PHYSICAL PROPERTIES OF THE X-RAY GAS AS A DYNAMICAL DIAGNOSIS FOR GALAXY CLUSTERS

Florence DURRET

Institut d’Astrophysique de Paris and
Sorbonne Université

COLLABORATORS

Tatiana Laganá
Unversidade Cruzeiro do Sul, São Paulo, Brazil

Paulo Lopes,
Observatorio do Valongo,
Rio de Janeiro, Brazil

Laganá, Durret & Lopes 2019, MNRAS 484, 2807

SUBSTRUCTURES IN CLUSTERS

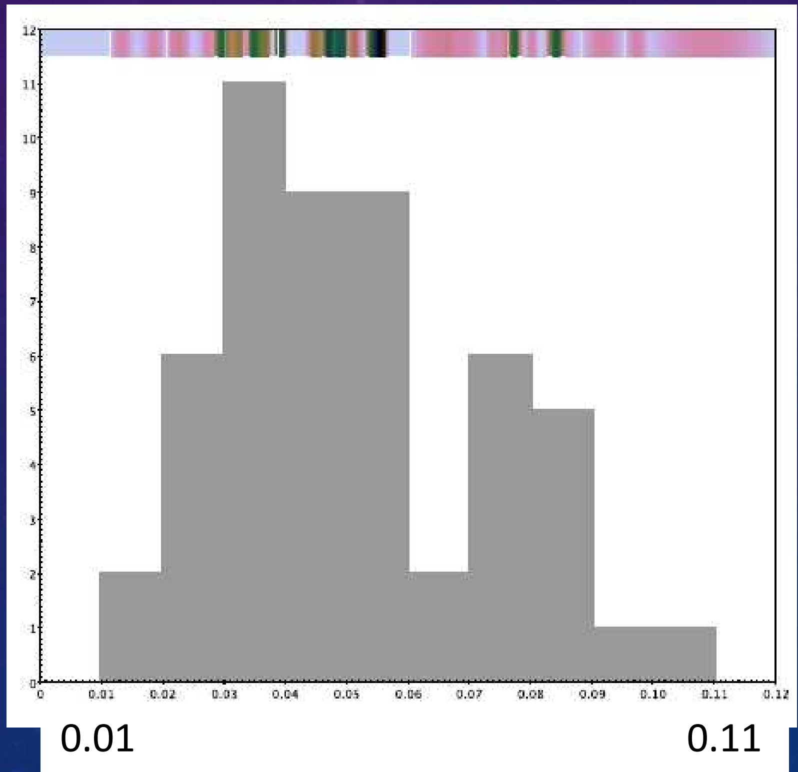
- Clusters are formed through the merging of smaller structures
- Simulations show that substructures should be common
- The degree of substructure give information on the cluster history, and so do various maps of the X-ray gas
- Three regimes: cool-core clusters (CC), non cool-core clusters (NCC) and an intermediate category
- The fraction of CC clusters depends on the detection method (X-rays, SZ etc.), as shown e.g. by Lopes+18

HOW CAN THE DYNAMICAL STATE OF A CLUSTER BE ESTIMATED?

- Offset between the X-ray centroid) and the brightest cluster galaxy (BCG)
- Magnitude gap between the two brightest galaxies
- Degree of substructures (depends on detection method)
- **X-ray maps of the emissivity, temperature, pseudo-entropy, pseudo-pressure and metallicity**

OUR SAMPLE

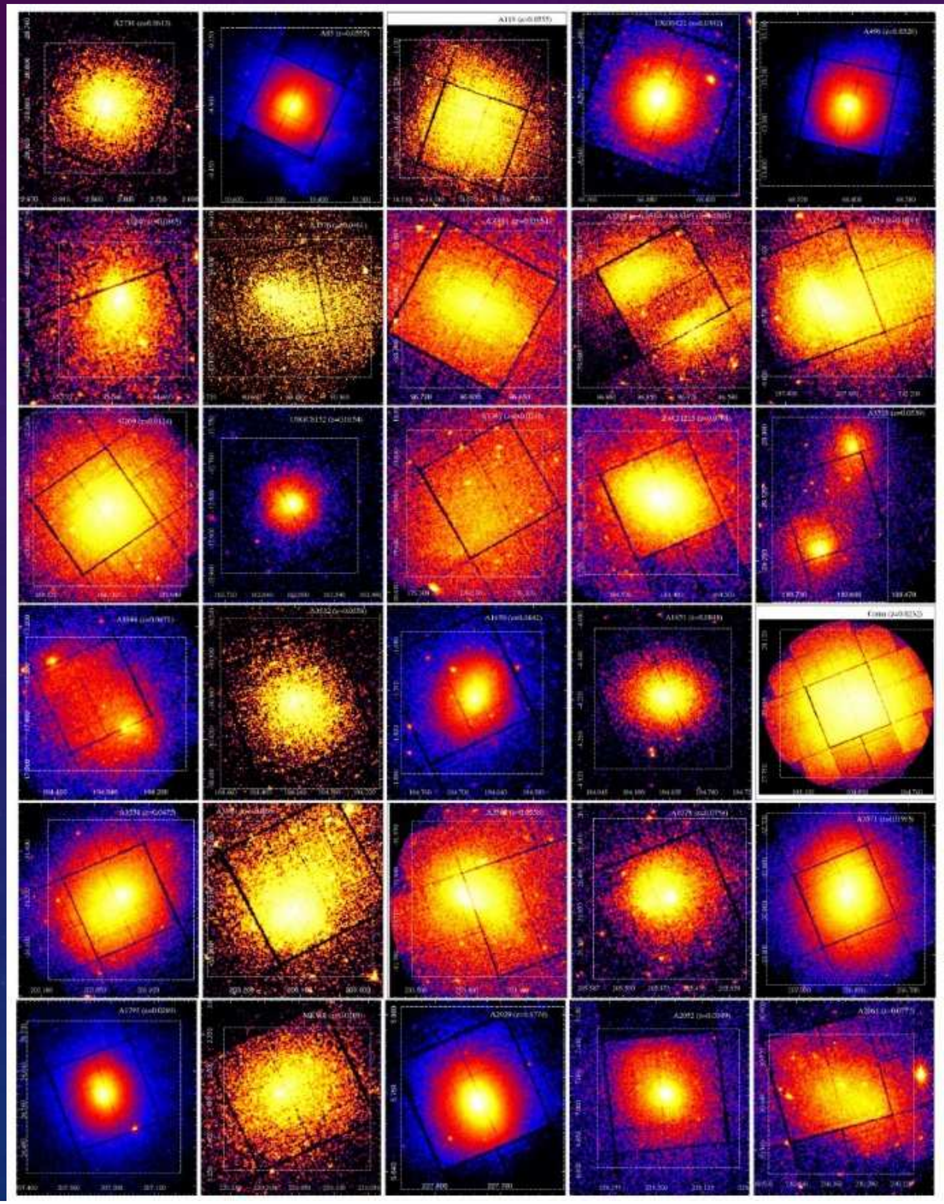
53 nearby clusters (z<0.11) from the Lopes et al. (2018) sample with « good » XMM-Newton data



METHOD

- Spectra extracted in the [0.7 – 7.0] keV band after usual reduction
- Fits with MEKAL XSPEC with fixed redshift and ≥15 counts per spectral bin give:
  - temperature kT
  - metallicity Z
  - pseudo-entropy $S = kT / I^{1/3}$ (I = intensity)
  - pseudo-pressure $p = kT \times I^{1/2}$
- 2D spectral maps in grid of 512 x 512 XMM-Newton EPIC pixels with minimum count number of 1500 after background subtraction, binned by 3x3 or 5x5 if necessary

SOME EMISSIVITY MAPS



- **Temperature**:

➢ Expected to be colder in the center for cool core clusters

- **Metallicity**:

➢ Peaks at the center of clusters

➢ Gives information on previous star formation

- **Entropy**:

➢ Expected to be symmetrical around the center and to increase towards the cluster outskirts

➢ Low entropy gas can be displaced by instabilities (cold fronts) or by gas stripping

➢ High entropy can also be due to local heating (AGN)

- **Pressure**:

➢ Sensitive to gravitational and non-gravitational processes

➢ Fluctuations trace departure from local equilibrium (shocks, pressure waves)

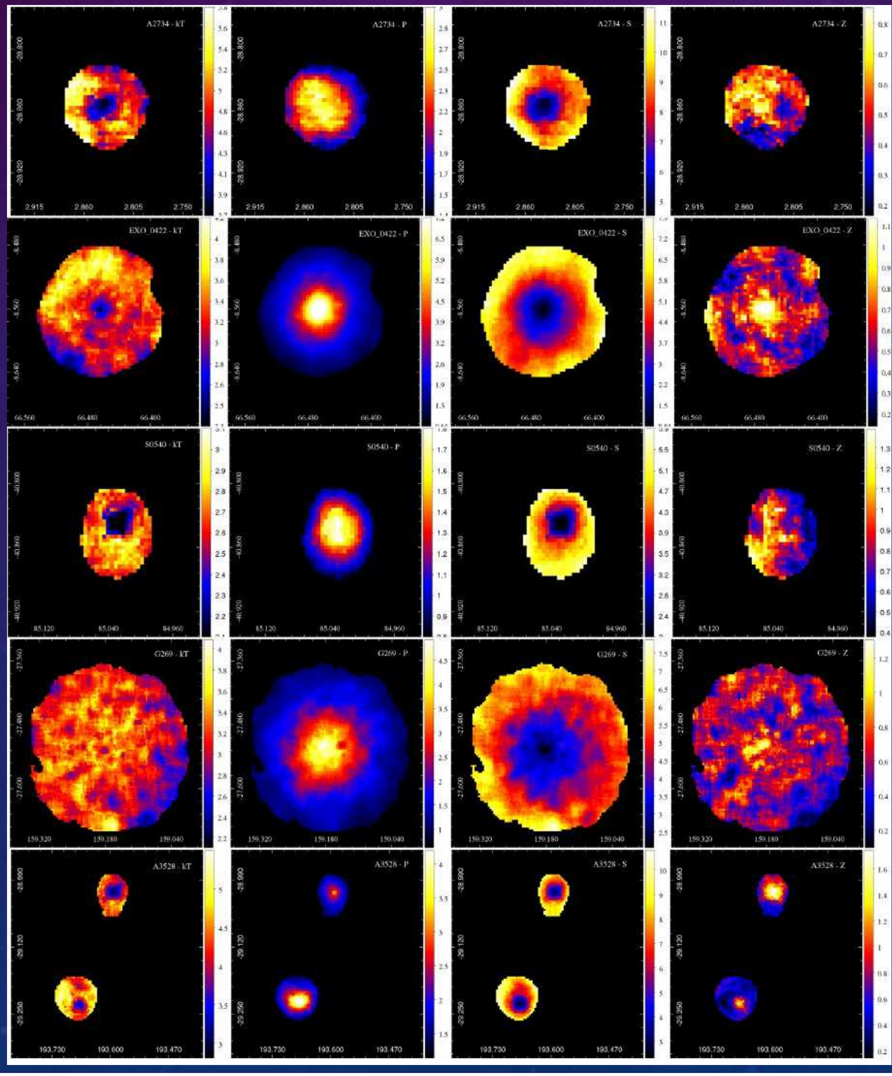
FOUR CATEGORIES OF CLUSTERS

- Cool core relaxed systems
- Cool core disturbed systems
- Non cool core relaxed systems
- Non cool core disturbed systems

Comparison with the classification based on the six criteria defined by Andrade-Santos et al. (2017) and Lopes et al. (2018)

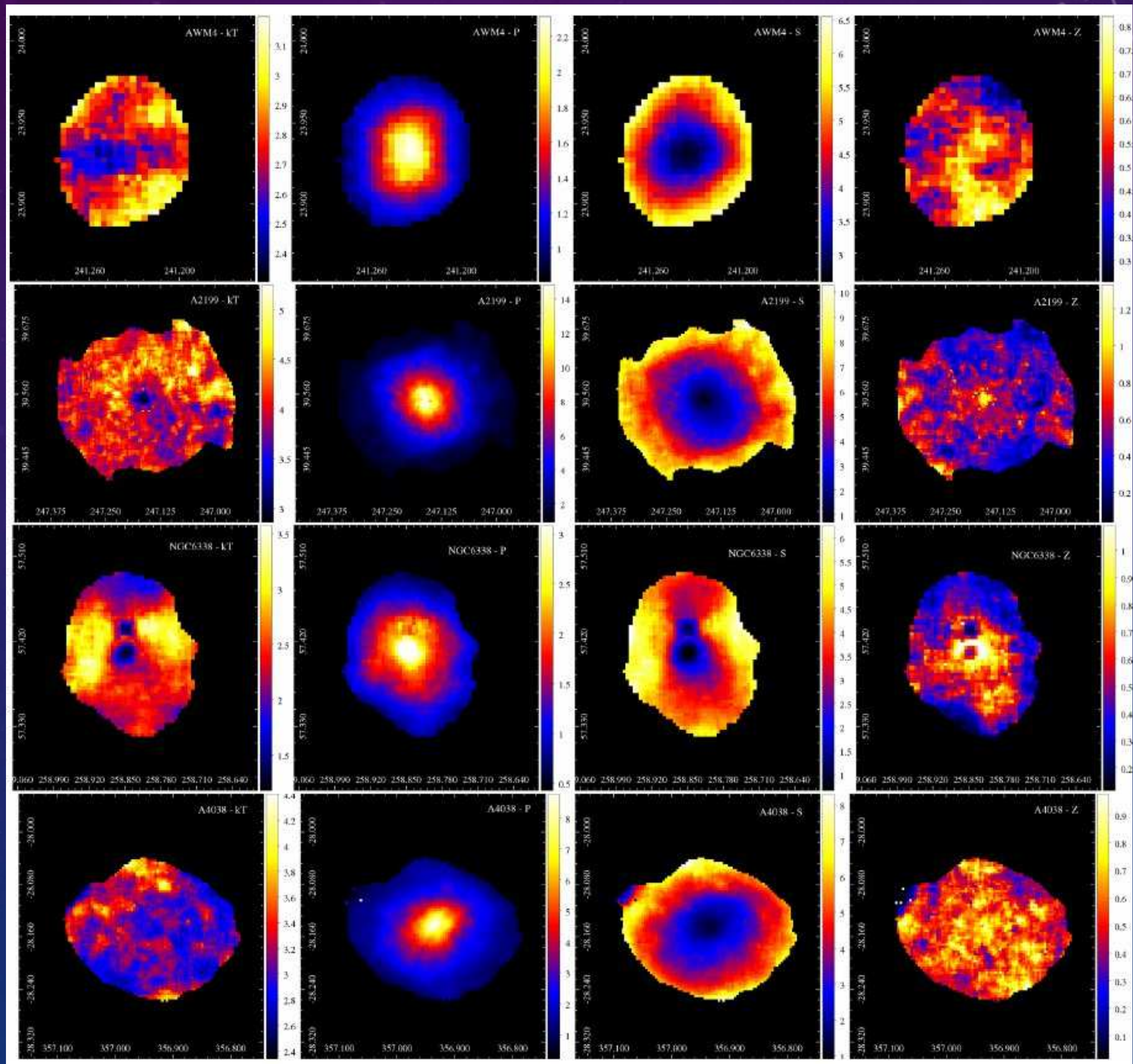
COOL CORE RELAXED SYSTEMS

kT p S Z



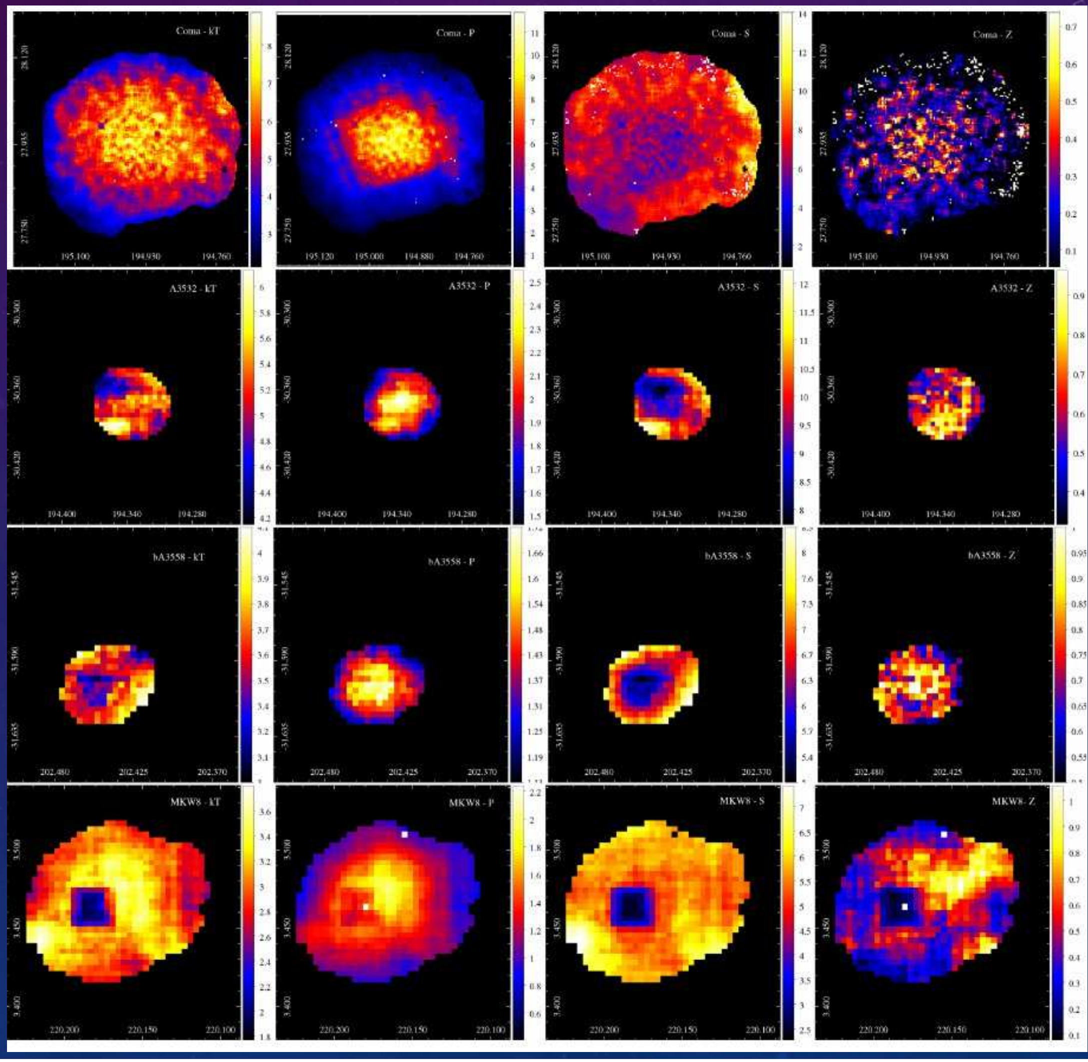
COOL CORE DISTURBED SYSTEMS

kT p S Z



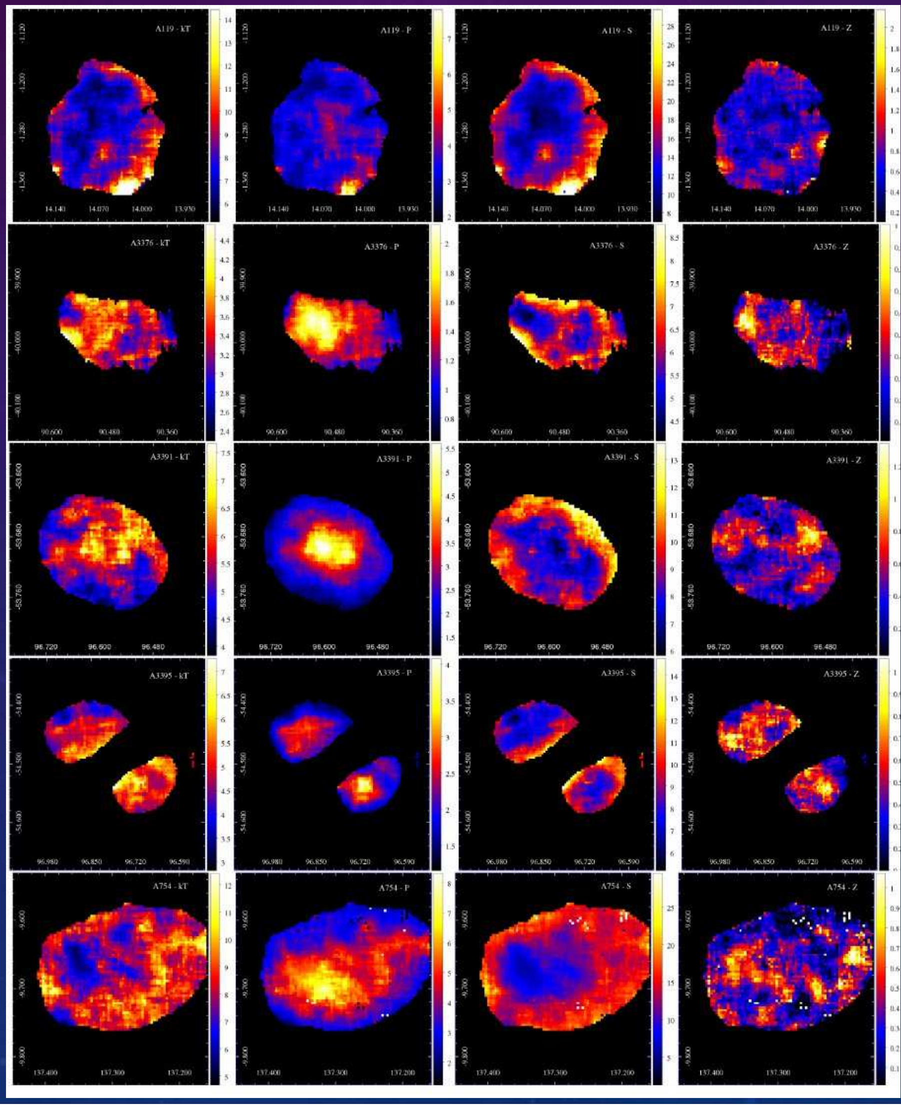
NON COOL CORE RELAXED SYSTEMS

kT p S Z



NON COOL-CORE DISTURBED SYSTEMS

kT p S Z



RESULTS AND DISCUSSION

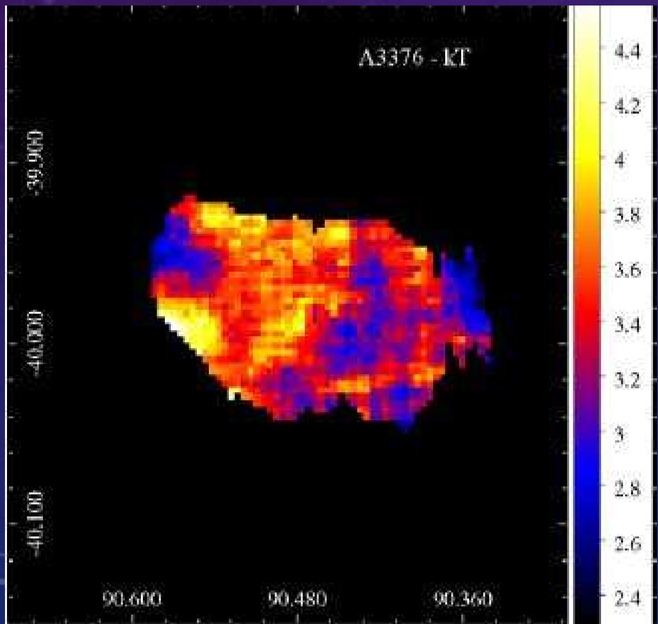
- Cool core relaxed systems: 17 but 4 show only a weak cool core in kT map. Only 5 are spherical, and 2 show interactions (p map)
- Cool core disturbed systems: 16, with a cool core, but disturbed structure due to recent or ongoing merger events
- Non cool core relaxed systems: 4
- Non cool core disturbed systems: 16

⇨ Power of 2D X-ray maps to understand in depth the dynamical state of clusters

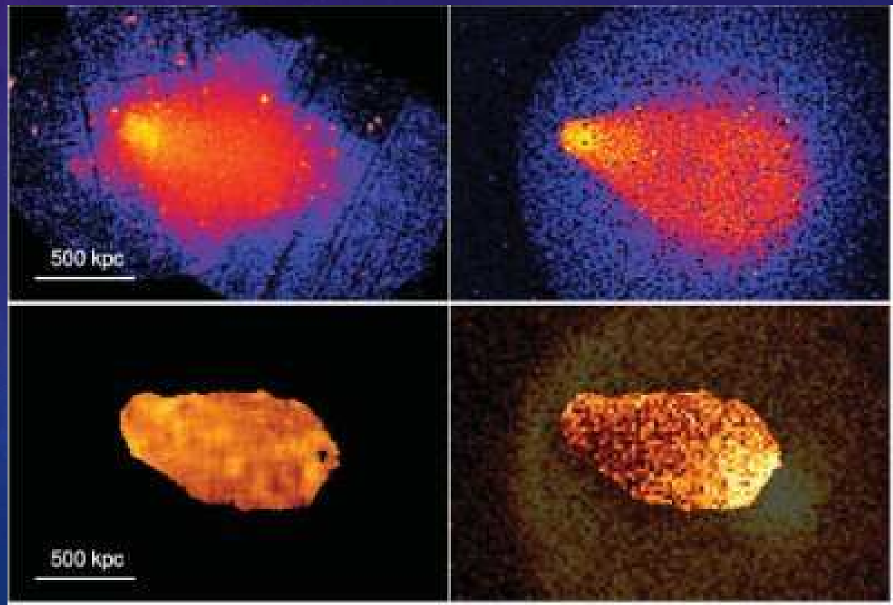
COMPARISON WITH HYDRODYNAMICAL SIMULATIONS: THE MERGING CLUSTER ABELL 3376

- Mass ratio 1/6 to 1/8
- Mach number M ≈ 4
- Age of merger 0.5 Gyr

Observations Model



Our kT map



I

kT

Machado & Lima Neto 2013, MNRAS 430, 3249

FUTURE WORK

- Comparison with more hydrodynamical simulations (Machado et al. in preparation)
- Dynamical analysis by comparison of X-ray substructures with substructures based on galaxy redshifts (Biviano et al. in preparation)

¡ Gracias !