X-ray Halos in Early-type Galaxies - the ATLAS^{3D} view

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(present here: Eric Emsellem, Michele Cappellari, Pierre-Yves Lablanche, Harald Kuntschner, Anne-Marie Weijmans)

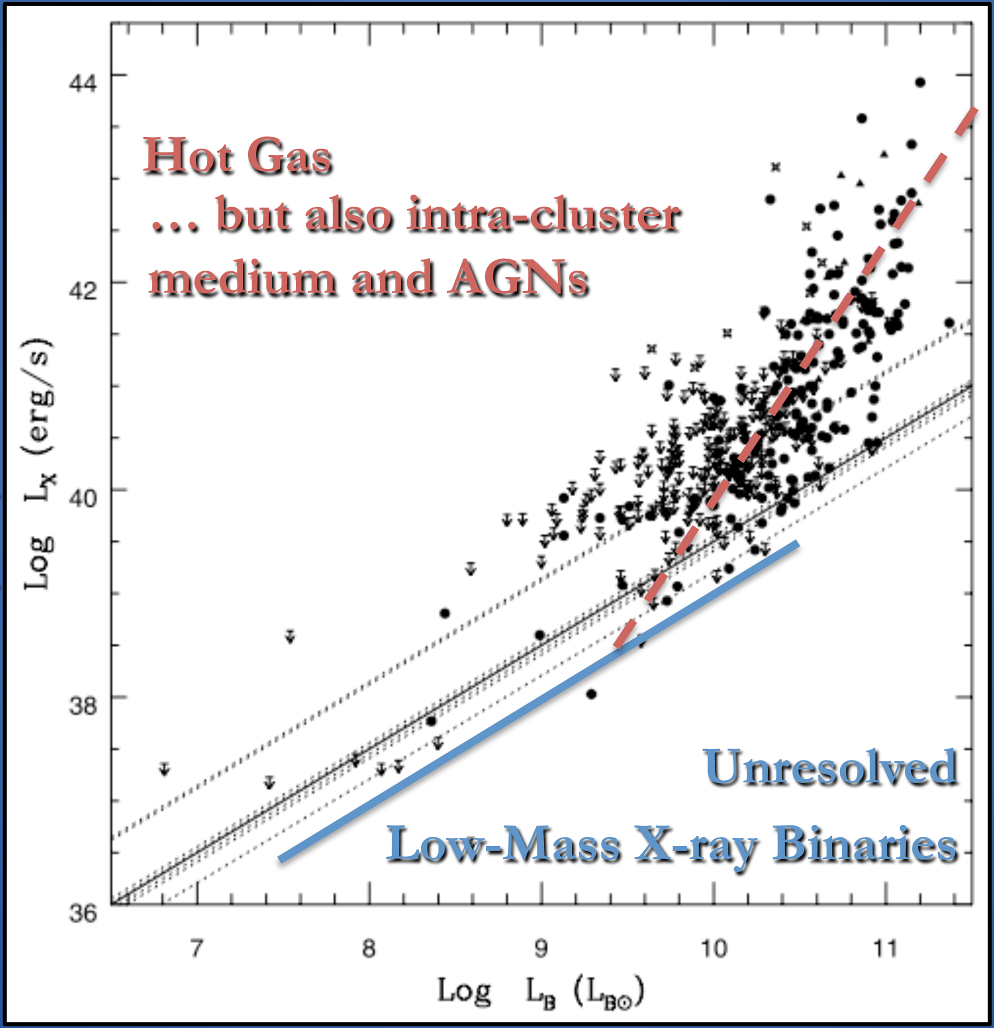
X-ray Halos in Early-type Galaxies

Motivation

- Halos of hot, X-ray emitting gas, bounded to their host galaxy potential, plays a key role in regulating the star-formation history of galaxies.
- Much as the intra-cluster medium may suppress the HI reservoir of galaxies falling in clusters and drive the cosmic rise of S0, the presence of an halo of hot gas around a galaxy may inhibit star formation triggered by the acquisition of gas-rich satellites (e.g., Nipoti & Binney 2007) and prevent the recycling of stellar-mass loss material (e.g., Mathews 1990).
- But what determines the hot-gas content of early-type galaxies?
- The key is to interpret the connection between the optical properties of ETGs and their X-ray emission

X-ray Halos around ETGs

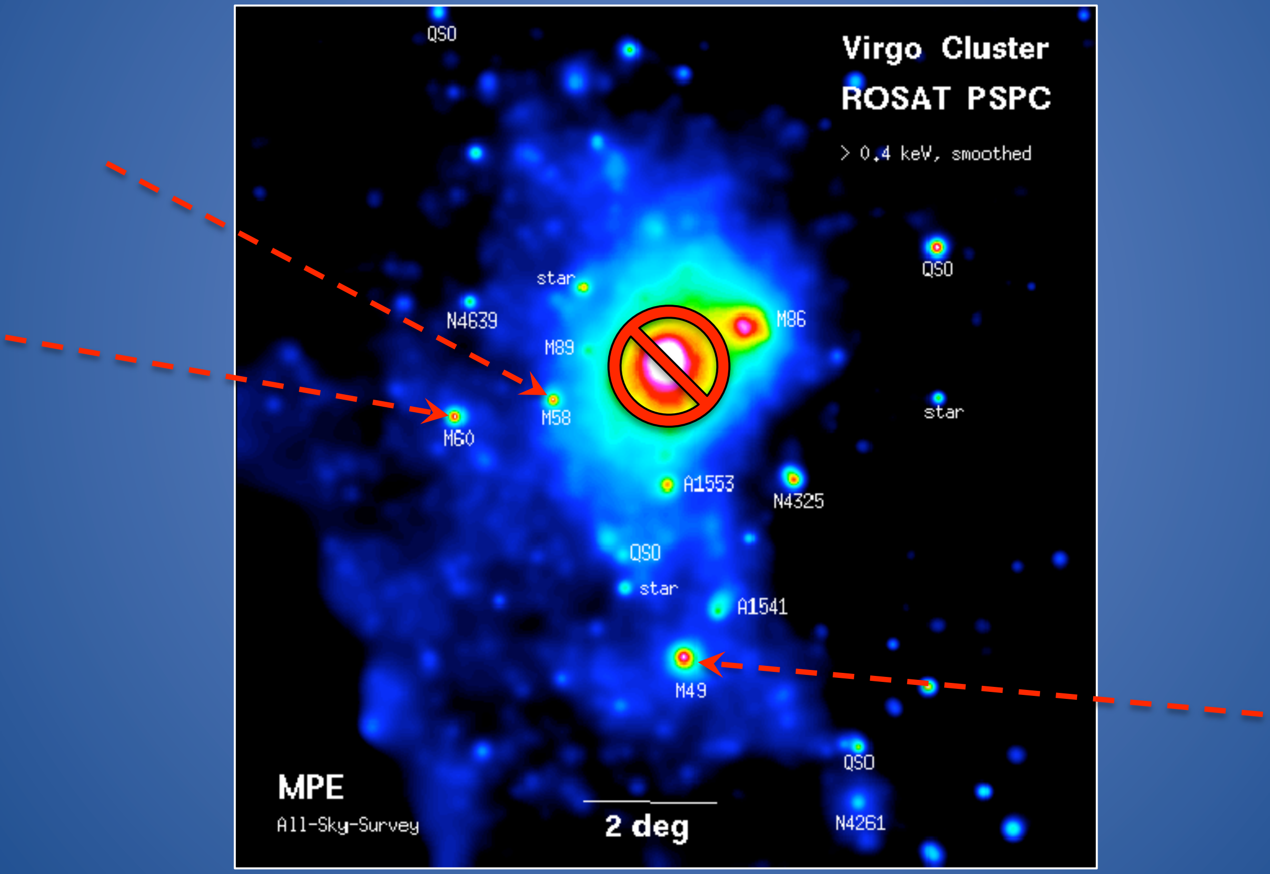
Background



From O'Sullivan et al. (2001)

X-ray Halos around ETGs

How to make the hot-gas halo of A galaxy



This talk is not about the Cluster or Group Medium

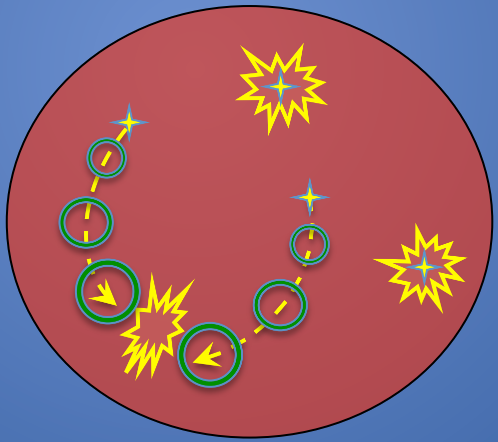
X-ray Halos around ETGs

How to make the hot-gas halo of a galaxy

- According to the current consensus, halos consists of stellar-mass loss material that was heated up at X-ray emitting temperatures through:

① The injection of the kinetic energy from SNs

② The thermalisation of the stellar kinetic energy inherited by the stellar ejecta, via shocks and collisions



- The ability to retain this halo may then depend on environmental effect, the dynamical mass or the intrinsic flattening of ETGs

X-ray Halos around ETGs

The way forward with ATLAS^{3D}

ATLAS^{3D} is a volume-limited integral-field spectroscopic survey of 260 ETGs (Cappellari et al. 2011), which provides us with consistently compiled or derived

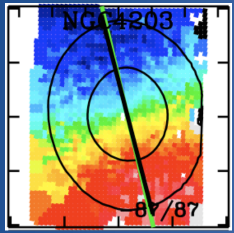
- Distances
- K-band luminosities
- Apparent Flattening
- Galactic Environment

and thanks to the IFS nature of our data

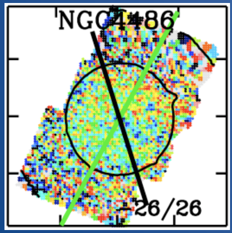
- Degree of rotational support (through the λ_R parameter of Emsellem et al. 2007)
- Dynamical Mass (through Jeans modeling, Cappellari et al. in prep)

X-ray Halos around ETGs

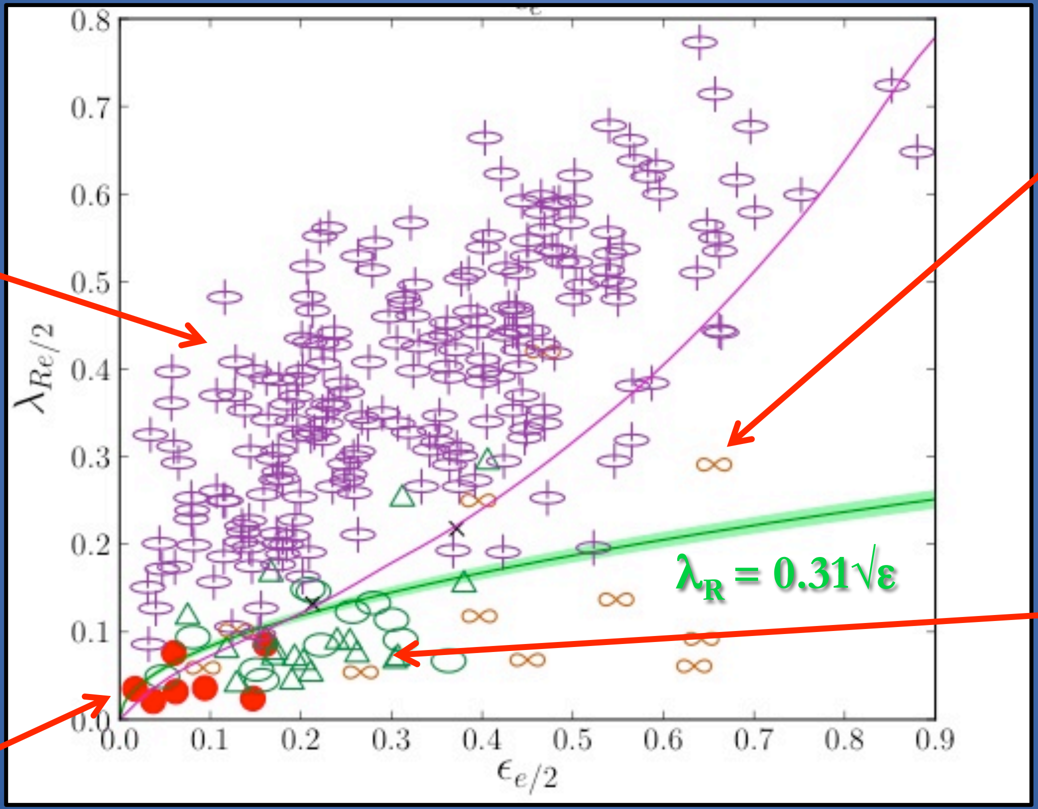
The way forward with ATLAS^{3D}



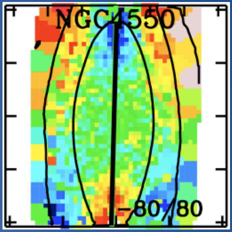
Fast-Rotators



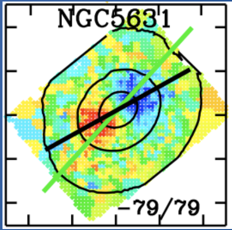
Non-Rotators



Emsellem et al. (2011)



Double-disks masquerading as Slow-Rotators

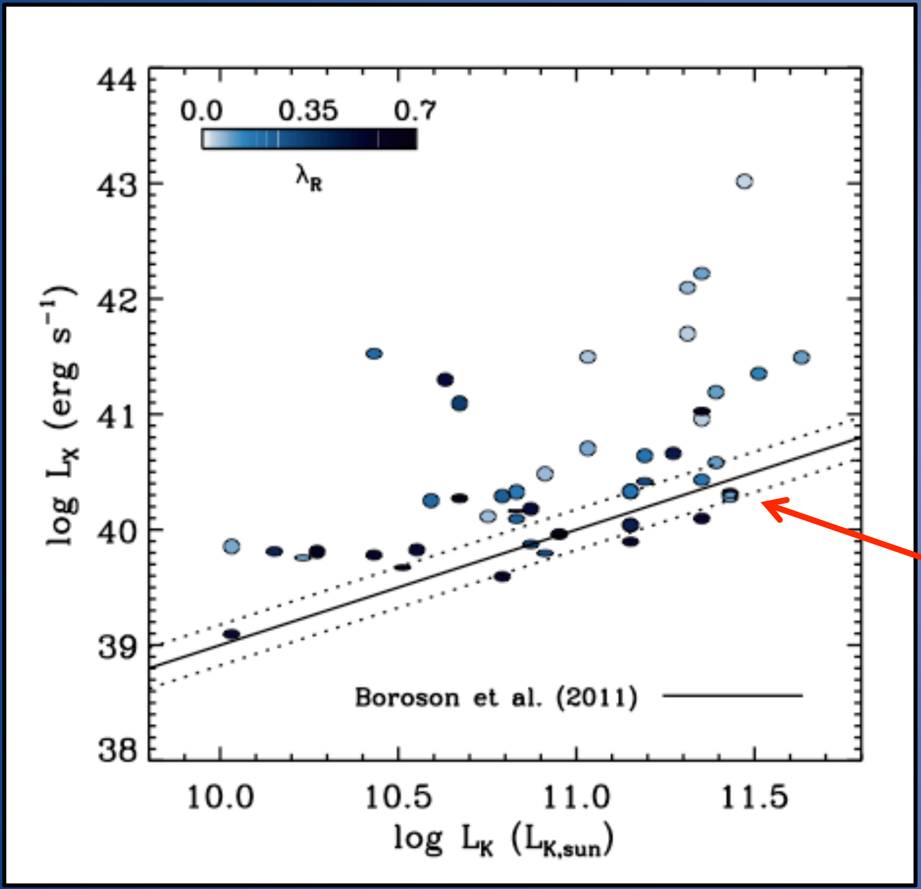


Slow-Rotators with KDC

ATLAS^{3D} complete λ_R view of ETGs

X-ray Halos around ATLAS^{3D}

ROSAT & ATLAS^{3D}



X-ray data from O'Sullivan (2001), Optical data from ATLAS^{3D}

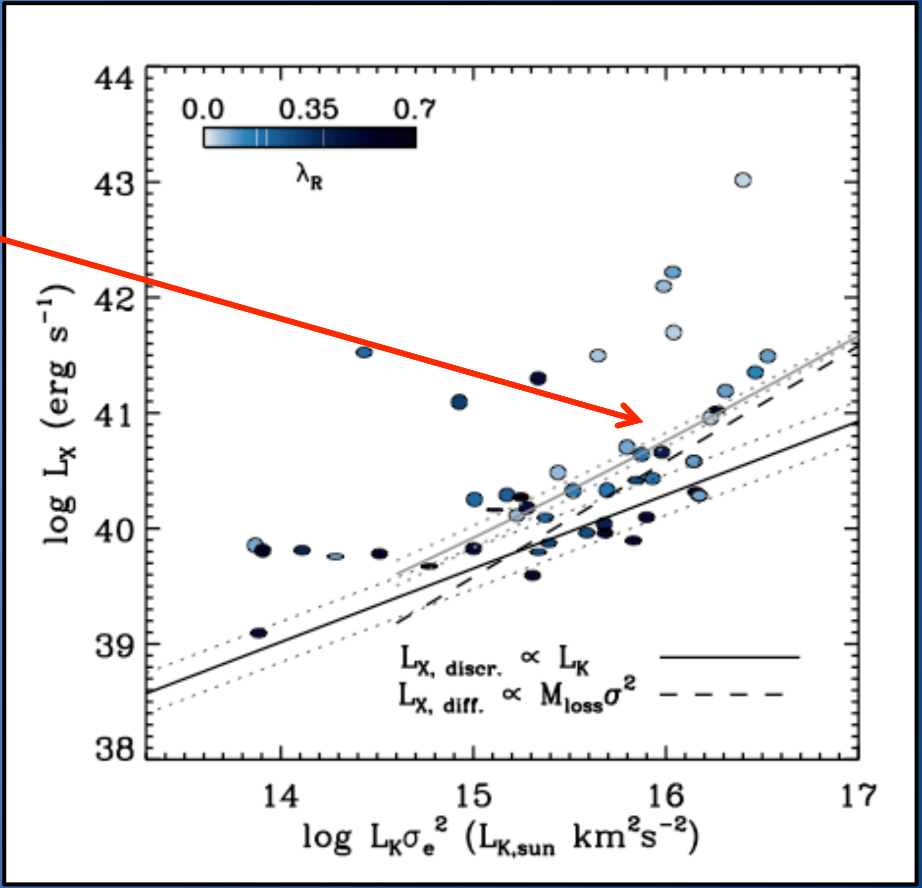
K-band version of the classical L_B-L_K relation

Contribution from unresolved low-mass X-ray binaries (LMXBs)

X-ray Halos around ATLAS^{3D}

ROSAT & ATLAS^{3D}

Total predicted L_X from LMXBs and diffuse gas originating from stellar-mass loss (Nagino & Matsushita 2009)

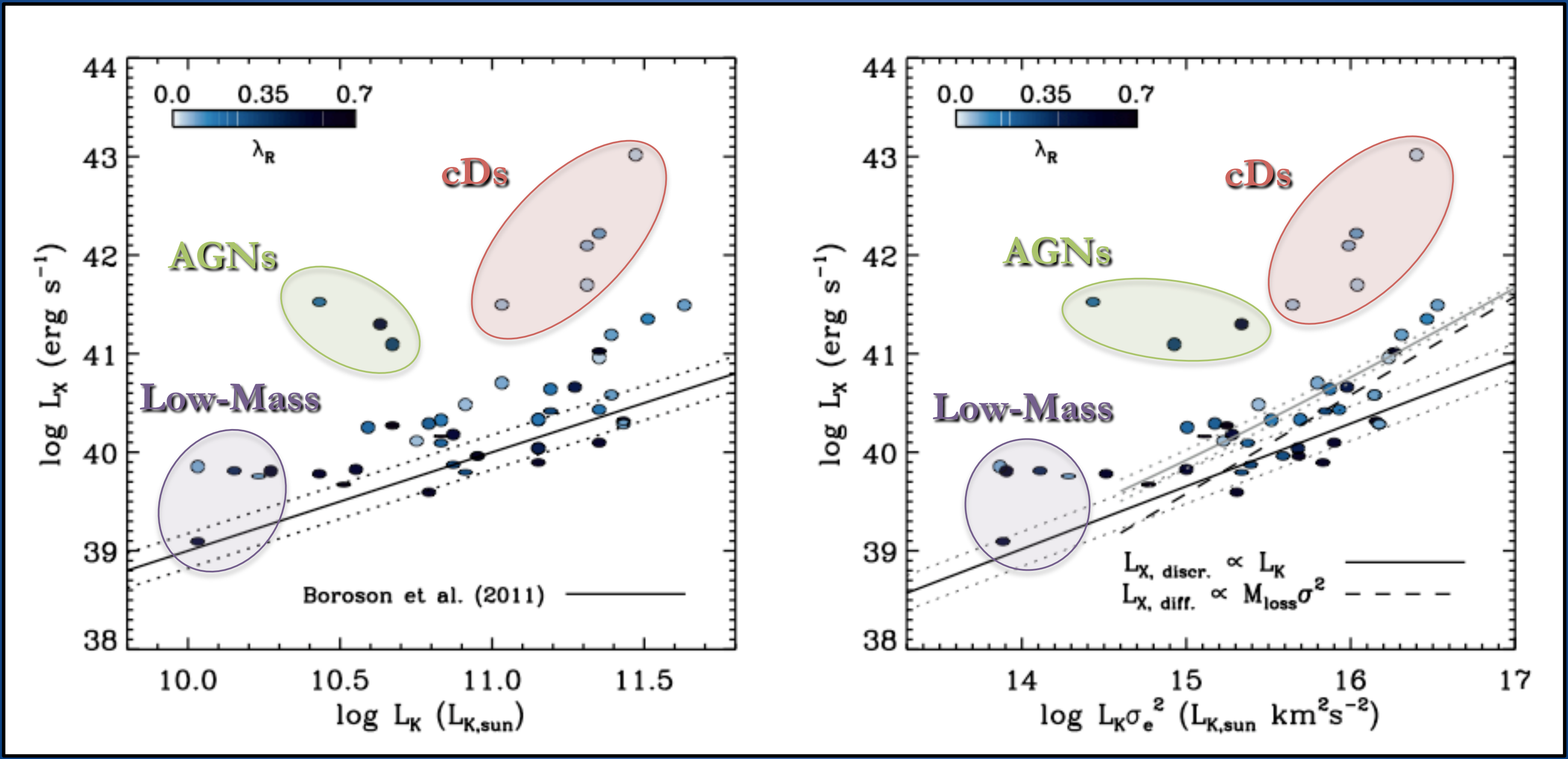


X-ray data from O'Sullivan (2001), Optical data from ATLAS^{3D}

K-band and integral-field version of the classical Lσ-L_X diagram

X-ray Halos around ATLAS^{3D}

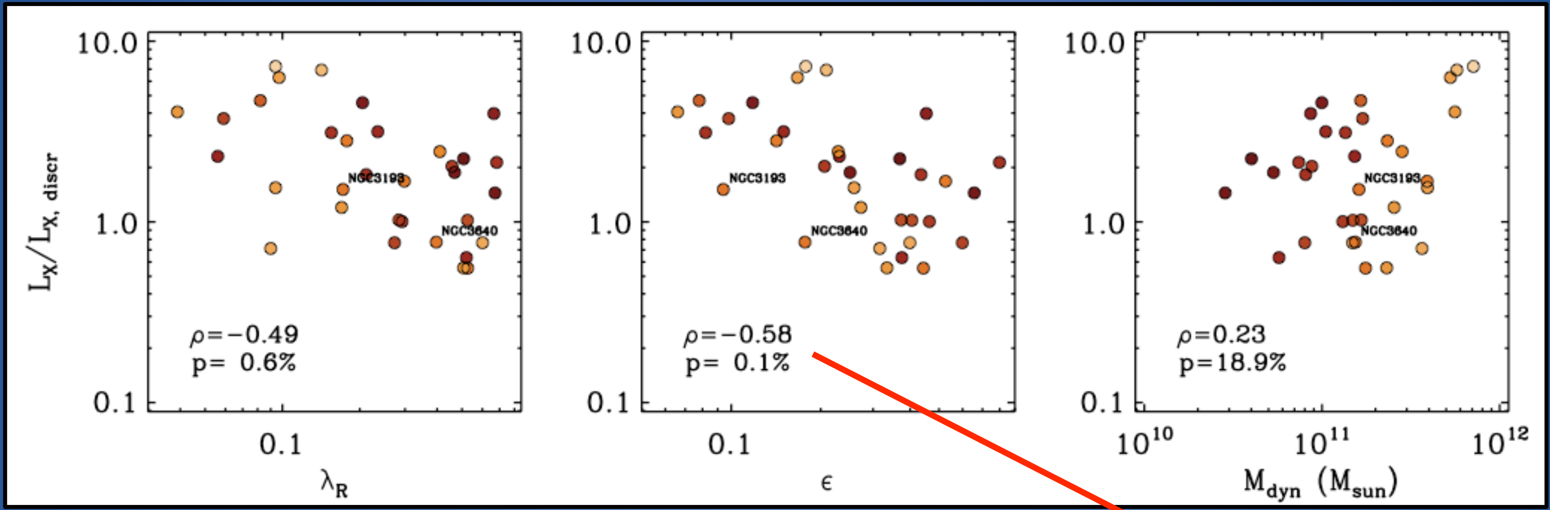
ROSAT & ATLAS^{3D}

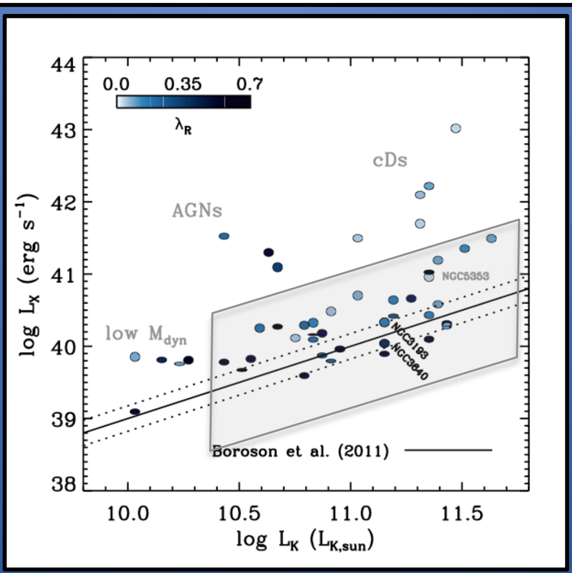


Excluding low-mass objects or those contaminated by the ICM or a central AGN we observe a trend with flattening and λ_R…

X-ray Halos around ATLAS^{3D}

ROSAT & ATLAS^{3D}



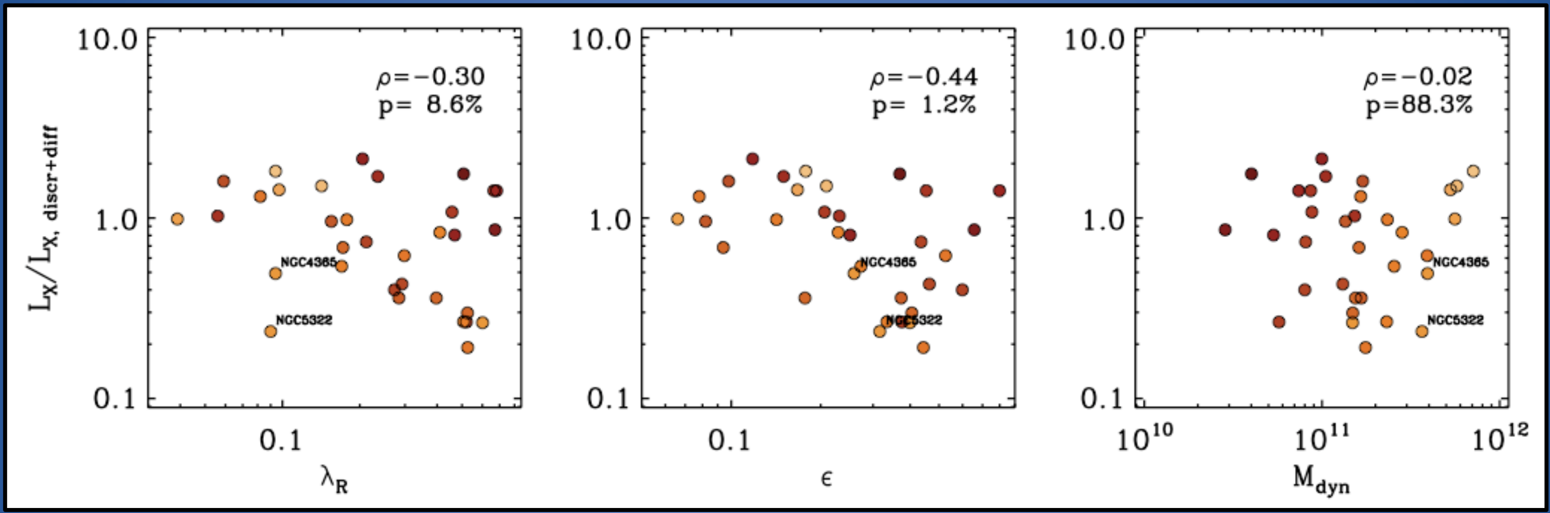


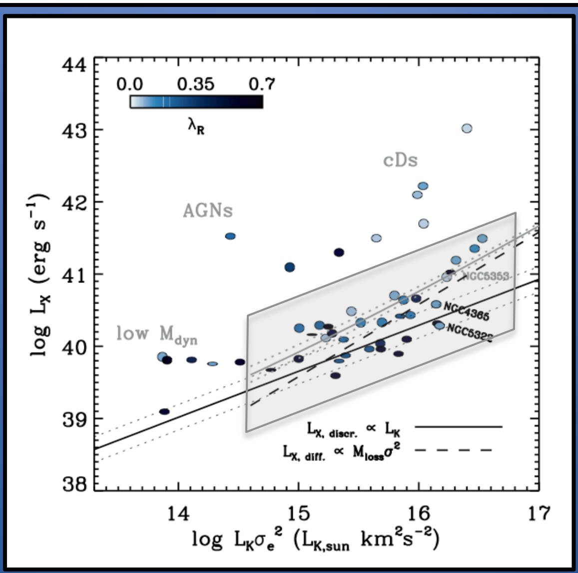
The rounder and less rotationally supported a galaxy, the larger its L_X/L_{LMXBs} excess

Spearman rank coefficient and null-hypothesis probability

X-ray Halos around ATLAS^{3D}

ROSAT & ATLAS^{3D}



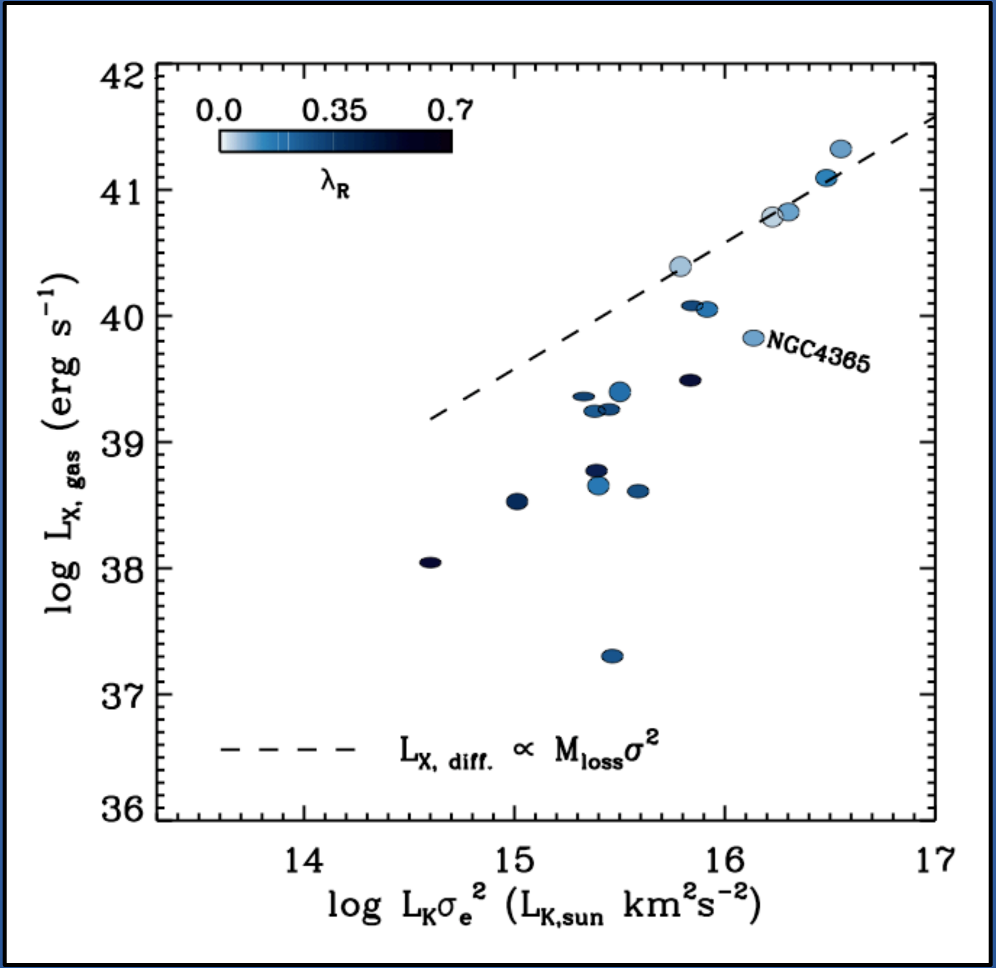


The flatter and more rotationally supported a galaxy, the larger its $L_X/L_{diff+discr}$ deficit

X-ray Halos around ATLAS^{3D}

Chandra & ATLAS^{3D}

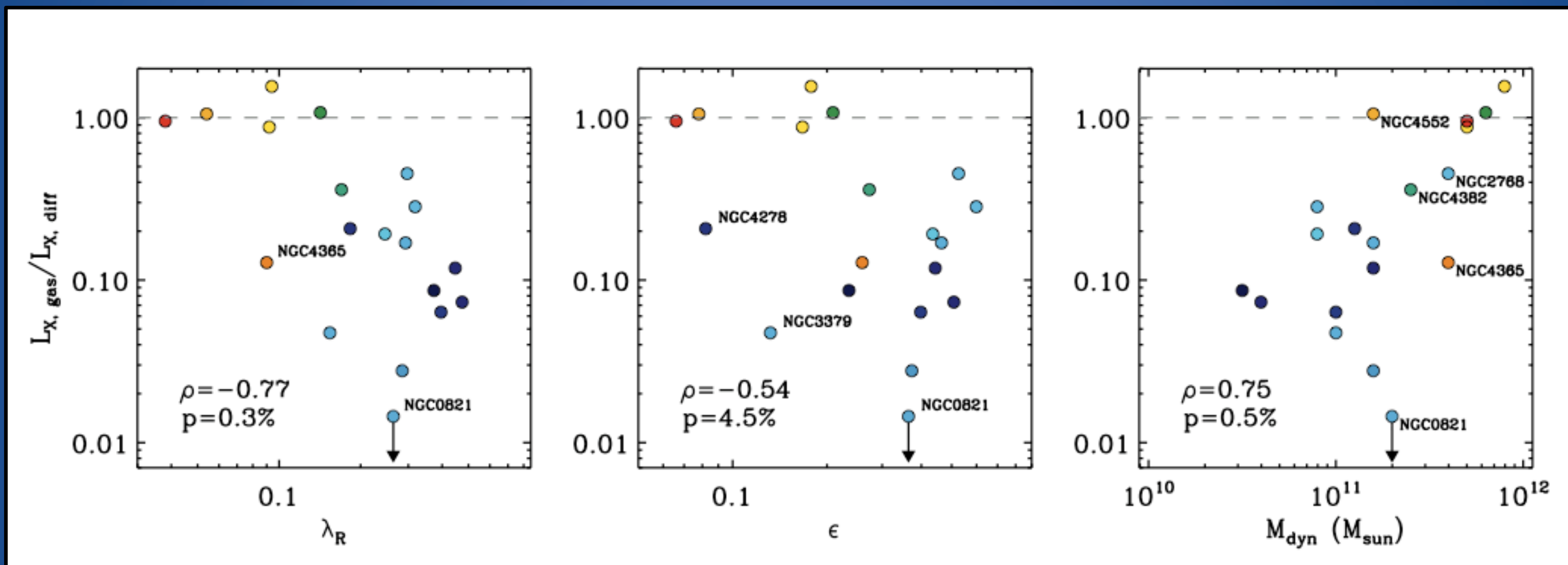
X-ray data from Boroson et al. (2011)



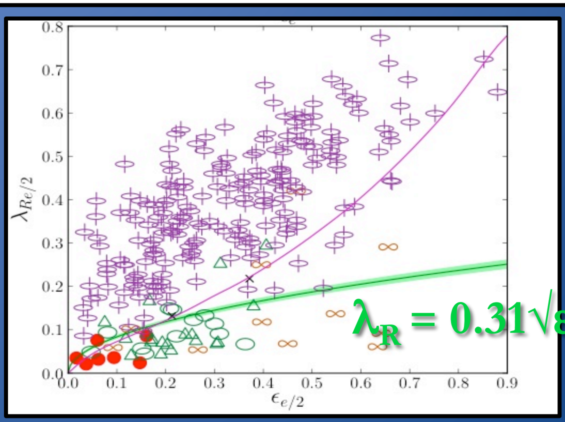
Optical data from ATLAS^{3D}

X-ray Halos around ATLAS^{3D}

Chandra & ATLAS^{3D}

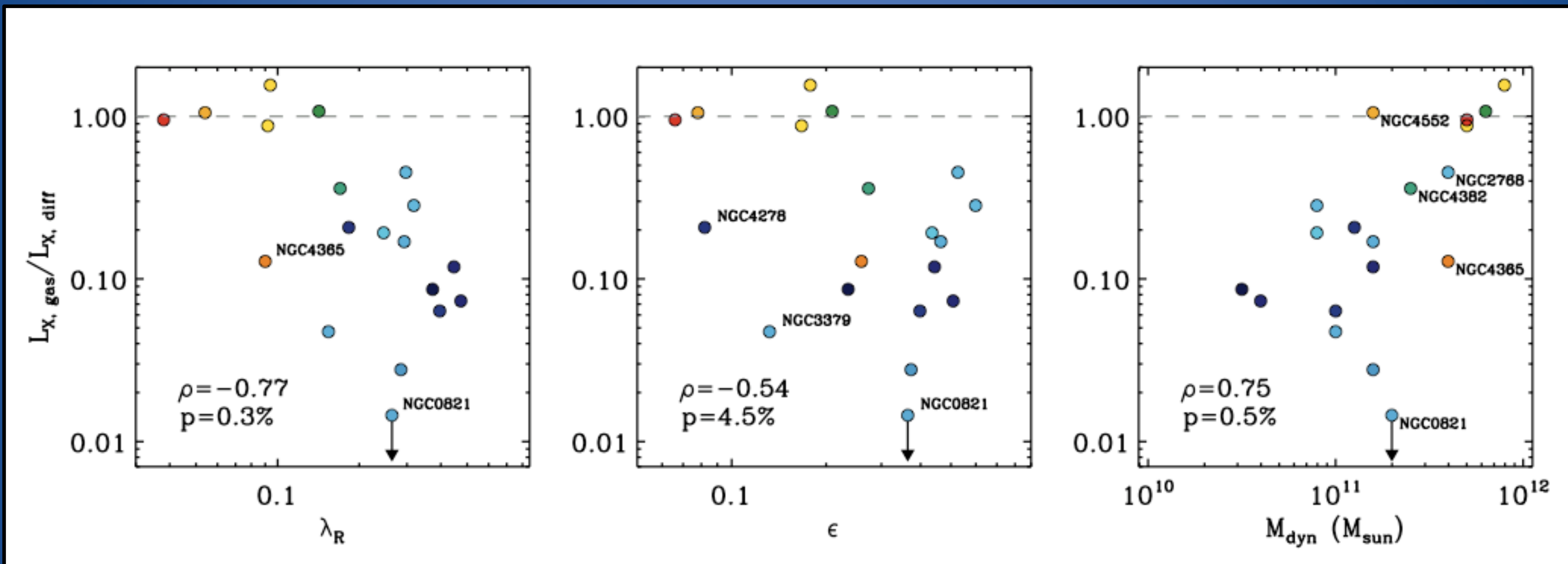


- Colour-coded by the distance from the dividing line between fast and slow rotators ($\lambda_R = 0.31\sqrt{\varepsilon}$)



X-ray Halos around ATLAS^{3D}

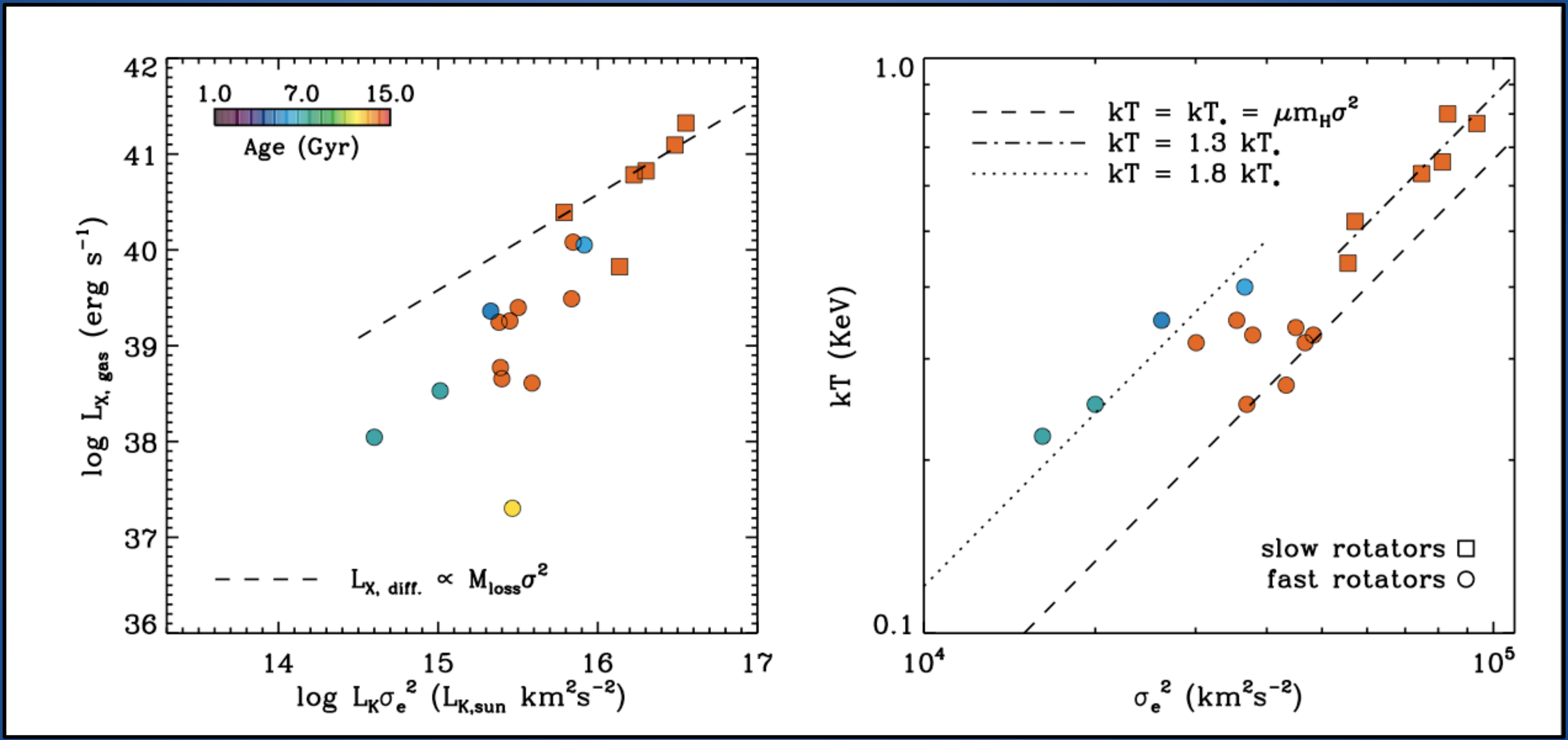
Chandra & ATLAS^{3D}



- Confirms the previous ROSAT-based results, although the X-ray deficit appears now to anti-correlates also with M_{dyn}. Yet, M_{dyn} is not the main driver (note the position of the slow-rotators NGC4365 and NGC4552)

X-ray Halos around ATLAS^{3D}

Chandra & ATLAS^{3D}

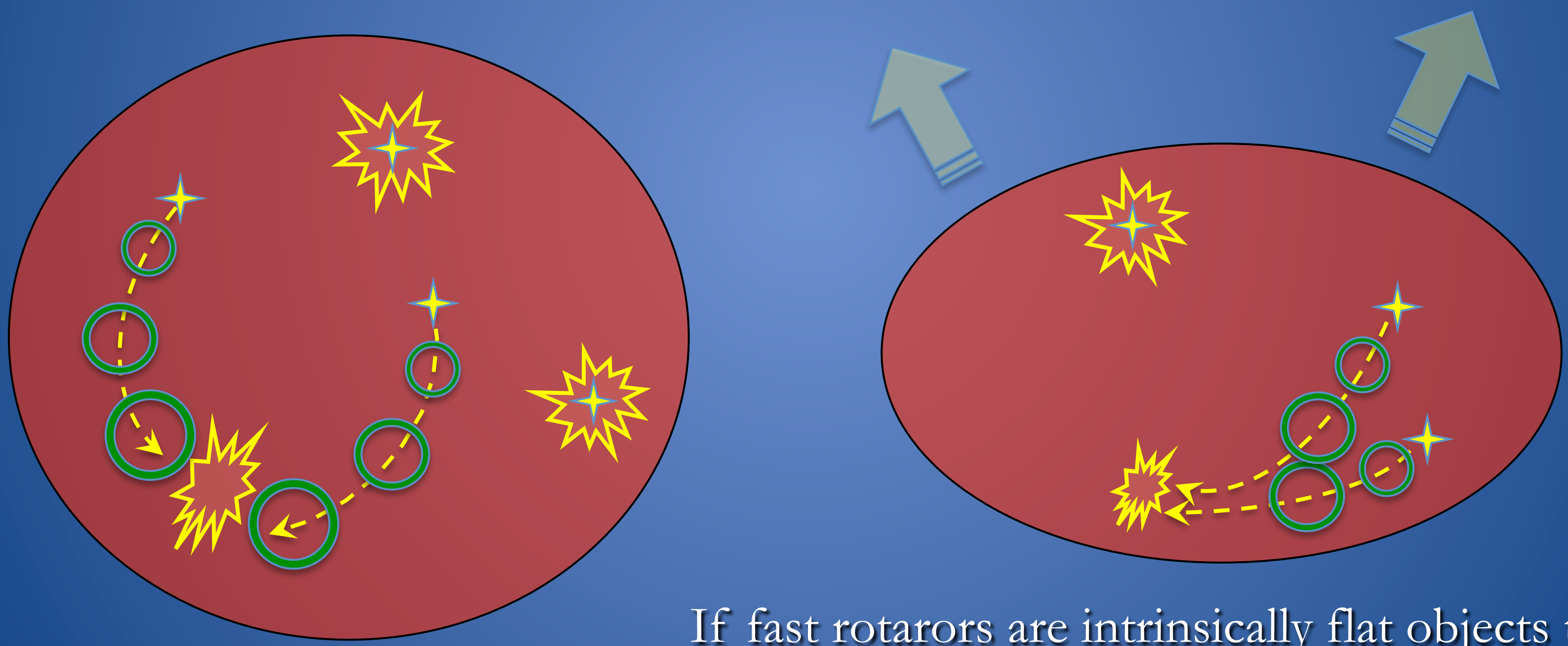


- Slow Rotators have both the expected amount and kT temperature for the X-ray gas. Fast rotators are not only systematically deficient in hot gas content, and only show a restricted range of kT values

X-ray Halos around ETGs

How to make an hot-gas halo

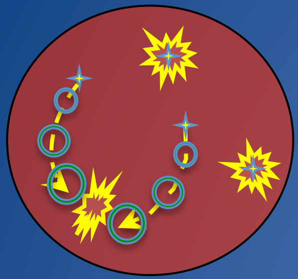
Slow vs. Fast Rotators

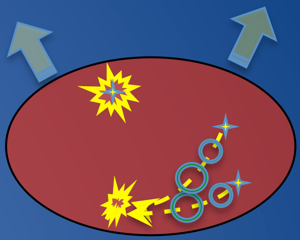


If fast rotarors are intrinsically flat objects they may have an harder time in retaining their hot gas (Ciotti & Pellegrini 1996). Furthermore, shocks between ejects may be less efficient.

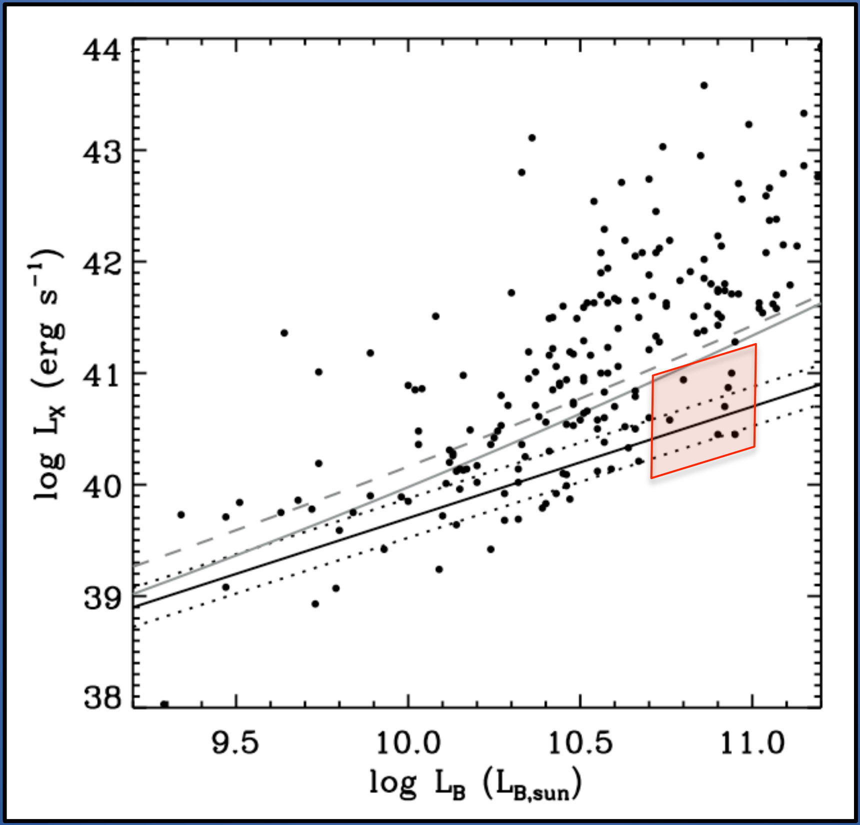
X-ray Halos around ETGs

Slow vs. Fast Rotators





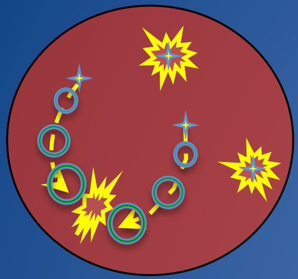
Further Steps:

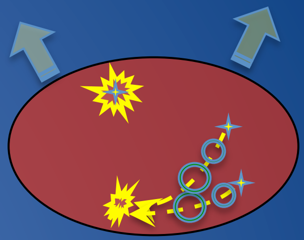


These low-liers are very massive but flat ETGs, that ought to be investigated.

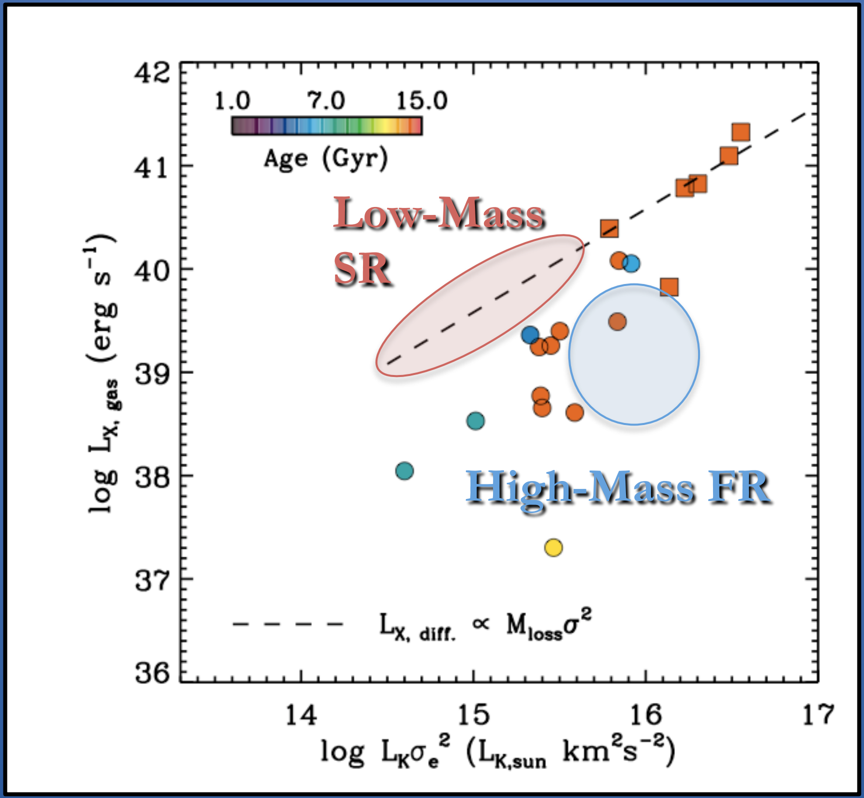
X-ray Halos around ETGs

Slow vs. Fast Rotators





Further Steps:



Similarly, to check our results it would be desirable to have Chandra data for more low-mass Slow-rotators and massive Fast-Rotarors

X-rays Halos in ETGs with ATLAS^{3D}

Conclusions

- Using the complete integral-field ATLAS3D database with both old ROSAT data (for 47 objects) or new Chandra data (for 19 objects) we could conclude that the X-ray content of ETGs depends dramatically on their intrinsic shape and dynamical state.
- For round slow rotators, the amount and temperature of hot X-ray emitting gas is consistent with what expected from stellar-mass loss material heated up at the kinetic energy of the stars, through the collision of the stellar ejecta and SNe explosions
- Fast rotators, and flat slow rotators, are X-ray deficient. They may have an harder time both in heating up the gas, as collisions between stellar ejecta happen at lower shock velocities and occurr less frequently, and in retaining their gas, as it easier for the gas to escape from a flatter galaxy (e.g., Ciotti & Pellegrini 1996).

X-rays in ATLAS^{3D}

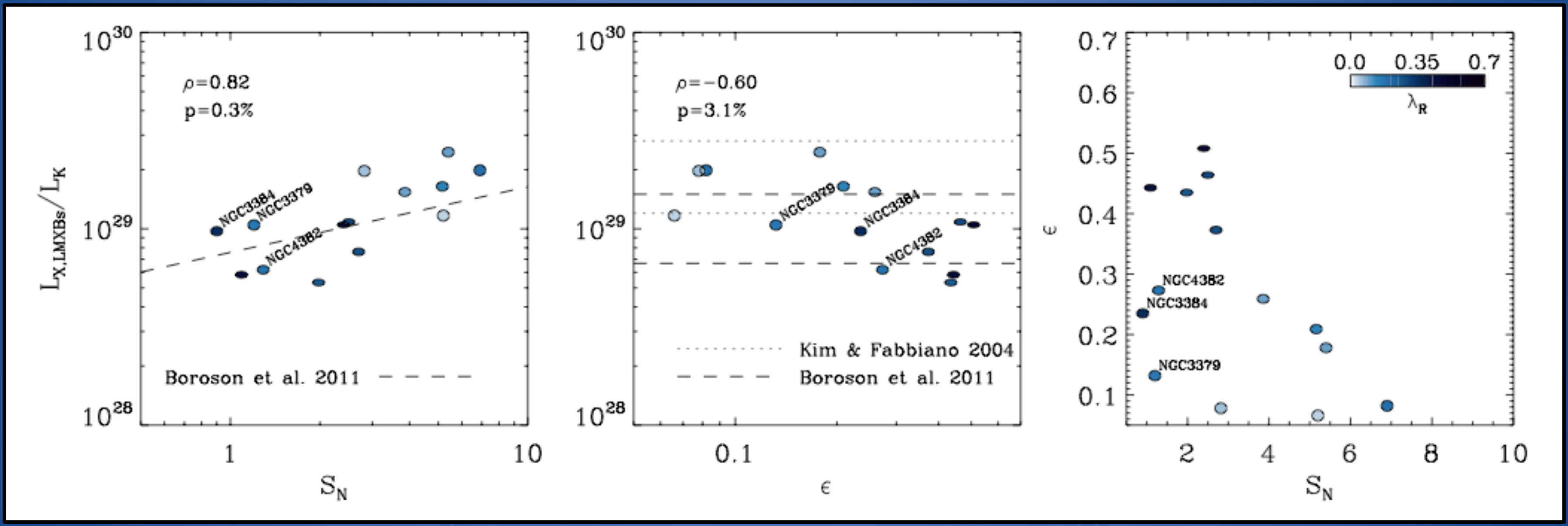
The role of GCs

1. Globular Clusters may be the birthplace of LMXBs in galaxies (Sarazin et al. 2000, White et al. 2002).
2. The specific frequency of GCs (S_N) has been claimed (Kundu & Whitmore 2001) to be lower in S0 than in Es, by a factor 2.4.
3. But nearly all S0 (94%) and most Es (66%) are fast-rottators (Emsellem et al. 2011)

⇒ So the L_X deficit of flat or fast rotating galaxies may come from a systematically smaller LMXBs population in these systems.

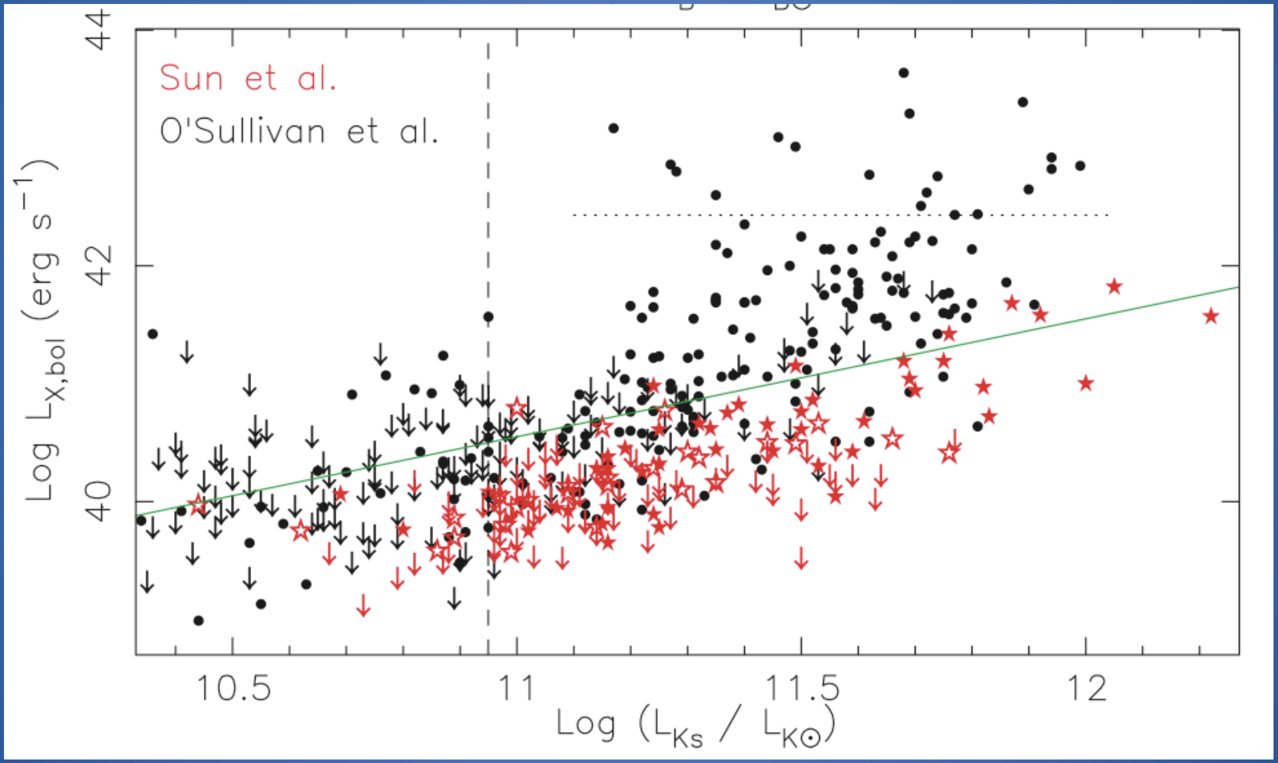
X-rays in ATLAS^{3D}

Globular Clusters and LMXBs



X-rays in ATLAS^{3D}

With Chandra, the scatter does not go away



- So the scatter we observe, on the bulk X-ray luminosity, cannot be only due to a different amount of LMXBs.

X-rays in ATLAS^{3D}

The role of GCs

1. Globular Clusters may be the birthplace of LMXBs in galaxies (Sarazin et al. 2000, White et al. 2002).
2. The specific frequency of GCs (S_{GC}) has been claimed (Kundu & Whitmore 2001) to be lower in S0 (which are FR) than in Es (which can be SR, in particular for massive Es), by a factor 2.4.

⇒ So the L_X deficit of flat or fast rotating galaxies may come from a smaller LMXBs population.

- GCs specific frequency with flattening can explain only part of the the observed scatter.
- Calibration bias may explain these low outlier