The impact of Galaxy Clusters on the AGN activity

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Outline

- Background
- Goal
- Virgo Cluster
- COCOA Project
- Preliminary Results
- Future Plans

Background

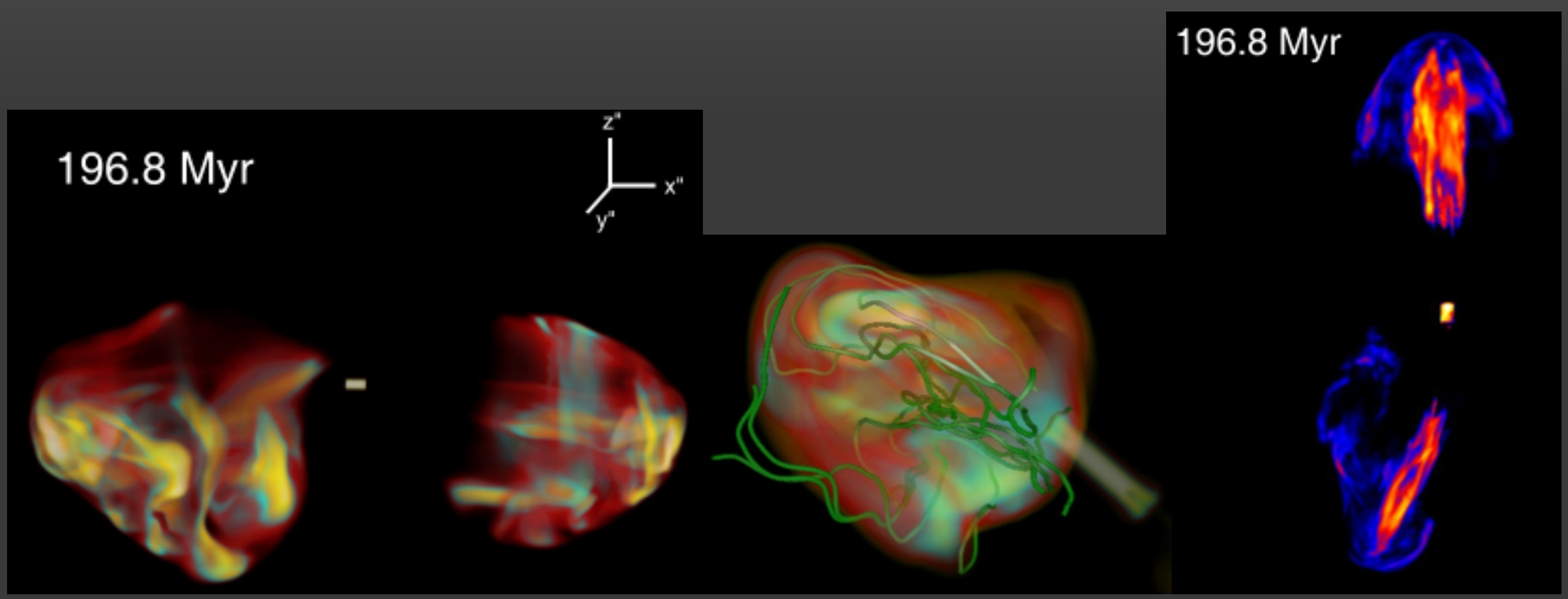
- The growth of super massive black holes (SMBHs) and the frequency of AGN activity depend on 1) how frequently and quickly the feedback process takes place and 2) how the accretion energy is converted to heat the ambient interstellar medium (ISM).

- Both the feedback process and the ISM content of galaxies can be well affected by the environment (e.g. Shin, Ostriker & Ciotti 2012).

- Most studies probing AGNs and their connections with the environment have been done in a statistical way using the optical wavelength (e.g. Choi, Woo & Park 2009) but detailed physics behind is still not well understood.

Goal

- Properties of AGNs and their host galaxies in the cluster environment
- Study how the AGN driven outflows interact with the cluster mediums



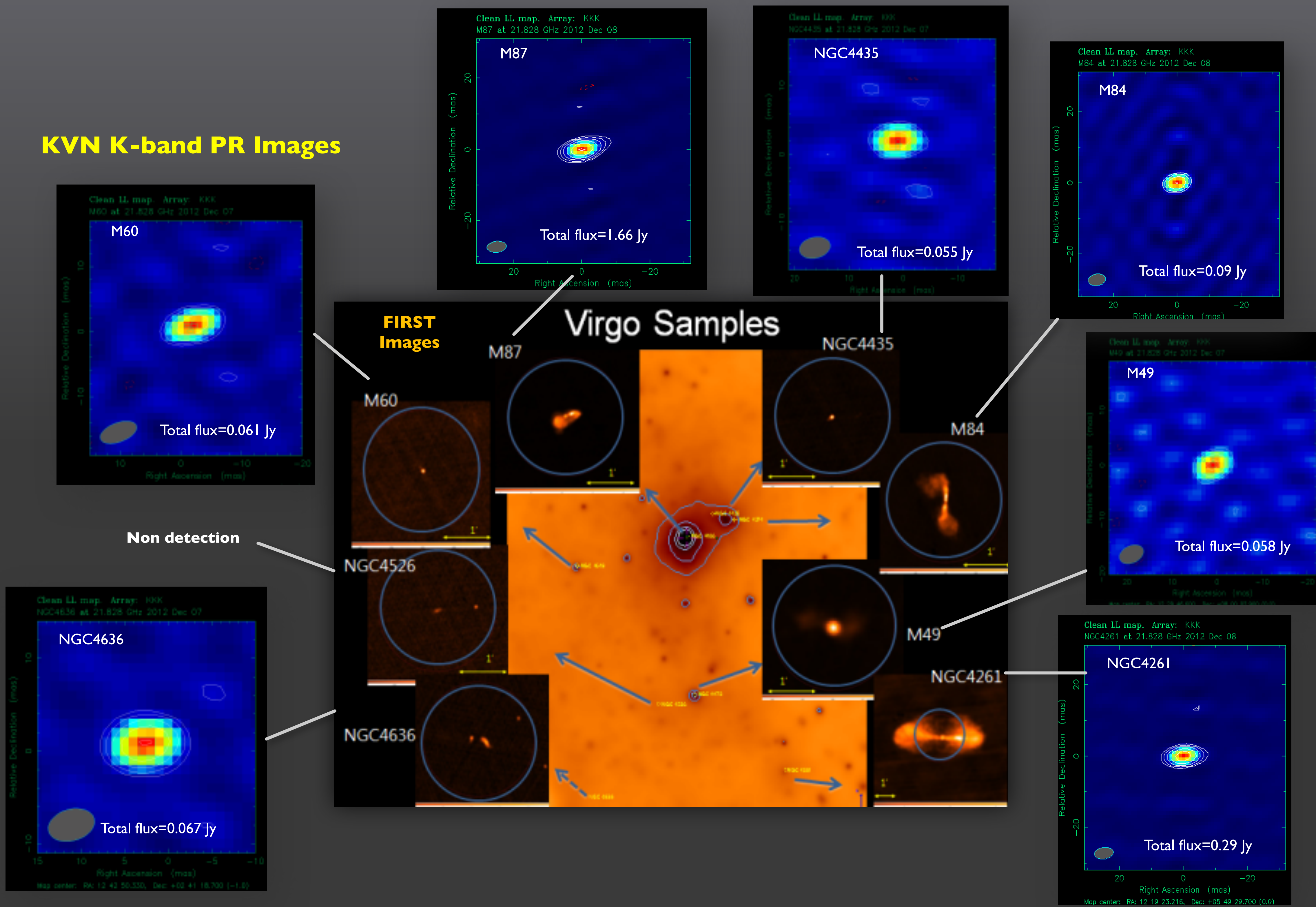
Mendygral et al. (2012)

Virgo project

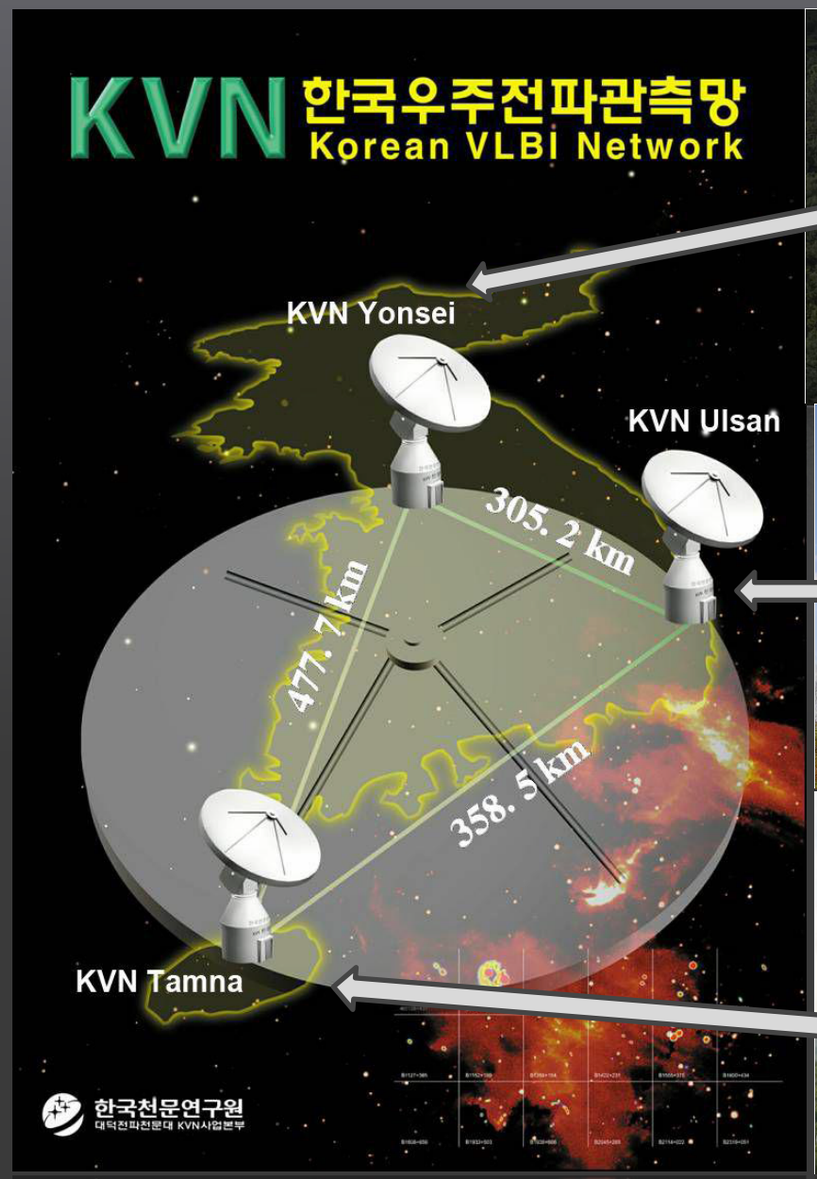
① AGN properties (power , age of AGN, jet morphology). Peculiarities in AGN outflows varying with the environment.

② The surroundings of our AGN sample. (ICM pressure using X-ray; tidal field strength by other galaxies or the cluster potential; stellar populations or nuclear activities of surrounding galaxies) Jet provides kinetic energy into the ICM which can affect neighboring galaxies.

Virgo Cluster

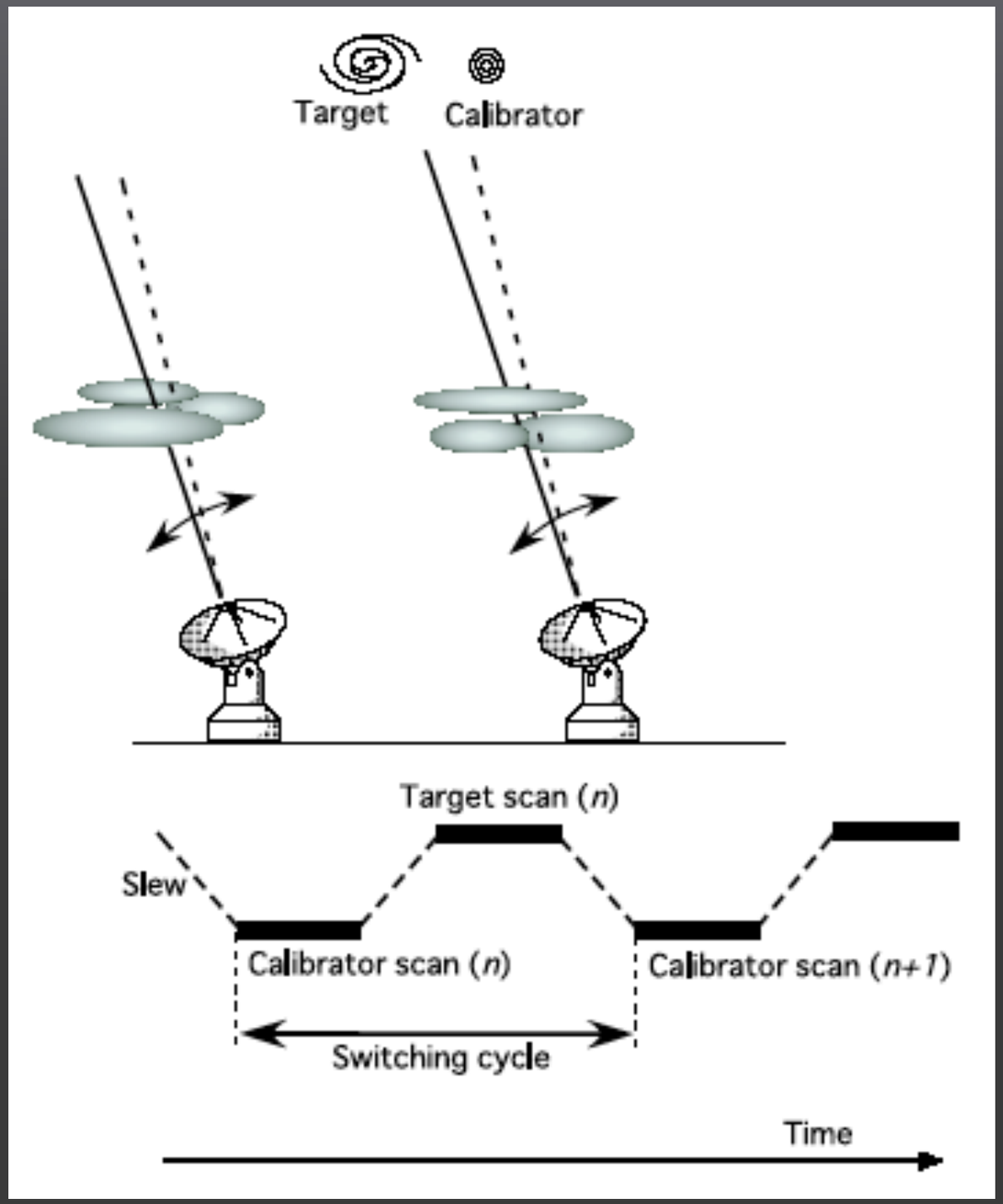


Observations



- 3 KVN stations (Yonsei, Tamna, Ulsan)
- K-band (22 GHz)
- Band width 16MHz x 16 Ifs
- Phase reference technique

Phase Reference

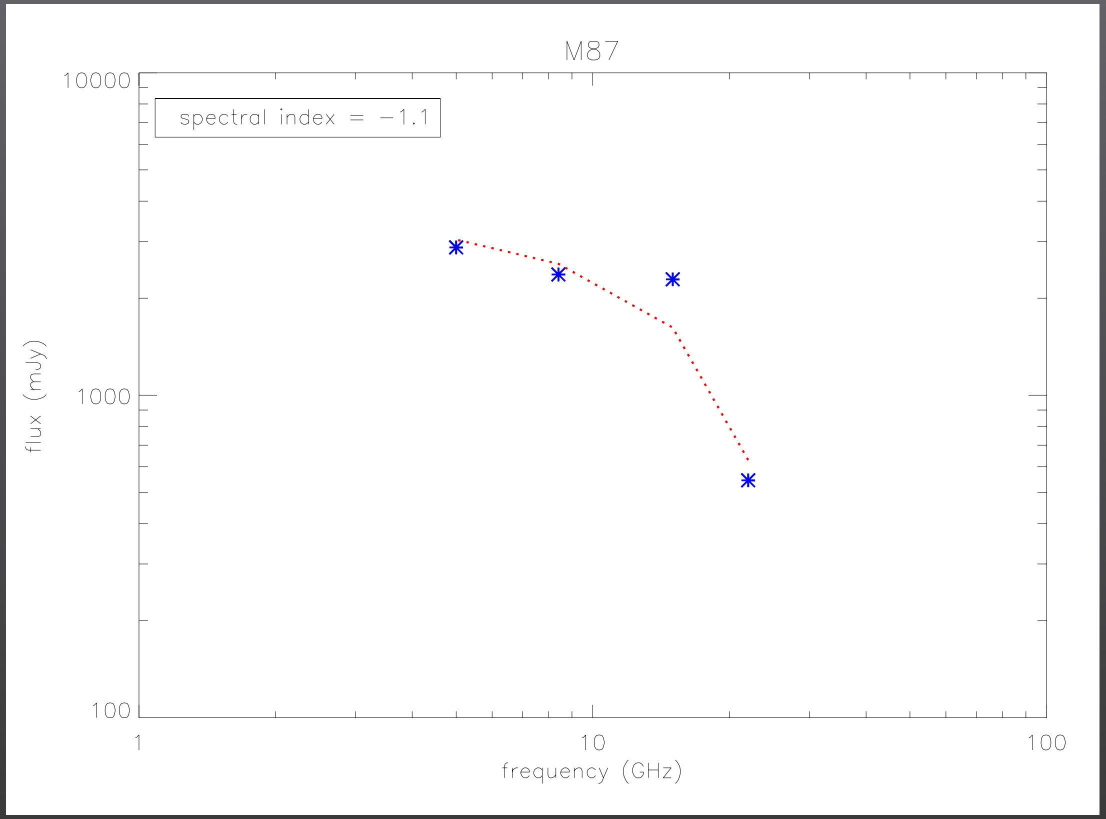


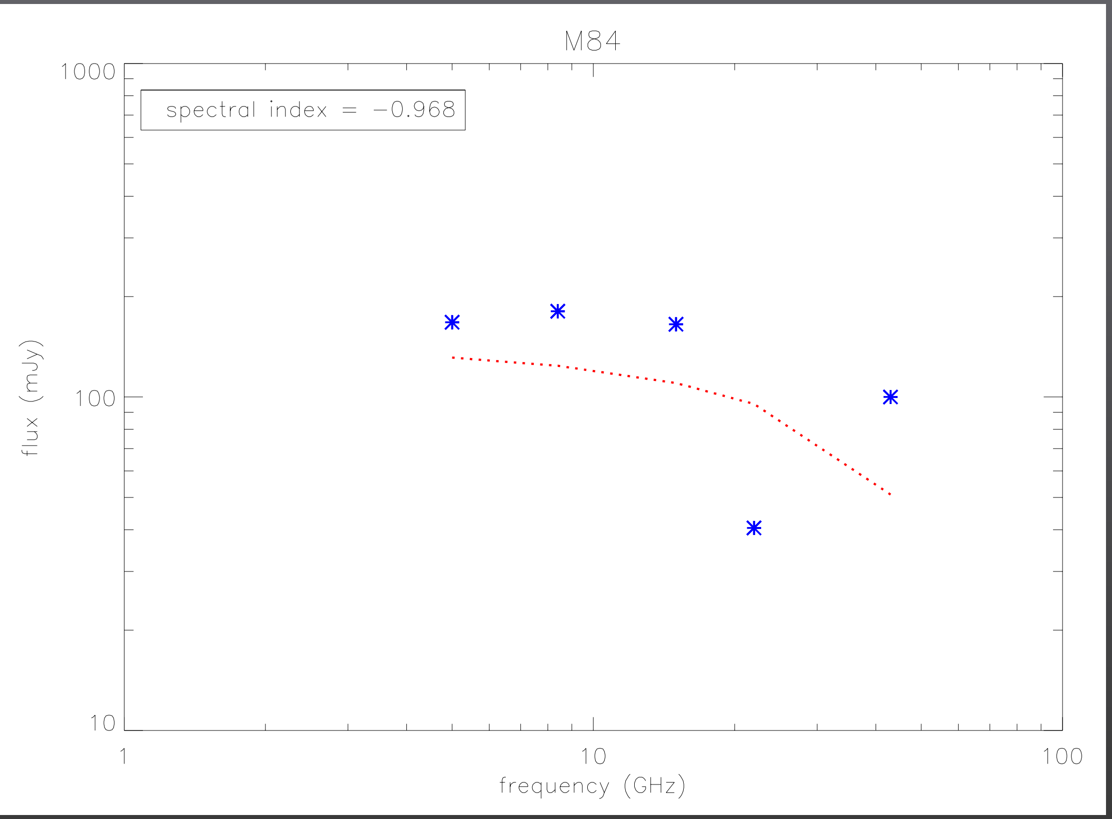
Asaki, 2007

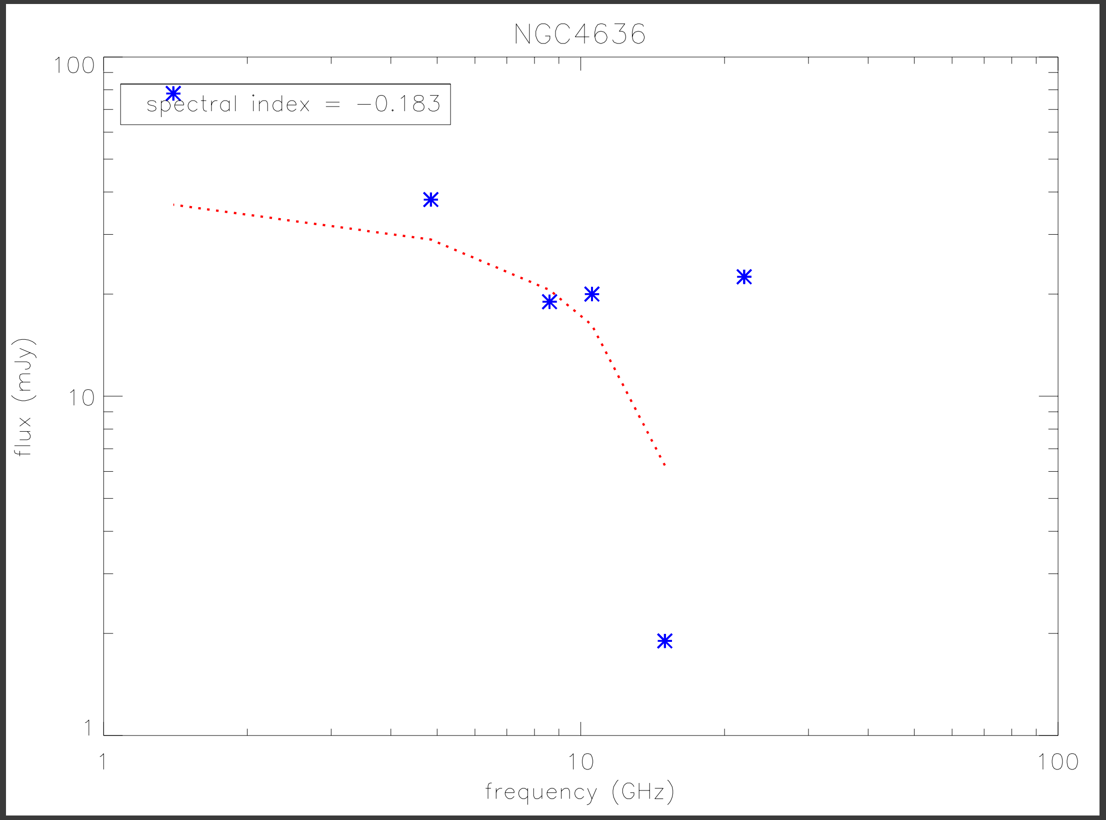
Data Reduction

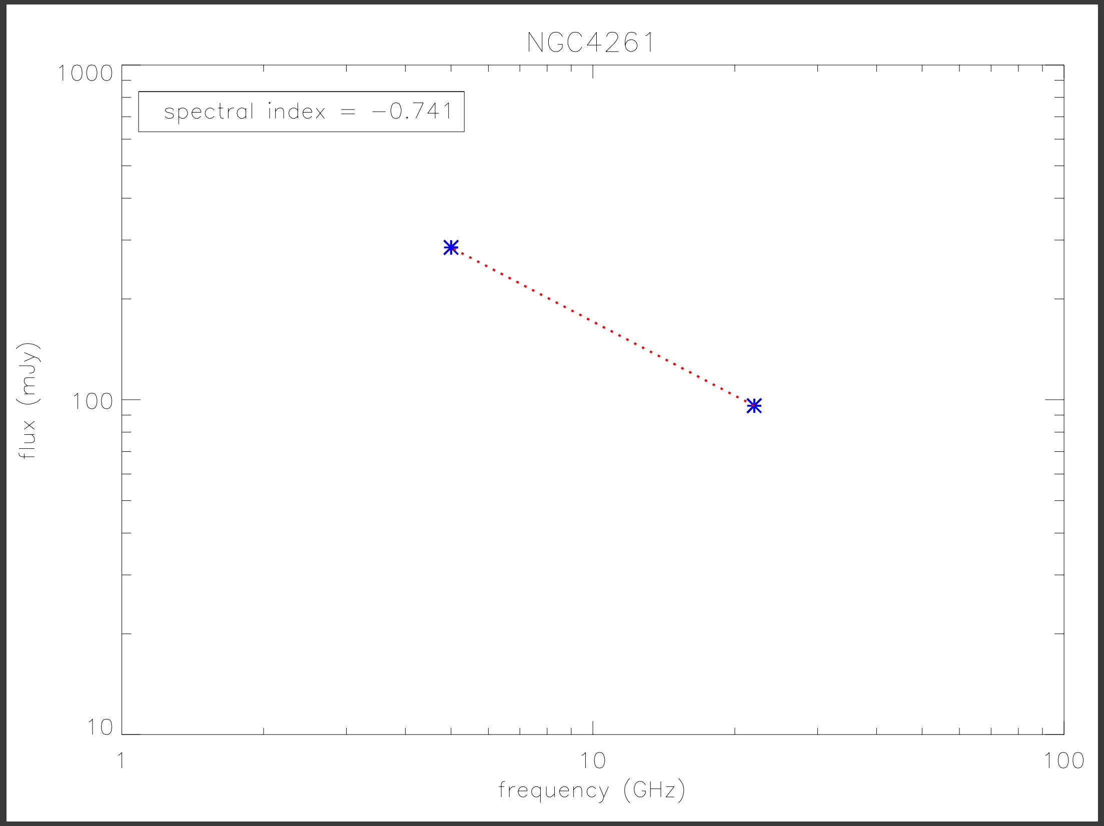
- AIPS (Data calibration)
  - ➢ Data normalization
  - ➢ Amplitude calibration
  - ➢ Phase calibration / Fringe finder
- DIFMAP (Imaging)
  - ➢ Average visibilities
  - ➢ Flagging “bad” data
  - ➢ Clean
  - ➢ Phase Self - calibration

Spectral indices (Virgo Cluster)









Synchrotron age (Virgo Cluster)

- **Radiative age** (the time it would take to radiate away all of its initial energy via synchrotron radiation)
- **Key parameter for any theoretical model** (origin and evolution of radio galaxies)
- **Break frequency** (clock indicator of time elapsed since their production)

$$t_s \simeq 2.6 * 10^4 \frac{B^{1/2}}{B^2 + B_R^2}((1+z)\nu_b)^{-1/2}$$

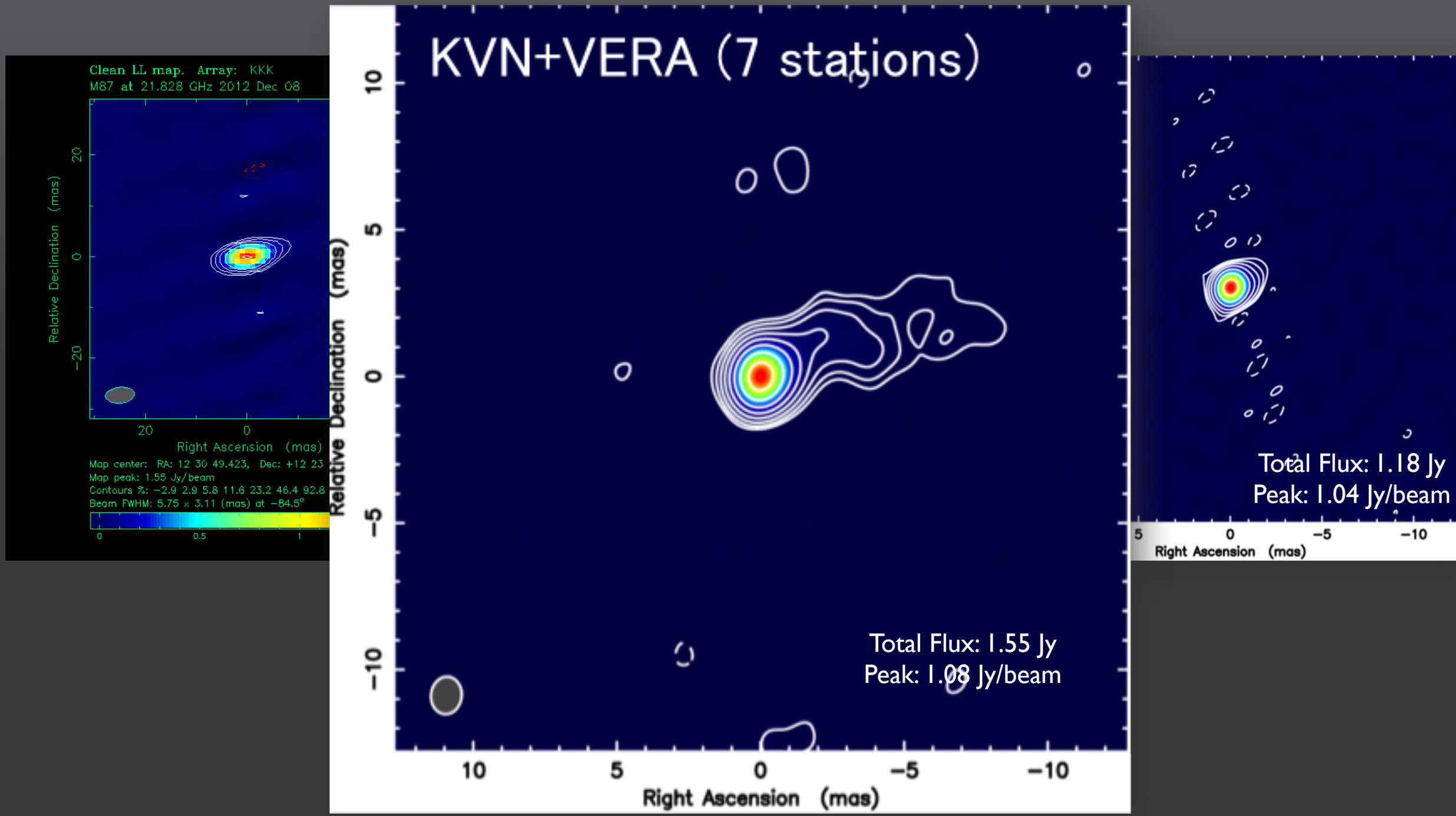
Van De Laan et al. (1969)

$$B = 1.4 * 10^{-4} * ((1+z)^{1.1}) * \nu_0^{0.22} * [\frac{S_{\nu_0}}{\theta_x * \theta_y * s}]$$

$$B_R = 4(1+z)^2 10^{-6}$$

Target	ν_B (MHz)	α_{22GHz}	B (Gauss)	t_s (yrs)	$T_{b,eq}$ (Kelvin)
M 87	138	-1.069	0.00409156	8438.31	$2.63445 * 10^{11}$
M 84	136	-1.012	0.00154267	36730.3	$2.17659 * 10^{11}$
NGC 4261	1100	-1.572	0.00126652	17327.6	$2.50698 * 10^{11}$
NGC 4636	108	-0.456	0.00181129	32404.0	$2.10471 * 10^{11}$

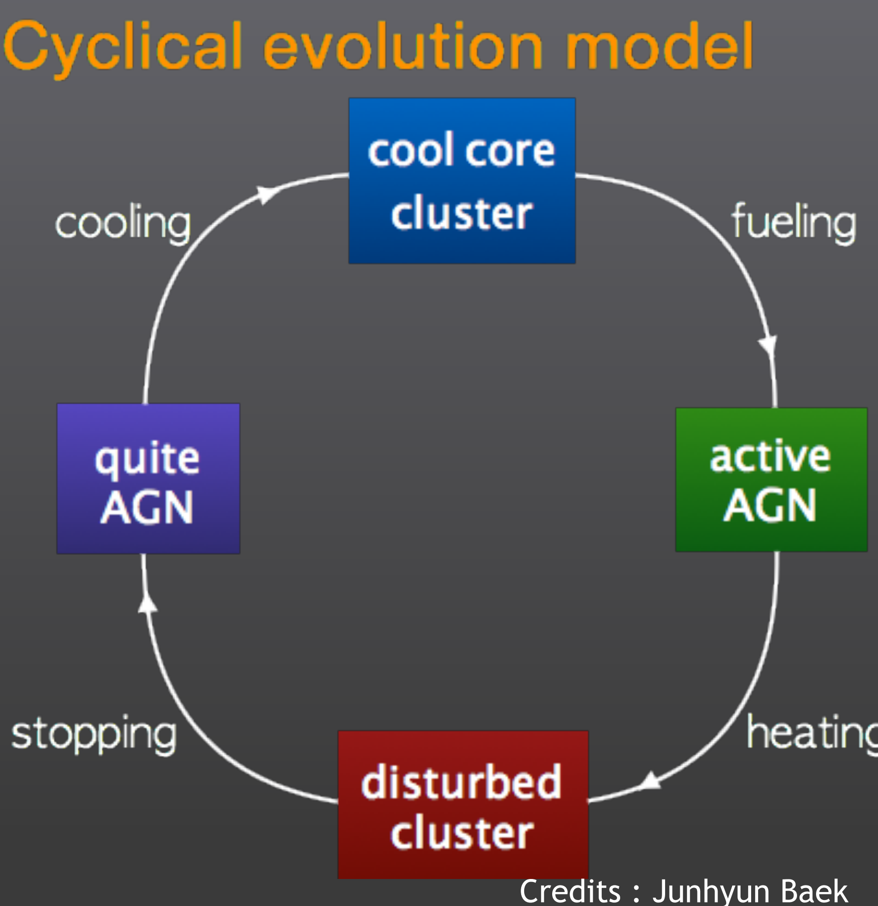
Future Plans



Credit :K. Niinuma

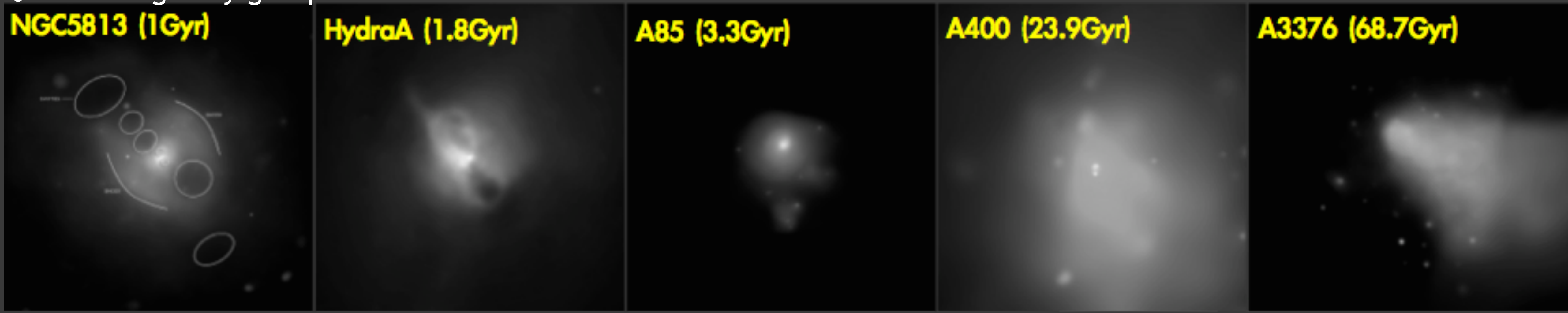
COCOA project

COCOA
CO-evolution of cluster
COres and the central
AGNs

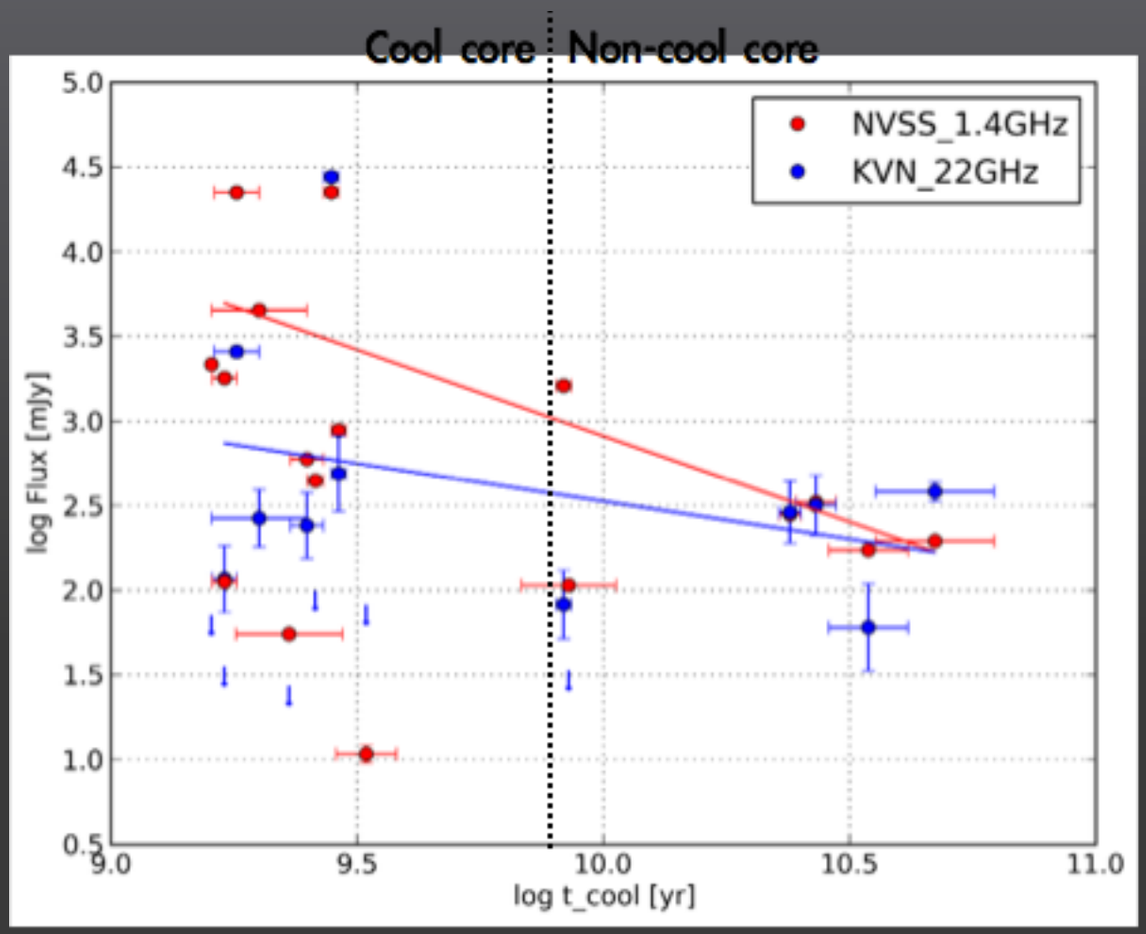


The Highest X-ray FLUx Galaxy Cluster Samples (HIFLUGCS)

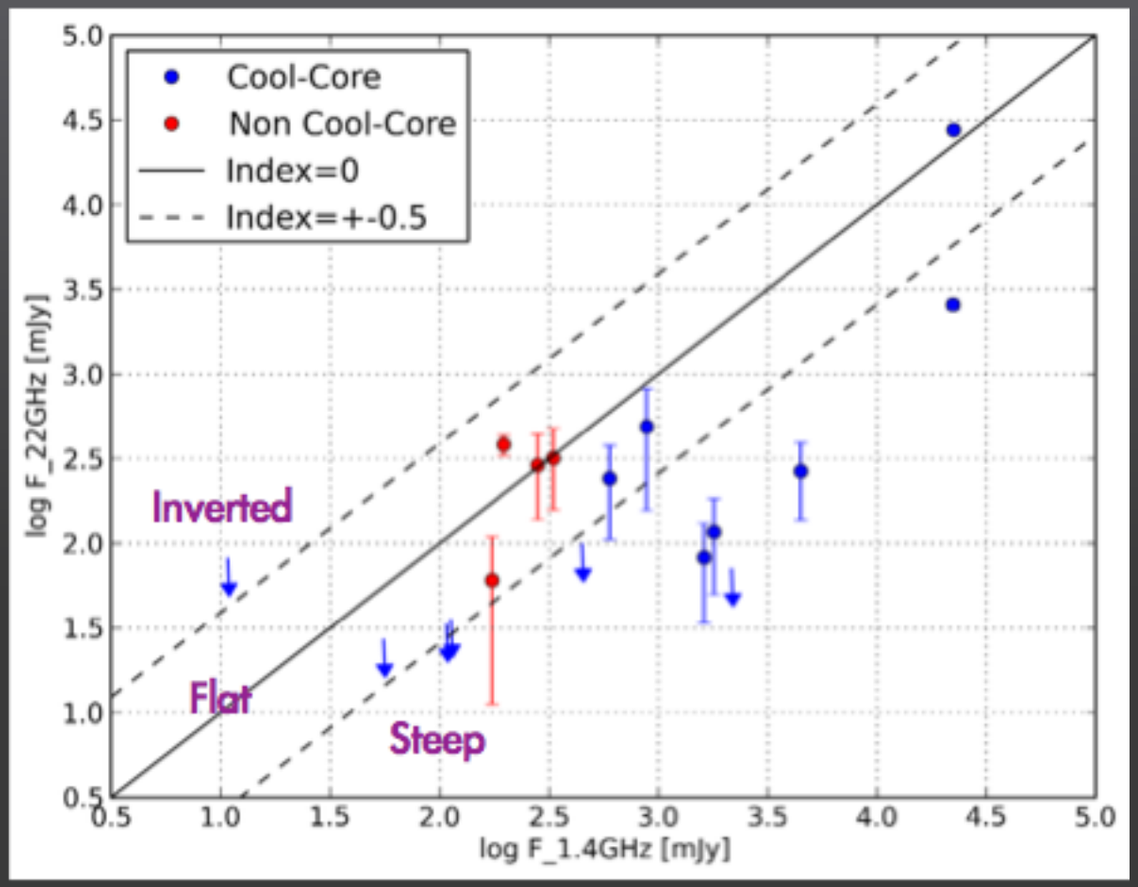
- ROSAT X-ray all sky survey
- Flux limited samples
- ~ 100 galaxy groups & clusters



COCOA project



ICM cooling state affect
the radio activity of AGN
starting from outer part



AGN activity in cool core
has not been transmitted
to the outer part of the AGN

Credits : Junhyun Baek

Questions

1) How does the interaction with ICM change the properties of AGN and AGN driven outflows (truncation radius of gas in host galaxies; the morphological peculiarities such as bent and rims in jets and lobes as a function of density; tracing mixing of ICM and AGN outflows)?

1) How does the AGN feedback affect neighboring galaxies (color, morphology and nuclear activities of surrounding galaxies as a function of AGN host galaxy properties)?