Searching for jets from M31* with VLBA and Tianma

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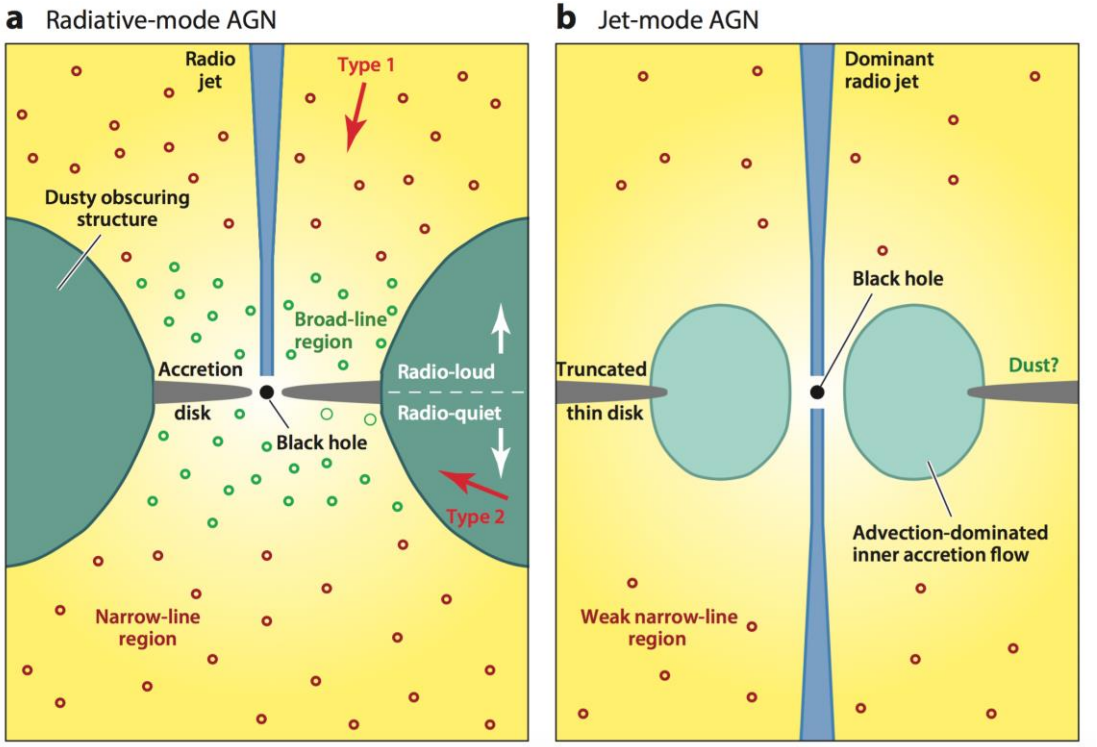
Outline

- Motivation
- Observation & results
- Summary

Motivation: Low-luminosity AGN

- Most massive galaxies host a central supermassive black hole
- In local universe, most SMBHs are LLAGN
- Physics of SMBH accretion & feedback at low-accretion rate



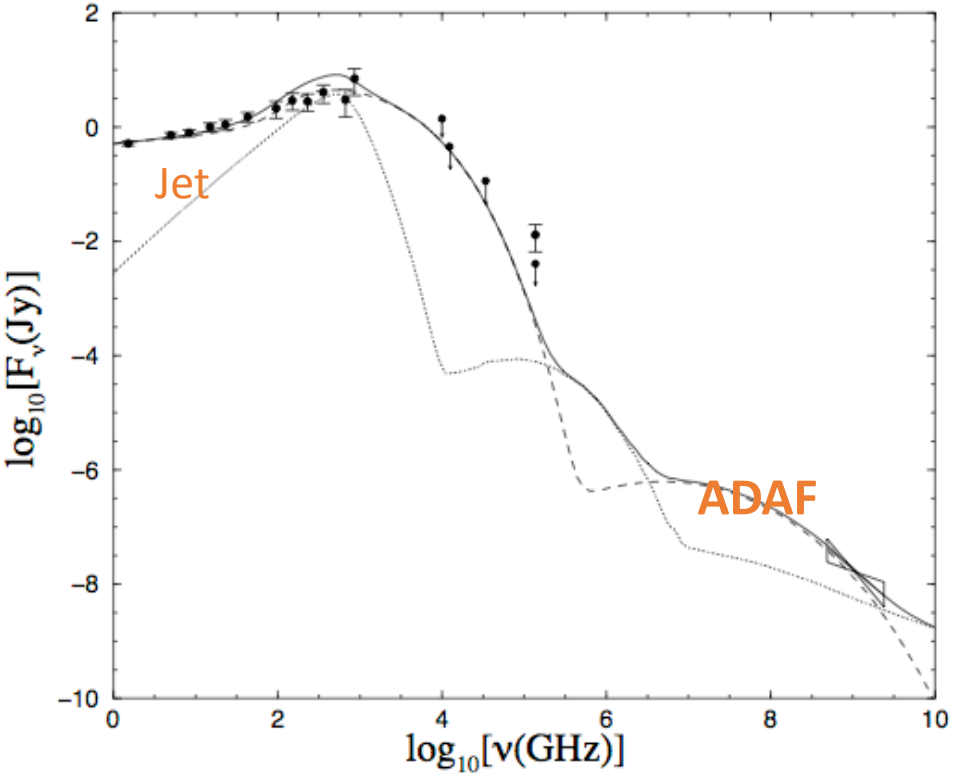
ADAF

Heckman et al. 2014

Motivation: Sgr A*

- $L_{bol} \leq 10^{-8}\, L_{Edd}$, least luminous AGN known
- Mass: $4 * 10^6\, M_{sun}$
- Prime target for Event Horizontal Telescope

- A jet-ADAF model can satisfactorily explain the broad-band SED of Sgr A*: jet accounts for the radio emission (synchrotron)
- However, the putative jet so far lacks of firm detection on all scales

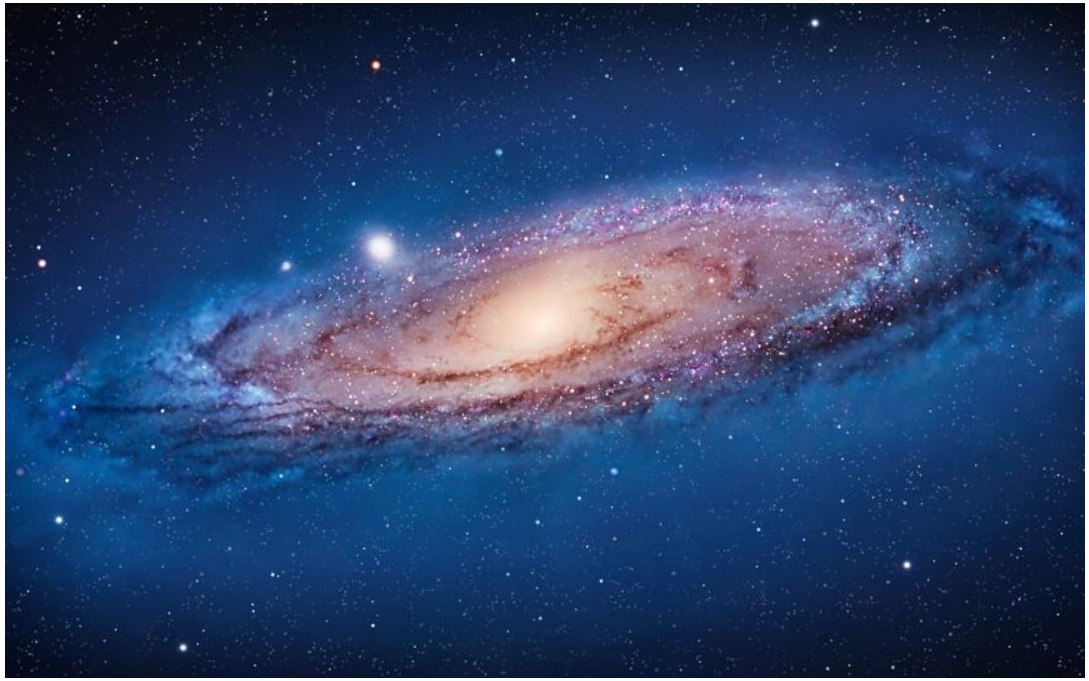


Yuan et al. 2003

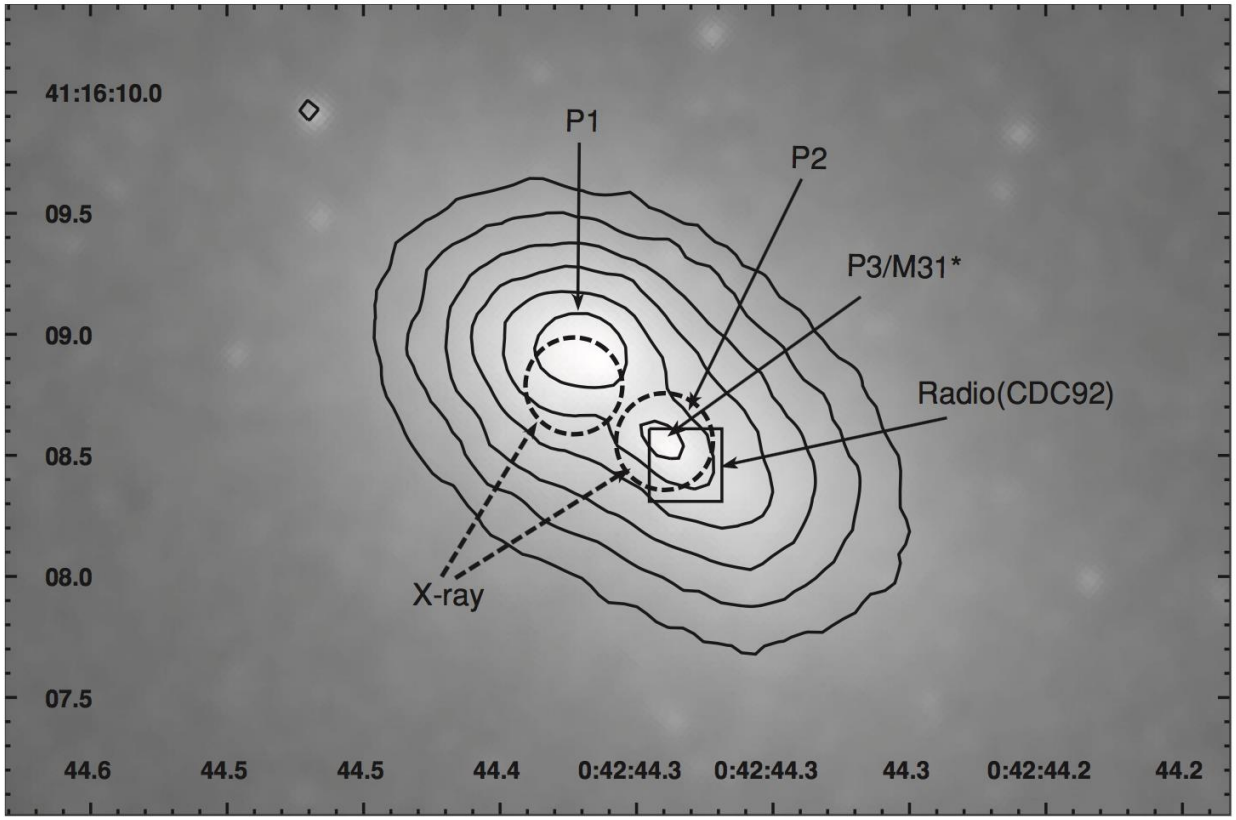
Motivation: M31*

- The Andromeda galaxy (M31) is the nearest massive galaxy (d=780 kpc)
- M31*: a dynamical mass of $1.4 * 10^8$ M_{sun} inferred from stellar kinematics. (Bender et al. 2005)
- Eddington ratio: ~10^{-8} similar to Sgr A*

A rare opportunity to study LLAGN

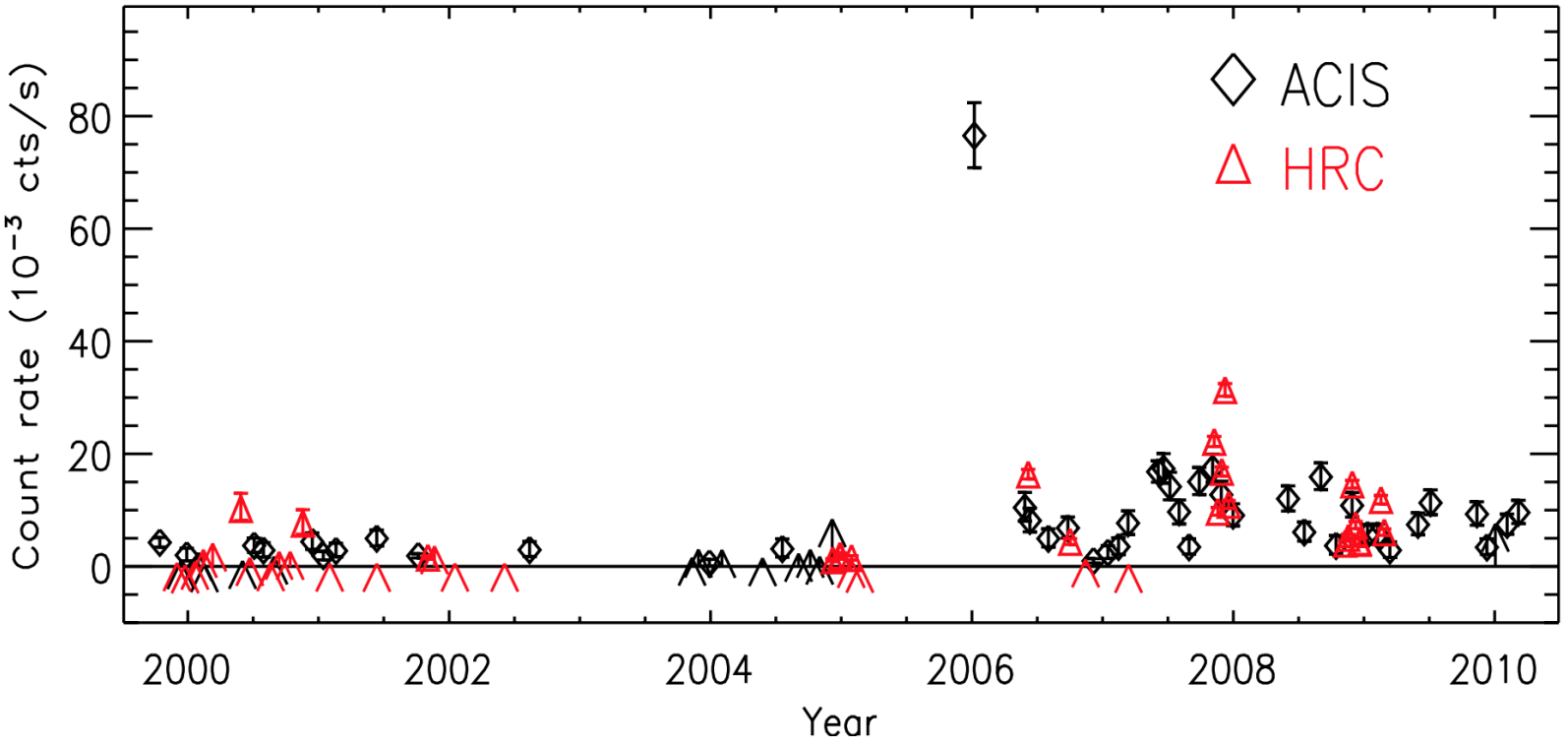


- Crane et al. (1992) first discovered a compact radio source at the nucleus of M31 using VLA (named M31*)
- An X-ray counterparts was identified by Garcia et al. (2010) with Chandra



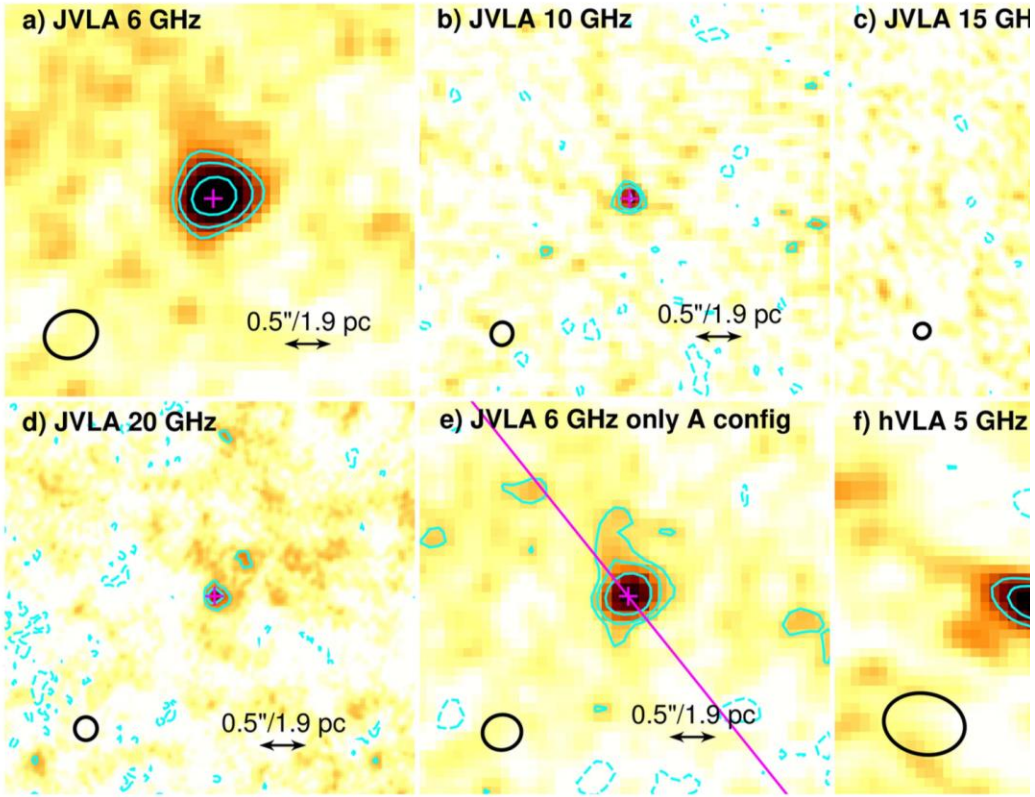
Garcia et al. 2010

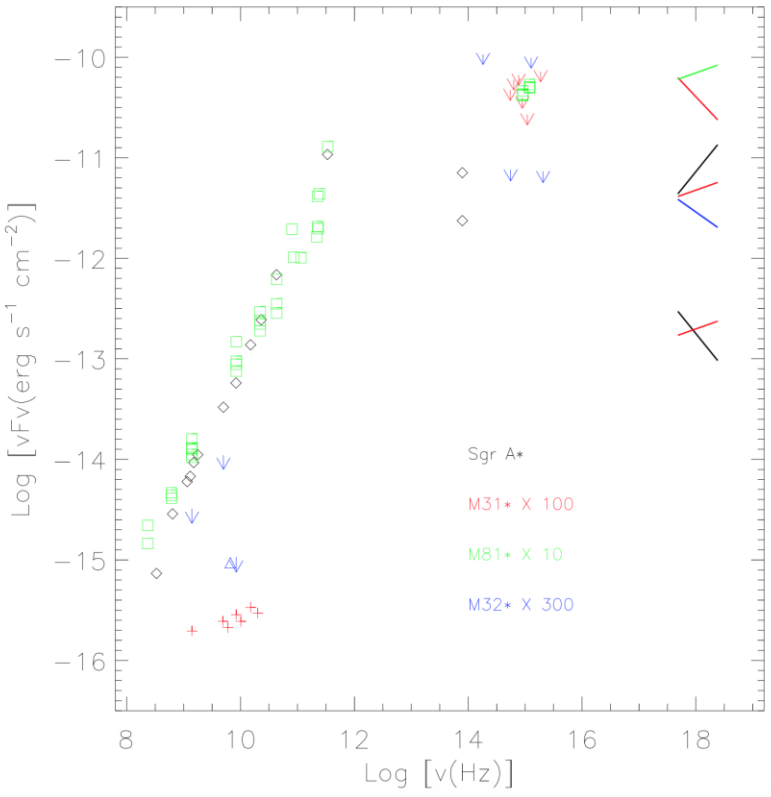
Motivation: M31*



- M31* produced an X-ray outburst on Jan. 6 2006, and subsequently it entered a more active state since then (Li et al.2011)
- The only second LLAGN known to show X-ray flares, after Sgr A*

Motivation: M31*

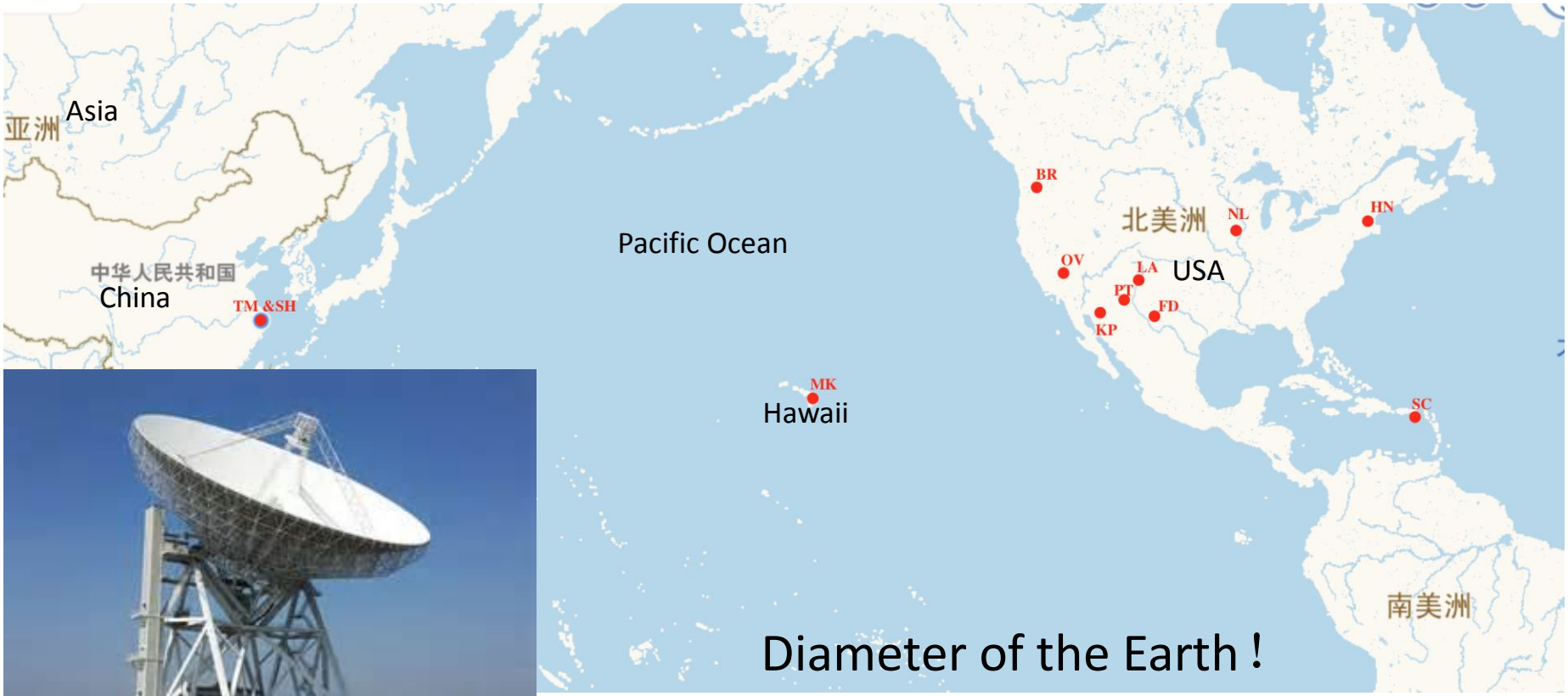




- We carried out VLA monitoring observations in 2011~2012 in four bands
- hints for pc-scale jet in C-band
- spectral index: $\alpha \sim -0.45$ ($S_\nu \sim \nu^\alpha$) consistent with jet synchrotron, different from Sgr A* (Yang et al. 2017)

Observation

- Using VLBA + Tianma-65m + Shanghai-25m to search for jets from M31*



Observation

Table 1: Information for project BL223

Project code	Epoch	Central freq.	Integral time	array*
BL223_A	2016-4-20	6GHz	7.0h	All VLBA
BL223_B	2016-8-29	5GHz	7.0h	TM + SH + VLBA - PT - SC
BL223_C	2016-10-4	5GHz	7.0h	TM + SH + All VLBA
BL223_D	2016-11-18	5GHz	7.0h	TM + VLBA - HN

- Phase-referenced mode, phase calibrator：J0038+4137
- The center of M31:

  RA = 00h42m44.32s, Dec = +41°16’08.50” (J2000)

Results

- **No detection** during any of four epochs
- 3-sigma upper-limit: ~27μJy for single epoch
- 5-sigma upper-limit for combined_BCD: 27μJy

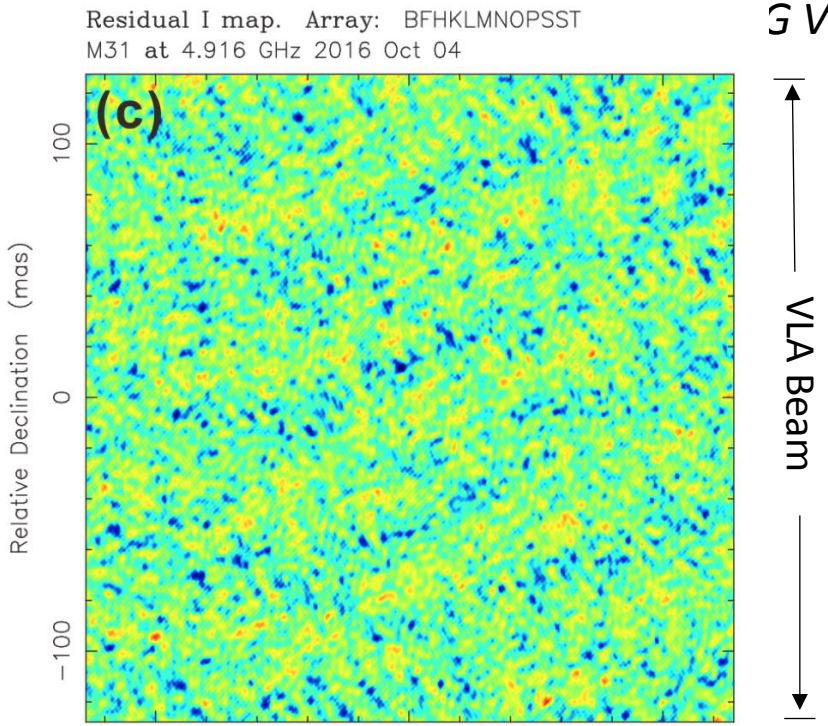


Table 2: Results of M31*

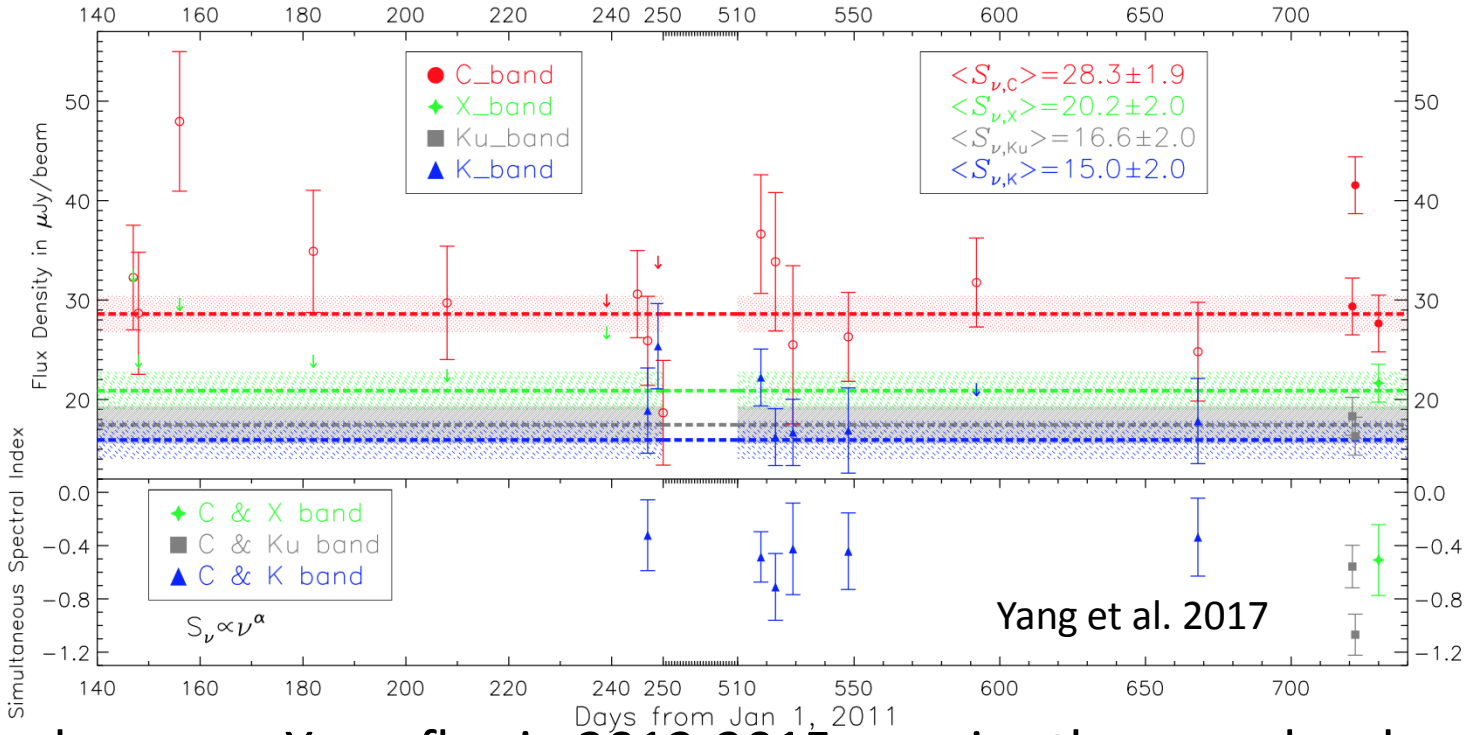
Project code	Central freq. (GHz)	Theoretic RMS ($\mu Jy/beam$)	Observed RMS* ($\mu Jy/beam$)	Synthesis aperture ($mas \times mas$, ^{o})
BL223_A	6	12.8	12.7	$1.27 \times 2.31, -34.5$
BL223_B	5	6.6	10.0	$0.74 \times 1.85, -6.4$
BL223_C	5	6.1	9.4	$0.72 \times 1.98, -2.8$
BL223_D	5	6.2	8.7	$0.71 \times 1.88, -4.4$
Combine_BCD	5	4.3	5.4	$0.72 \times 1.90, -4.4$

* Observed RMS of last three epochs is obviously higher than its theory maybe due to the EVN Calculation for TM and SH is not suitable.

Discussion: two possibilities

-- **Fading radio emission ?**

- 2002~2005: average flux density 60.0 ± 10.0 μJy at 5 GHz in VLA
- 2011~2012: 28.3 ± 1.9 μJy at 6GHz in VLA (extrapolate to ~31 μJy in 5GHz)
- 2016： 5 sigma upper-limit 27 μJy in VLBA+Tianma



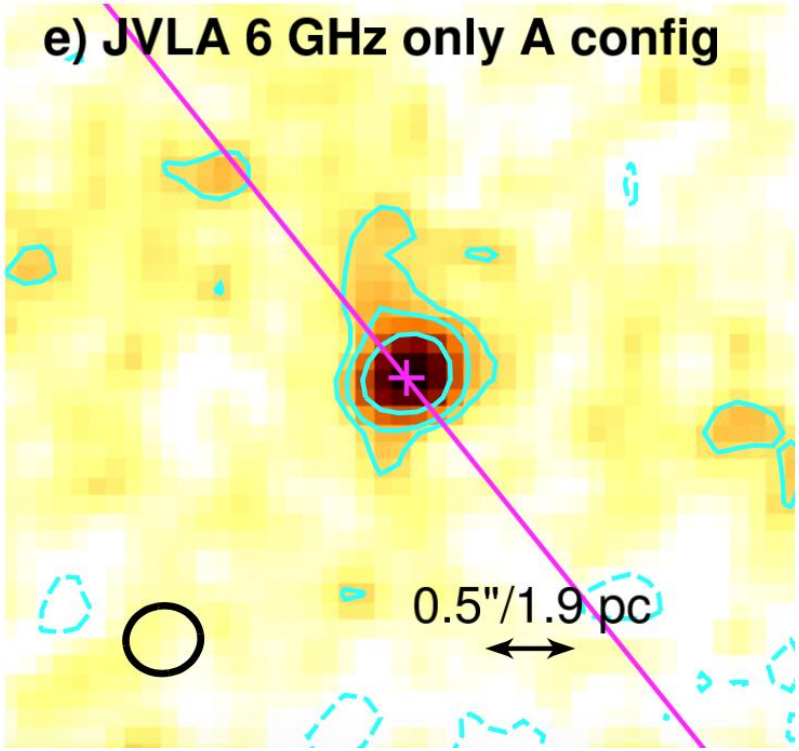
- however, X-ray flux in 2012-2015 remains the same level as before 2012(work in preparation)

Discussion: two possibilities

-- **Extended jets**

- VLA A-array has a resolution at 0.3”/1 pc , corresponding to 10^5 R_{Sch}
- With VLBA + Tianma, we achieved 0.7mas /10^{-3} pc, corresponding to 200 R_{Sch}

- The extended jets dominate the total radio flux detected by VLA, now resolved on mas-scales

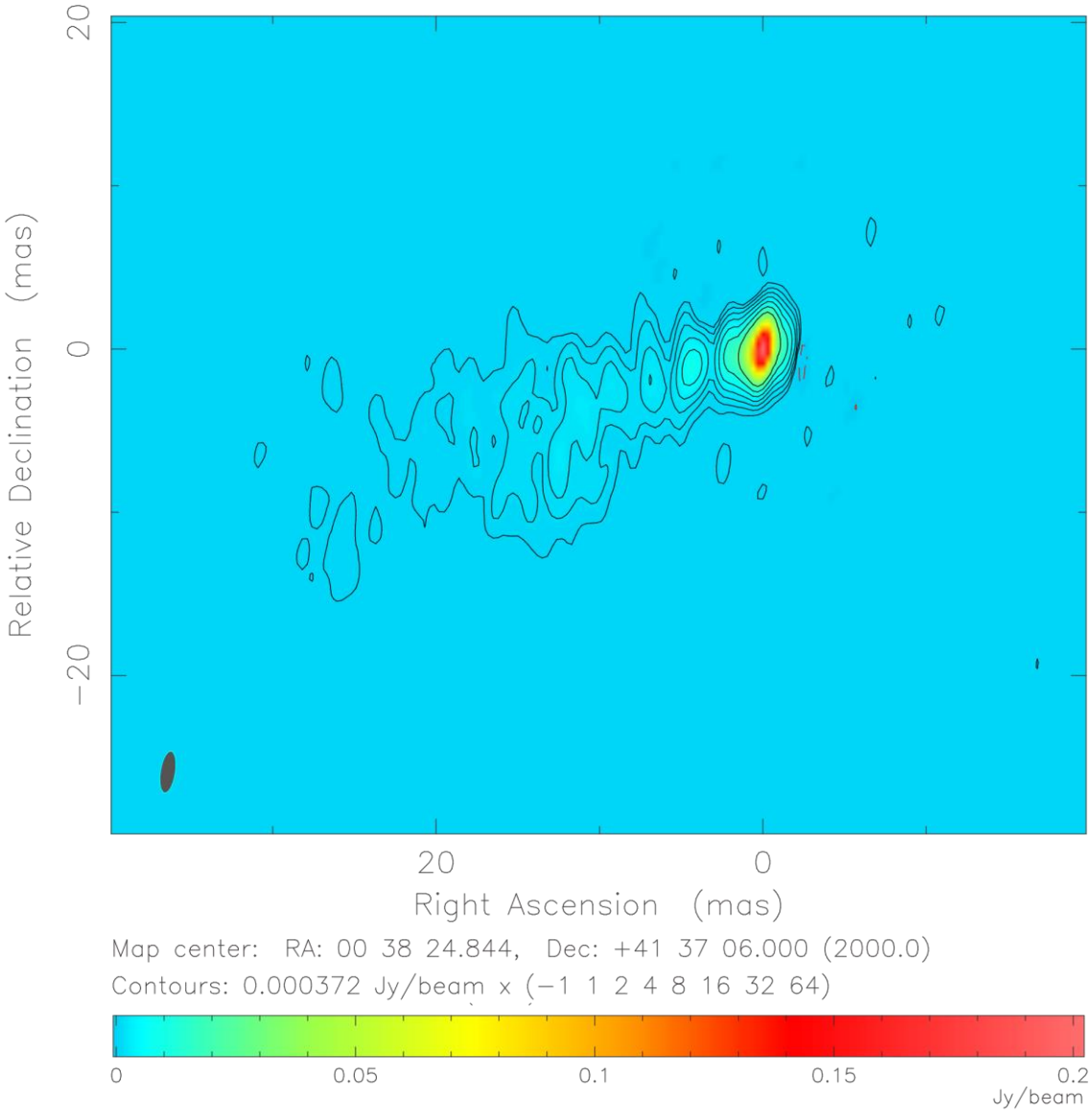


Yang et al. 2017

Summary and prospect

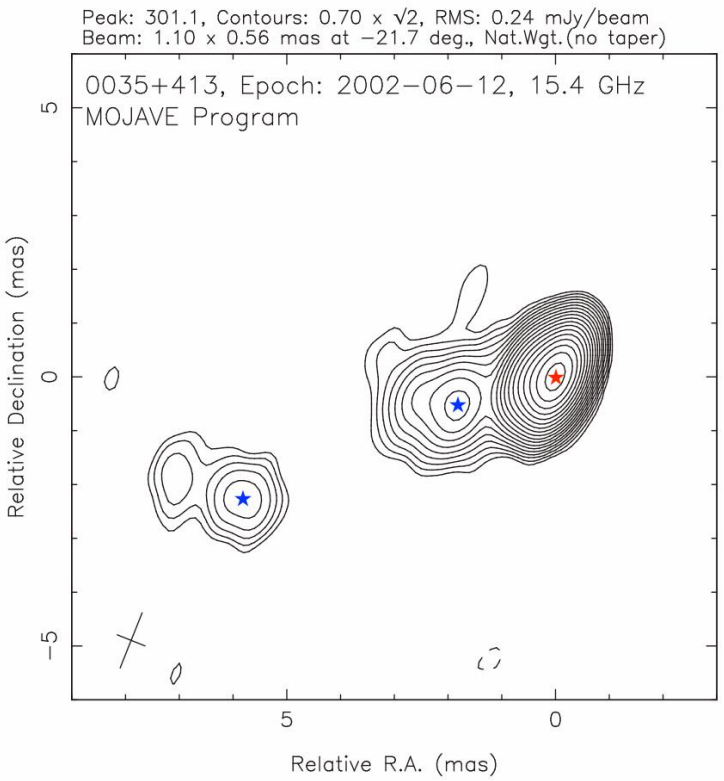
- Joint observations of VLBA, Tianma 65-m and Shanghai 25-m at C-band in four epochs in 2016.
- Our resolution reaches 0.7mas (~$200\ R_{Sch}$).
- No detection on 5-sigma upper-limit in M31*.
- May suggest extended jets.
- Prepare apply for EVN+EAVN observations

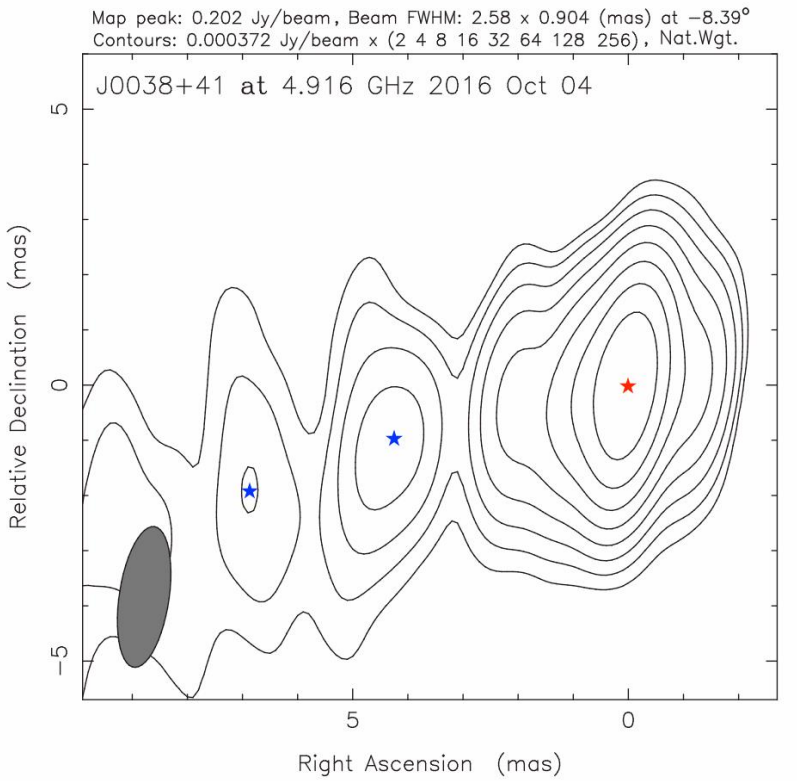
Discussion: J0038+4137



- Z=1.35
- High resolution image in C-band
- Rms: 74.4 μJy/beam
- Peak: 0.202 Jy/beam

Discussion: J0038+4137





- Left: the image of J0038+4137 on 15GHz in 2002;

  Right: the image of J0038+4137 on 5 GHz in 2016
- Red: Core Blue: Jet's components