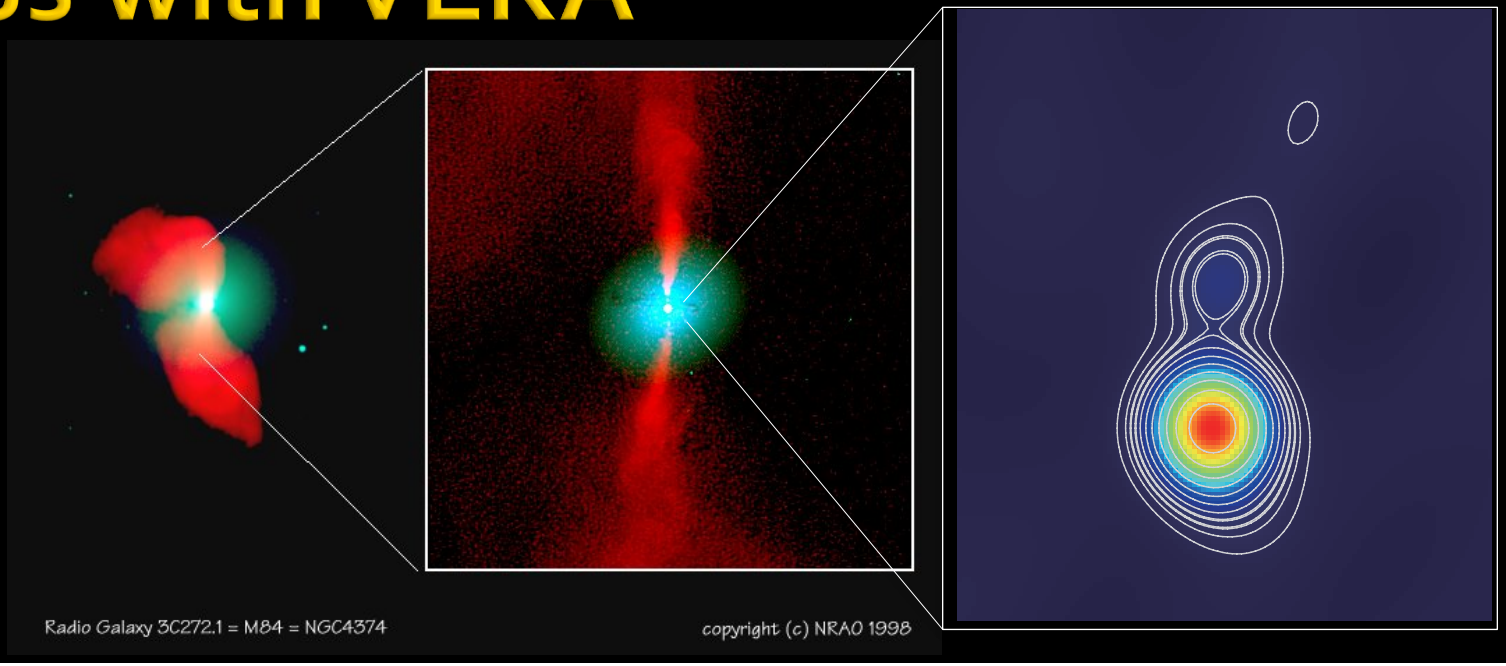
Multi-epoch, quasi-simultaneous 22/43GHz observations of the M84 nucleus with VERA



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Introduction

low-luminosity AGN:LLAGN is defined as AGN with Hα luminosity < 10^{40} erg s^{-1}

High

Accretion/Emission rate

Low

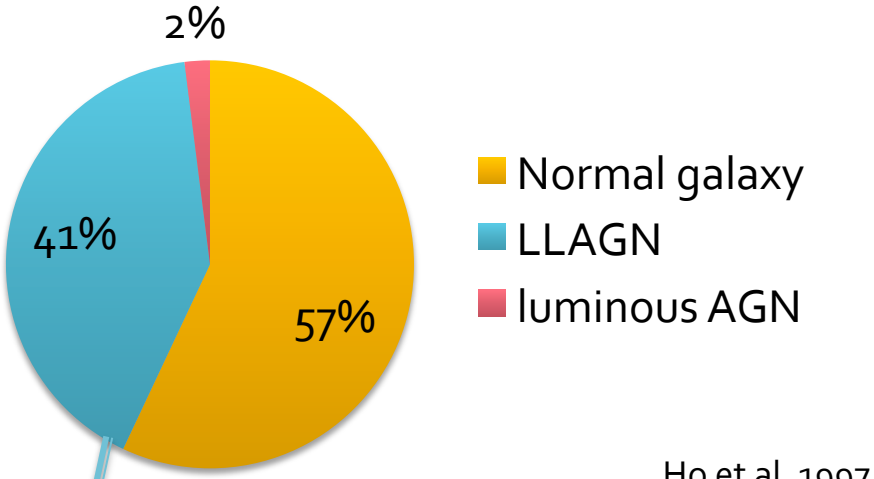
High-luminosity AGN
Quasar

$L_{bol} \approx L_{edd}$

Low-luminosity AGN
LINER/Seyfert

$L_{bol} \ll 10^{-4} L_{edd}$

AGN proportion in nearby galaxies

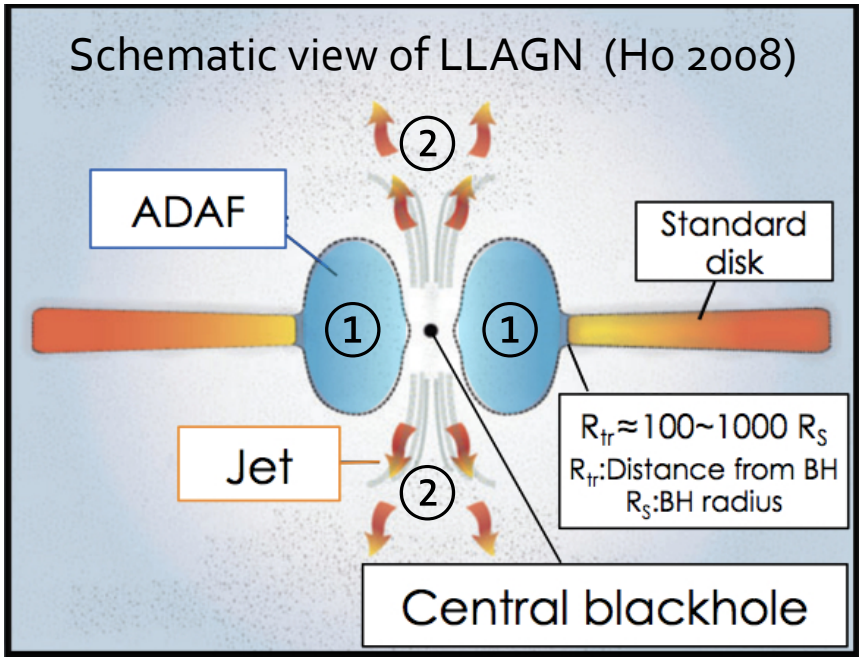


Ho et al. 1997

LLAGN

Occupy more than 95% of nearby AGNs !

Origin of the nuclear radio emission



Emission model

① **ADAF**

Advection Dominated Accretion Flow

Synchrotron from thermal electrons

② **Jet**

Synchrotron from non-thermal electrons

The origin of emission from the nucleus region (< few x 100 R_s) has not been clear for LLAGNs

Nagar et al. 2001; Anderson et al.2004

How to distinguish emission models?

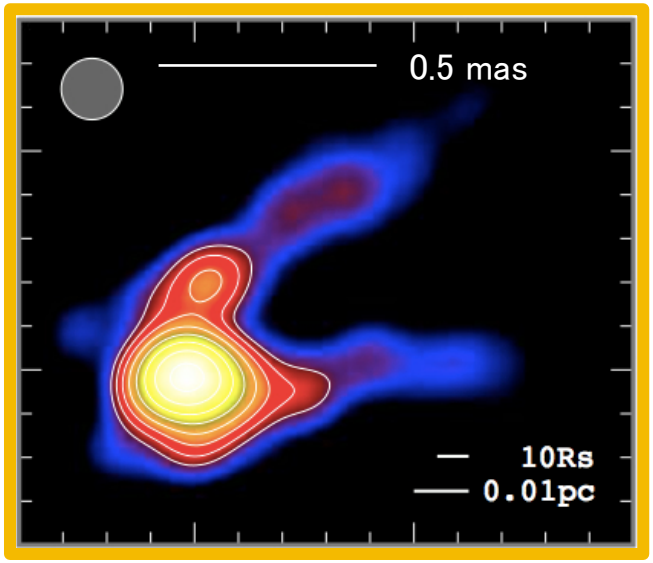
Nuclear properties on mas scales

1.Nuclear structure　2. Nuclear spectra (spectral index・radio power)

with VLBI are crucial to distinguish emission models

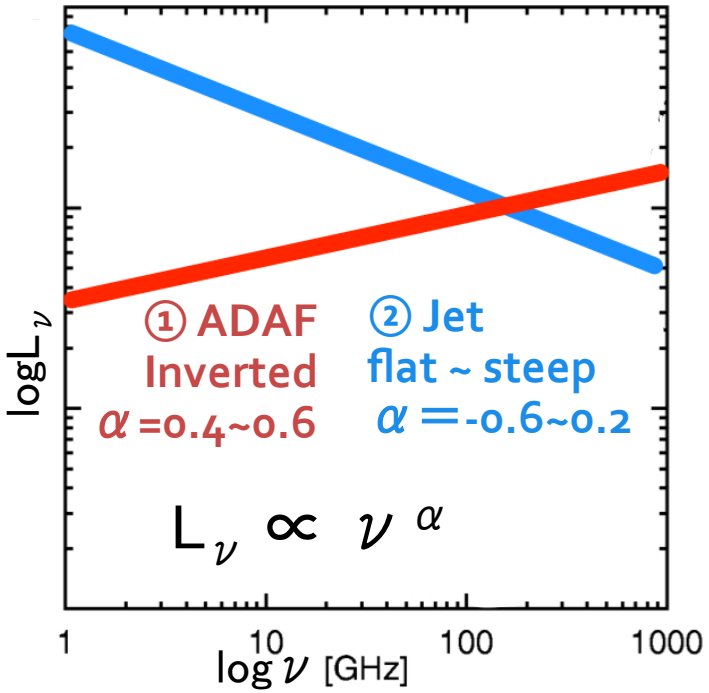
Anderson et al. 2004; Doi et al. 2005; Hada et al. 2013

Is there Jet-like component ?

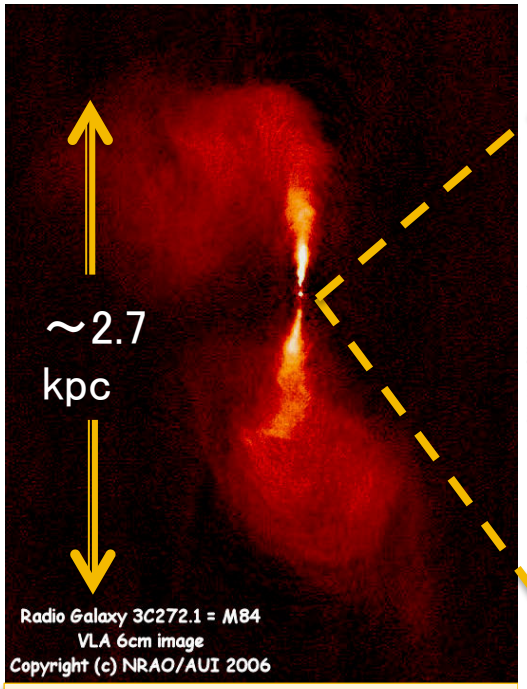


M87 @ VLBA 43 GHz　Hada et al. 2013

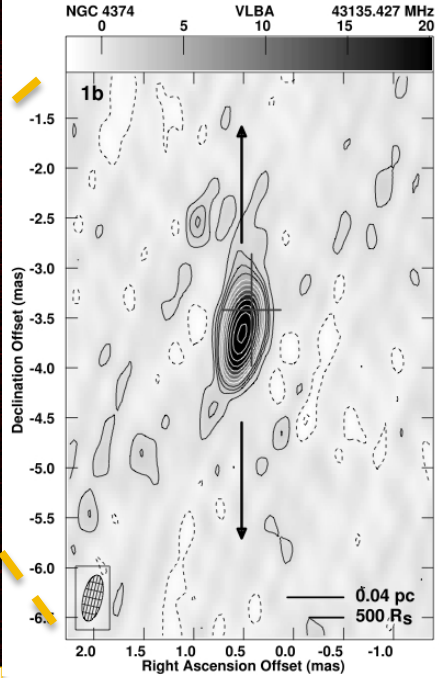
Schematic view of spectra



Introduction
M84



1mas=0.089pc=582Rs



Ly et al. 2004 VLBA 43GHz

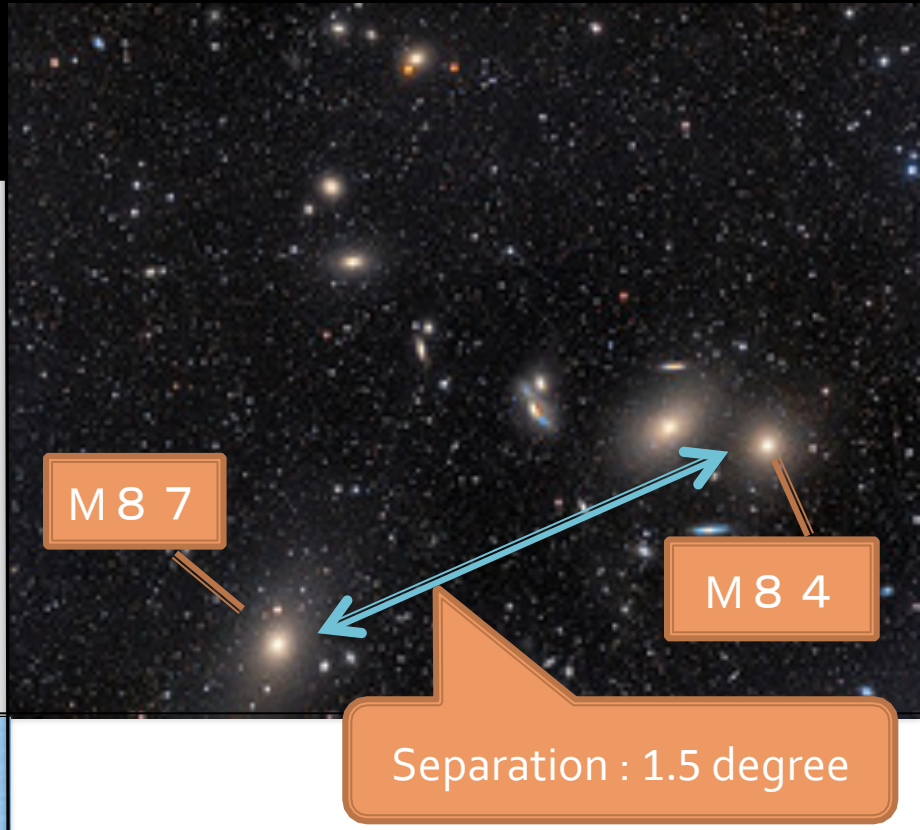
- Elliptical galaxy in the Virgo cluster
- FR I radio galaxy
- Distance :18.4 Mpc
- Low-Luminosity AGN ($L_{bol} \sim 4.3\times10^{-6} L_{Edd}$:Bower et al 1997)
- 5th apparent BH radius

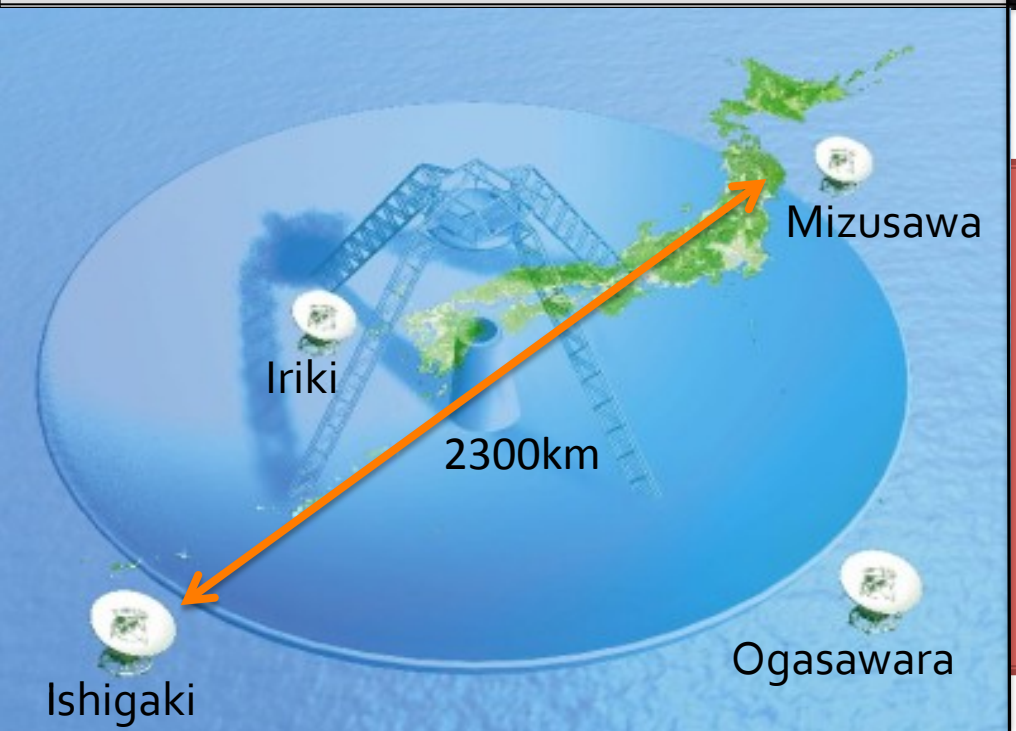
Doi et al. 2009

M84 is a suitable object to observe the immediate vicinity of the black hole (< ~few hundred R_S) with VLBI technique.

Observations

Telescope : VERA
Date : Feb/2012 ~ May/2012,
Feb/2013 ~ May/2013,
1 observation every 3 weeks
Frequency : 22 GHz(1.3 cm)/43 GHz(0.7 cm)
exposure time : 4 hours per each
epoch / frequency
Phase referencing calibrator : M87





◆ Specifications of VERA
- 4 stations
- Dual-beam phase-referencing
- Diameter : 20 m
- Baseline length D : 2300 km
- Resolution: 1.4×0.8 mas @22 GHz
0.65×0.45 mas @43 GHz

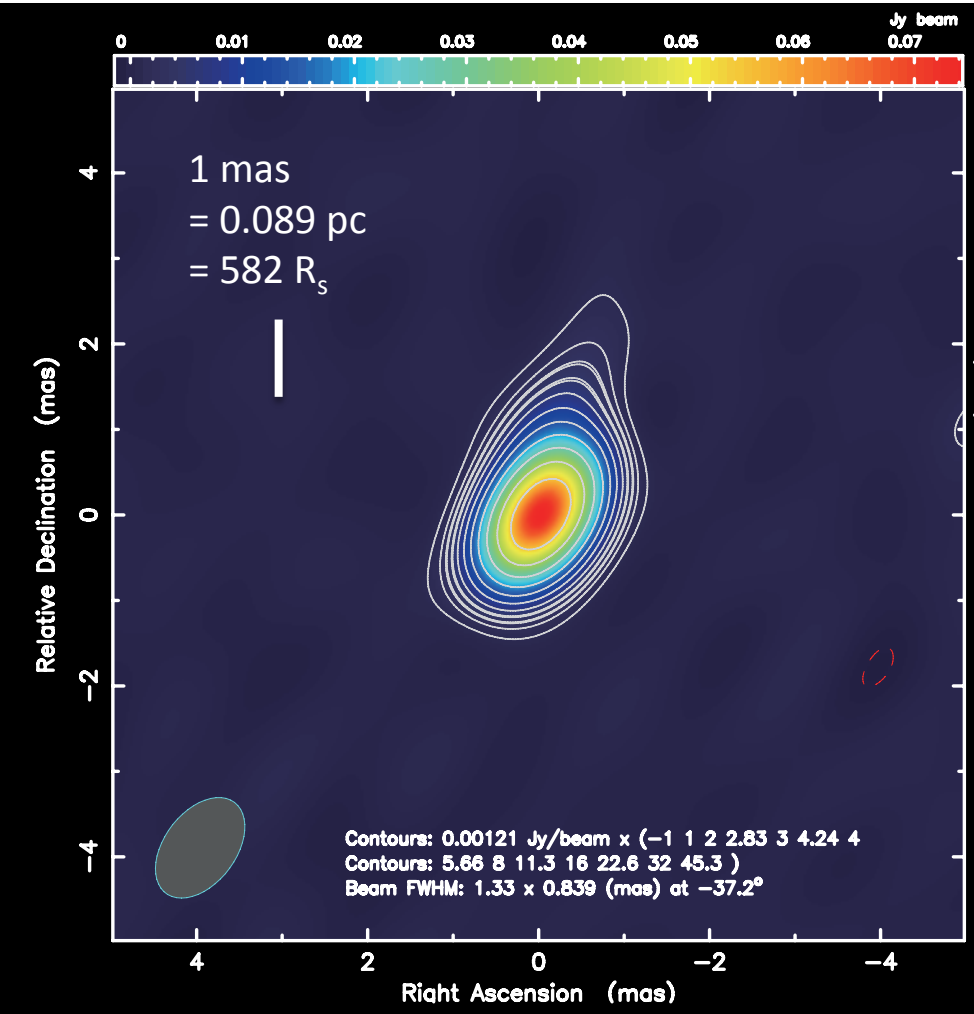
http://milkyway.sci.kagoshima-u.ac.jp/vera/vera1.html

Results

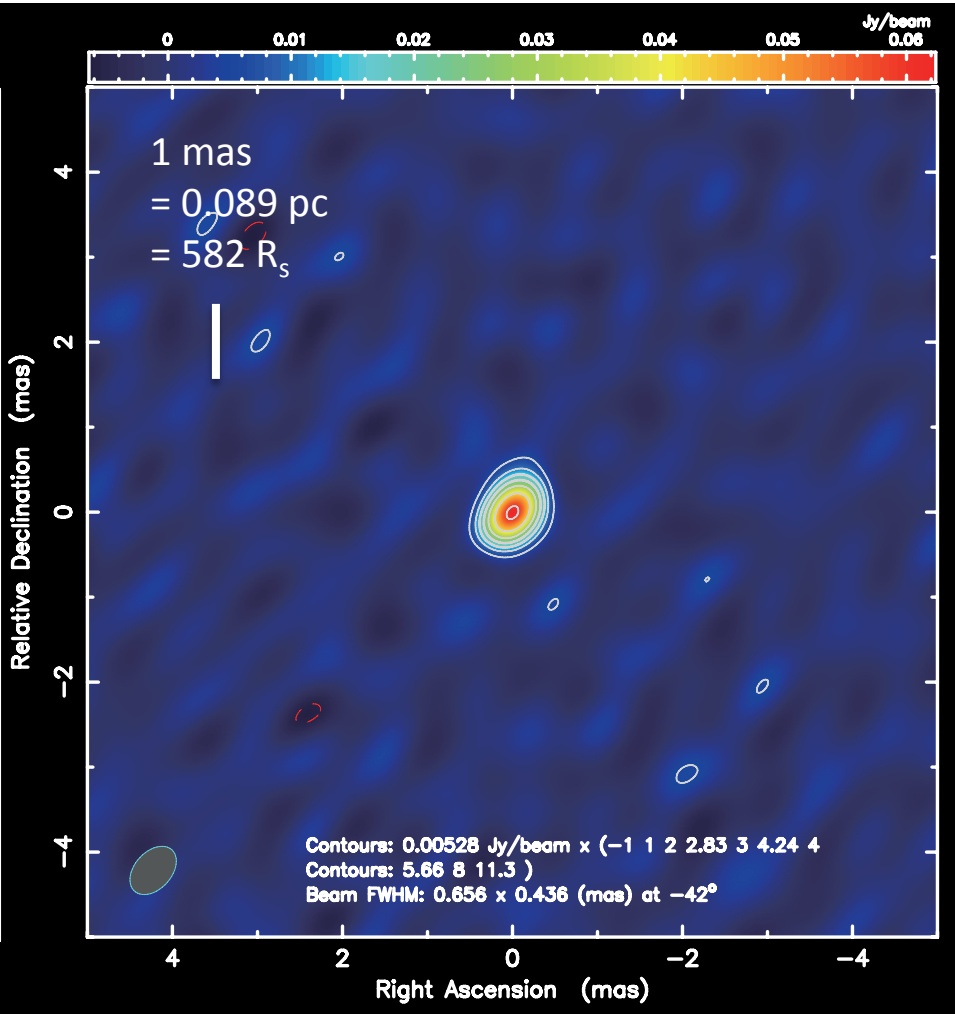
First ever VERA images of M84

10epochs
for each frequency

March 2012 22GHz

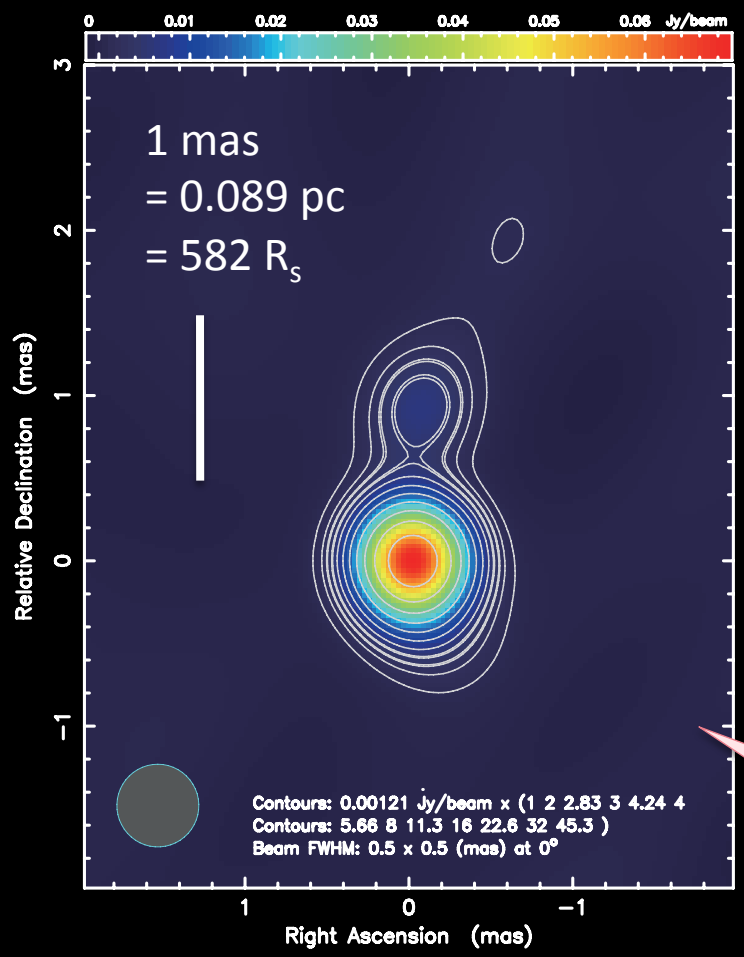


March 2012 43GHz

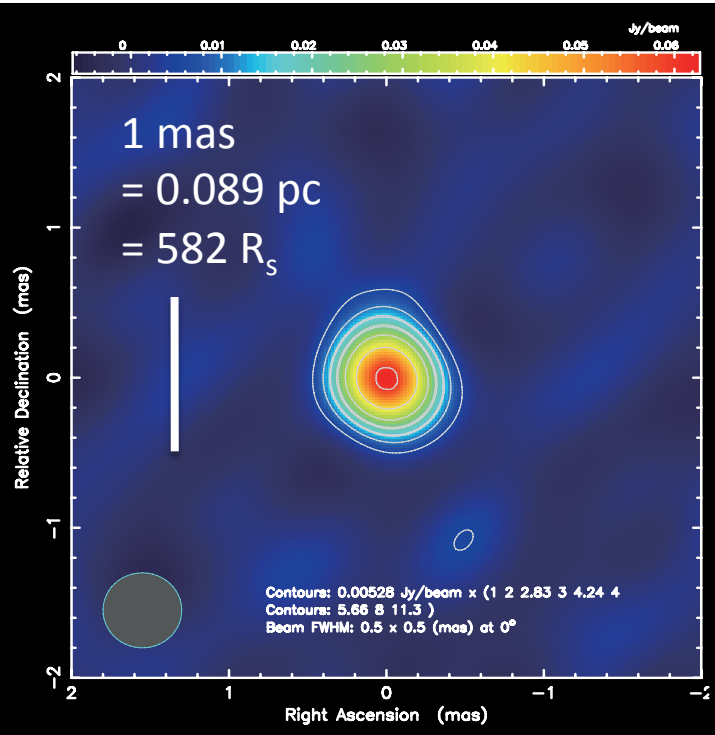


Zoomed up view of the central region

March 2012 22GHz



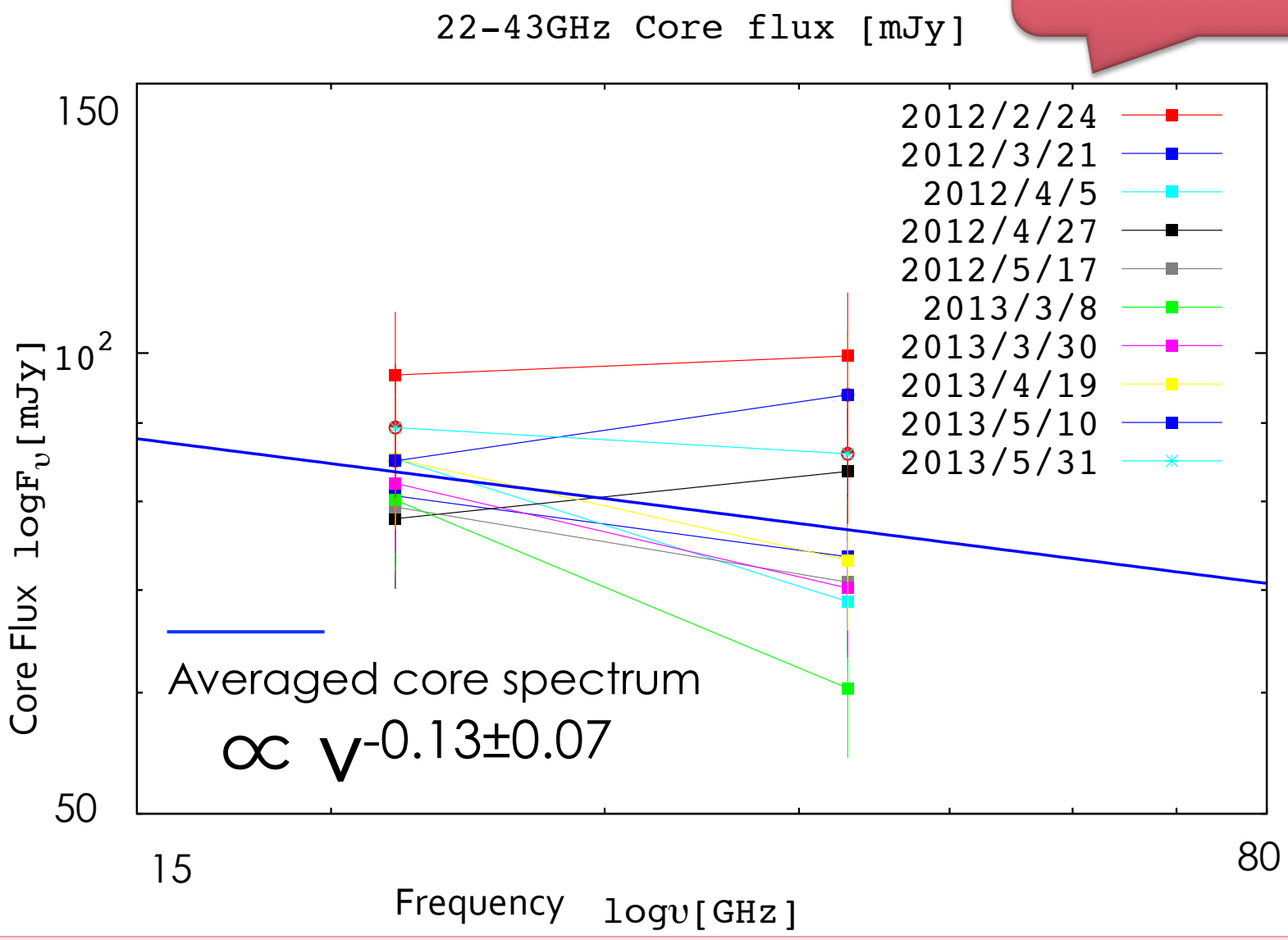
March 2012 43GHz



Jet-like component

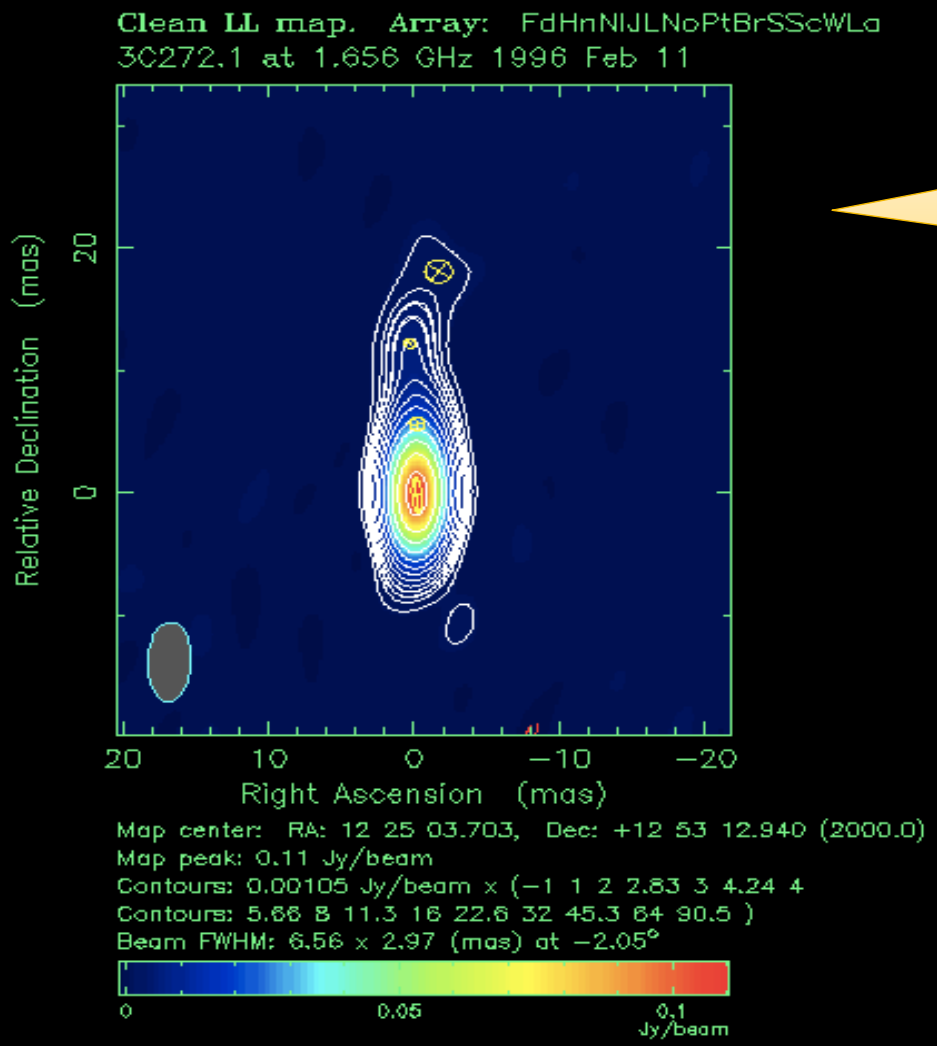
22-43GHz Core spectra

Simultaneous spectra
10 epochs



Flat - steep spectra

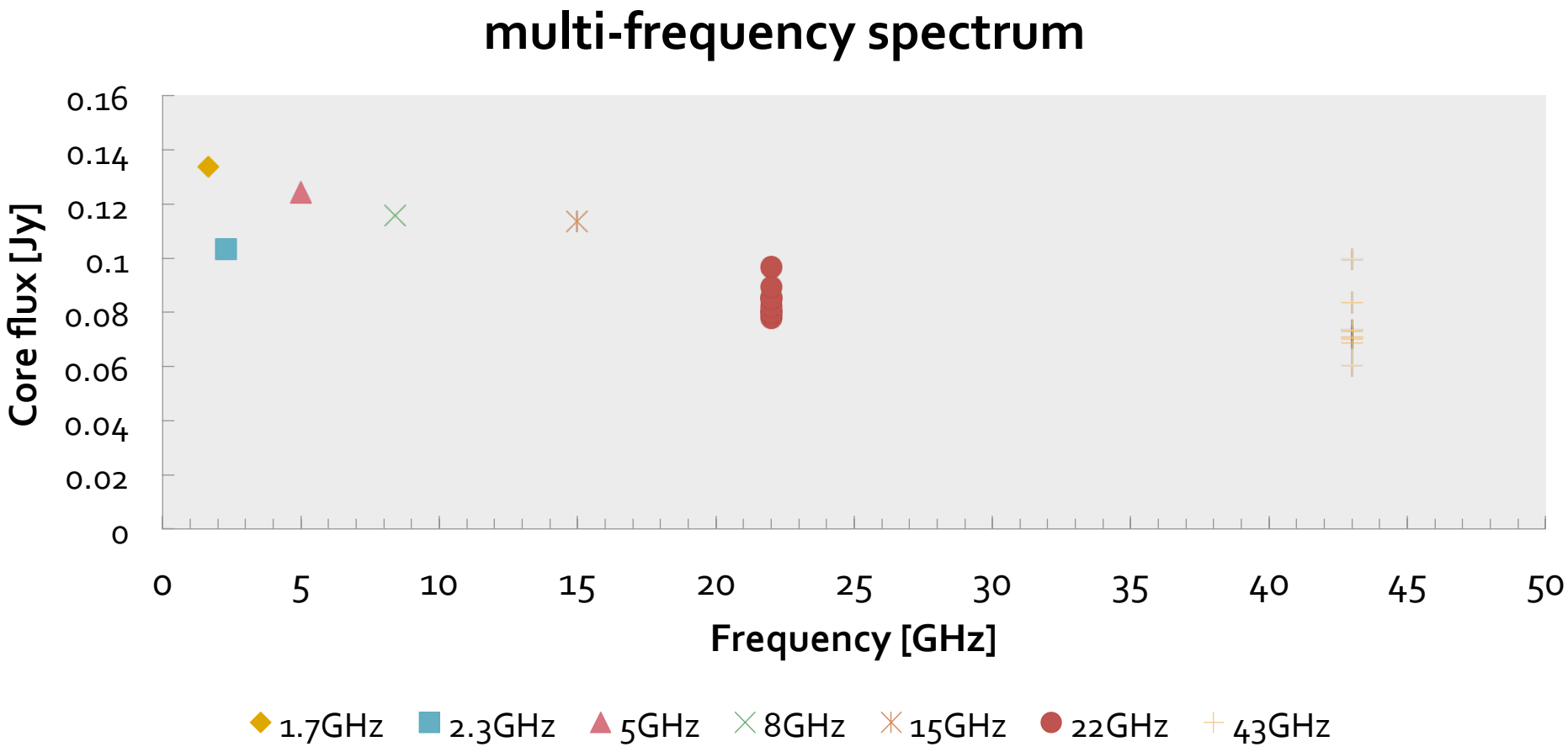
global-VLBI & VLBA data



Gabriele's 1.7 GHz data (Feb/1996)

Combine VERA, VLBA and global-VLBI data 1.7 /2.3 / 5 / 8 / 15 / 22 / 43 GHz

multi-frequency spectrum



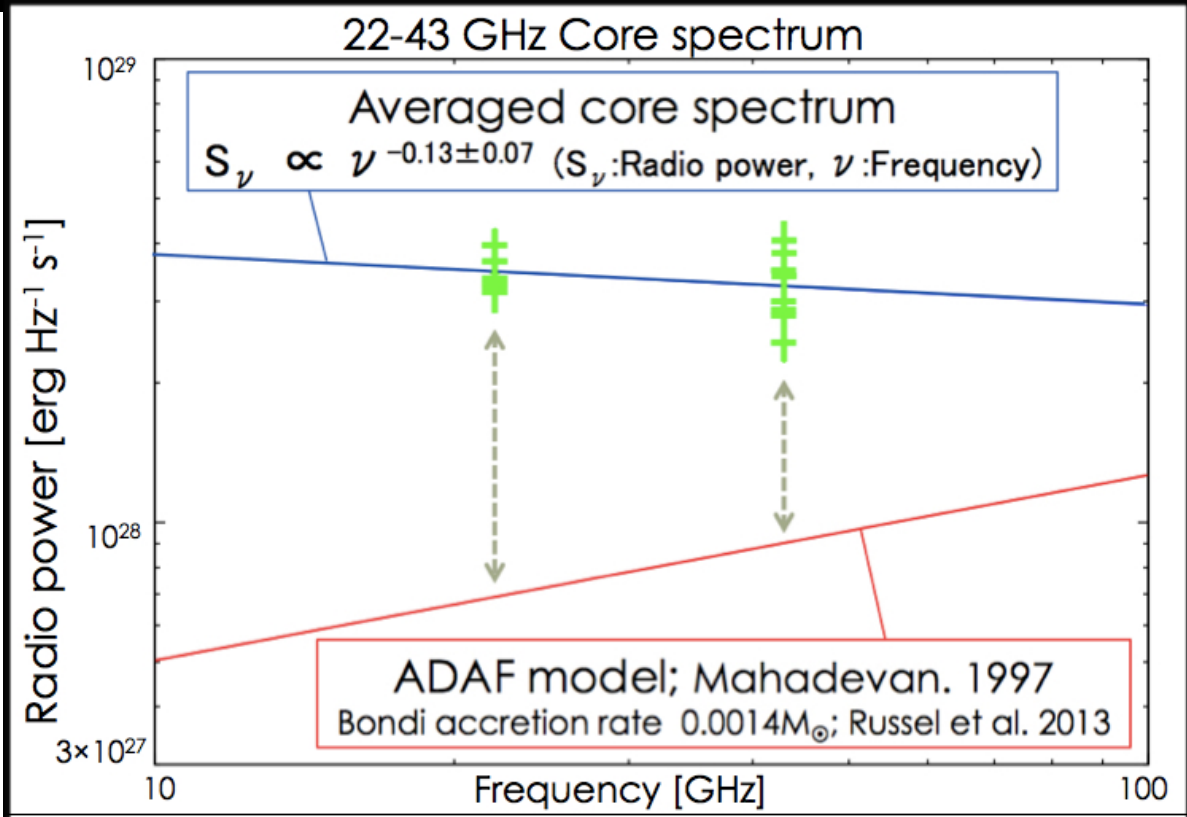
Consistent with VERA spectrum

Discussion : ADAF or Jet?

1 . Nuclear structure
→ **Detected jet-like component**

2. Spectral indices
→ **flat - steep**
Jet dominated?

3 . Radio power
→ **difficult to be explained only by thermal ADAF**



Green points : Observation data in 2012 and 2013
Blue line : Averaged core spectrum
Red line : Theoretical value of thermal emission from ADAF of M84

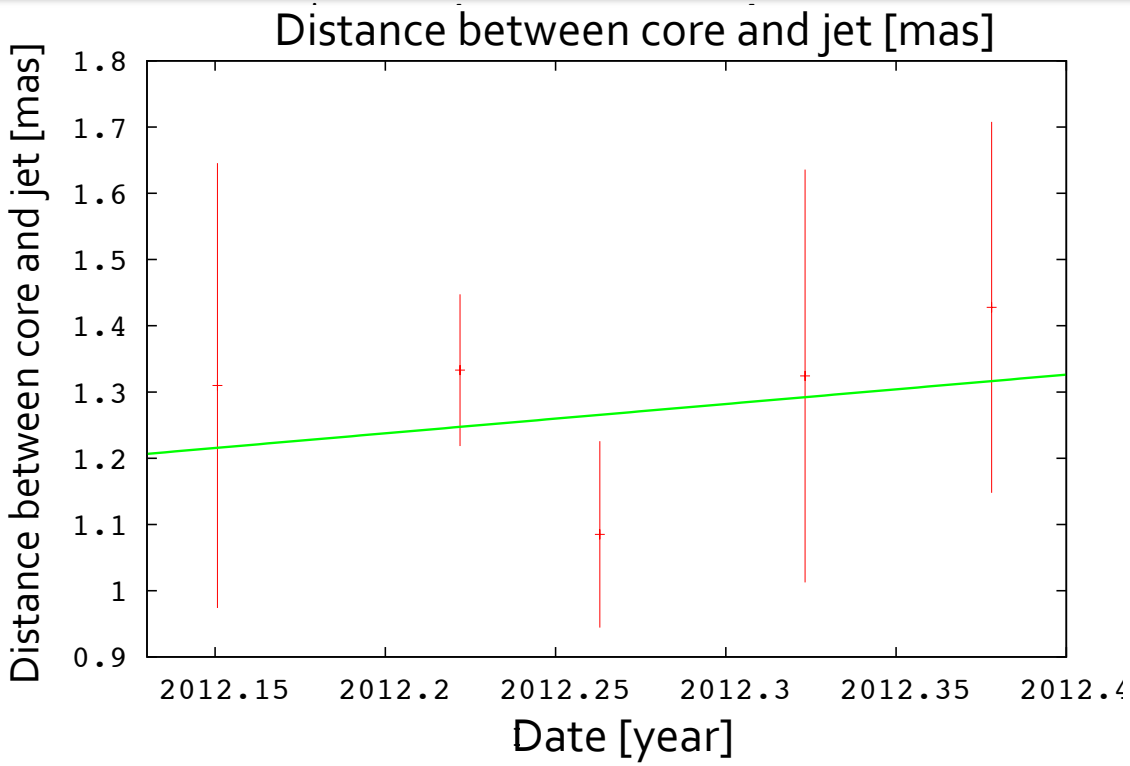
It is most likely to think that the nuclear radio emission of M84 is dominated by the jet base, where the physical scale is likely to be within a jet formation and collimation scale.

Future works

Constrain properties of the M84 jet
(within ~1000 R_S from the central engine)

■ Jet speed ■ Core shift ■ Magnetic field..

Preliminary



Jet hardly moving?

Jet speed in 2012

$\beta_{app} \sim 0.1\ c$
$\pm 0.3\ c$

Still large uncertainties

→ More dense sampled datasets in 2014 (8 epochs) will help us to derive the more accurate kinematics

Summary

Grazie !

- To study the origin of radio emission of M84 nucleus, we observed M84 at 22/43GHz quasi-simultaneously by VERA.
- We obtained the first VERA images of M84, and detected a jet component at 22GHz.
- The observed core spectra tend to show flat to gradually steep spectral indices, suggesting that the radio core emission is dominated by the base of Jet.

Grazie per atention !