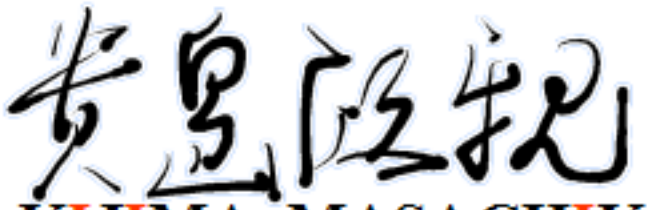
The Graduate University for Advanced Studies
Sokendai

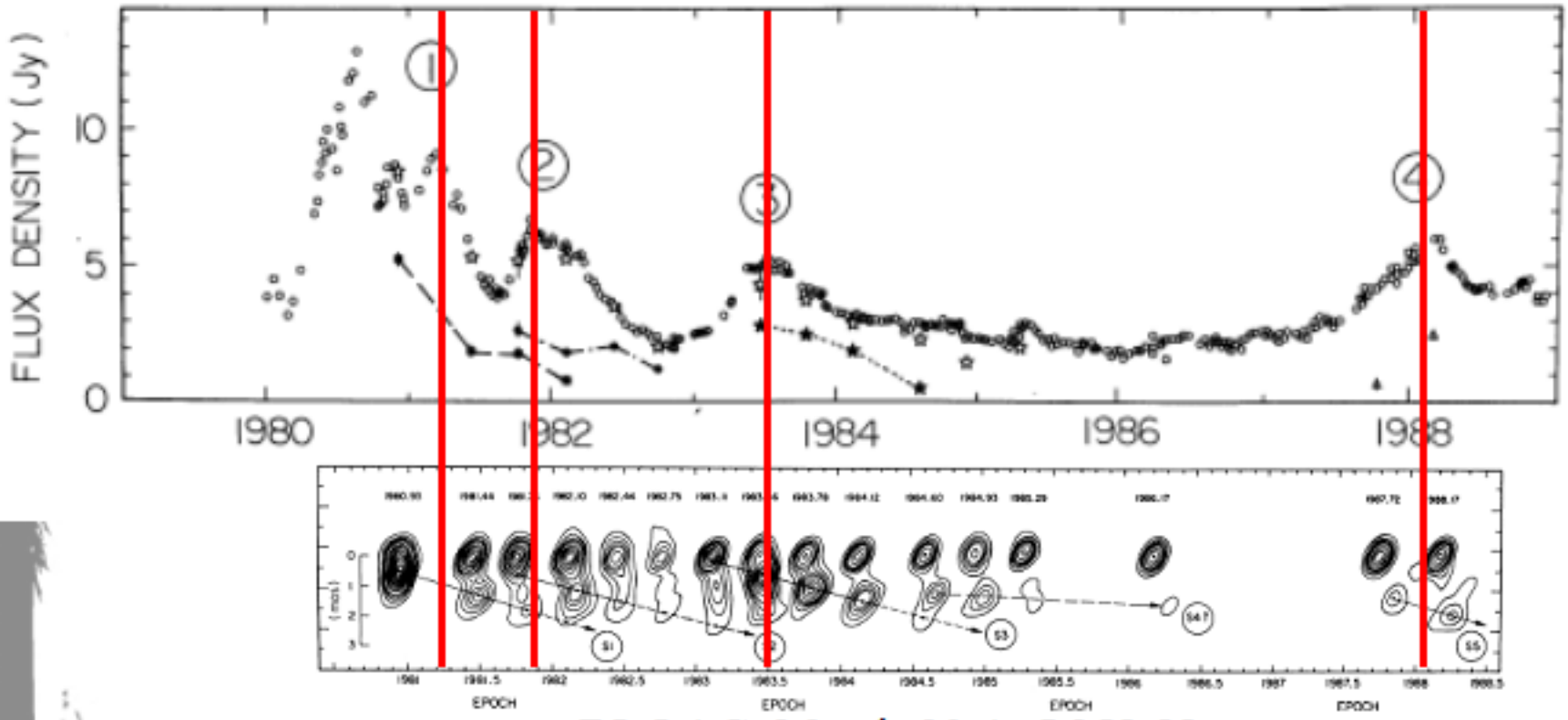
Application of Geodetic-VLBI Data to Obtaining Long-Term Light-Curves for Astrophysics

SOKENDAI(ph-D3) + NAOJ



KIJIMA MASACHIKA
(Family name) (first name)

VLBI-images reveal the origins of flux-variation.



BL LAC, Mutel+90 ApJ 352 82

Close correlation between flux-variation and structure-variation.

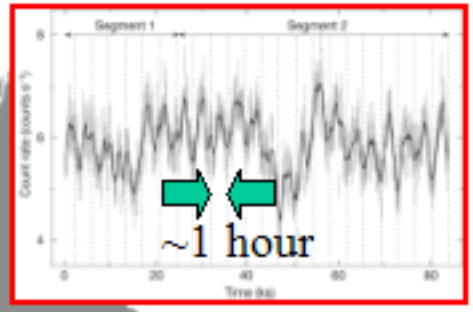
This is one of the good case to be explained with simple scenario.

However, many other cases are complex.

Further investigations are needed.

Phenomenon => Mechanisms and Time-Scales

QPO

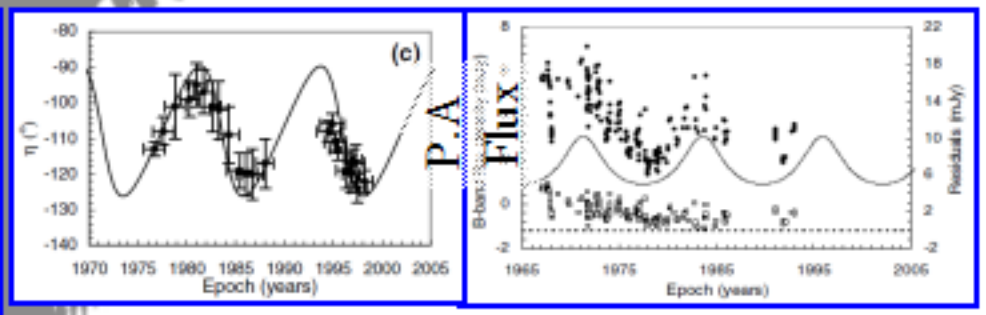


$O(kHz)@10M_{\odot} \Rightarrow O(1\ hour)@10^{6\text{-}8}M_{\odot}$

This is first observational evidence

RE J1034+396:Gierlinski+08(Nature),XMM-Newton

Precession



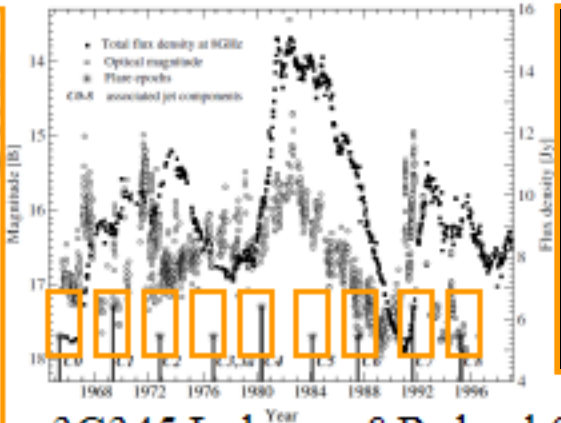
$O(10?,10^{3}?)yr@10^{6\text{-}8}M_{\odot}$

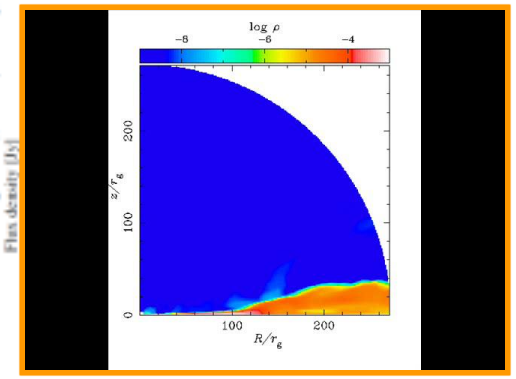
BinaryBH? KerrBH? Magnetic?

At most 10 sources.

3C120:Caproni&Abraham 04b, VLBI+light curve

Disk instability





$O(10^{2})sec@10M_{\odot}$

$\Rightarrow$ 3-300yr@$10^{6\text{-}8}M_{\odot}$

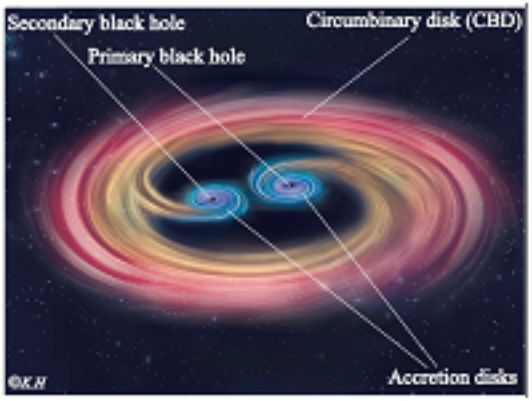
No one mentioned in detail for AGNs

3C345:Lobanov&Roland 05 Periodic knot ejection, VLBI+light curve

Ohsuga 06, simulation, disk-instability

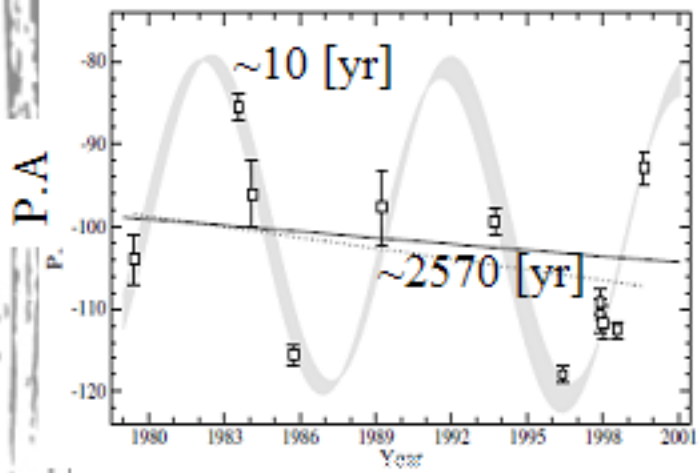
Debated Precession Mechanism

- Binary Black Hole
  - P~10^1 yr : Caproni+04ab, Abraham+99, etc
  - P~10^3 yr : Lobanov+05
- KerrBH-disk misalignment
  - P~10^1 yr : Caproni+04c
  - P~$10^{3\text{-}6}$yr : Lu+05
- Helical trajectory? Instability in the jet?
- Time-scale & mechanism are still unclear



Hayasaki 09

Triple disk? (simulation)



Epoch [yr] Lobanov+ 05 3C345

Source	BBH time-scale	ref	KerrBH ref
3C345	10	Caproni+04a	Caproni+04c
	2570	Lobanov+05	Lu+05

Light-curves and VLBI-images are still important.
We need more target sources!!

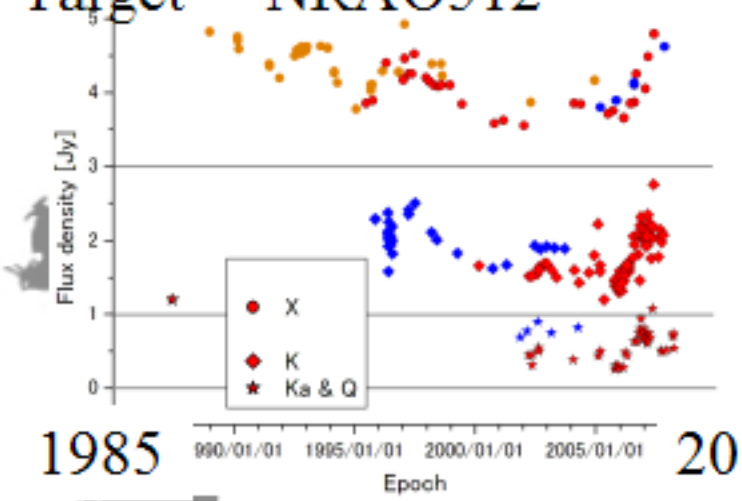
VLBI-data is TREASURE for long-term light-curves

Wavelength		Observatory	Sources	duration	
X		RXTE		1995-	14
		MAXI	all-sky	2009-	0
OPT		MAGNUM(**Japan**)	60		8
		Wise Observatory	42	1991-1998	7
		Shajn		1960?-	
IR		KANATA(**Japan**)	40	2006-	3
Radio	C,X,U	UMRAO	200	1964-	45
	K,Ka,W	MRO	157	1985-	24
	L,Ka	Effelsberg	53	1991-1995	4
	S,X	GreenBank	33	1979-1985	6
Radio-X		WEBT-campaign			
Radio(VLBI)	P,L,S,C,X,Ku,K	VLBA		1993-	16
	I,P,L,C,X,U,K,Q,V,W	VLA		1980-	29
	S,X,K,Q	VERA(**Japan**)		2005-	4
	S,X,C,K,Q	JVN/OCTAVE(**Japan**)		2005-	4
	S,X	Geodetic VLBI		1979-	30

- Opt/IR observations have inevitable lack due to LST changing.
  - Radio observations can be conducted at daytime and nighttime.
- Radio observations have been conducted by UMRAO and MRO.
- Geodetic-VLBI provide us the long-term light-curves.
- Radio/Opt(or IR,X, γ) correlation is noted lately. (ex.WEBT campaign)

Tentative Results of the Light-curves drawn with VLBI-data

Target NRAO512



1985 2010

Kijima(PASJ) will be submitted.

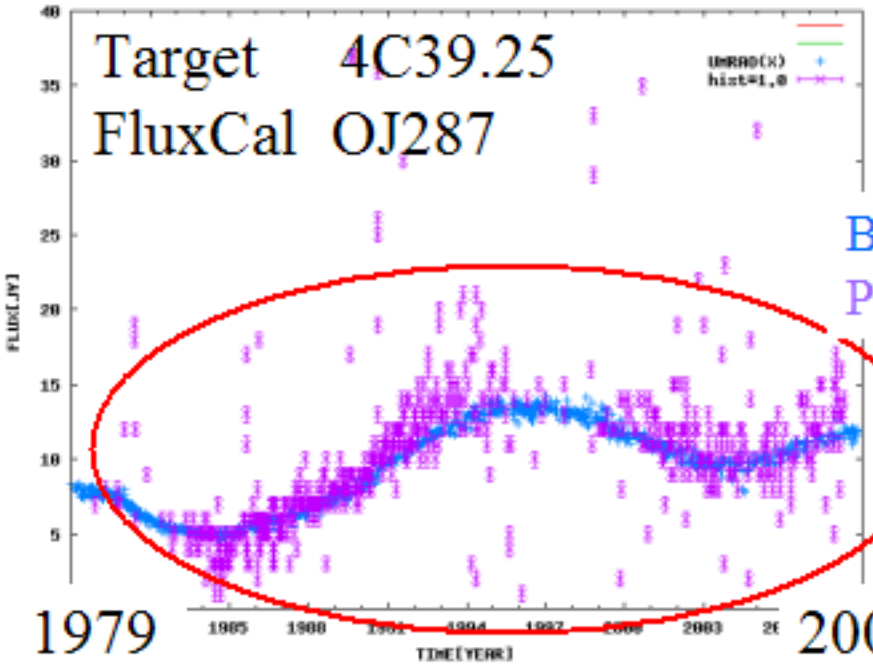
Blue: SingleDish

Red&Orange :interferometer
(VERA,OCTAVE,VLA,VLBA)

Geodetic-VLBI (example)

$$S_{target} = \frac{\rho_{calibrator}}{S^{Michigan\_univ.}_{calibrator}} \rho_{target}$$

Target 4C39.25
FluxCal OJ287



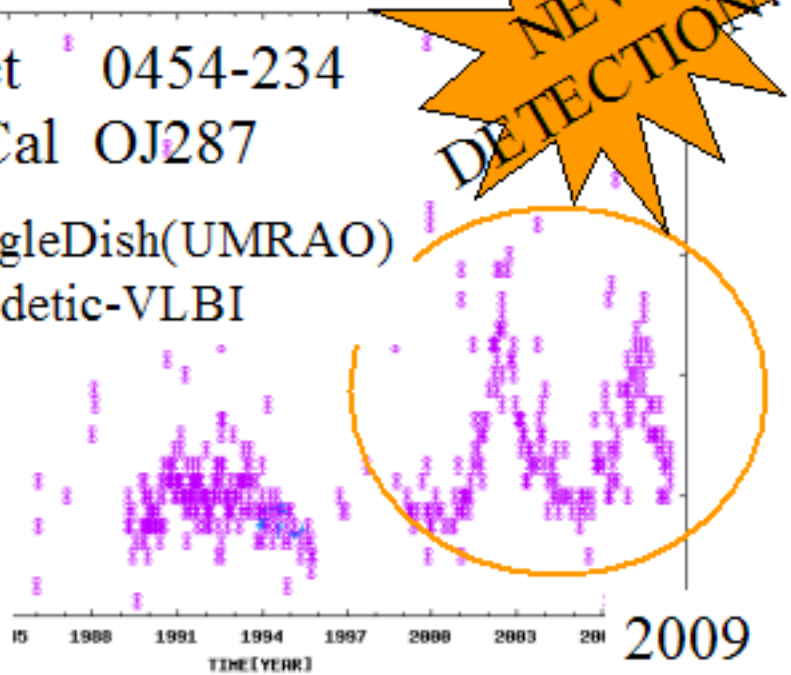
1979 2009

0454-234 (cal=OJ287)

Target 0454-234
FluxCal OJ287

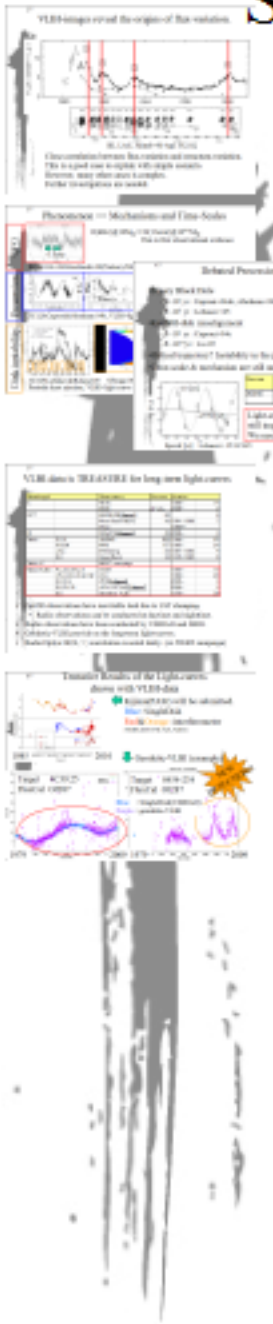
NEW DETECTION!!

Blue : SingleDish(UMRAO)
Purple : geodetic-VLBI



1979 2009

Summary: Thank you geodetic-VLBI community



Flux-variation is investigated with VLBI-images.
=>Correlation: Flux-variation – structure-variation

yr-order variability and mechanism.
but highly debated.

VLBI-data ,especially geodetic-VLBI, are treasure for drawing light-curves as well as Single-Dish.

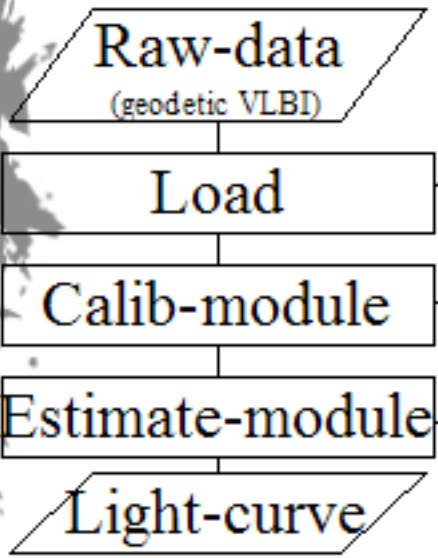
I analyzed all IVS-data automatically, but roughly yet.
I showed my tentative results so far.
Future: establish this method, astrophysical analysis.

p.s. My program includes Hobiger(NICT)-program for translation data-format(MK3binary to NetCDF). Thank you.

I'm Eru. (・ω・▼)ノシ
Please speak very slowly with short sentence.
My brother want to discuss anytime. (ω＜▼)ノシ

Thank you very much for your kind attention

Schematic view of program



MK3binary => ASCII Calc (U,V,W), format	completed
Calc correlate-flux for each visibility	completed : basic-module **Adding : outlier-module**
Estimate (total) flux from each visibility	**Under development** **Under consideration**

DATA-table & MODULE in brief

LOAD-MODULE						CALIB-MODULE		ESTIMATE-MODULE
DATE	TIME	SOURCE	BASELINE(i, j)	(U, V, W)	ρ	SEFDij	CORRELATE-FLUX	FLUX
value	value	value	value	value	value	value	value	
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Calibration-methods

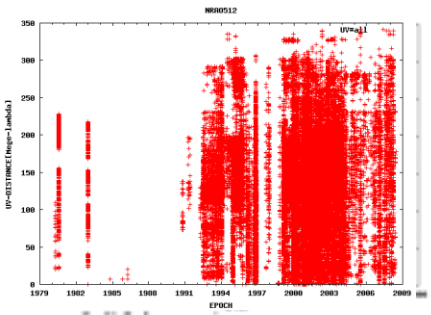
- Use fixed-SEFD for each station
  - Flux = $(SEFD_i \times SEFD_j)^{0.5} \times \rho_{ij}$
  - Plan-A : IVS-opened SEFD (1999~)
    - Can not use data observed by old-stations
  - Plan-B : Estimated SEFD from ϕ, η, Tsys
    - Suppose η (Aperture efficiency) & Tsys(system temperature)
    - Can not deal with ϕ (diameter)-change, c.f. DSN, moving-station.
- Use flux-calibrator sources
  - $Flux_{calibrator}$ = Flux observed by Single-Dish(Michigan univ.)
  - $Flux_{calibrator} = (SEFD_i \times SEFD_j)^{0.5} \times \rho_{ij,calibrator}$
  - $Flux_{target} = (SEFD_i \times SEFD_j)^{0.5} \times \rho_{ij,target}$
    - Can trace sensitivity-variation(ϕ, η, Tsys) with time
    - Have to consider source-structure
      - => restrict UV-distance

Parameter (definition)

- UV_range [λ] : Range of UV-distance
- Polate_range [day] : Range for interpolating flux of calibration-source
  - re-sampling : 1 [day]
- Calib_range [day] : Range for averaging SEFD
- Estim_range [day] : Range for estimating target-flux

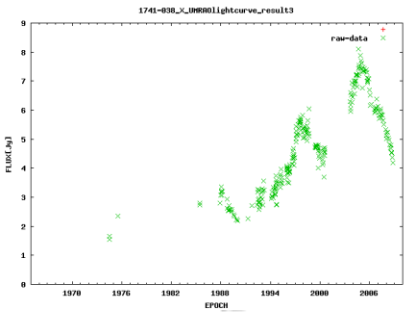
UV_range = 0～50 [M λ] Polate_range = 0, 30, 300000 [day] Estim_range= 180, 1825 [day]

UV-distance



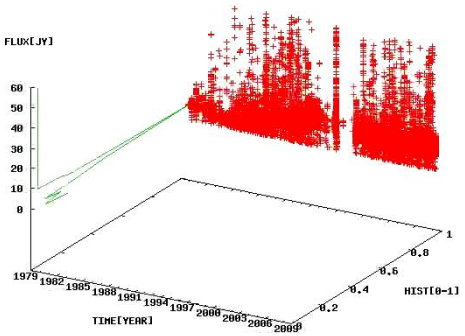
EPOCH

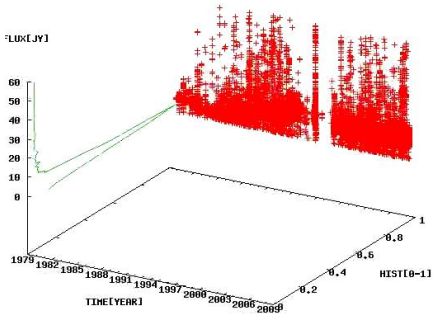
$FLUX_{UMRAO}$



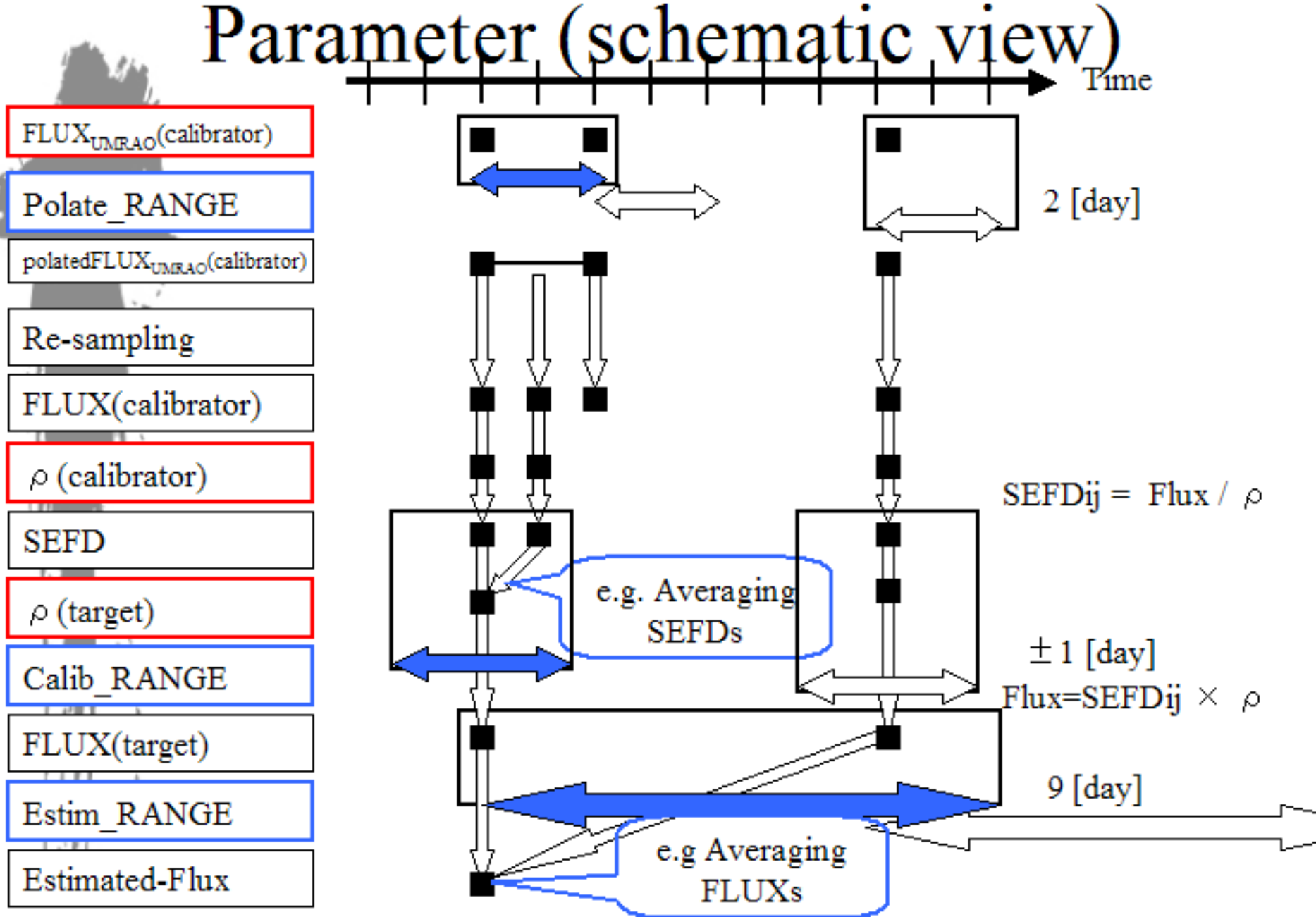
EPOCH

$FLUX_{IVS}$





Parameter (schematic view)

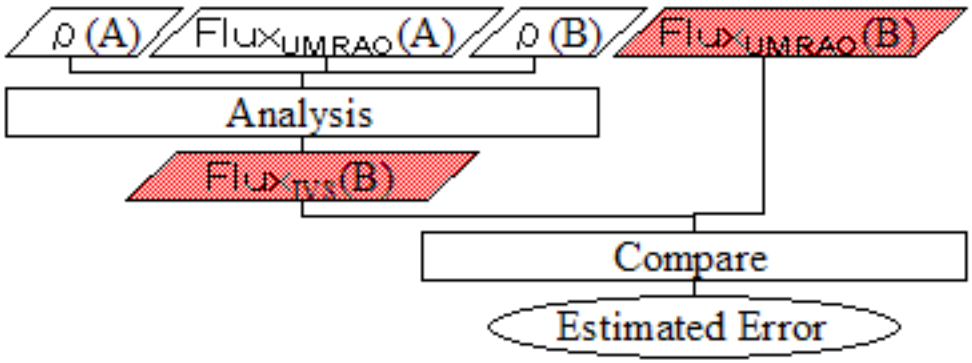


Diagnosis of analysis

- Calibrator-A, Calibrator-B
  - DATA: ρ (A), $Flux_{UMRAO}$(A), ρ (B), $Flux_{UMRAO}$(B)

⇒Calibrator-B as **target-source**

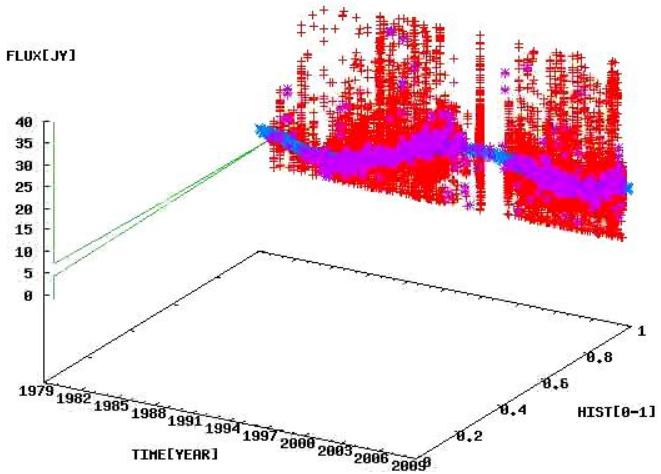
  - ρ (A), $Flux_{UMRAO}$(A), ρ (B)=> $Flux_{IVS}$(B)
  - Compare $Flux_{IVS}$(B) with $Flux_{UMRAO}$(B)

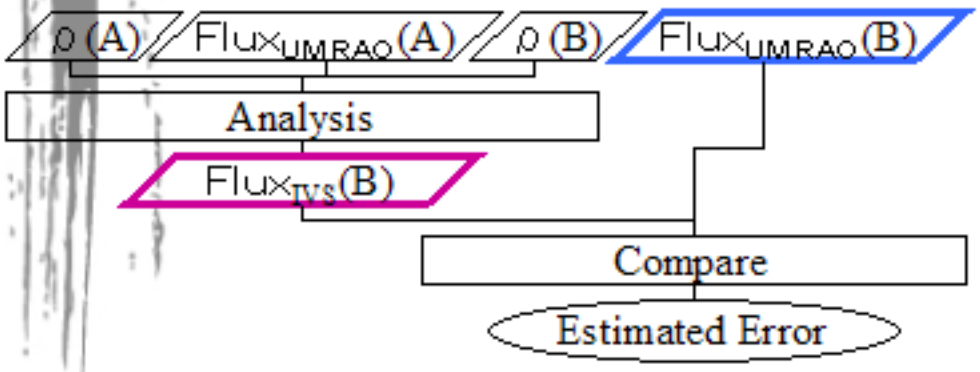


Tentative result so far

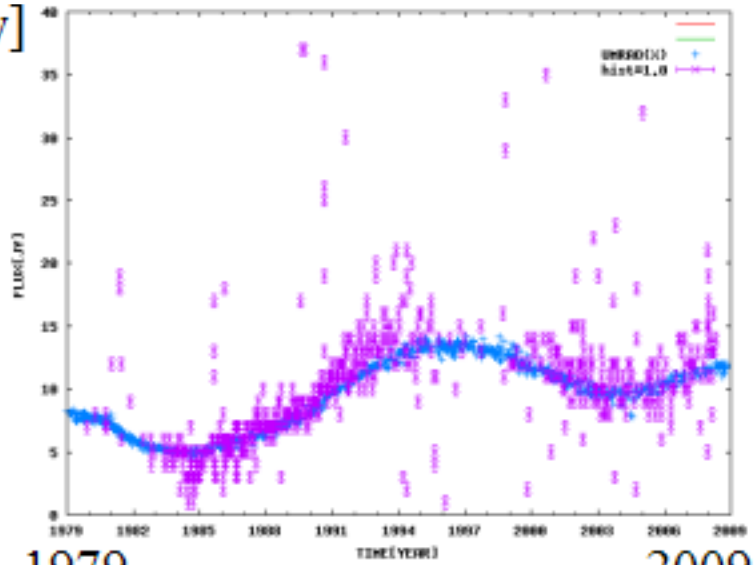
- Target = 4C39.25
- Calibrator = OJ287
- UV_range = 0～50 [Mλ]
- Polate_range = 300000 [day]
- Calib_range = ±1 [day]
- Estim_range = 10 [day]

Red : Visibility
Green : Histogram of visibility
Purple : Maximum of histogram
Blue : Flux (Michigan univ.)





40 [Jy]



1979 2009