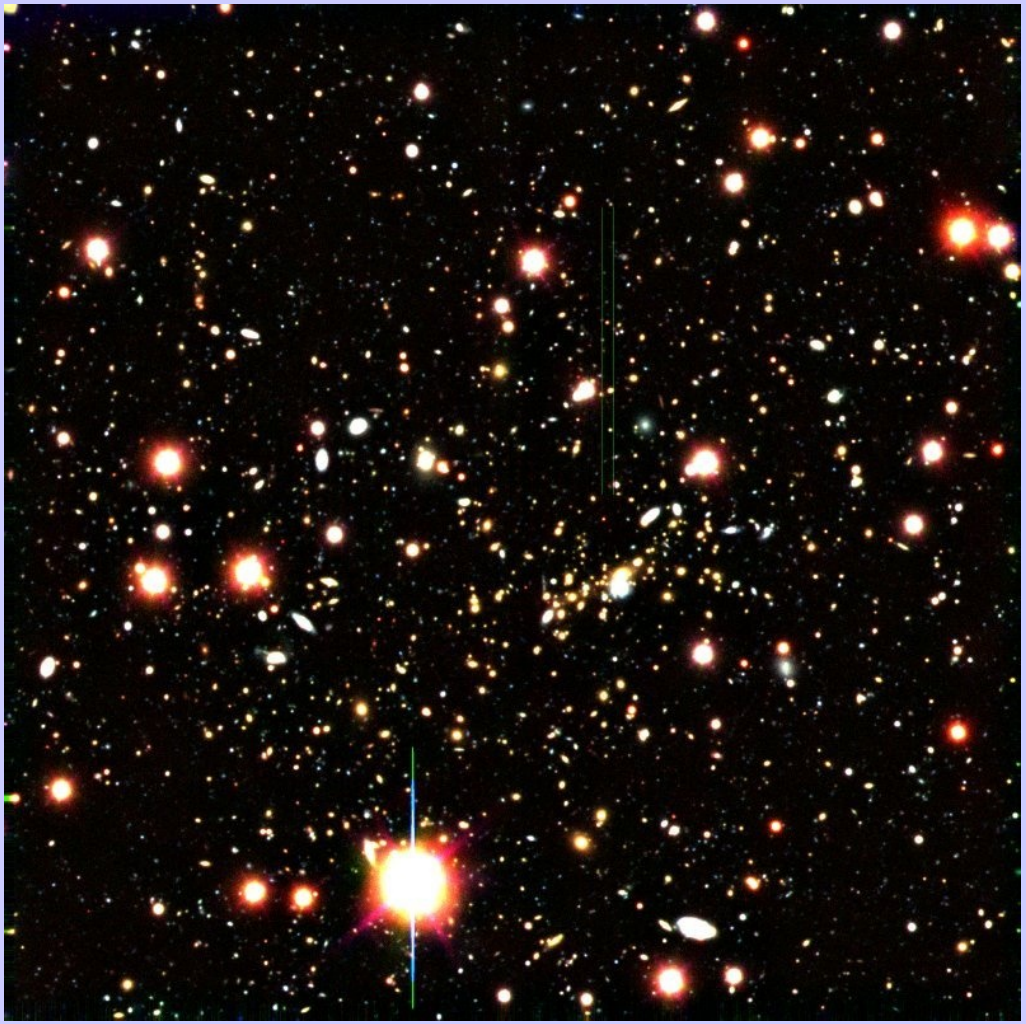
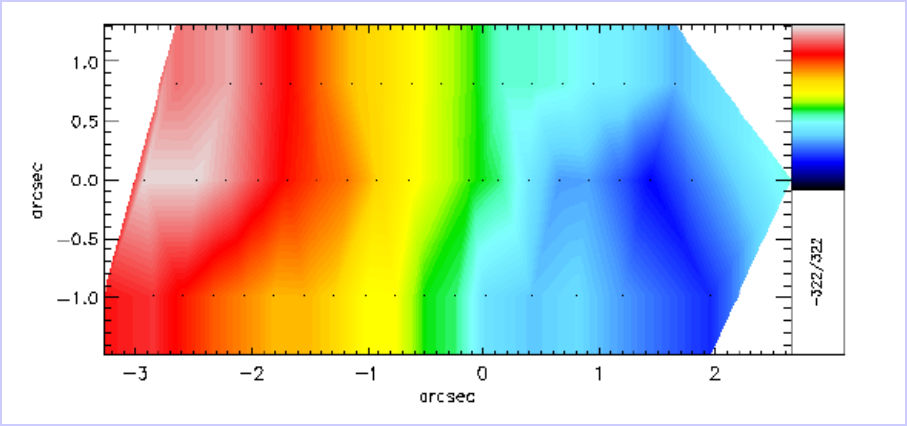
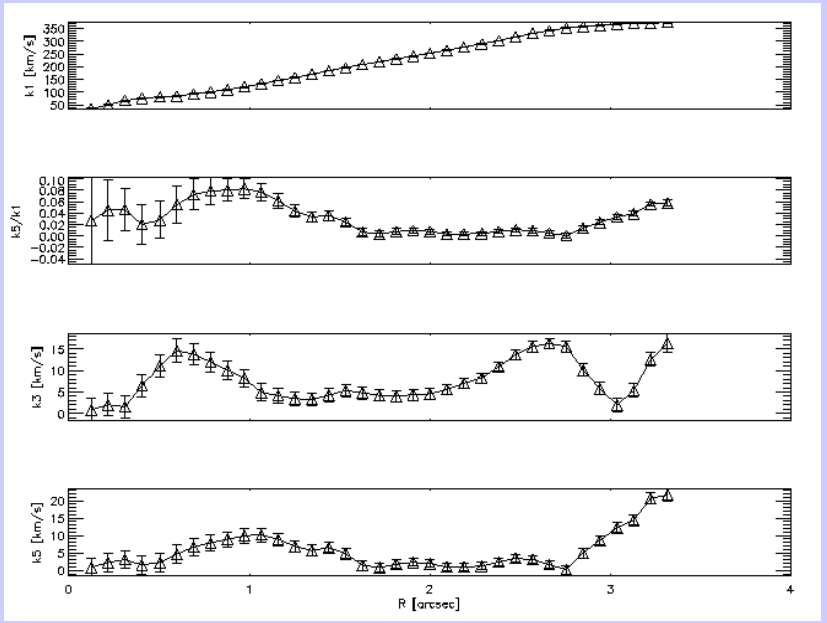
Bodo Ziegler
AIfA Bonn & IAG Göttingen
«Galaxy interactions in distant clusters seen with 2D velocity fields and structure and compared to SPH simulations»







FORS/VLT

Cluster MS0451-03 ($z=0.5$)

Goals:
- Quantify galaxy evolution
- Effect of environment
- Efficiency of interaction processes

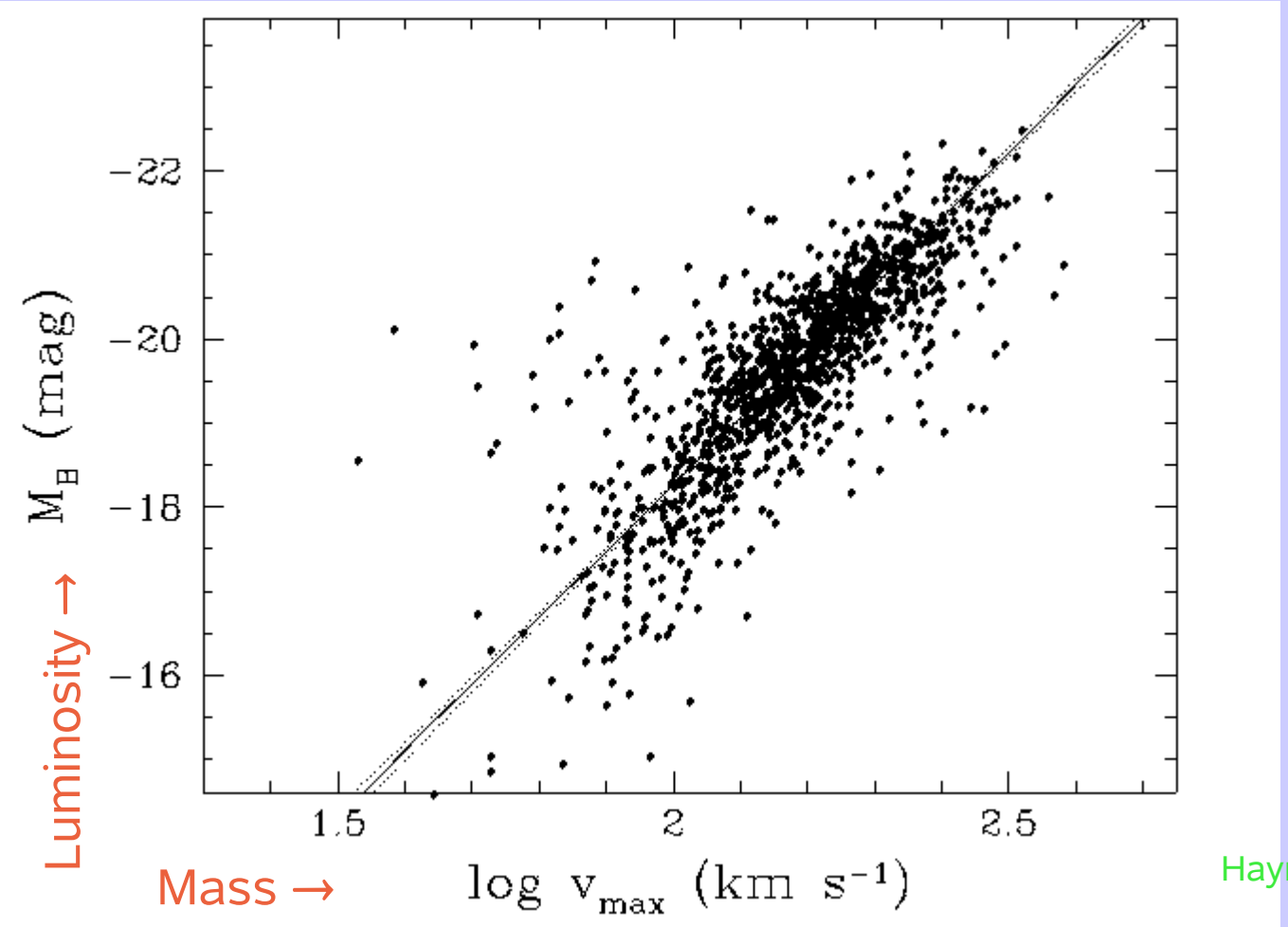
Tools:
- Spectroscopy to get velocity fields
- HST imaging to get structure
- N-body/SPH simulations (Springel's Gadget2) for comparison

Targets:
- Galaxies in clusters at $z \approx 0.5$

➔ close to assembly epoch

➔ peak of infall rate & interaction frequency (?)

Local Tully-Fisher Relation

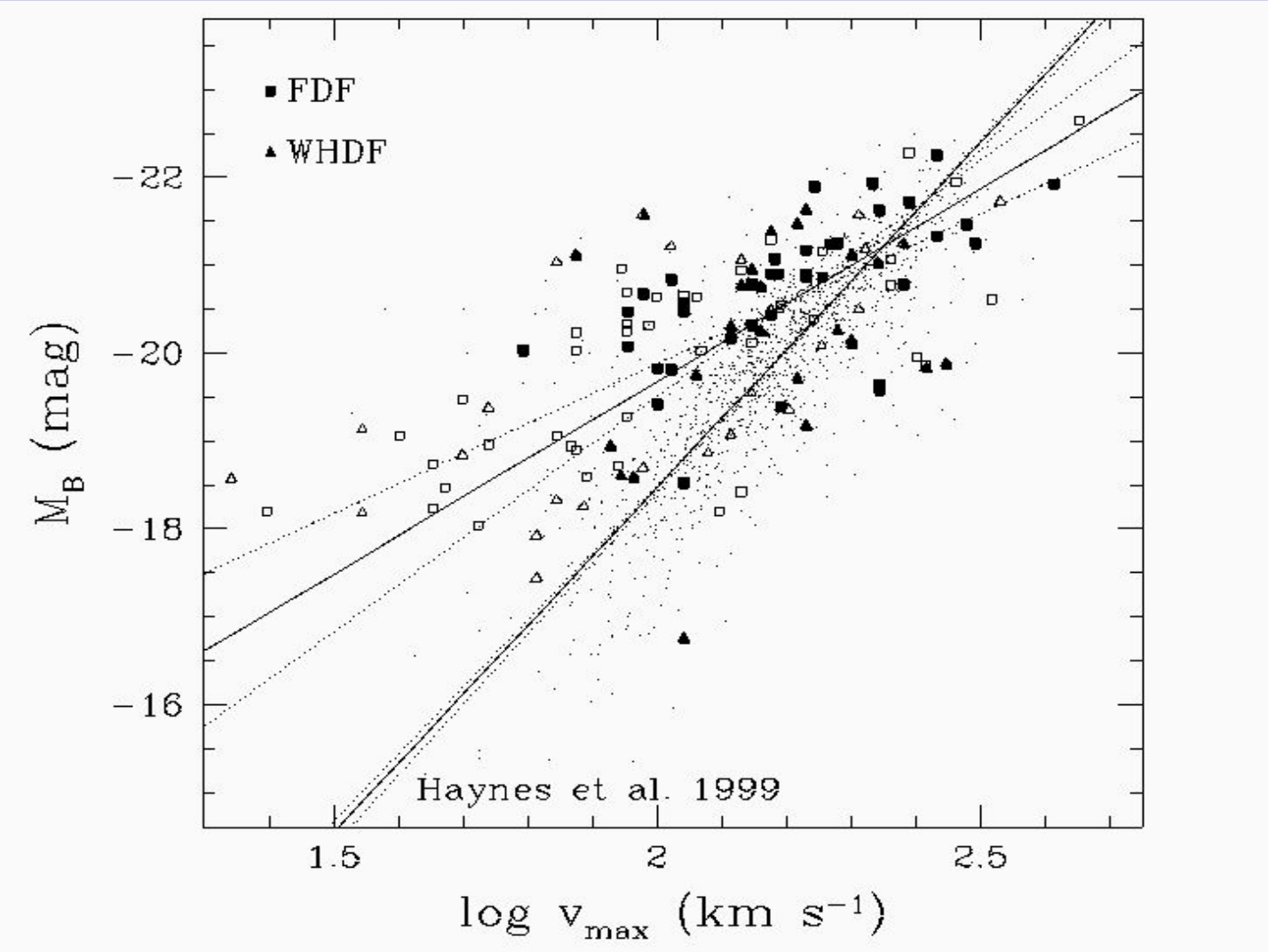


Haynes et al. 1999

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

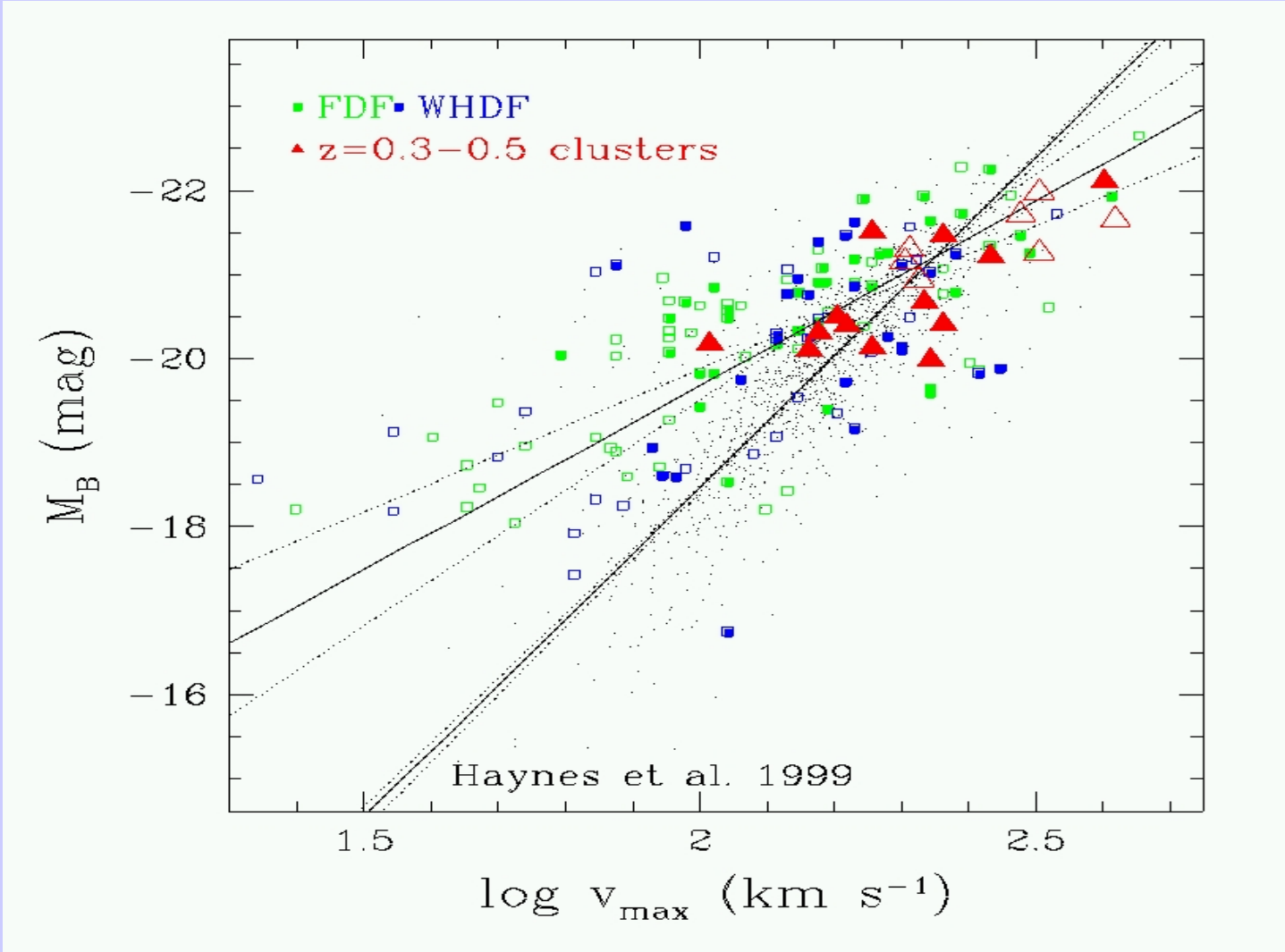
v_{max} ≙ mass scale: "normalization" for luminosity

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



Ziegler et al. 2002, 2005; Böhm et al. 2004, Böhm & Ziegler 2007

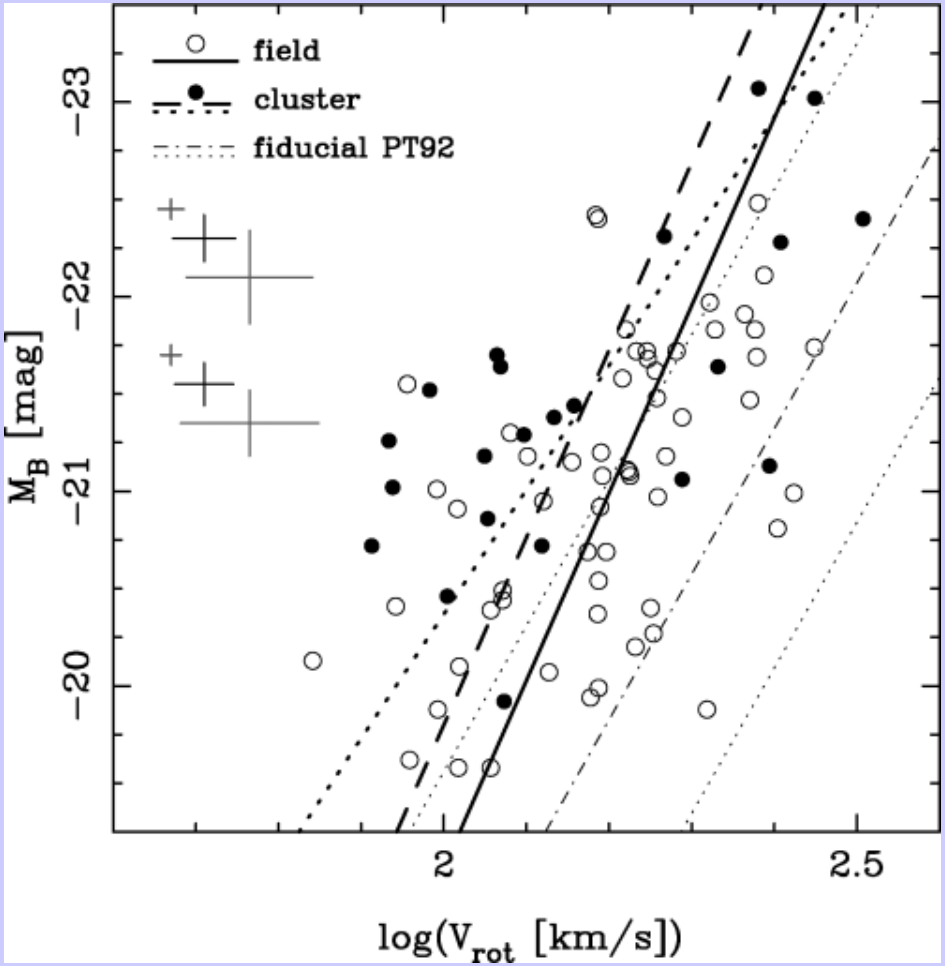
Tully-Fisher Relation of z≈0.5 *Cluster* Galaxies



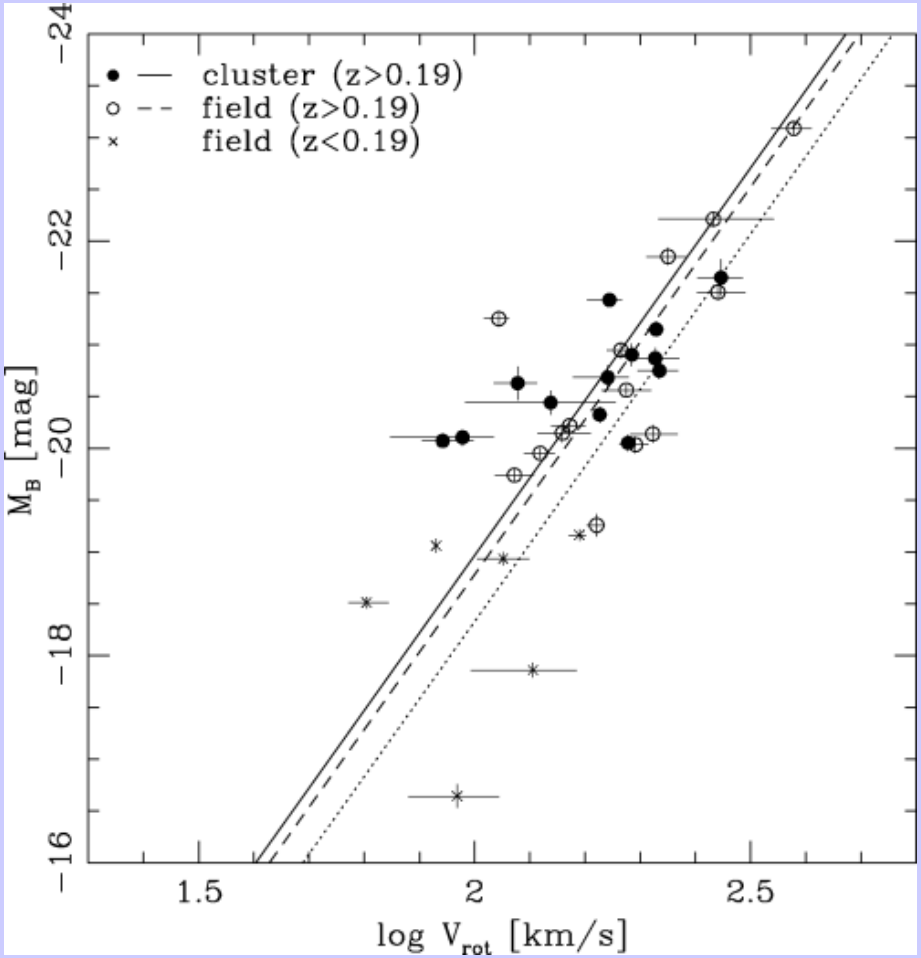
Ziegler et al. 2003

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

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



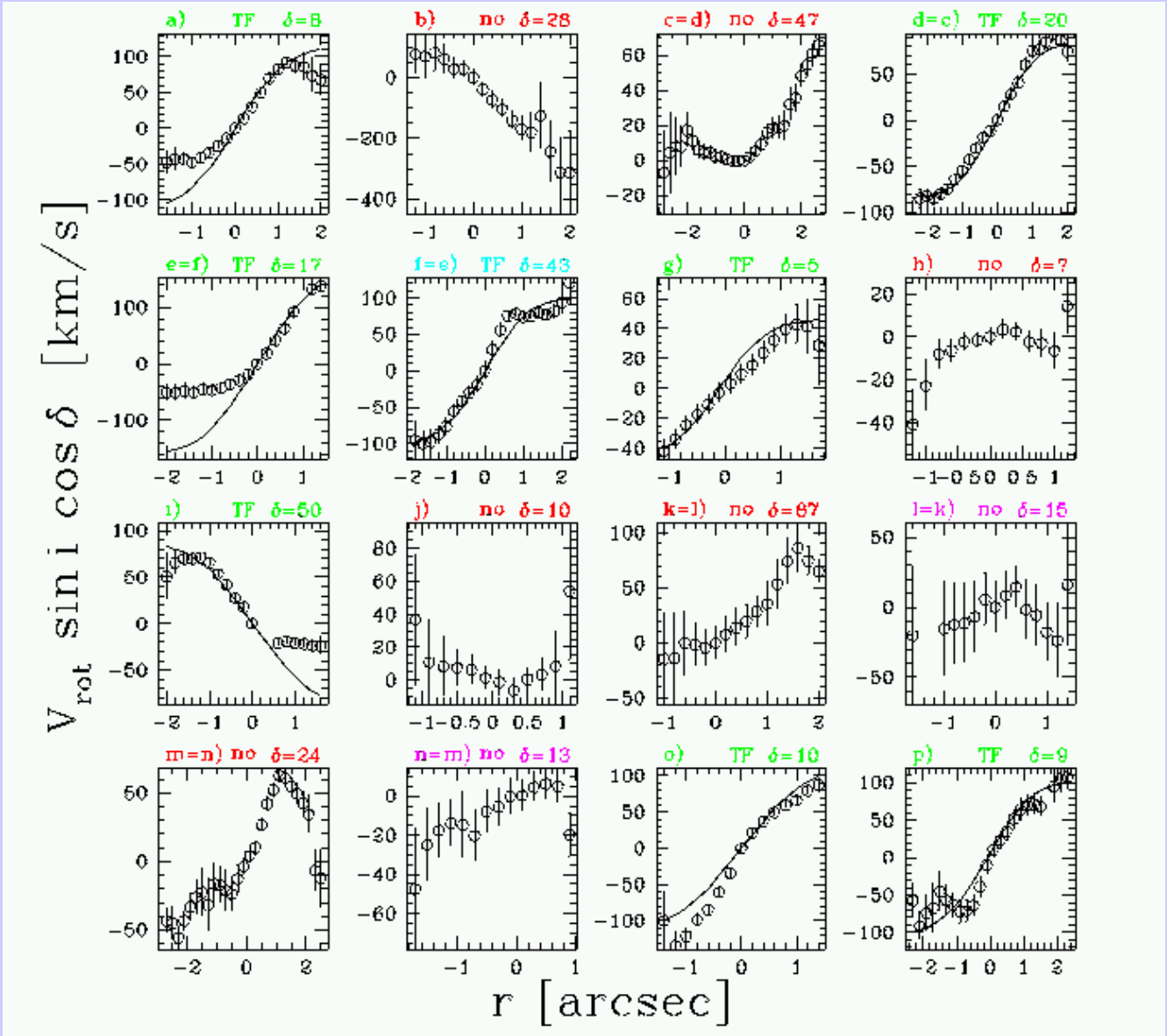
Bamford et al. 2005



Nakamura et al. 2006

Discrepant results for distribution of field & cluster spirals.

Rotation curves (PVDs) of MS1008 cluster spirals at z=0.3



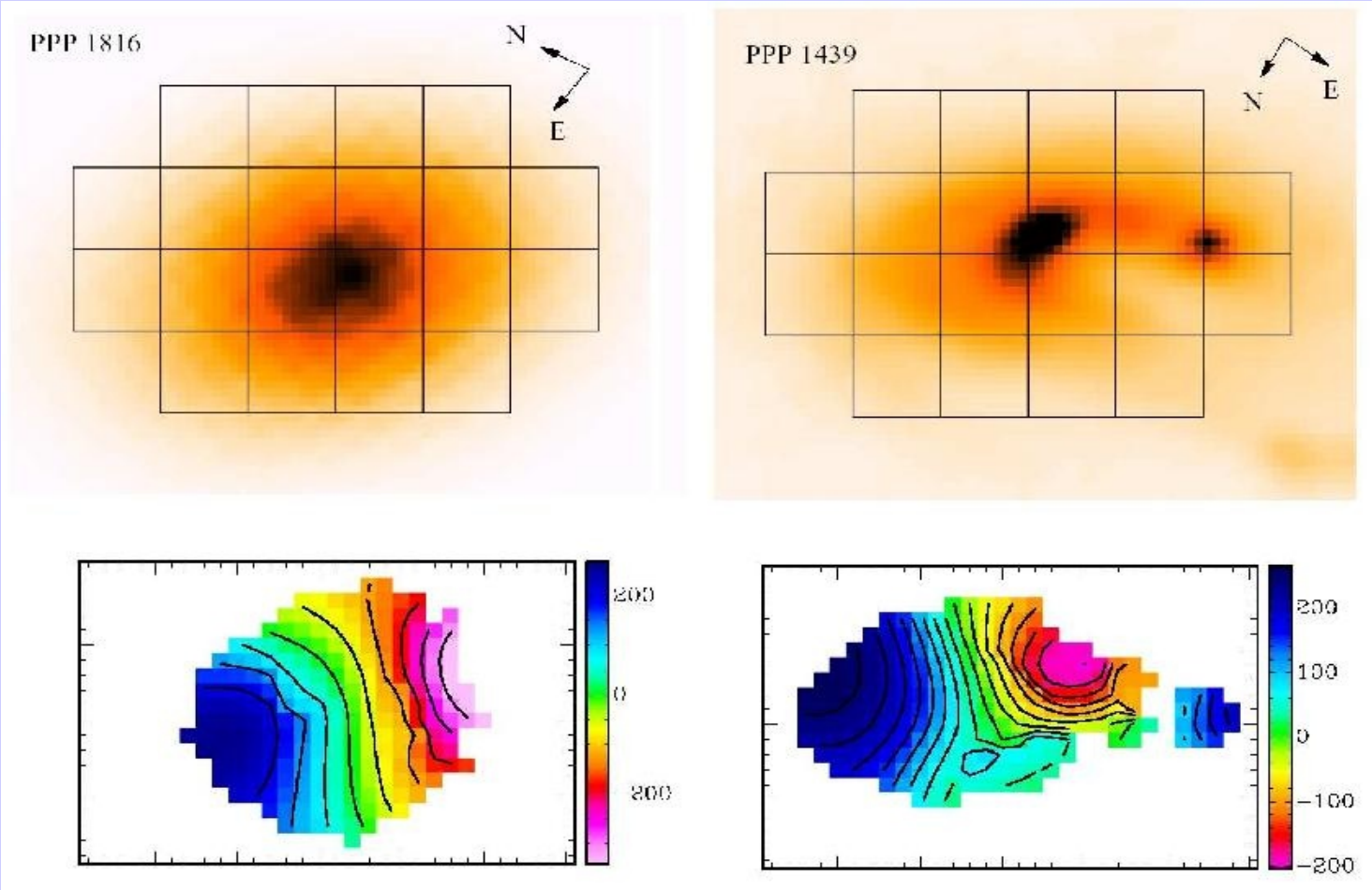
Ziegler et al. 2003,
Jäger et al. 2004

Many cluster spirals have distorted or peculiar kinematics!

Spiral Sample in Distant Clusters

Cluster	**z**	**setups**
MS 1008-12	0.30	2 MOS
MS 2137-23	0.31	2 MXU
Cl 1447+23	0.37	2 MXU
Cl 0303+17	0.42	2 MOS
Cl 0413-65	0.51	2 MOS
MS 0451-03	0.54	1 MXU
Cl 0016+16	0.55	2 MXU

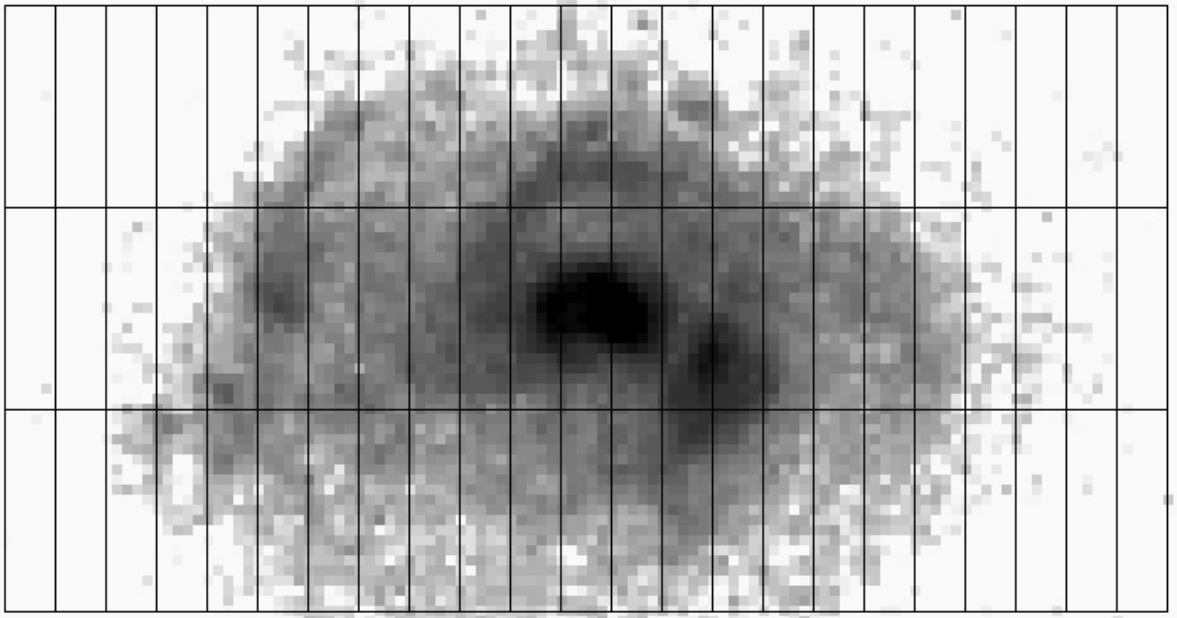
3d-spectroscopy ⇒2d-velocity fields



Vergani et al. 2005

VLT/FLAMES IFU spectroscopy of *z=0.5* spirals

3d-spectroscopy ⇒2d-velocity fields

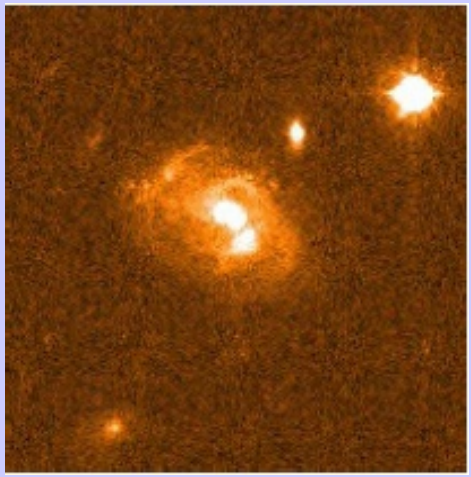


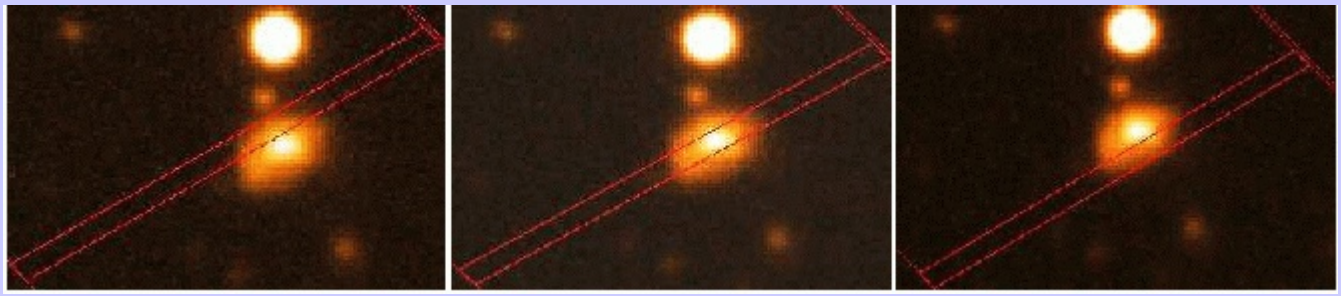
IFU "simulation":

- 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

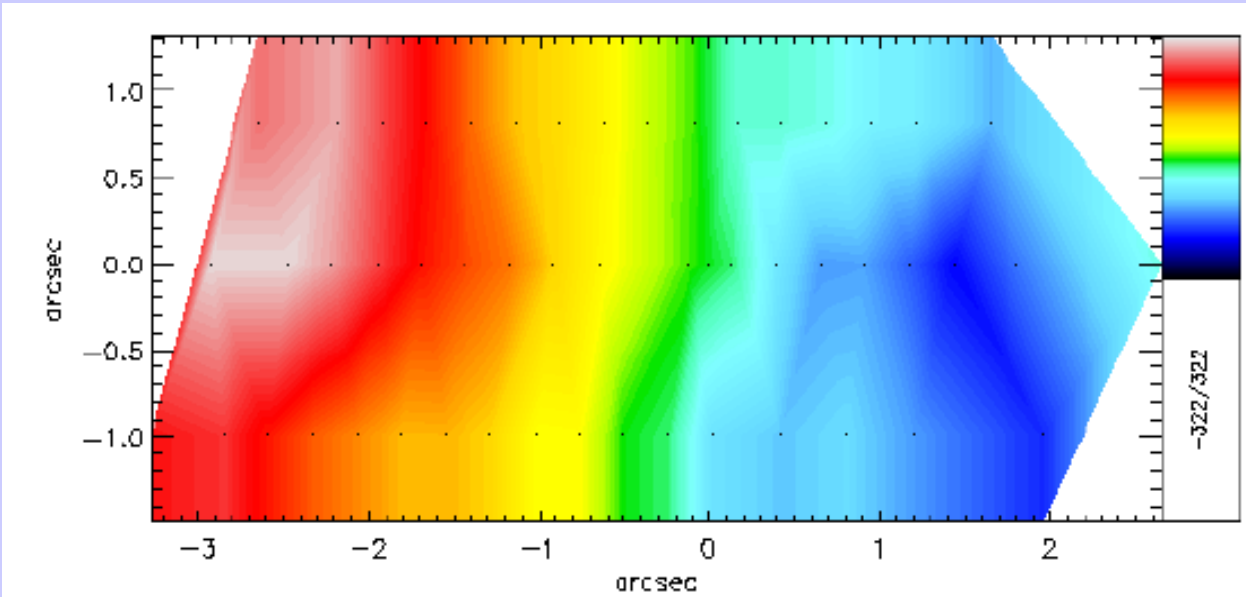
Velocity Field of Regular Spiral Cluster Member

HST/ACS





VLT/FORS



Ziegler et al. 2006
Kutdemir et al. 2007

MS0451-03 Gal05 z=0.532

Kinemetry Analysis (Krajnović et al.)

Assumption: mean velocity of spiral disk galaxy best fitted by ellipses in projection:

$$V(a,\Psi) = V_0 + V_c(a)cos\Psi$$

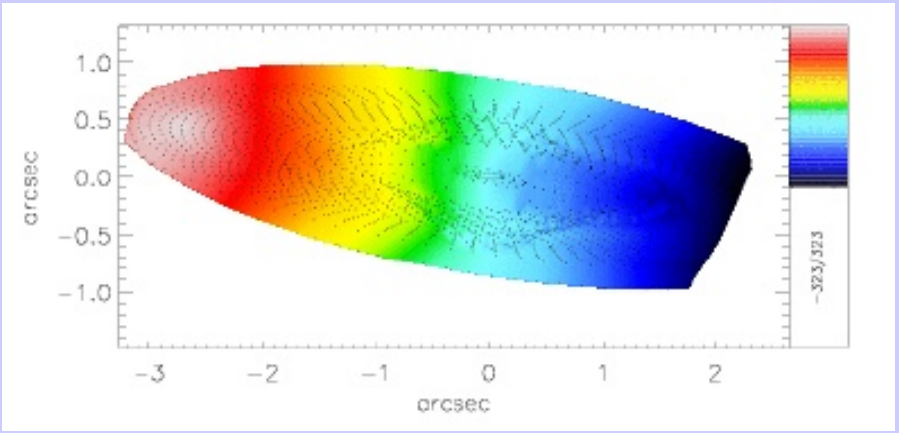
Best fitting ellipses as *f(r)* found for grid of position angles Γ and flattenings *q*.

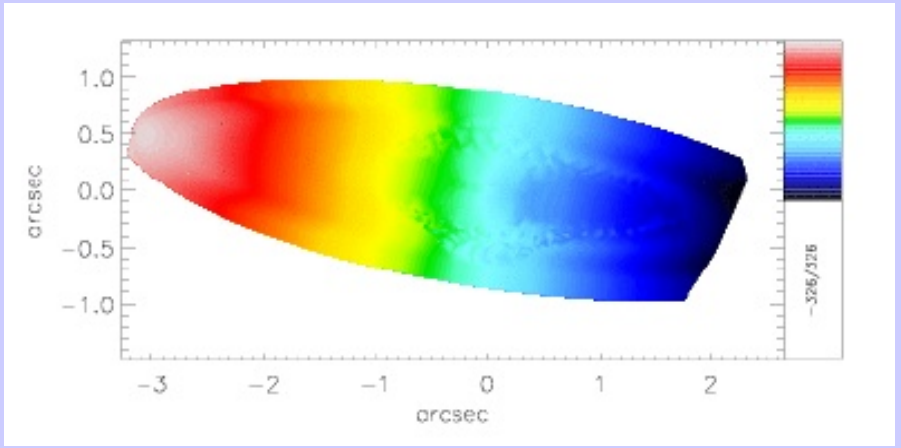
Deviations from simple rotation quantized by harmonic expansion along ellipses:

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

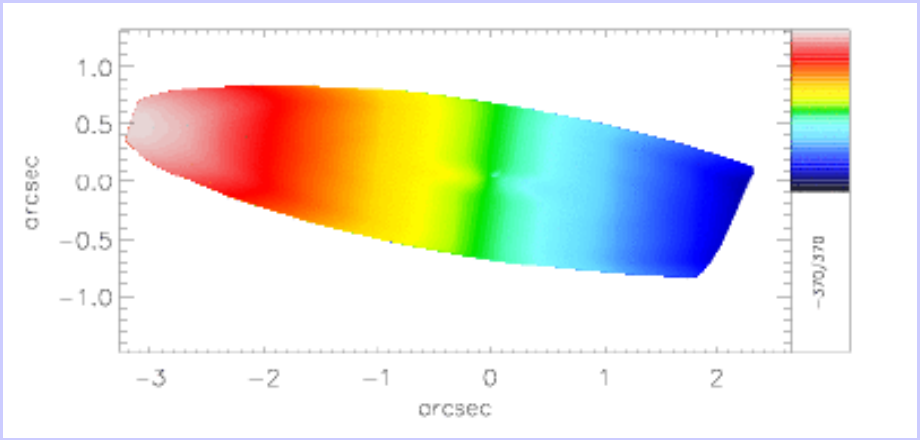
k_1 corresponds to bulk motion in velocity field: «rotation curve»
k_3 describes first correction to simple rotational motion
k_5 represents kinematic separate components in velocity field

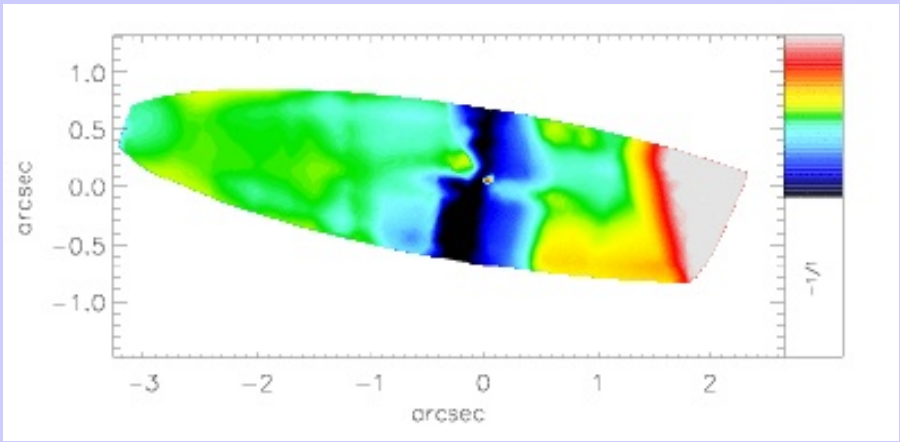
Kinemetry of Regular Spiral Cluster Member





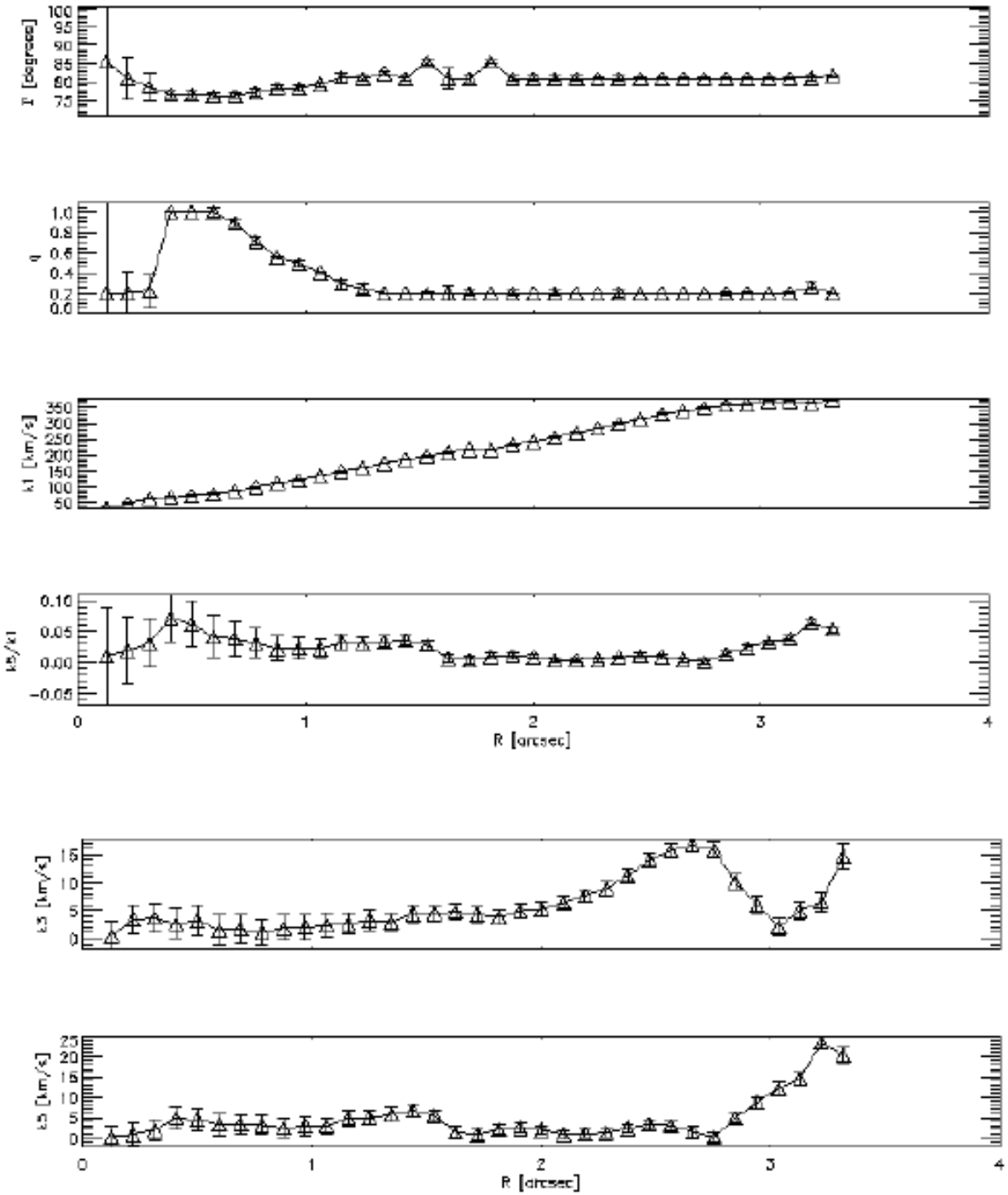
Reconstructed maps with best fitting ellipses using low (left) and higher order Fourier terms.





Simple rotation map fixing position angle and flattening to a global value & its residual map.

MS0451-03 Gal05 z=0.532



Position Angle

Flattening (b/a)

Bulk Motion

Deviation from simple rotation

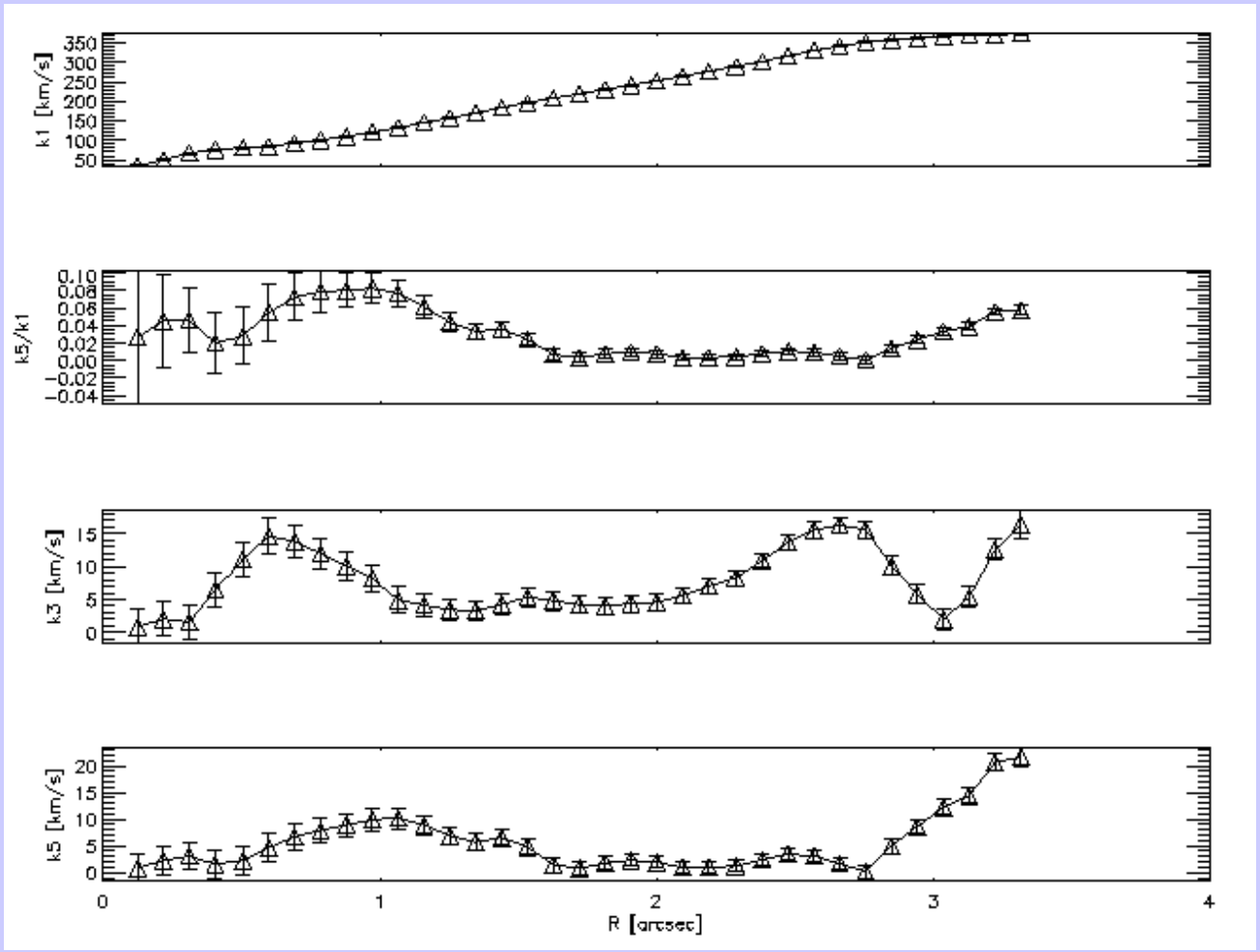
Separate kinematic components

Position angle

& flattening

fixed to

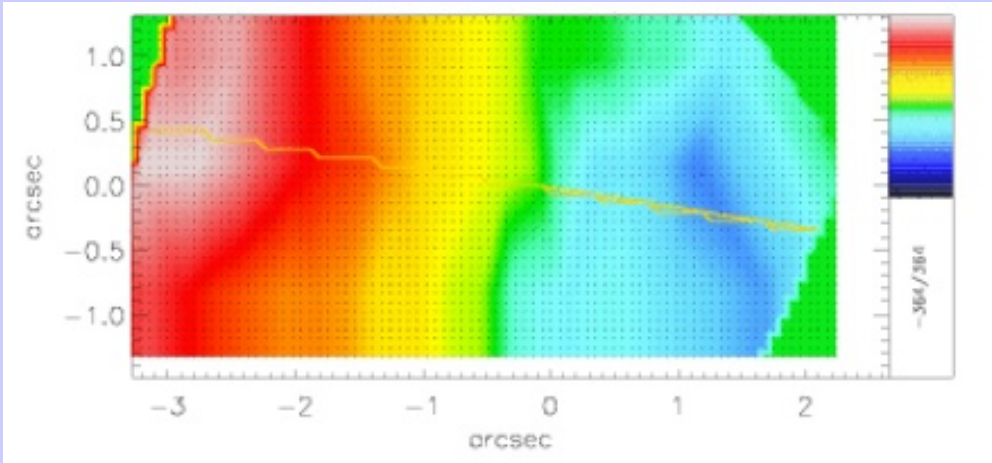
global value.



Bulk Motion

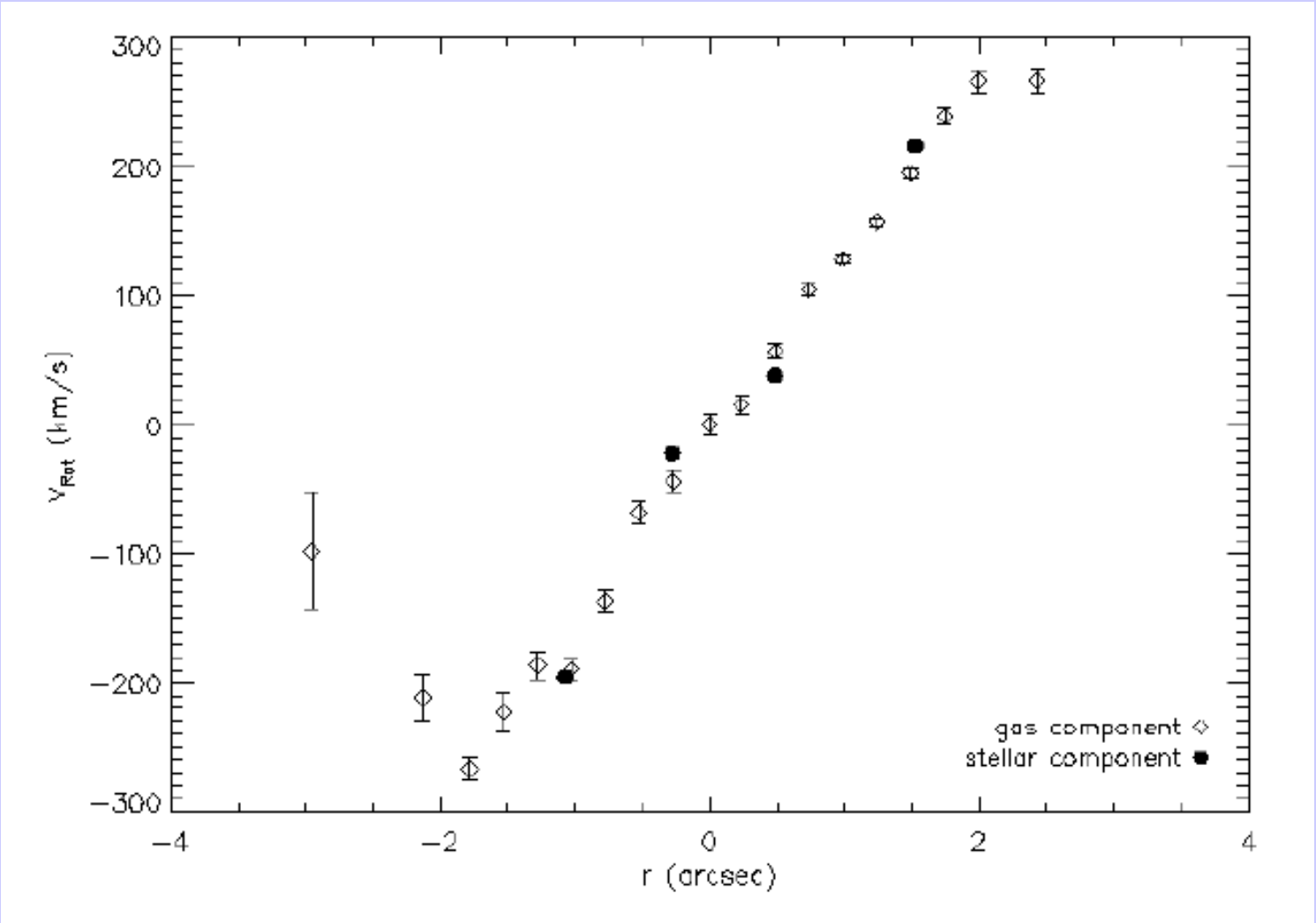
Deviation from simple rotation

Separate kinematic components



Kinematic axis

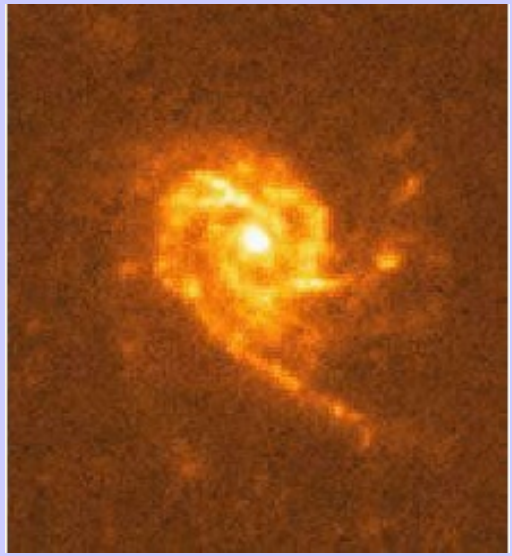
Stellar & Gas Rotation Curve of Spiral Cluster Member

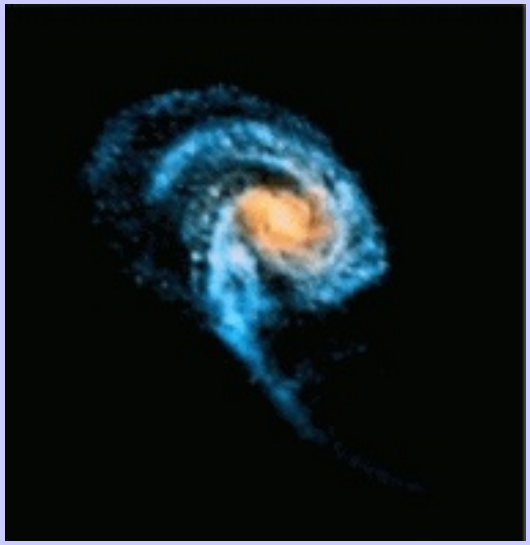


Ziegler et al. 2006
Kutdemir et al. 2007

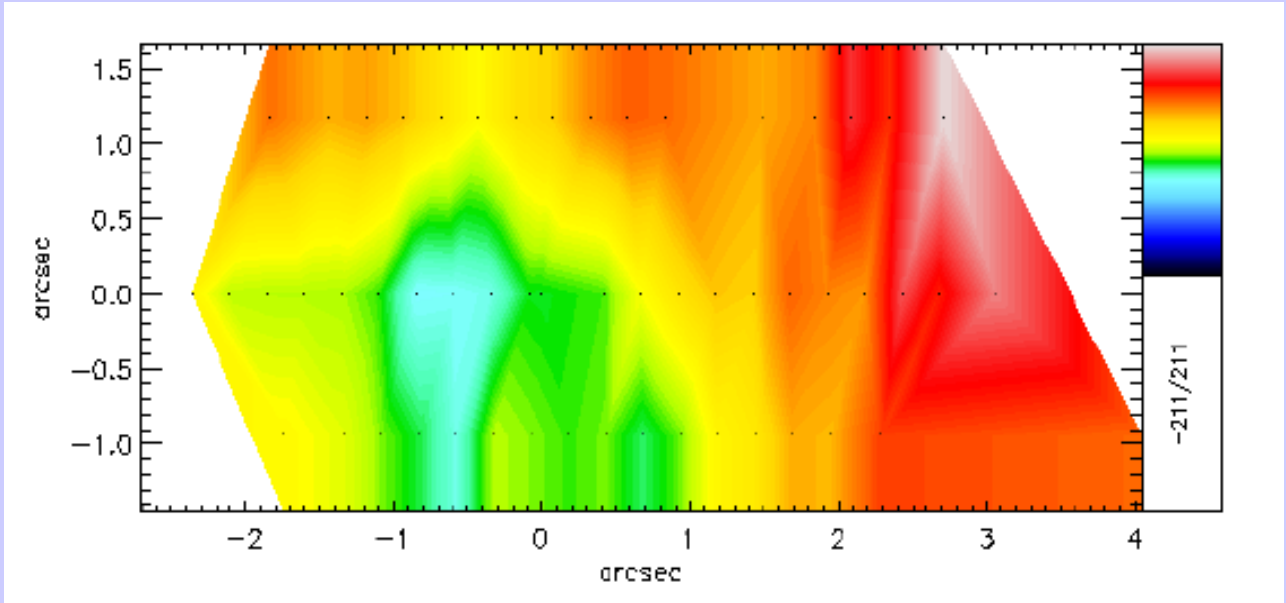
MS0451-03 Gal05 z=0.532

Velocity Field of Peculiar Spiral Cluster Member



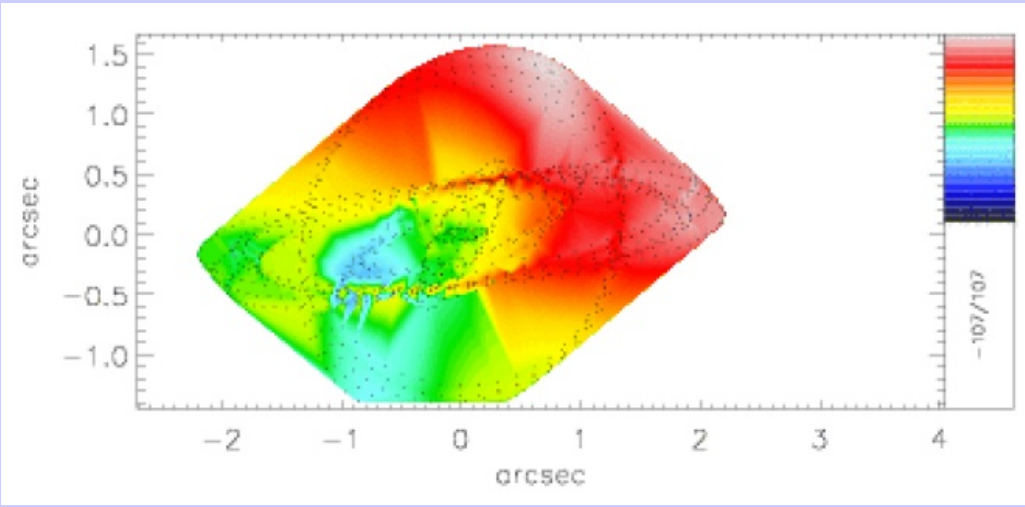


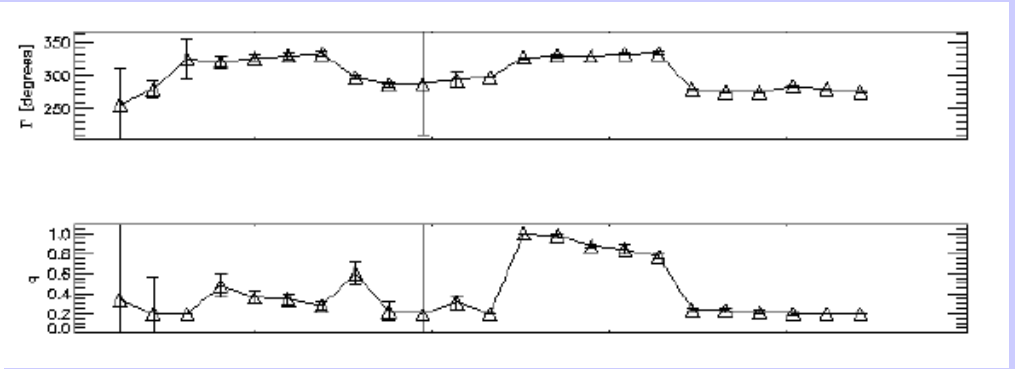
Simulation of minor merger
(8:1 mass ratio)
seen after second passage

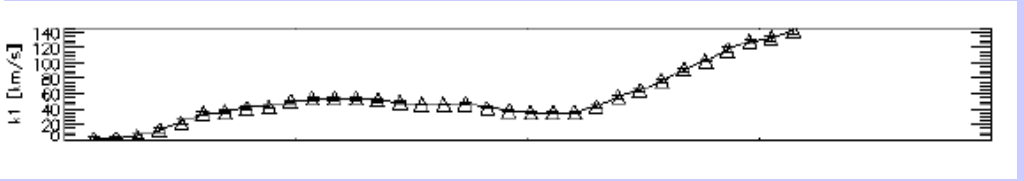


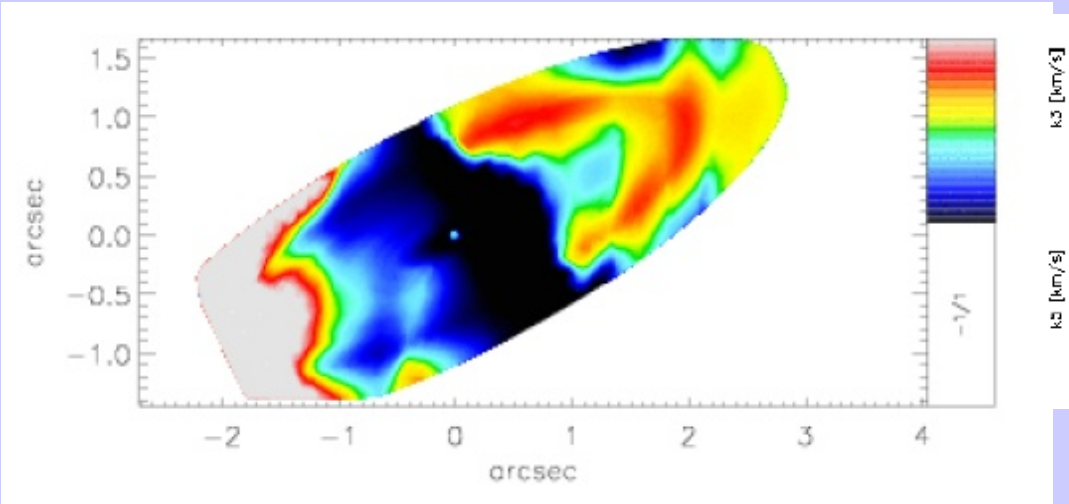
MS0451-03 Gal06 z=0.528

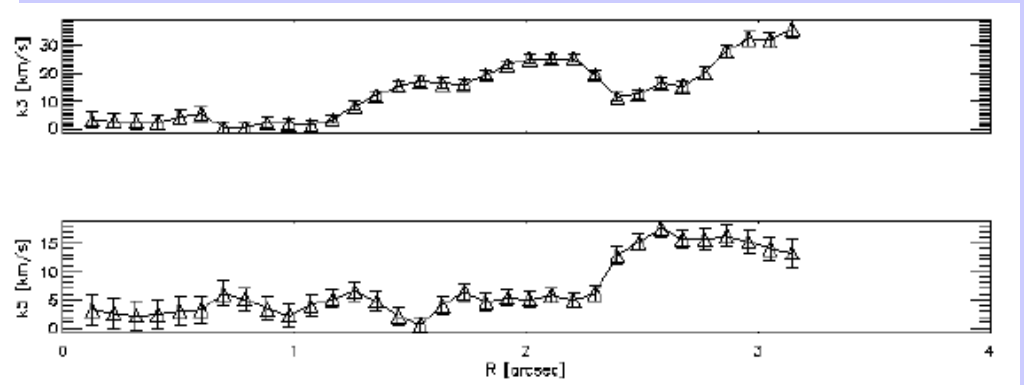
Velocity Field of Peculiar Spiral Cluster Member





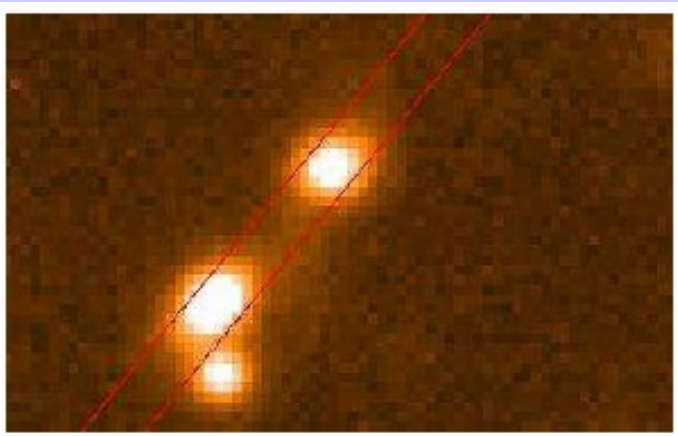


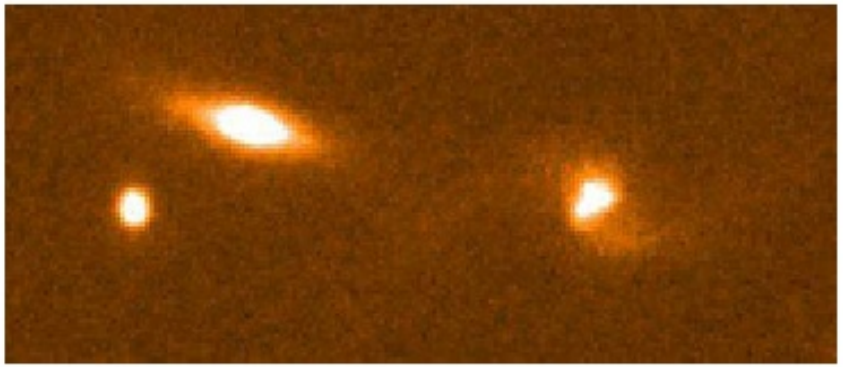


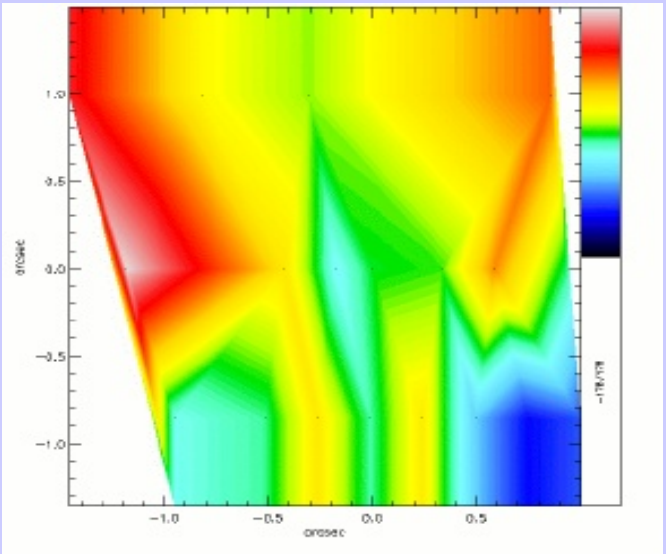


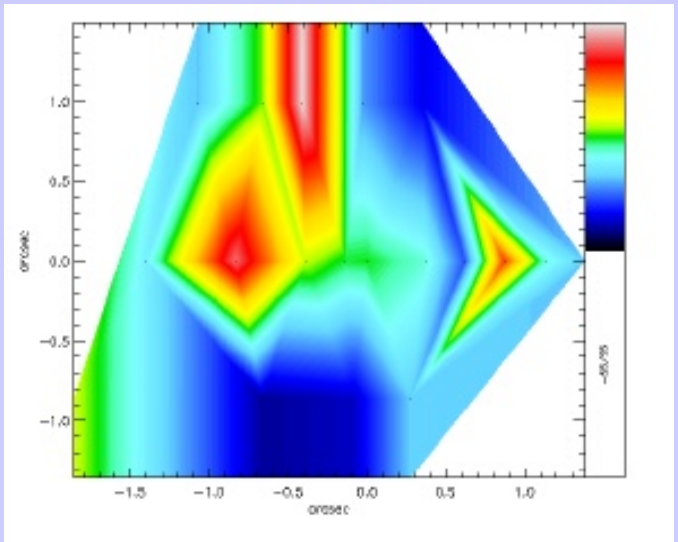
MS0451-03 Gal06 z=0.528

Spiral member w. regular stellar structure but complex VF



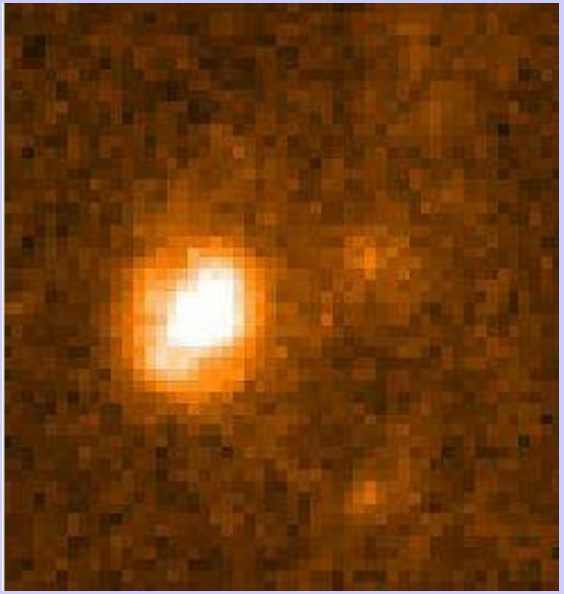


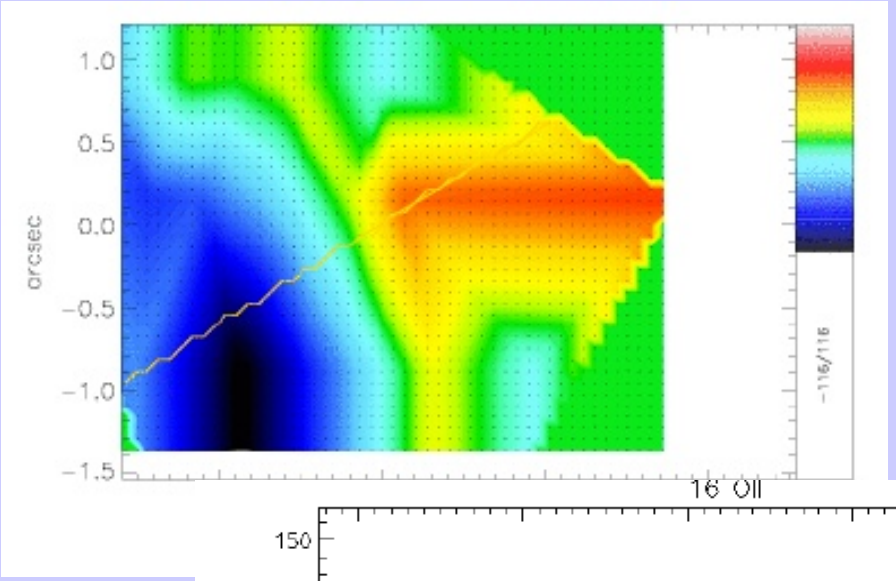


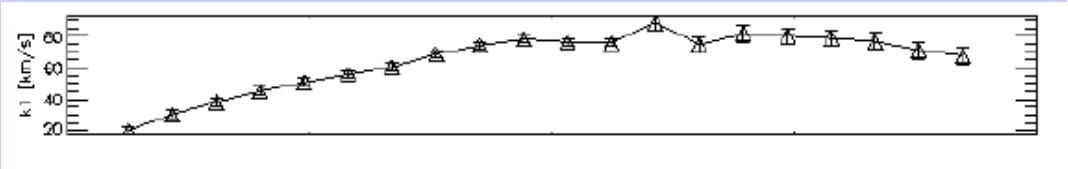


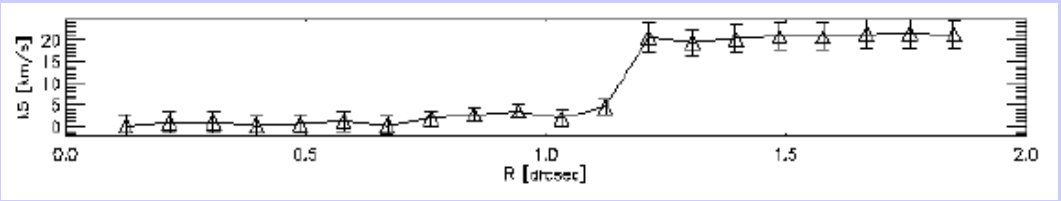
MS0451-03 Gal09 z=0.53

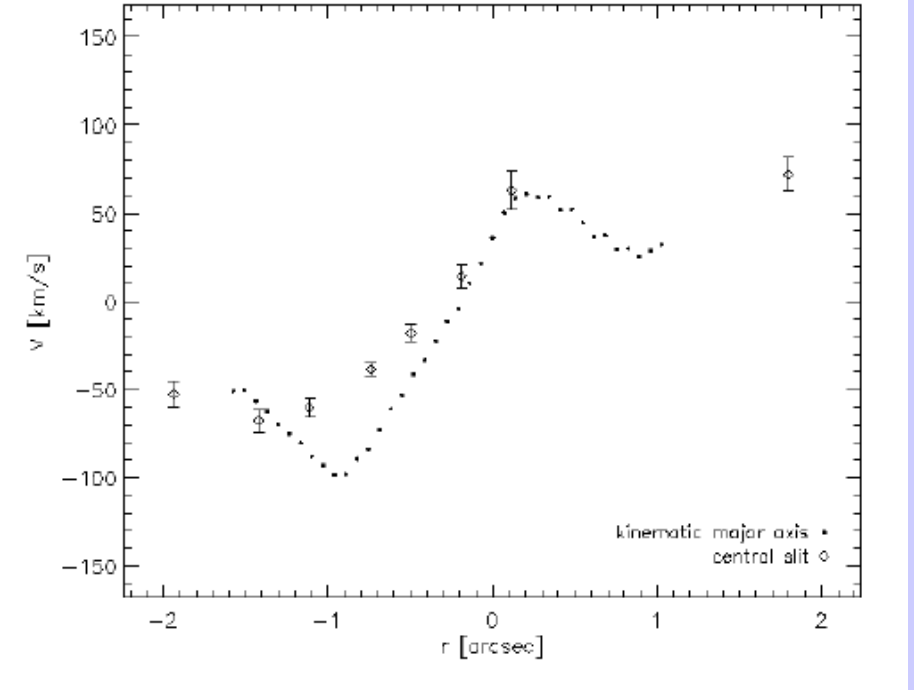
Spiral member w. declining rotation curve





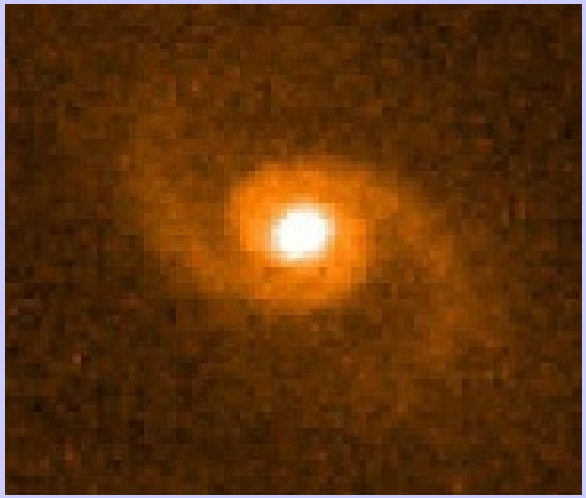


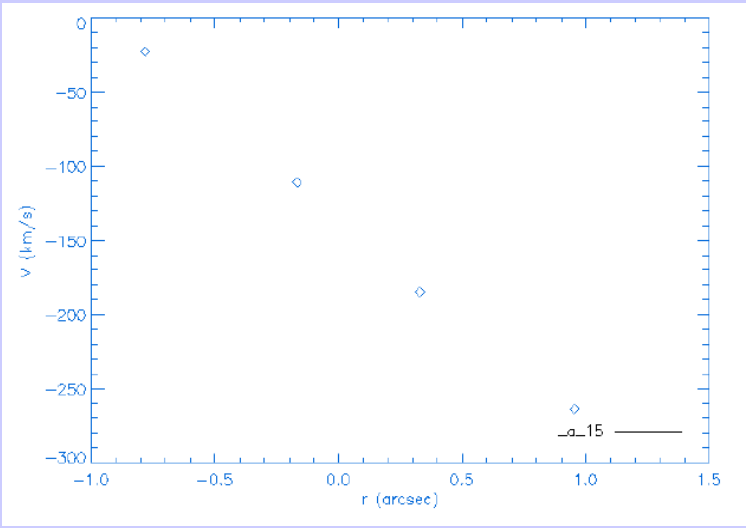




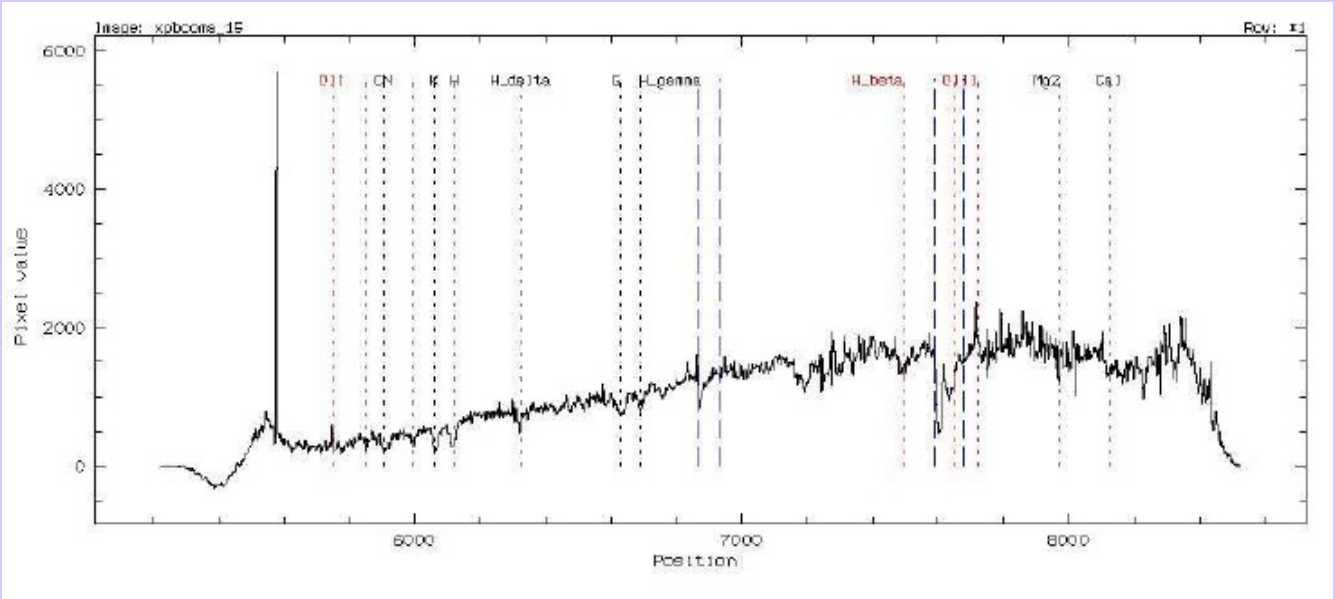
MS0451-03 Gal16 z=0.53

Spiral member without emission lines



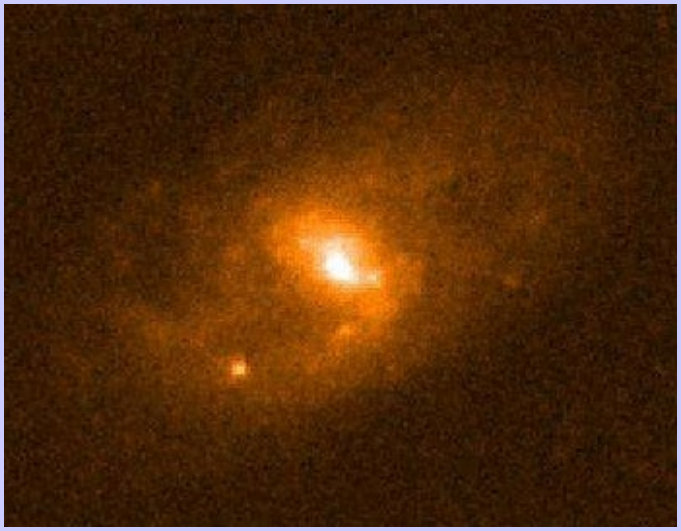


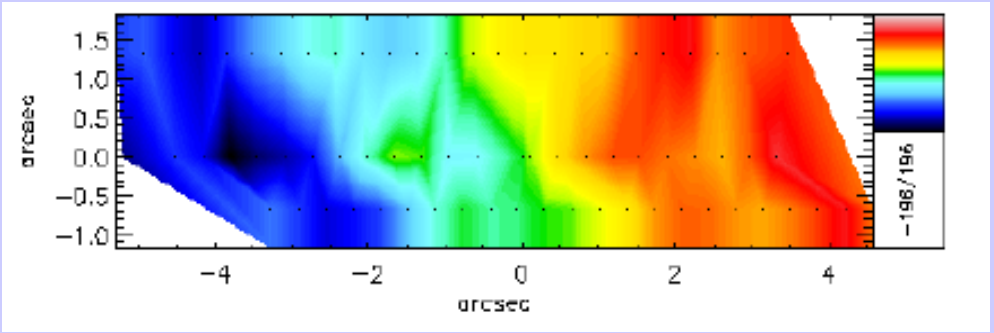
stellar rotation curve

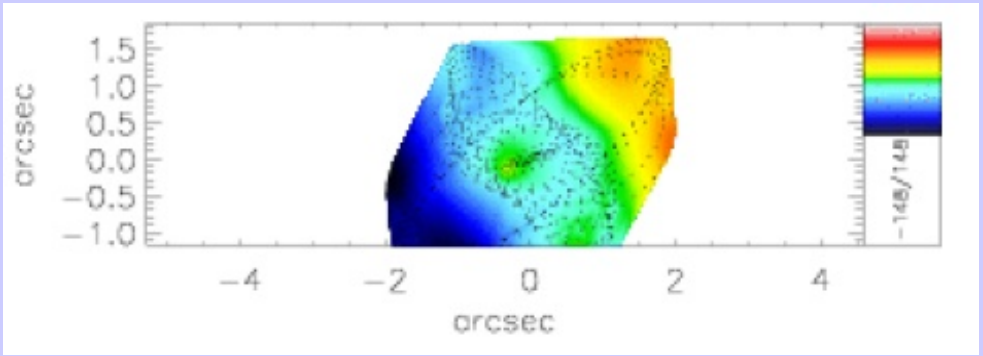


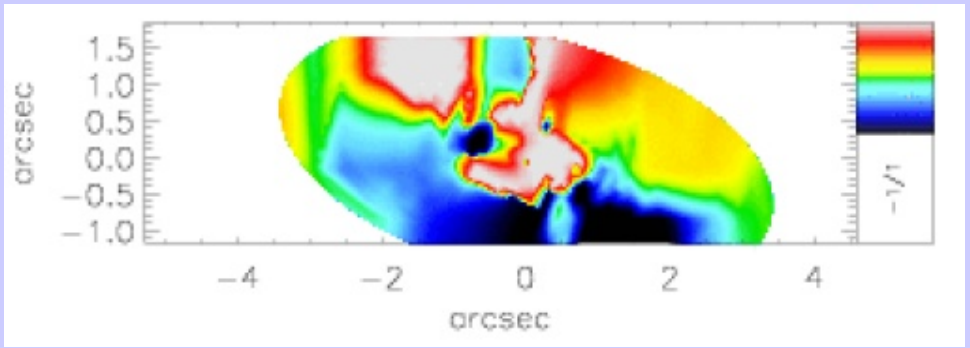
MS0451-03 Gal15 z=0.53

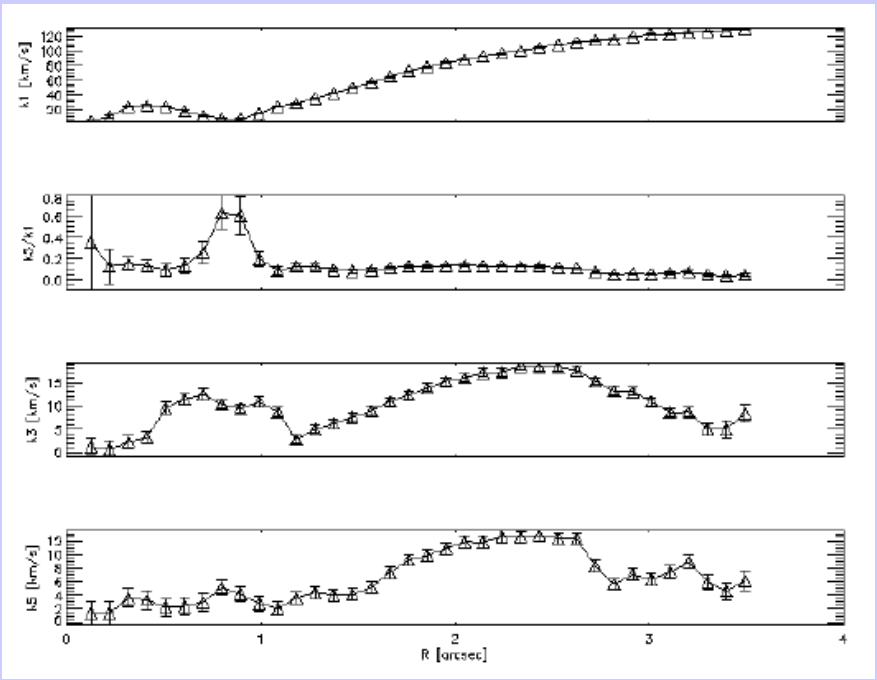
Field spiral w. counter rotating core





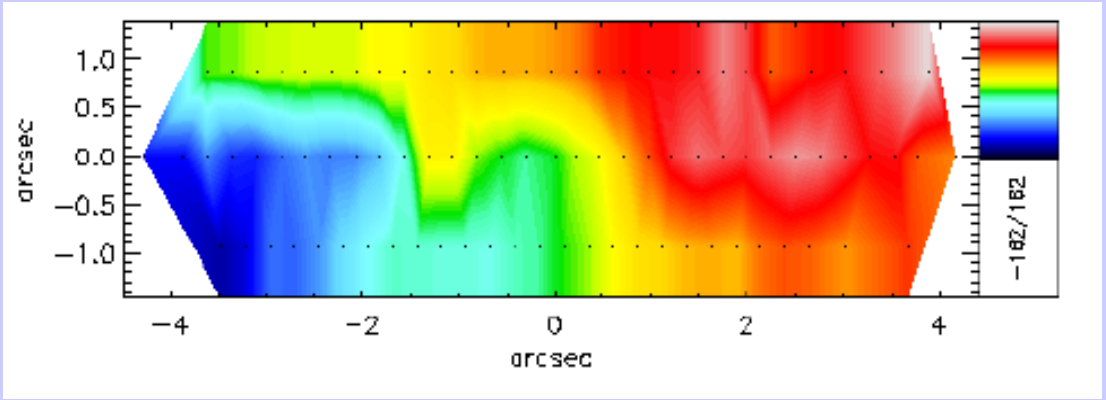


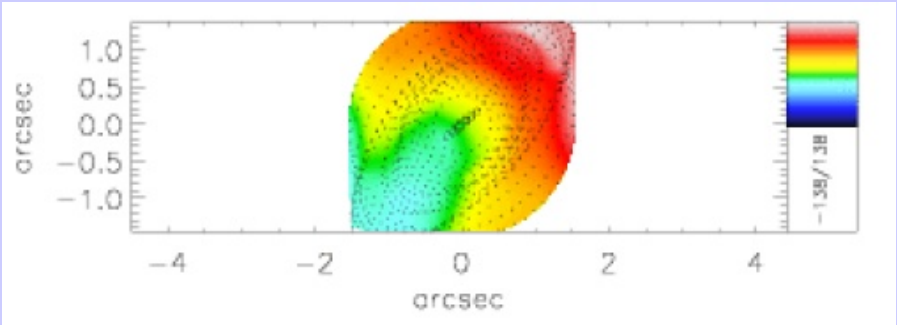


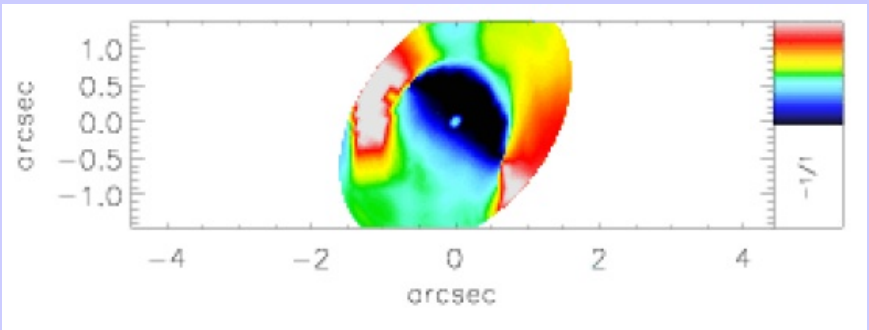


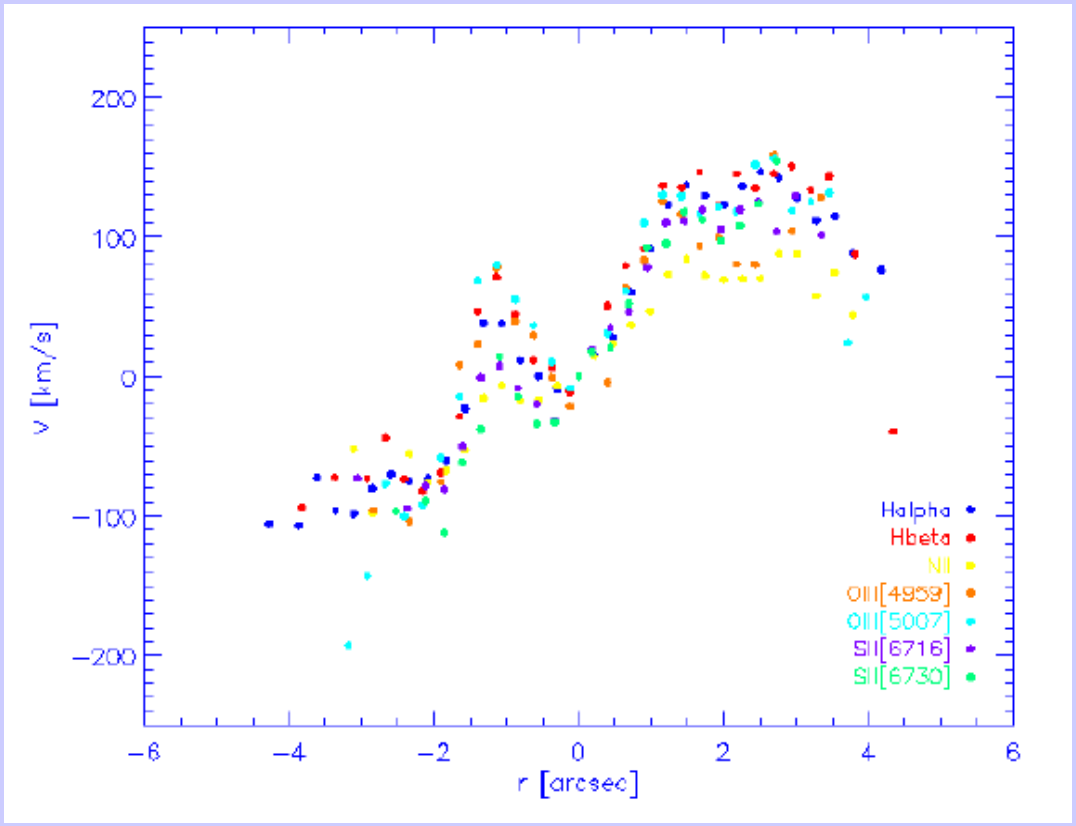
Gal20 z=0.1

Field spiral



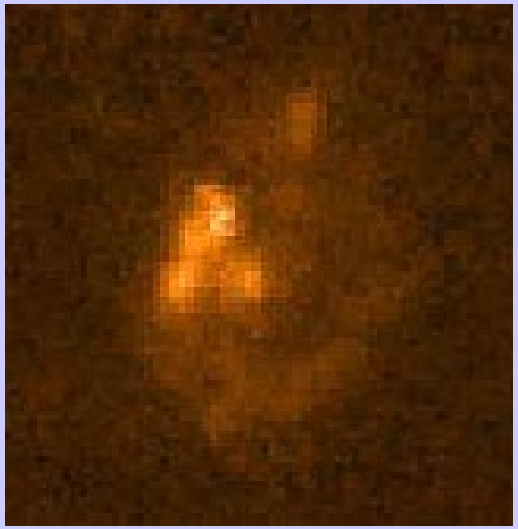


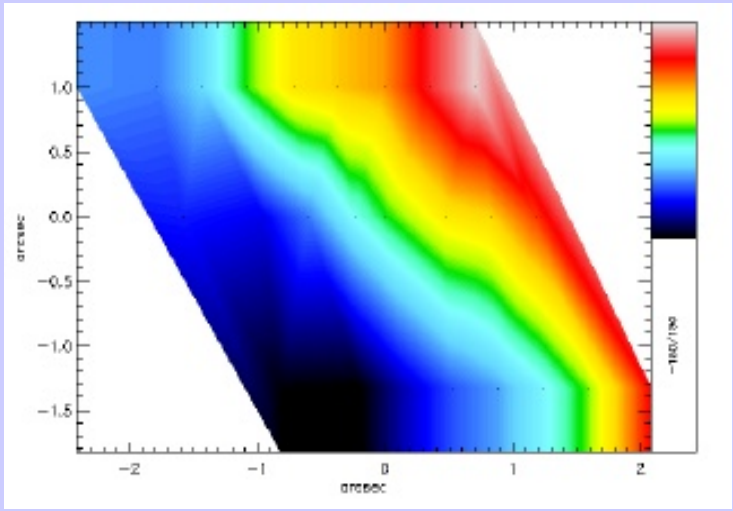


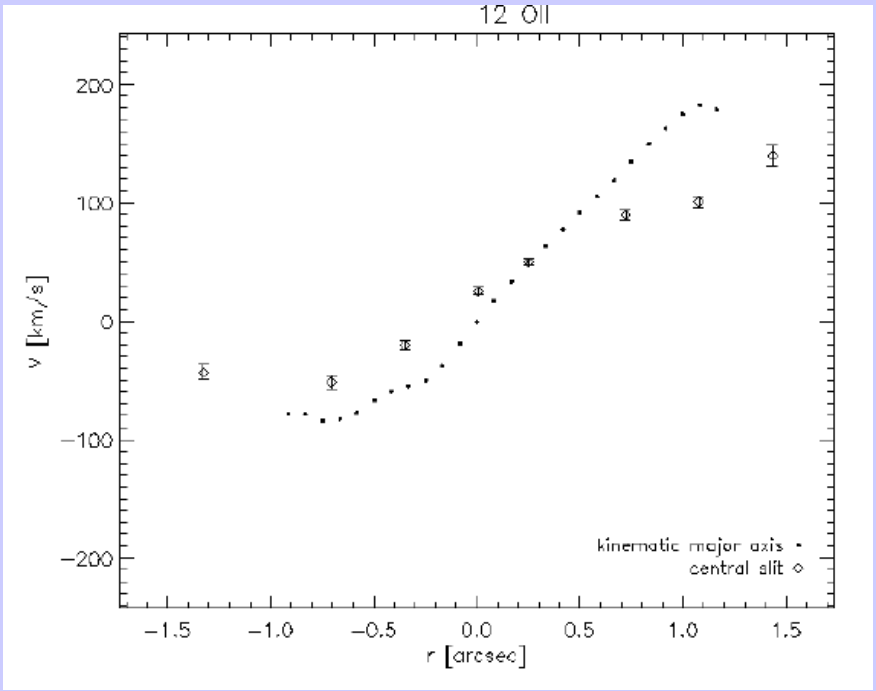


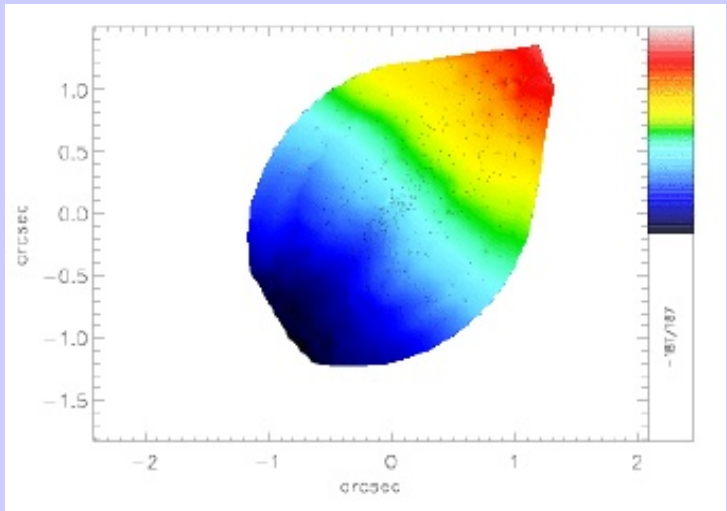
Gal02 z=0.15

Field spiral w. complex stellar structure but regular VF



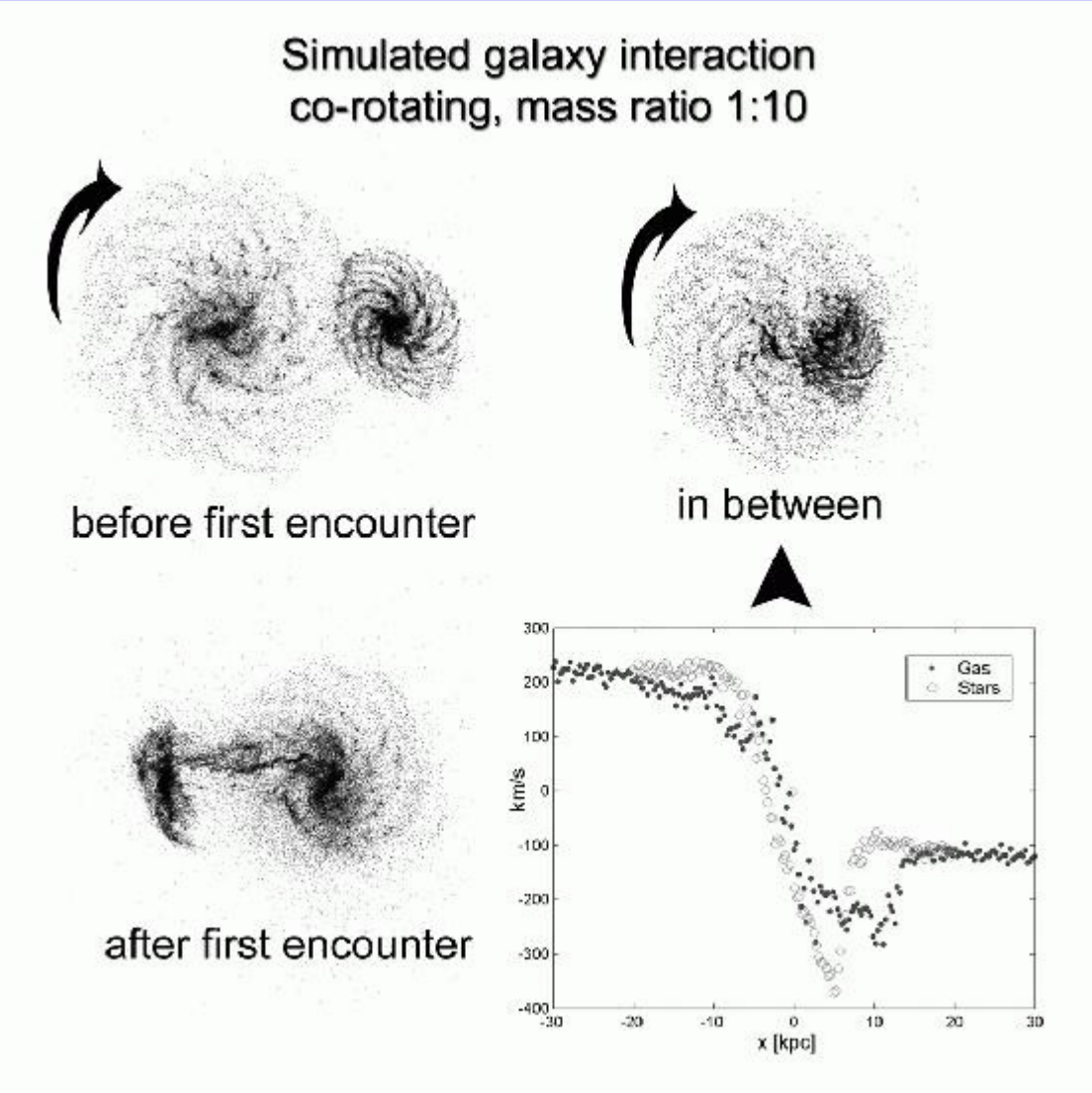






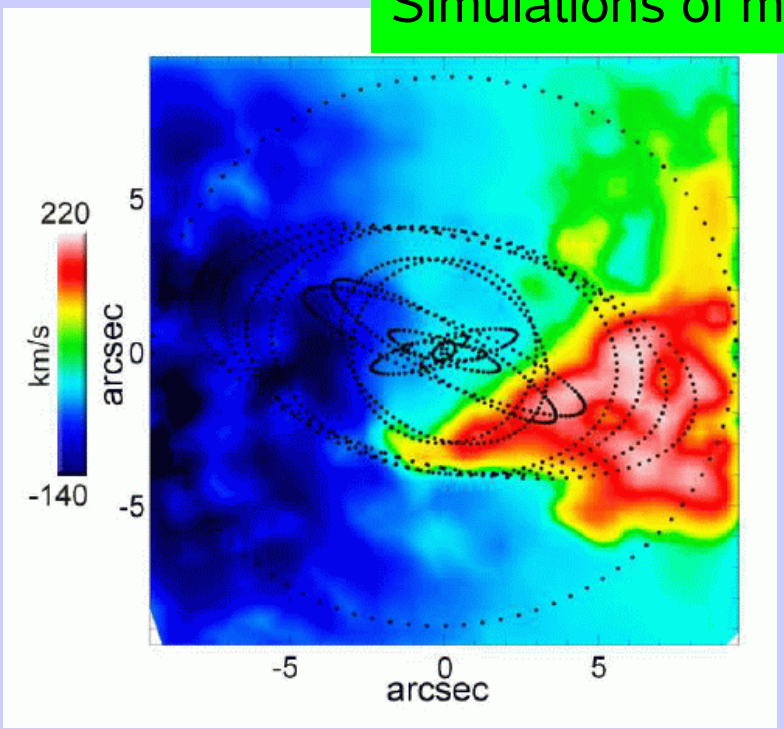
Gal12 z=0.91

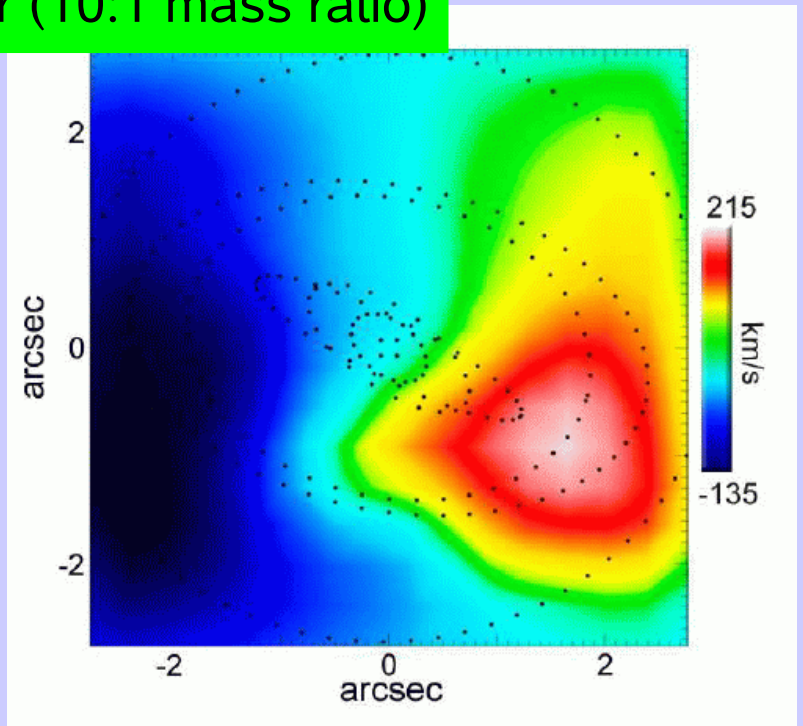
N-body/SPH simulations of galaxy collisions

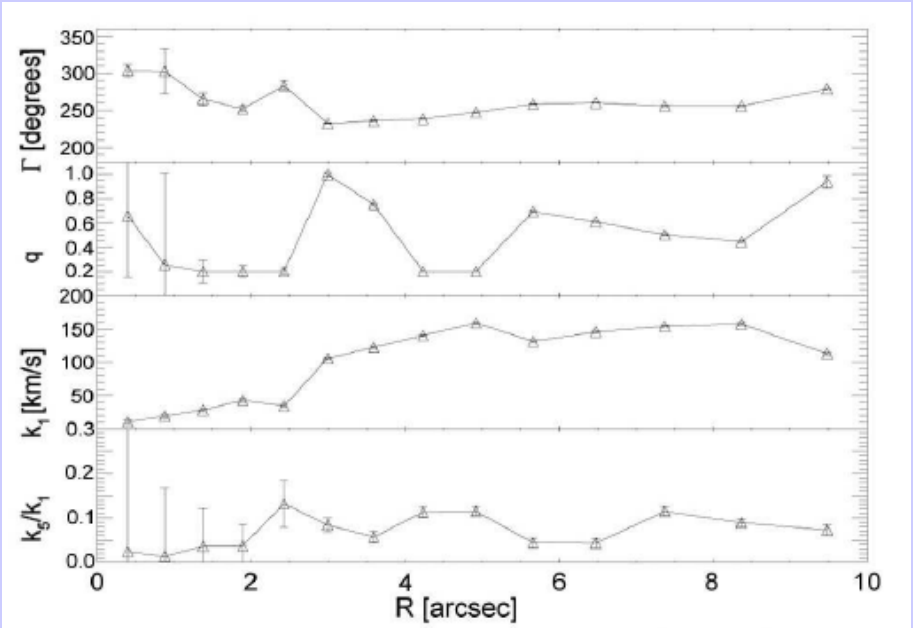


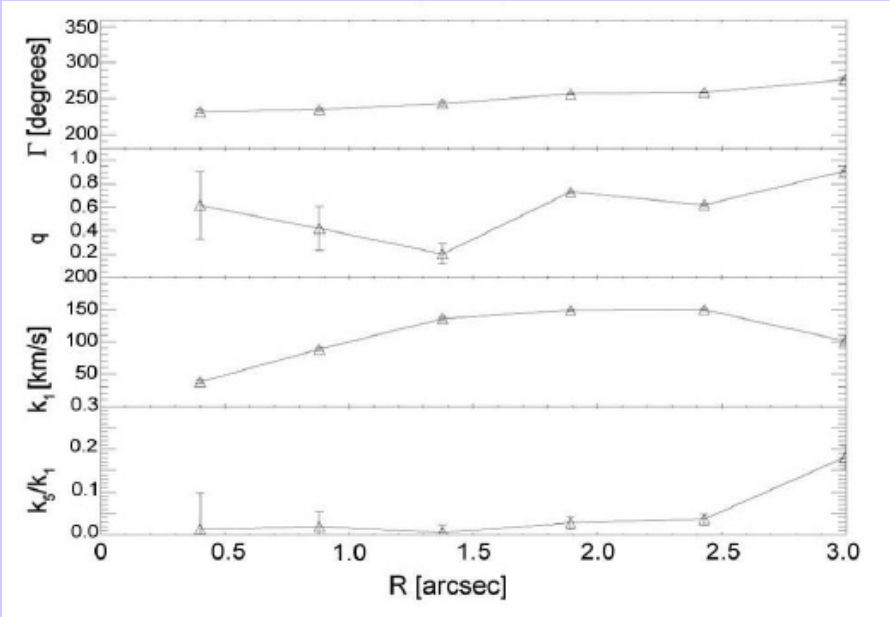
Kapferer et al. 2006,
Kronberger et al. 2006
Kronberger et al. 2007

Simulations of minor merger (10:1 mass ratio)







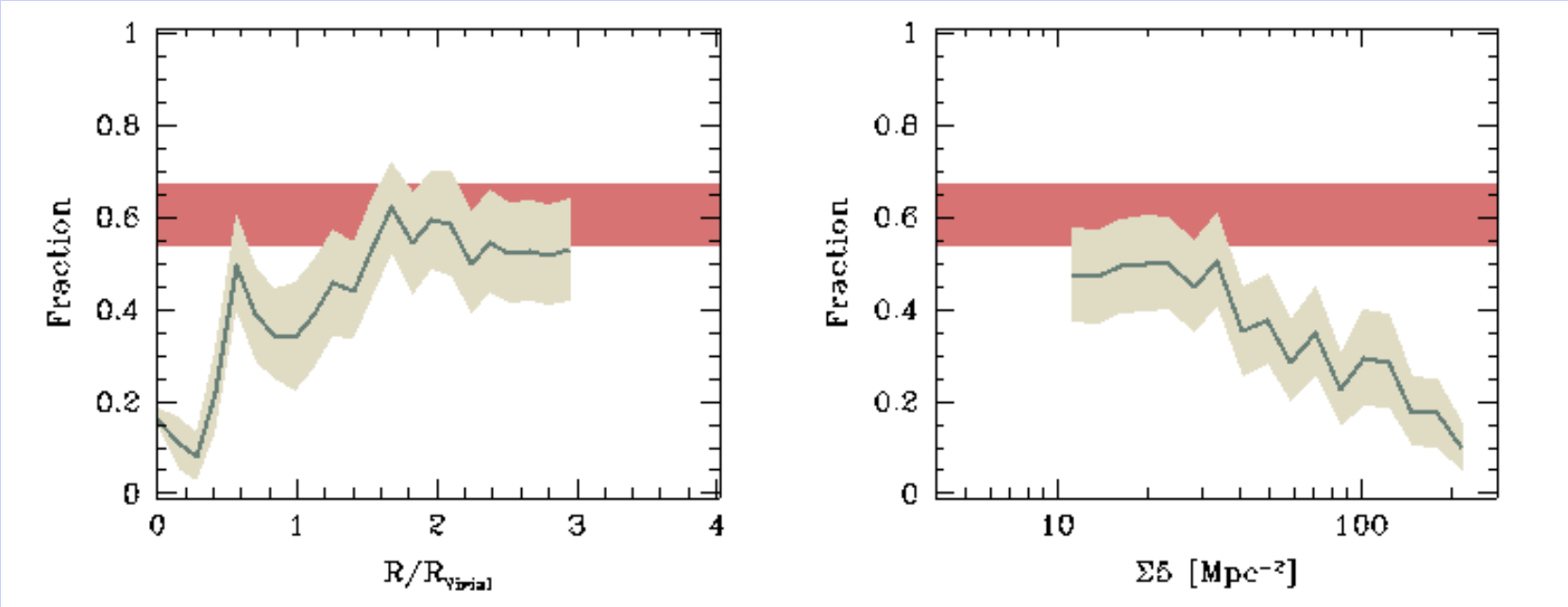


z=0.1

Kronberger et al. 2007

z=0.5

Star formation activity in distant cluster galaxies



Verdugo et al. 2007

Fraction of SF galaxies as f(distance) & f(density).
834 galaxy spectra out to 3-4 virial radii in 6 *z~0.2* clusters.

Summary

- TF analysis of regular symmetric spiral galaxies:
  similar distribution of field & cluster galaxies (?)
- Many spiral cluster members peculiar or distorted

➔ 3D spectroscopy to probe 2D velocity field

- mismatch between photometric & kinematic axes/centers
- distortions indicating tidal interaction, minor merger etc.
- regular stellar structure but distorted gas velocity field (*vv*)

Look at poster by
Kutdemir, Ziegler, Peletier
for more information!