ESSSP 2013

Investigating the correlation between the properties of cluster core galaxies and their hosts

星系團與成員星系的關係

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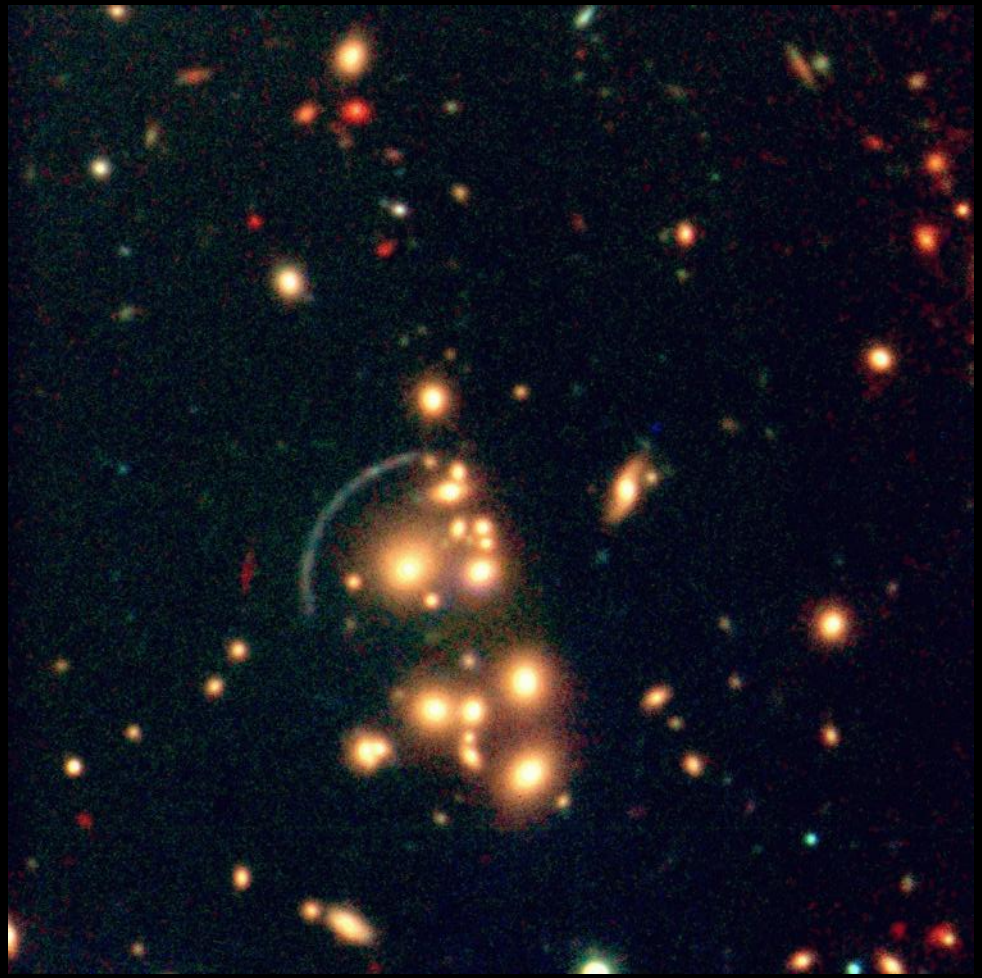
Outline

1. Galaxy cluster evolution & Brightest Cluster Galaxies (BCGs)
2. Motivation of this Project & Methodology
3. Data analysis.
   - I. X-ray clusters
   - II. Comparison with previous work
4. Discussion
5. Future work



Credit: European Southern Observatory

Galaxy Cluster

Member galaxy

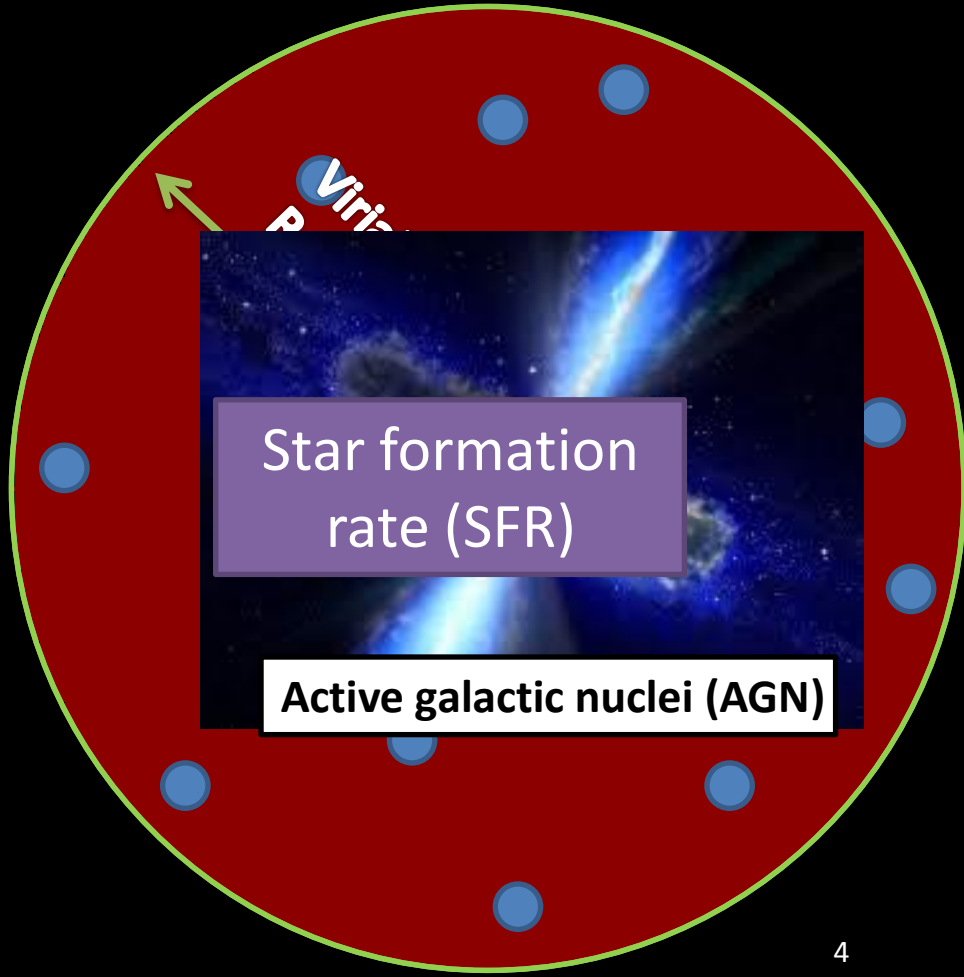
Brightest cluster galaxy (BCG)

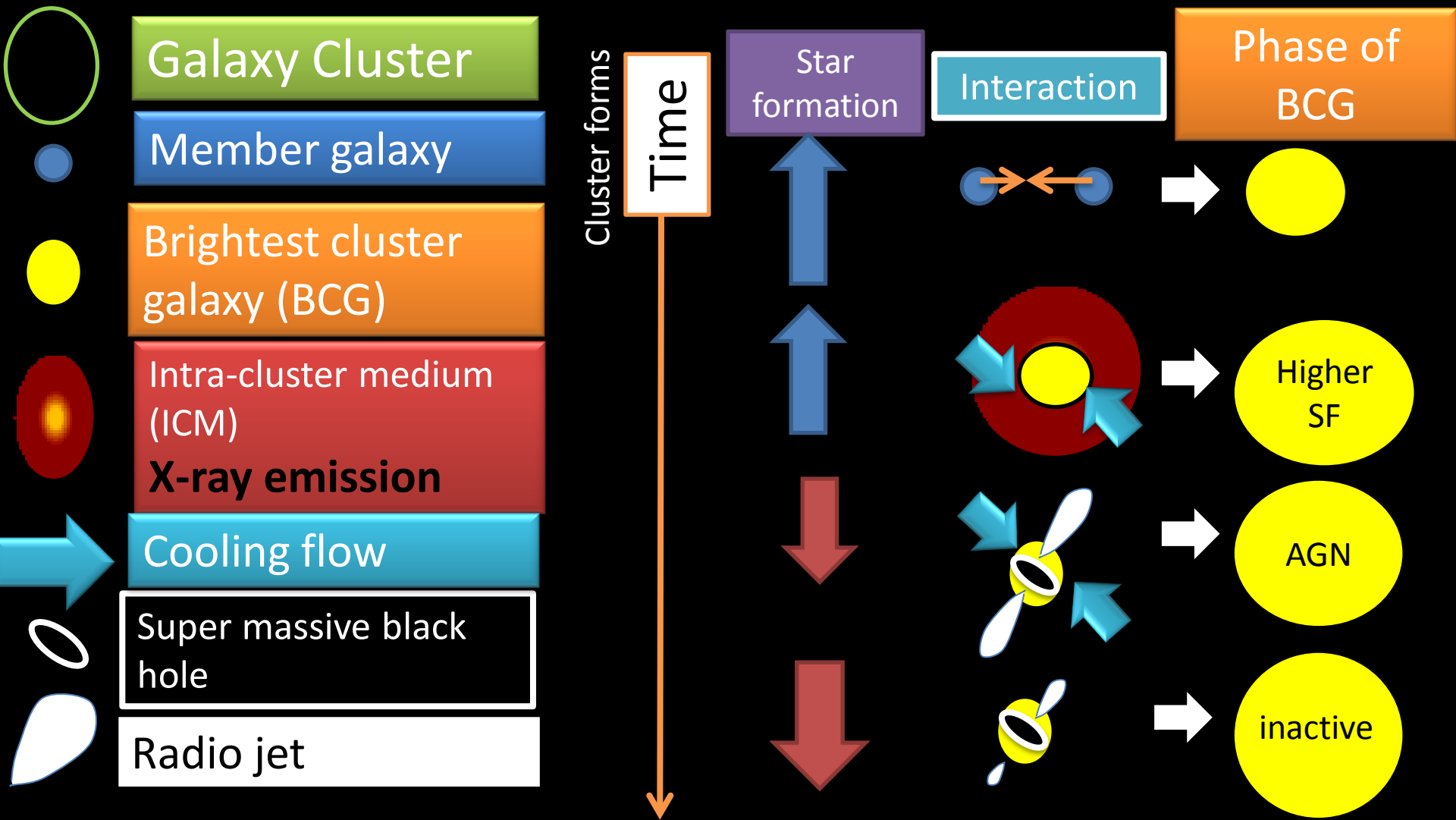
Intra-cluster medium (ICM)
X-ray emission

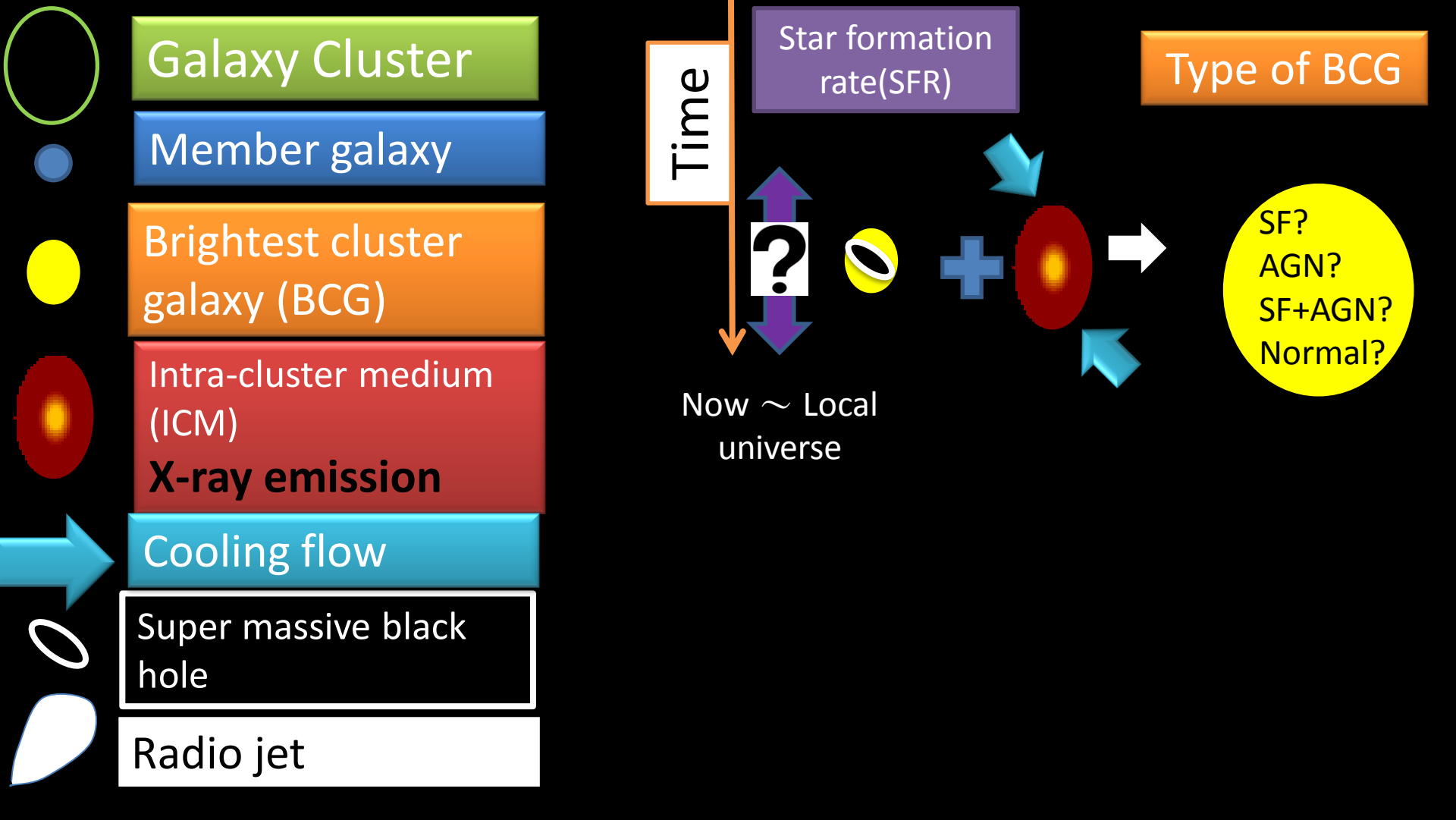
Cooling flow

Super massive black hole

Radio jet

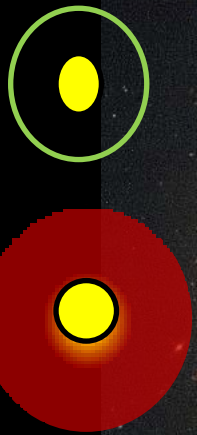



Galaxy Cluster
Member galaxy
Brightest cluster galaxy (BCG)
Intra-cluster medium (ICM)
X-ray emission
Cooling flow
Super massive black hole
Radio jet
Cluster forms
Time
Star formation
Interaction
Phase of BCG
Higher SF
AGN
inactive


Galaxy Cluster
Member galaxy
Brightest cluster galaxy (BCG)
Intra-cluster medium (ICM)
X-ray emission
Cooling flow
Super massive black hole
Radio jet
Time
Star formation rate(SFR)
Type of BCG
?
Now ～ Local universe
SF?
AGN?
SF+AGN?
Normal?

Brightest Cluster Galaxy (BCG)

- BCG is generally the most luminous and massive galaxy in a galaxy cluster, ***usually*** located in the center of cluster.
- According to the BCG properties, we can infer that the BCG environment is different from other galaxies.
- Star formation rate of BCG is a good indicator of the evolution stage of the host cluster.



M87 © Anglo-Australian Observatory
Photo by David Malin

Motivation of this Project

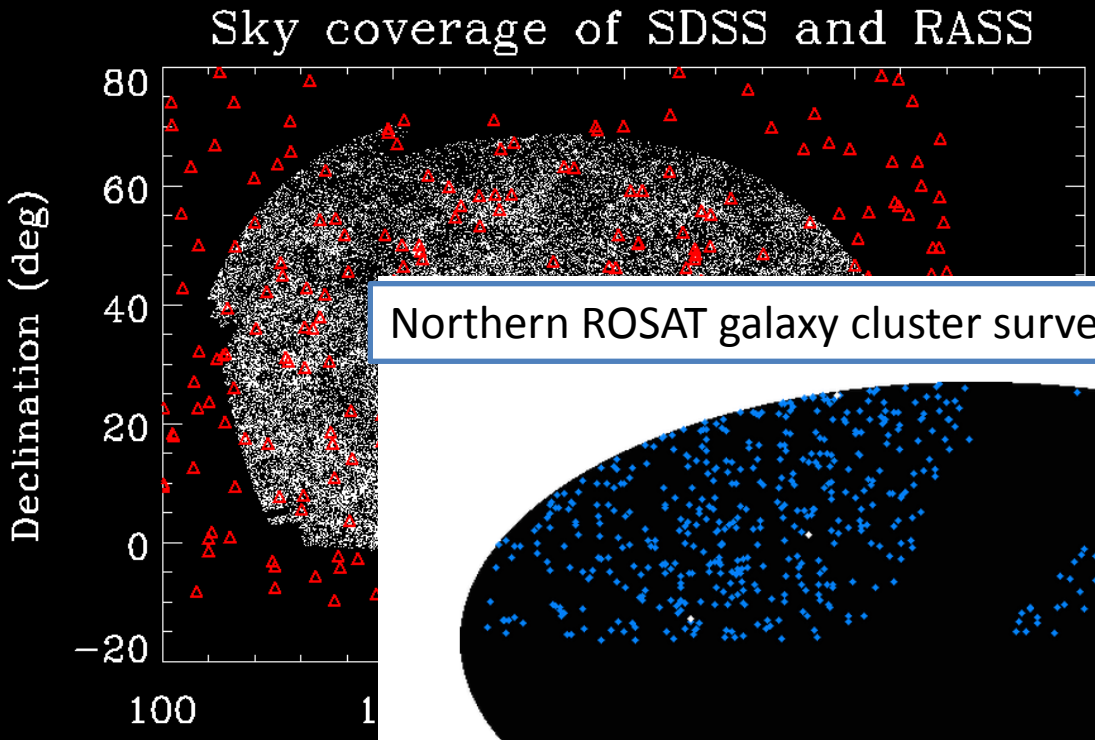
- How does the environment of BCG influence its star formation (SF) compared to other galaxies?
- What effects of AGN feedback influence the BCG SF at X-ray cluster center in local universe?
- How do we investigate the redden BCG with only photometric data due to large distance?

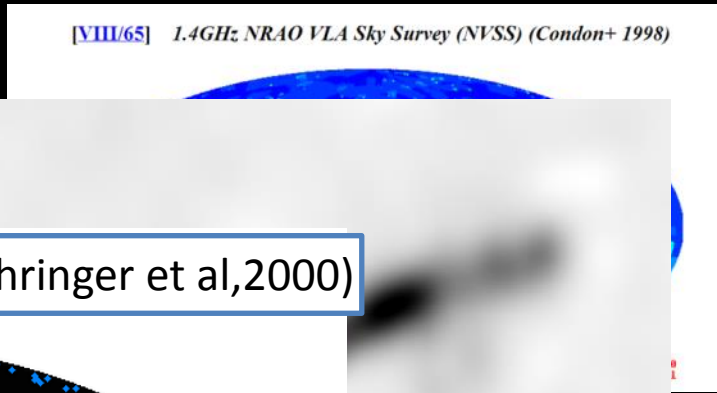
Active galactic nuclei

Sloan Digital Sky Survey

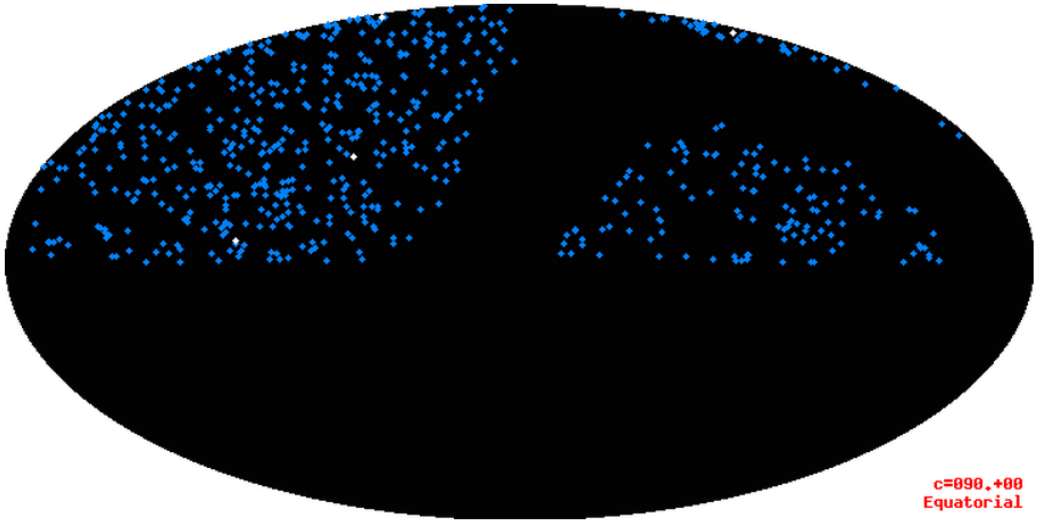
ROSAT All sky survey

NRAO VLA Sky Survey





Northern ROSAT galaxy cluster survey (Böhringer et al,2000)



tional Radio
observatory of Very

Dots are

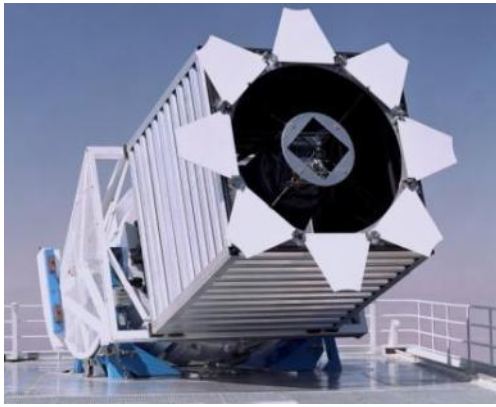
Cross are

Optical catalog

Sloan Digital Sky Survey Data Release 8 galaxy clusters (Tempel, et al. 2012)

– Complete spectroscopic data

- Emission line data



Credit: DSS3.com

- **Derived physical properties. [DR9]**
  i.e. Star formation rate (solar mass per year)

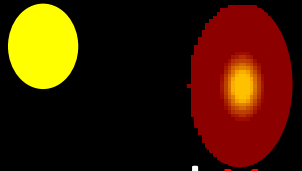
(derived by a team of Johns Hopkins University, the Max-Planck-Institute for Astrophysics)

Overview of data analysis

Optical galaxy cluster

– Number of member galaxies >> **Physical galaxy cluster**

– Luminosity >>>>>>>>>>>>>>>> **Brightest Cluster Galaxy**



X-ray counterpart

– Position separation between cluster and X-ray source
>>>>>>>>>>>>>>>>>>>>>>>>>>>> **To find the X-ray cluster**

Star formation rate of BCG

– >>>>>>>>>>>>>>>>>>>>>>>>>>>> **Indicator of cluster phase**

Criteria

Brightest Cluster Galaxy

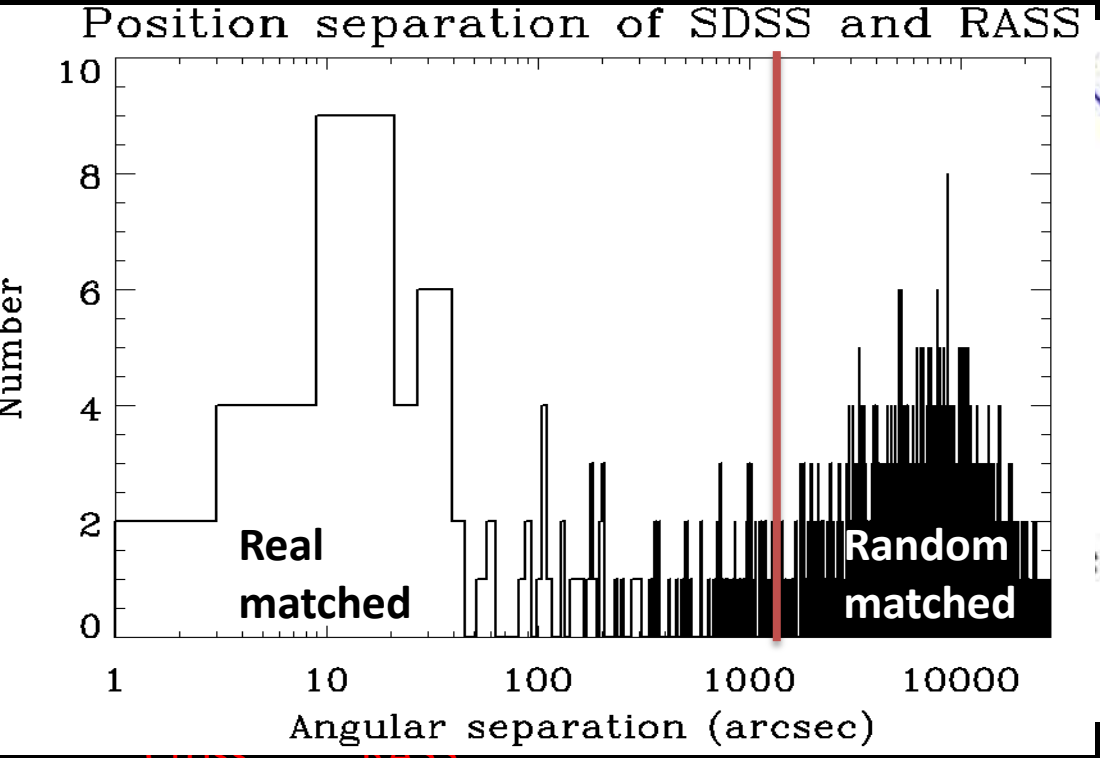
- Number of cluster members have to be $\geqq$ 9.
- Most luminous cluster galaxy

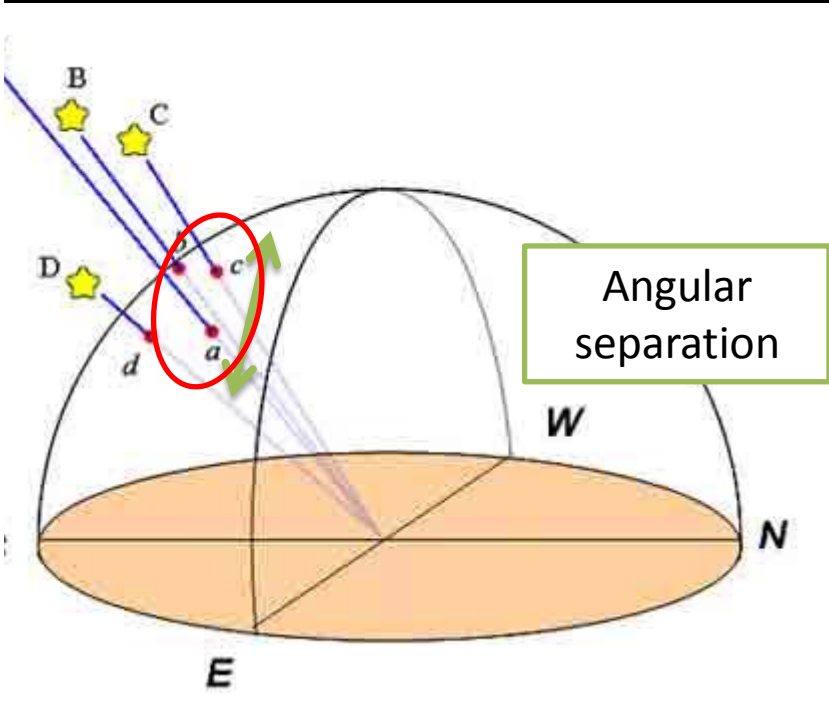
X-ray Cluster **candidates**

followed the Northern *ROSAT* all-sky (NORAS) galaxy cluster survey

- Extended radius $\geqq$ 25 arcsec
- Extent likelihood $\geqq$ L = 7
- Count rate $\geqq$ 0.06 count/ sec

Cross-matched SDSS DR8 with *ROSAT* all sky survey

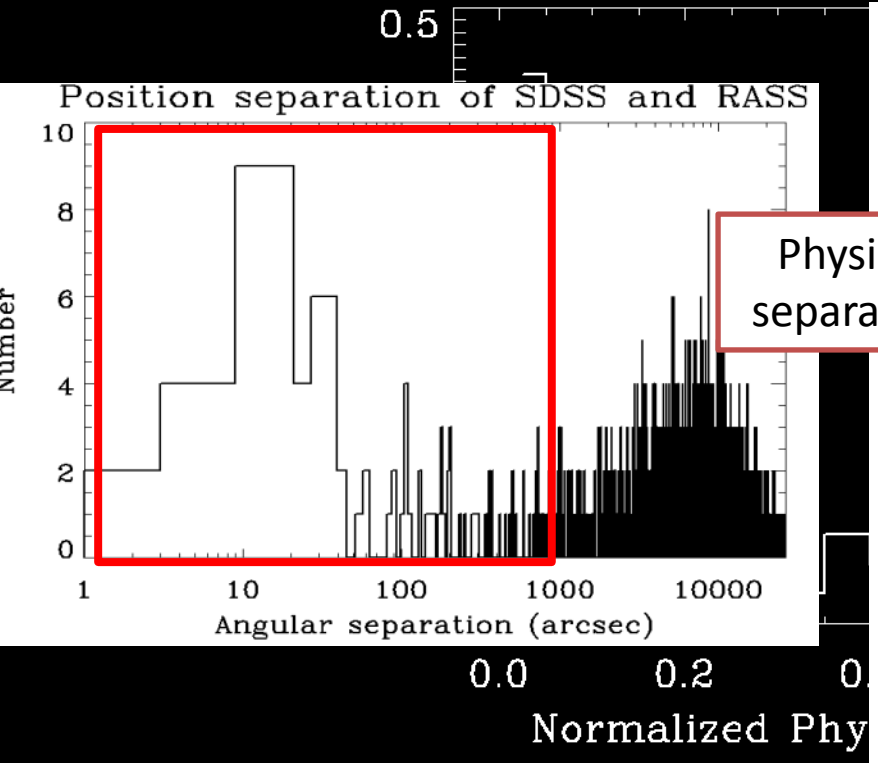


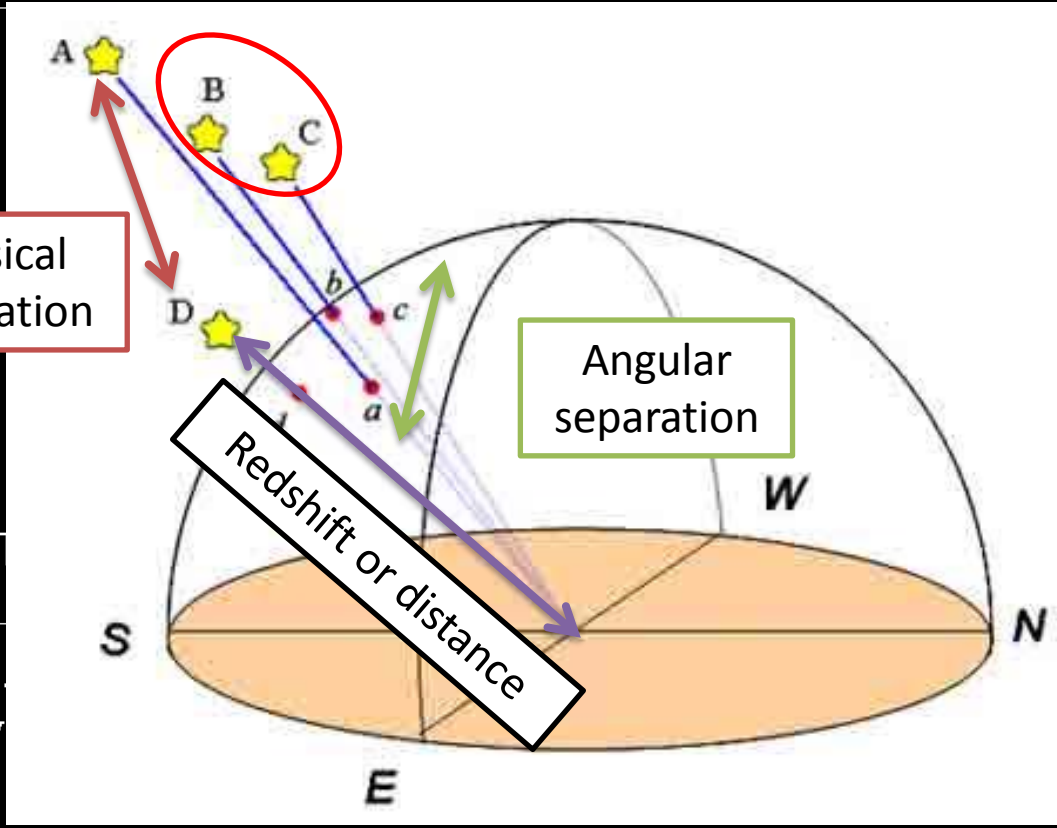


Cross : RASS

Triangles : SDSS DR8

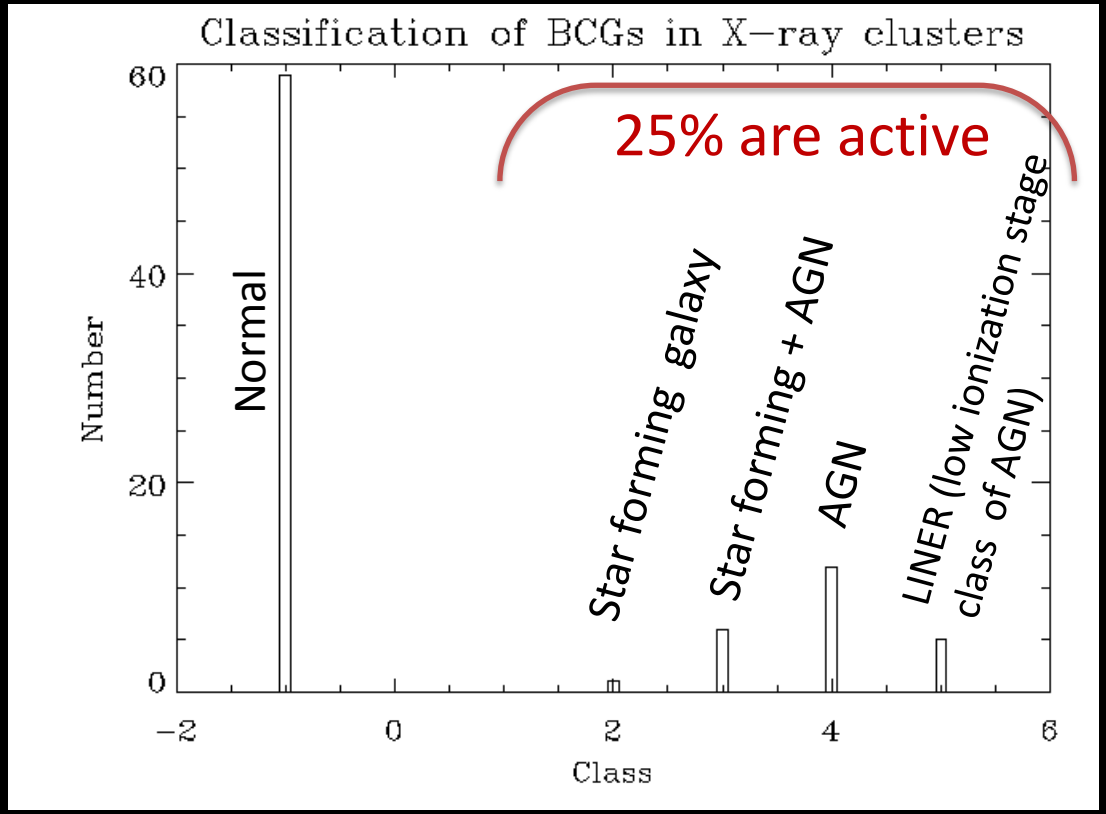
Histogram of Normalized Physical Separation





Assuming the X-ray sources have same redshift as BCG, and calculate the physical separation.

BCG class in X-ray cluster



Normal class:
BCG is weak or no emission line to classified

(classification is made by a team of Johns Hopkins University, the Max-Planck-Institute for Astrophysics)

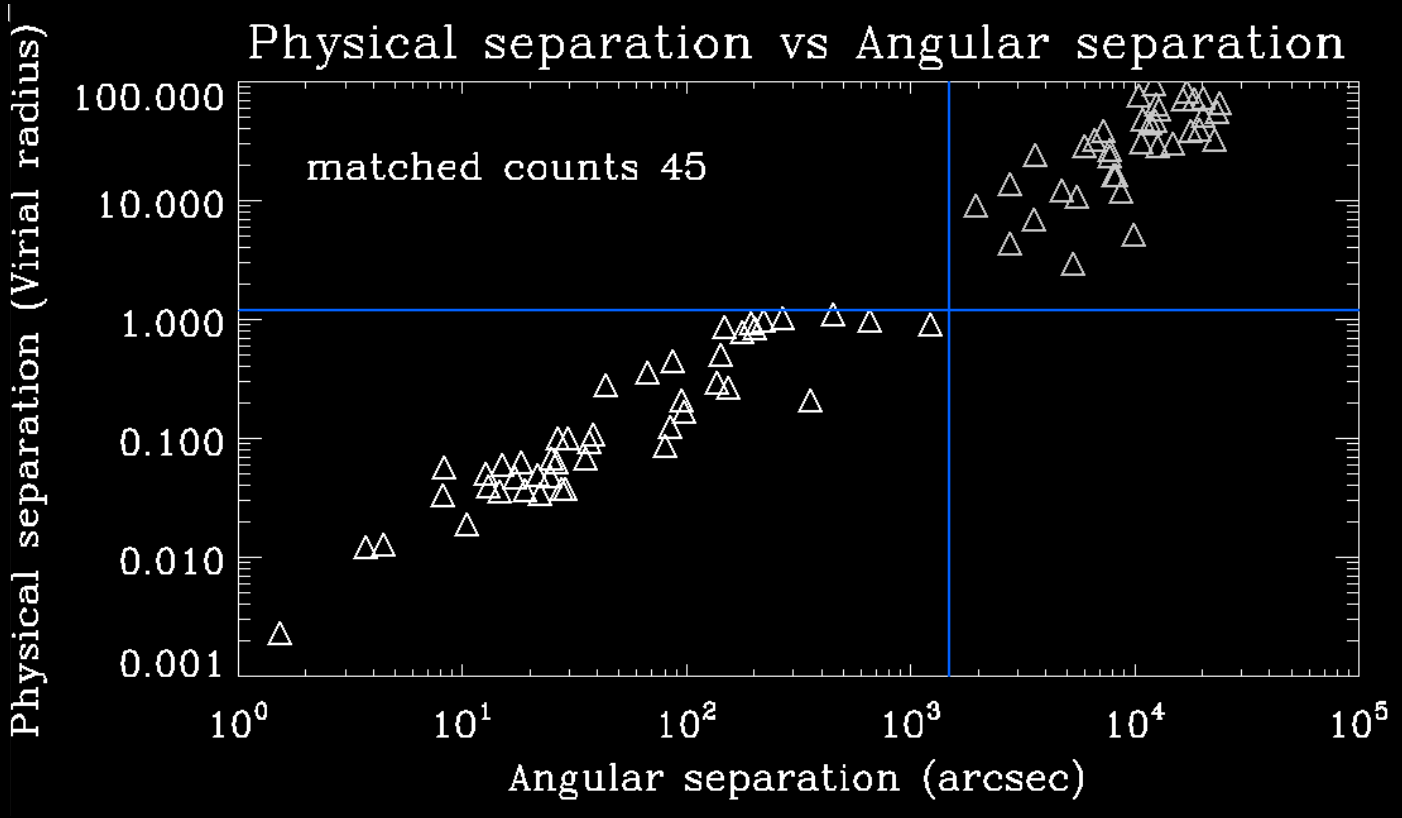
Compared with previous work

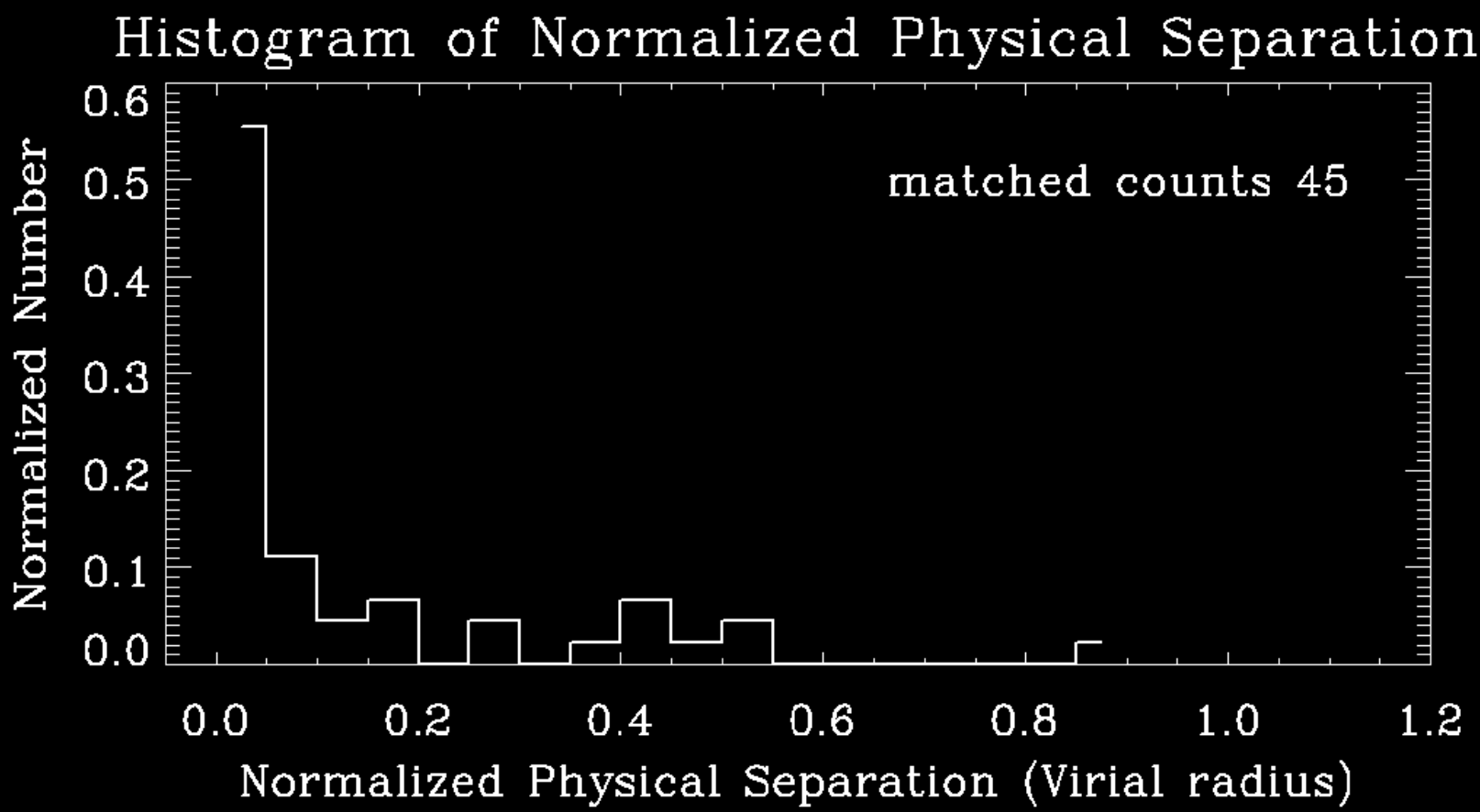
Northern *ROSAT* all-sky (NORAS) galaxy cluster survey (Böhringer et al, 2000)

- For checking the properties of X-ray clusters with others results

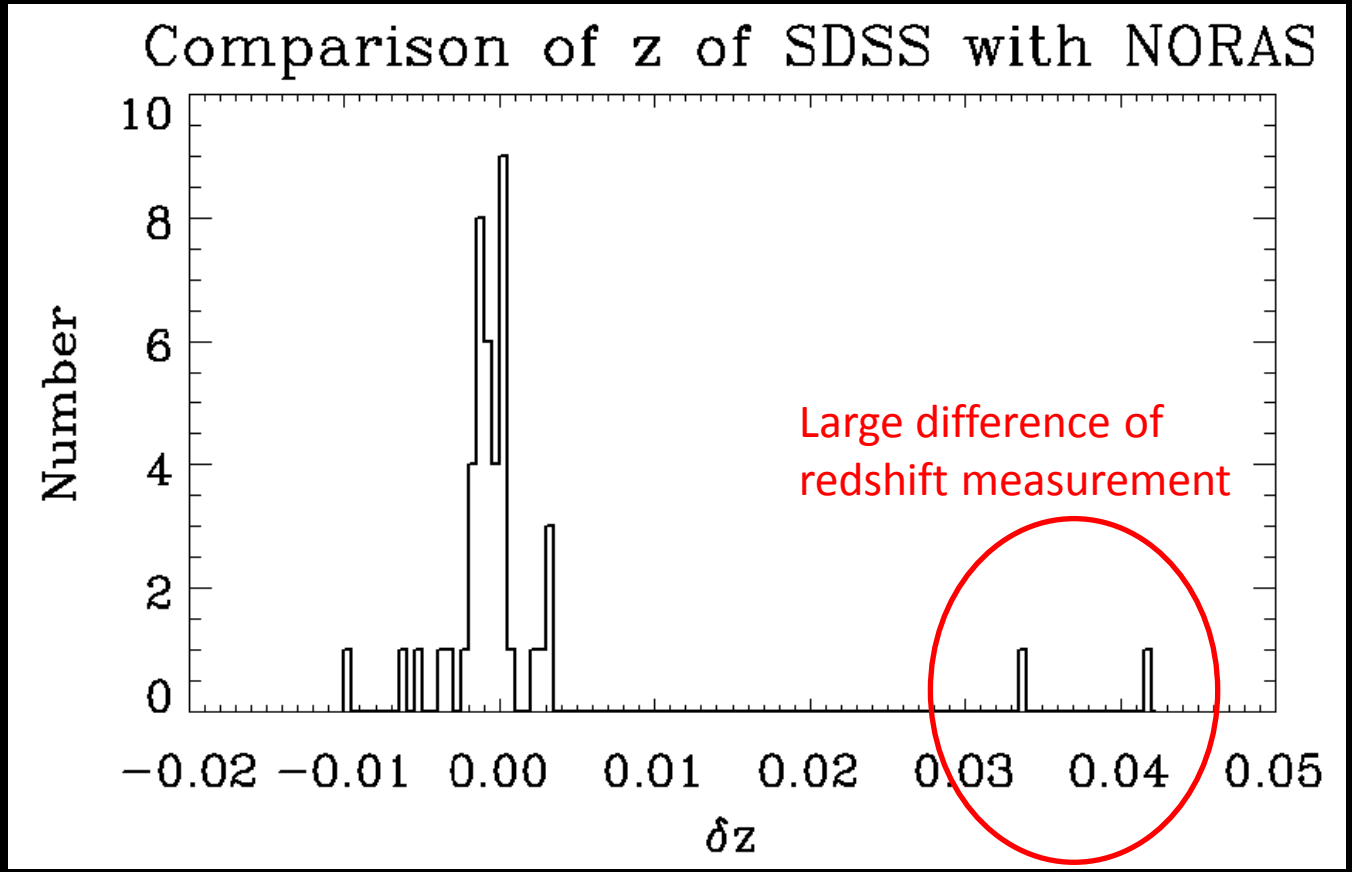
- Give the completeness check of our data

Cross-matched to NORAS with our X-ray clusters




Histogram of Normalized Physical Separation
matched counts 45
Normalized Number
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.0
0.2
0.4
0.6
0.8
1.0
1.2
Normalized Physical Separation (Virial radius)

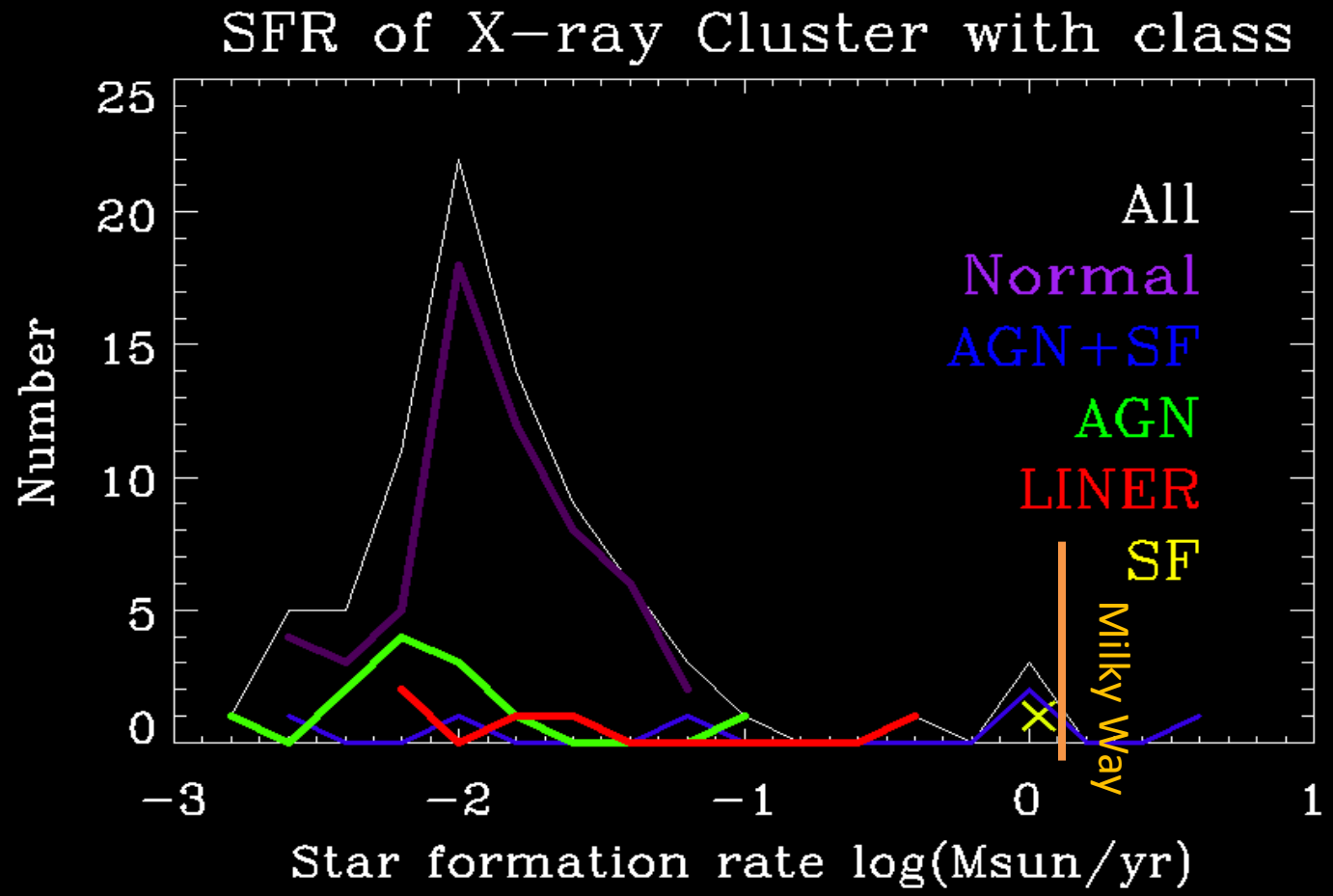
Comparison of Redshift measurements

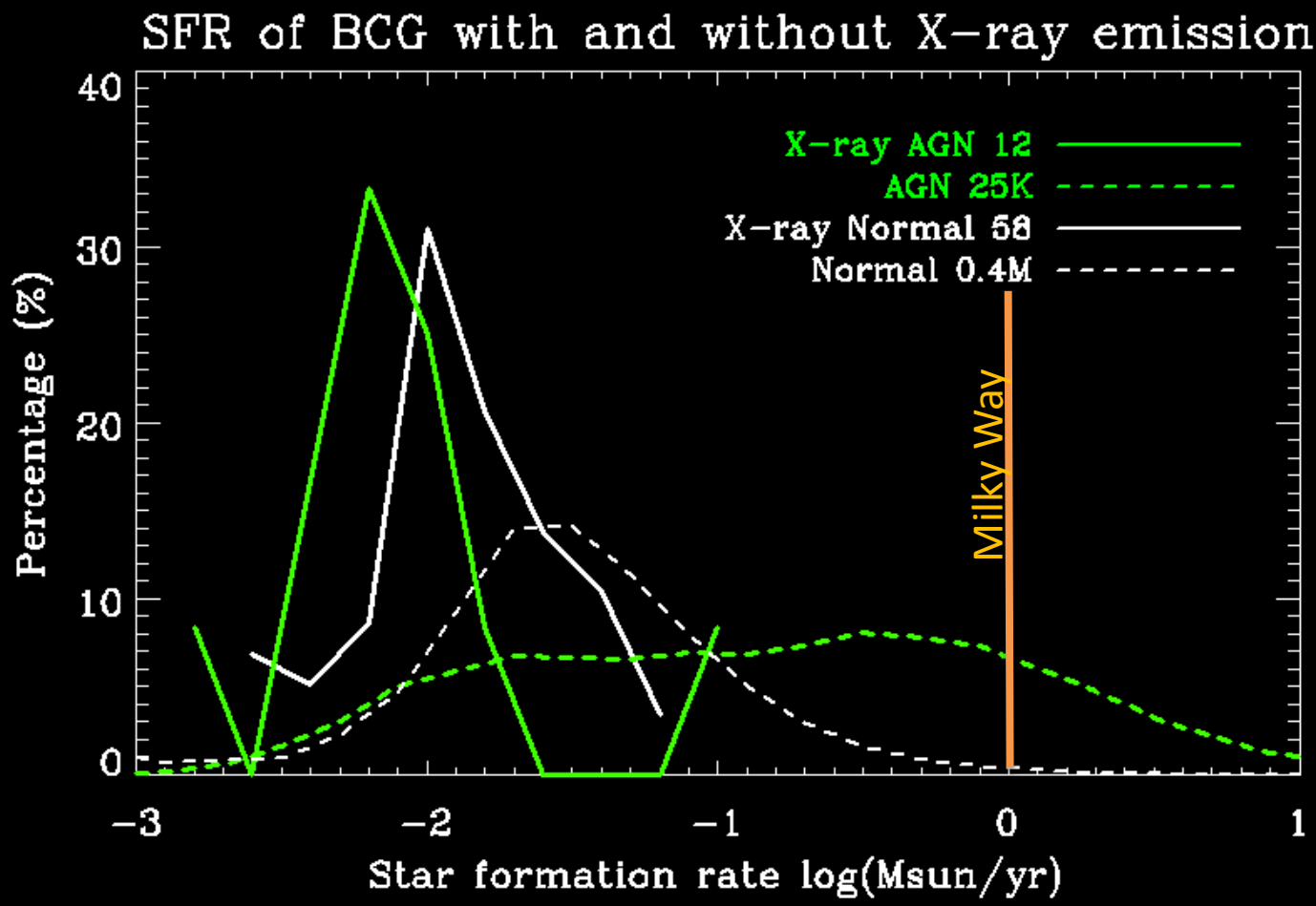


Star formation rate investigation

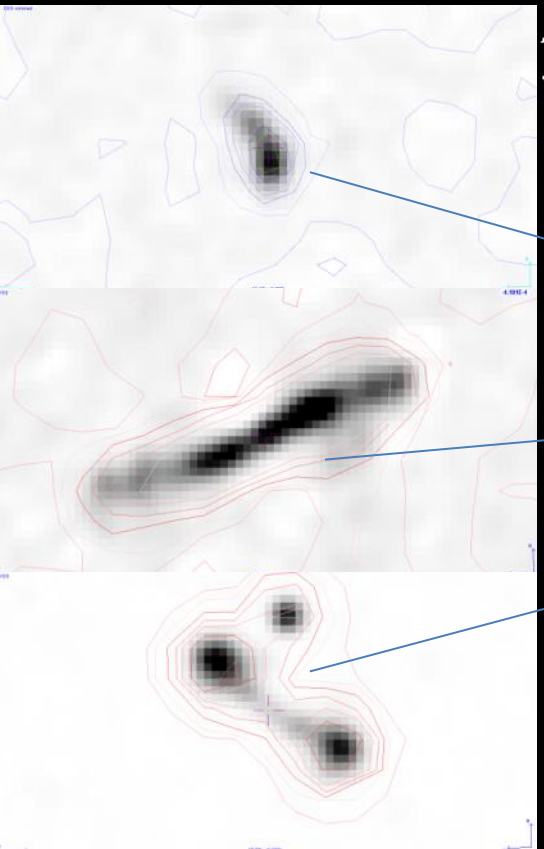
- SFR of BCG is a good indicator of cluster evolution stage.
- The SFR of Milky Way is 1 solar mass per year.
- Do you remember this?

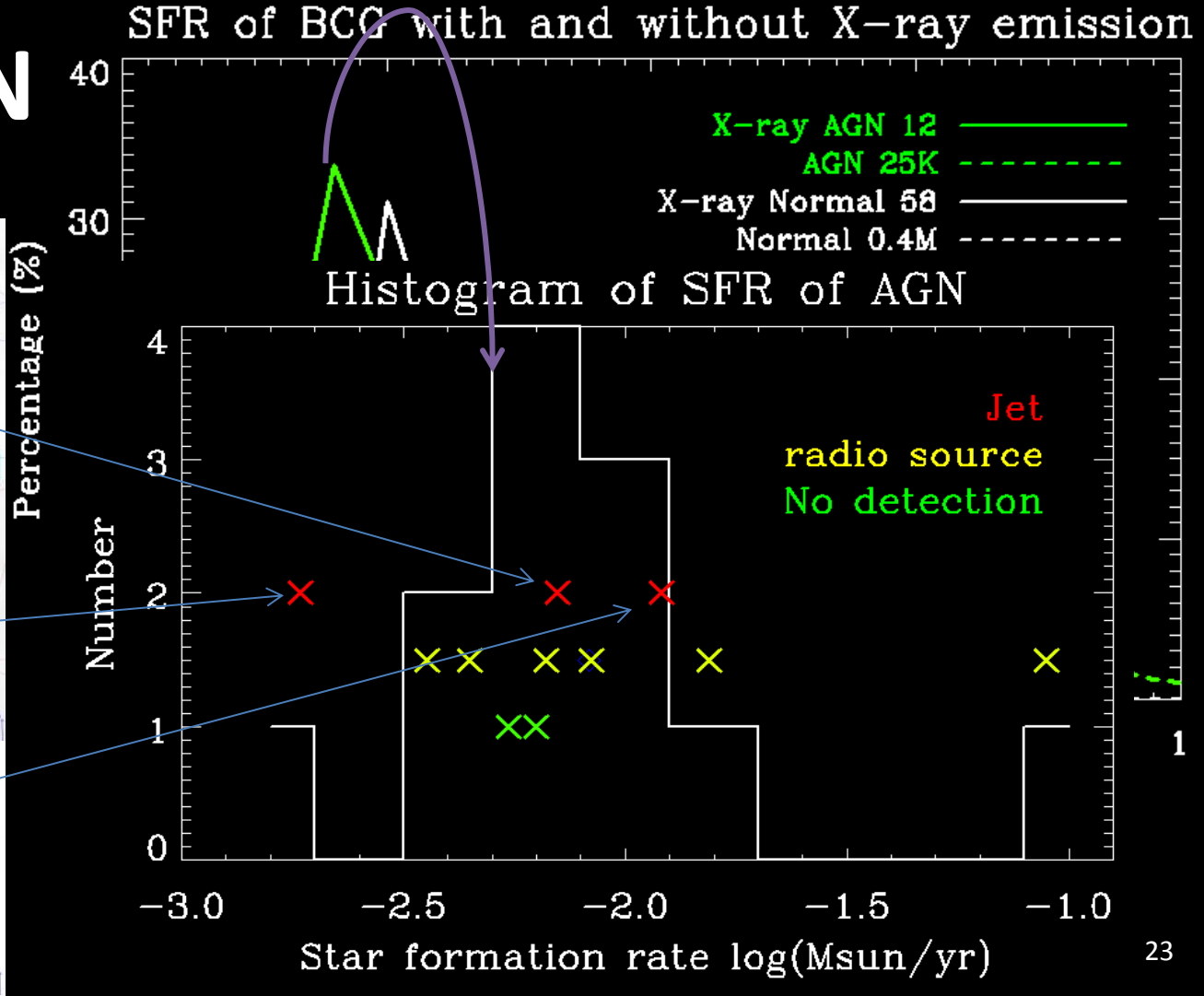
Star formation rate of BCG in X-ray cluster




SFR of BCG with and without X-ray emission
X-ray AGN 12
AGN 25K
X-ray Normal 58
Normal 0.4M
Milky Way
Percentage (%)
40
30
20
10
0
−3
−2
−1
0
1
Star formation rate log(Msun/yr)

SFR of AGN




SFR of BCG with and without X-ray emission
X-ray AGN 12
AGN 25K
X-ray Normal 58
Normal 0.4M
Histogram of SFR of AGN
Jet
radio source
No detection
Percentage (%)
Number
40
30
4
3
2
1
0
−3.0
−2.5
−2.0
−1.5
−1.0
Star formation rate log(Msun/yr)

Discussion

1. Most BCG in X-ray cluster are not active
   – Local universe>>>> higher redshift?

2. SFR of BCG in X-ray cluster is smaller than that of average galaxies of the same spectral class
   – Evolution stage of X-ray cluster in local universe

Discussion (cont.)

3. AGN feedback

Radio	Jet	Point source	No detection
Feedback	Strong	Weak	very weak

>> No influence on star formation?

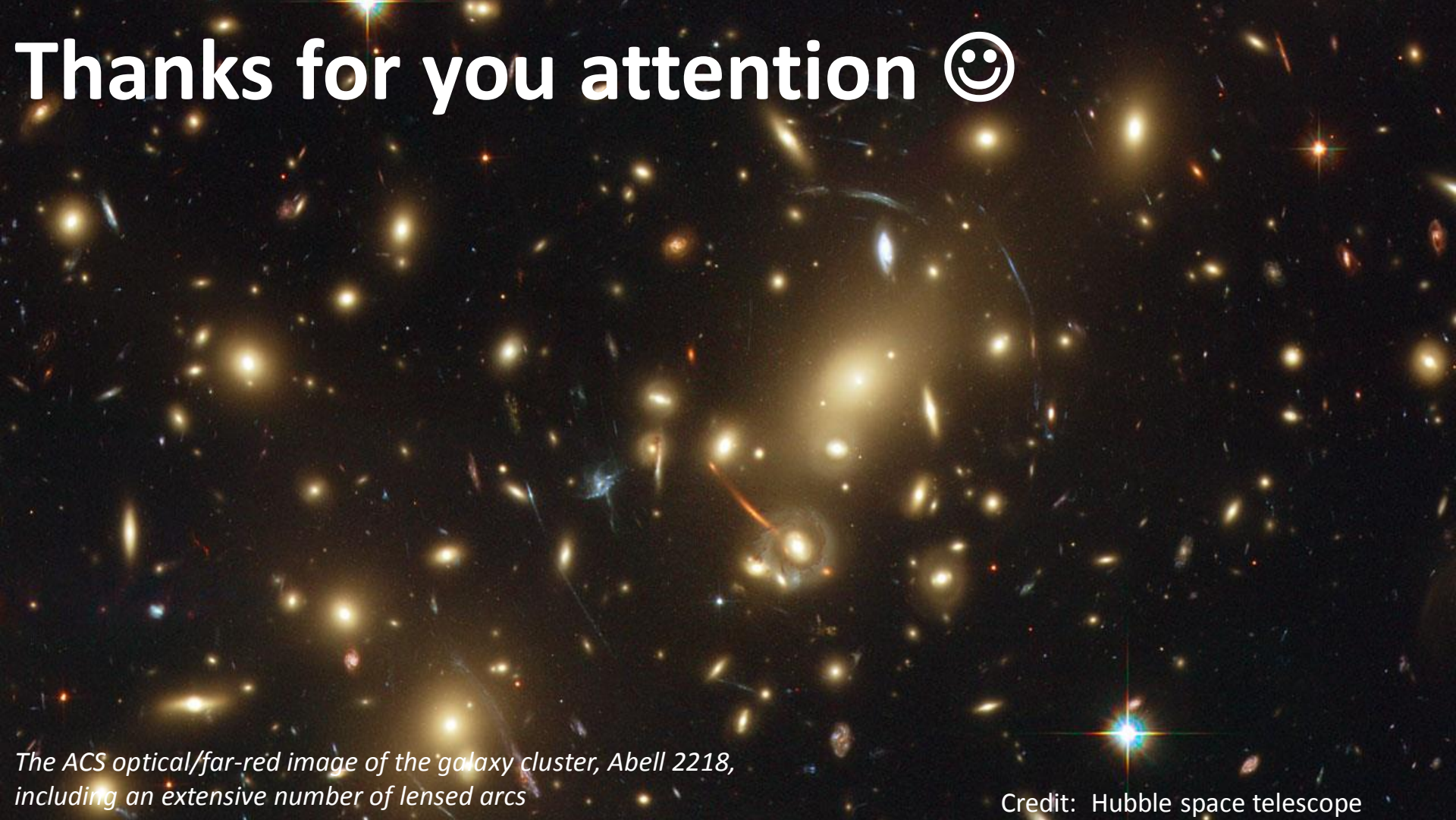
>> lack of statistically meaningful data

Future works

- X-ray selected BCGs are more often have enhanced star formation than **optical** selected BCGs. (Wang, 2010. Liu, 2012.)

- X-ray cavities in massive clusters do not have strong evolution up to z~0.6. (Hlavacek-Larrondo et al, 2012)

Thanks for you attention ☺



The ACS optical/far-red image of the galaxy cluster, Abell 2218, including an extensive number of lensed arcs

Credit: Hubble space telescope