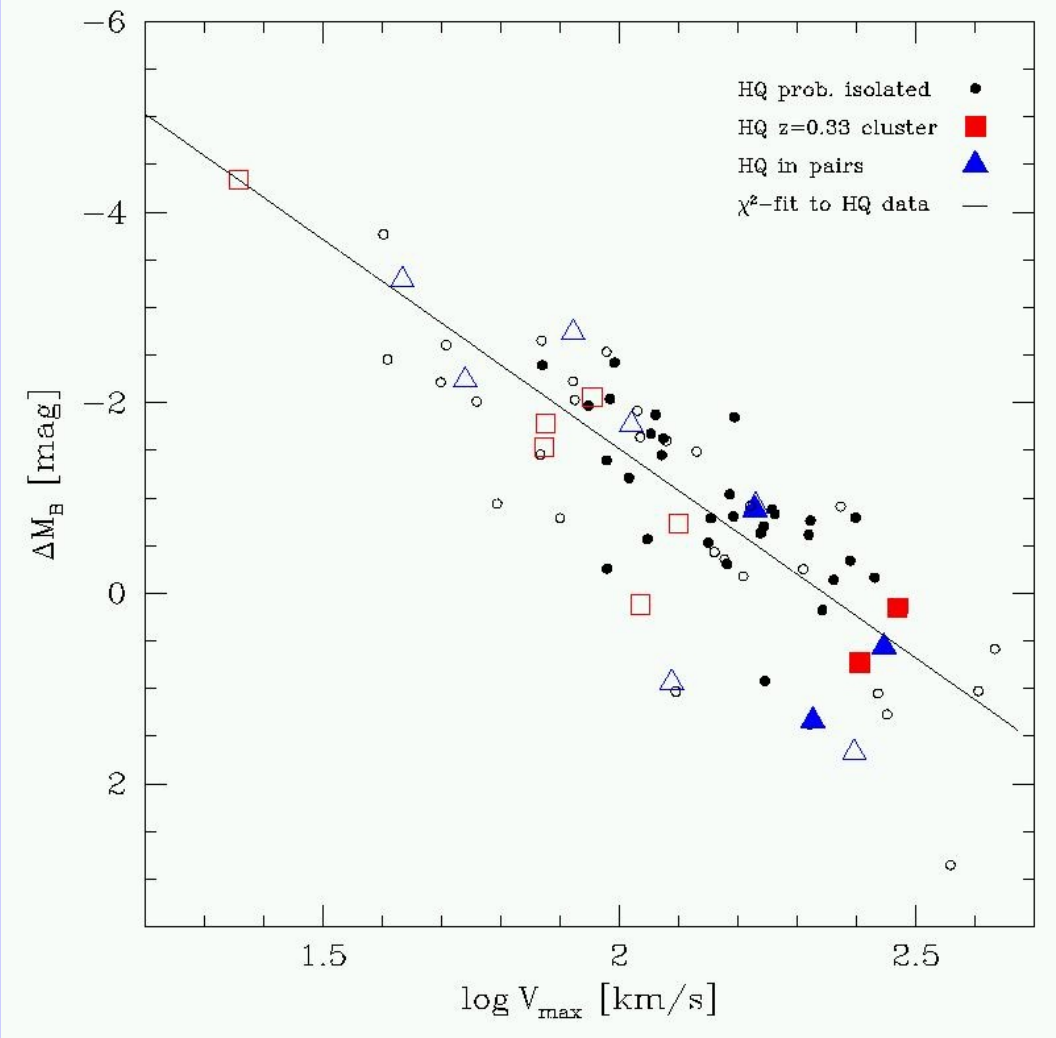




Böhm et al. 2004

Some dependence on type
beware of selection effects!

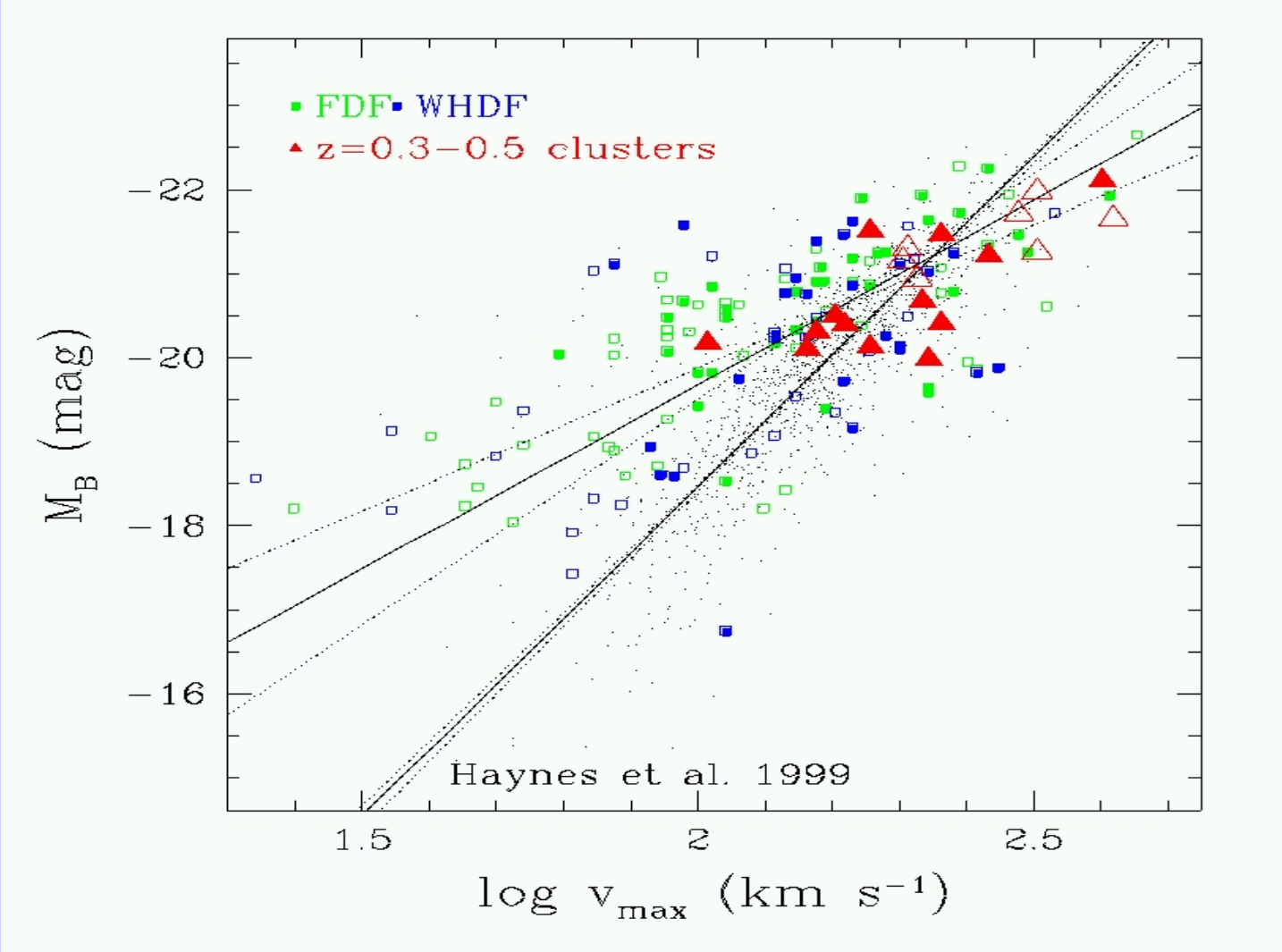
Tully-Fisher Relation at half the Hubble time



Pair definition:
(Lambas+03)
$D_{proj} < 100$kpc
$\Delta V_{sys} < 250$km/s

No difference in z-evolution of TFR
between isolated & pair galaxies nor with cluster spirals

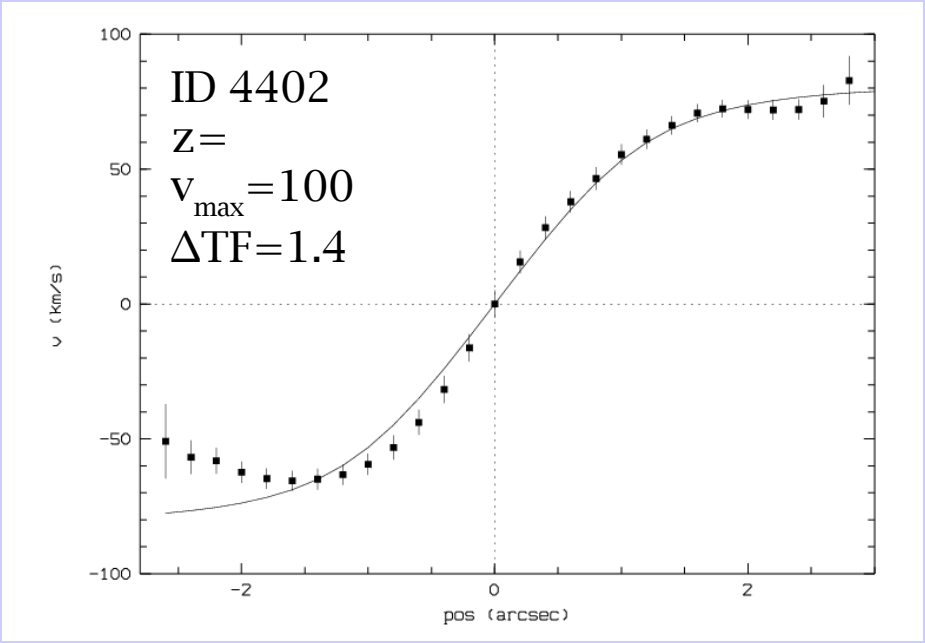
Tully-Fisher Relation of z≈0.5 *Cluster* Galaxies

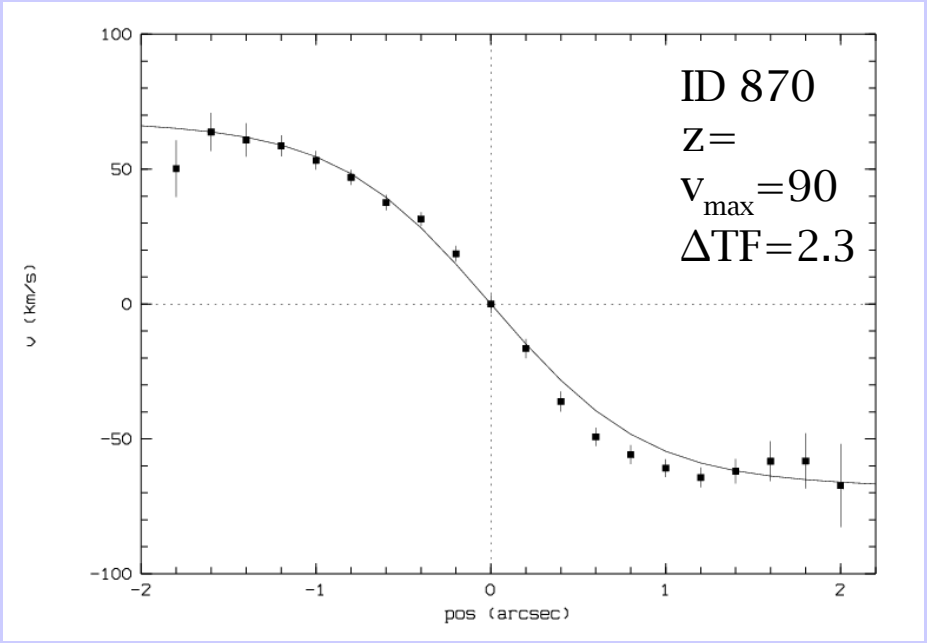


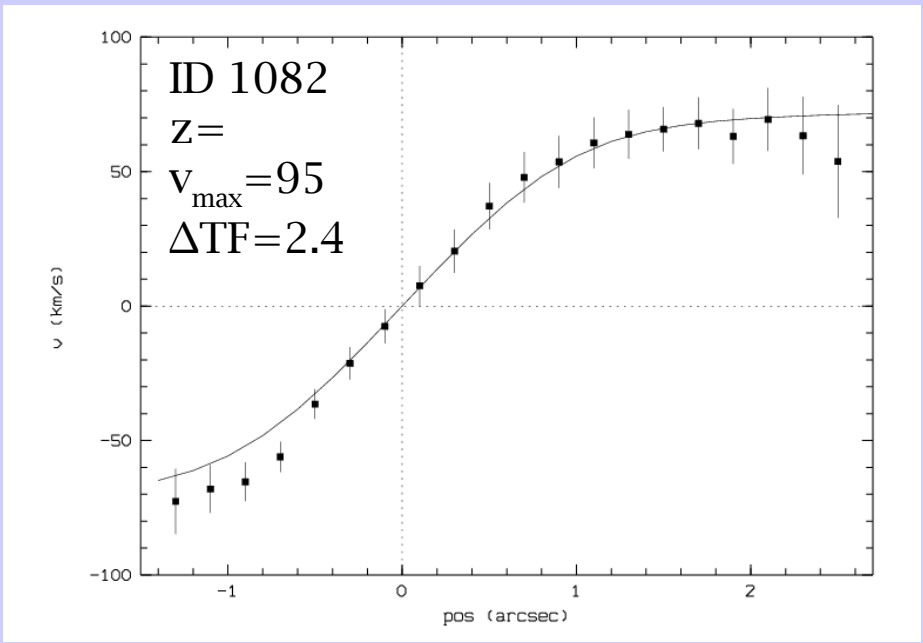
Ziegler et al. 2003,
Jäger et al. 2004

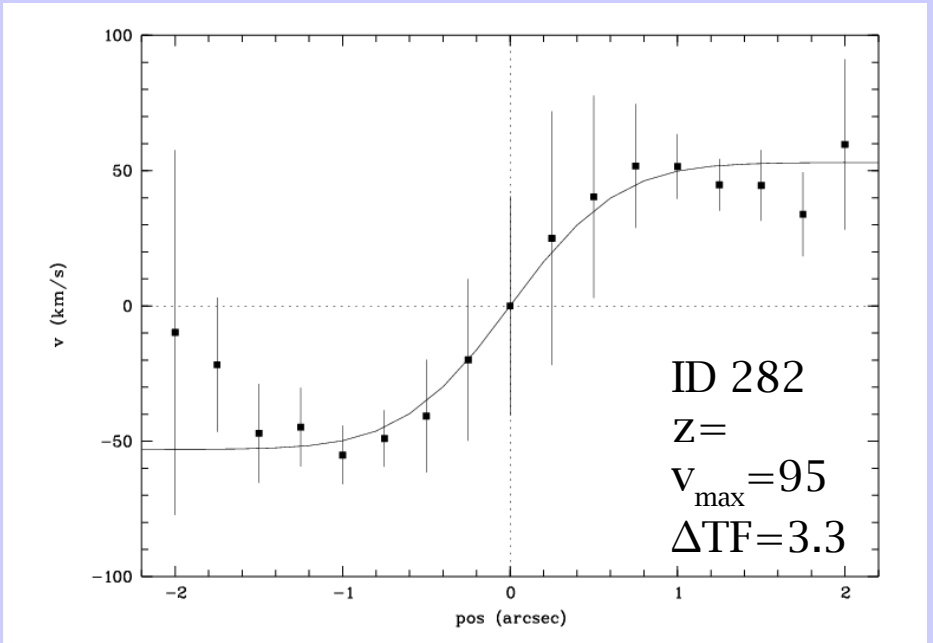
Distribution of field & cluster spirals very similar!
Effect of cluster-specific interactions?

Example rotation curves of low-mass spirals

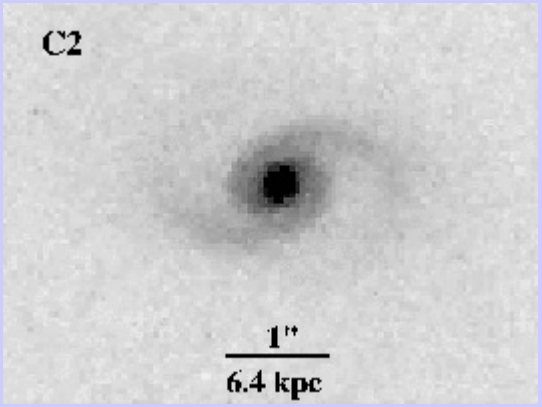


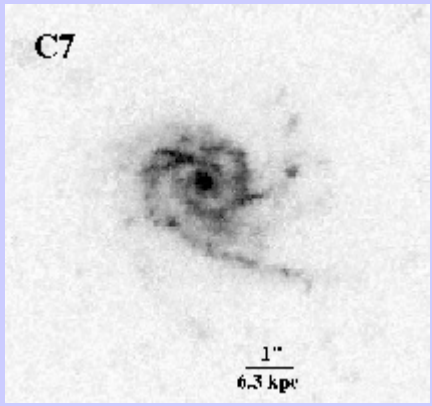


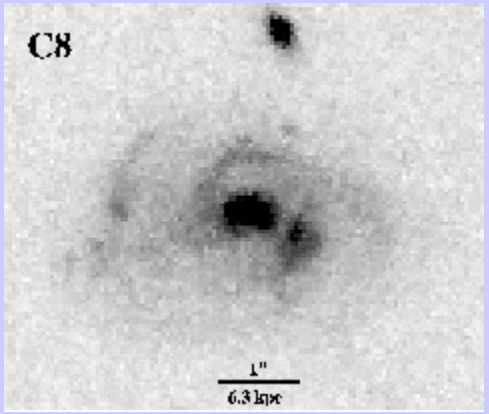




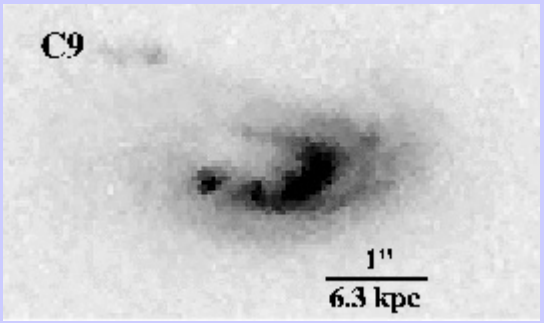
Environment: Interactions in Clusters

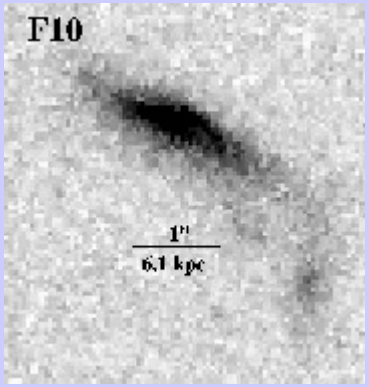




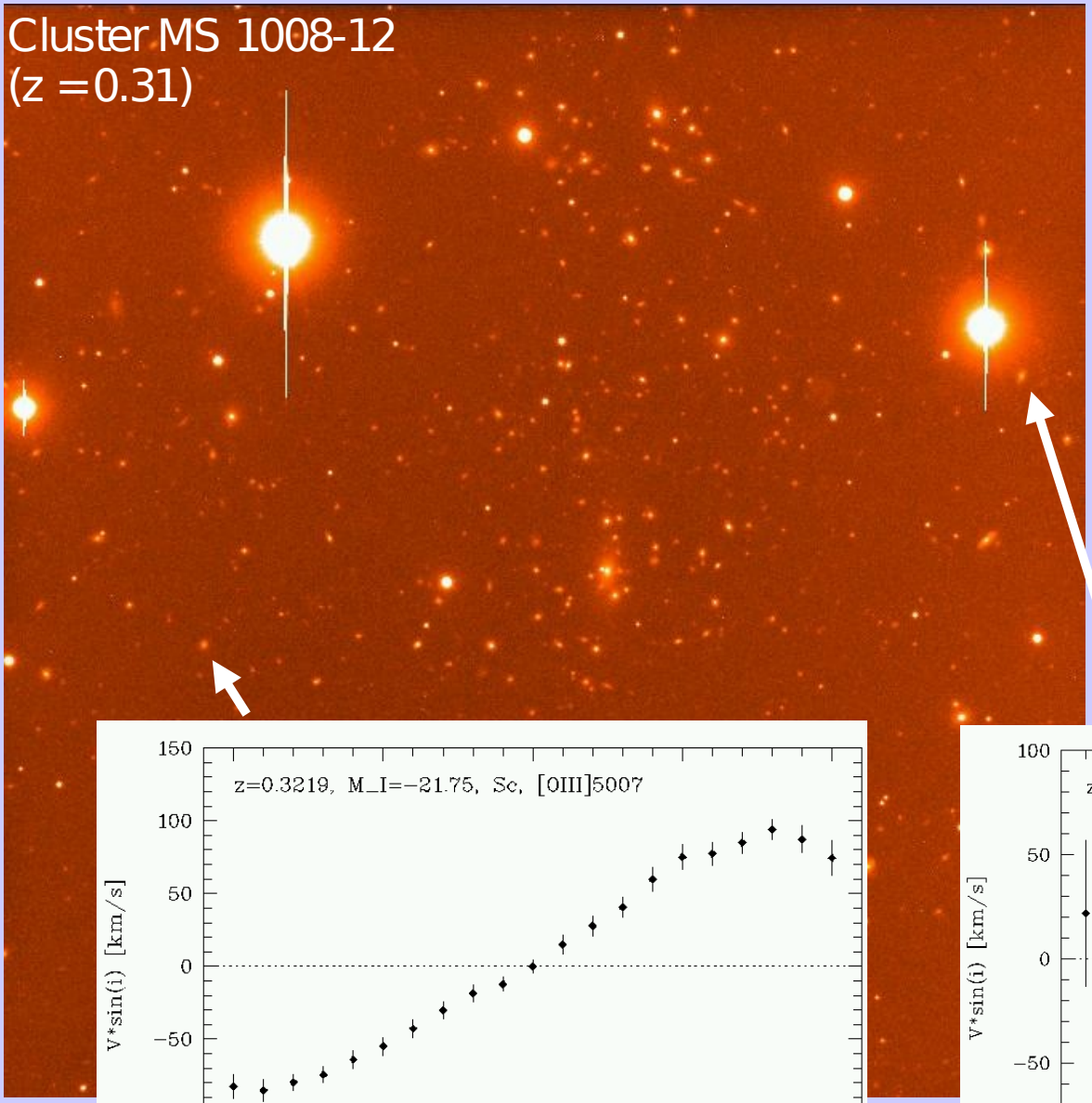


- tidal (gravitational) interactions
- merging, accretion
- ram-pressure stripping by intracluster medium (hot x-ray gas)
- harassment
- strangulation, suffocation, starvation





Kinematics of spirals in distant **clusters**

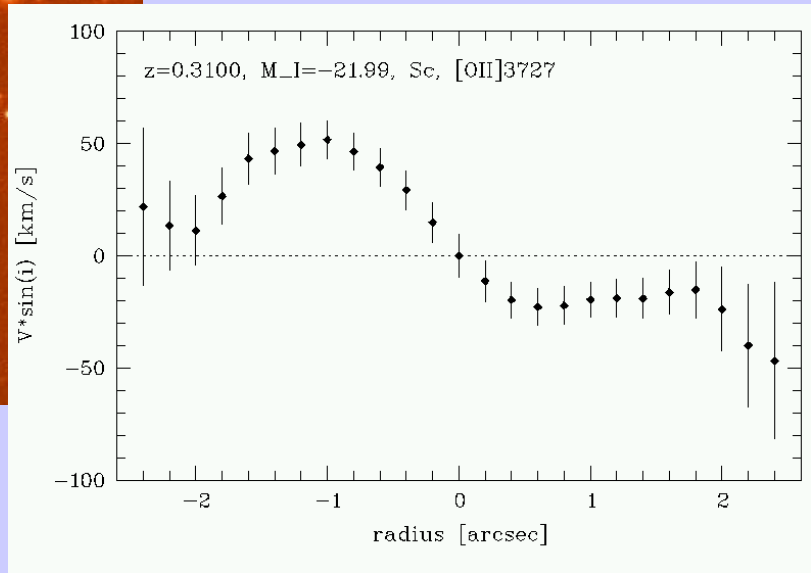


FORS

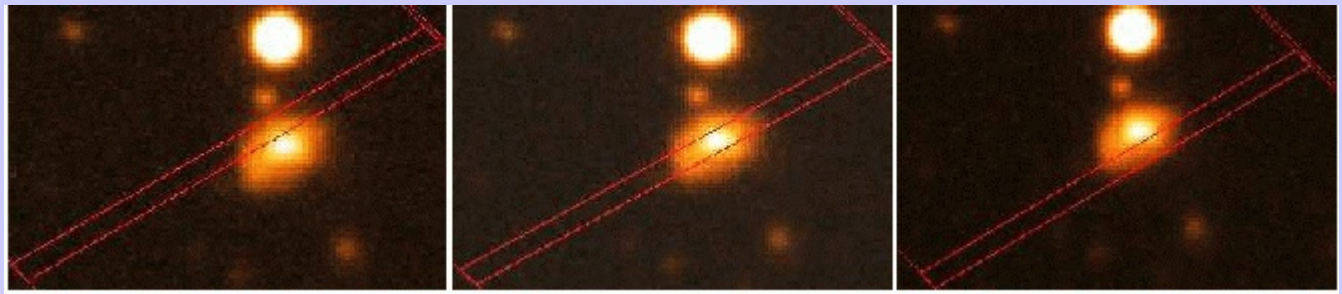
Hierarchical growth of structure:
late cluster assembly ($z \approx 1$)
merging frequency (efficiency)
& infall rate increases with z

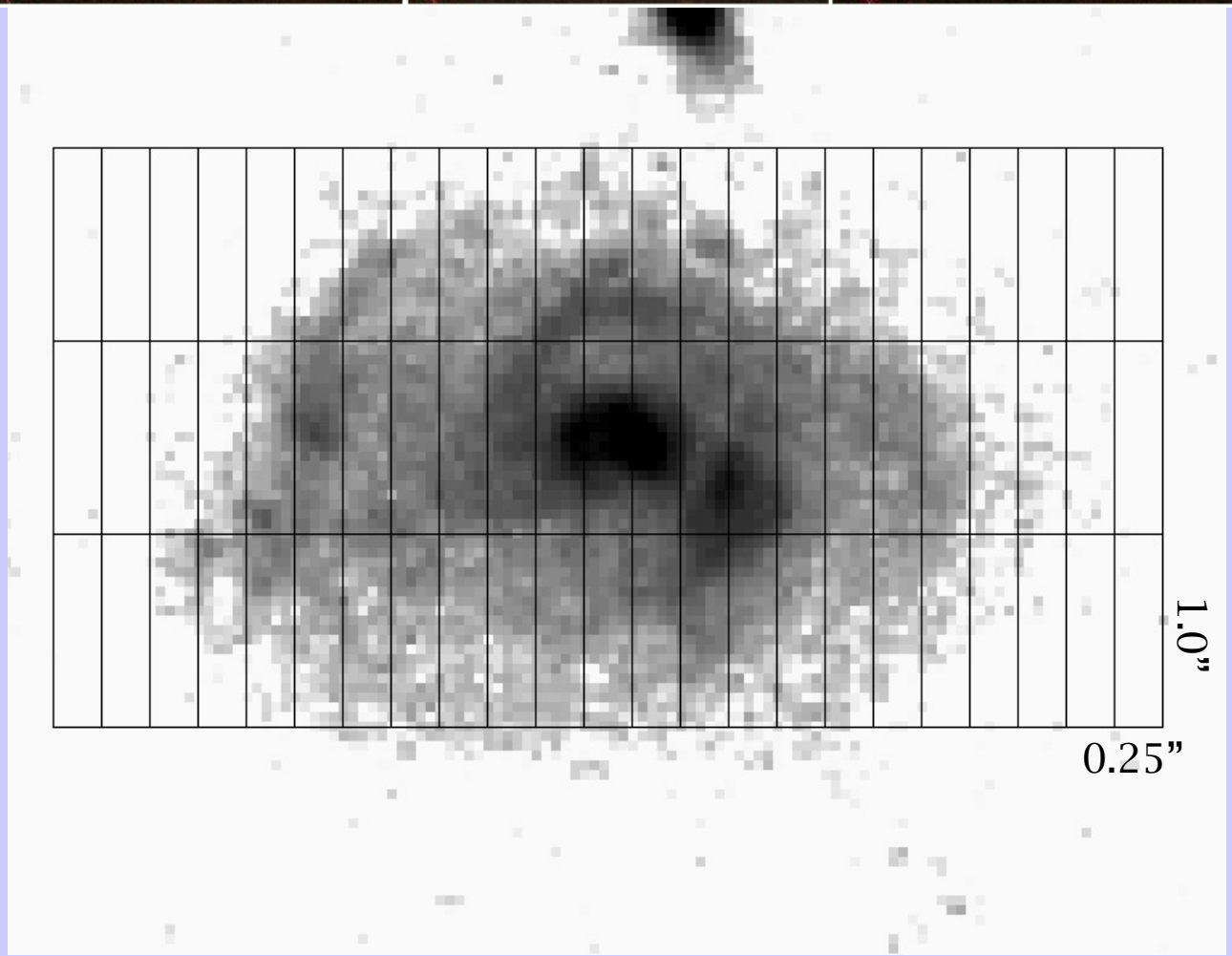
Project for 7 clusters $0.3<z<0.6$
get rotation curves of
20-40 galaxies each
$\Rightarrow$ 250 galaxies

Some distorted RCs due to geometry $\Rightarrow$ need 2d–velocity fields

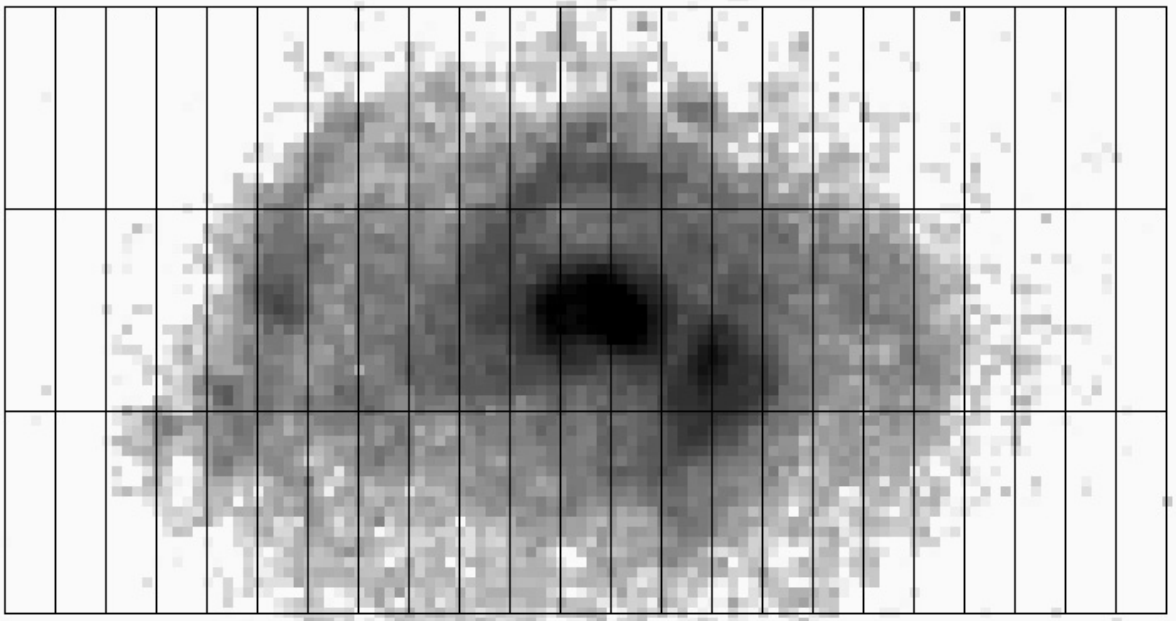


Velocity fields with FORS2 «IFU simulation»





Velocity fields with FORS2

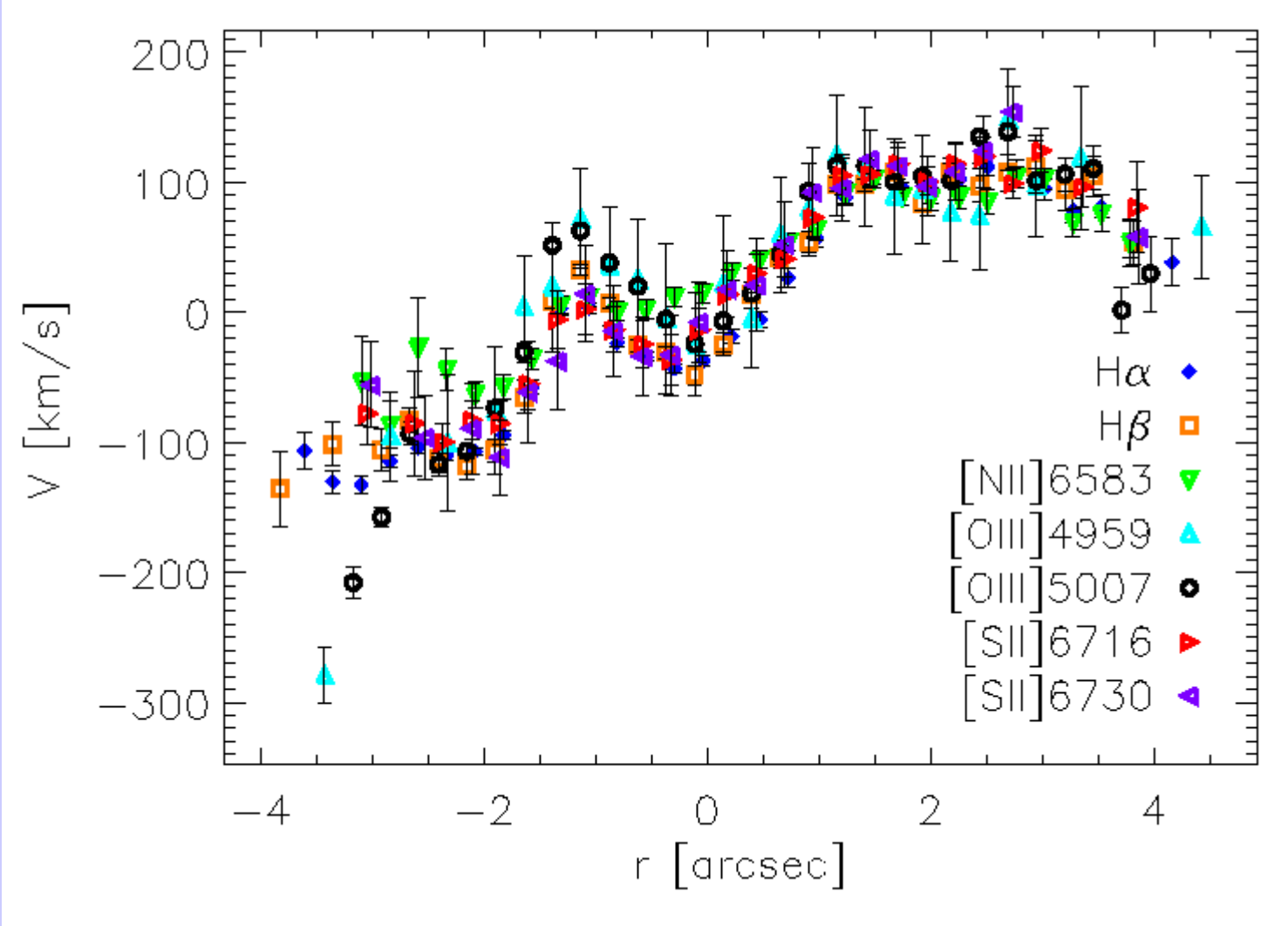


IFU "simulation":

- MXU masks of VLT/FORS2 for 3D-spectroscopy
- matched spatial coverage
- sufficient spatial resolution
- large wavelength coverage
- high efficiency: large target number
- economic exposure times
- → 4 nights VLT time spent
- & HST/ACS imaging of all cluster fields

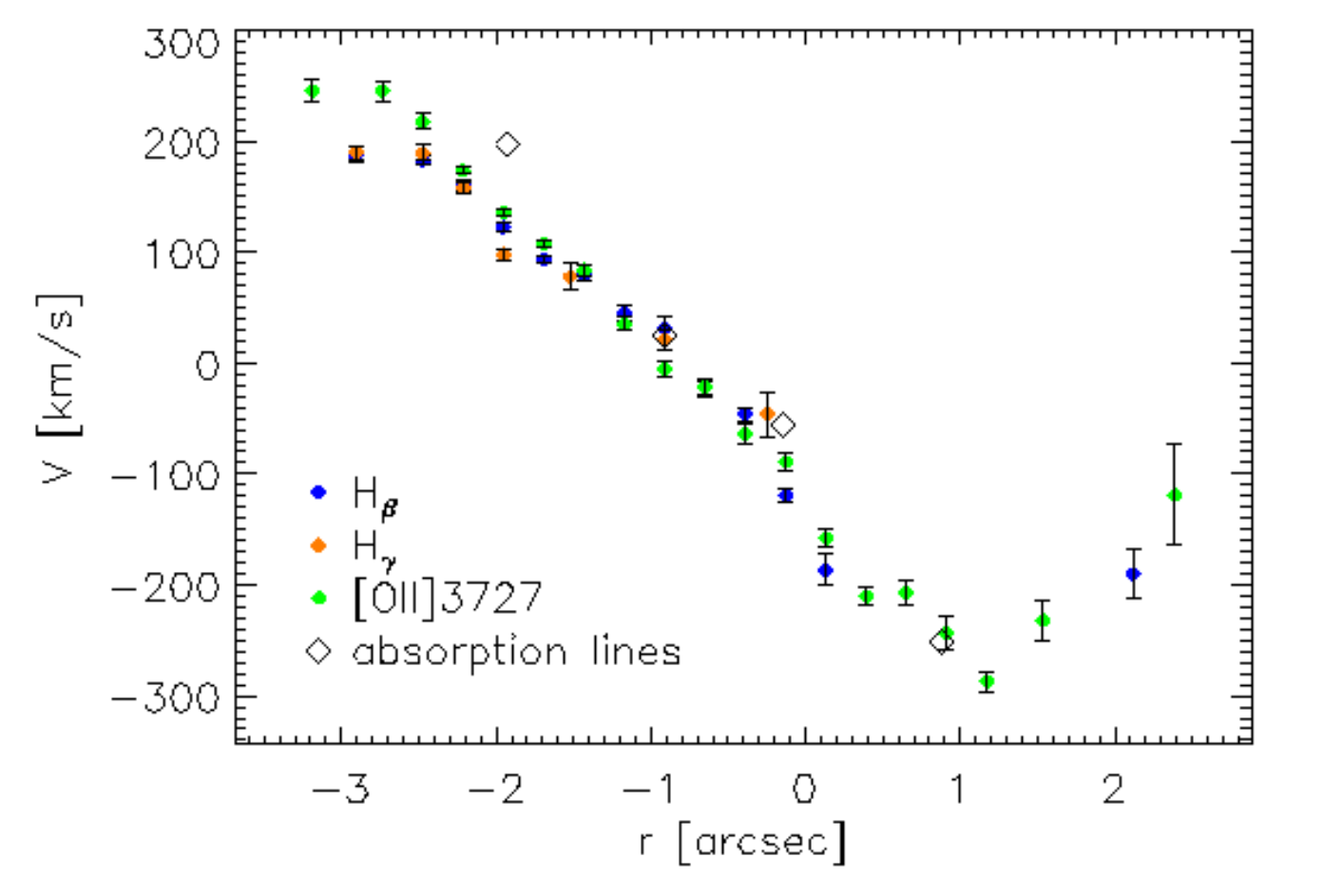
Ziegler et al. 2007

Rotation Curve from different Emission Lines



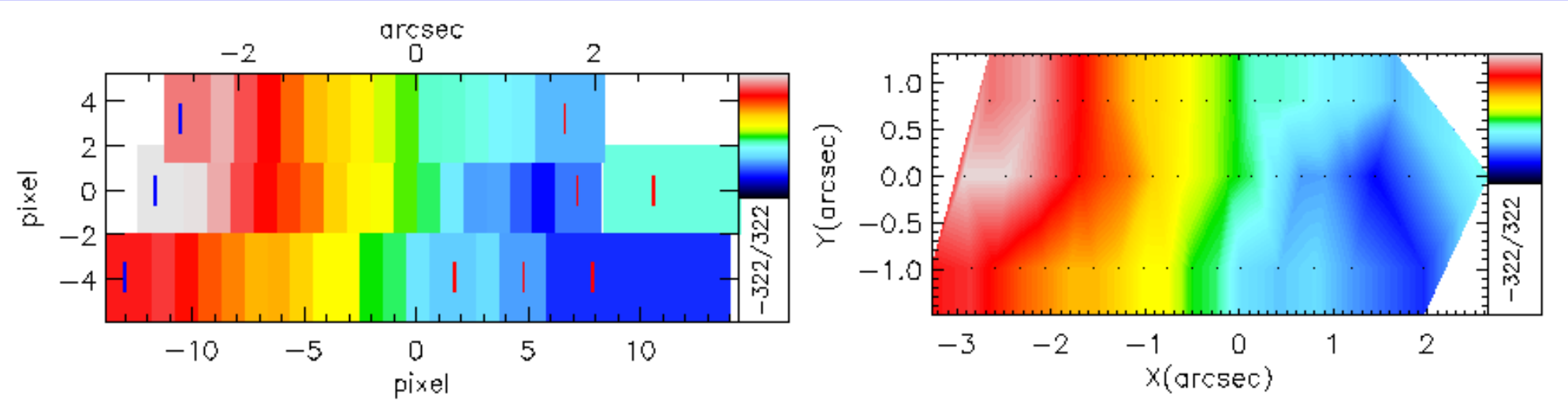
Field galaxy at z=0.16

Stellar & Gas Rotation Curve of Spiral Cluster Member



Cluster galaxy at z=0.53

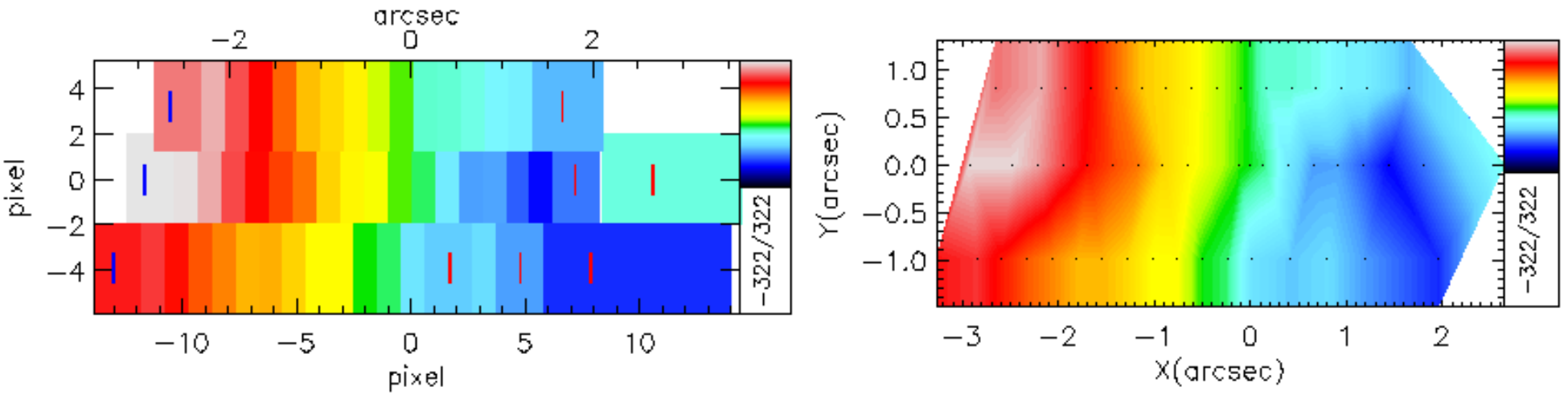
Velocity Field of Regular Spiral Cluster Member



Kutdemir et al. 2008

MS0451-03 z=0.53

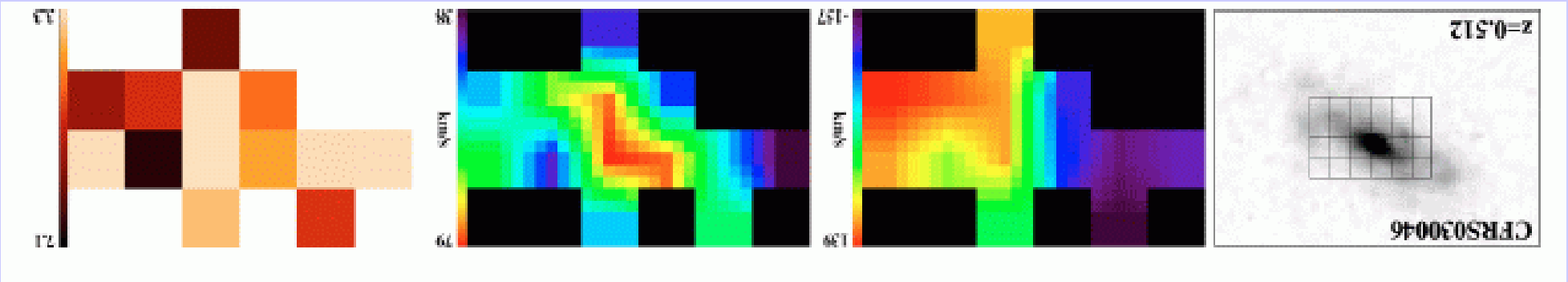
Velocity Field of Regular Spiral Cluster Member



Kutdemir et al. 2008

MS0451-03 z=0.53

cf. with 3"x2" FLAMES IFU, see Hammer

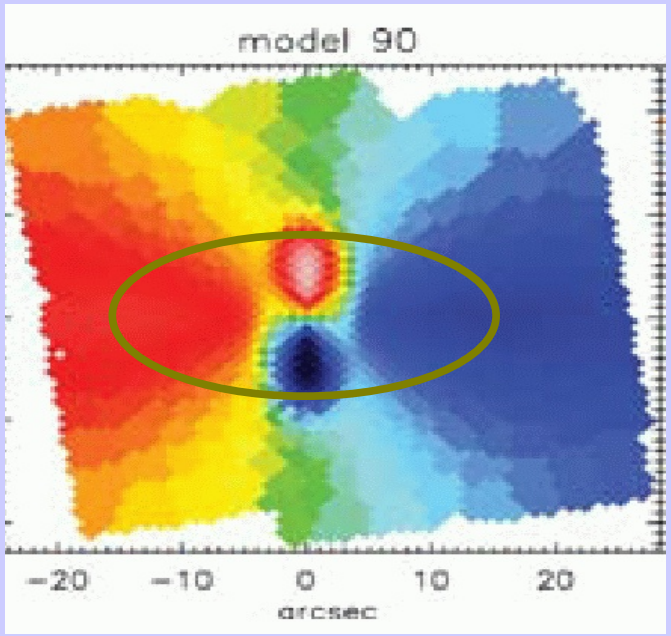


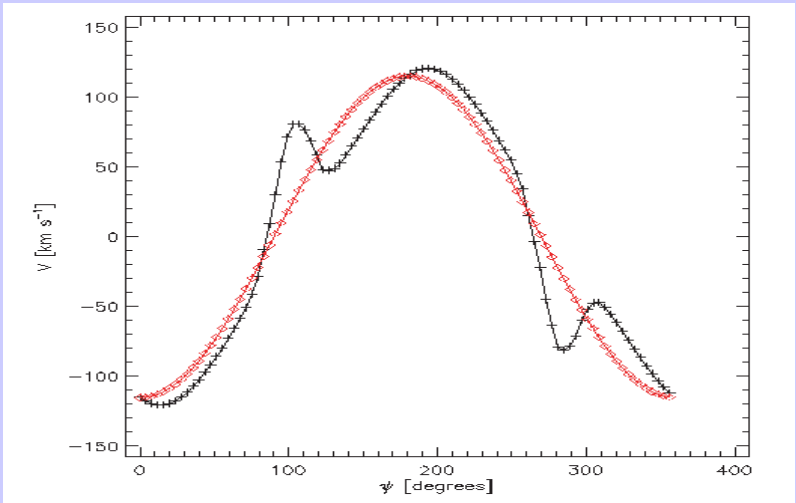
Kinemetry Analysis

For flat disk galaxy, velocity profile along best fitting ellipse has cosine form:

$$V(R, \psi) = V_0 + V_c(R) \sin i \cos \psi$$

R: radius of ring, V_0: system. velocity, V_c: circular velocity, Ψ: azimuthal angle





Krajnović et al. 2006

Kinemetry Analysis

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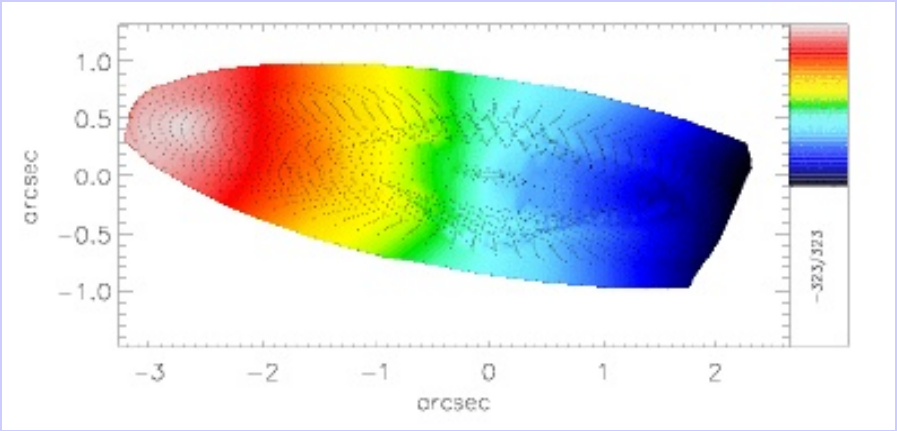
Deviations from simple rotation quantized by harmonic expansion along ellipses:

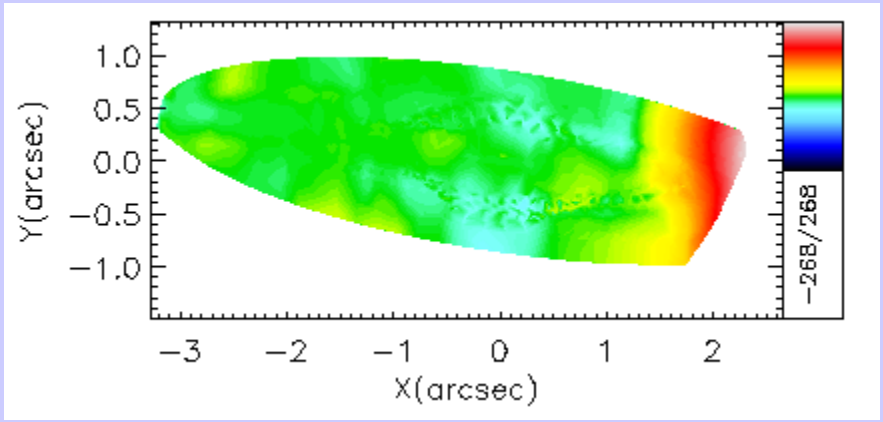
$$V(a, \Psi) = \sum_{n=1}^{N} k_n(a) cos[n(\Psi - \phi_n(a))]$$

k_1 corresponds to bulk motion in velocity field: «rotation curve»
k_3 describes first correction to simple rotational motion
k_5 represents kinematic separate components in velocity field

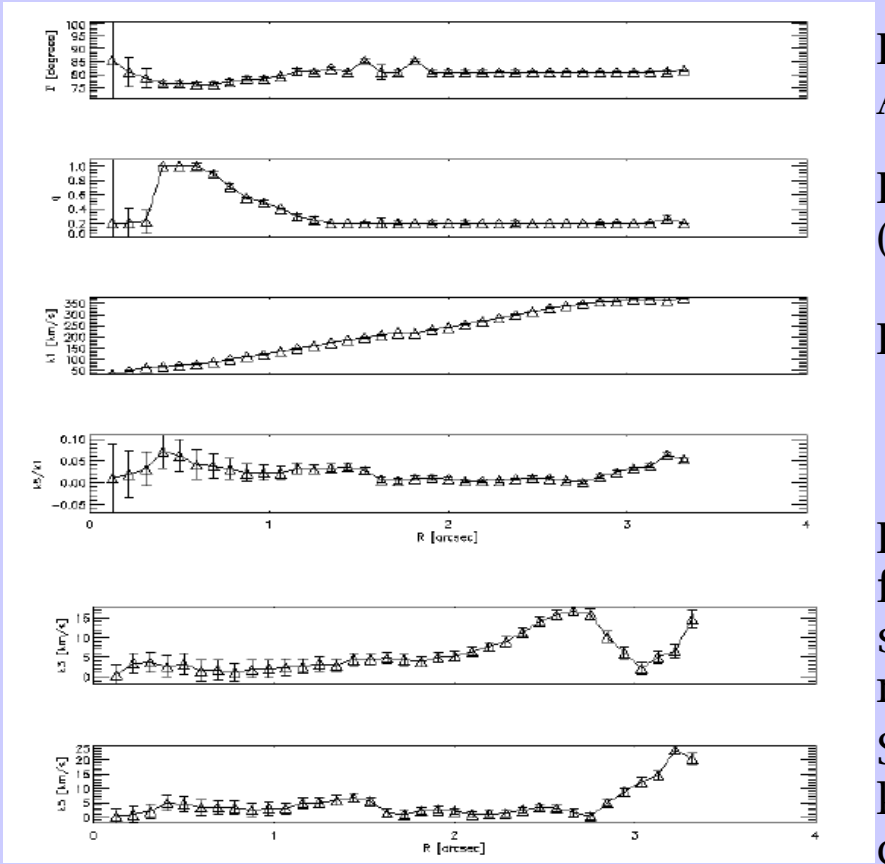
Krajnović et al. 2006

Kinemetry of Regular Spiral Cluster Member





Reconstructed map with best fitting ellipses
using higher order Fourier terms & its residual map.



R (distance from center)

Position Angle

Flattening (b/a)

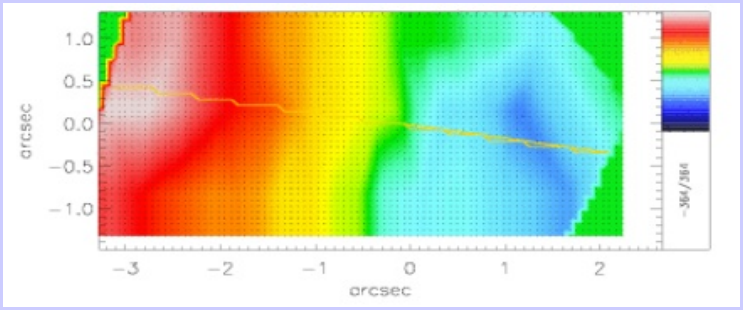
Bulk Motion

Deviation from simple rotation

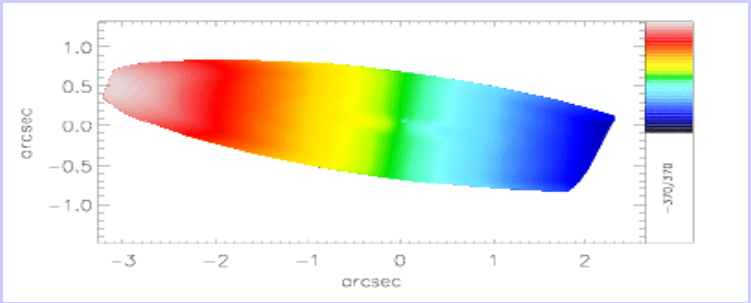
Separate kinematic components

Kutdemir, Ziegler et al. 2008

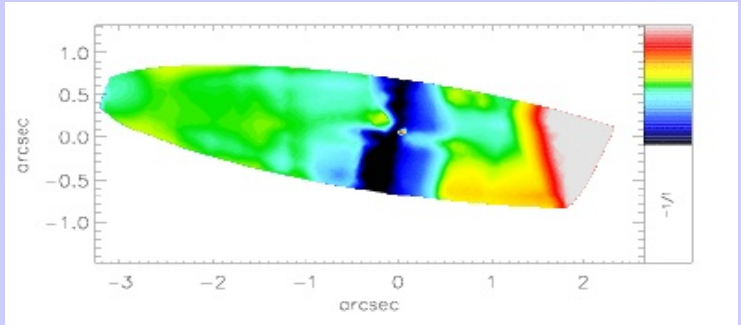
Kinemetry of Regular Spiral Cluster Member (z=0.5)



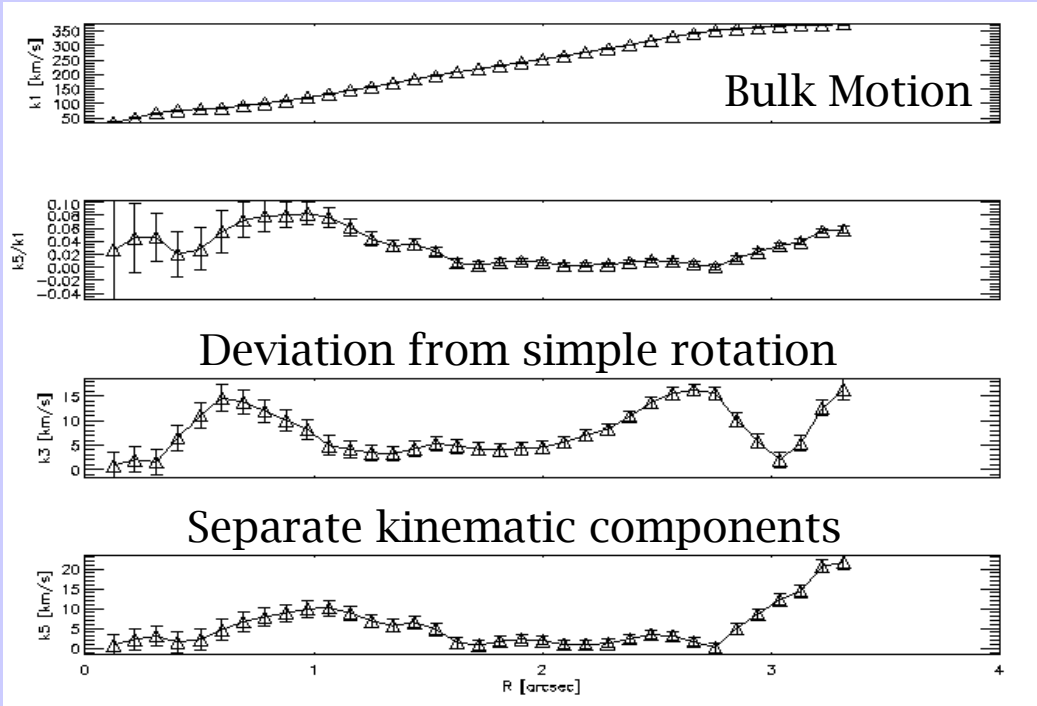
Kinematic axis



Simple rotation map



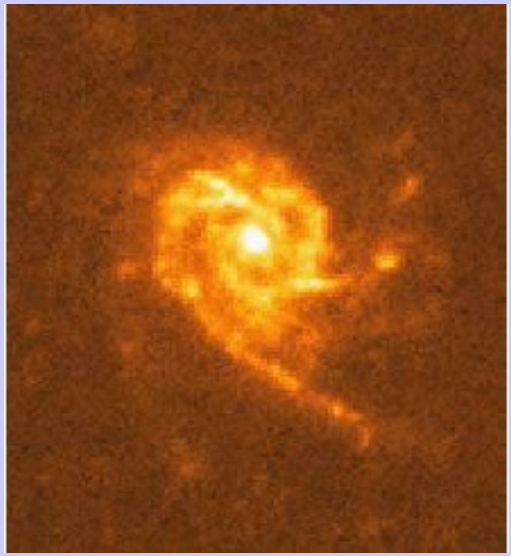
Residual map

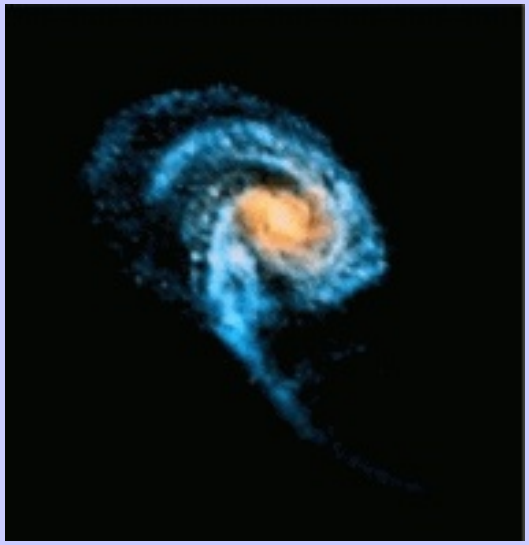


Position angle & flattening

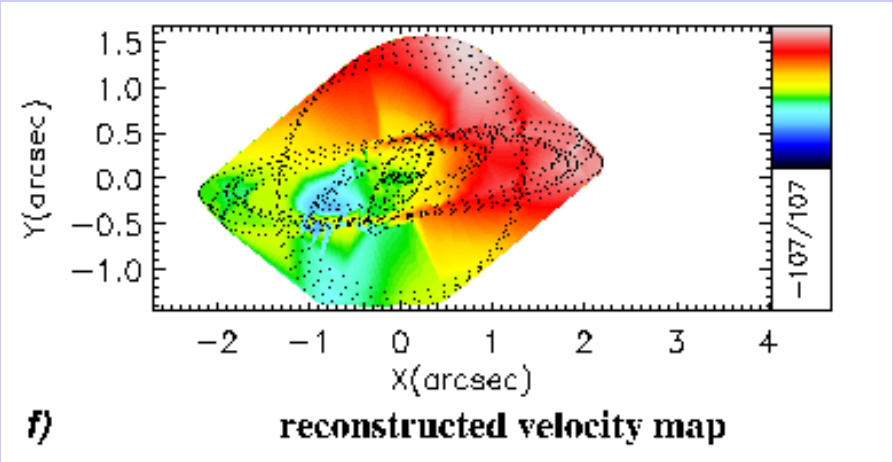
fixed to global value.

Velocity Field of Peculiar Spiral Cluster Member

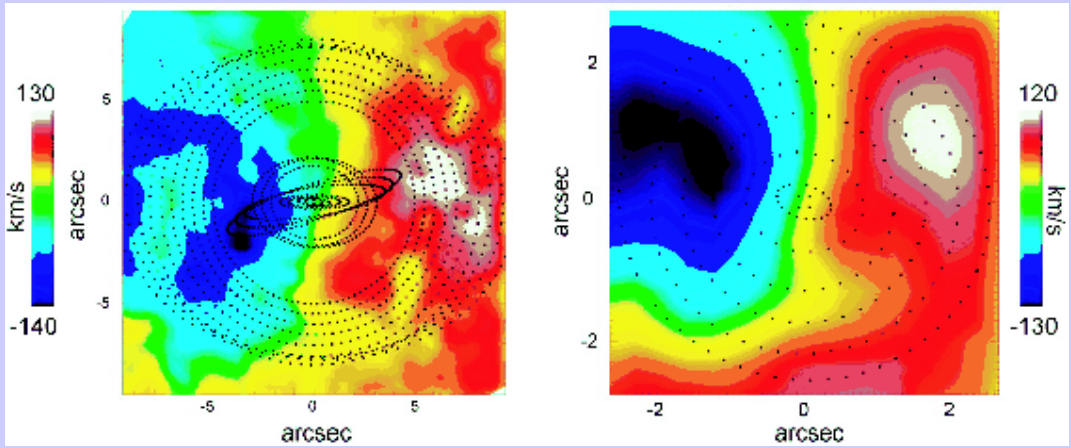




Simulation of minor merger
(8:1 mass ratio)
seen after second passage

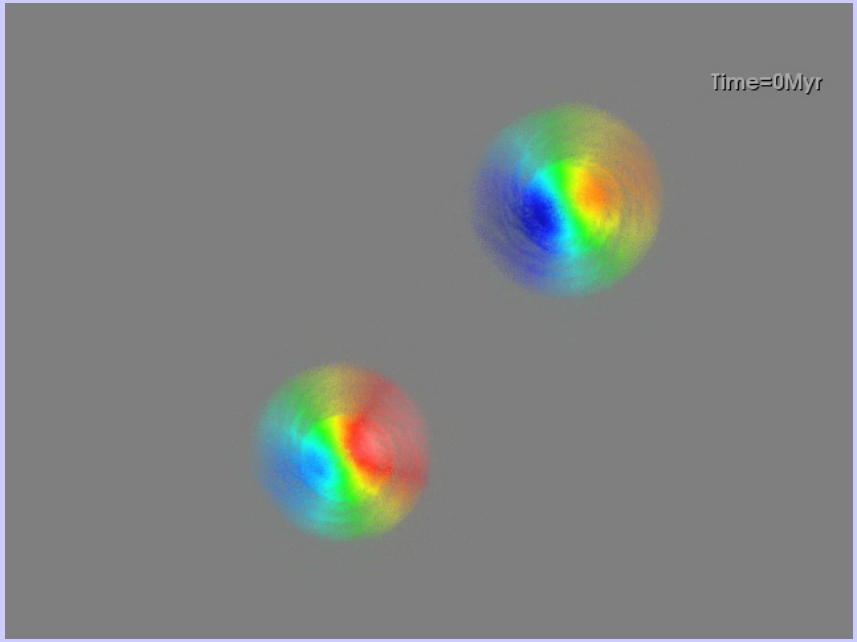


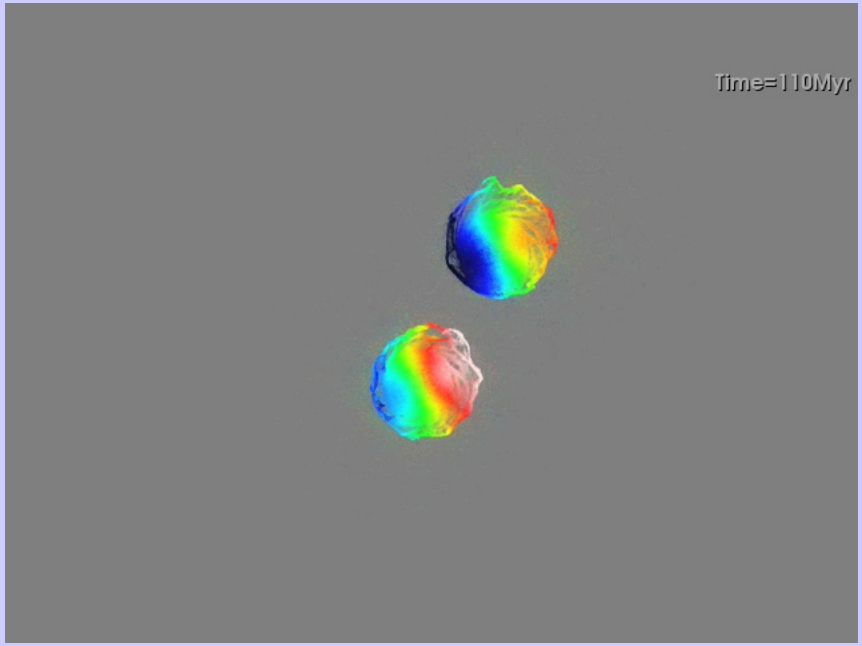
Kutdemir et al. 2008

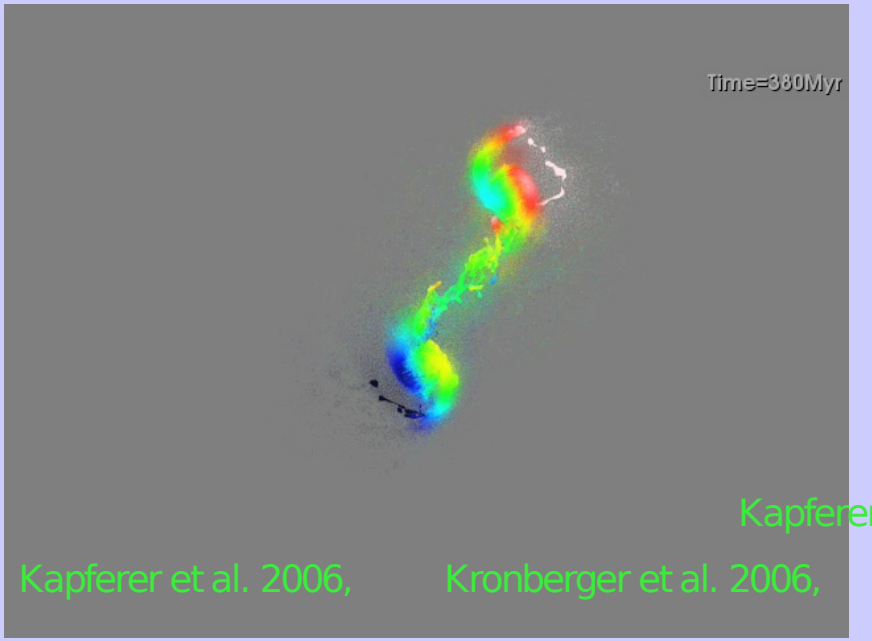


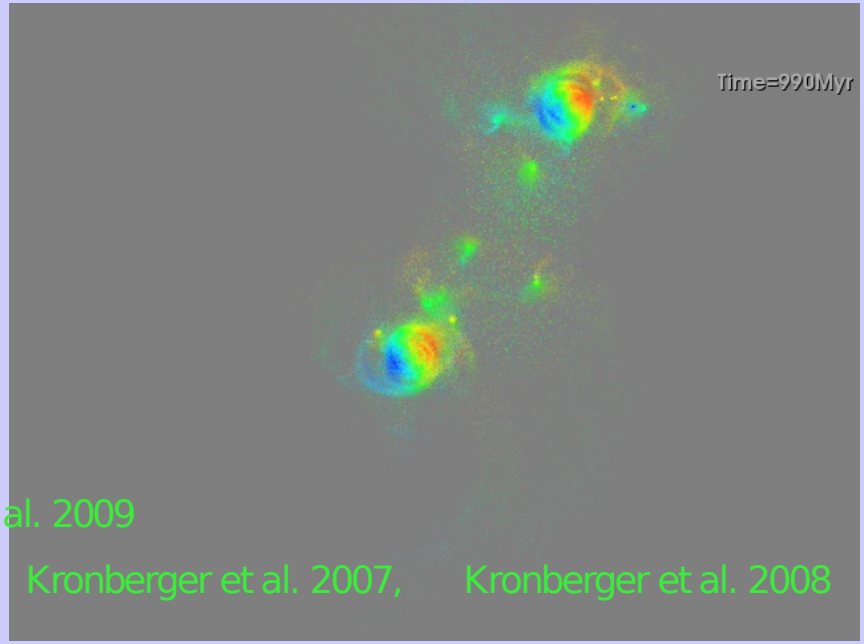
Kronberger et al. 2007

Simulation of merger & ram-pressure stripping









Kapferer et al. 2009

Kapferer et al. 2006, Kronberger et al. 2006, Kronberger et al. 2007, Kronberger et al. 2008

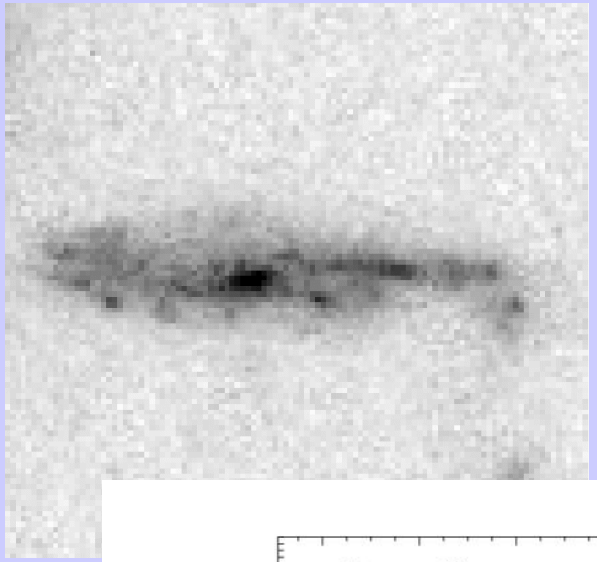
Collaboration with Kapferer, Kronberger & Schindler (Innsbruck)

Cluster sample

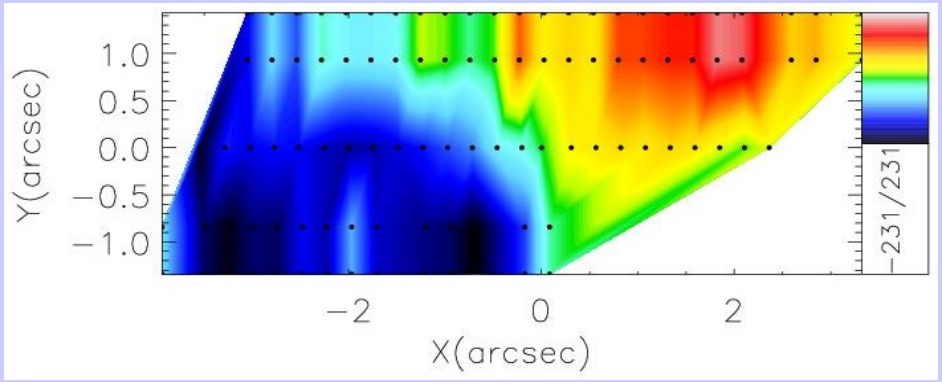
Cluster	z	VFs
MS 1008-12	0.30	16
MS 2137-23	0.31	10
Cl 1447+23	0.37	-
Cl 0303+17	0.42	-
Cl 0413-65	0.51	11
MS 0451-03	0.54	12
Cl 0016+16	0.55	-
	total:	49

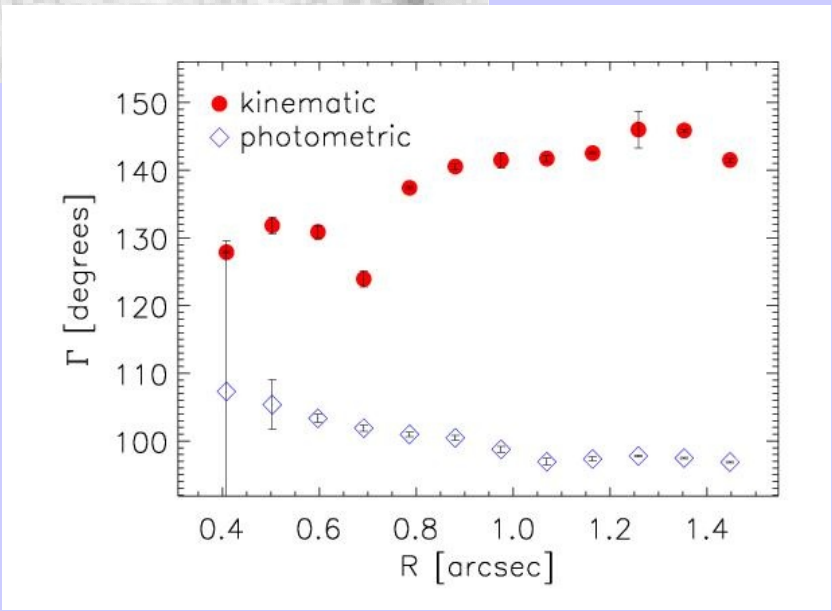
Parametrization of irregularity : Δ_Φ

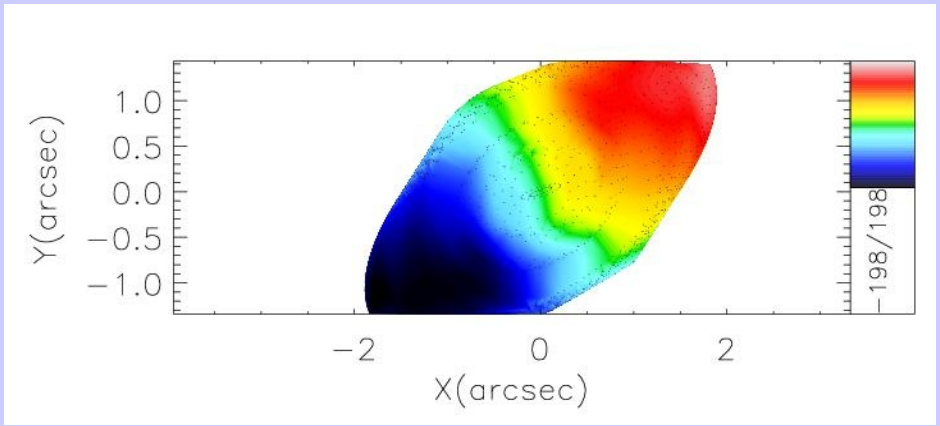
Δ_Φ : Mean difference between photometric & kinematic Position angle



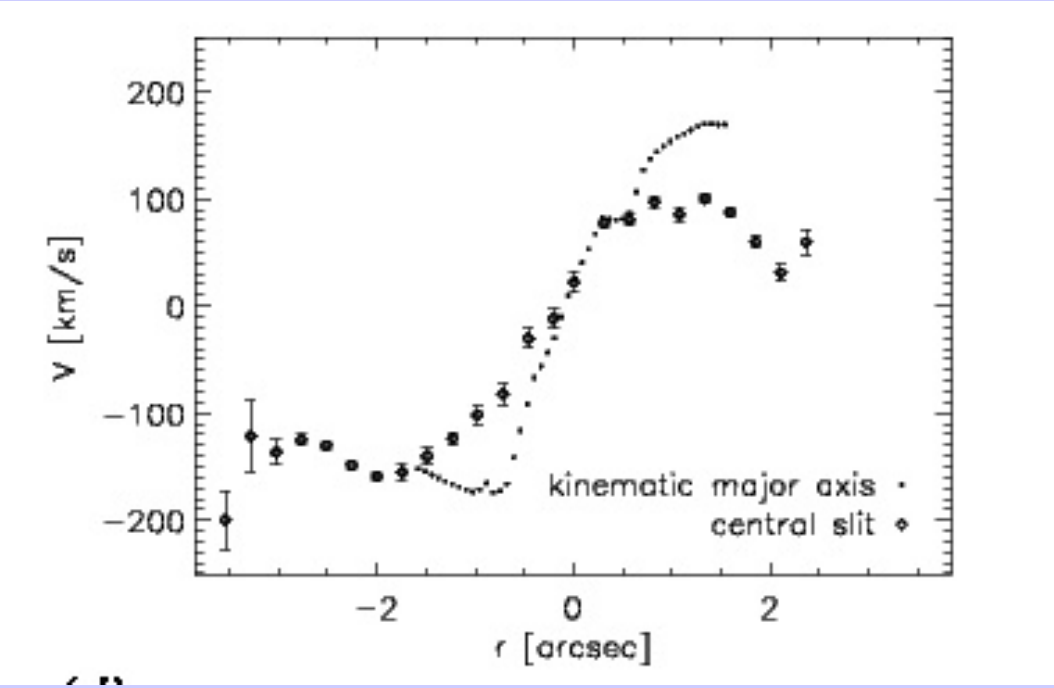
z=0.36



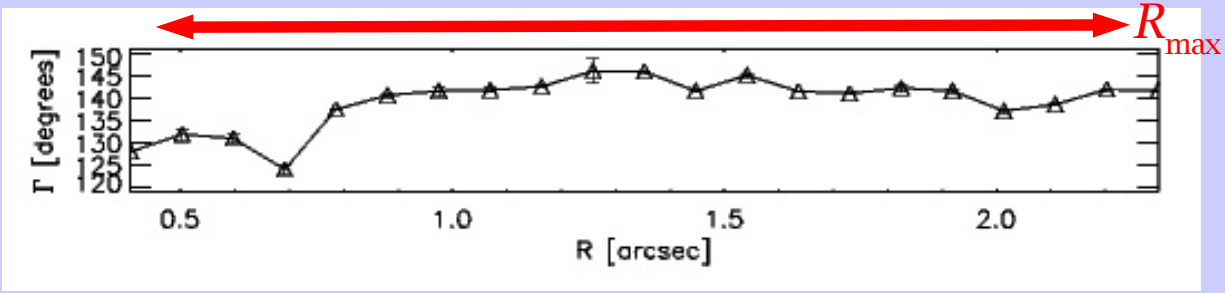




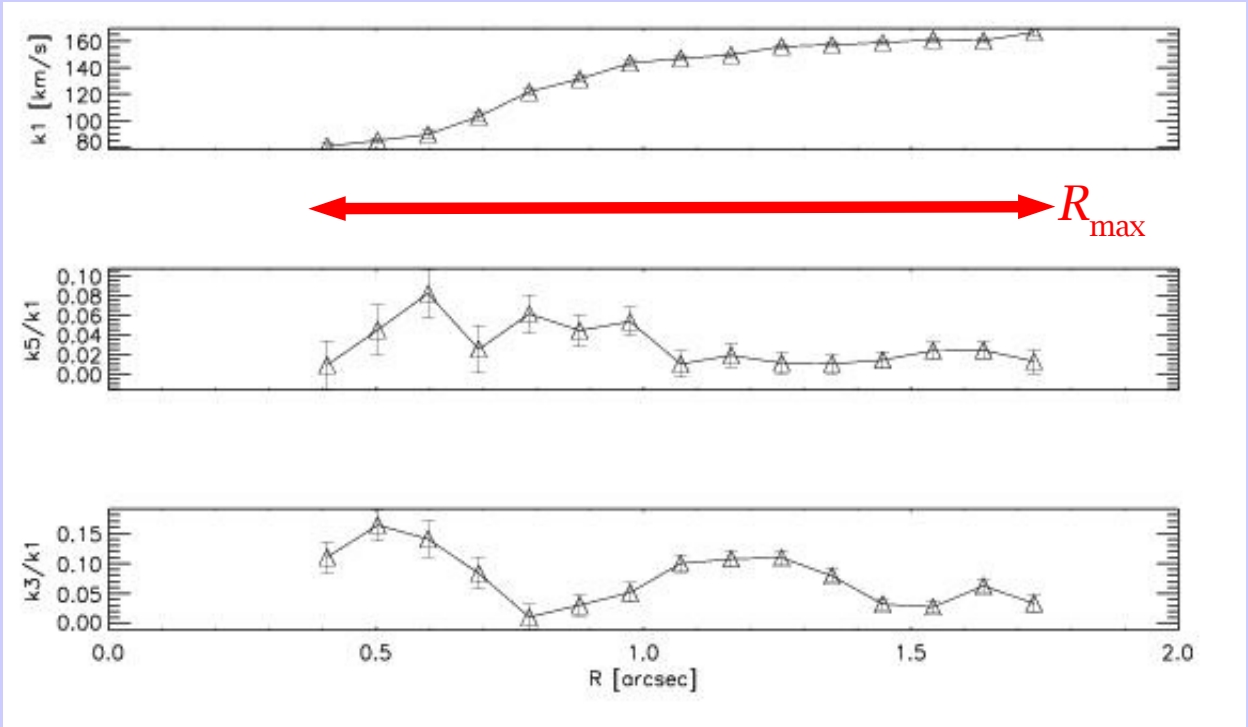
Rotation curve along phot. & kin. major axis



Parametrization of irregularity σ_{PA} & $k_{3,5}$

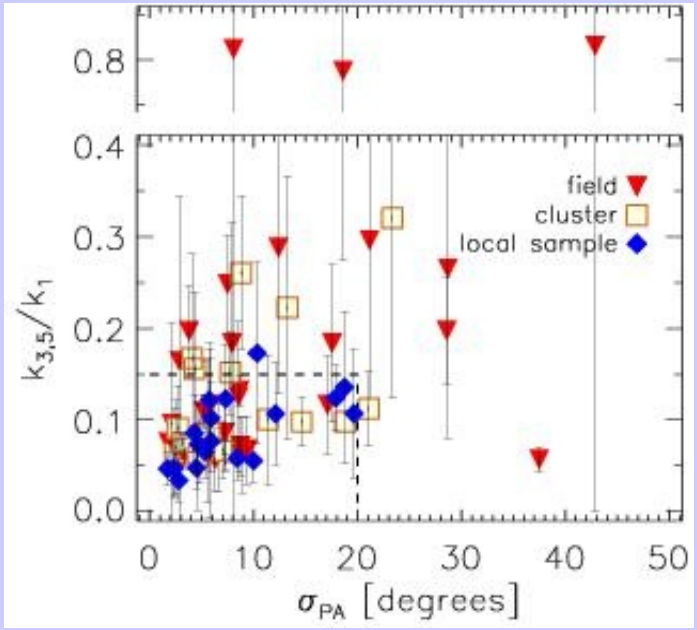


σ_{PA}
Standard deviation kin. Position angle



$k_{3,5} = (k_3 + k_5)/k_1$
Average of higher Fourier coefficients

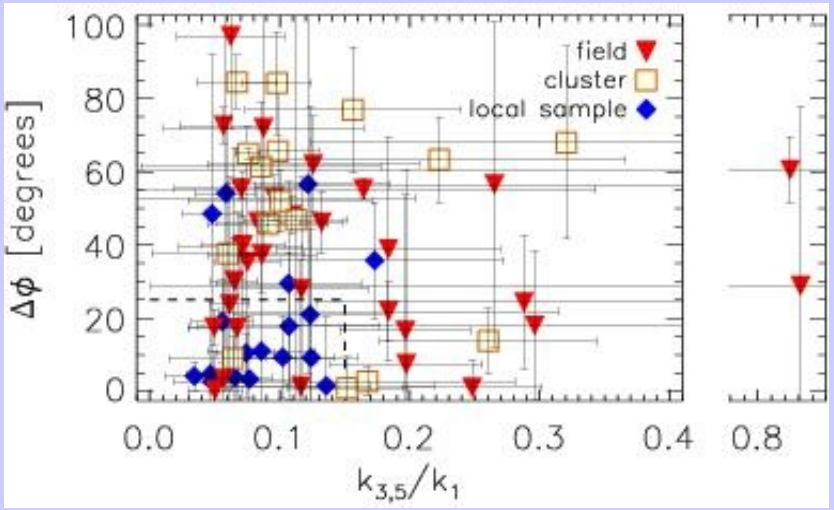
Definition of irregularity



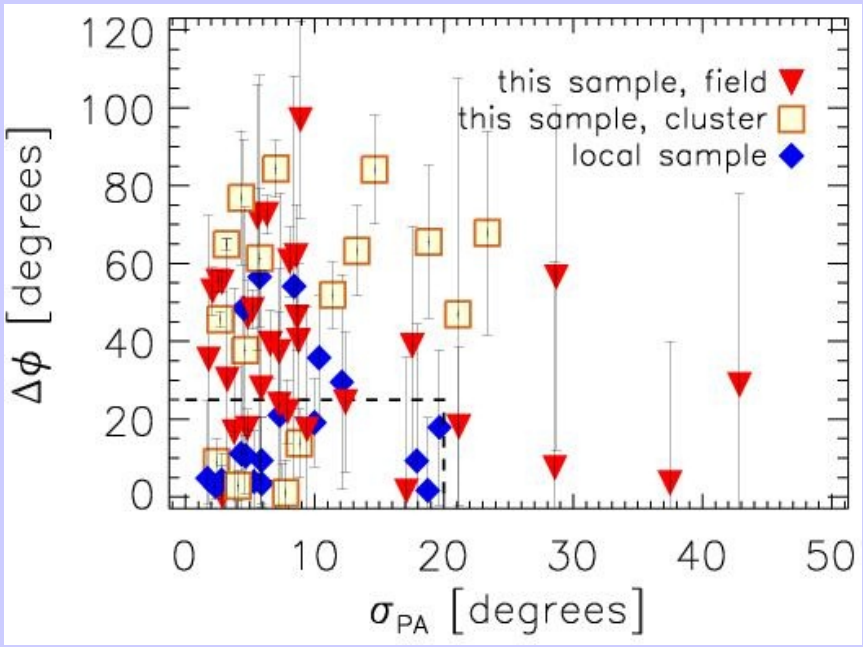
Local sample: Daigle et al. 2006

Limit: $\sigma_{PA} = 20$

Kutdemir et al. 2009

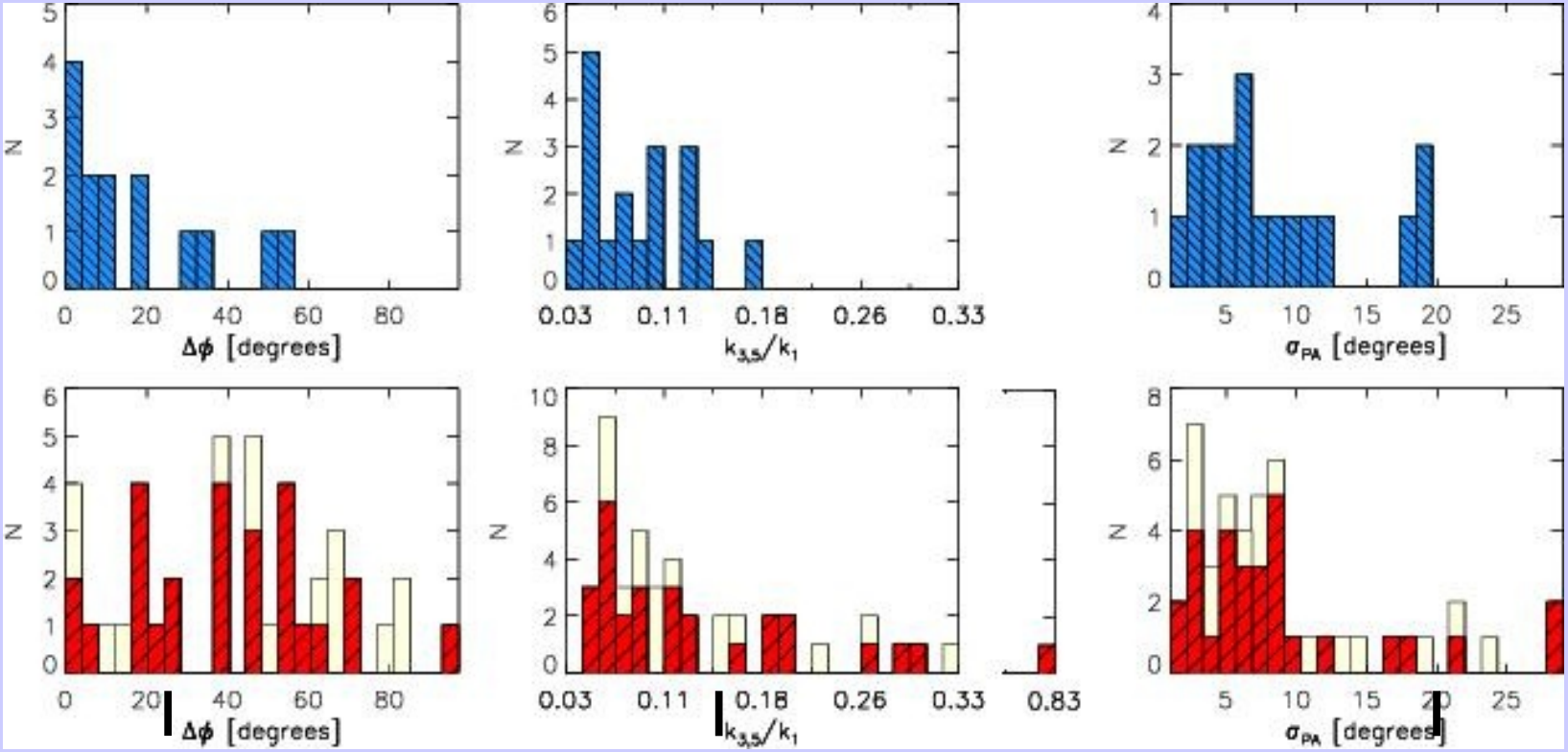


Limit: $k_{3,5} = 0.15$



Limit: $\Delta_\phi = 25$

Abundance of irregularities



Local sample

Distant sample
red: field
yellow: clusters

Table 5. Irregularity fraction.

	$frac_{\sigma_{PA}}$ (1)	$frac_{\Delta\phi}$ (2)	$frac_{k_{3,5}/k_1}$ (3)	$frac_{any}$
field & cluster	11 ± 5 %	68 ± 7 %	32 ± 7 %	80 ± 6 %
only field	10 ± 6 %	65 ± 9 %	32 ± 9 %	76 ± 8 %
only cluster	13 ± 8 %	73 ± 11 %	31 ± 12 %	88 ± 8 %

Kutdemir et al. 2009