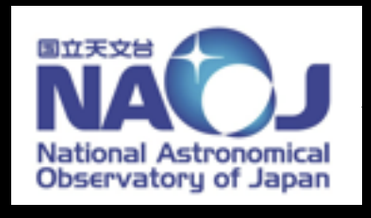
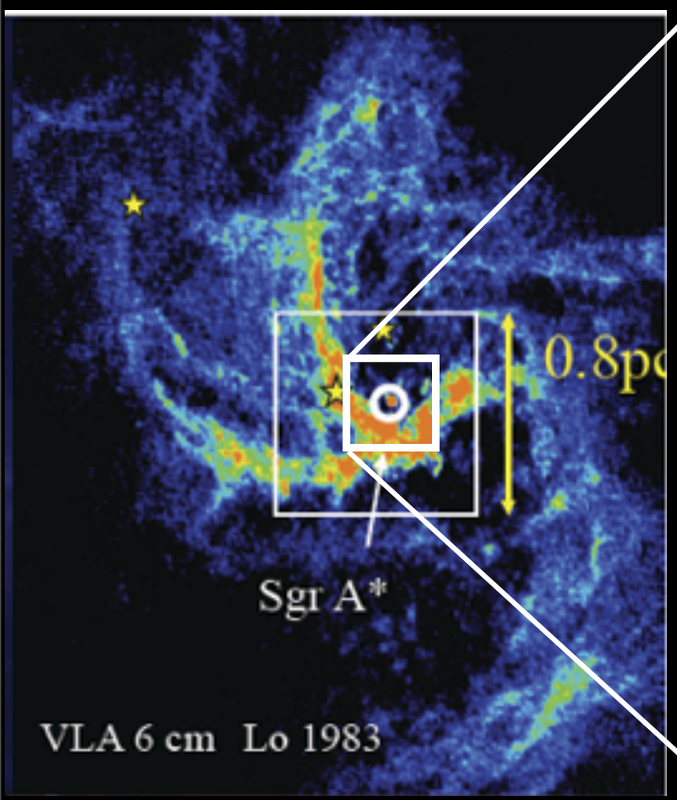
VERA and KaVA (KVN+VERA) observations of Sgr A* in 2013

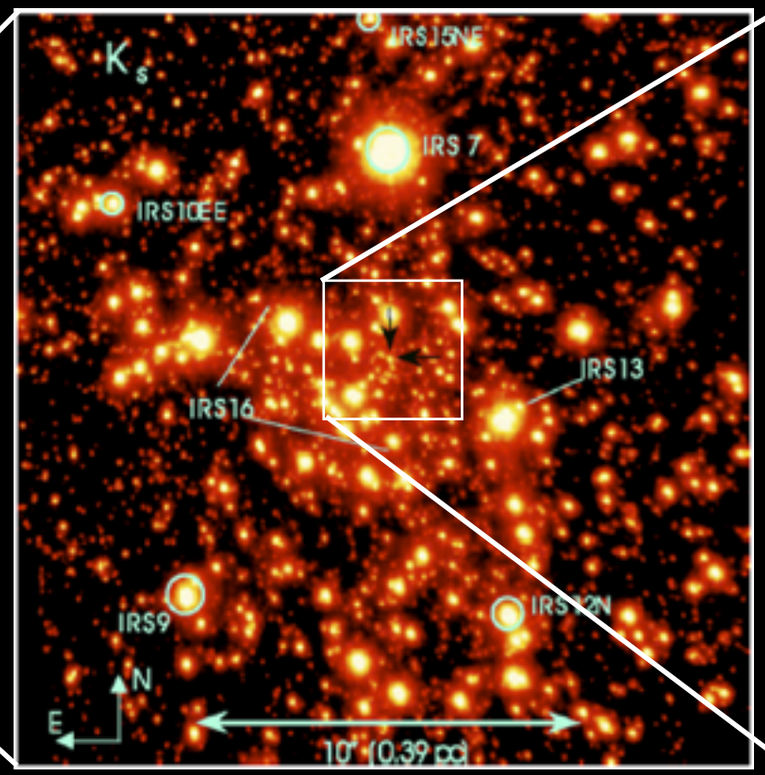
Kazunori Akiyama
(U. Tokyo / NAOJ / JSPS Research Fellow)

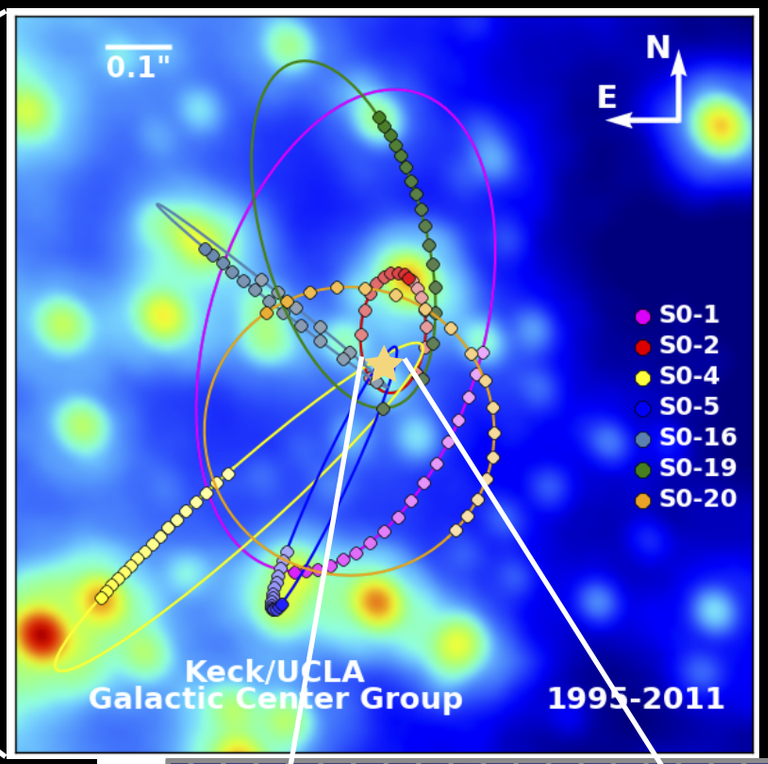
on the behalf of KaVA AGN WG et al.



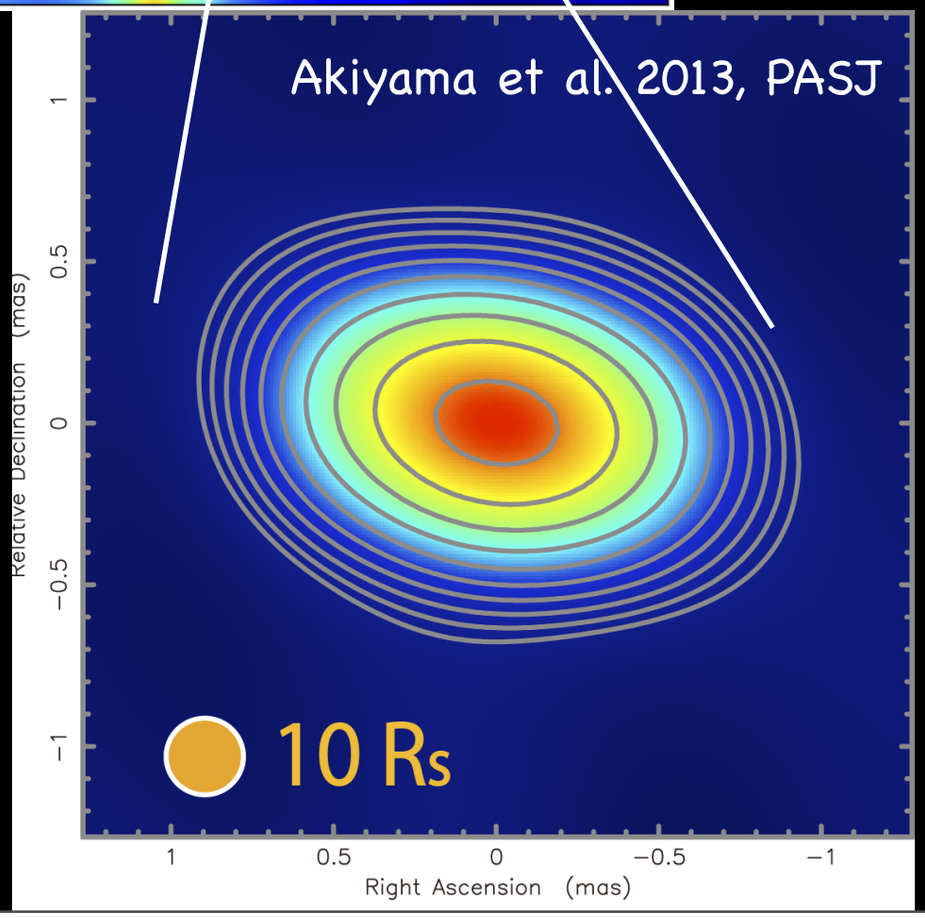
What is the Galactic Center Sgr A*





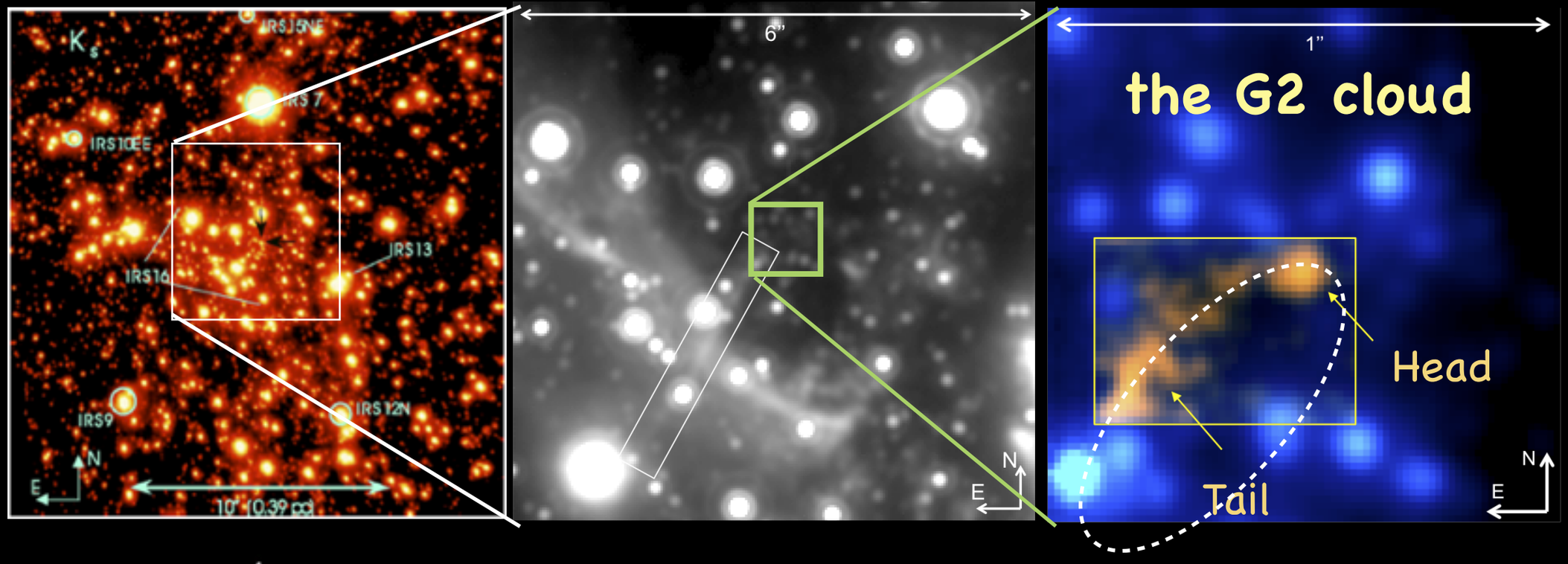


Genzel+



- The nearest SMBH
  (8 kpc / 4 x 10^6 M_{solar})
- Largest angular size of
  the Event horizon (1 Rs = 0.01 mas)
- The best laboratory to study
  an environment around SMBH

The Gas Cloud G2

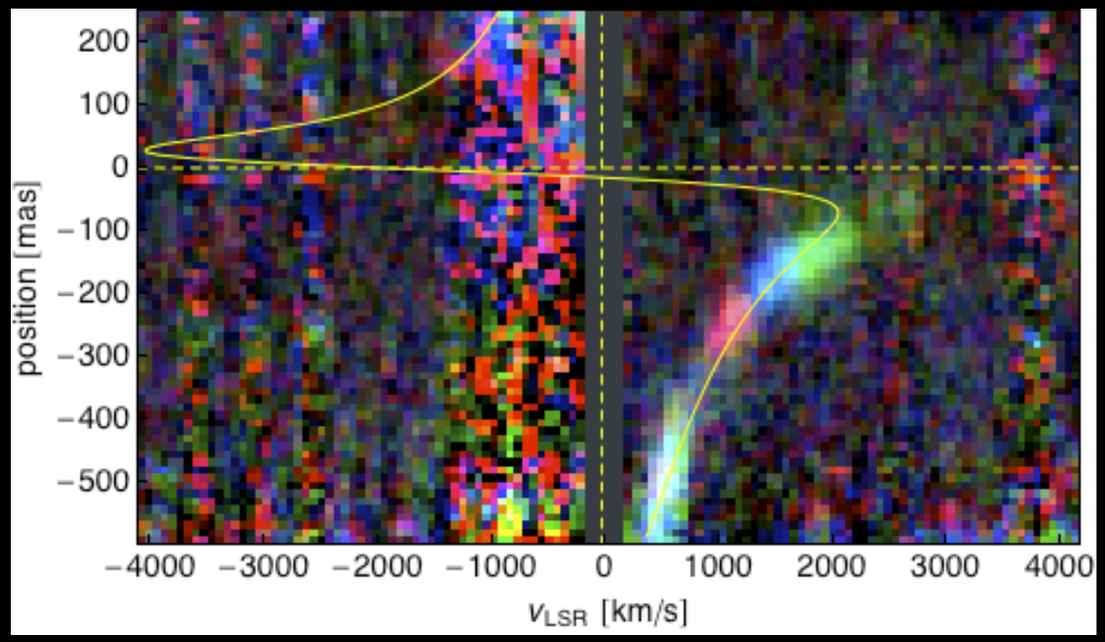


The Gas Cloud with 3 M_{Earth} is approaching to the galactic SMBH Sgr A*

(Gillessen et al. 2012, Natrue)

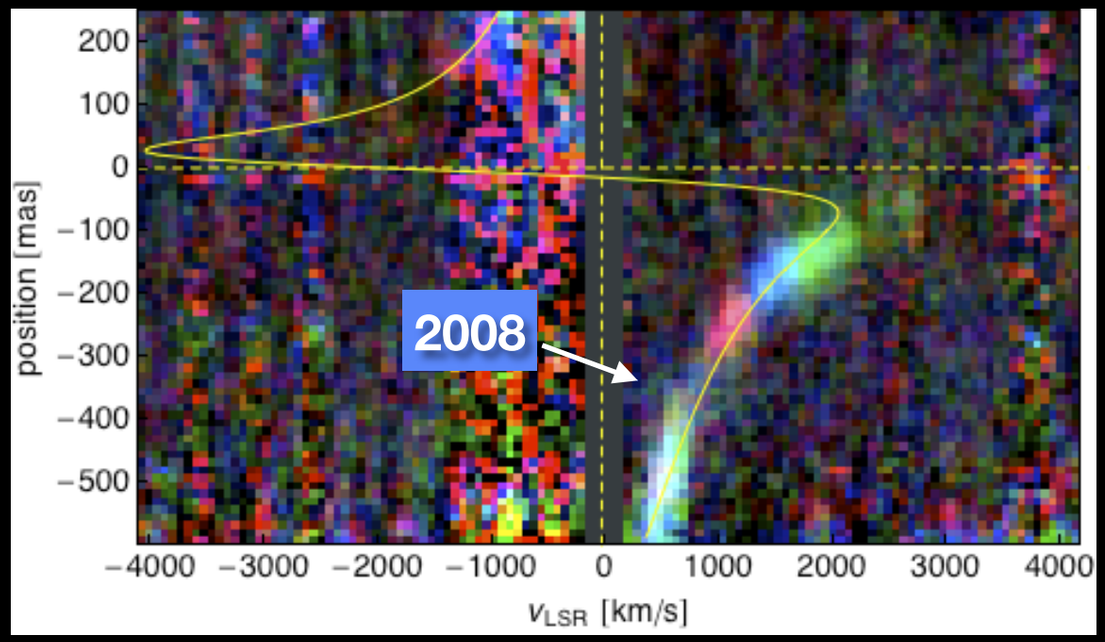
"Once-in-a-lifetime event" for VERA and KaVA to have a look at the dinner of SMBH

Sgr A* will encounter main part of the G2 cloud in 2014



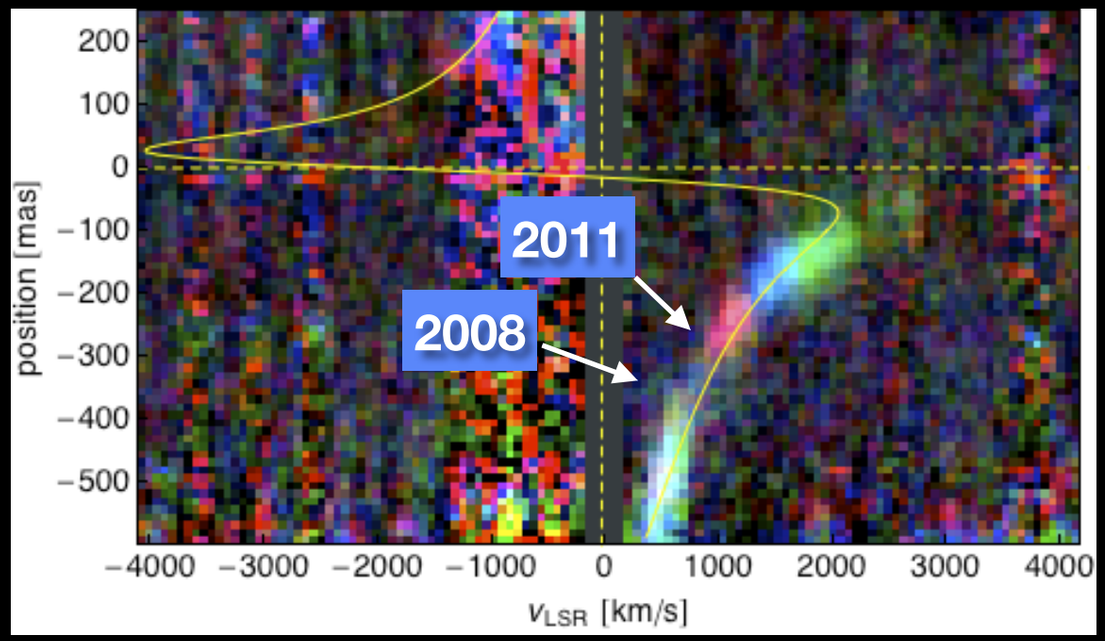
(Gillessen et al. 2013a)

Sgr A* will encounter main part of the G2 cloud in 2014



(Gillessen et al. 2013a)

Sgr A* will encounter main part of the G2 cloud in 2014



(Gillessen et al. 2013a)

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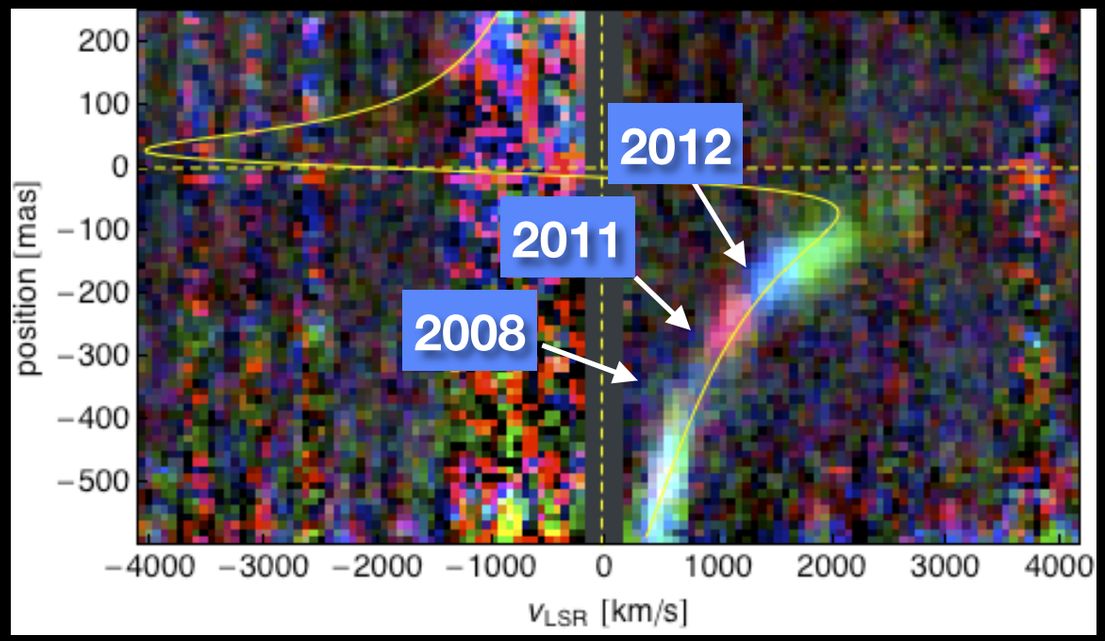
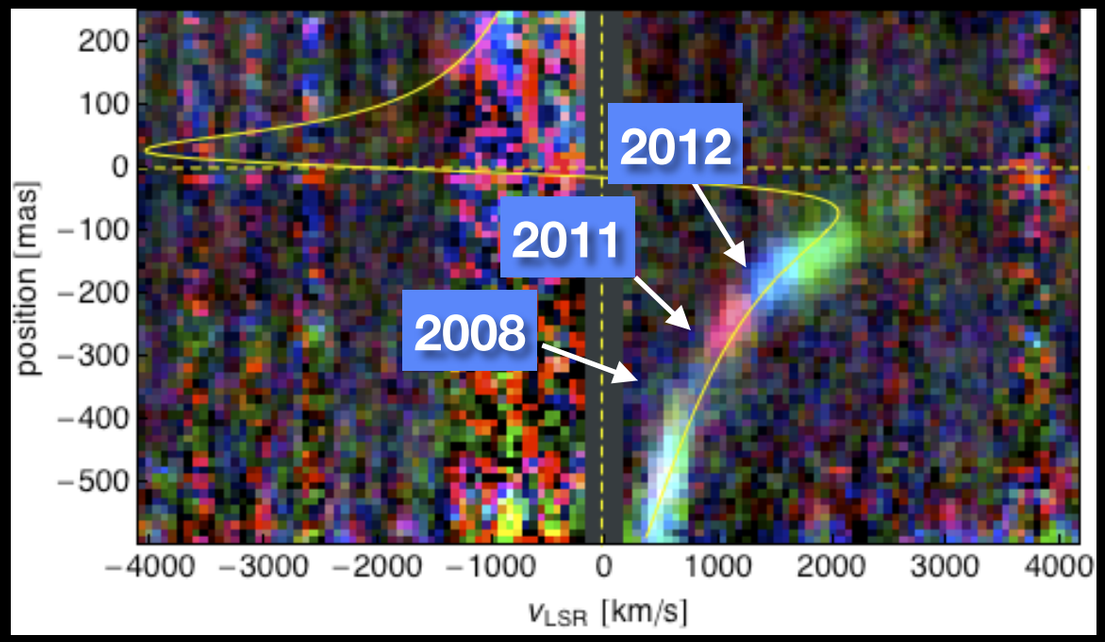
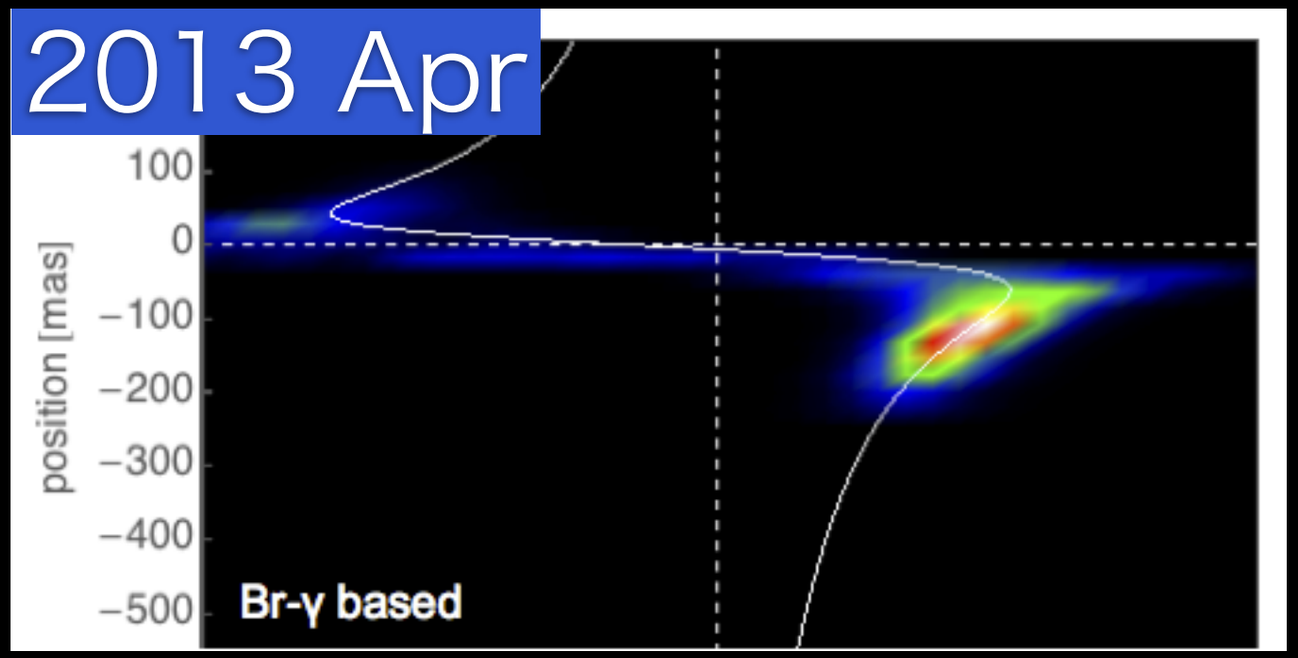


(Gillessen et al. 2013a)

Sgr A* will encounter main part of the G2 cloud in 2014



(Gillessen et al. 2013a)



(Gillessen et al. 2013b)

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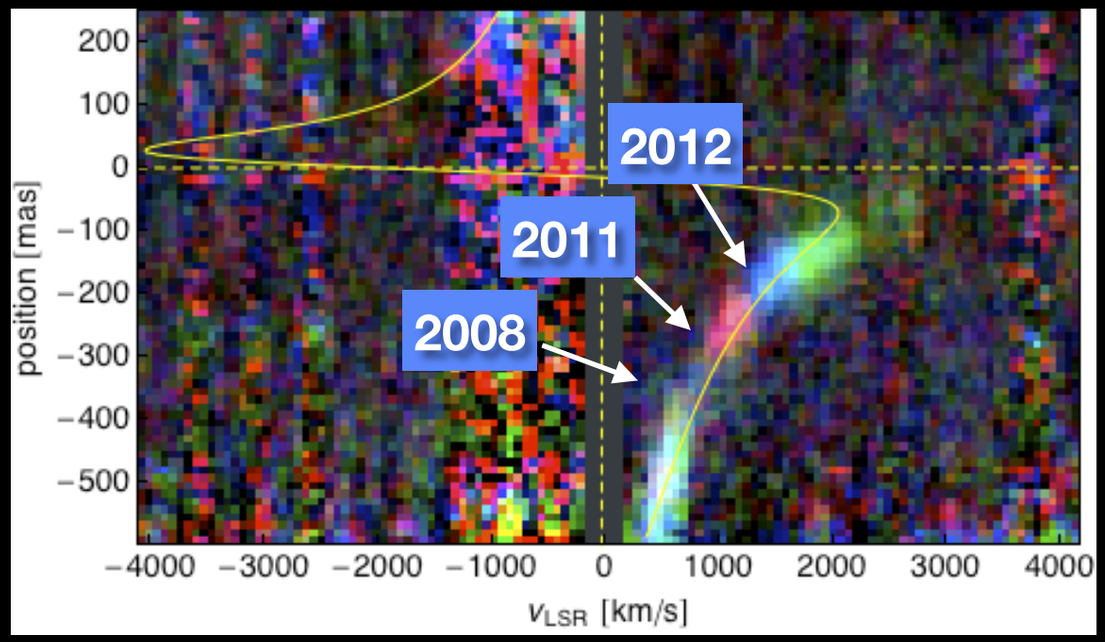

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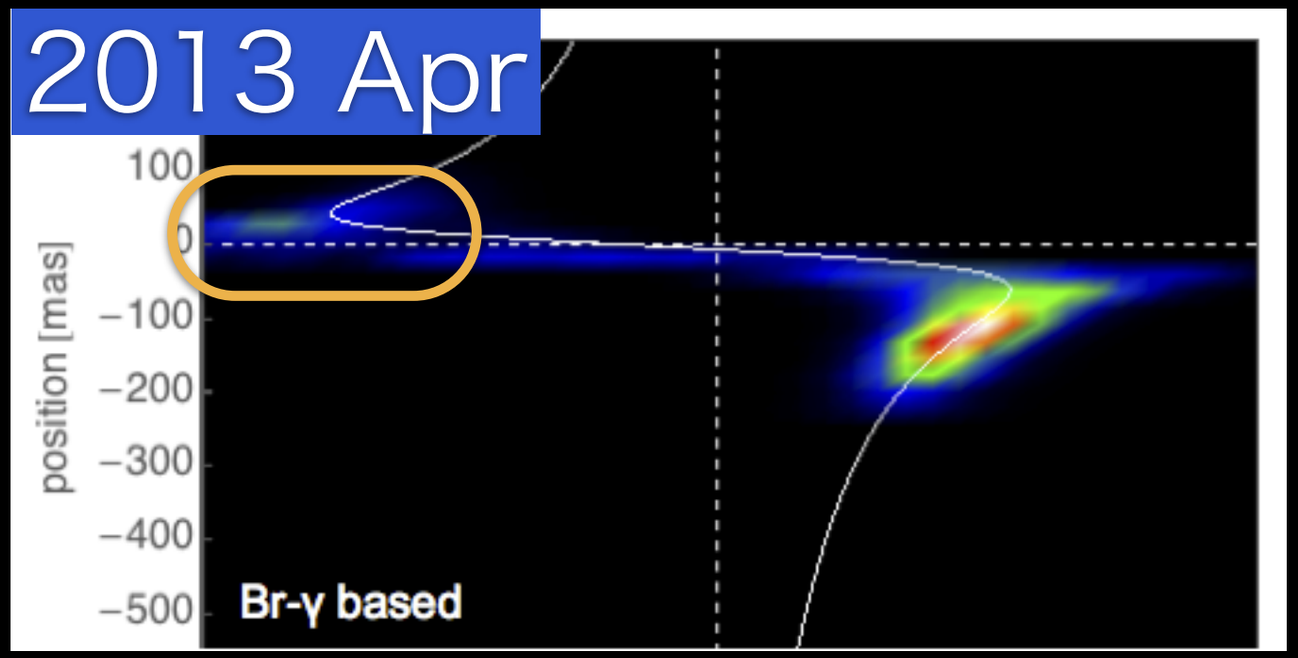
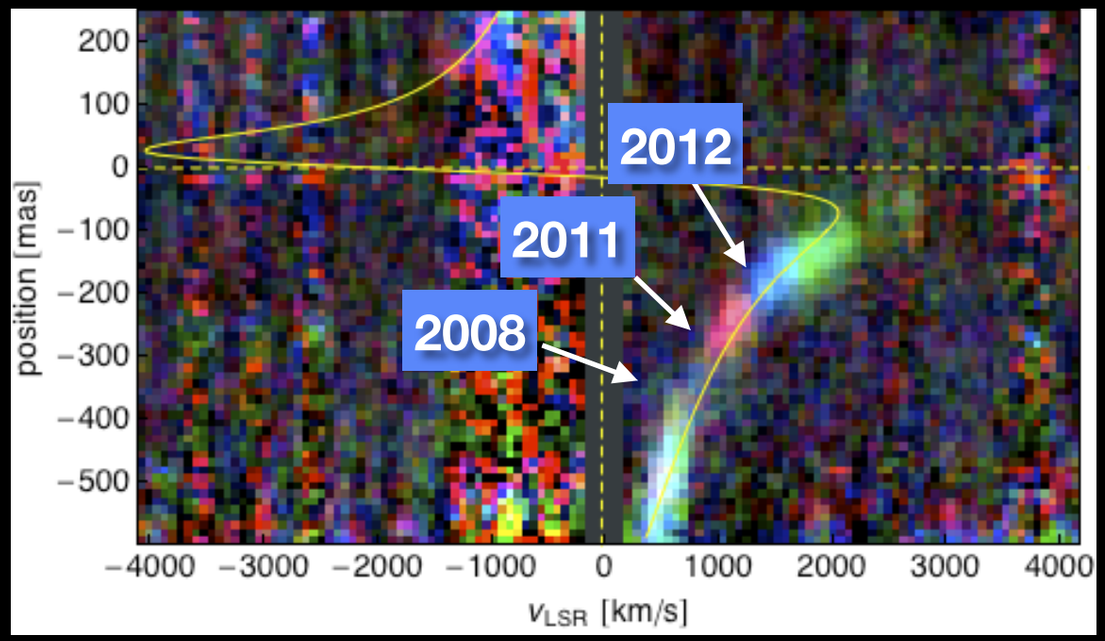


(Gillessen et al. 2013b)

- The point of the G2 head already passed pericenter in April 2013

(Gillessen et al. 2013b)

Sgr A* will encounter main part of the G2 cloud in 2014



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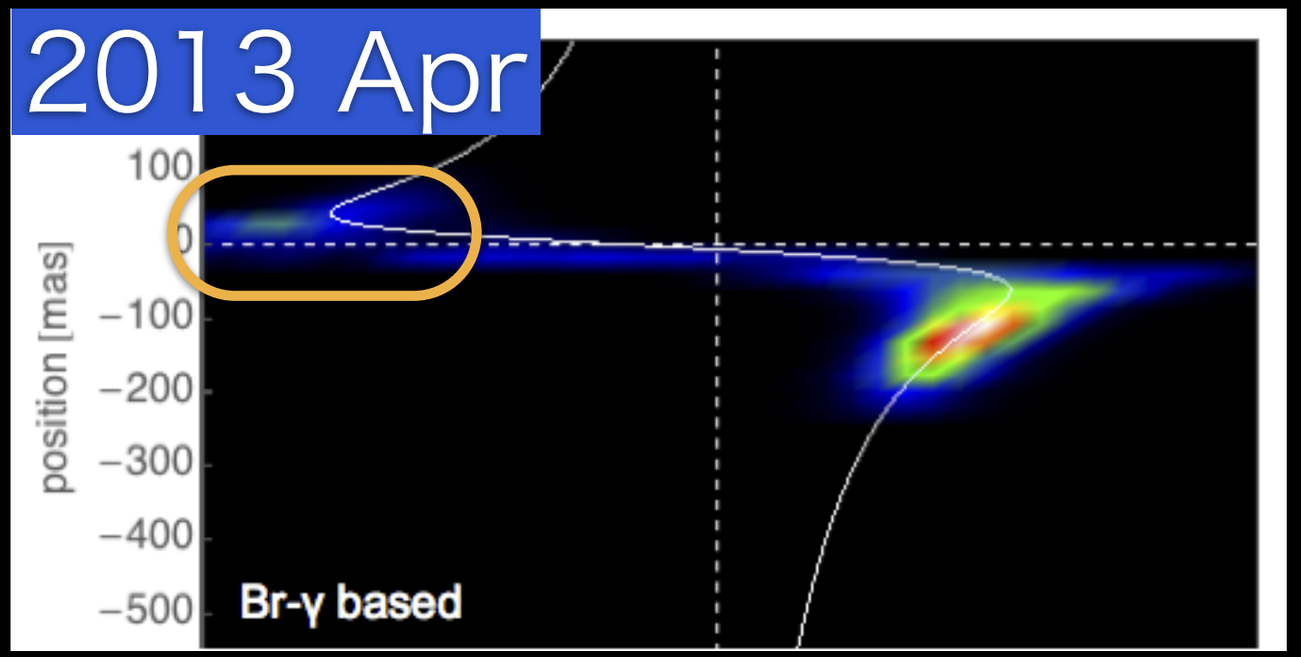
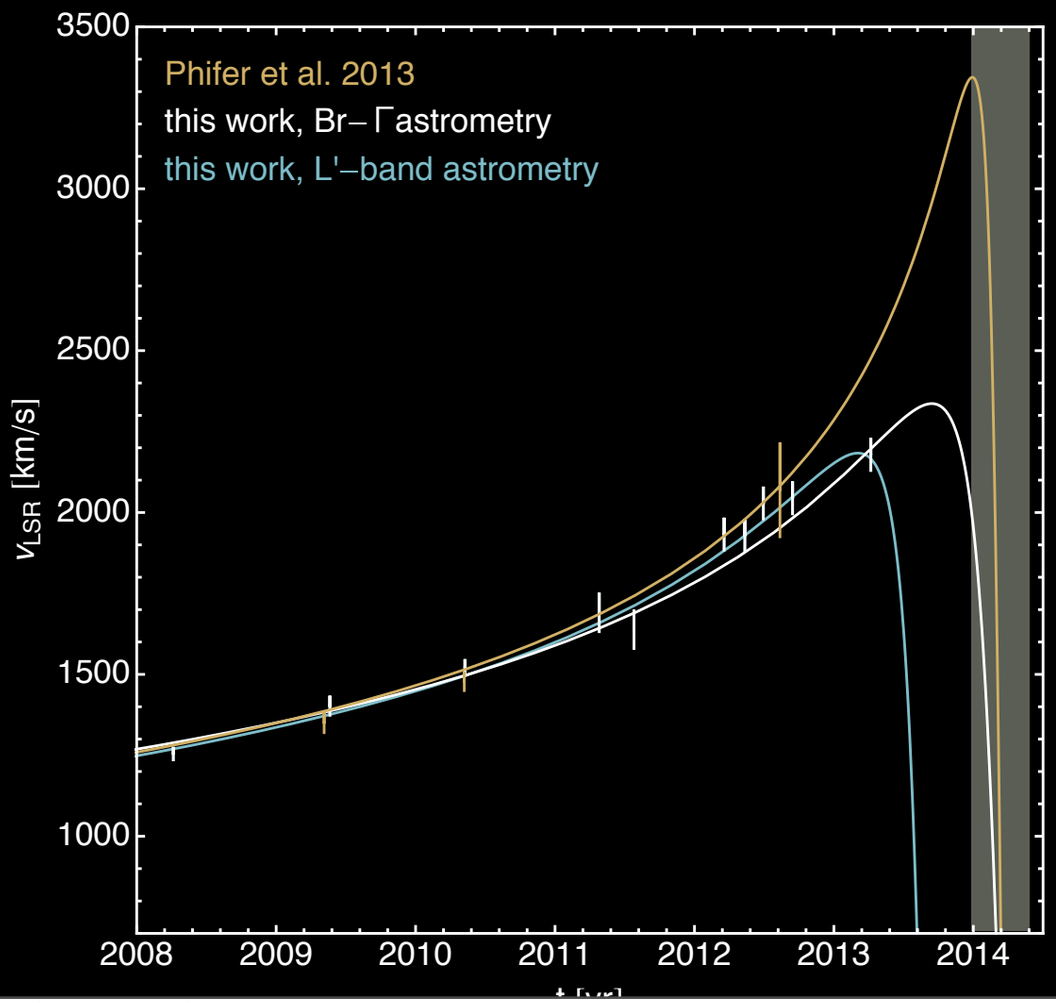


(Gillessen et al. 2013b)



- The point of the G2 head already passed pericenter in April 2013

  (Gillessen et al. 2013b)

- Main part of the G2 cloud will arrive at pericenter in early 2014

  VLT : Gillessen et al. 2013b
  Keck 10m: Phifer et al. 2013

(Gillessen et al. 2013b)

Expected phenomena related with G2 encounter

1. flare of recombination lines (in NIR)

before pericenter passage
(early 2014?)

2. flare of the G2 bow shock (in radio)

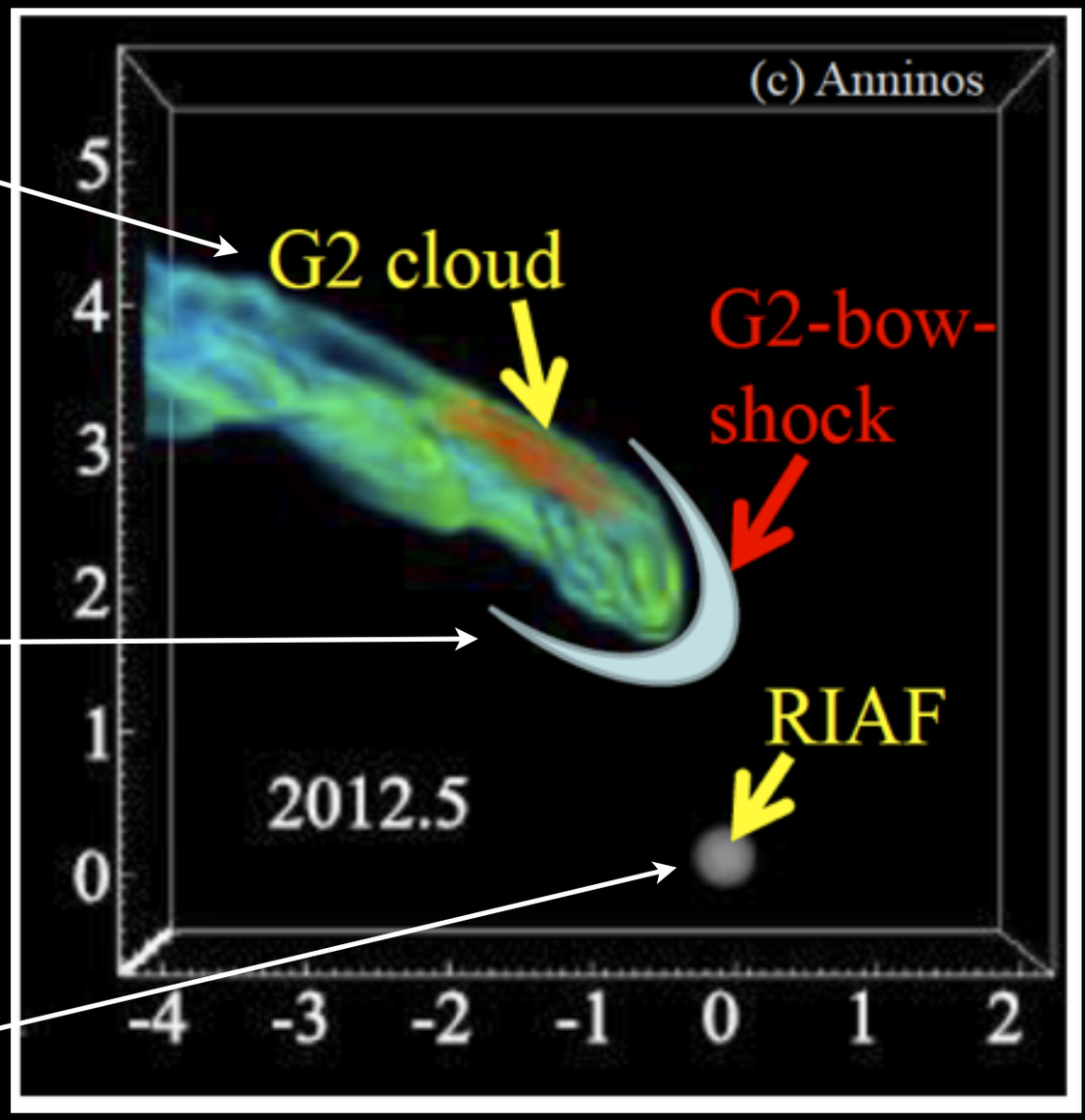
around pericenter passage
(early 2014?)

Possibly detected with VLBI

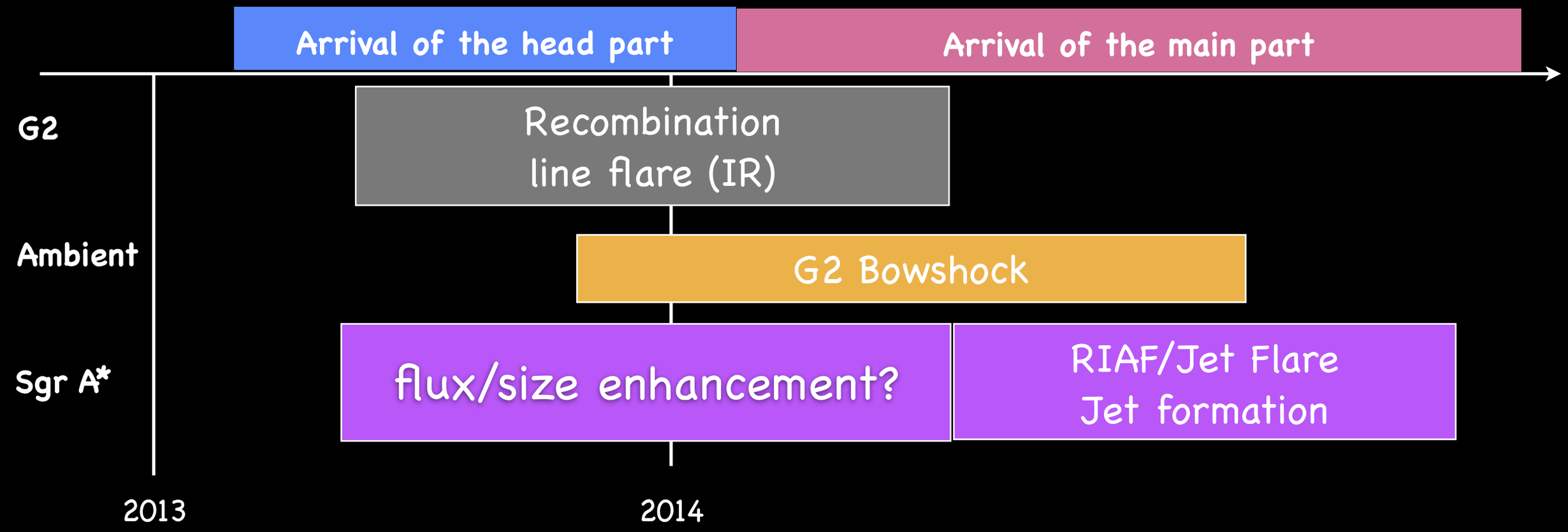
3. flare in Sgr A* (in radio, NIR, X-ray)

after pericenter passage
(middle/late 2014?)

Increase in its radio flux and size
Possible jet formation



Expected timeline and observations of our groups



1) Monitoring Project (Jan. 2013 ~)

1) VERA Monitor of the radio flux and size at 43 GHz (an interval of 3 weeks)

2) Single Dish Monitor (Weekly/bi-weekly)

- 1.4/2.4/8 GHz using Medicina/Noto 30 m Telescopes (Giroletti et al.)
- 22/43/86 GHz in KVN (Sohn, Lee et al.)

2) Baseline measurements with KaVA (VERA + KVN) at 22/43 GHz

Quasi-simultaneous observations with EHT 230 GHz (Doeleman et al.)
and GMVA 86 GHz (Trippe et al.) in March/May 2013

3) ToO observations: astrometric observations with KaVA at 22/43 GHz

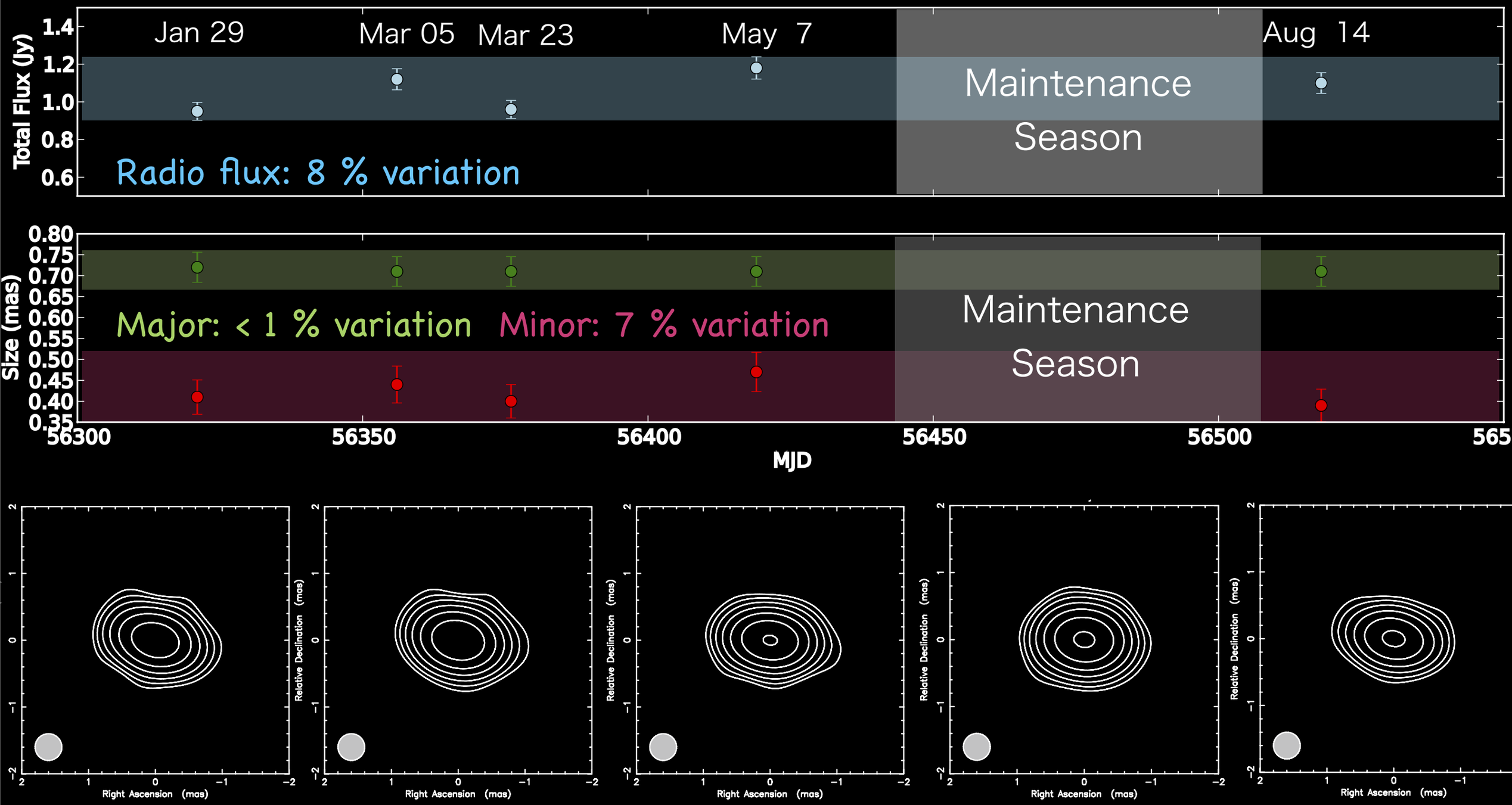
Further collaborations

Subaru ToO Proposal
(Accepted in 2013B, submitted for 2014A; Nishiyama et al.)
- **SUBARU+VERA collaboration** to trace possible jet formation in Sgr A*

The XVP Projects (International MWL collaborations)
- X-ray: Nustar (Barriere+), Chandra (Neilsen+), XMM (Goldwurm+),
  Swift (Degenaar+)
- γ -ray: HESS (Kosack+), Fermi (Su+)
- NIR: VLT (Gillessen+, Eckart+), Keck (Ghez+), SUBARU (Nishiyama+),
- Radio: EHT (Doelemann+), VLBA (Bower+), **KaVA (Akiyama+),** ALMA (Falcke+)

and many other scientists (e.g. theoreticians)

Preliminary results of VERA Monitor at 43 GHz until Aug. 2013



Although the head part of the G2 cloud passed pericenter before April 2013,
no obvious variations was appeared in the nucleus of Sgr A* until August 2013.

Preliminary results of VERA Monitor at 43 GHz until Aug. 2013

Freefall time scale from pericenter to Sgr A* ~ few months

some fraction of the head part of the G2 gas might arrive at Sgr A* in the middle of 2013.

Luminosity of the central engine

Accretion disk : $L \propto \dot{M}^2$ (Mahadevan 1997)

Jet case : $L \propto \dot{M}^{1.4}$ (Falcke et al. 1995)

size at mm-wavelength

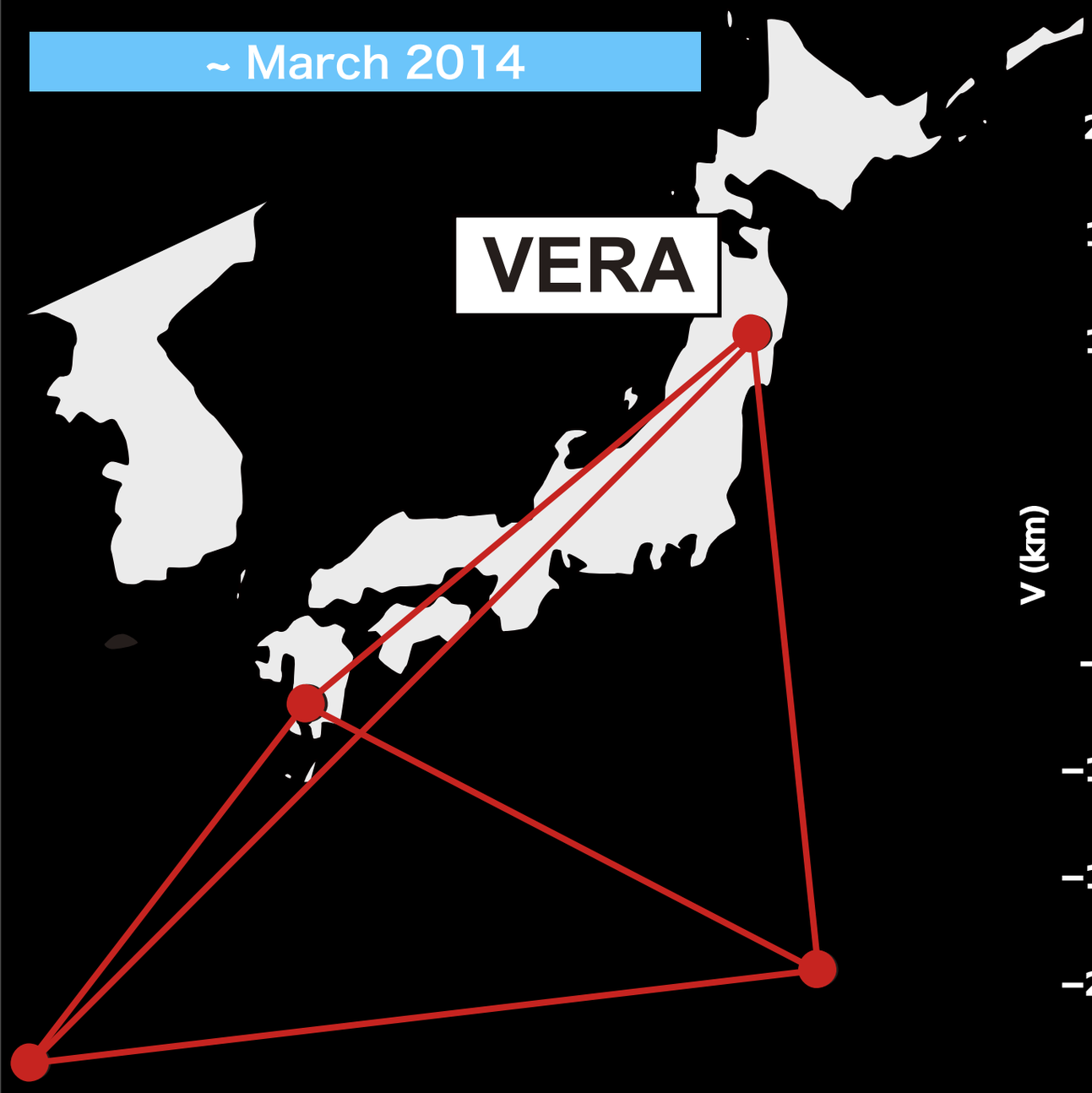
Accretion disk : size $\propto \dot{M}$ (Mahadevan 1997)

Jet case : (?)

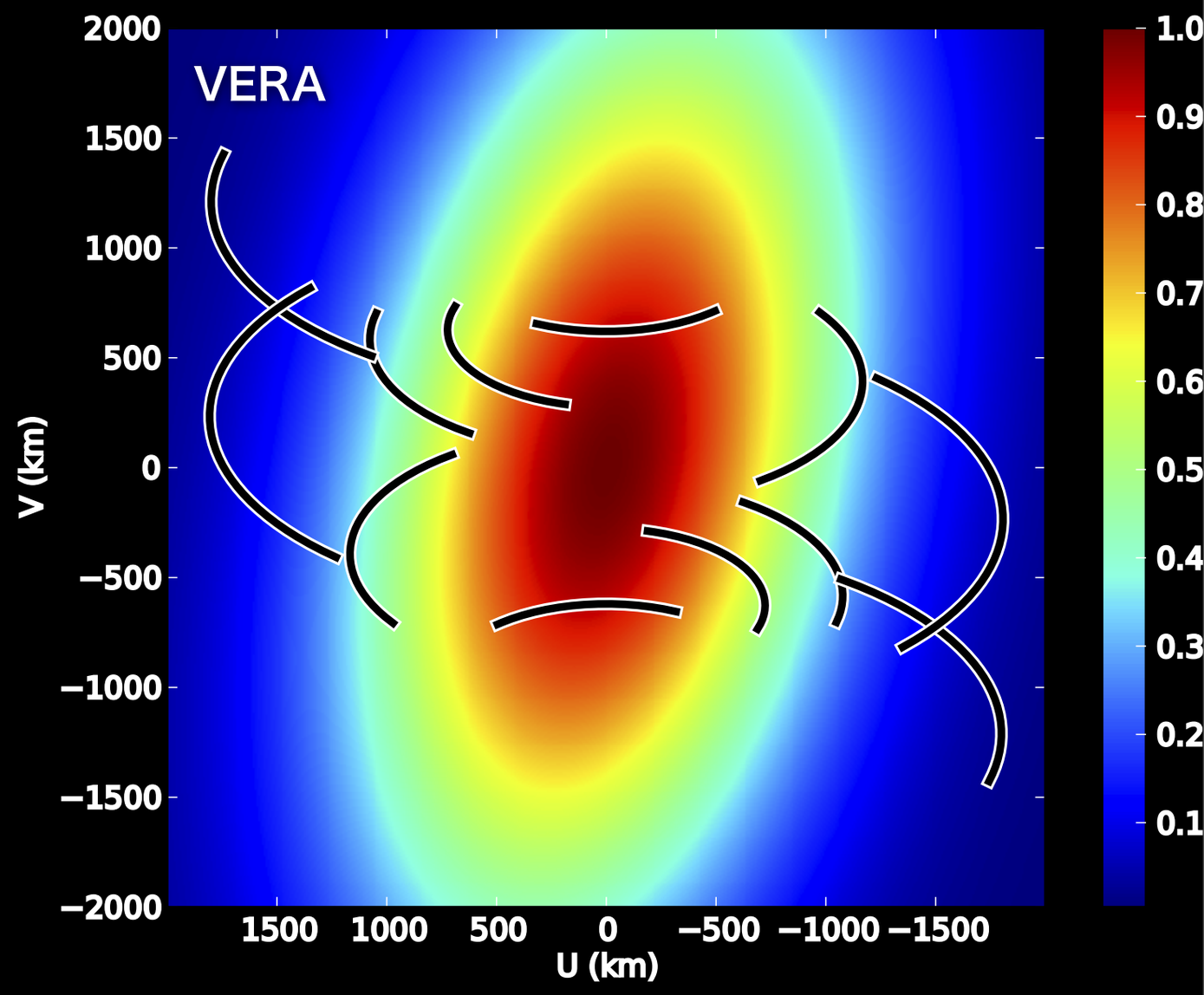
→ No obvious variation in mas-scale structure indicates current feeding rate from the G2 cloud to the central engine was lower than typical mass accretion rate.

Future observations with KaVA (March 2014 -)

~ March 2014



UV coverage and Visibility amplitude of Sgr A*

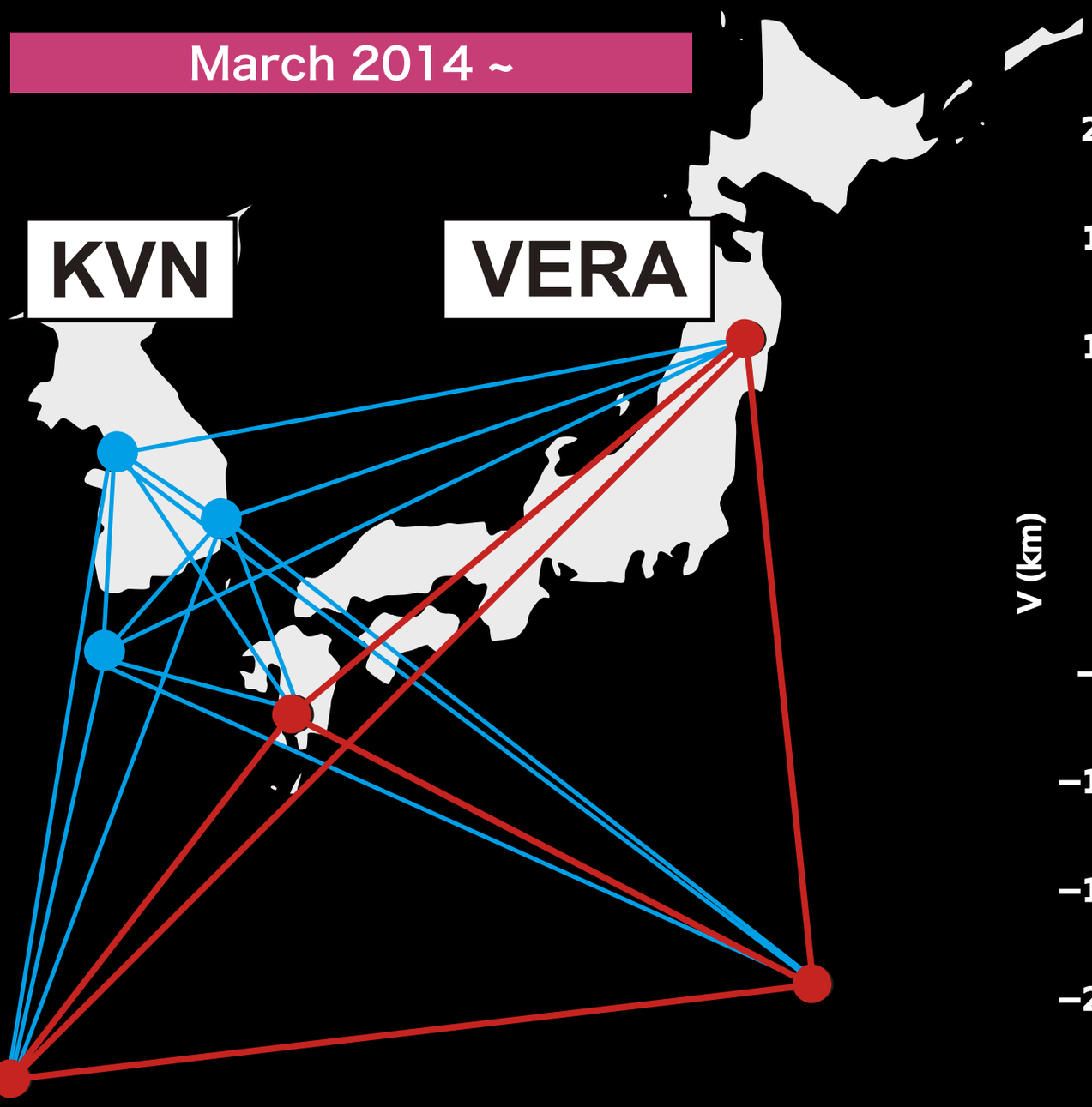


VERA monitor --> KaVA Monitor

- More accurate determination of the size
- Better imaging quality (for possible formation of jet and bowshock)

Future observations with KaVA (March 2014 -)

March 2014 ~



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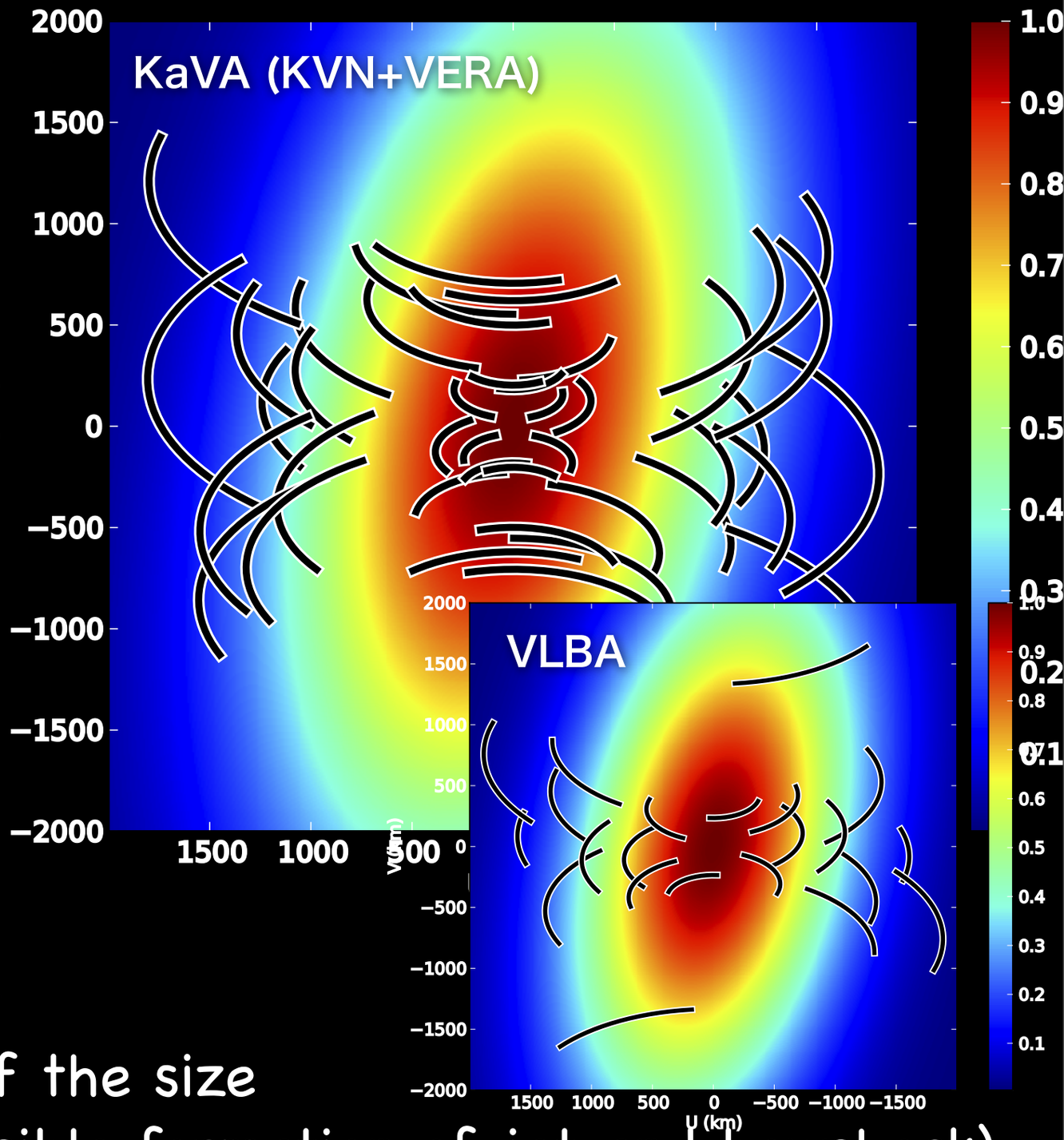


VERA monitor --> KaVA Monitor

- More accurate determination of the size
- Better imaging quality (for possible formation of jet and bowshock)

Our Suggestions about "open-use" KaVA observations

Considering the current status of KJCC, there has been a large risk of taking a lot of time to correlate KaVA 1 Gbps data with KJCC.

- Difficult to reduce scientifically important data required to be published quickly (e.g. Sgr A* data) in reasonable time scale.

- Slow speeds of KJCC correlation possibly put pressure on amounts of available D2K tapes andMark 5B disk packs

Suggestion
Please open simultaneous recording with D1K and 1 Gbps in semesters 2014A, 2014B

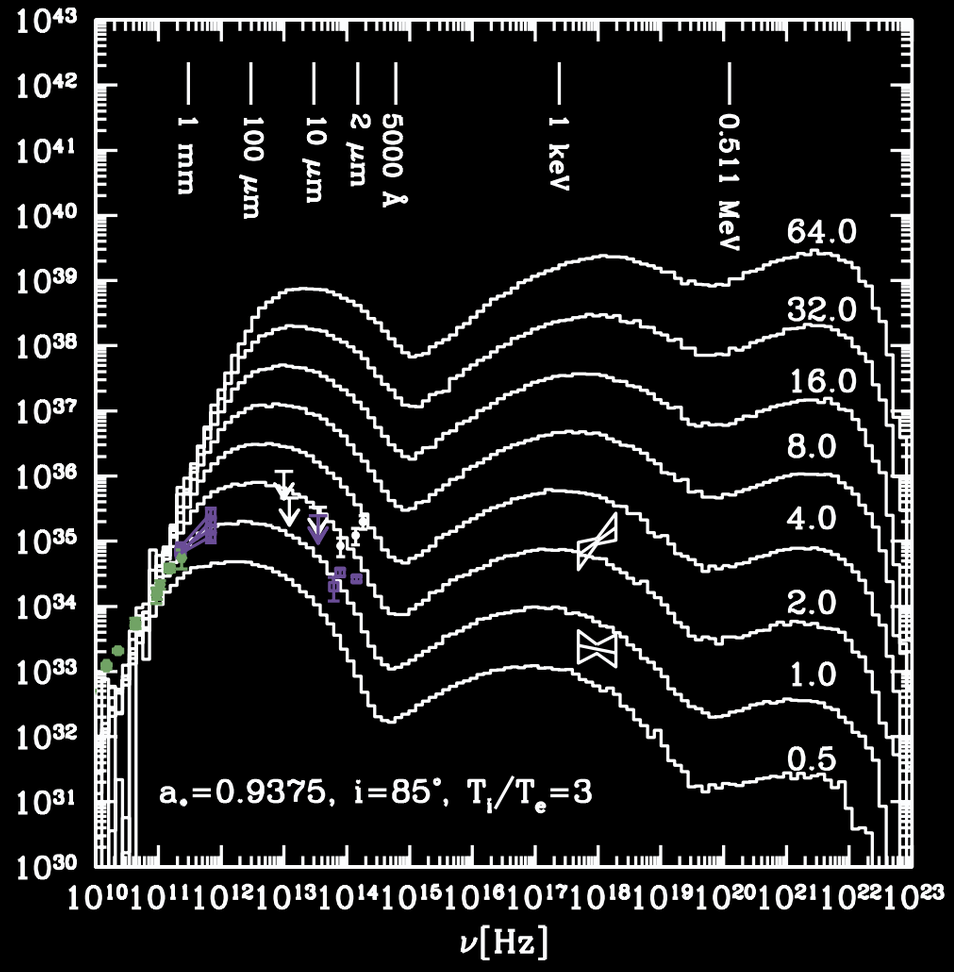
- A lot of KaVA data have been correlated with Mitaka FX correlator. This would provide us the robust data delivery.

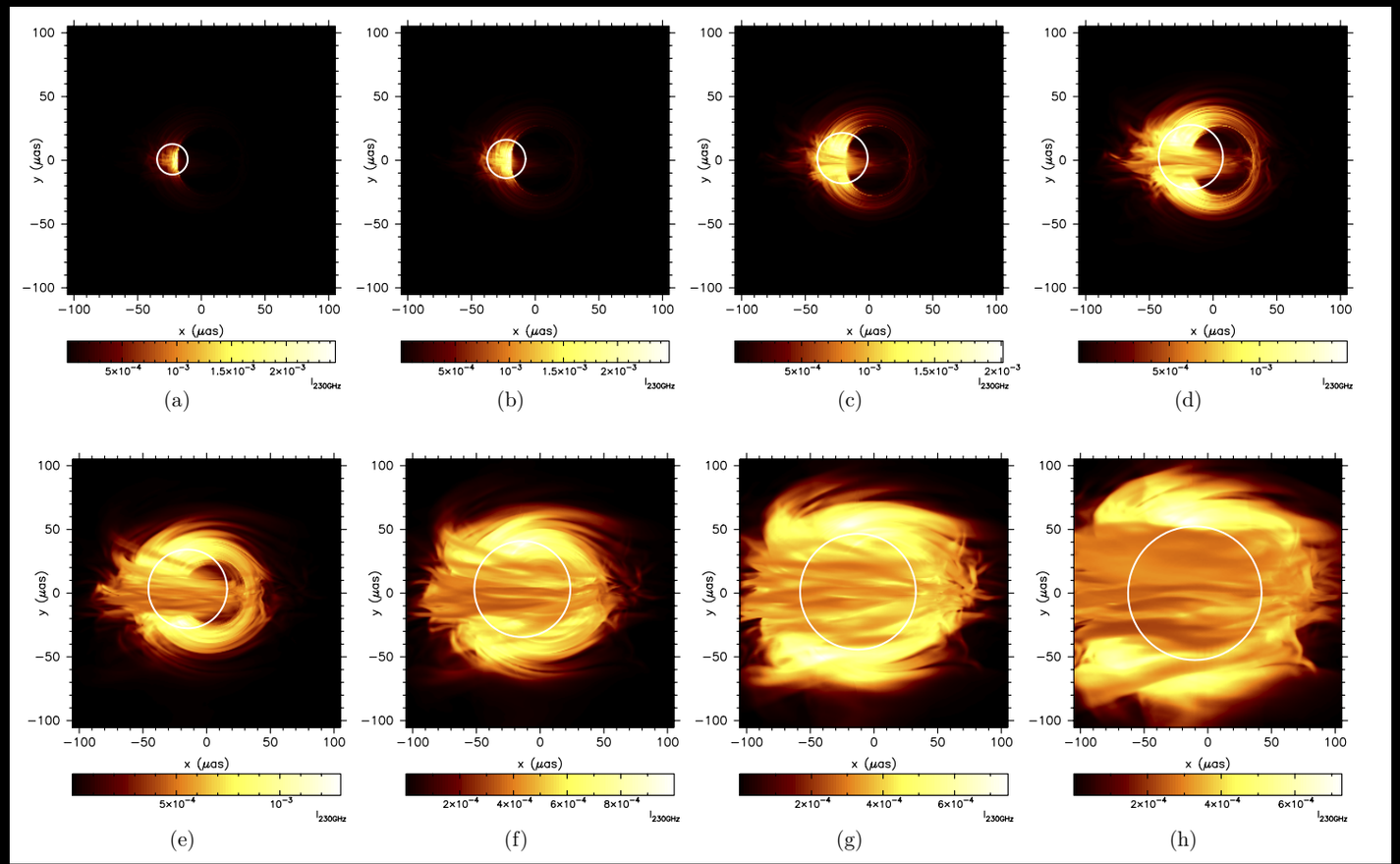
- Even in the worst case of shortages of D2K tapes and Mark 5B disk packs, we can substitute D1K data, and release D2K and 1 Gbps data.

We will continue on looking at the "dinner" of the galactic supermassive black hole

supporting slides

Flare in Sgr A*





Moscibrodzka et al. 2012

1) increase in its luminosity (detectable in Radio, IR, X-ray)

Accretion disk : $L \propto \dot{M}^2$ (Mahadevan 1997)

Jet case : $L \propto \dot{M}^{1.4}$ (Falcke et al. 1995)

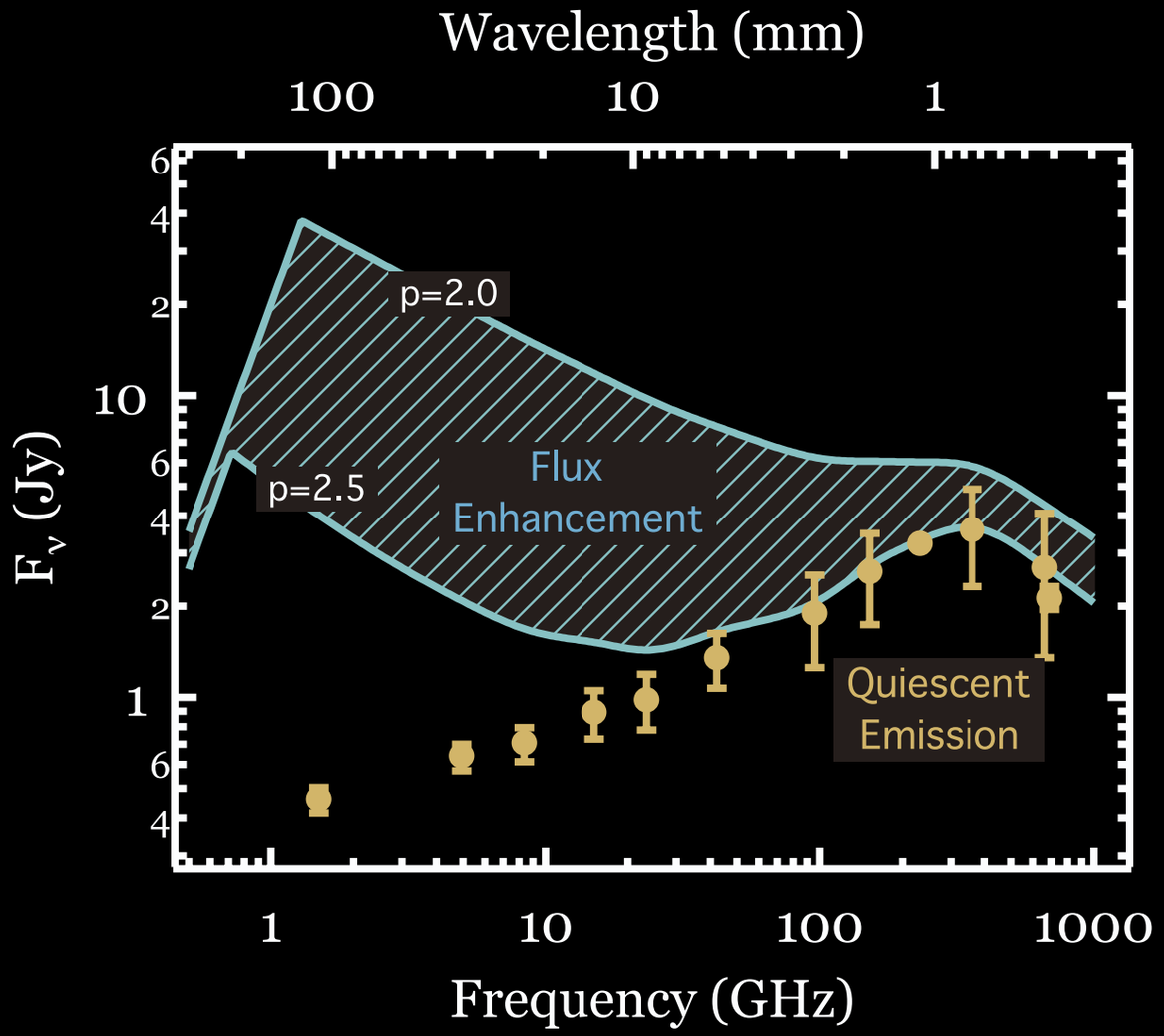
2) increase in its size at mm-wavelength

Accretion disk : size $\propto \dot{M}$ (Mahadevan 1997)

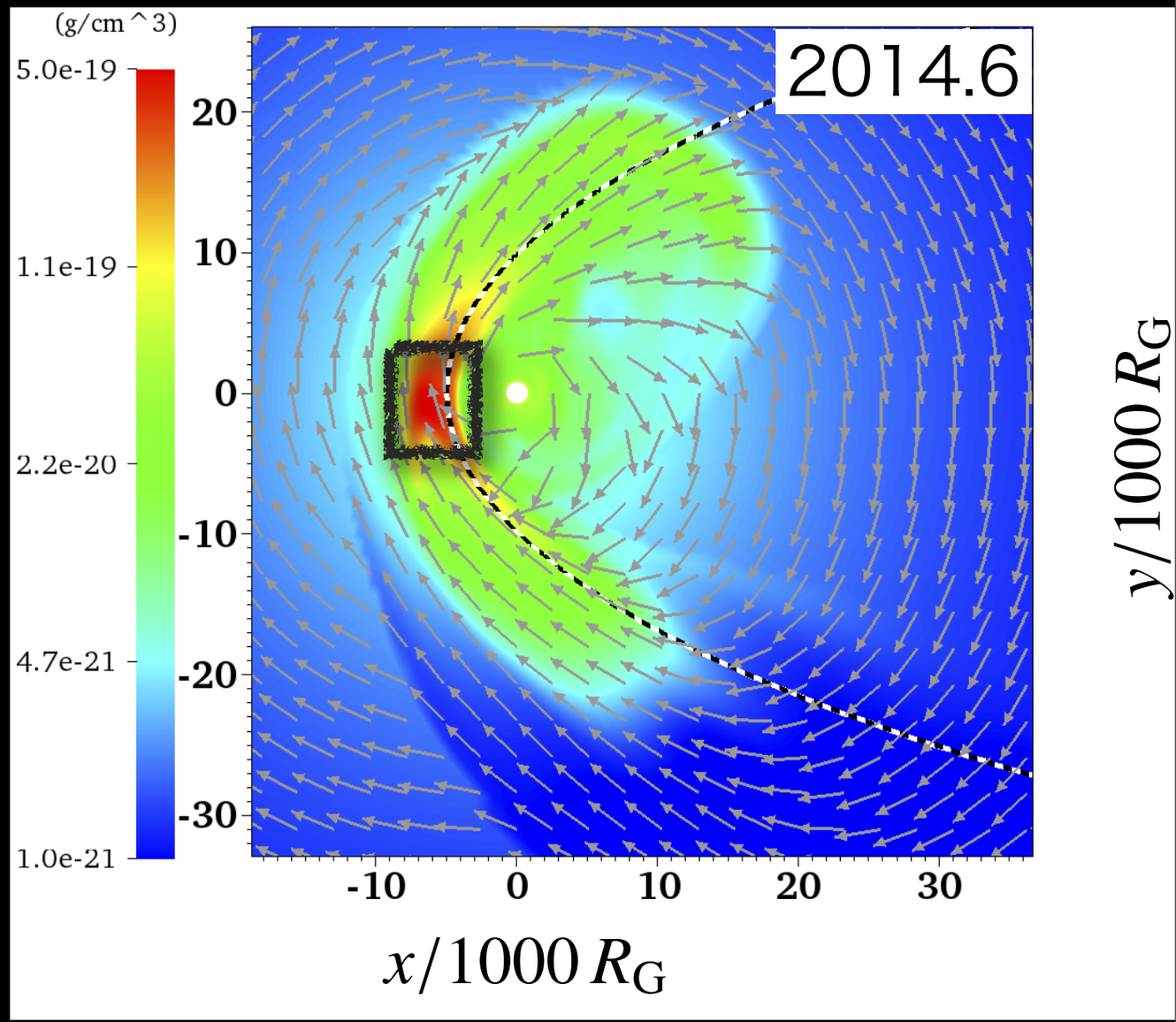
Jet case : (?)

3) first discovery of the jet ejection from the Sgr A*

Expected size of the G2 Bow-shock



Narayan et al. 2012
Sadowski et al. 2013a, 2013b



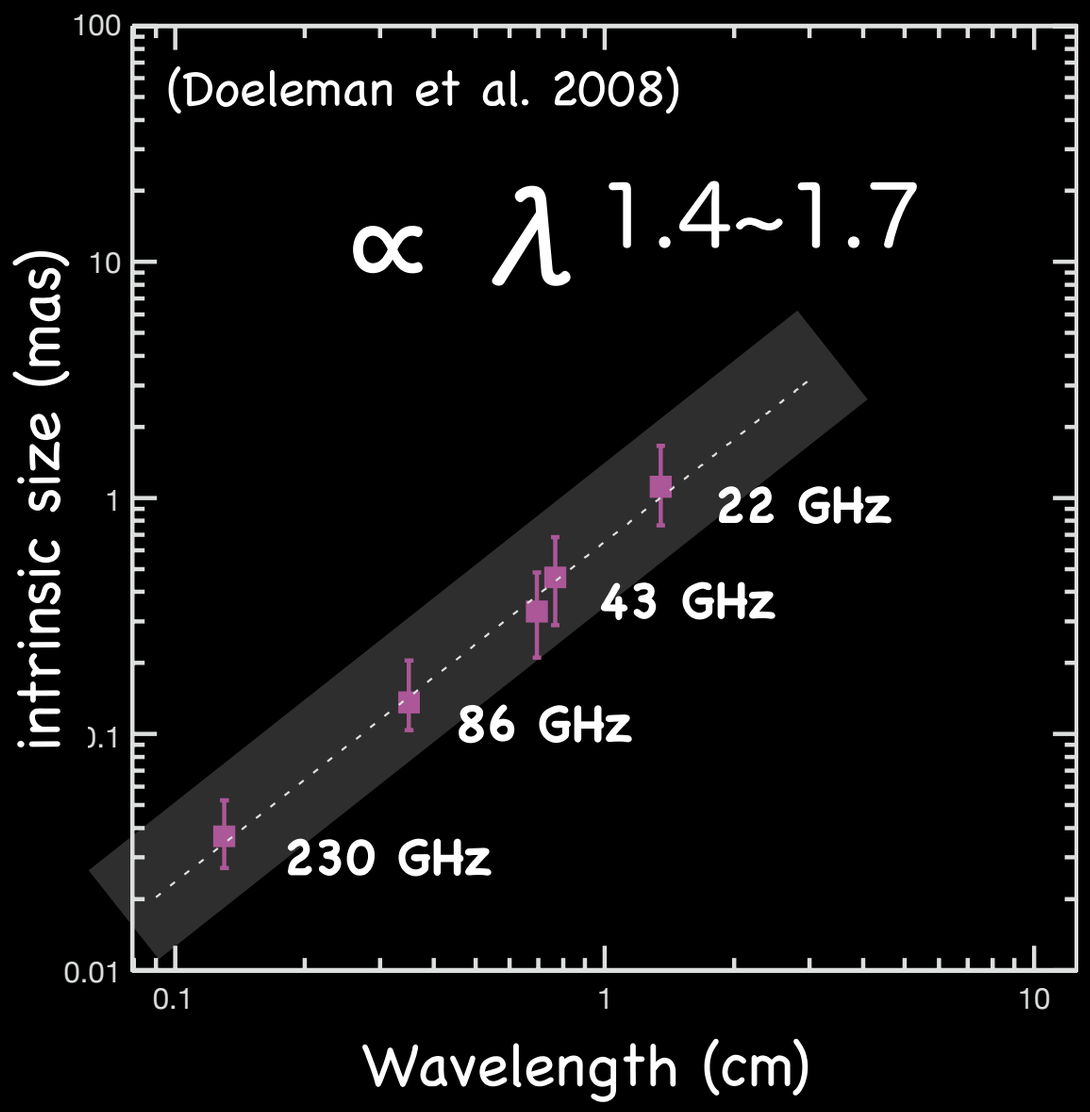
Abarca, Sadowski & Sironi 2013

The size of shocked region ~ several x 10^3 R_{sch} ~ several x 10 mas

→ possibly detected with VLBI

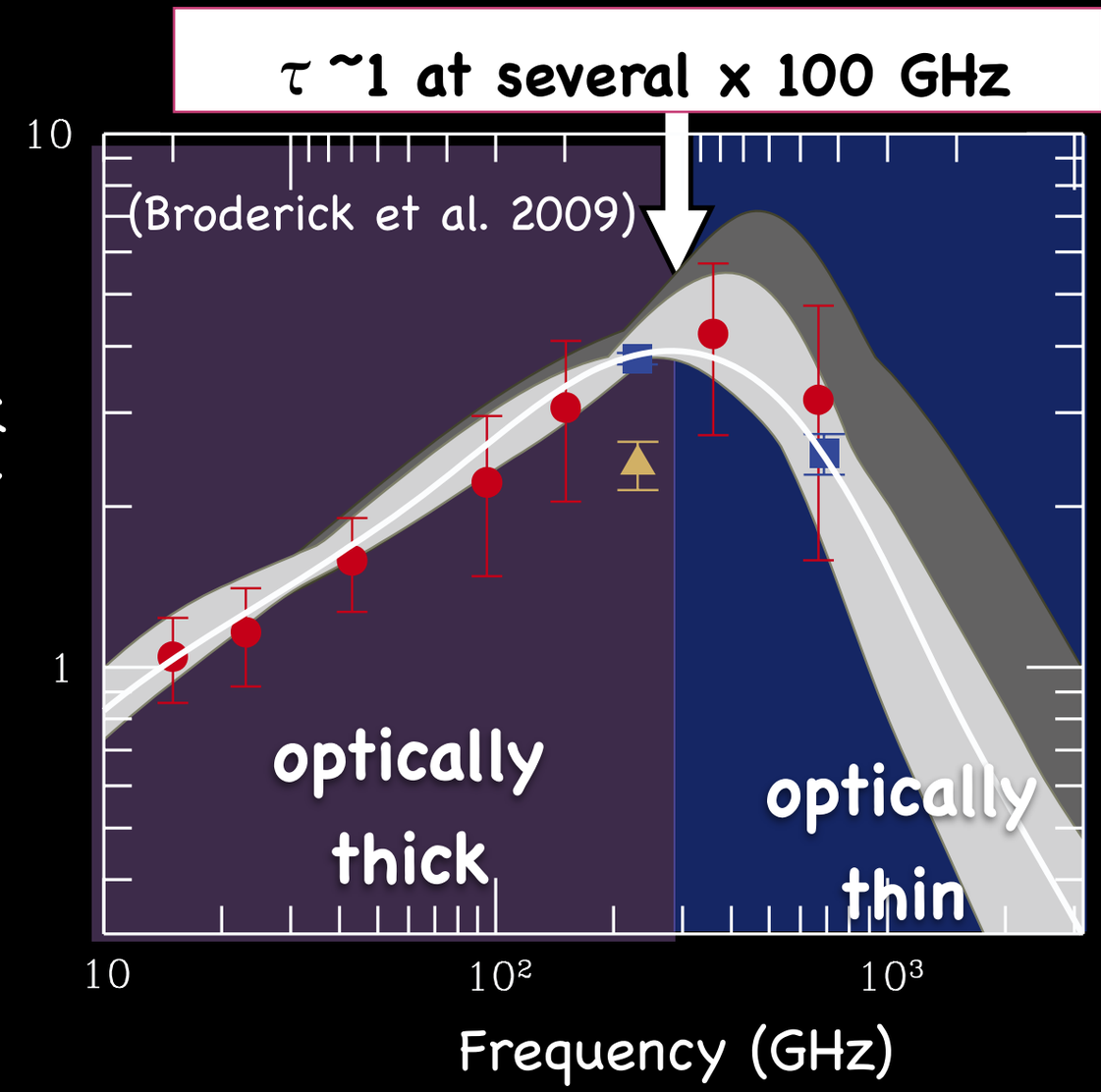
Introduction: Intrinsic structure of Sgr A* at cm/mm

λ-dependence of intrinsic size



+

Sub-mm Bump in SED



- Radio emission of Sgr A* comes from λ-dependent photosphere
  (e.g. Ozel et al 2000, Loeb & Waxman 2007, Falcke et al. 2009)

- The photosphere size at 43 GHz has a variability (Bower et al. 2004)