Science cases with mmVLBI

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In the last few years, we (EA) have produced a number of mmVLBI-related scientific results particularly on M87

Here I will overview mostly these EA-led M87 works – would help to consider our future scientific strategy or initiative in this field

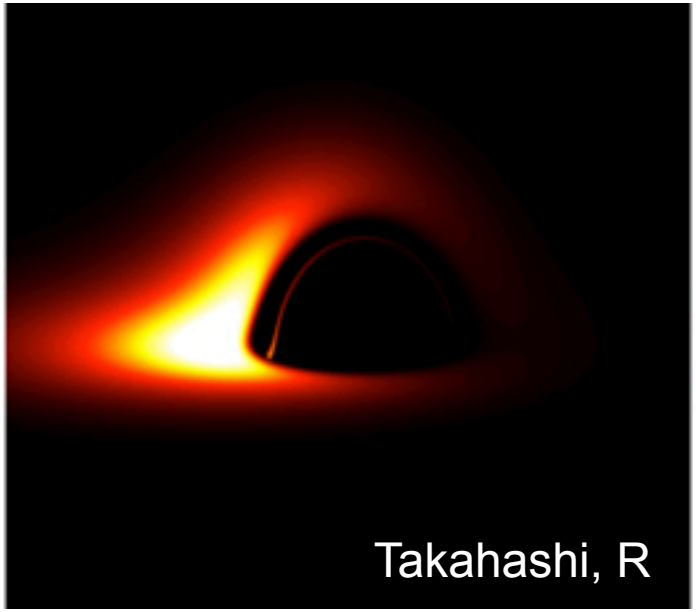
mmVLBI: motivations so simple

The pursuit of higher angular resolution & transparency toward AGN cores

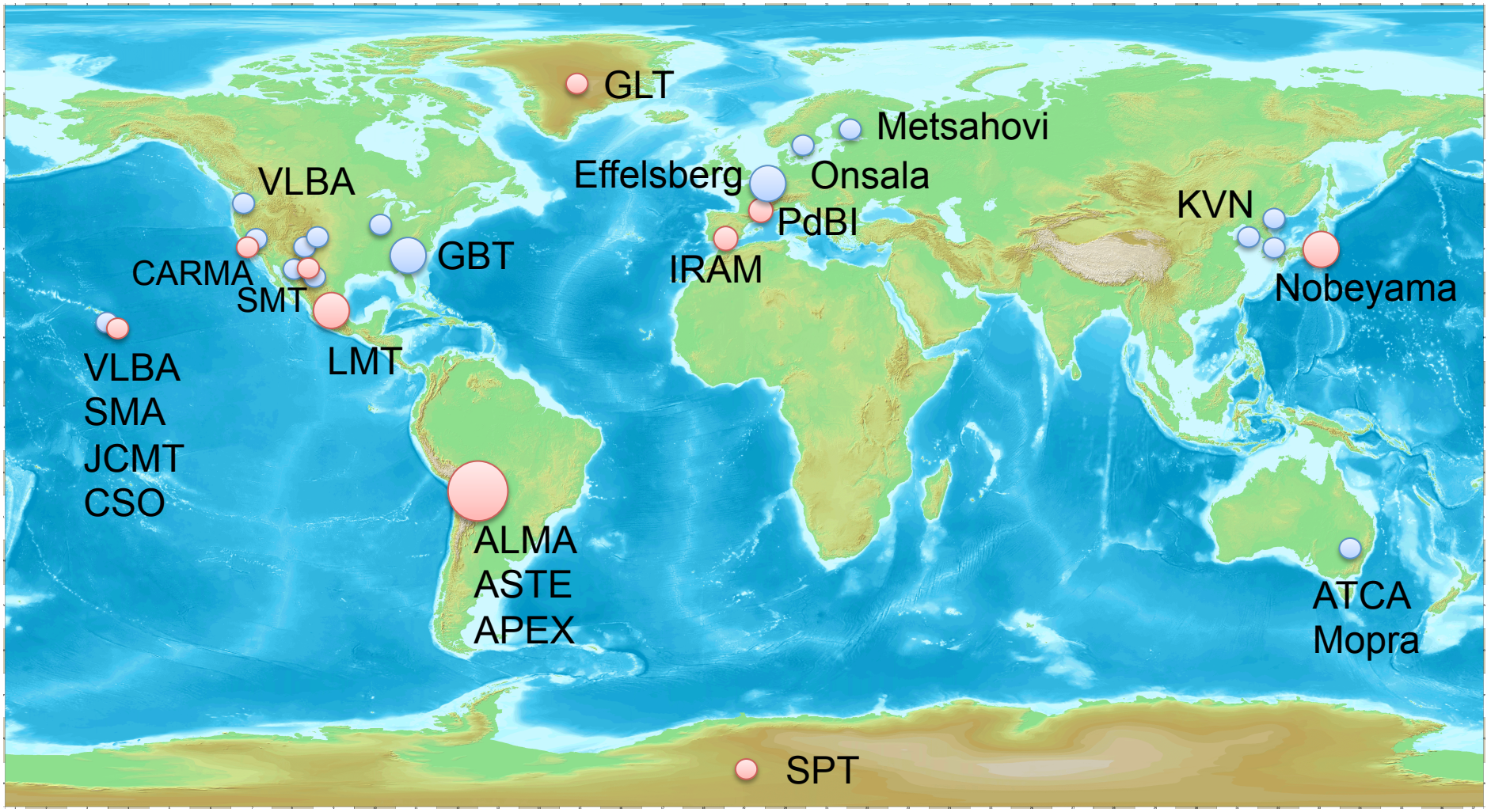
$$\theta = 34 \left(\frac{\lambda}{1\mathrm{mm}} \right) \left(\frac{D}{6000\mathrm{km}} \right)^{-1} \ (\mu\mathrm{as})$$

$$\alpha_\nu^{\mathrm{syn}} \propto n_e B^{(p+2)/2} \nu^{-(p+4)/2}$$

- **Resolve and image a black hole shadow**
- **Direct test of GR, BH spin**
- **Physics of accretion flow, jet launch**

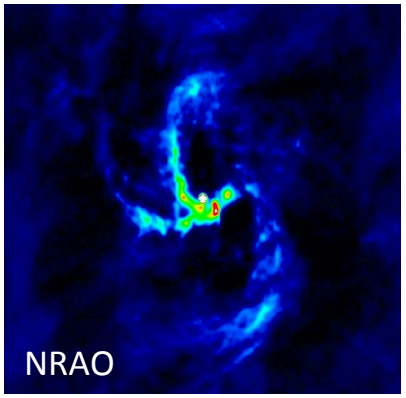


mm/submm telescopes



3mm (86GHz)

3mm (86GHz) & 1.3mm (230GHz)

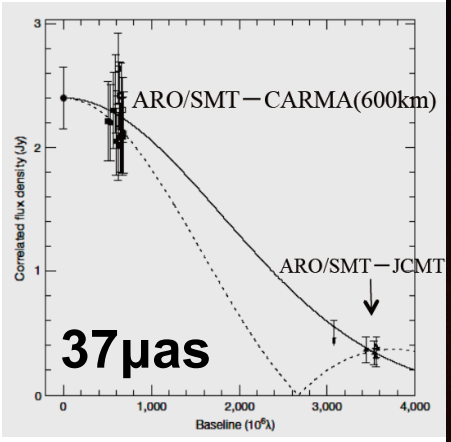


Targets

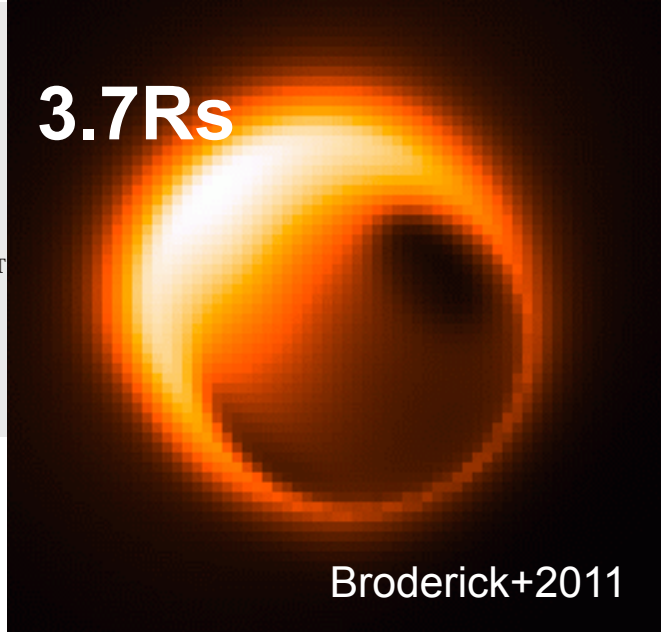
Object	M_{BH} (10^8 M_{sun})	D (Mpc)	2Rs (μas)
SgrA*	0.04	0.008	20
M87	60	16.7	14
(NGC1277)	170	73	9
Sombrero	10	9.0	4.5
M84	8.5	17	2
Cen A	0.5	3.8	0.5
3C84	3.4	68	0.2
BL Lac	2.0	270	0.03

SgrA*

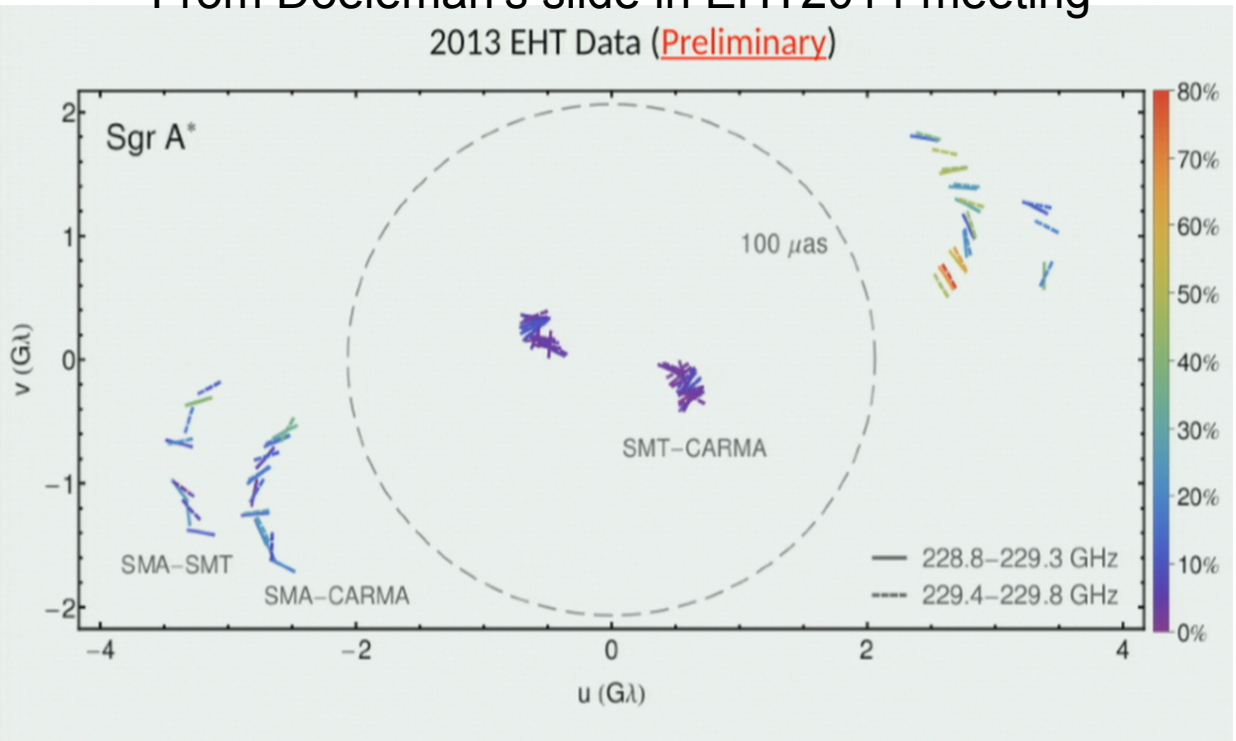
- **The best laboratory for probing black hole accretion**
  - **3.7Rs emitting size**



Doeleman+2008



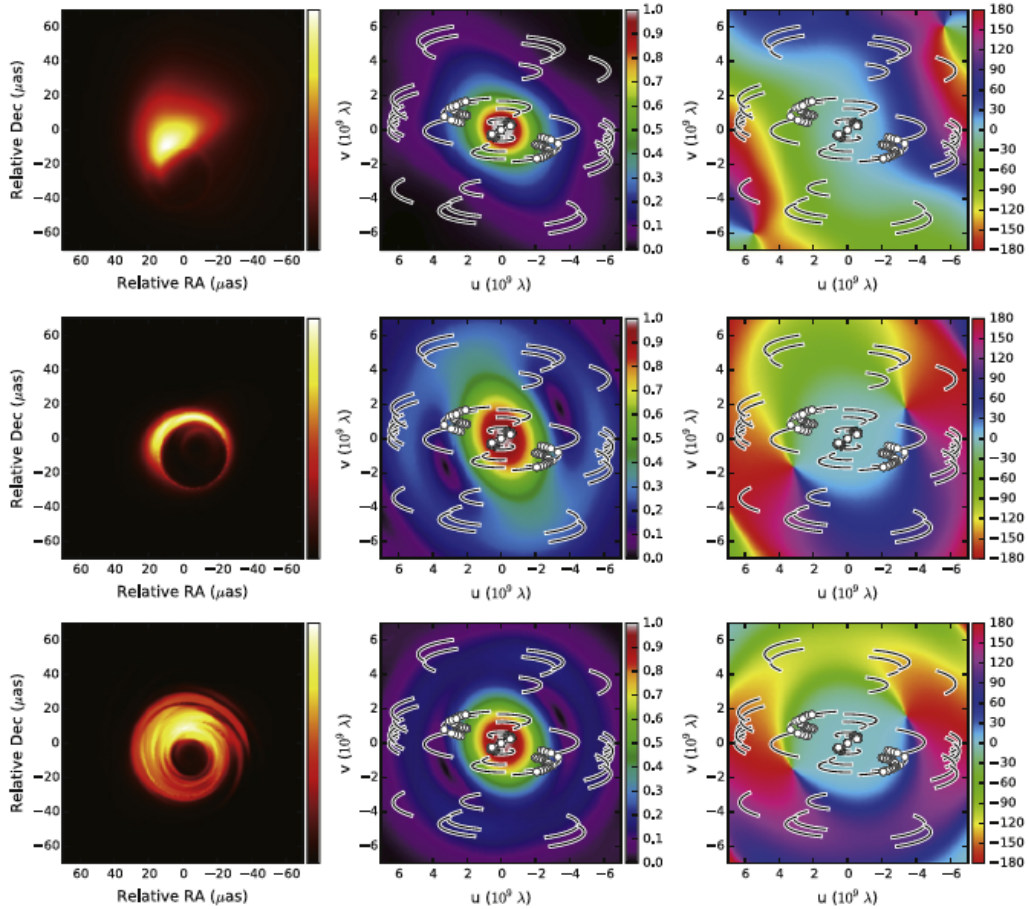
From Doeleman's slide in EHT2014 meeting

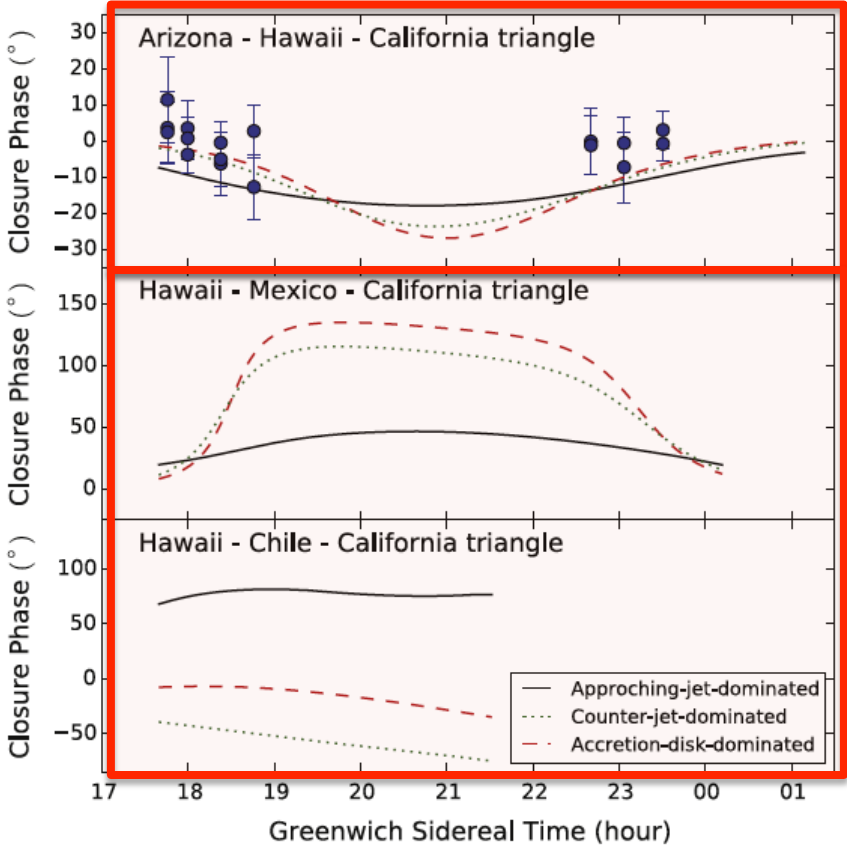


- **Detection of highly polarized (P~70%) signals on Hawaii-CARMA baselines**
- **Presence of ordered B fields on horizon scales**

M87

- **40μas (~6Rs) size core@1.3mm**
- **1.3mm intra-US closure phases consistent with zero**
  - **jet-base emission is symmetric on ~6Rs scale**





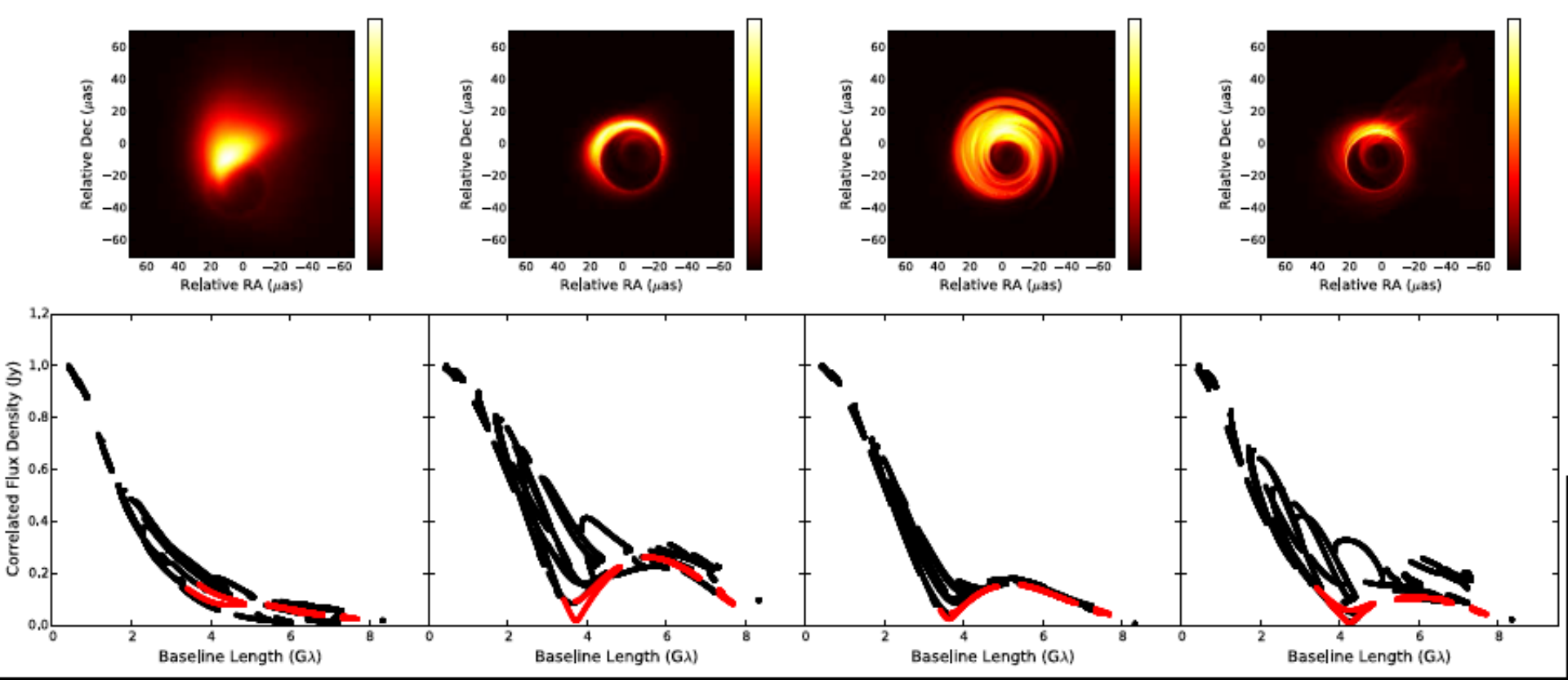
Akiyama+2015

Adding LMT or ALMA baselines will allow to disentangle a zoo of launch emission models

And…

From Akimama-san's slide in EAVN meeting

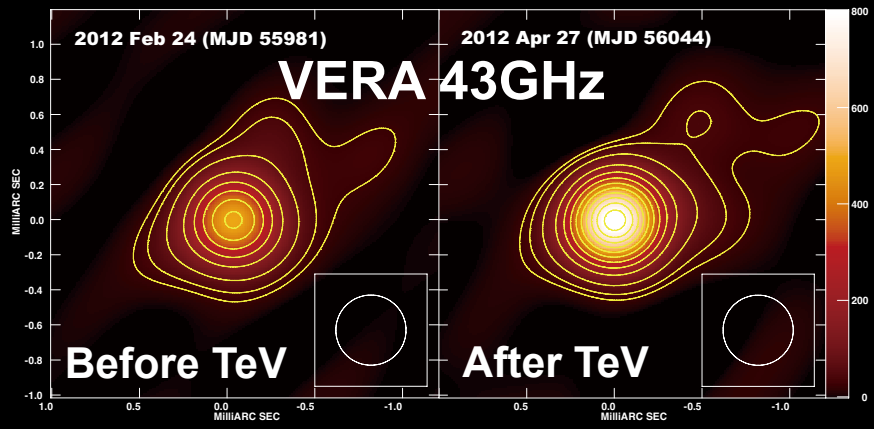
Simulations how Nobeyama works out

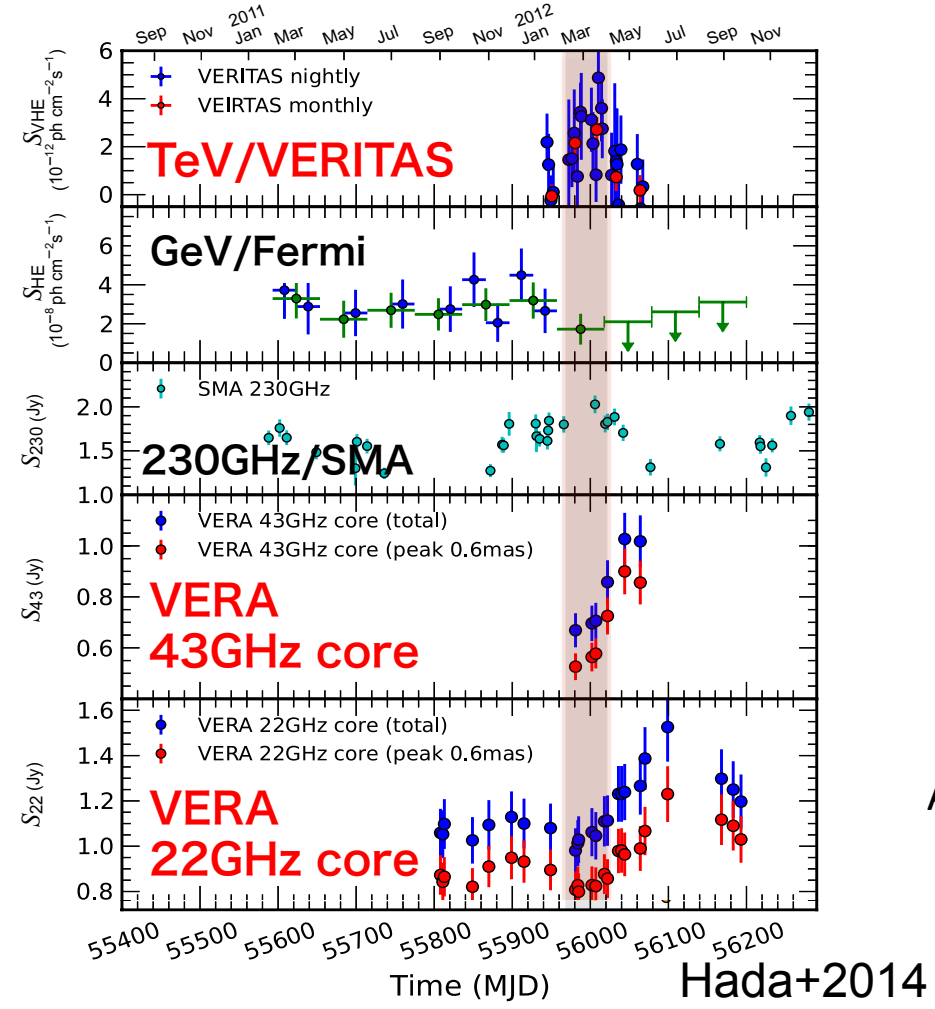


NRO baselines are **exactly** located between the first and second null regions
(*uv*-coverage is really effective to study the presence of the shadow)

—> Why not performing 1.3 mm-VLBI observations with Nobeyama (SPART and 45m Telescope)!?

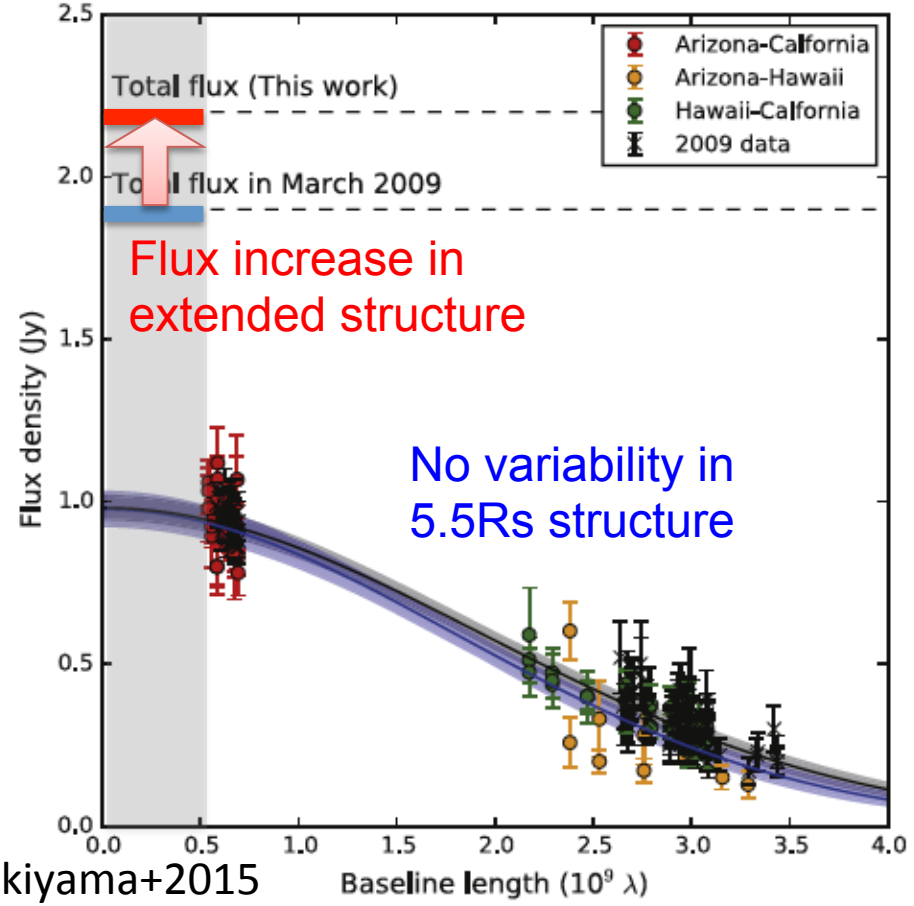
Resolving TeV site near BH?





Hada+2014

230GHz VLBI in the middle of TeV flare



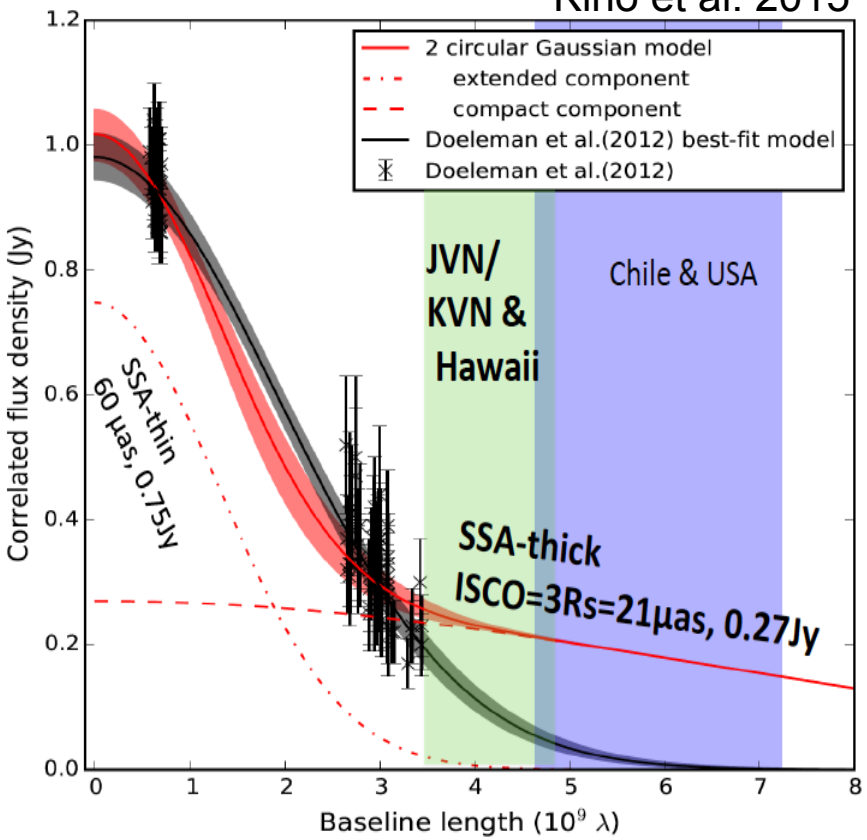
Akiyama+2015

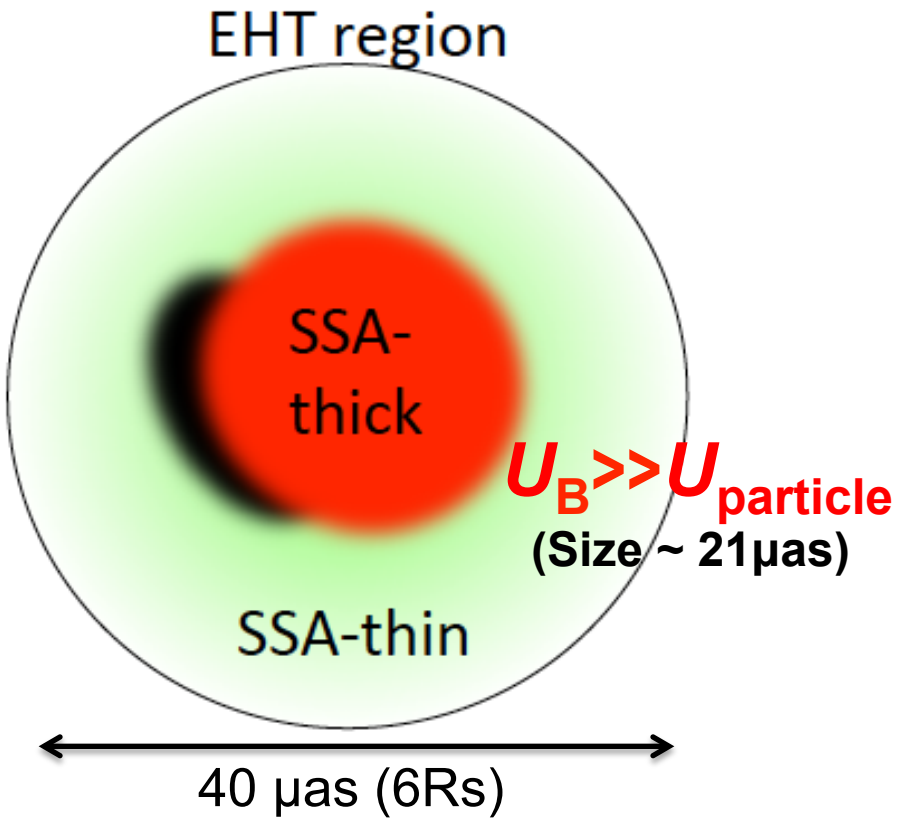
20Rs < R_{TeV} < 60Rs ?

(EHT) (VERA)

Magnetization degree (U_e/U_B): Testing the *B*-driven jet paradigm

Kino et al. 2015





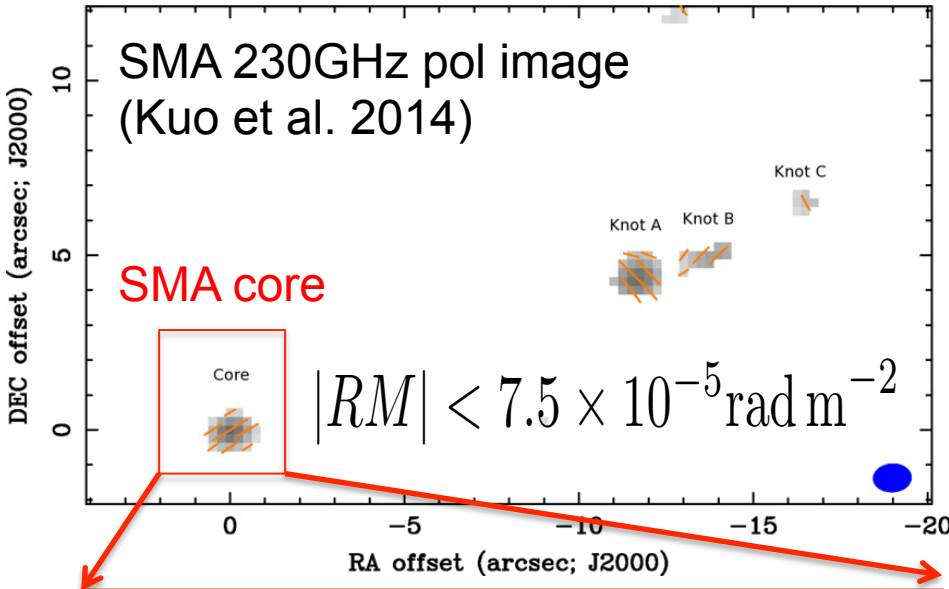
A highly B-dominated substrcuture (~20μas) is required to exist within the 40μas structure

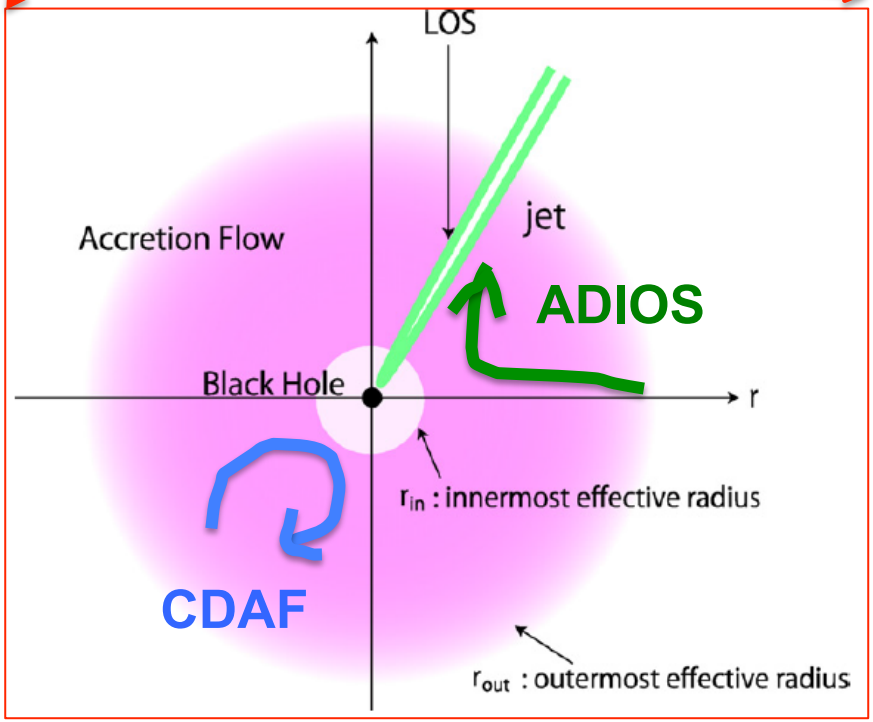
Constraining accretion flow via mm-polarimetry

- **|RM| observed in 230GHz band constrained a maximum mass accretion rate onto BH:**

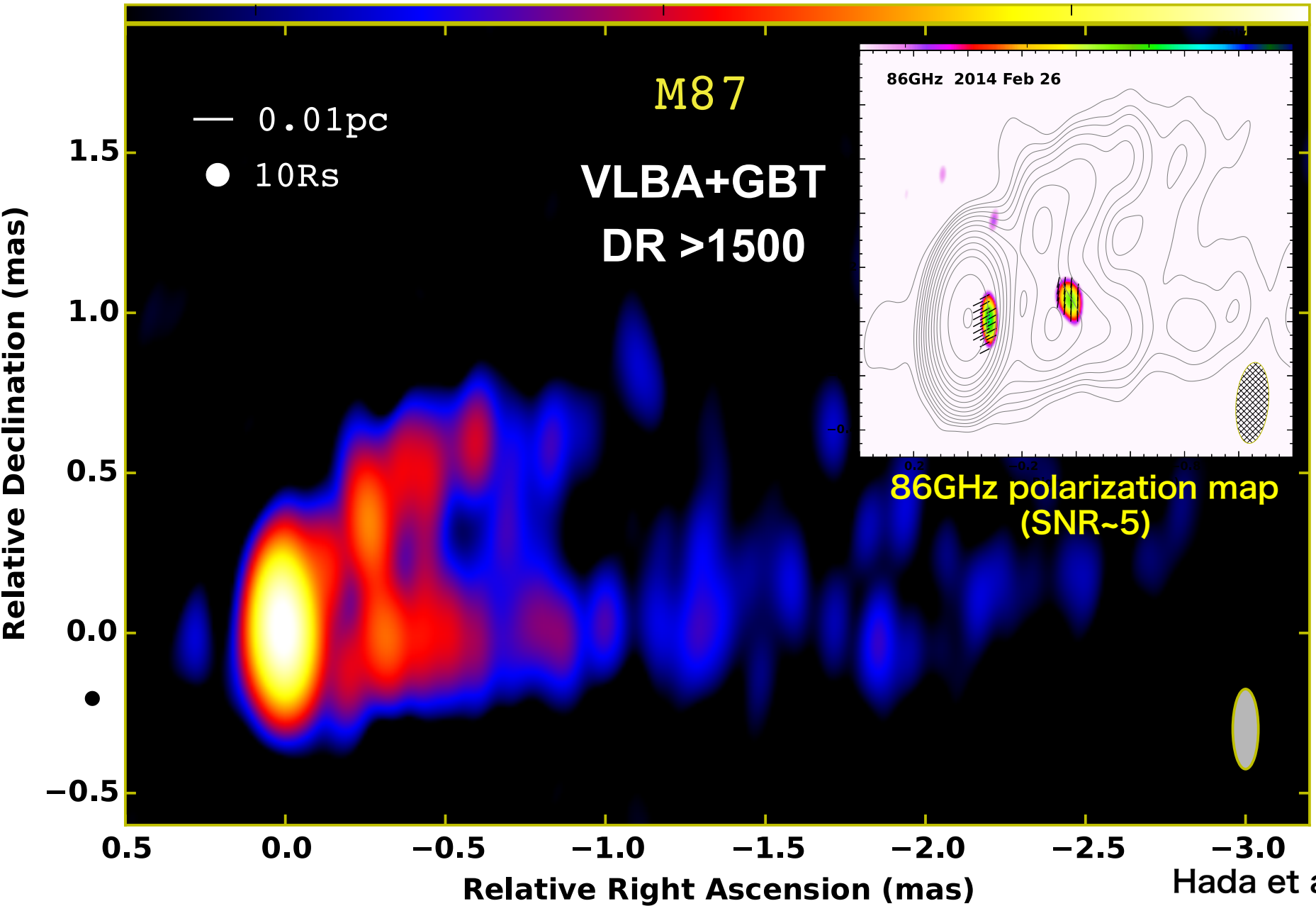
$$\dot{M}_{r=21R_s} < 0.0074\dot{M}_{r_{\rm Bondi}}$$

- **Mm-VLBI polarimetry may allow to obtain a spatial gradient of $M_{dot}(r)$ profile**





86GHz high-sensitivity VLBI imaging



Hada et al.

Ongoing mmVLBI-related activities in EA

- **1.3mm EHT data analysis**
  - Akiyama-san, Asada-san
- **3mm GMVA/VLBA data for M87&more**
  - Asada-san, Koyama-san, Hada
- **Theoretical ground (analytical + simulation)**
  - Kino-san, ASIAA (Nakamura-san, Pu-san)
- **Sparse modeling**
  - Honma-san, Kuramochi-san, Tazaki-san
- **Synergetic monitor with VERA/KaVA**
  - Kino-san, Niinuma-san, Hada
- **KVN mm multi-freq. phase-ref**
  - Jung-san
- **JCMT, GLT, SPART/Nobeyama**
  - Asada-san, Fujisawa-san, Saitoh-san, Miyoshi-san
- **Balloon**
  - Doi-san

We have our own data, theory, technique, technology, telescopes, & brains!

Summary: Why don't we boost/accelerate our(all-EA) collaboration? Now the best timing

- A number of scientific/technical developments in EA
- Soon: open-sky use of APP (ALMA for VLBI) at band-3/6(?) will be available in the next year (Cycle-4)
- To take initiative, we need powerful science cases and ability to achieve them
- Focus on M87? Also SgrA* or other sources (blazars/nearby RGs)? Which band?