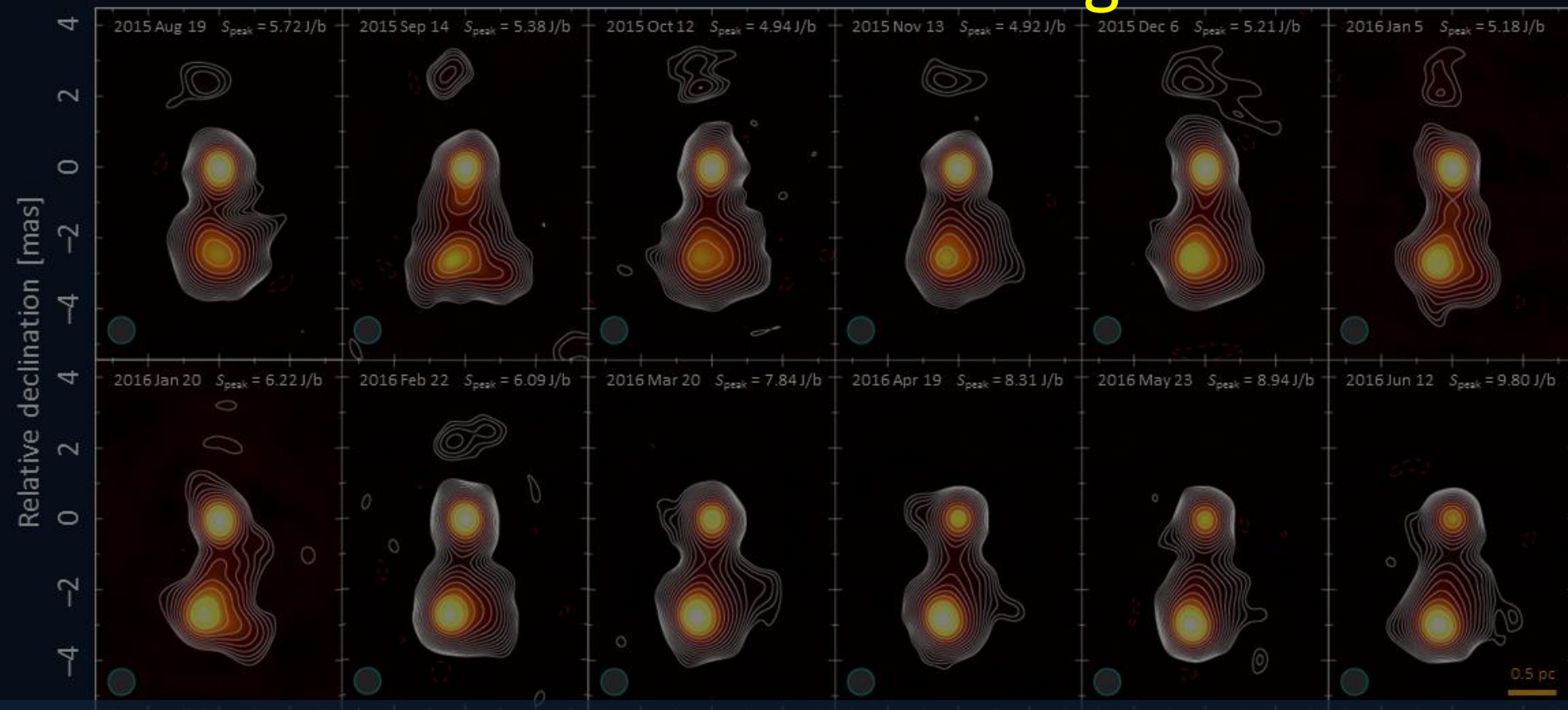


Long-Term KVN and KaVA Monitoring of 3C 84 at Millimeter Wavelengths



WAJIMA, Kiyooki (Corea Istituto di Astronomia e Spazio Scientifico)

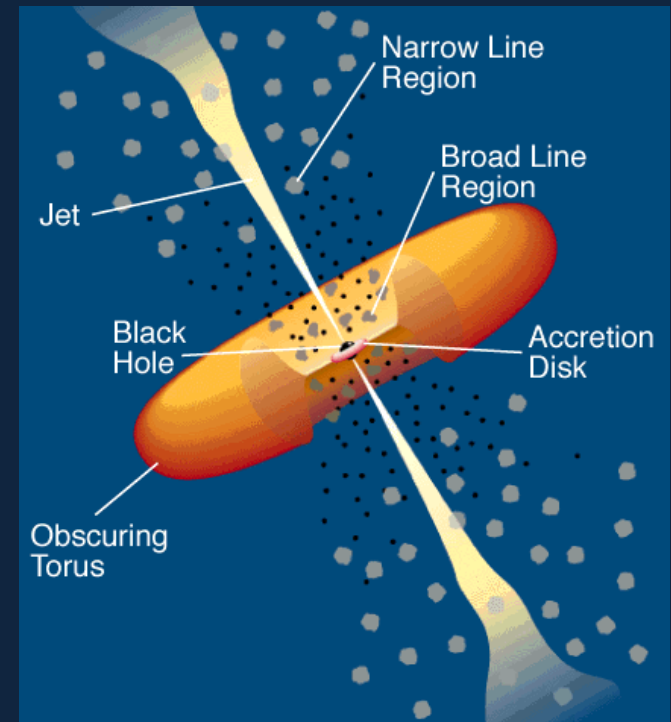
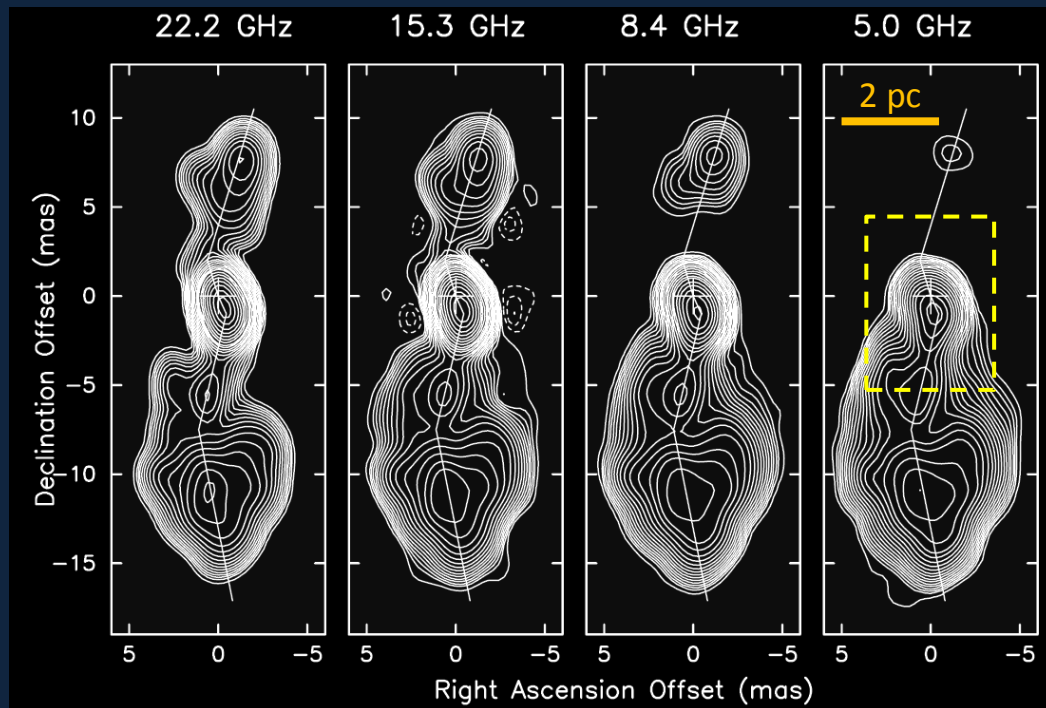
KINO, Motoki (Università di Kogakuin/NAOJ), KAWAKATU, Nozomu (NIT, Kure College),

SAWADA-SATOH, Satoko (Università di Kagoshima), Collaborazione di GENJI

30 ottobre, 2017 Workshop sulla EATING VLBI

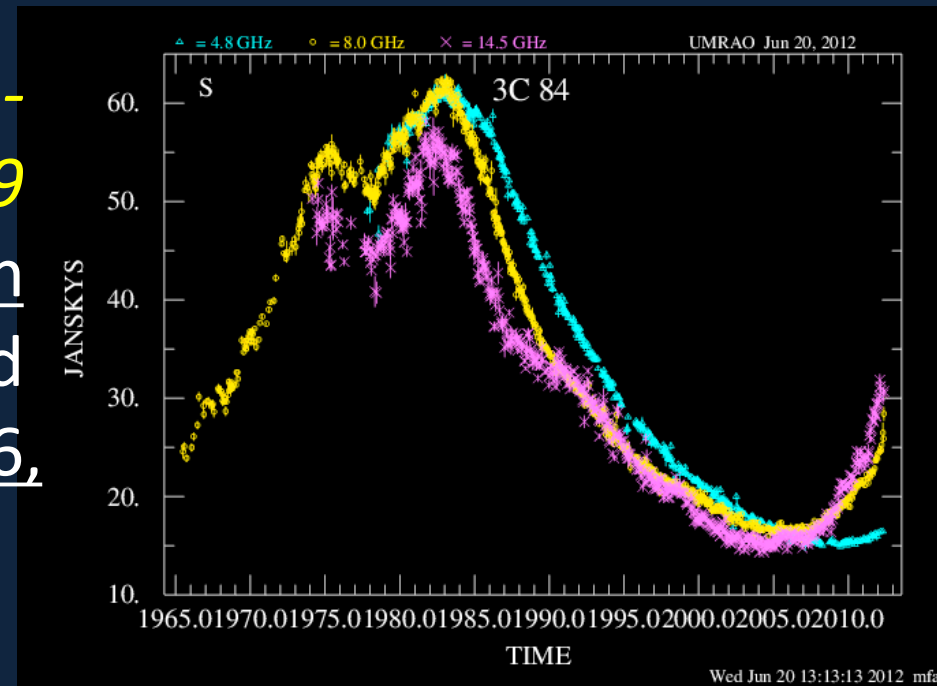
3C 84

- $z = 0.0176$ (1 mas = 0.36 pc)
- Discovery of 10 pc-scale free-free-absorbed (FFA) plasma torus with multifrequency VLBI at cm-wavelength (Walker et al. 2000, ApJ, 530, 233)



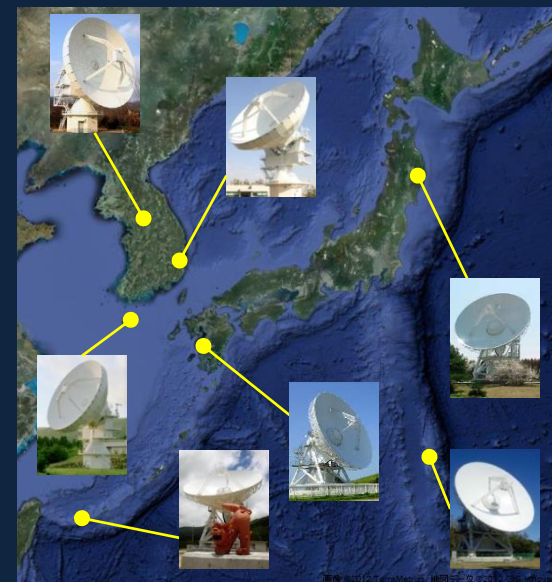
3C 84

- $z = 0.0176$ (1 milliarcsecond [mas] = 0.36 pc)
- Increase of the total flux at cm-wavelength from 2005 (UMRAO Database)
 - *The total flux reached 45 Jy at 11 GHz in November 2016* with long-term monitoring by RATAN-600 (Trushkin et al. 2016, ATel, 9791)
- *Detection of VHE gamma-ray on 2016 October 29* with MAGIC (Mirzoyan 2016, ATel, 9689) and VERITAS (Mukherjee 2016, ATel, 9690)



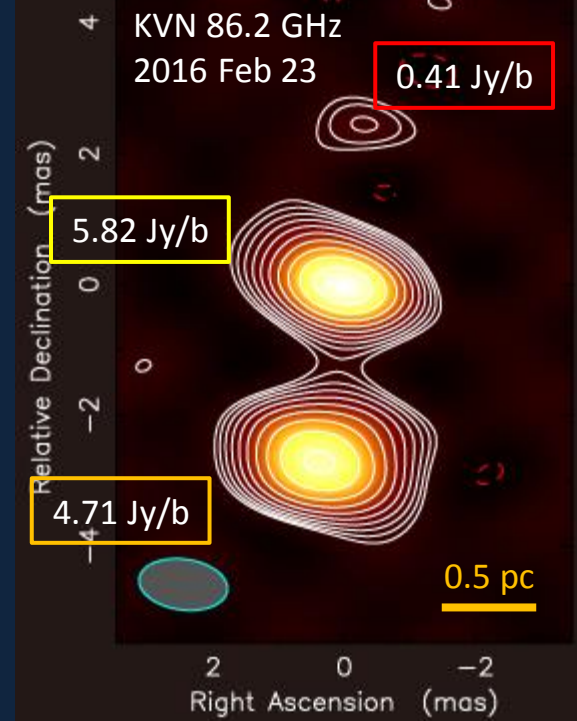
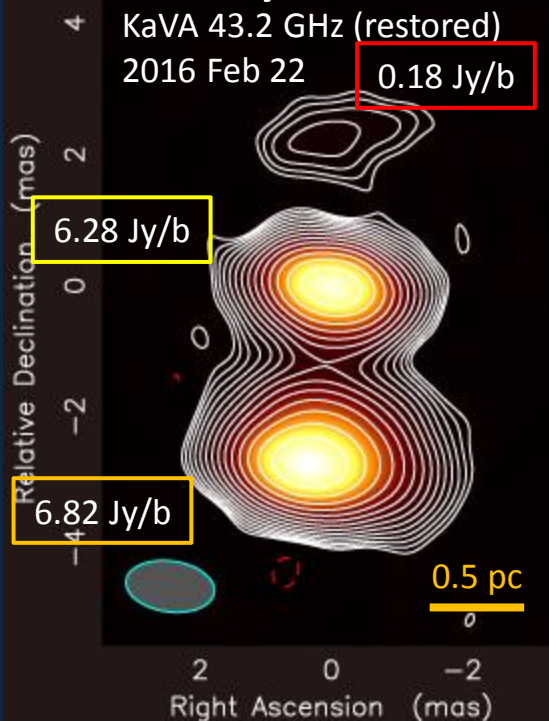
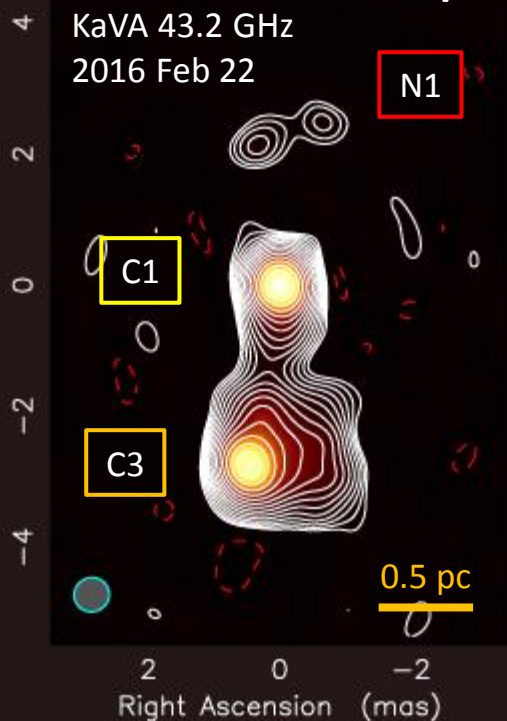
Multi-Epoch Monitoring of 3C 84 with KVN and KaVA (Aug 2015 – Oct 2017)

- *Monthly VLBI monitoring with KaVA at 43 GHz* (26 epochs)
 - *KVN observations at 86 GHz* (5 epochs) *and 129 GHz* (2 epochs)
- Results of *monthly monitoring for the first 12 epochs* (Aug 2015 – Jun 2016) *with KaVA at 43 GHz*
 - Results of *quasi-simultaneous observations on 2016 Feb 22* (KaVA 43 GHz) *and 23* (KVN 86 GHz)

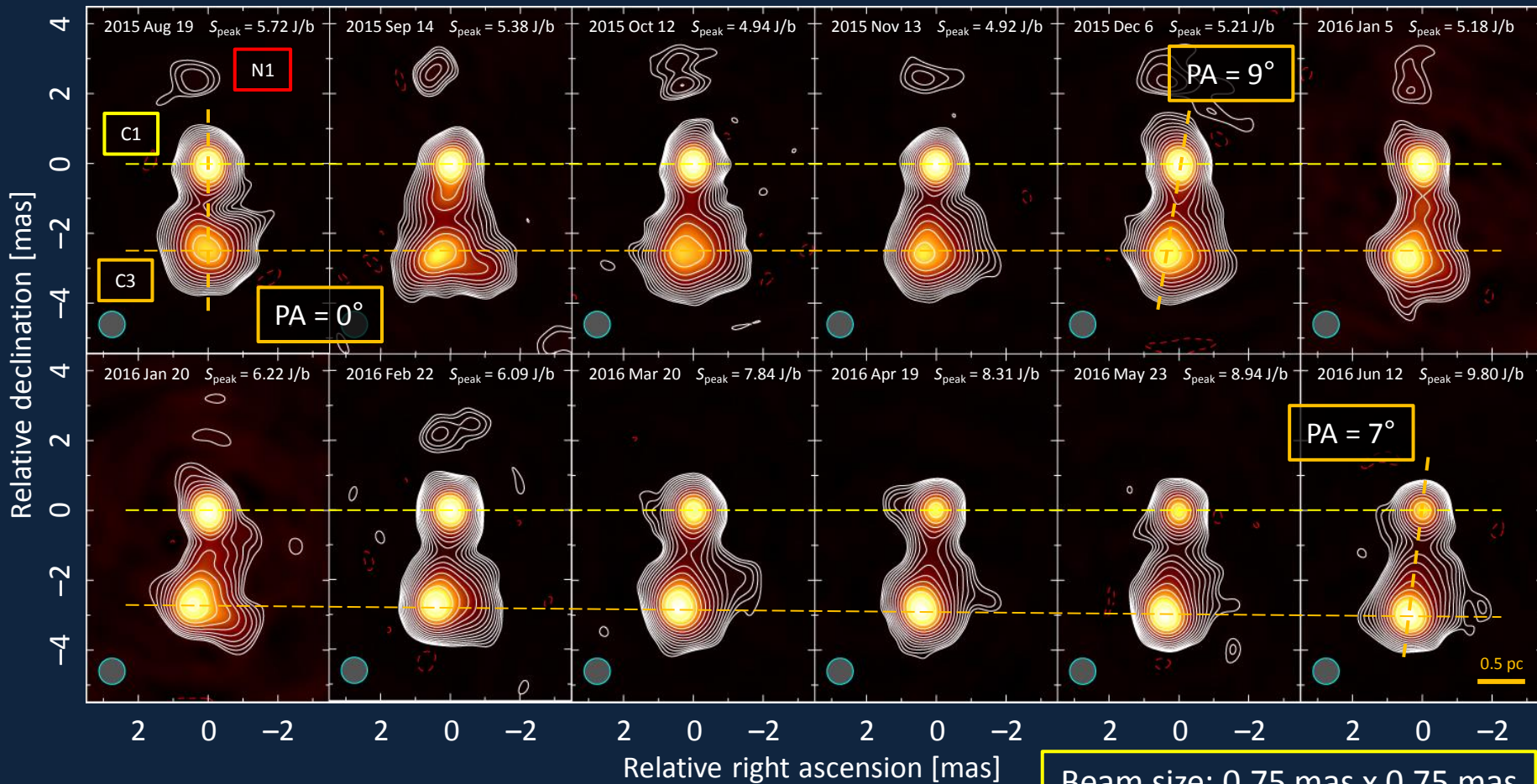


KaVA/KVN Images of 3C 84 at 43/86 GHz

- Distance between new peak position (N1) C1, $N1 - N2 = 1.5$ mas C1
 → Intrinsic distance θ between C1 and N1: 1.4 pc
 (assuming $\theta_{obs} = 40''$)
 Peak intensity of N1: 0.18 Jy/beam (restored KaVA 43 GHz)
 0.41 Jy/beam (KVN 86 GHz)
- Distance between C1 - C3: 2.7 mas → We could not detect a component at a symmetric position of C3.
 - First detection of N1 at 86 GHz (cf. Fujita+17).

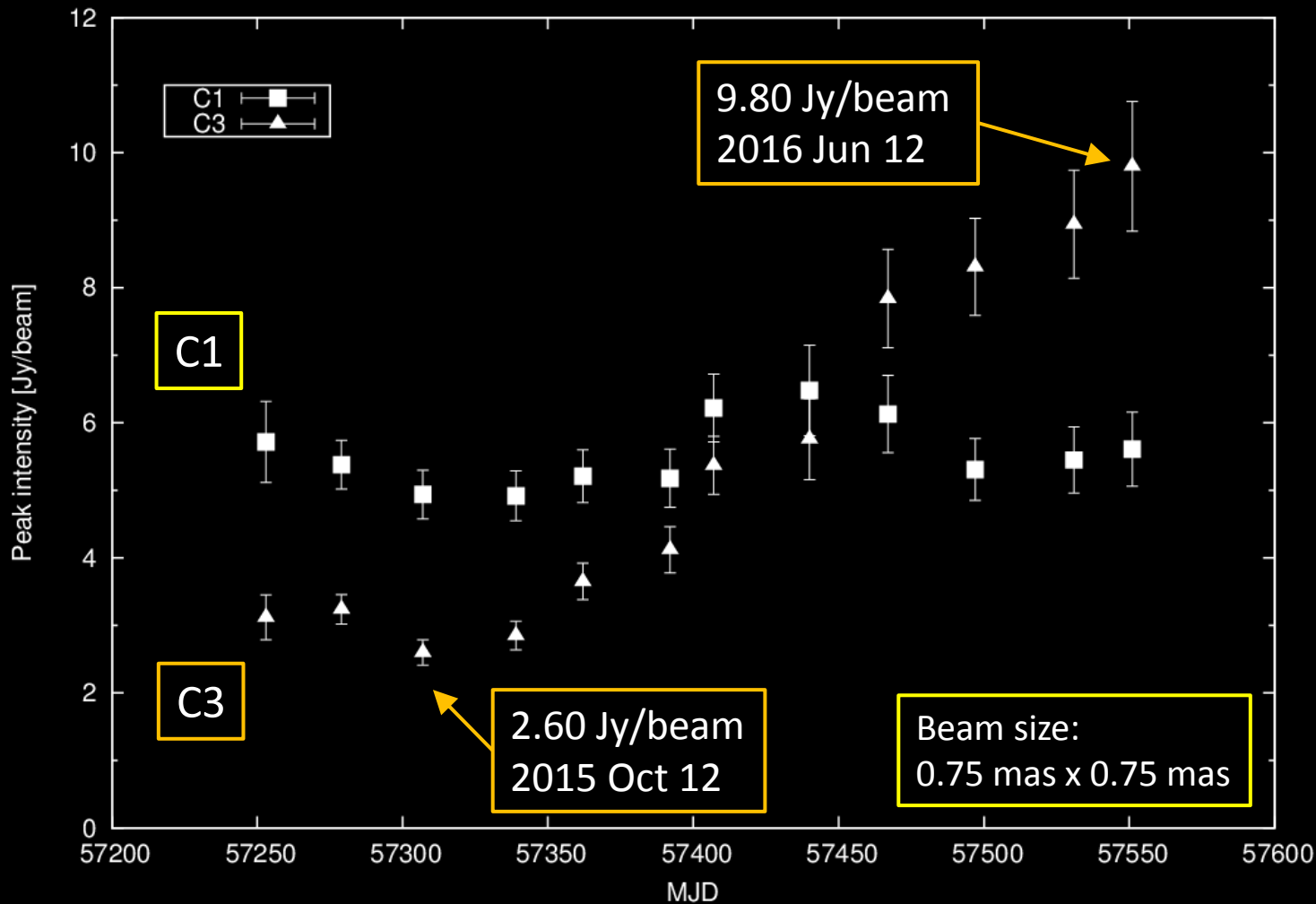


12-Epoch Images of 3C 84 at 43 GHz



- Detection of *new northern component (N1)* (cf. [Fujita, Nagai 2017, MNRAS, 465, L94](#))
- Abrupt *flux increase of C3* (cf. [Hodgson et al. 2016, arXiv:1612.07874](#))
- *Transverse* \rightarrow *outward motion* of C3

43 GHz Light Curve



Peak intensity of C3 was increased by 3.7 times over eight months.

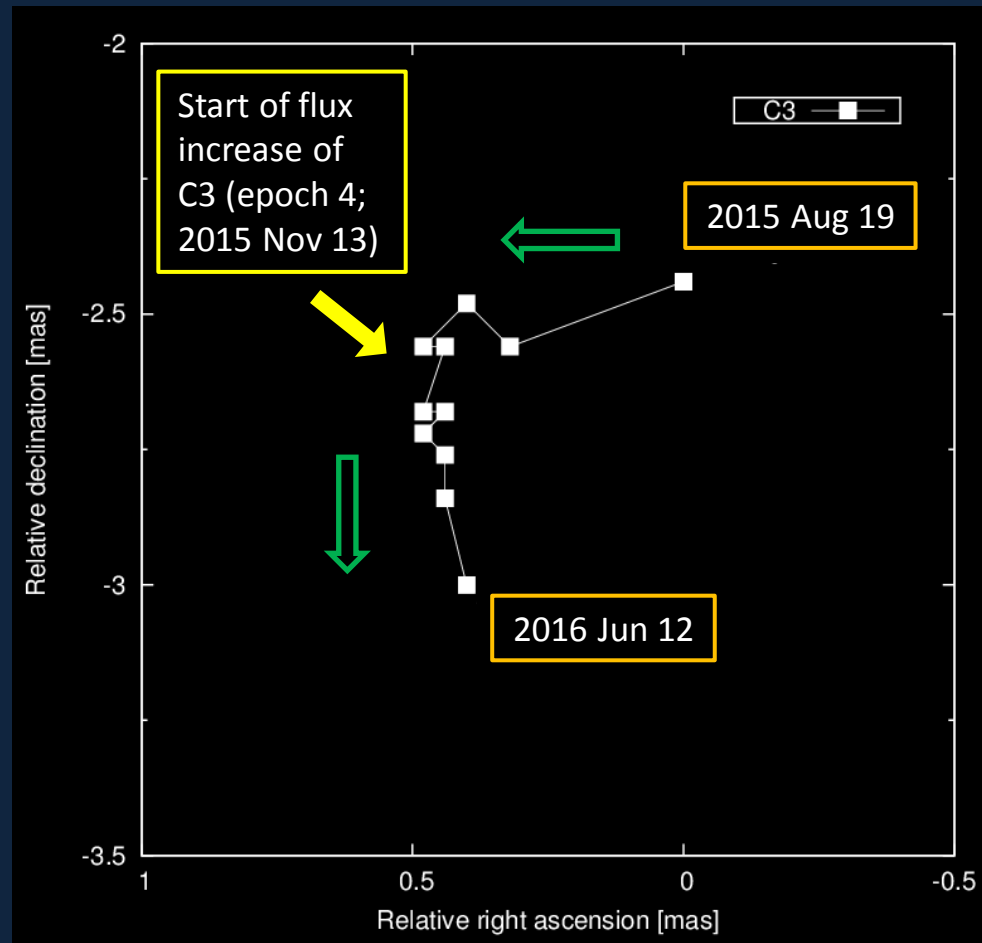
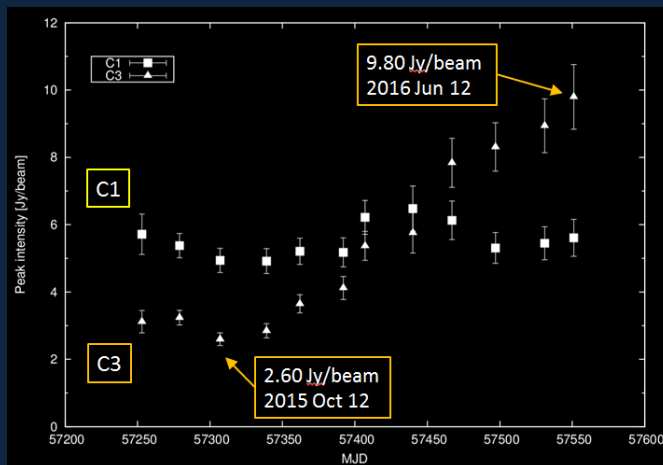
Relative Position of C3

- Relative peak intensity position of C3 with respect to C1 (0, 0)

Change in motion of C3
(transverse → outward)

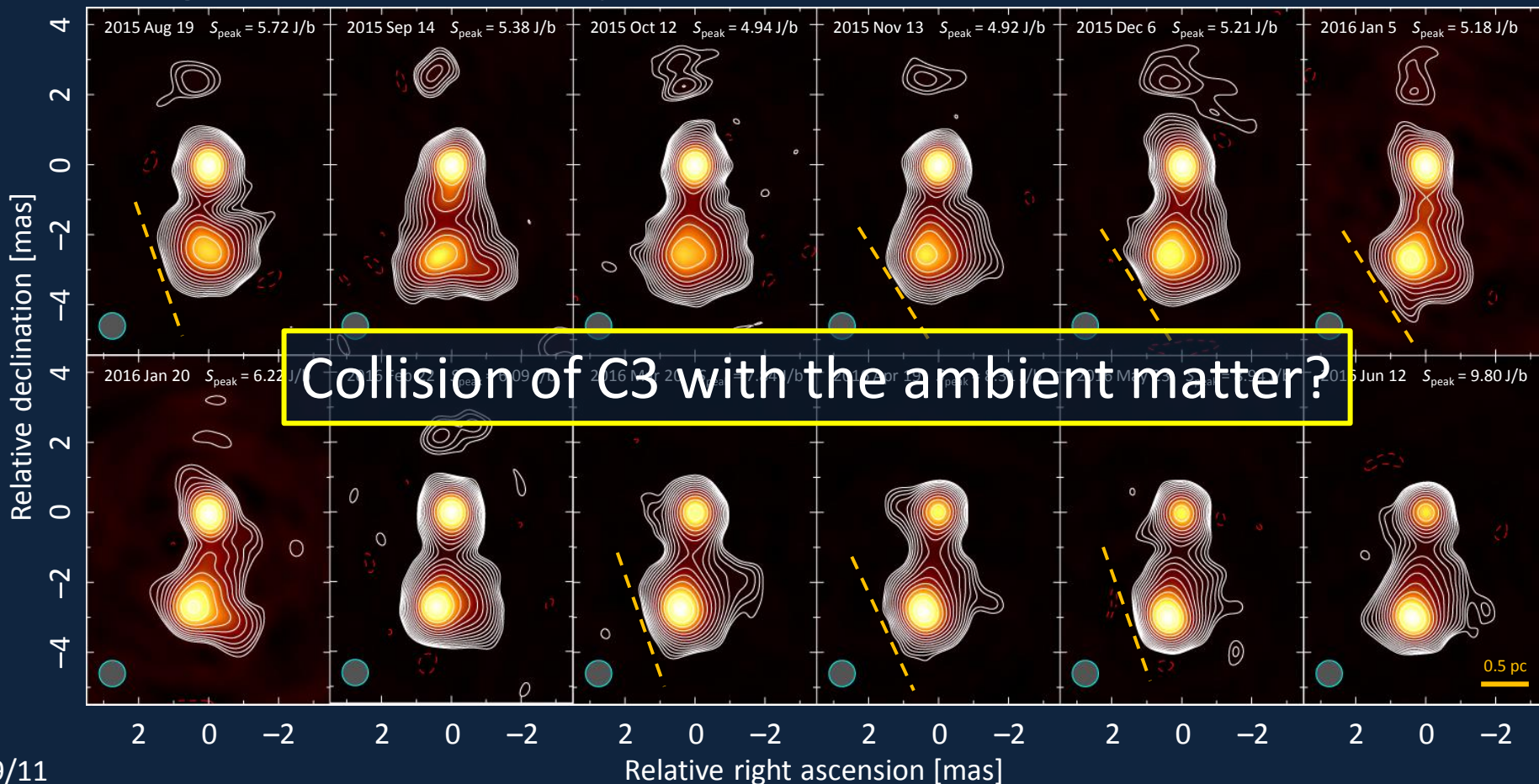


Start of flux increase of
C3 at 43 GHz

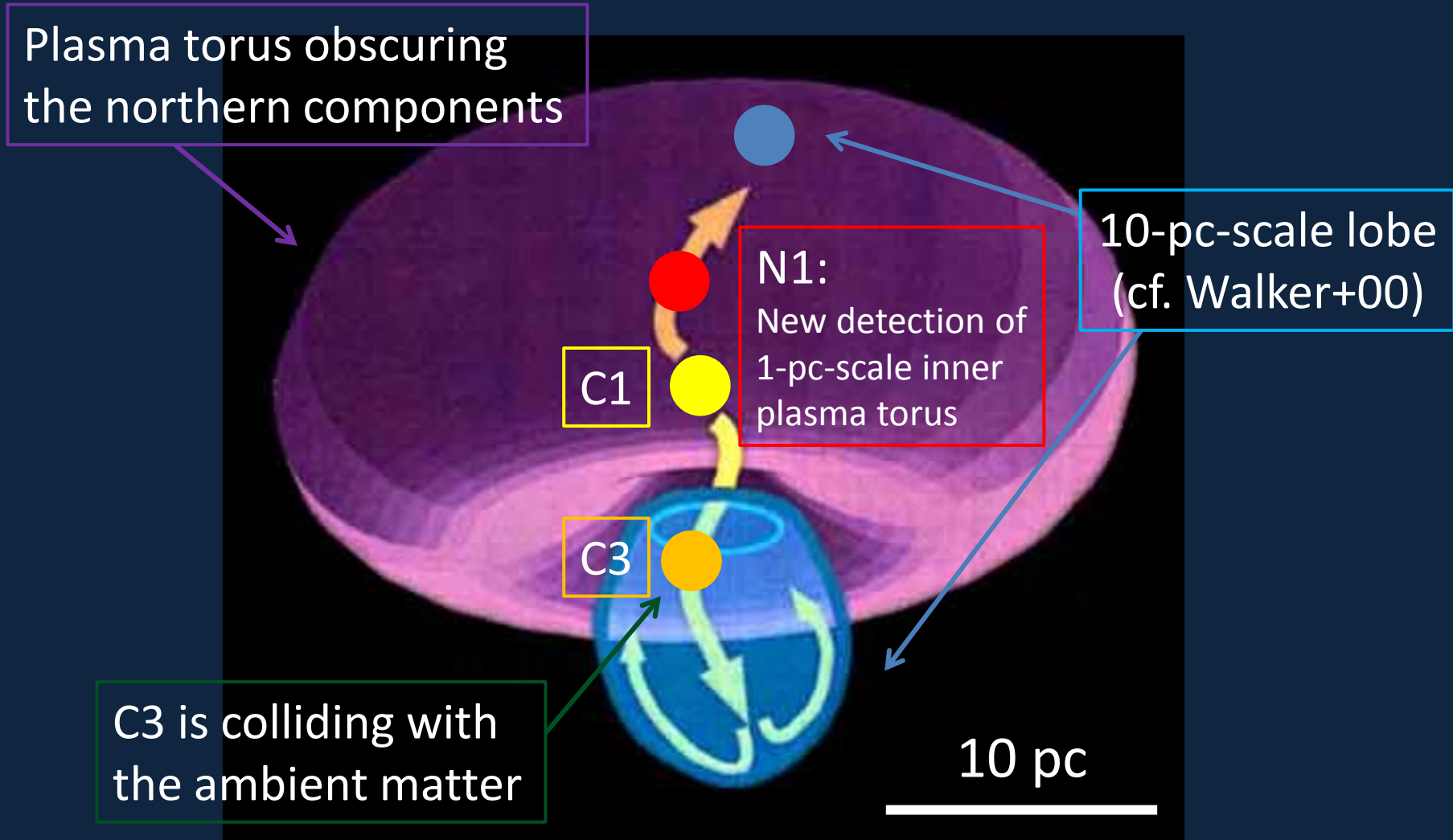


Limb-Brightening Feature in C3

- Limb-brightening and compressed features* can be seen in the southeast of C3 for several epochs (cf. Nagai et al. 2014, ApJ, 785, 53)



Schematic Diagram of (sub-)pc-Scale Structure in 3C 84



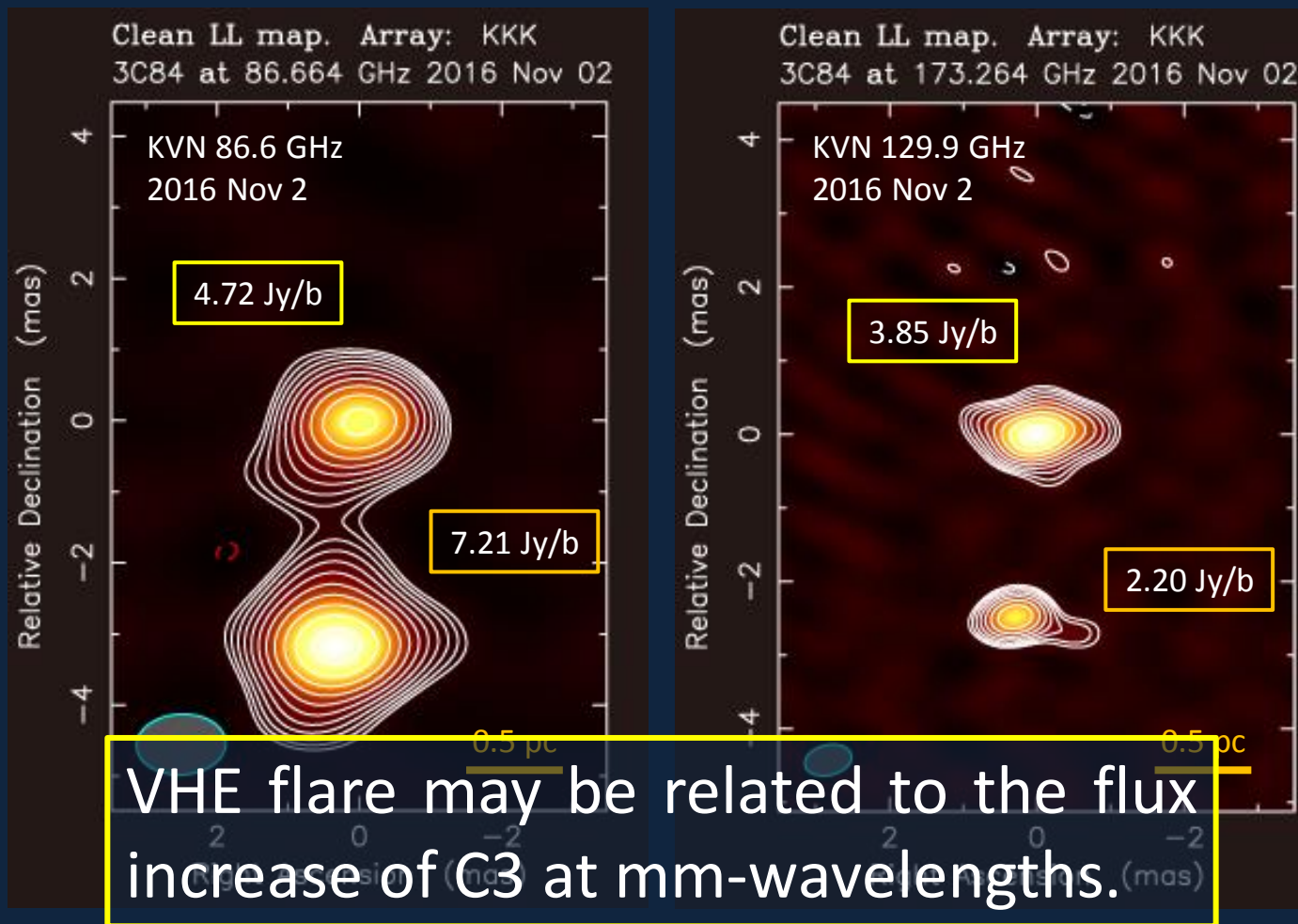
(Image courtesy: Seiji Kameno (NAOJ))

Summary

- Purpose: To investigate **1 pc-scale circumnuclear region and ambient environment of AGN**
- Observations: Multi-epoch VLBI observations of **3C 84** with **KVN 86(/129) GHz** and **KaVA 43 GHz**
- Results:
 - *Discovery of a new optically-thick component N1* at both 43/86 GHz
 - *Abrupt flux increase of C3* accompanied with change in motion with respect to C1
- Possible explanation:
 - N1: *Gas disk which hides a component at the symmetric position of C3* (+ clumpy gas clouds which temporarily hide N1)
 - C3: *Collision of C3 with the ambient matter*

86/129 GHz Images Just after the VHE Flare

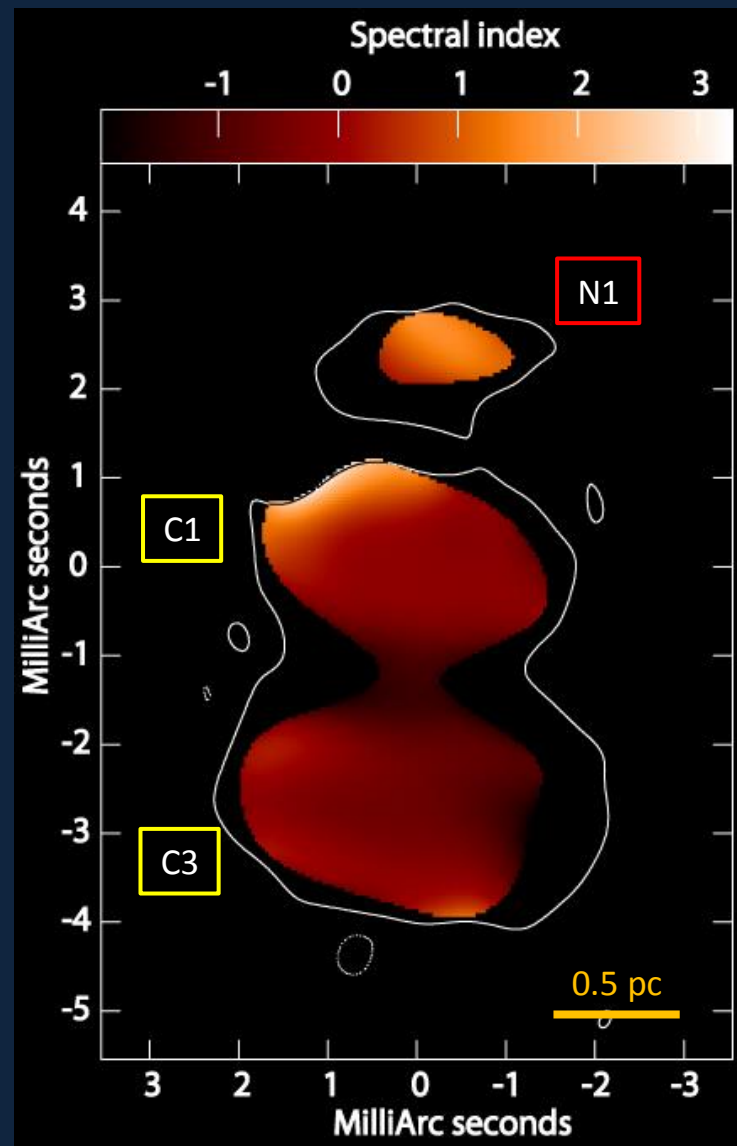
- **KVN observation at 86/129 GHz on 2016 November 2**
(cf. VHE gamma-ray flare on 2016 October 29)



Spectral Index Distribution (43/86 GHz)

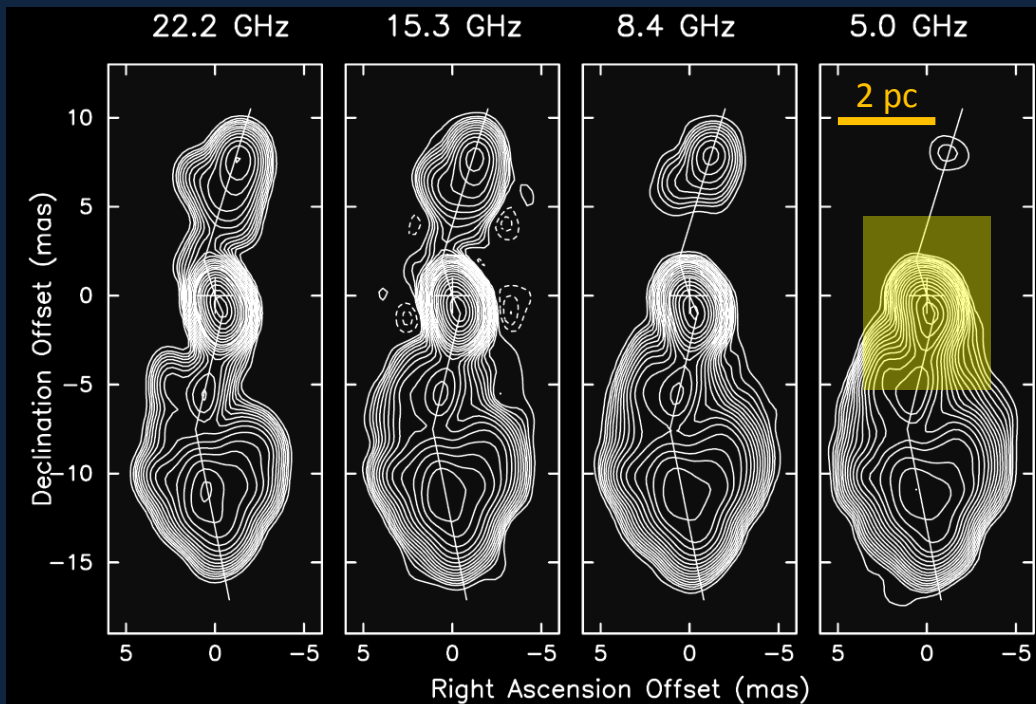
- Registration of 43/86 GHz images with respect to C1 and C3 (accuracy of relative position of C1 and C3 is less than 1/10 of KVN's beam size)
- Spectral index α at the peak intensity of each component ($S_\nu \propto \nu^{+\alpha}$)
 - C1: -0.1 , C3: -0.5 , N1: $+1.2$

Only N1 has an optically-thick α between 43/86 GHz



Cause of Asymmetric Structure in 3C 84

- Apparent velocity of C3 is $0.23c$ (Nagai et al. 2010, PASJ, 62, L11) \rightarrow Difficult to make an asymmetric structure by the beaming effect of N1
- Existence of '1 pc-scale gas disk' inside the '10 pc-scale FFA plasma torus' (cf. Walker+00)



(Walker et al. 2000)

Cause of Asymmetric Structure in 3C 84

- Long-term monitoring by VLBA MOJAVE at 15.4 GHz (Dec 1999 –) (<http://www.physics.purdue.edu/MOJAVE/>)
 - Detection of a new component on and after 2015 Sep 6
 - The component was not detected with observations on 2016 Jun 18 and before

1 pc-scale gas disk which
stationarily exists and
hides N1

+

Clumpy gas clouds which
temporarily hide N1

