GENJIプログラム：VLBIモニター観測による電波銀河3C 84のsub-pcスケールジェットの運動

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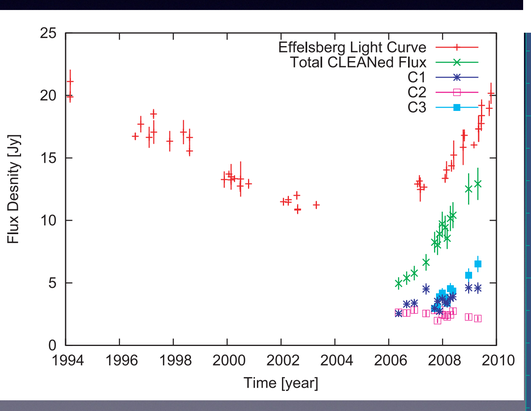
1. Introduction

Radio galaxy 3C 84 (FR I)

Distance: 75 Mpc



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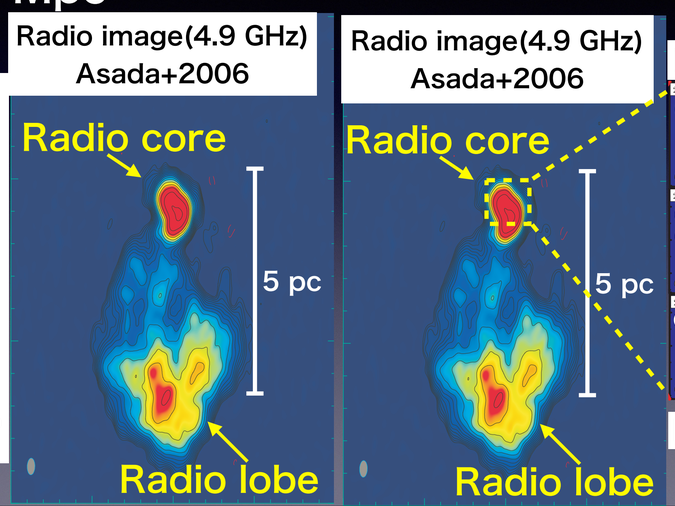
22 GHz radio images(Nagai+2010)



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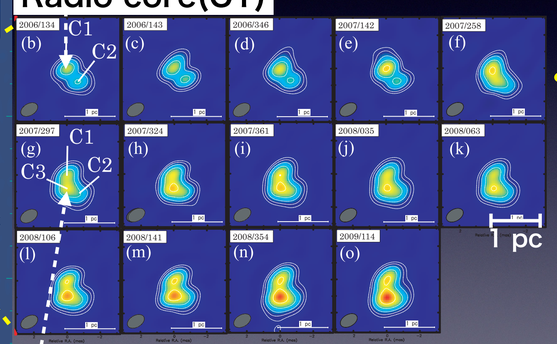
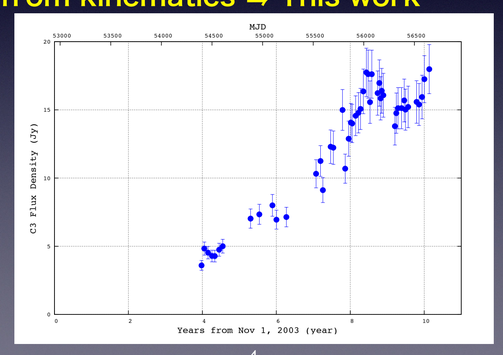
Radio core(C1)



Newly ejected component(C3)

What is C3?

- Approach from light curve ⇒ Chida+2014, ASJ Annual Spring Meeting, S04a
  - ✤Flux increase in 6 years ⇒ Similar behavior to “hot spot” in radio lobe, not “jet knot”
- Approach from kinematics ⇒ This work



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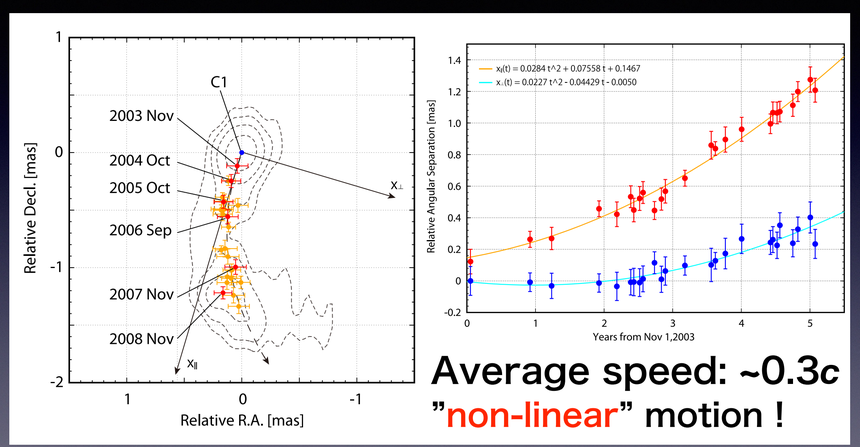
Change in relative separation from C1 to C3 @43 GHz (Suzuki et al. 2012)



Average speed: ~0.3*c*

”non-linear” motion !

What is the subsequent motion of C3?

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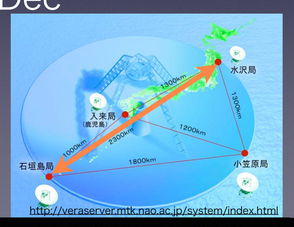
2. Observation

VERA (VLBI Exploration of Radio Astronomy)

- Frequency band : 22 GHz(K-band)
- Bandwidth : 176 MHz (16MHz × 11IF)
- ON source time : ~50 min./epoch
- Max baseline length : ~2300 km
  - ⇒ Spatial resolution : ~1.2 mas
  - ⇒ linear scale : ~0.42 pc
- Obs. epoch : 2007/Oct - 2013/Dec (**80 epochs**)



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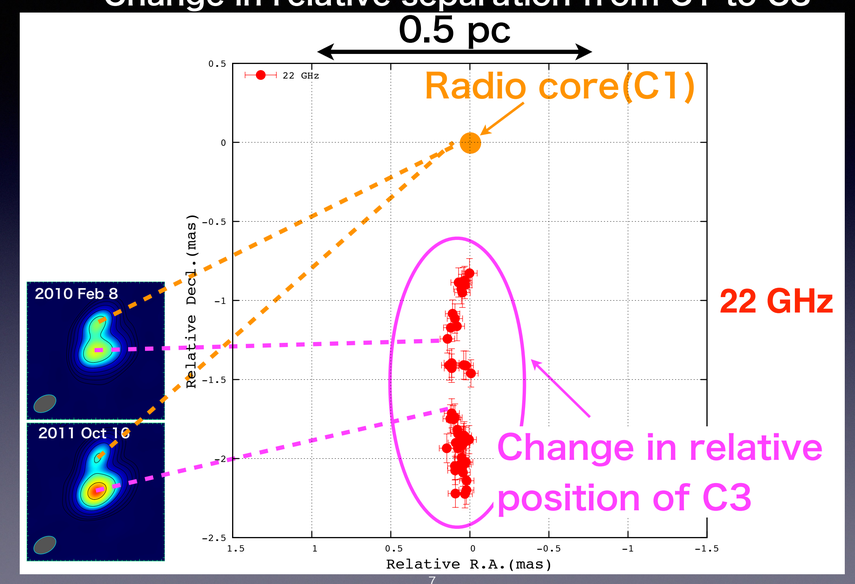
3. Results

Change in relative separation from C1 to C3



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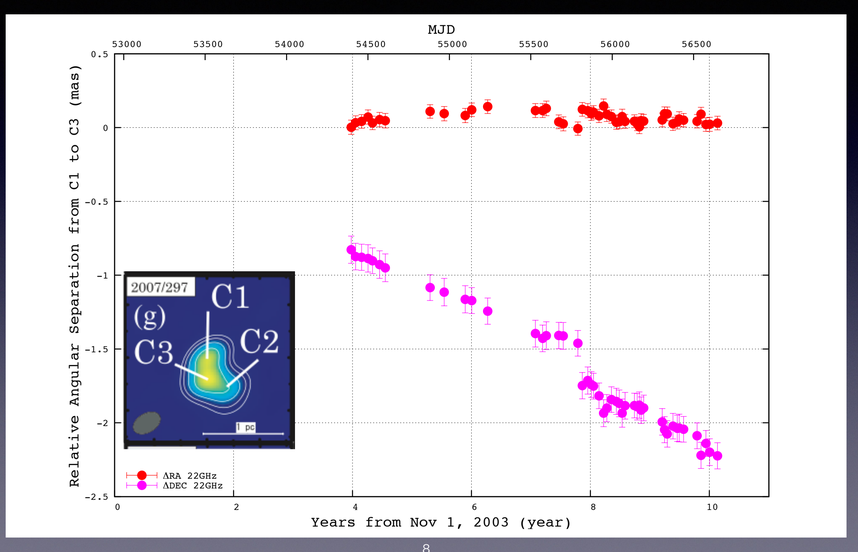
Change in relative separation from C1 to C3



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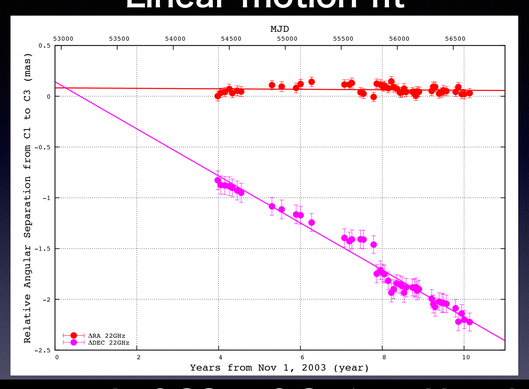
Change in relative separation from C1 to C3

Linear motion fit



- Average speed of C3 : ~0.3*c* (e.g. Nagai+2006)
- Almost constant speed (Kawakatu & Kino 2006)

⇓

Similar behavior to hot spot in mini-radio-lobe

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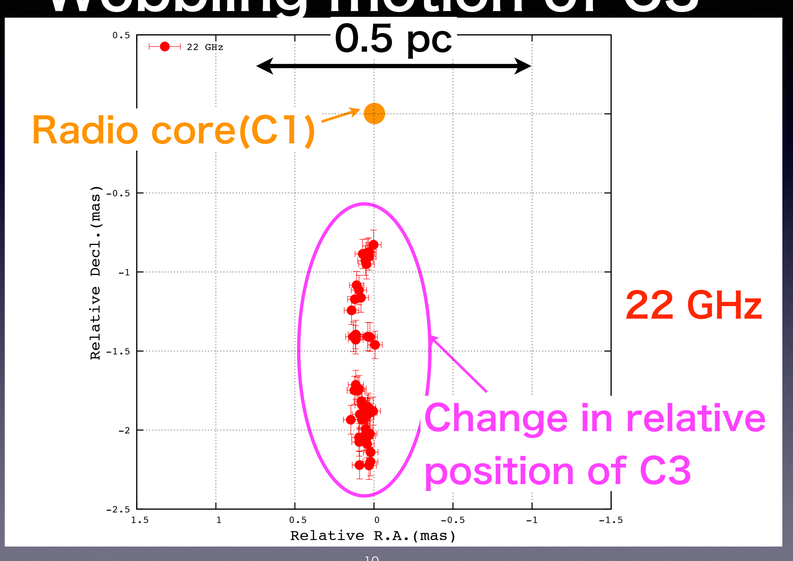
4. Discussion

Wobbling motion of C3



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Fitting functions

- Linear motion model
  - ΔR.A.(t) = at + b
  - ΔDec.(t) = ct + d
- (Periodic + linear) motion model
  - ΔR.A.(t) = a sin(b(t+c)) + dt + e
  - ΔDec.(t) = f sin(b(t+g)) + ht + i

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Model selection

- **F-test**
- **Akaike Information Criterion(AIC)**
  - AIC = (residual chi square) + 2×(# of model parameters)
  - The model with the lower AIC value is the one to be preferred.
- **Bayesian Information Criterion(BIC)**
  - BIC = (residual chi square) + (# of model parameters)× ln(# of data points)
  - The model with the lower BIC value is the one to be preferred.
  - The BIC generally penalizes free parameters more strongly than does the AIC.

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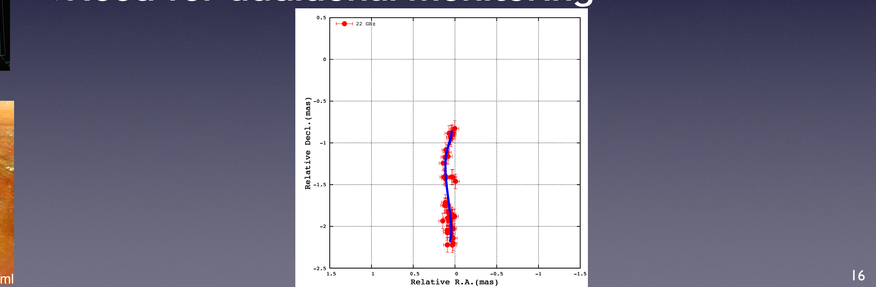
Change in relative separation from C1 to C3

(Periodic + linear) motion fit



Period: 5.6 ± 0.8 yr

Amplitude(R.A.): 0.013 ± 0.003 pc

Amplitude(Dec.): 0.028 ± 0.007pc

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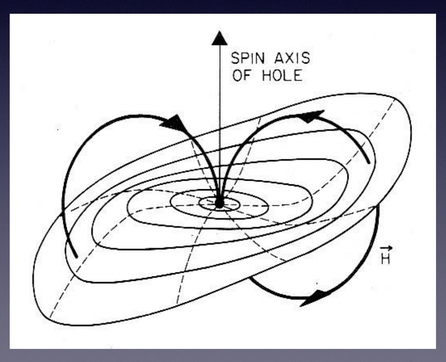
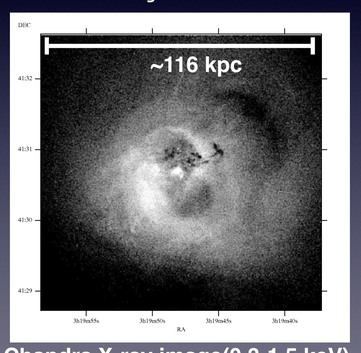
Factor causing a wobbling motion of C3

- Precession
  - Bardeen Petterson effect (Bardeen & Petterson 1975)
    ⇒ The precessional period becomes shoter with time.
  - 3.3×10^7 yr @100 kpc-scale (Falceta-Gonçalves+2010)





Chandra X-ray image(0.3-1.5 keV)
Fabian+2003

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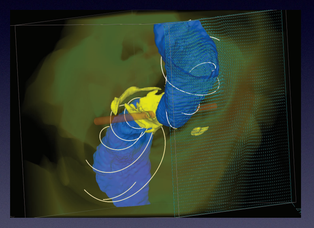
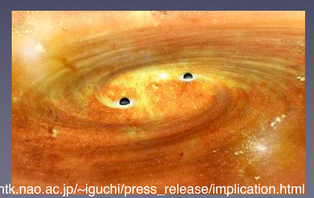
Factor causing a wobbling motion of C3

- Precession
  - Bardeen Petterson(BP) effect (Bardeen & Petterson 1975)
    ⇒ Acting at all times
  - Magneto-spin effect (McKinney+2013)
    ⇒ Beyond BP effect in a strong magnetic field
  - Binary BH effect ⇒ Acting when two BHs resides in the system





15 http://alma-intweb.mtk.nao.ac.jp/~iguchi/press_release/implication.html

5. Conclusion

- VERA monitoring of the sub-pc-scale jet in radio galaxy 3C 84 over 6 years (80 epochs)
- Almost constant speed(~0.3*c*) of C3
  ⇒Hot spot in mini-radio-lobe
- Possible periodic motion of sub-pc-scale lobe
  ⇒Need for additional monitoring

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