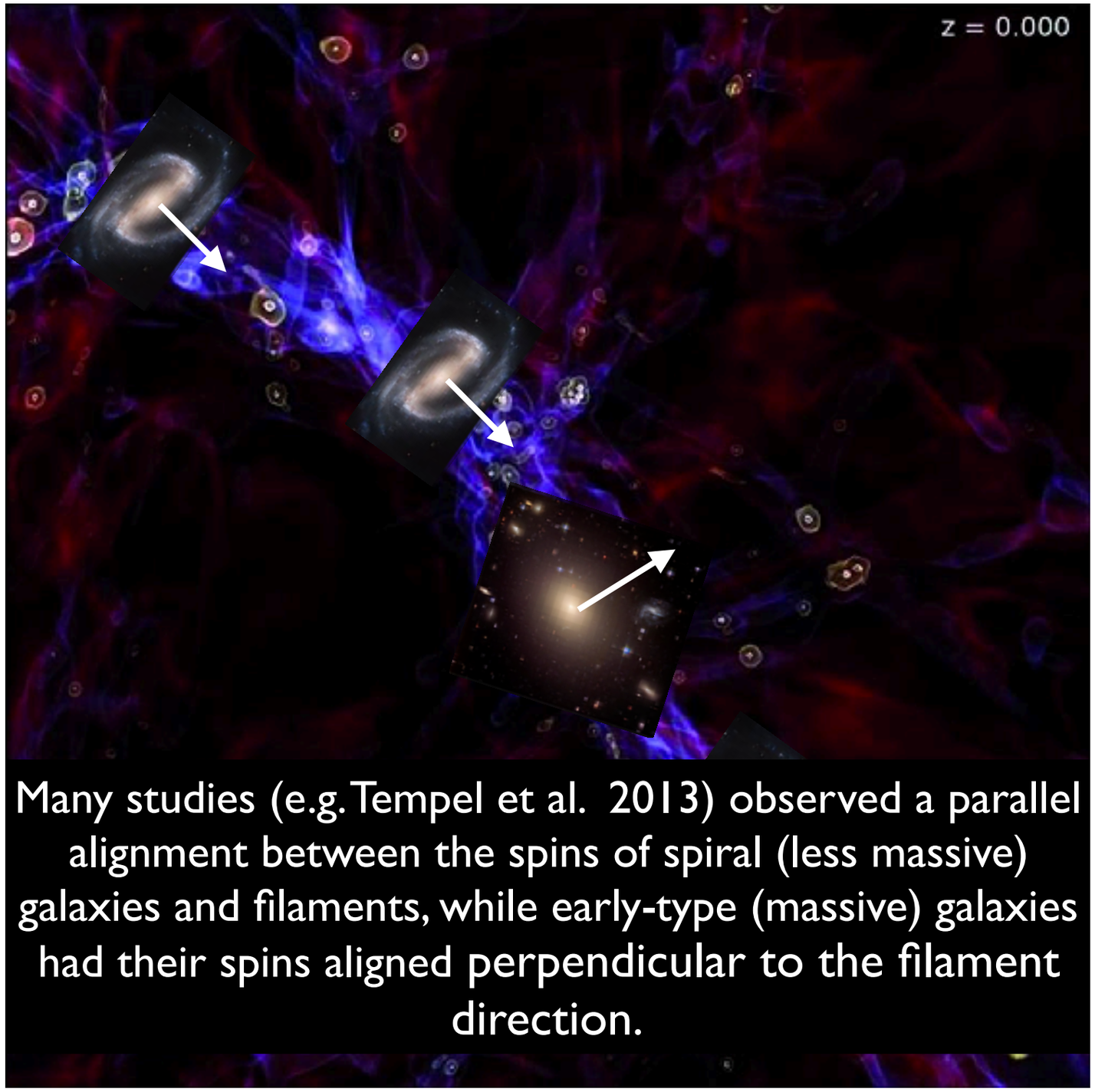
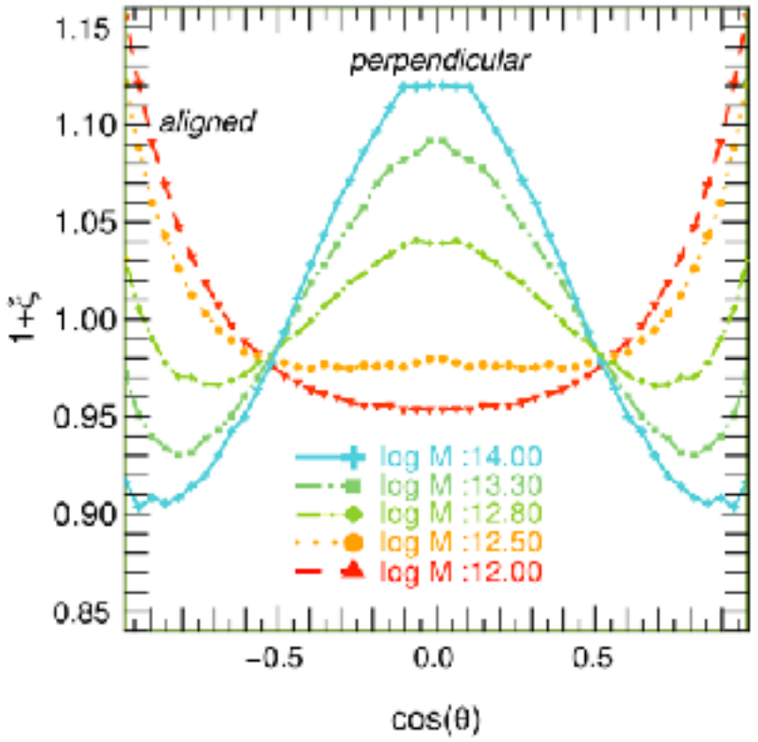
Kinematic Alignments of Early-type Galaxies in Cluster Environments

Hyunjin Jeong
and collaborators

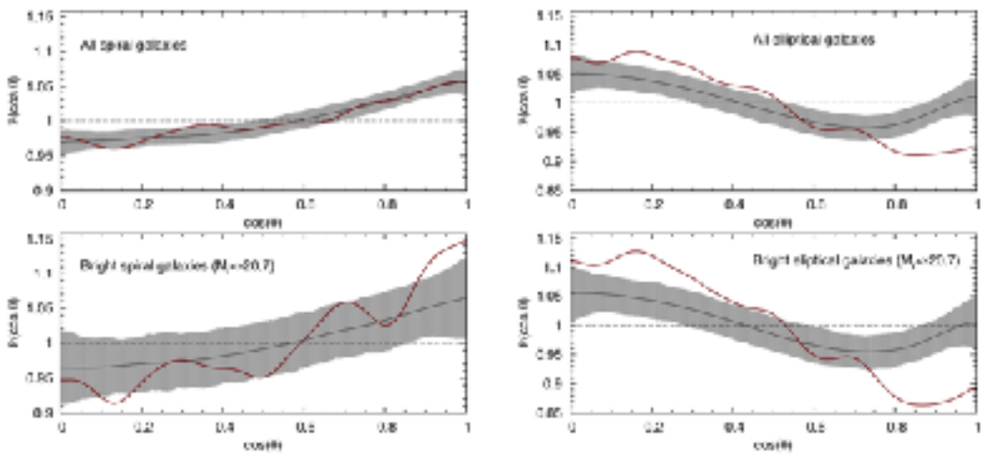
Kinematic Alignment in Filaments



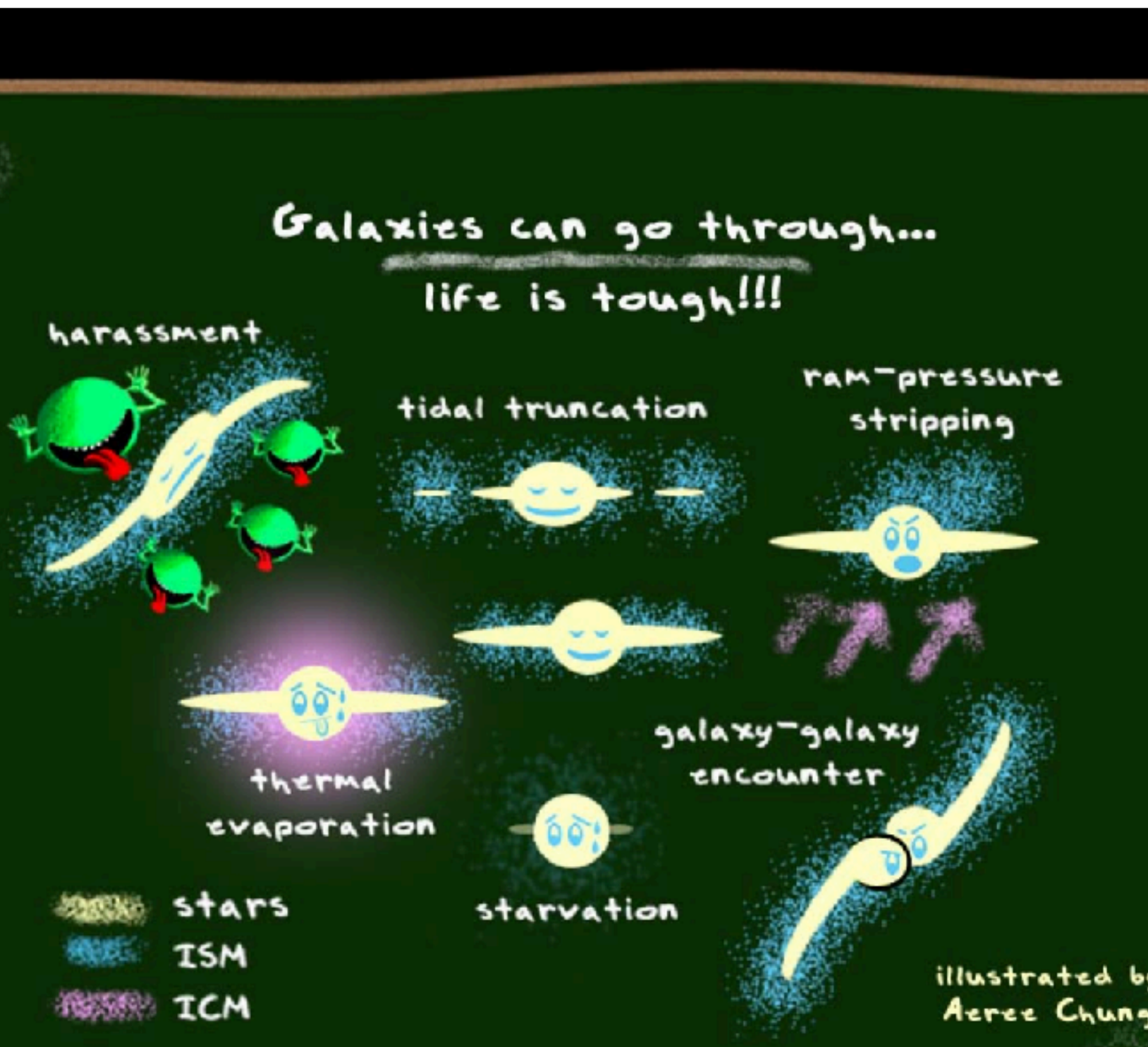
Many studies (e.g. Tempel et al. 2013) observed a parallel alignment between the spins of spiral (less massive) galaxies and filaments, while early-type (massive) galaxies had their spins aligned perpendicular to the filament direction.



Codis et al. 2012



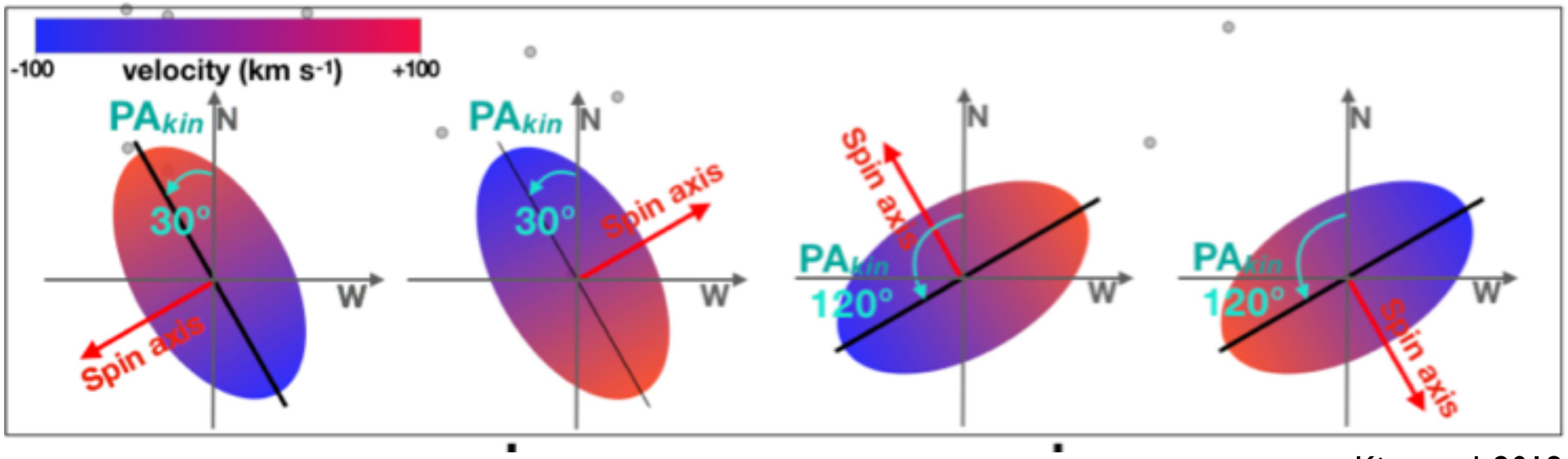
Tempel et al. 2013



How about in galaxy clusters?

Various observations indicate that the cluster environment can affect the structure and dynamics of galaxies.

Kinematic Position Angle: PAkin

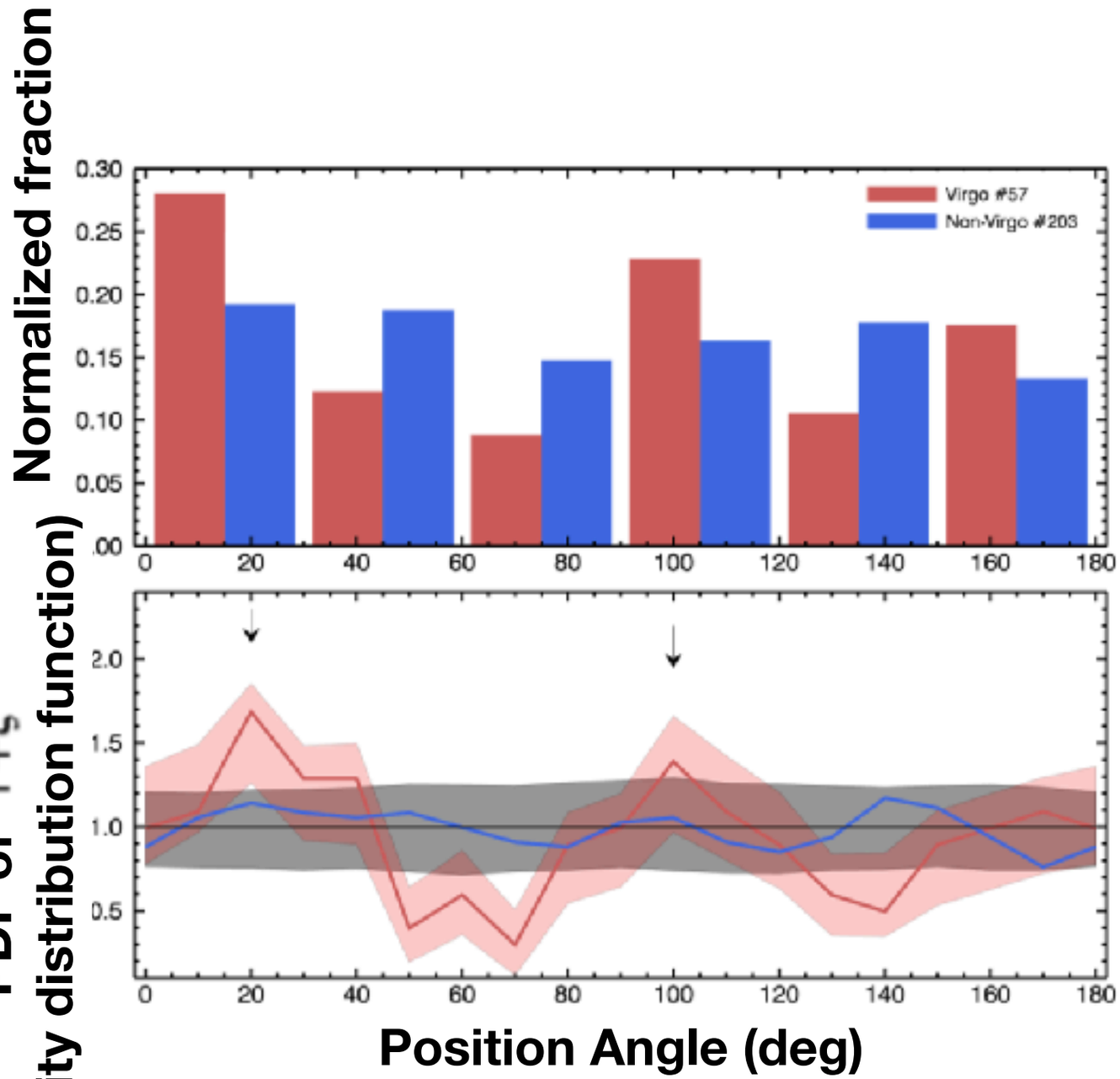


Kim et al. 2018

The PA*kin* is defined as the angle between the north and the receding part of the velocity map in a counterclockwise direction, which is, in principle, **perpendicular to the spin axis**. In this talk, however, the values of PA*kin* are rearranged to be **in the range of 0° to 180°** by not considering whether the receding or preceding parts of the velocity map.

Kinematic Alignments in the Virgo Cluster

based on 57 Virgo-Atlas3D galaxies



ξ : the excess probability Kim et al. 2018

The *Virgo* early-type galaxies (red histogram) **prefer specific values for PA*kin* roughly 20° and 100°**,

while the distribution of PA*kin* for the *non-Virgo* galaxies (blue histogram) is relatively uniform.

This implies that some Virgo early-type galaxies could be kinematically aligned each other in terms of PA*kin*.

Is the Virgo special?

Abell 119 & Abell 168

Jeong et al. 2019

Table 1. The properties of Abell 119 and Abell 168

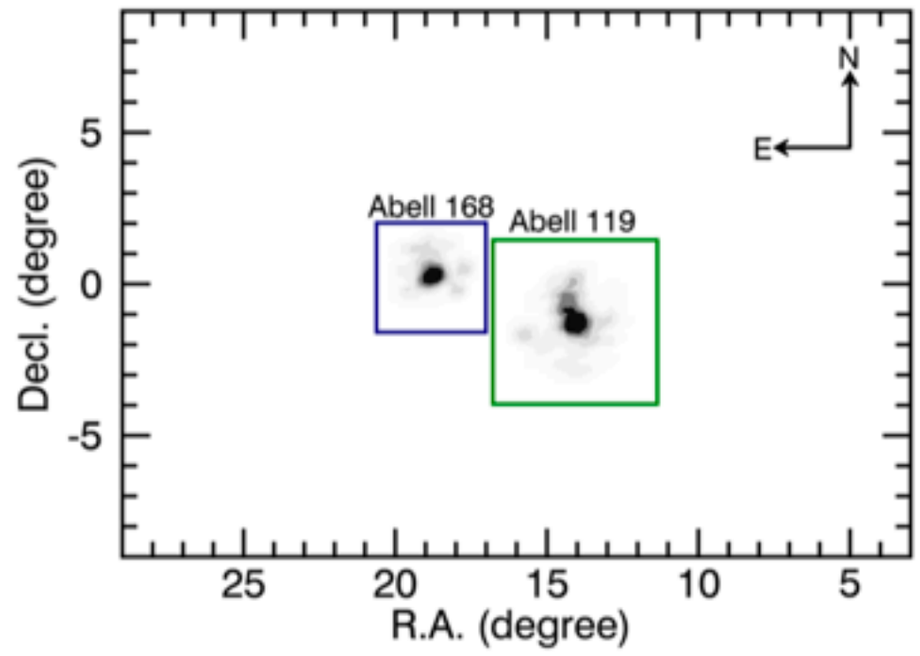
Cluster	R.A.	Decl.	z	M_{200}	R_{200}
	J2000	J2000		($10^{14}M_{\odot}$)	(Mpc)
Abell 119	14.067150	-1.255370	0.0442	8.6 ± 3.1	2.04
Abell 168	18.815777	0.213486	0.0449	1.9 ± 1.1	1.32

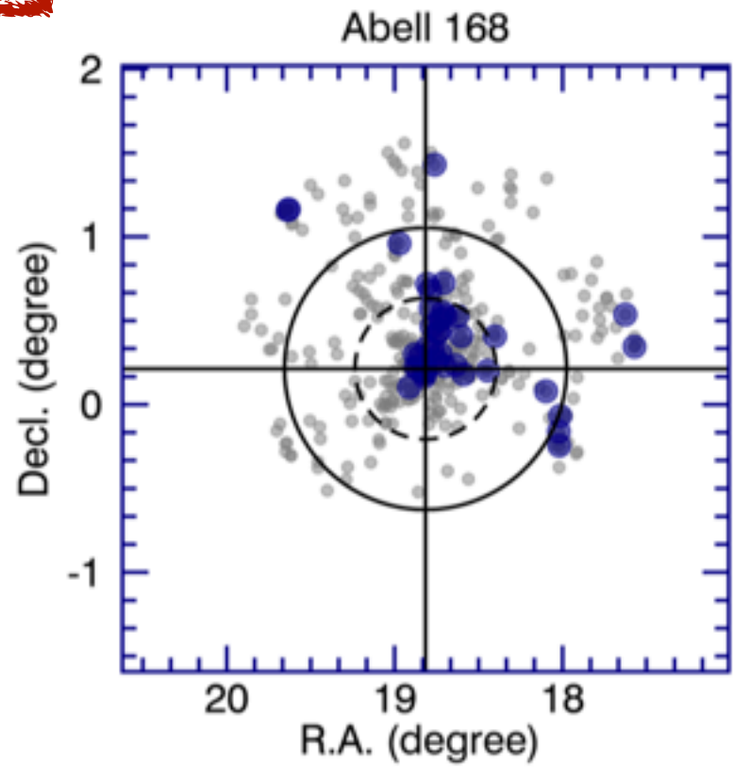
NOTE—R.A., decl., z, M_{200}, and R_{200} are all from Owers et al. (2017).

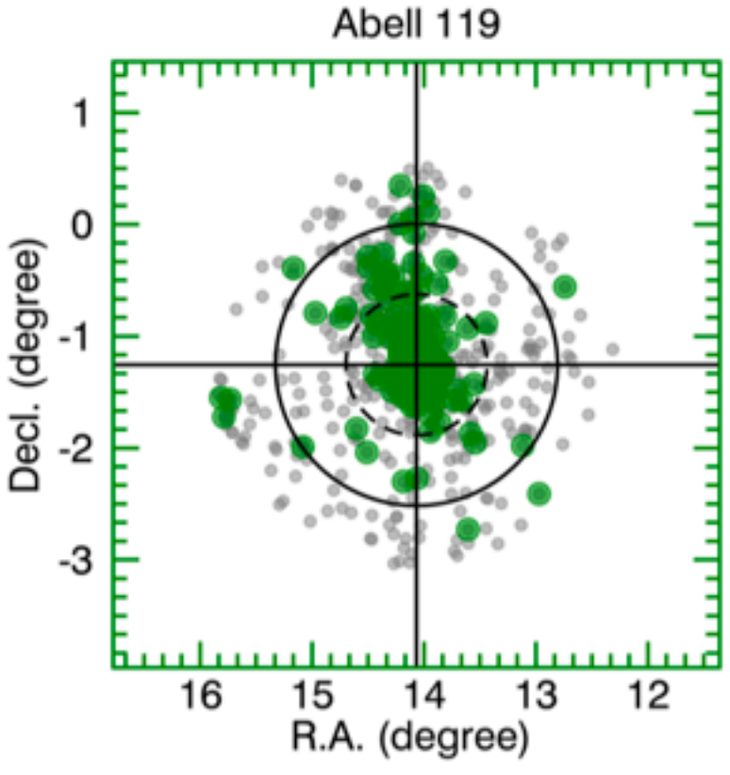
Table 2
Results of Sample Selection

Cluster	$N_{\rm mem}$	$N_{\rm ETG}$	$N_{\rm ETG,PA_{kin}}$
A119	695	133	79
A168	364	40	24

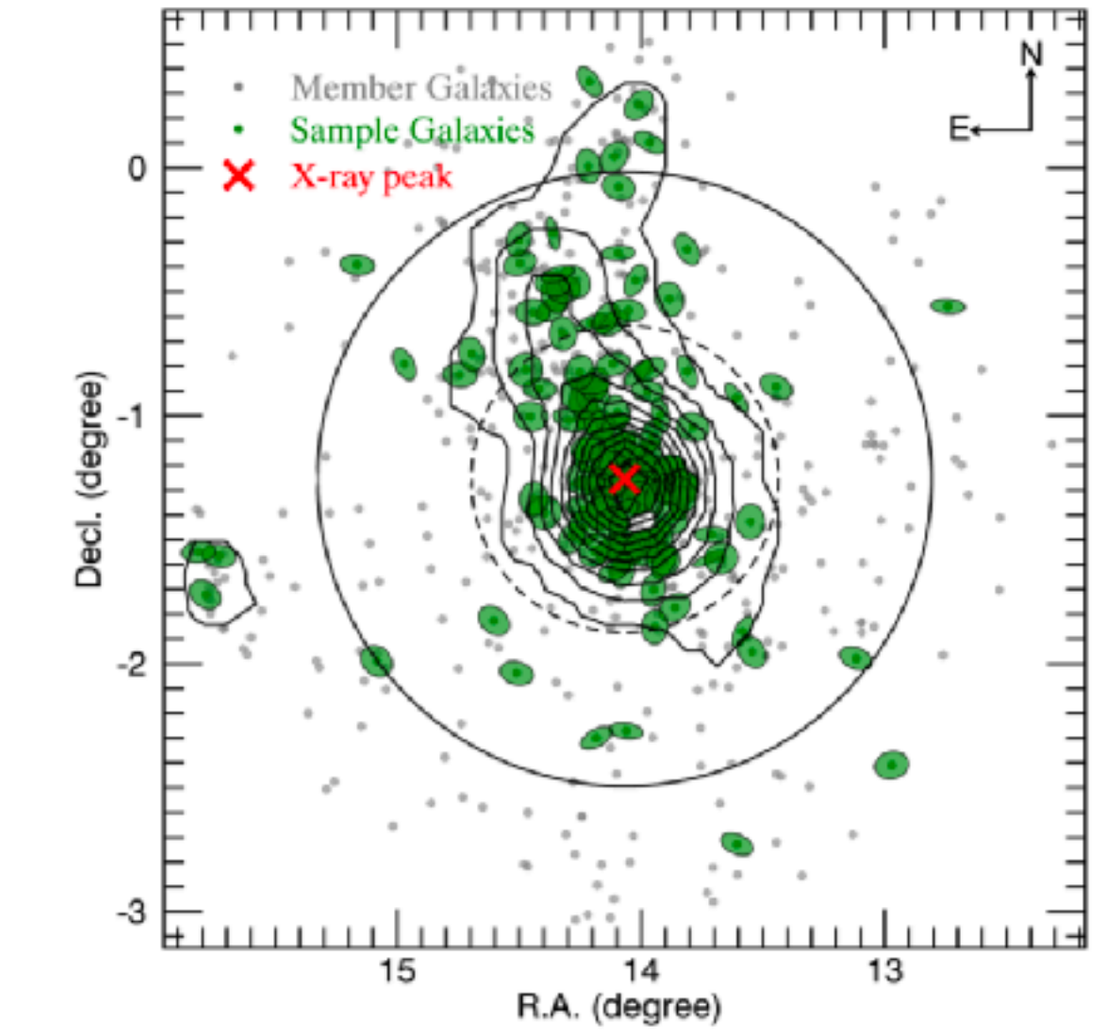
Note. $N_{\rm mem}$ is the total number of member galaxies in each cluster from Owers et al. (2017). $N_{\rm ETG}$ is the total number of luminous early-type members ($M_r \leqslant -19.5$ mag) that are used in this study, while $N_{\rm ETG,PA_{kin}}$ is the number of galaxies with the $\rm PA_{kin}$ from SAMI among our sample.







Abell 119: Early-type sample galaxies in A119 prefer the specific PA value of ~ 95°.



Jeong et al. 2019

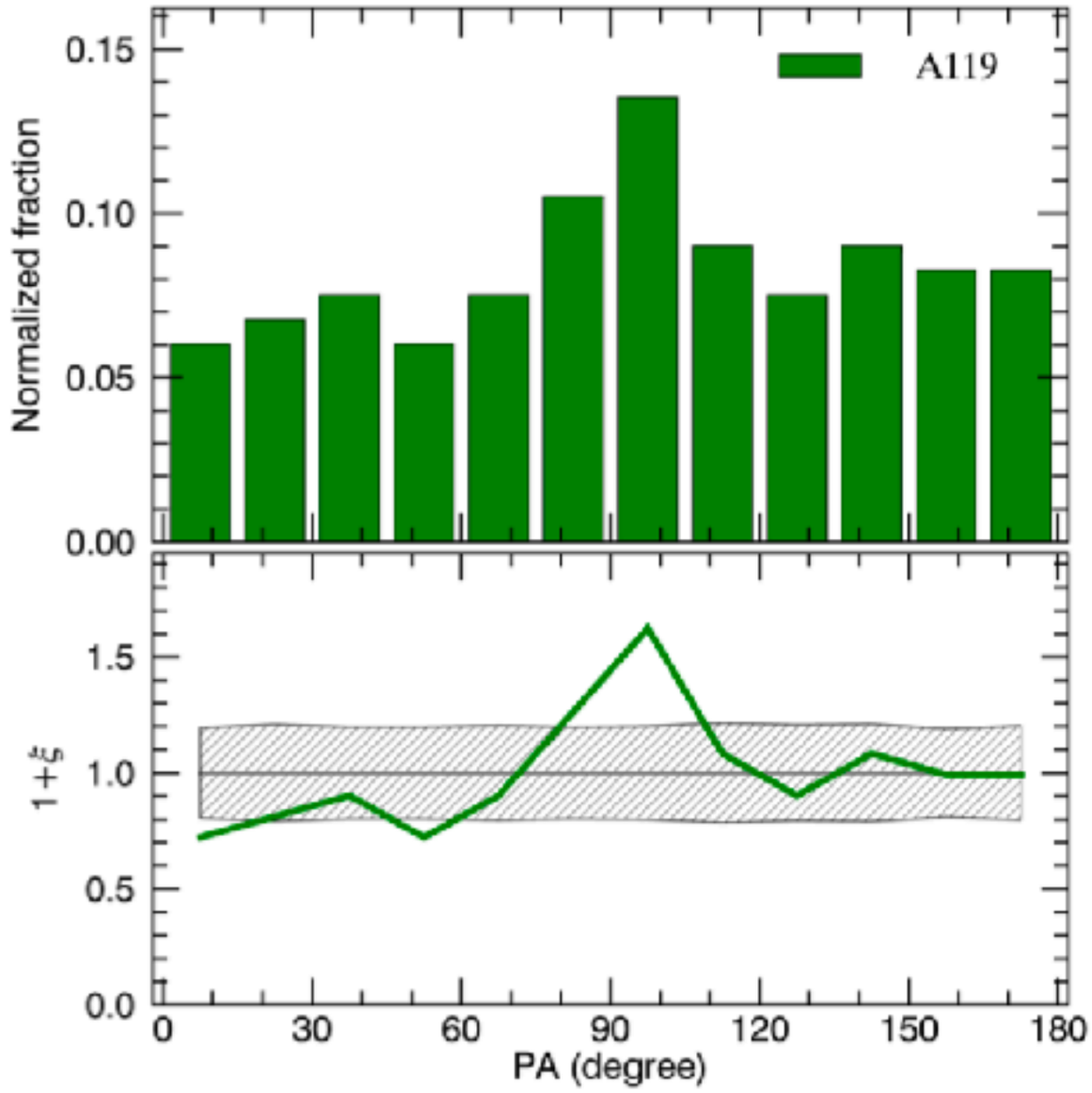
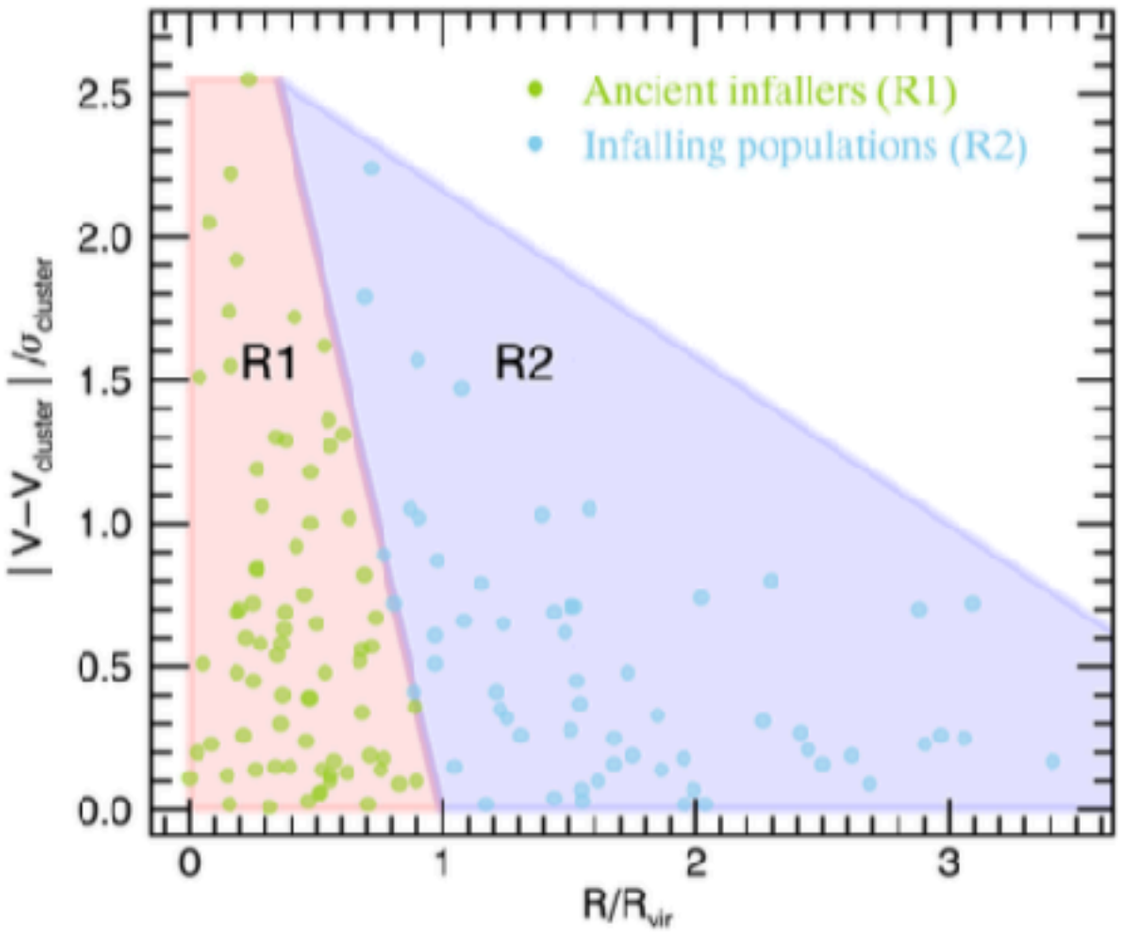
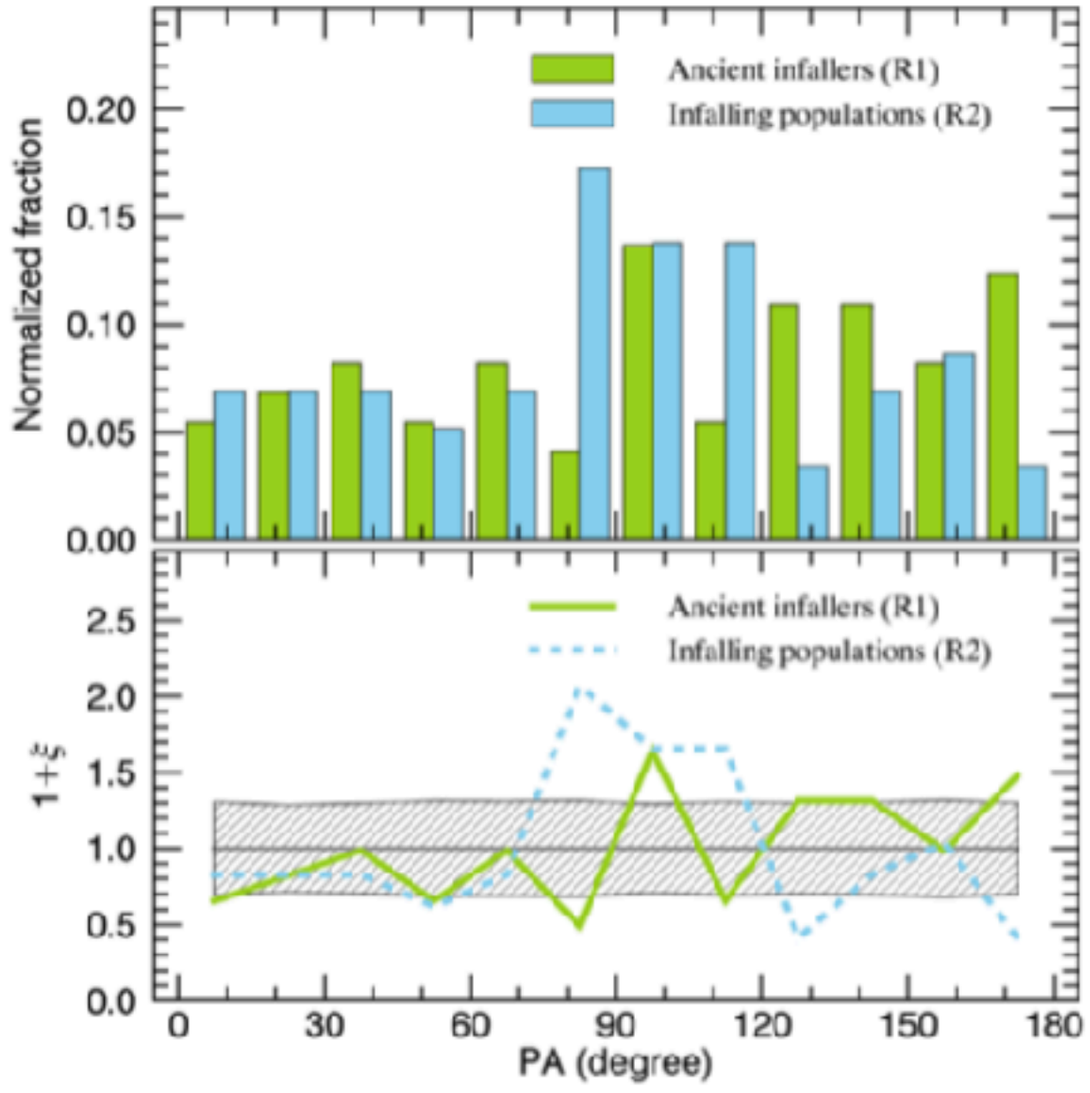


Figure 4. Distribution of the position angles (PA; top) and the probability distribution function (PDF; bottom) of $1+\xi$ for our 133 luminous early-type sample galaxies in Abell 119, with a bin width of 15°. The PDF of the uniform distribution is shown as the gray solid line in the bottom panel, and the $1\,\sigma$ confidence level is also presented as gray shaded regions.

Abell 119: Galaxies in the outer regions of the cluster exhibit a more prominent alignment signal.

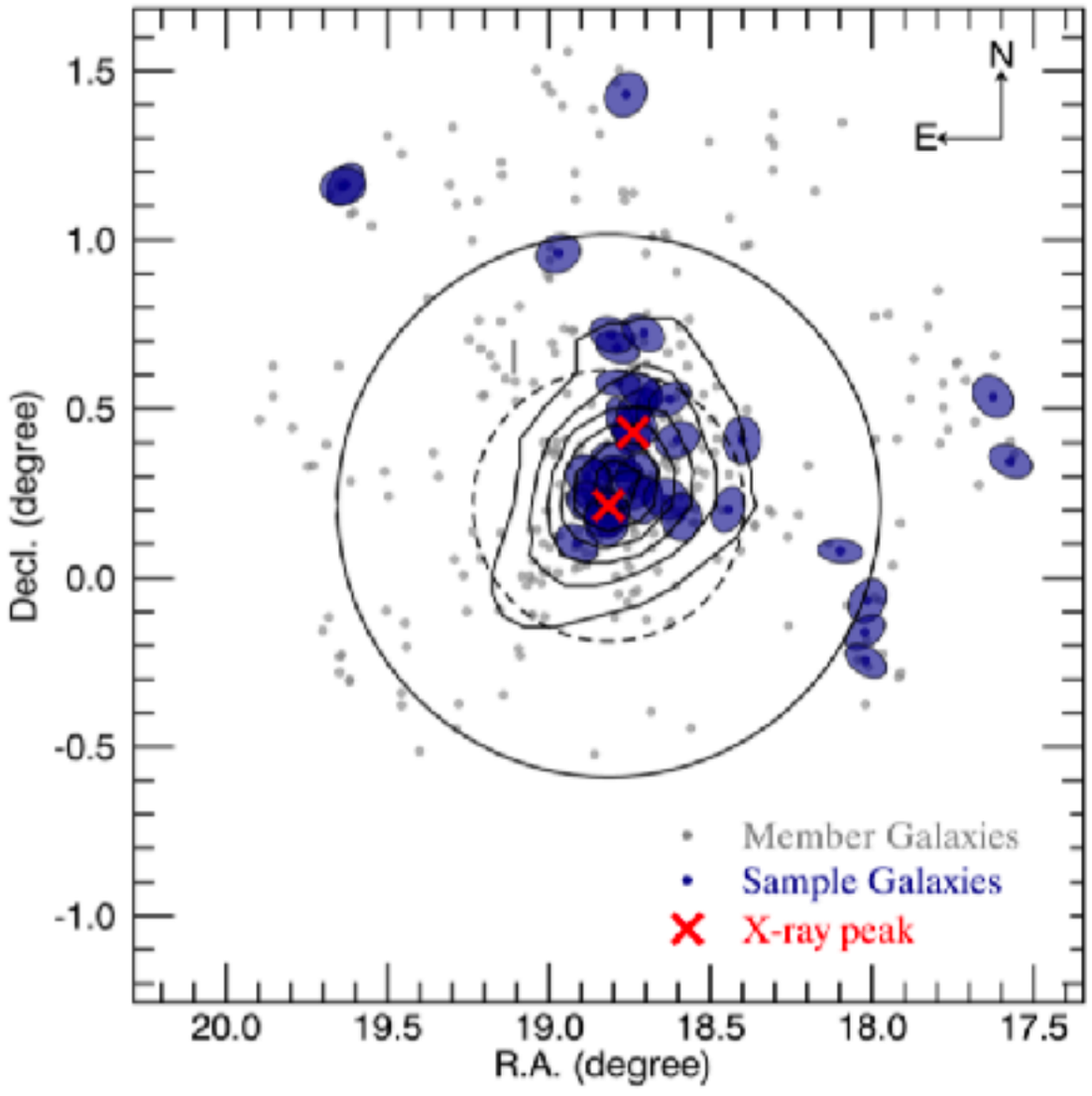




Jeong et al. 2019

According to the simulation, **cluster environments do not efficiently re-orient galaxy spin vectors** unless a merger or strong tidal perturbation was encountered. Nevertheless, **the change in the spin axis tends to increase with time** after infall of a galaxy into the cluster.

Abell 168: Early-type sample galaxies in A168 prefer the specific PA value of ~ 95°.



Jeong et al. 2019

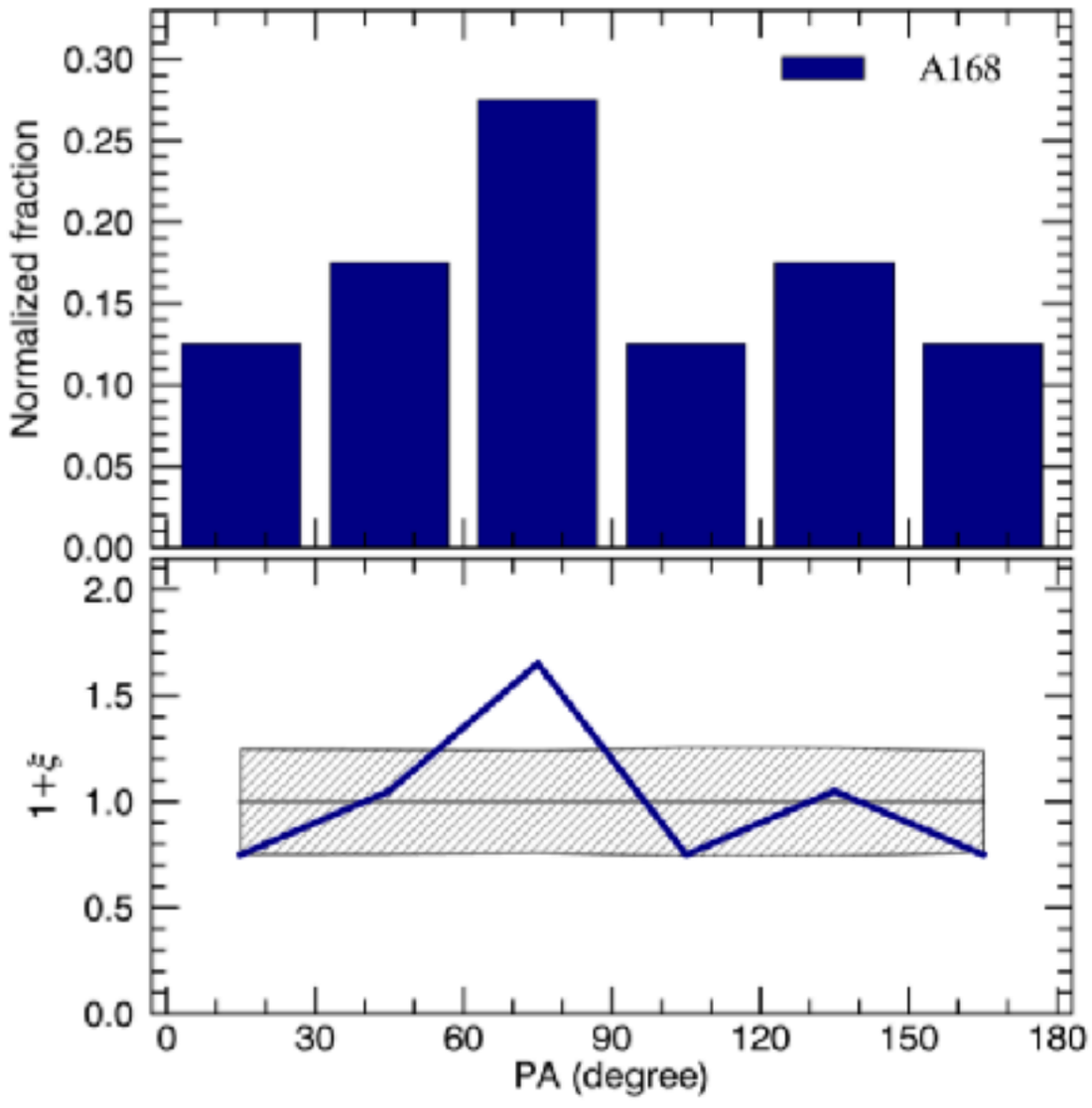
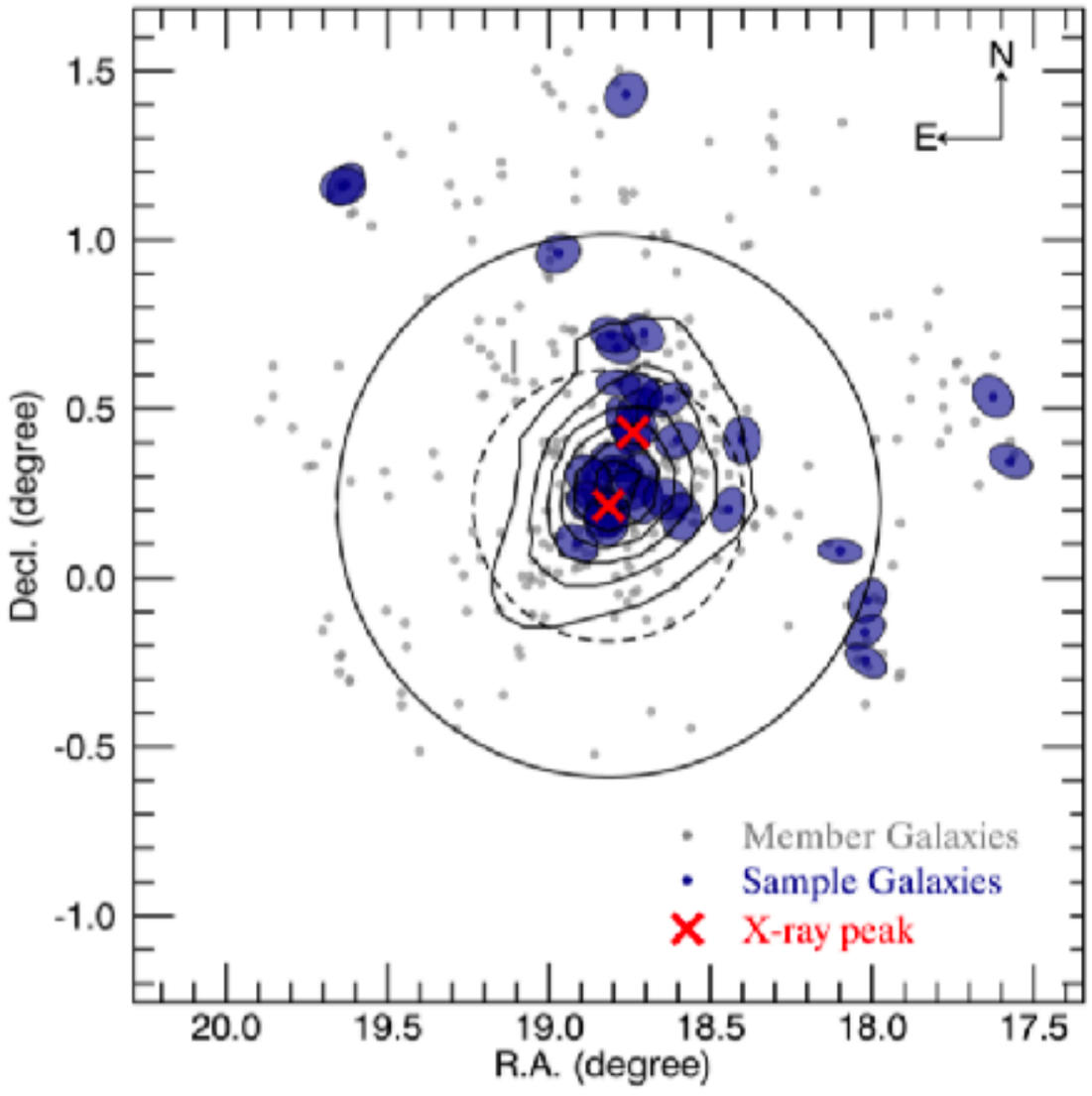


Figure 8. The PA Distribution (top) and the PDF of 1+ξ (bottom) for our 40 luminous early-type sample galaxies in Abell 168, with a bin width of 30°. For comparison, the PDF of the uniform distribution with the 1 σ confidence level is shown in gray in the bottom panel.

Abell 168: We found another peak of the PA distribution at roughly 135°



Jeong et al. 2019

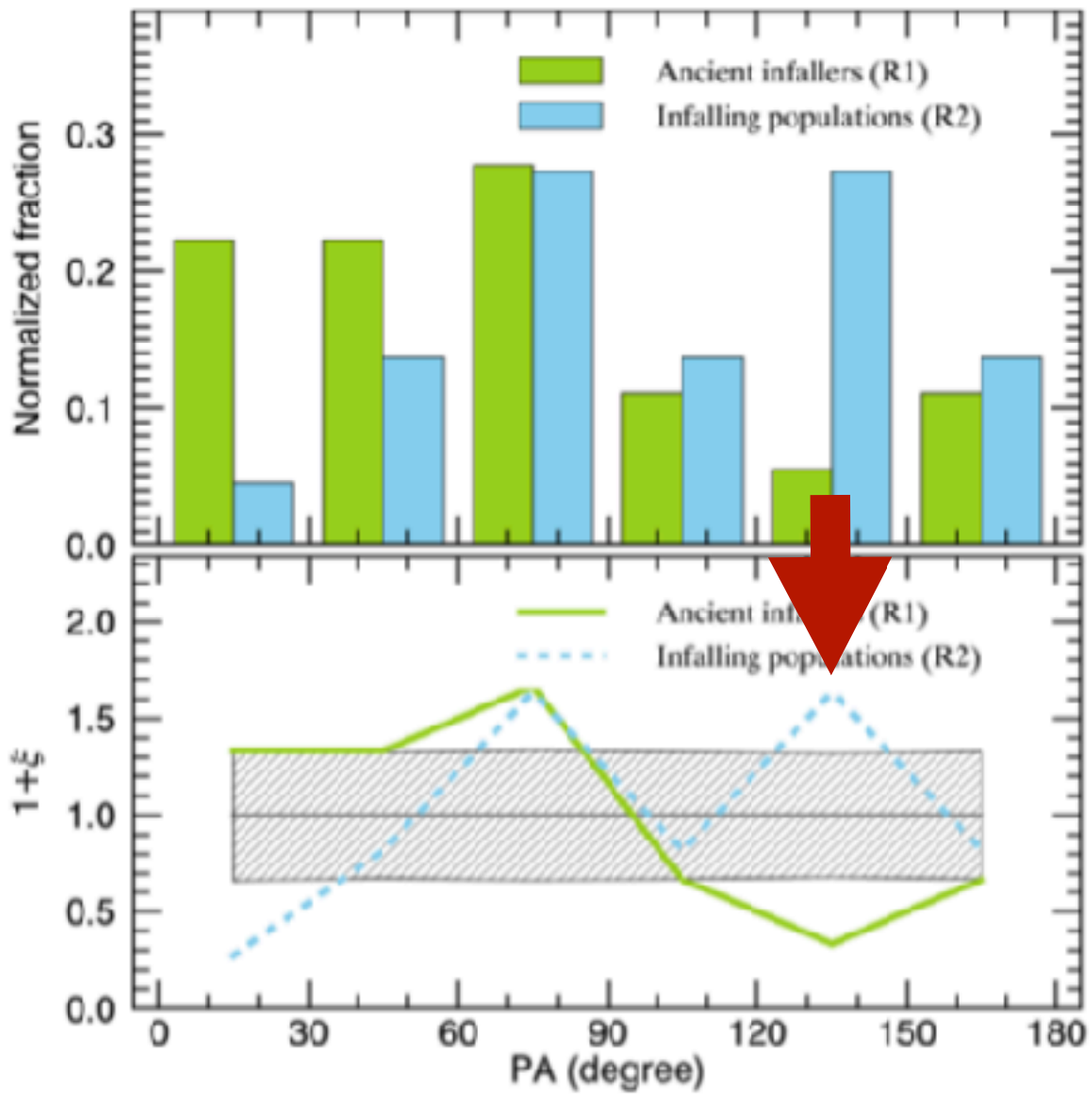
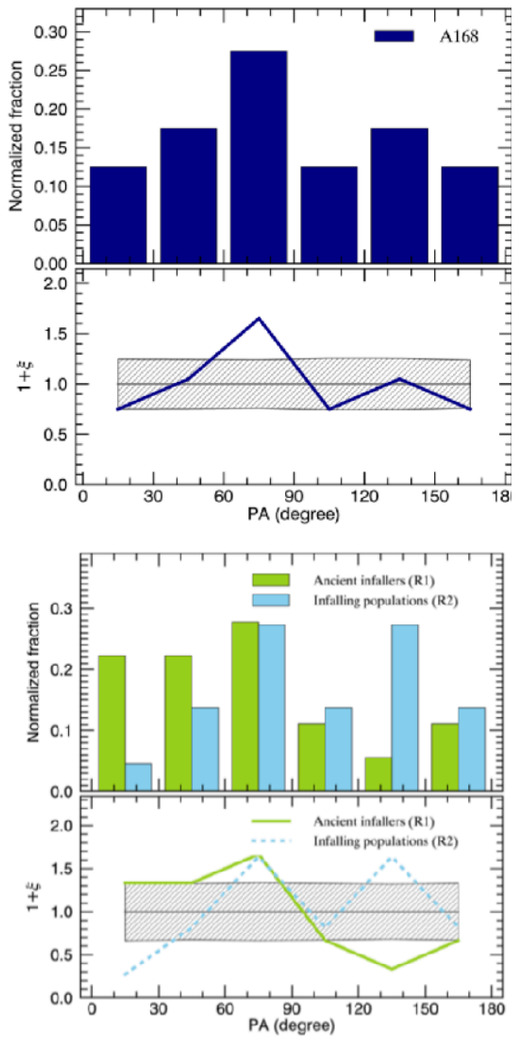
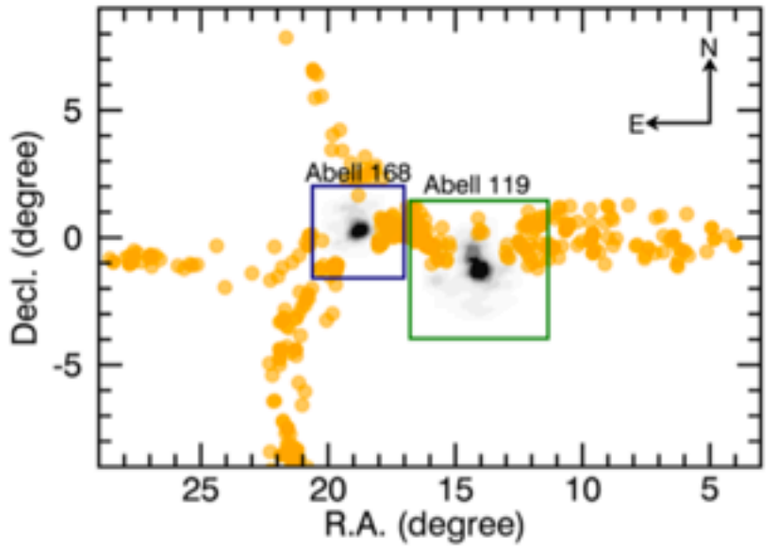


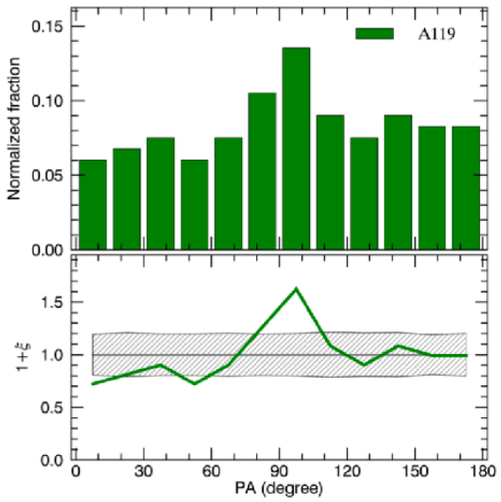
Figure 11. Same as Figure 9, but for two subsamples divided by the position in a phase-space diagram (see Figure 10). Light green represents ancient infallers (18 galaxies in R1 of Figure 10), while sky blue indicates infalling populations (22 galaxies in R2 of Figure 10). The PDF of the uniform distribution is also shown for comparison in gray, with the 1σ confidence level in the bottom panel.

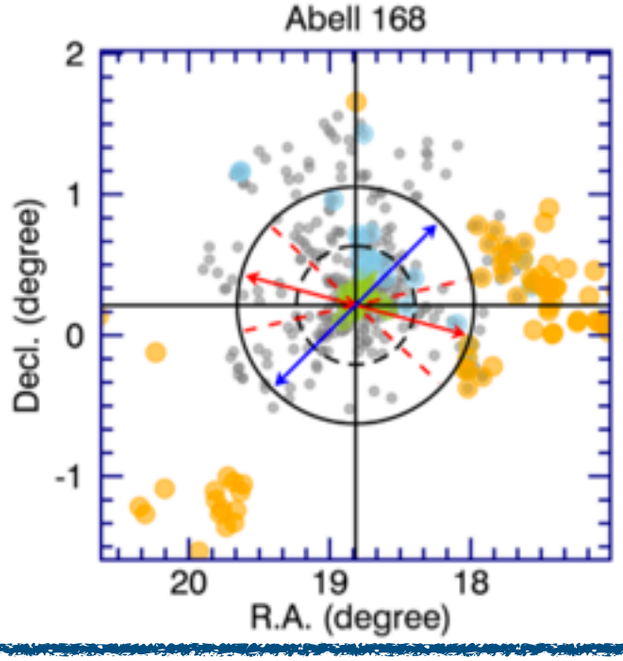
Alignment & Filamentary Structures

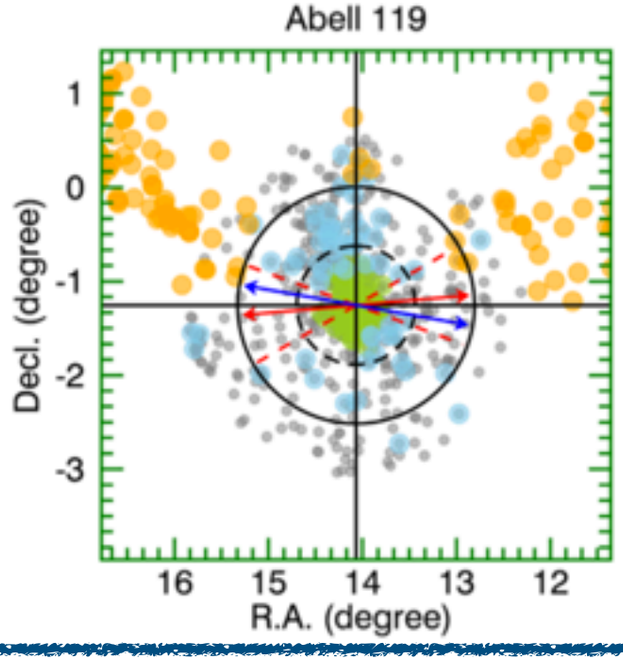


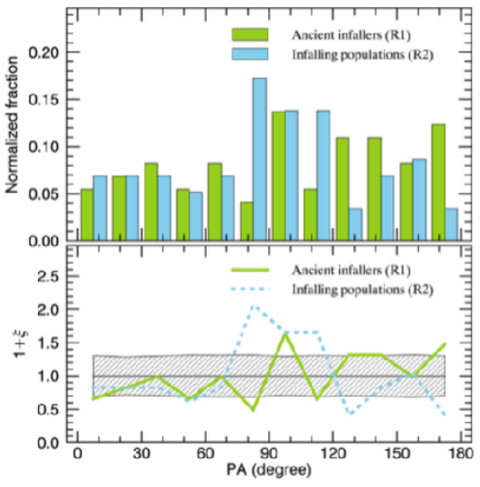


Jeong et al. 2019





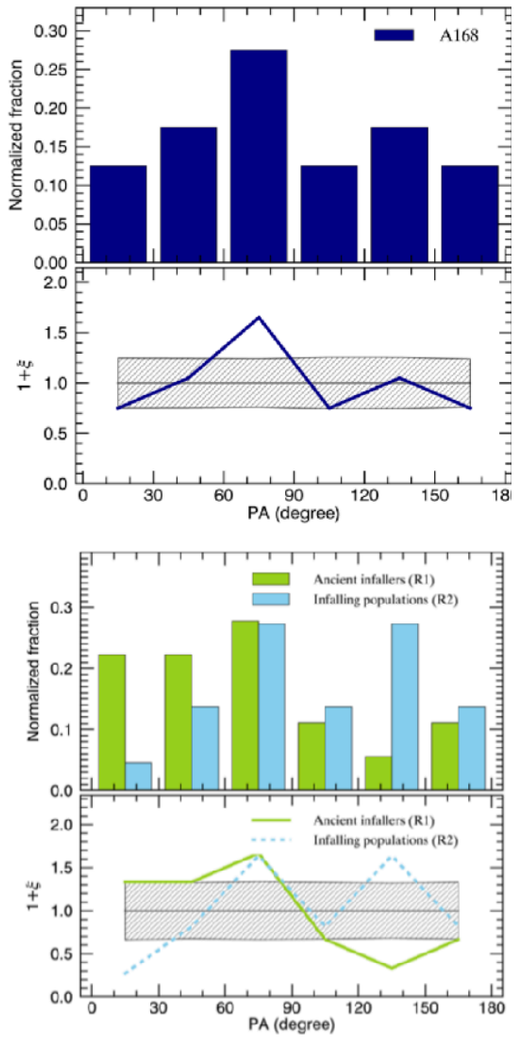


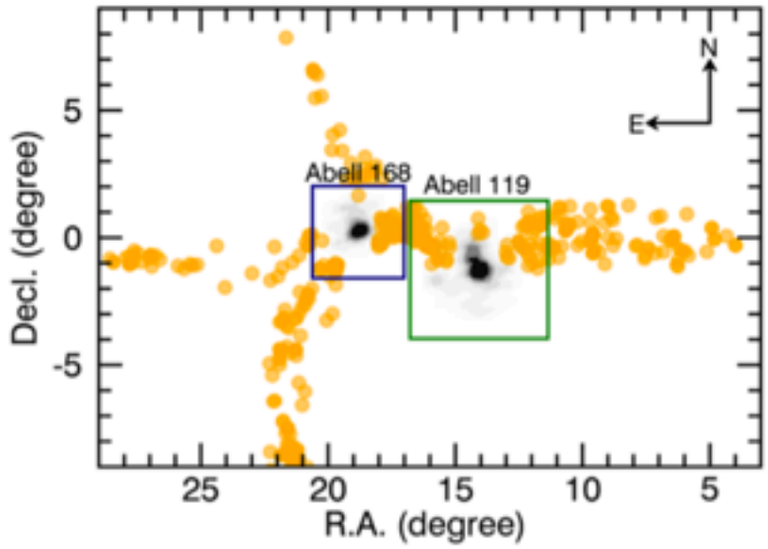


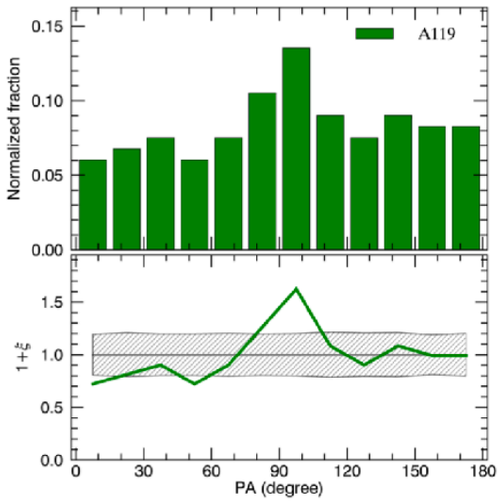
The most important point is that the **alignment angles are closely related to the directions of the filamentary structures around clusters**.

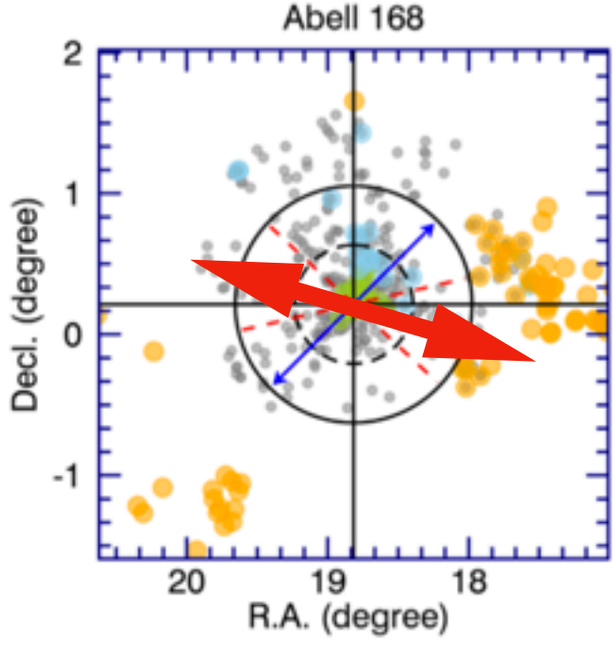
Alignment & Filamentary Structures

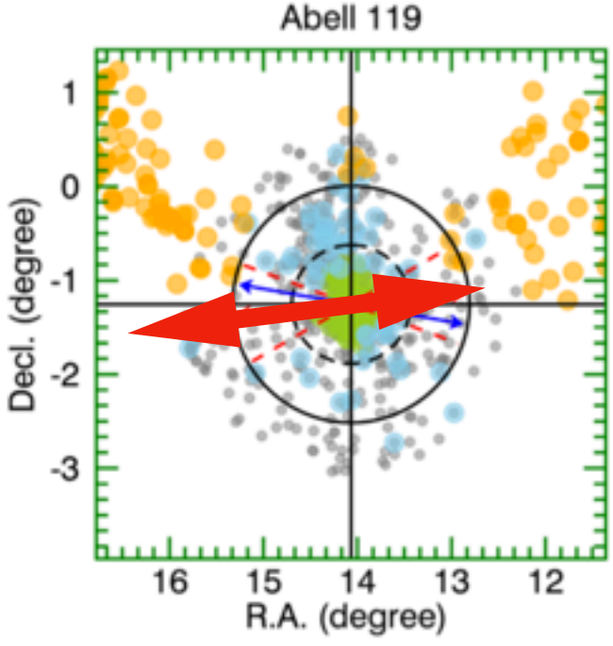
Jeong et al. 2019

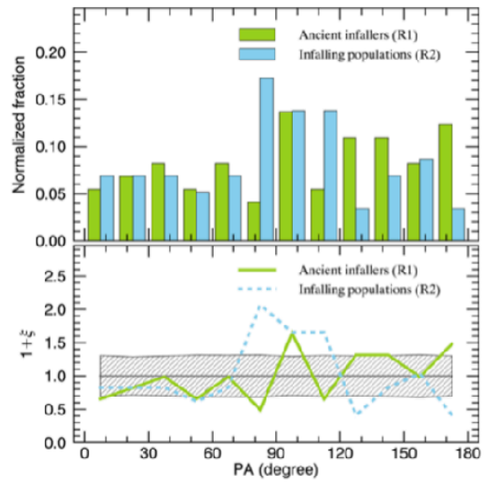








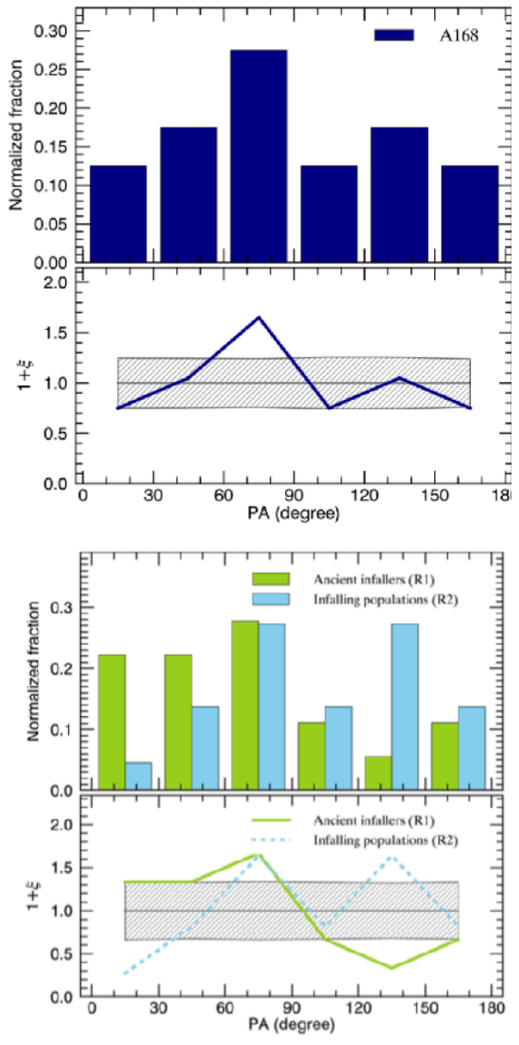


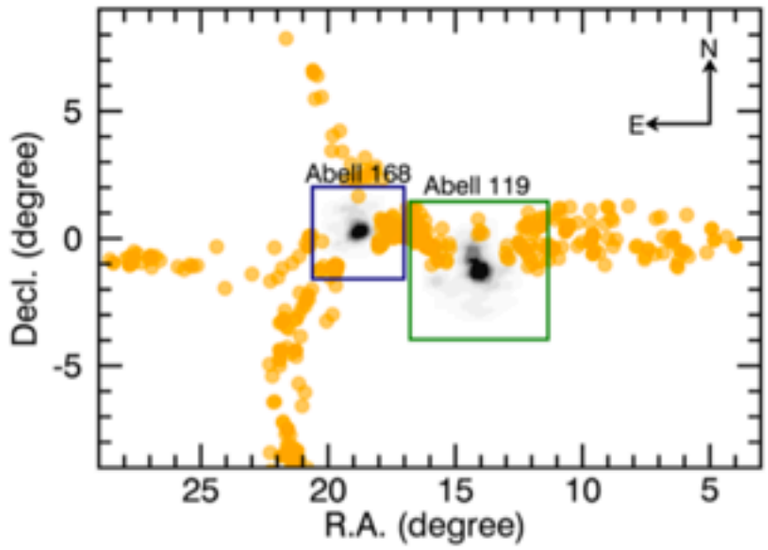


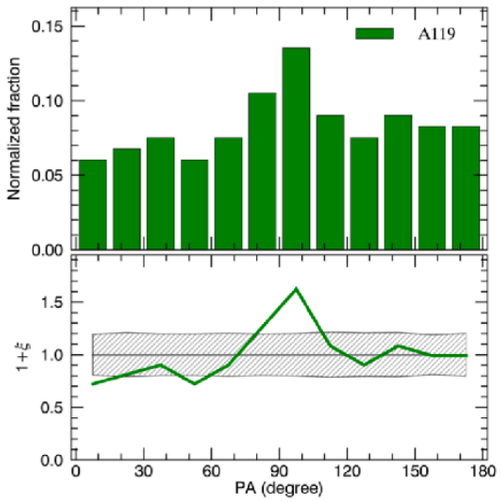
Red arrow: preferred PA of each cluster

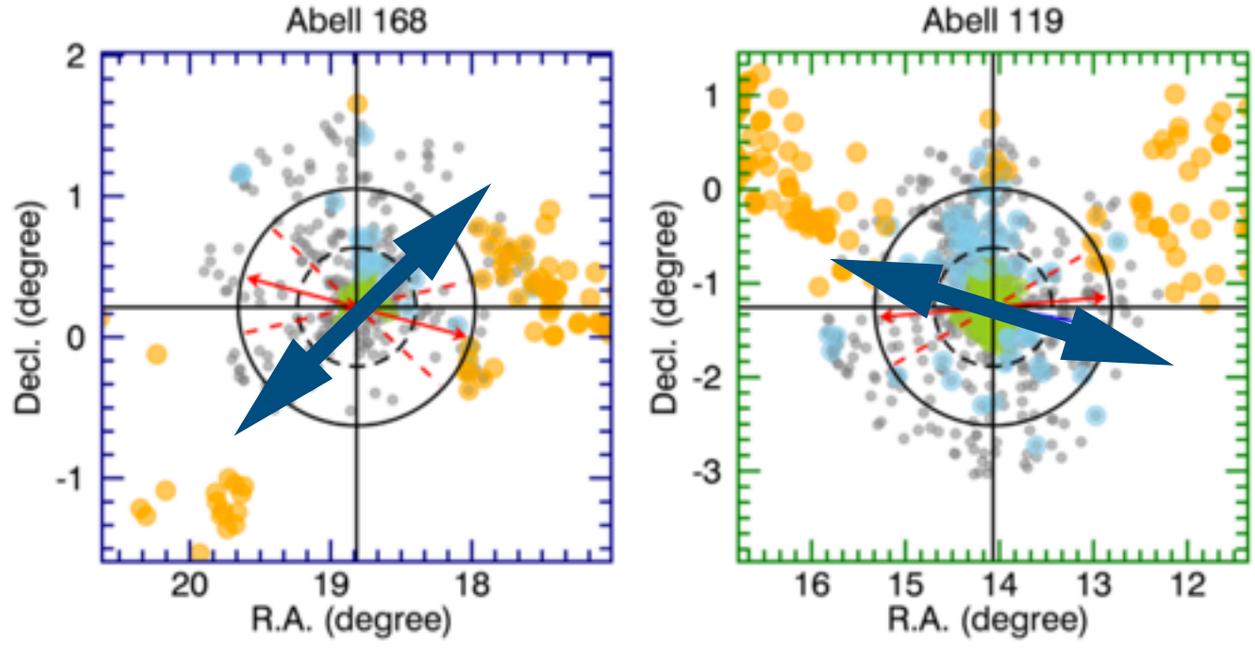
Alignment & Filamentary Structures

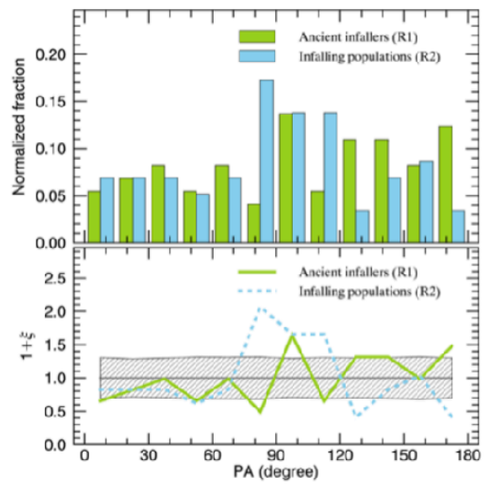
Jeong et al. 2019





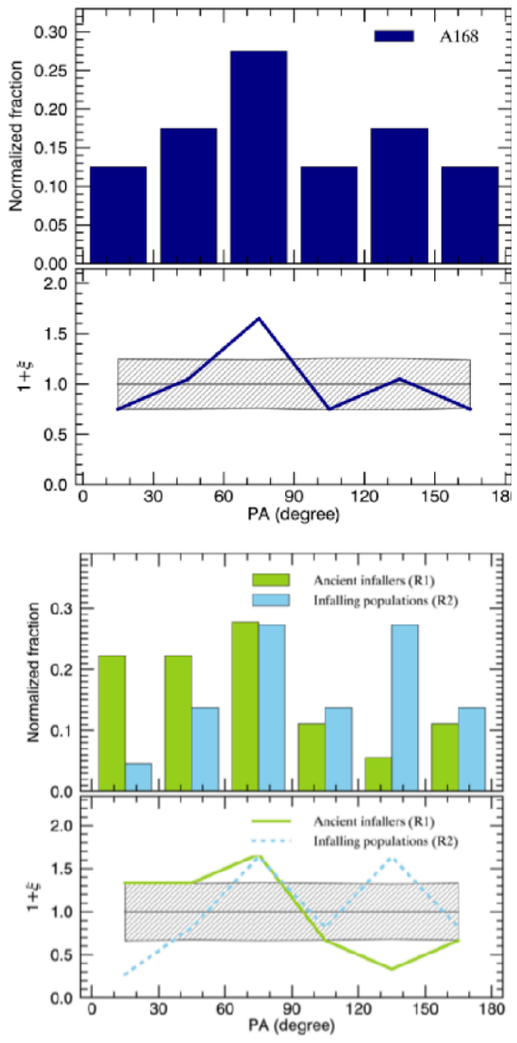


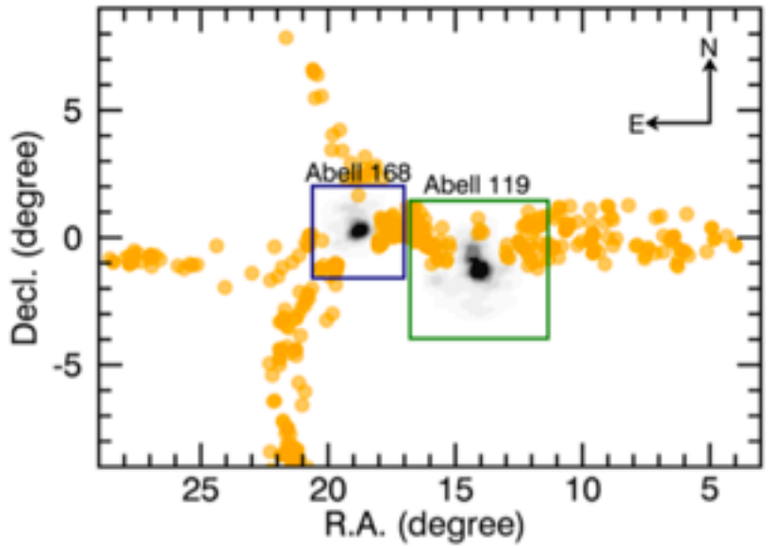




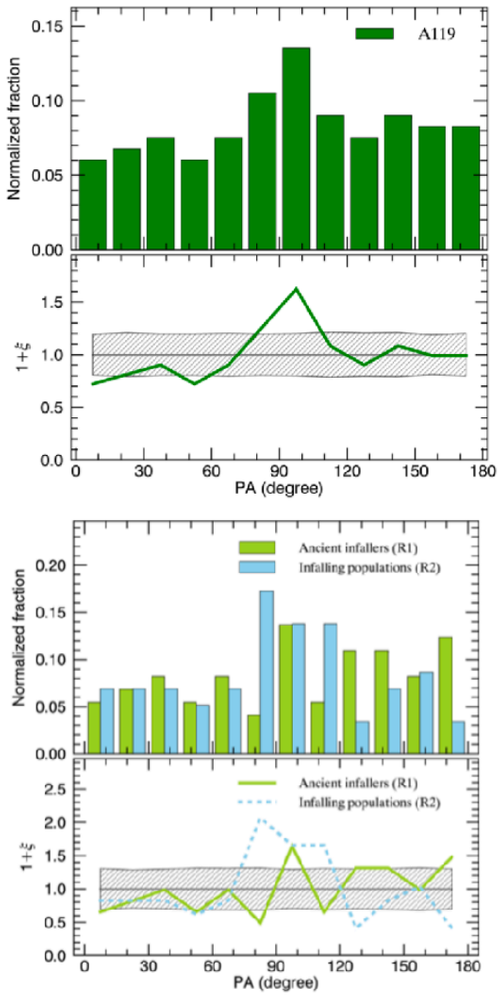
Blue arrow: additional PA associated with infalling populations of each cluster

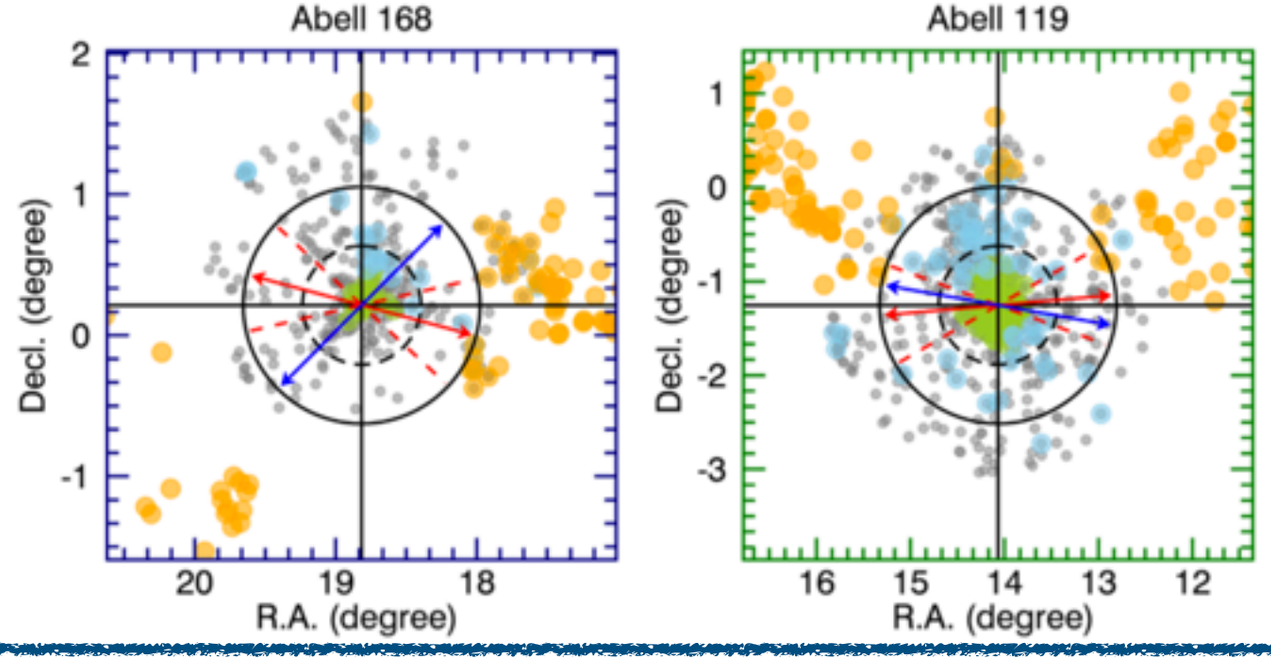
Alignment & Filamentary Structures





Jeong et al. 2019

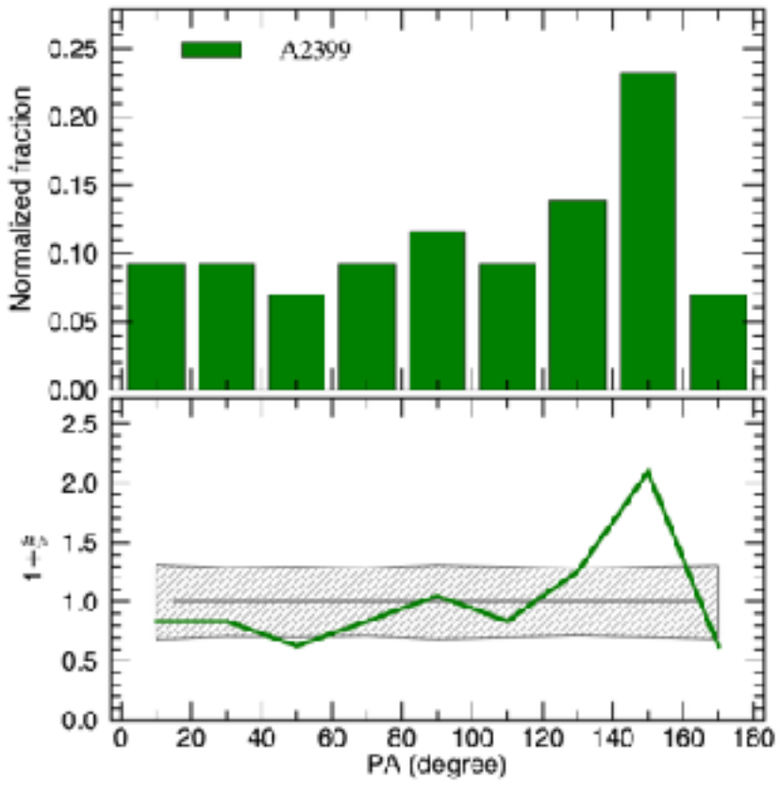


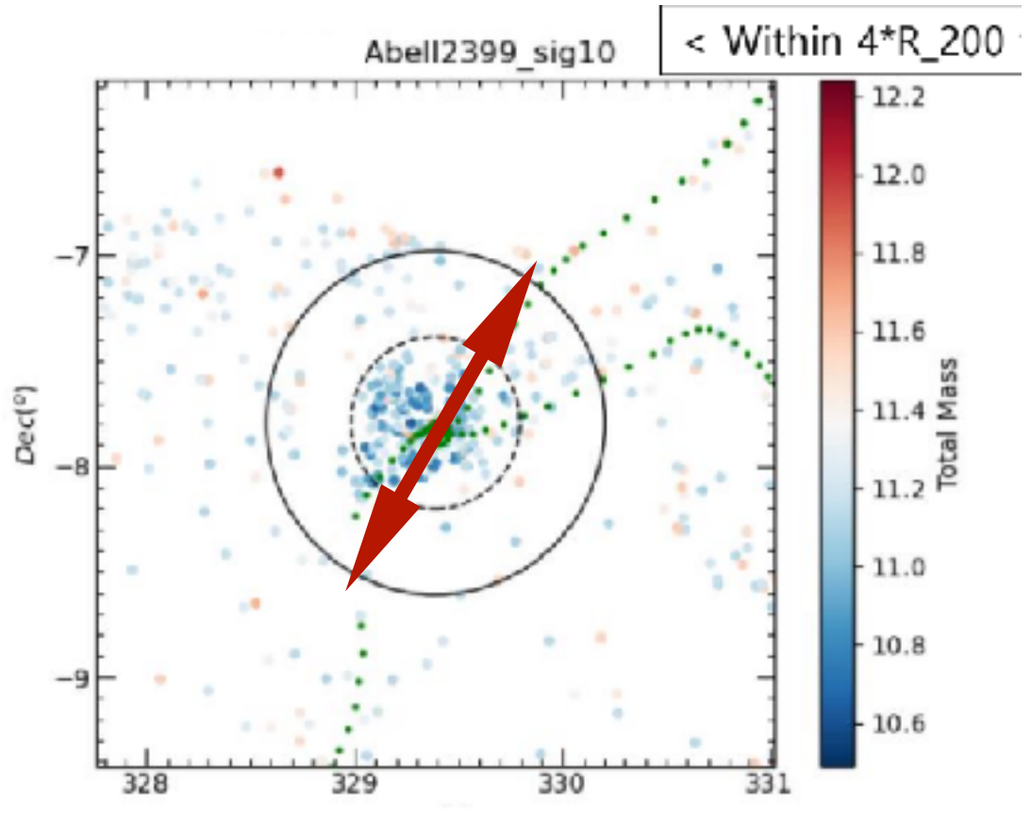


The coincidence between the kinematic alignment angle and the directions of the filaments suggests that the **orientation of the spin axes** of our sample galaxies is **strongly related to the filamentary structures** around this cluster.

Future Work: Abell 2399

Jeong et al. In prep.





Early-type sample galaxies in **A2399 prefer the specific PA value of ~ 150°**, and it may be related to the filaments around the cluster.

* PAkin for 35 galaxies & PA phot for 8 galaxies

Summary

- We investigate the kinematic alignments of luminous early-type galaxies (Mr < -19.5 mag) in Abell 119 and Abell 168 using the kinematic position angles from SAMI IFU survey.
- To increase the size of our sample for statistical significance, we also use the photometric position angles for some galaxies, if their ellipticities are higher than 0.15.
- Our early-type sample galaxies in cluster environments tend to prefer the specific position angles.

Summary

- The alignment signal is more prominent for galaxies in the outer regions of the clusters, that is, recently infalling galaxies.
- The alignment angles are closely related to the directions of the filamentary structures around clusters.
- We conclude that many cluster early-type galaxies are likely to be accreted along filaments while maintaining their spin axes, which are pre-determined before cluster infall.

Thank you!