Probing synchrotron self-compton turnover of blazars with VLBI+ALMA

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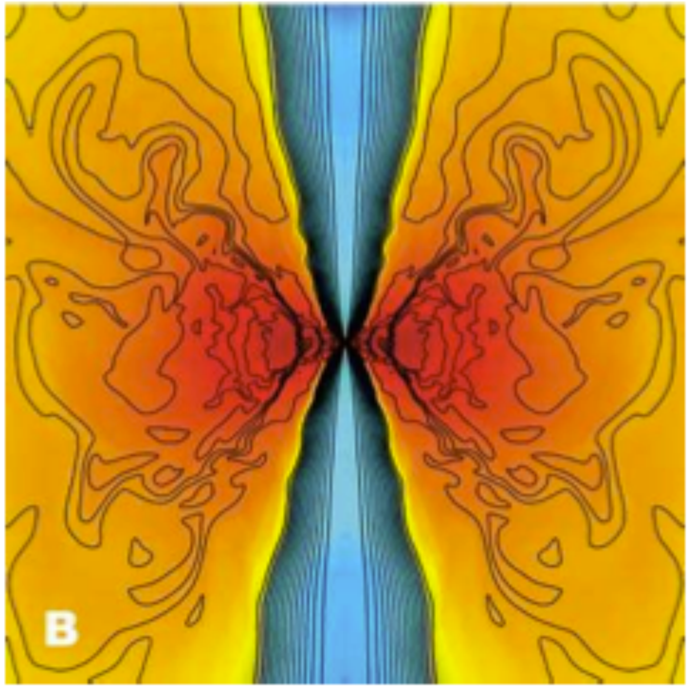
Introduction

- Magnetically driven jets
  - How much is the actual value of the strength of the magnetic field at the base of the jet?



McKinney+06

Introduction

- Spectral indices of blazars at cm wavelength are usually flat because we observe sum of multiple components
- Many blazars show optically thin spectral indices with ALMA (≥86 GHz) (Nagai+, ALMA OT)
- To estimate the value of magnetic field strength using synchrotron self-absorption turnover, we need to know the spectrum turnover of the optically thick region

$$B_{ssa} \propto \theta^4 \nu_m^5 S_m^{-2}$$

How to estimate Bssa using $B_{ssa} \propto \theta^4 \nu_m^5 S_m^{-2}$?

- We assume that the 86 GHz core size is the size of optically thick region
  - It is important to determine the accurate core size at 86 GHz by obtaining long baselines in both east-west and north-south direction including ALMA baselines
- To estimate the SSA turnover frequency and flux, we need to decompose the ALMA flux into optically thin region and optically thick region
  - We estimate the flux of optically thick region with VLBI at <86 GHz by scaling the factor of the cross section ratio
  - We derive the spectral index of the optically thin region using high sensitivity VLBI imaging, and extrapolate the index to ALMA region
    - 15-43 GHz: VLBI data (MOJAVE, KaVA, BU, Radio Astron etc.)
    - at 86 GHz: GMVA+KVN+phased-ALMA
    - at 230 GHz: EHT (if possible)

Why GMVA+phased-ALMA?

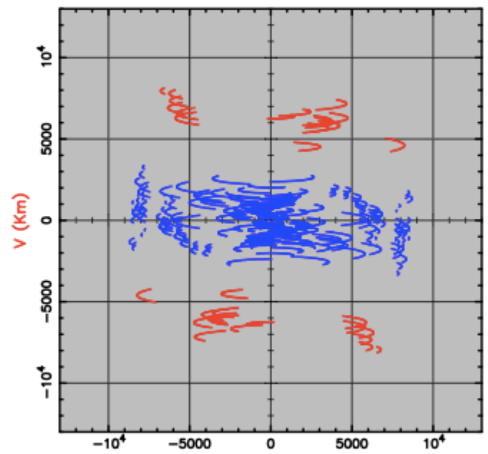
high baseline sensitivity (7σ)

$$\Delta B = 14.5mJy\left(\frac{SEFD_{ALMA}}{52Jy}\right)^{1/2}\left(\frac{SEFD_{PV}}{653Jy}\right)^{1/2}\left(\frac{\Delta\nu}{512MHz}\right)^{-1/2}\left(\frac{\tau_{ff}}{10\sec}\right)^{-1/2}$$

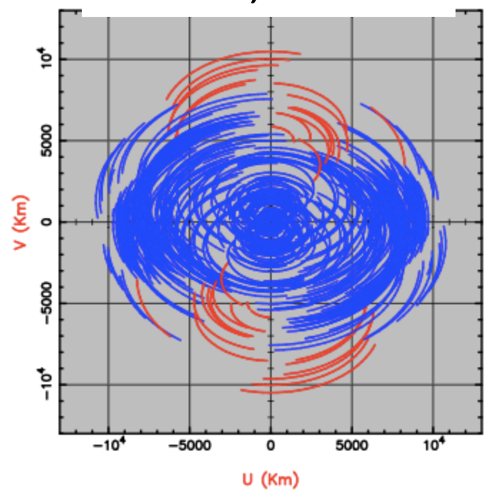
$$\Delta B = 115mJy\left(\frac{SEFD_{VLBA}}{3300Jy}\right)^{1/2}\left(\frac{SEFD_{PV}}{653Jy}\right)^{1/2}\left(\frac{\Delta\nu}{512MHz}\right)^{-1/2}\left(\frac{\tau_{ff}}{10\sec}\right)^{-1/2}$$

uv-coverage

3C 279, δ~5°

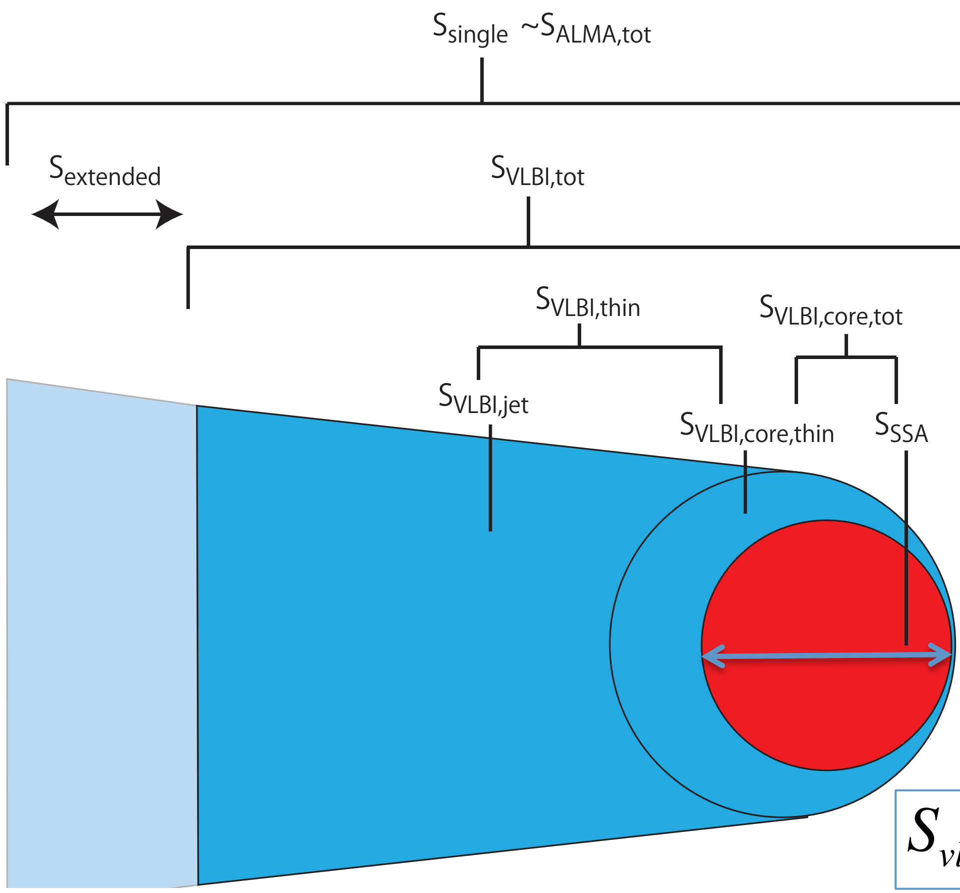


3C 345, δ~38°



- Baseline sensitivity of ALMA baselines are ~several times higher than VLBA baselines
  →High imaging sensitivity to detect jet emission
- ALMA baselines fill the uv-coverage toward north-south direction
  →Determination of core size in all direction

How to estimate Sssa?



VLBI at ≤86 GHz

$$S_{SSA,86G} \sim S_{vlbi,core,tot,86G}$$

$$S_{SSA,15G} \sim S_{vlbi,core,tot,15G} \times \frac{\theta^2_{vlbi,core,86G}}{\theta^2_{vlbi,core,15G}}$$

$$\theta_{ssa} \sim \theta_{vlbi,core,86G}$$

$$S_{vlbi,thin} = S_{vlbi,tot} - S_{SSA}$$

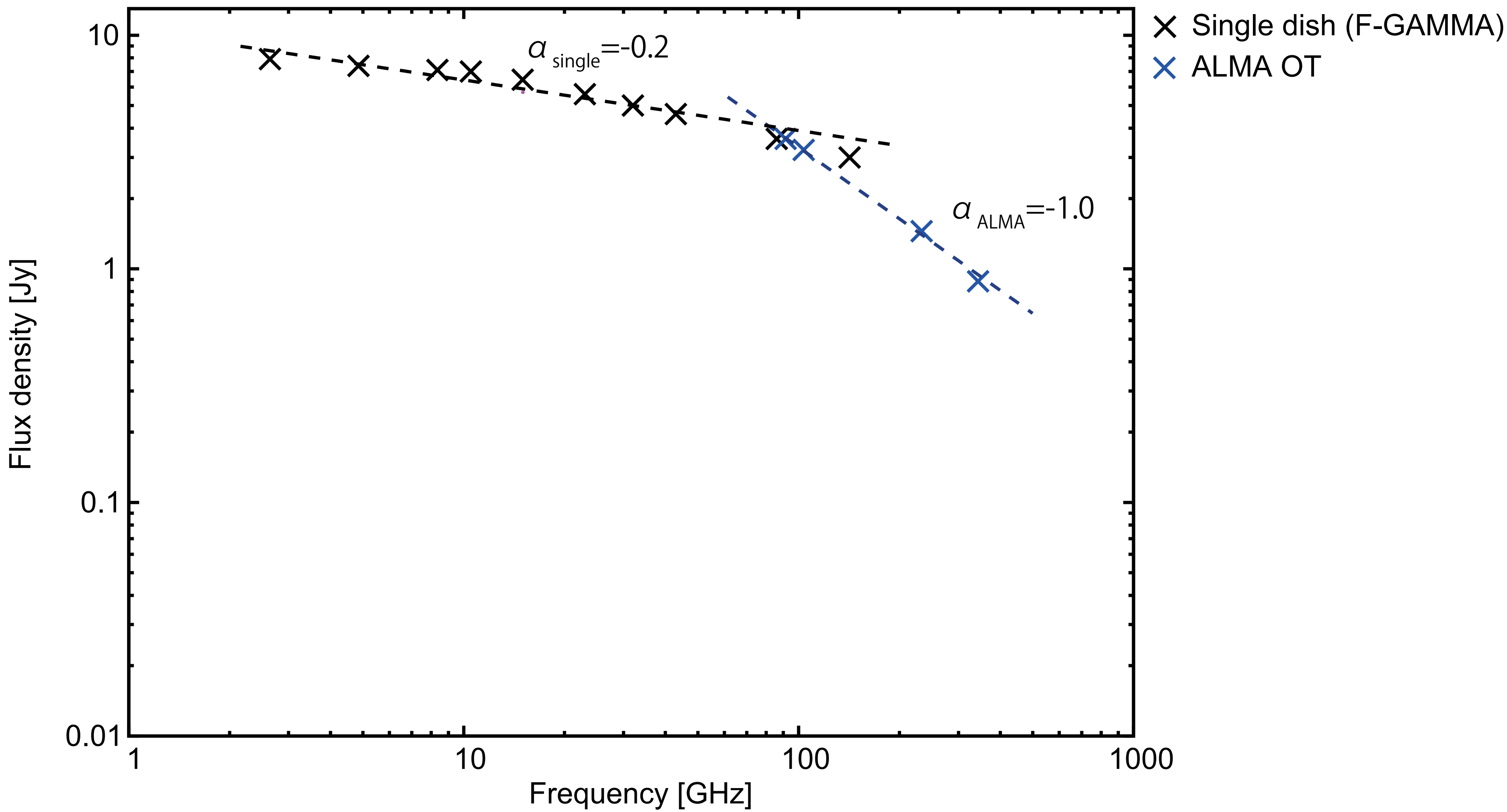
$$S_{vlbi,ext} = S_{single,tot} - S_{vlbi,tot}$$

extrapolate the index obtained ≤86 GHz

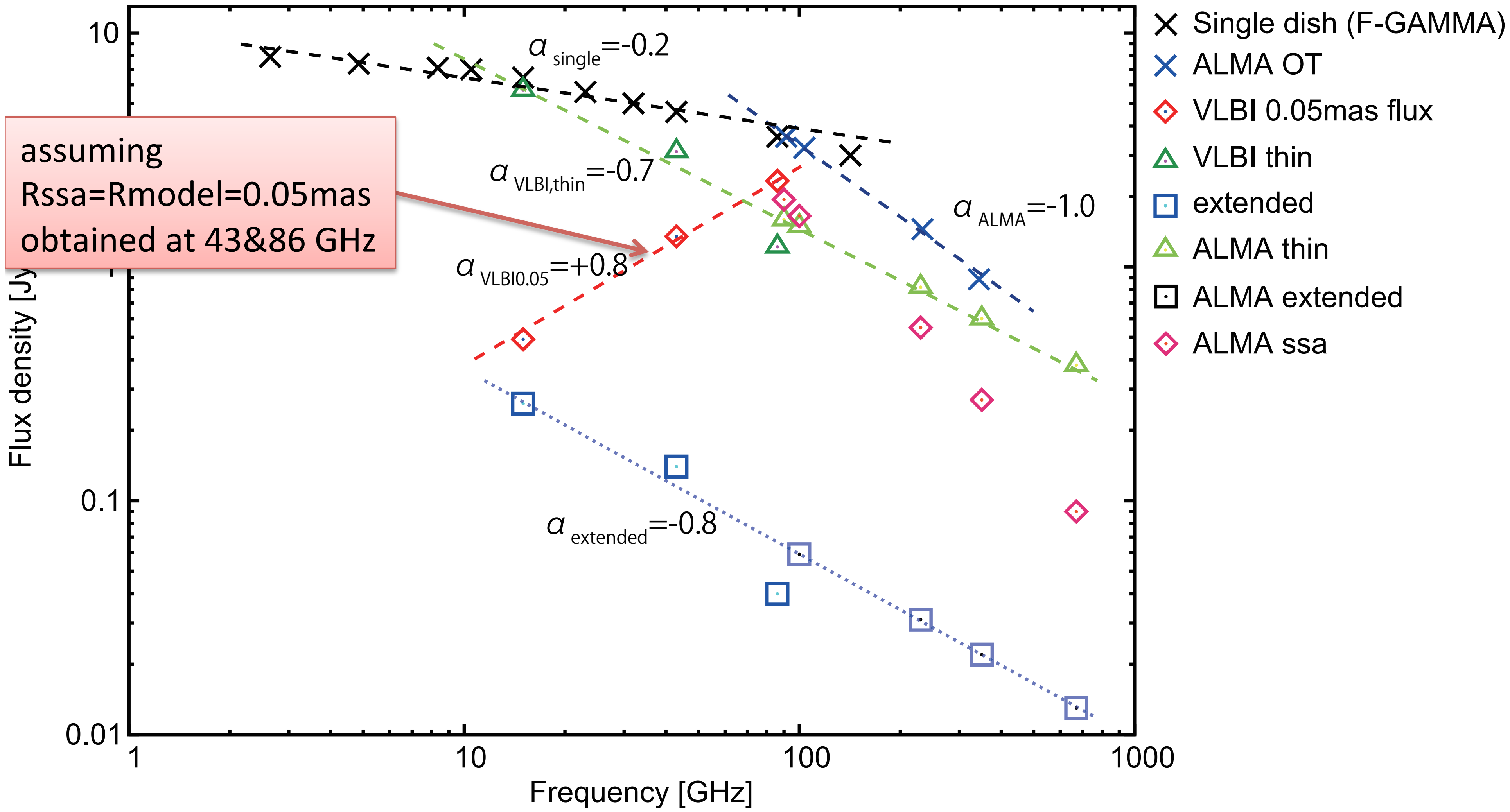
ALMA

$$S_{SSA} = S_{ALMA,tot} - S_{ALMA,ext} - S_{ALMA,thin}$$

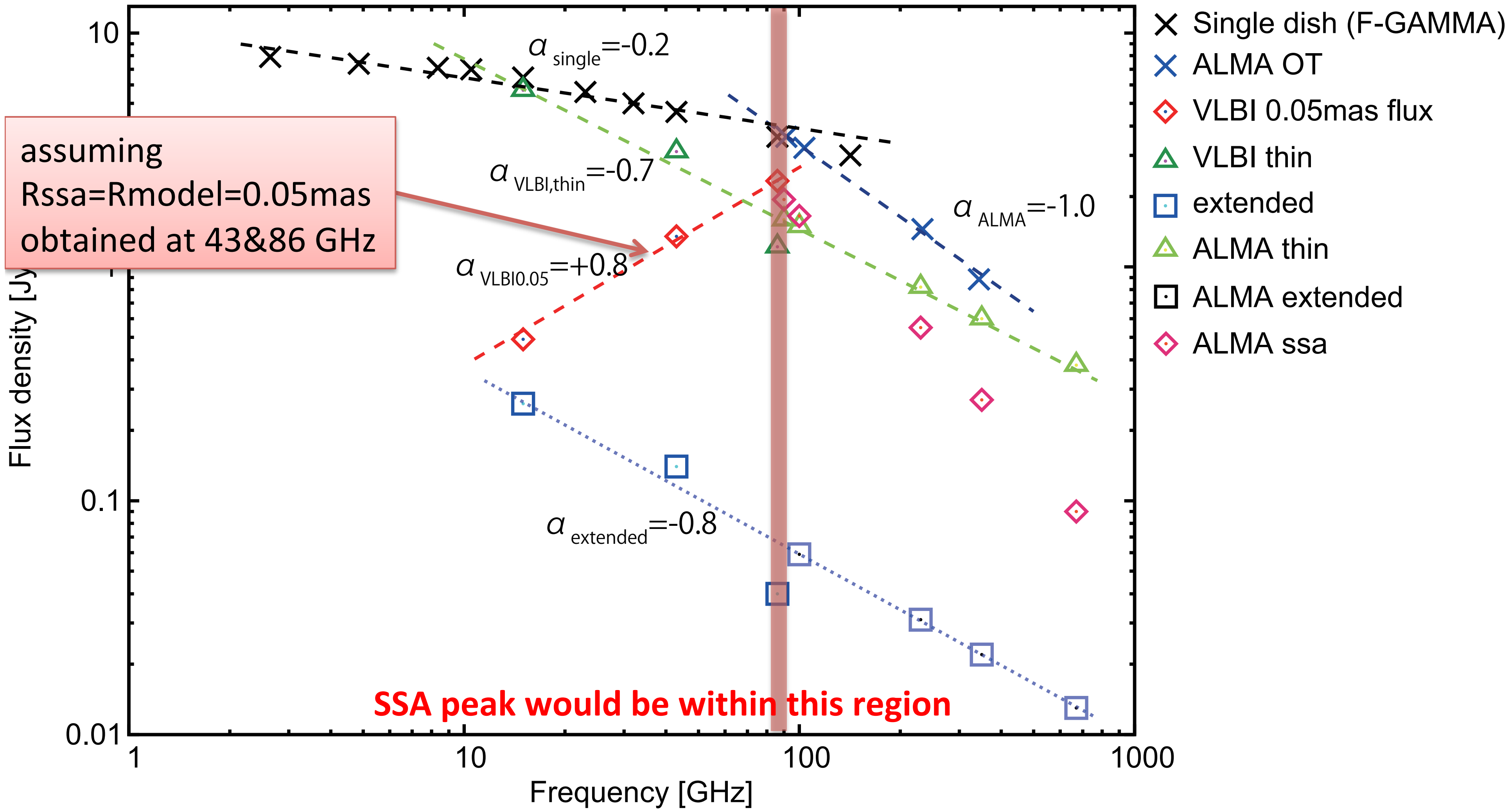
Example for quasar 3C 345



Example for quasar 3C 345



Example for quasar 3C 345



Estimation of Bssa

$$B_{ssa} \sim 0.04G\left(\frac{\theta}{90\mu as}\right)^{4}\left(\frac{\nu_{m}}{90GHz}\right)^{5}\left(\frac{S_{m}}{2.2Jy}\right)^{-2}\left(\frac{\delta}{12}\right)\left(\frac{1}{1+z}\right)$$

→Consistent with the value of the magnetic field strength at the jet base derived by using core-shift measurement

Remaining problems

- Spectral index of optically thick part~0.9 ≠ 2.5
  - SSA region size could be smaller than our assumption
  - The fluxes of SSA region at lower frequencies could be lower than the values we used because of core shift effect
    → derived SSA fluxes are upper limit
- VLBI total flux
  - It should be measured with the same minimum uv distance

Future works

- Which sources are the best for this study?
  - apply the method to other sources, e.g., OJ 287, 3C 279, 3C 454.3, CTA 102, etc.
- We will consider the upper/lower limit and the errors to put stronger constraint on physical parameters

THANK YOU FOR LISTENING