15 GHz Monitoring of Gamma-ray Blazars with the OVRO 40 Meter Telescope in Support of Fermi

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Science

- Study targets: Blazars = jet-aligned AGN
  - Superluminal motion, extreme variability
  - High apparent luminosity from radio to γ-ray
- Key questions
  - AGN/Blazar Phenomenology
    - Correlation between luminosity, variability, beaming?
    - Correlation between wavelengths?
      - Time lags between flares?
    - Variability vs. spectral properties?
    - Cosmic evolution?
  - Jets
    - How accelerated? confined? collimated?
    - Composition?
    - Emission mechanism? Location?

F-GAMMA: Project

http://www.mpifr-bonn.mpg.de/div/vlbi/fgamma/fgamma.html

- Multi-wavelength γ-ray blazar monitoring
- MPIfR (Bonn) + Caltech
- Key Instruments:
  - MPIfR: Effelsberg 100 m, Pico Veleta (IRAM) 30 m
  - Caltech: OVRO 40 m
- Light curves/spectra since 2007
- Also: Optical, IR, sub-mm programs

Posters by W. Max-Moerbeck, L. Fuhrmann, E. Angelakis.

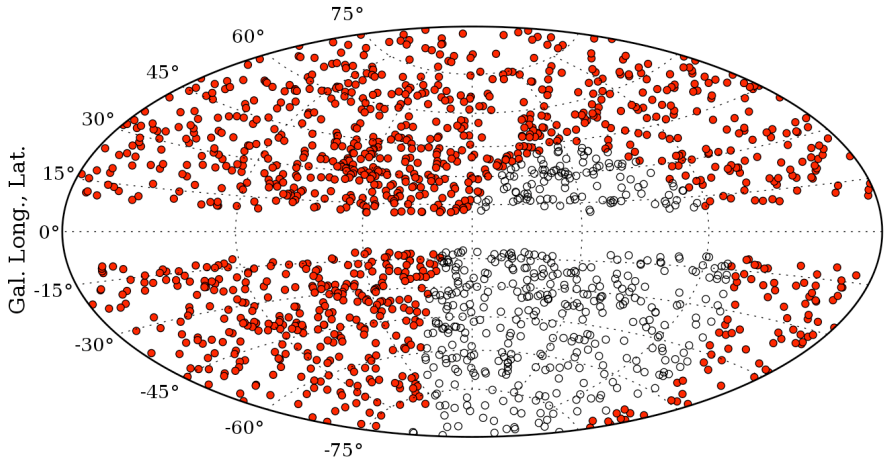
F-GAMMA: Strategy

- Complementary Monitoring Strategies
  - MPIfR: Concentrate on a “few” sources
    - 60 sources, hand-picked to be “interesting”
    - ~ monthly
    - 12 frequencies (2.7 – 270 GHz)
  - Caltech: Larger, statistically-defined sample
    - 1158 CGRaBS sources
    - ~ twice weekly
    - 1 frequency (15 GHz)

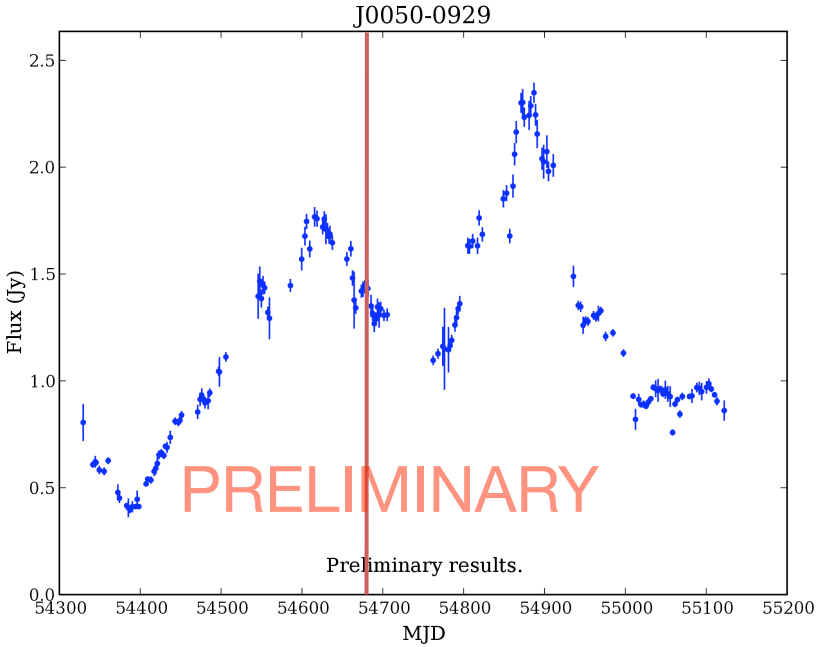
OVRO 40 m Program

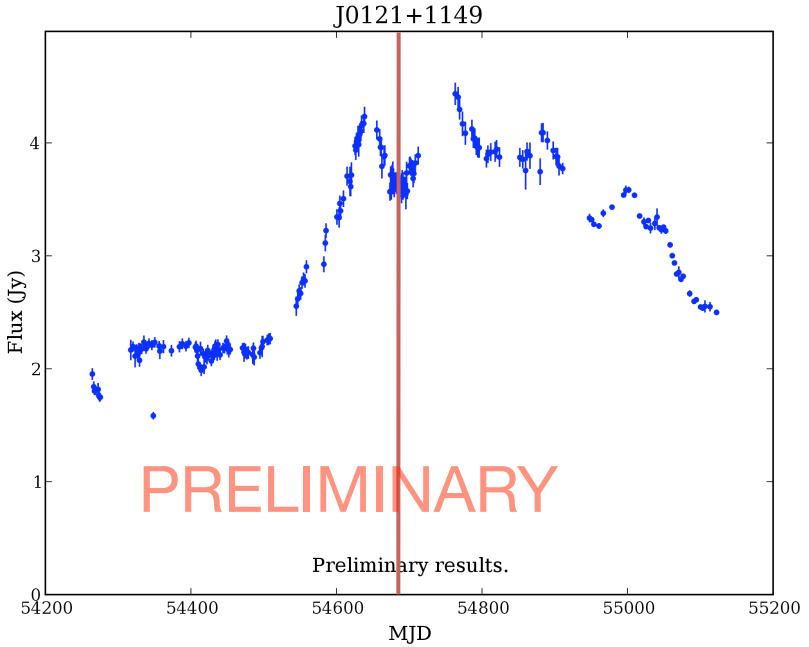
- 1158 CGRaBS (δ>–20°) (~1300 total)
  - Selected by flat radio spectrum + radio flux + X-ray flux
  - FoM modeled after EGRET detections
- ~ 2x per week
- ~ 5 mJy noise floor
- Started mid-2007

(Healey et al., 2008, ApJS, 175, 97)



CGRaBS Sources


J0050-0929
Flux (Jy)
MJD
PRELIMINARY
Preliminary results.


J0121+1149
Flux (Jy)
MJD
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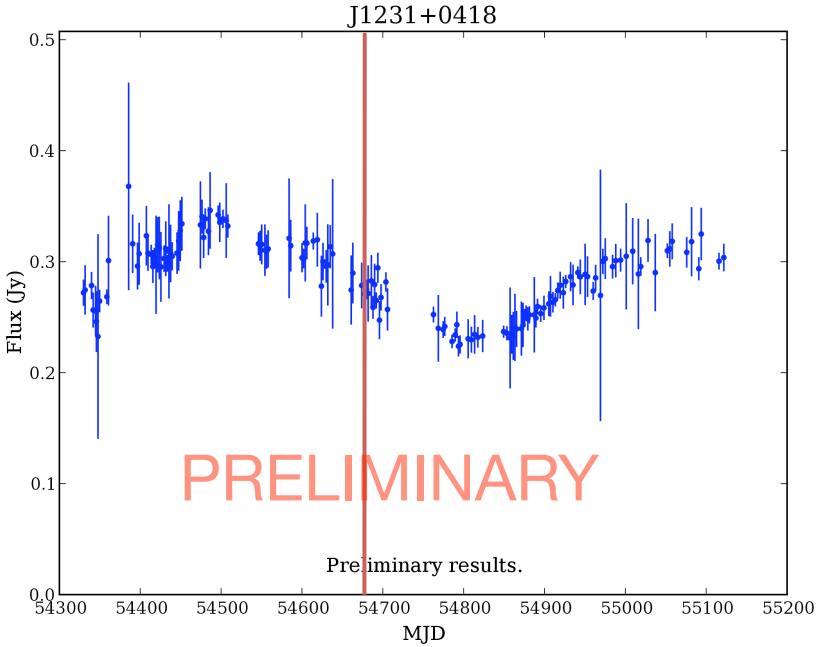
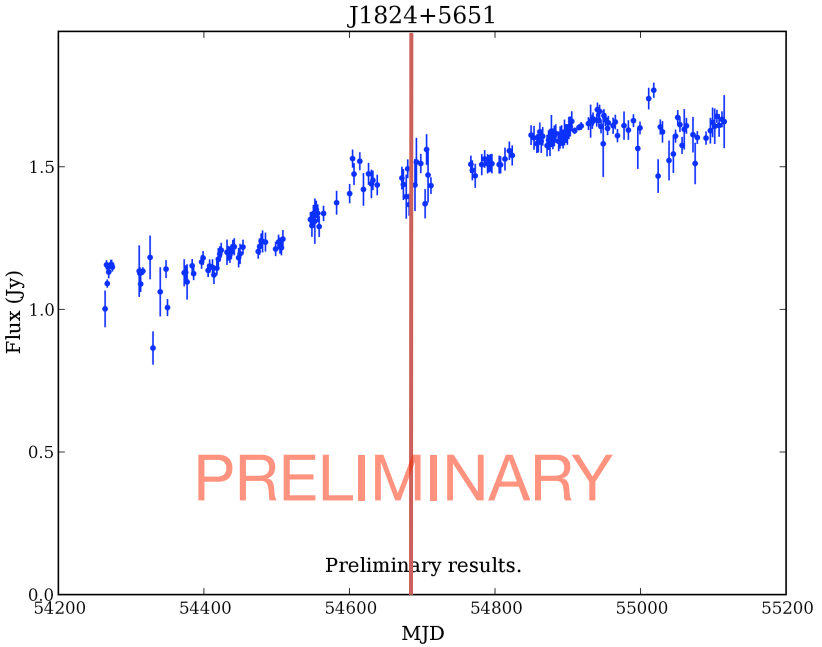
Preliminary results.


J1231+0418
Flux (Jy)
MJD
PRELIMINARY
Preliminary results.

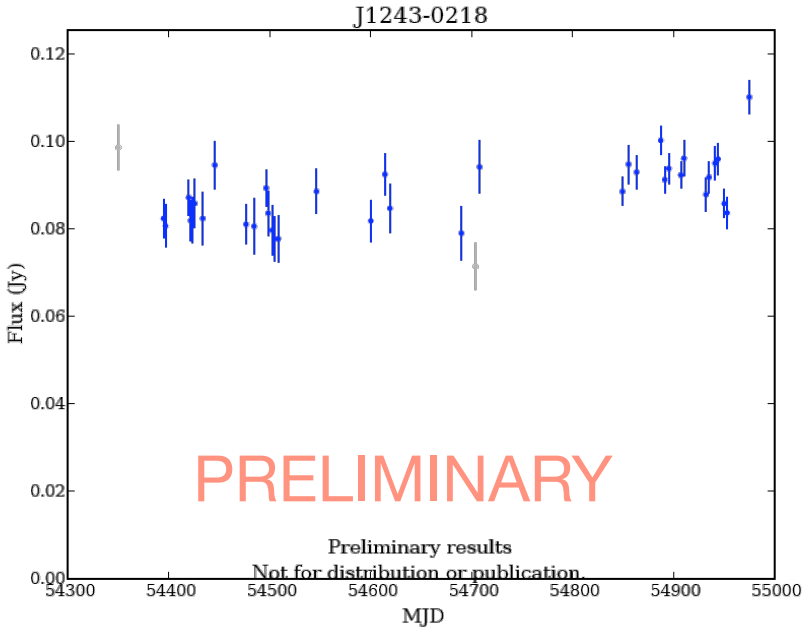

J1824+5651
Flux (Jy)
MJD
PRELIMINARY
Preliminary results.

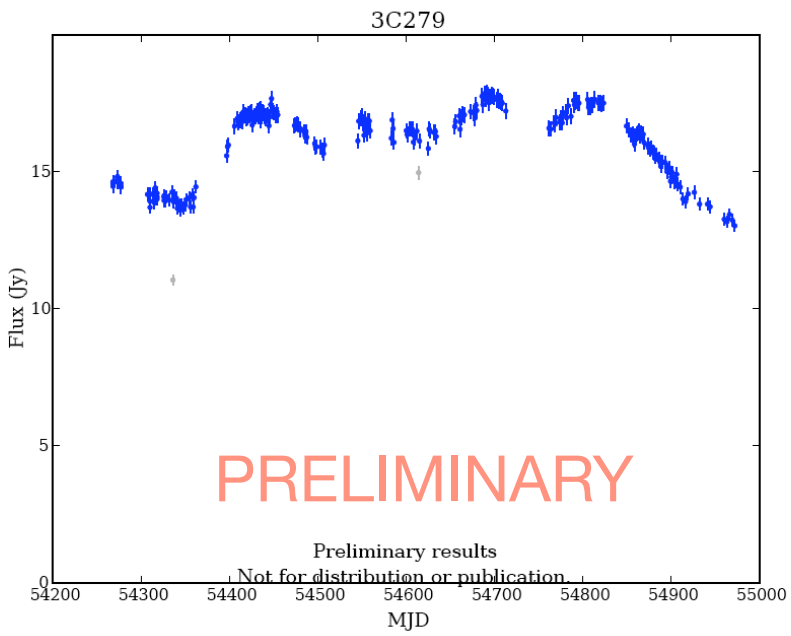
Variability Amplitude I

- Various standard methods exist
  - Do not quantify uncertainty well
  - Difficult to compare unless data sets uniform
- Introduce *intrinsic modulation index*

$$m \equiv \frac{\sigma_S}{< S >}$$

- Determined from likelihood analysis
  - Accounts for measurement uncertainties, number of data points


J1243-0218
Flux (Jy)
MJD
PRELIMINARY
Preliminary results
Not for distribution or publication.


3C279
Flux (Jy)
MJD
PRELIMINARY
Preliminary results
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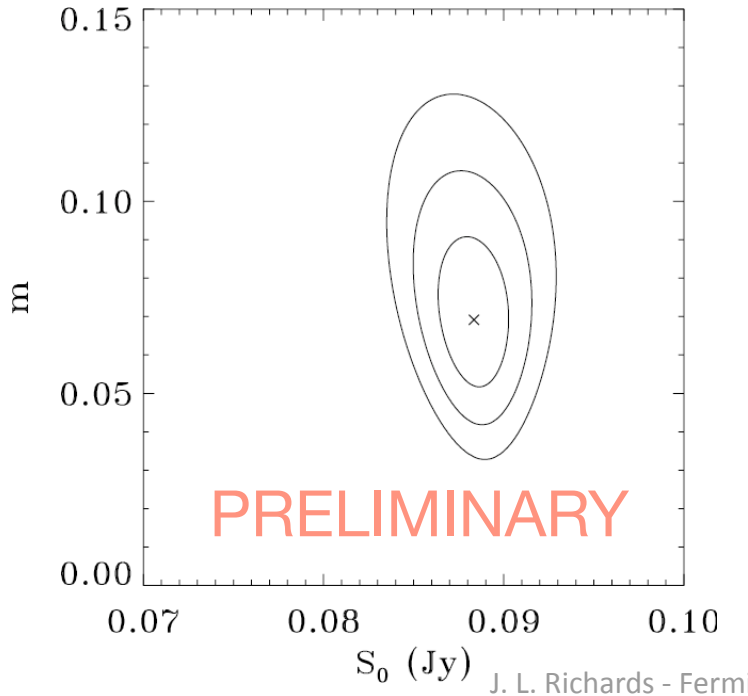
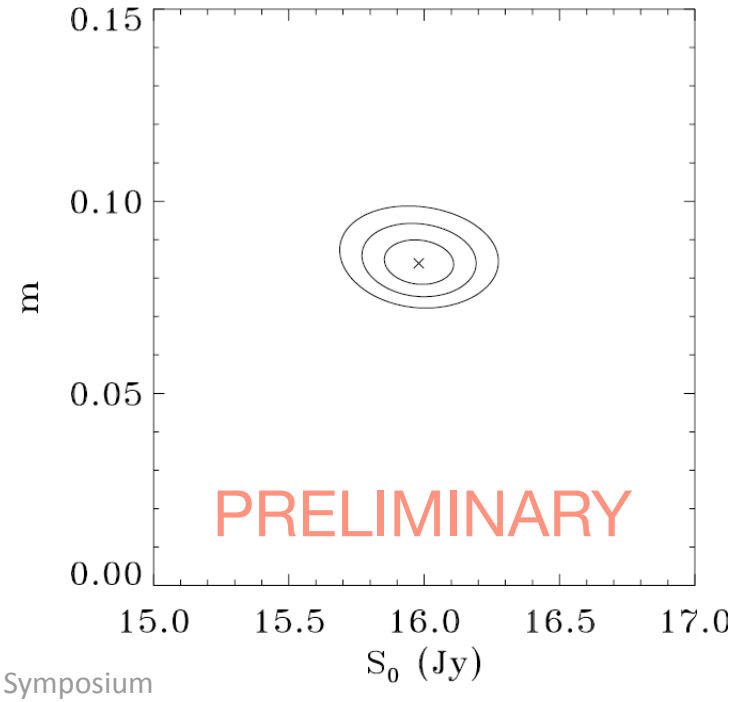
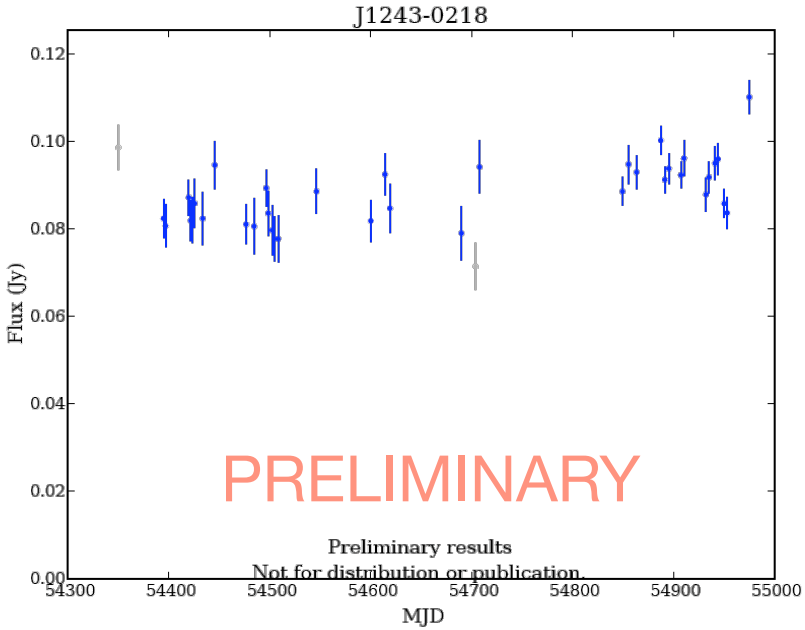

m
S_0 (Jy)
PRELIMINARY


m
S_0 (Jy)
PRELIMINARY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Flux (Jy)
MJD
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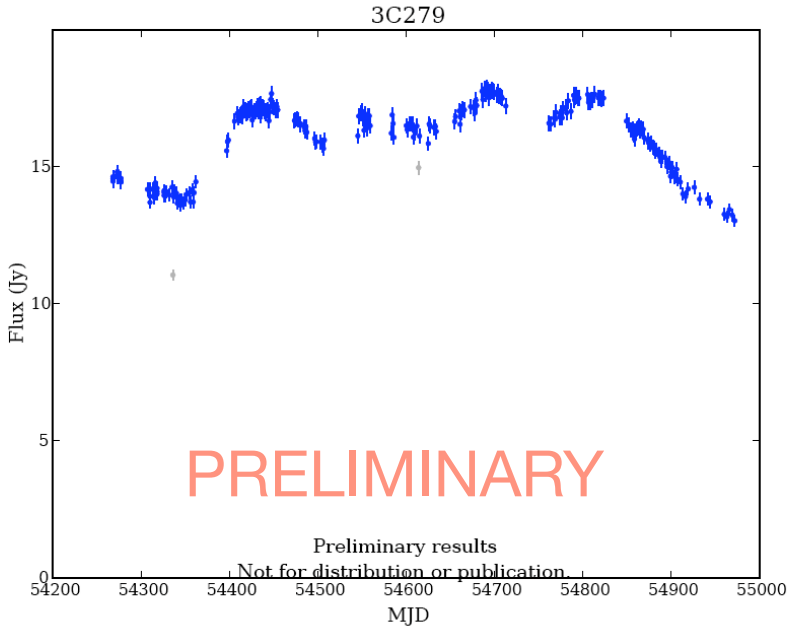
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Flux (Jy)
MJD
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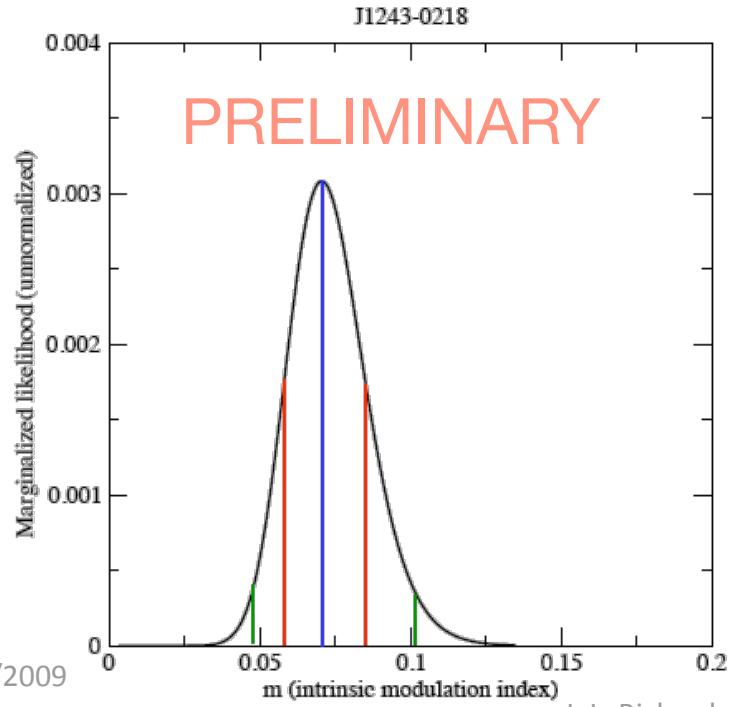
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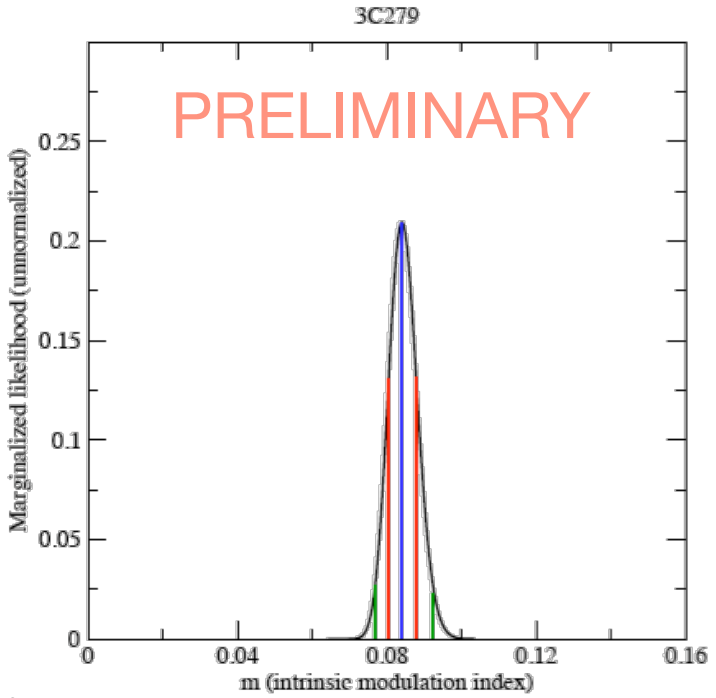
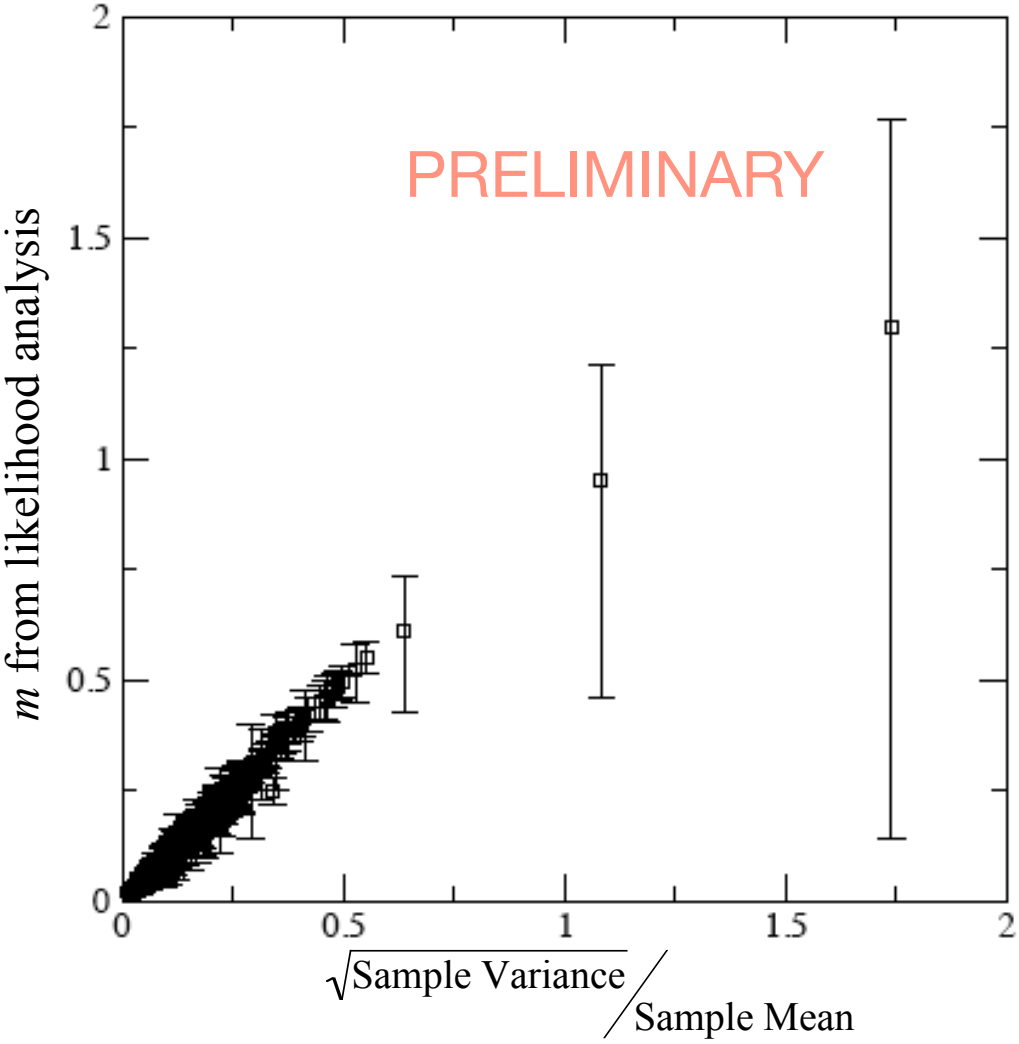
PRELIMINARY
Marginalized likelihood (unnormalized)
m (intrinsic modulation index)


3C279
PRELIMINARY
Marginalized likelihood (unnormalized)
m (intrinsic modulation index)

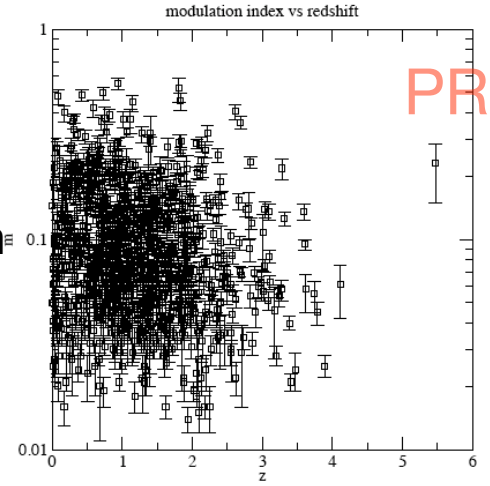
Variability Amplitude II

Intrinsic modulation index is consistent with typical modulation indices.

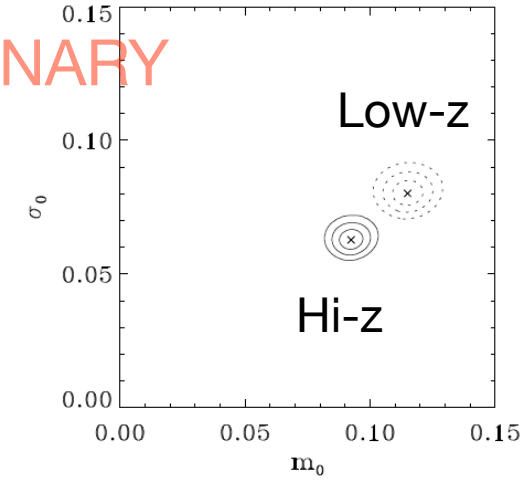


Population Studies

Redshift Distribution

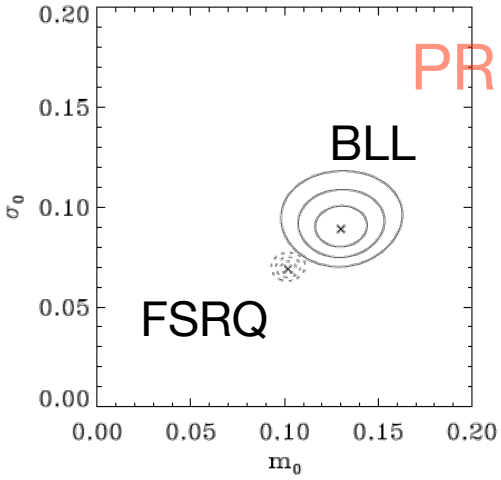


PRELIMINARY



High-/Low-z Populations

FSRQ vs BL Lac



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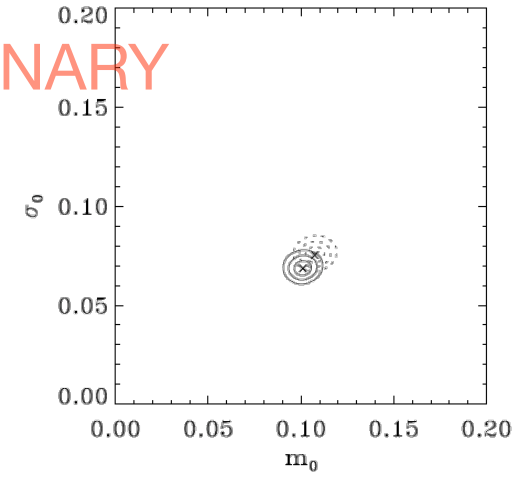
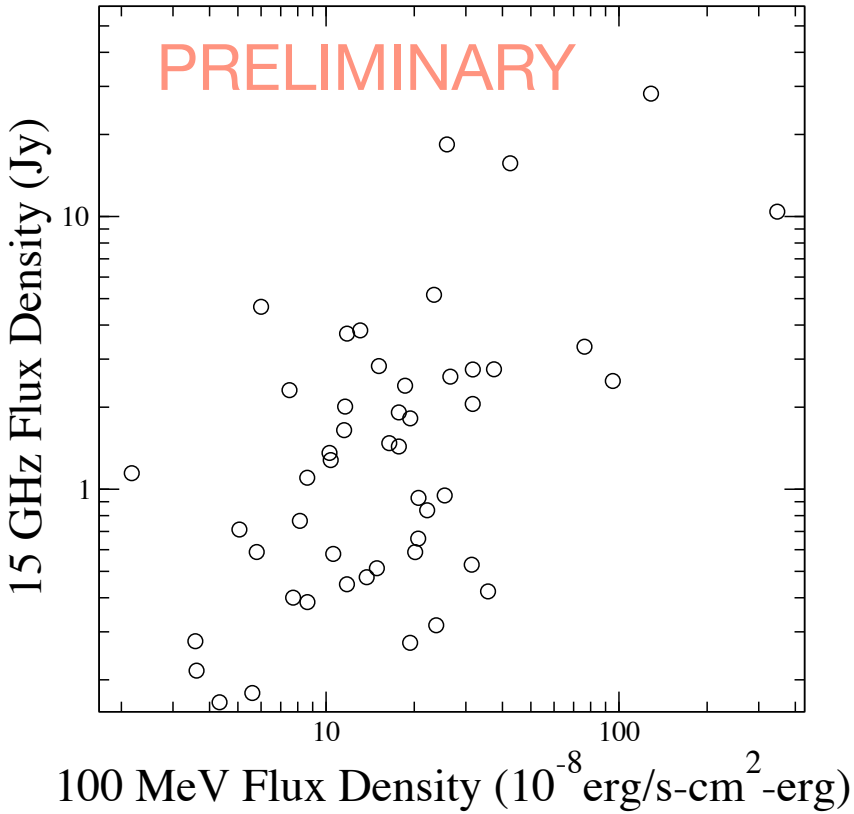


Random Sub-samples

Radio-γ Flux Correlation I

- *Fermi*-LAT bright AGN data (3-month average) (Abdo et al, 2009, ApJ, 700, 597)
- Simultaneous 3-month average radio data
- Correlated, *but...*

- Method: Monte Carlo to estimate chance probability
  - Reshuffle data
    - Permute radio/γ luminosities
    - Apply randomly chosen z
    - Limit to original flux dyn. range
    - Evaluate correlation, repeat...
  - Accounts for
    - Red shift effects
    - Malmquist bias
    - Non-quantitative selection criteria



Radio-γ Flux Correlation II

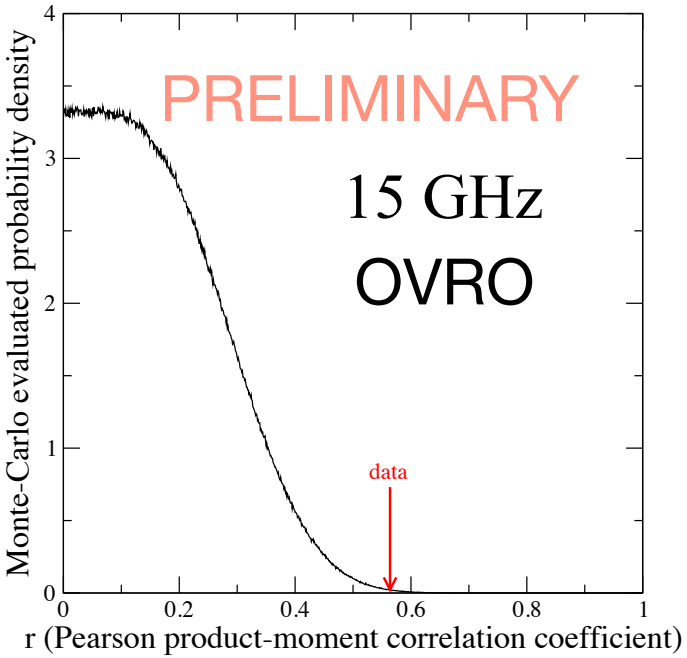
F-GAMMA Sample

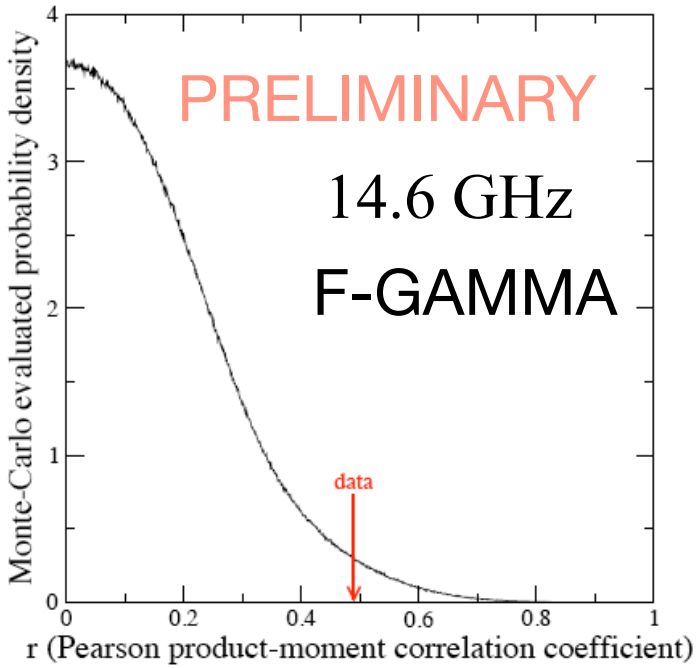
Frequency [GHz]	Correlation Coefficient	P(chance)
142	0.89	4×10^{-5}
86	0.86	2×10^{-5}
43	0.83	7×10^{-4}
32	0.74	6×10^{-4}
22	0.59	1%
14.6	0.49	3%
10.5	0.43	5%
8.4	0.40	6%
4.8	0.40	8%
2.6	0.43	6%

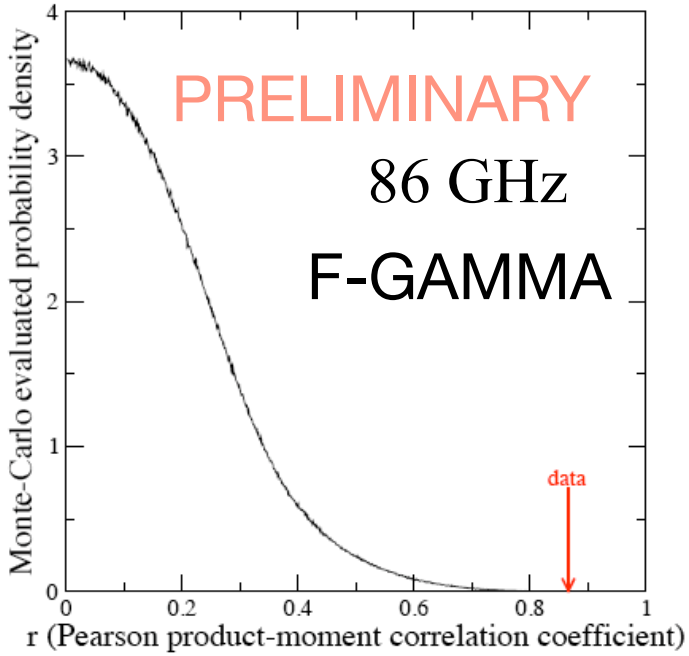
OVRO CGRaBS Sample

Frequency [GHz]	Correlation Coefficient	P(chance)
15	0.56	5×10^{-4}

- Statistically significant correlation!
- Stronger with increasing radio frequency


PRELIMINARY
15 GHz
OVRO
data
Monte-Carlo evaluated probability density
r (Pearson product-moment correlation coefficient)
0
1
2
3
4
0
0.2
0.4
0.6
0.8
1


PRELIMINARY
14.6 GHz
F-GAMMA
data
Monte-Carlo evaluated probability density
r (Pearson product-moment correlation coefficient)
0
1
2
3
4
0
0.2
0.4
0.6
0.8
1

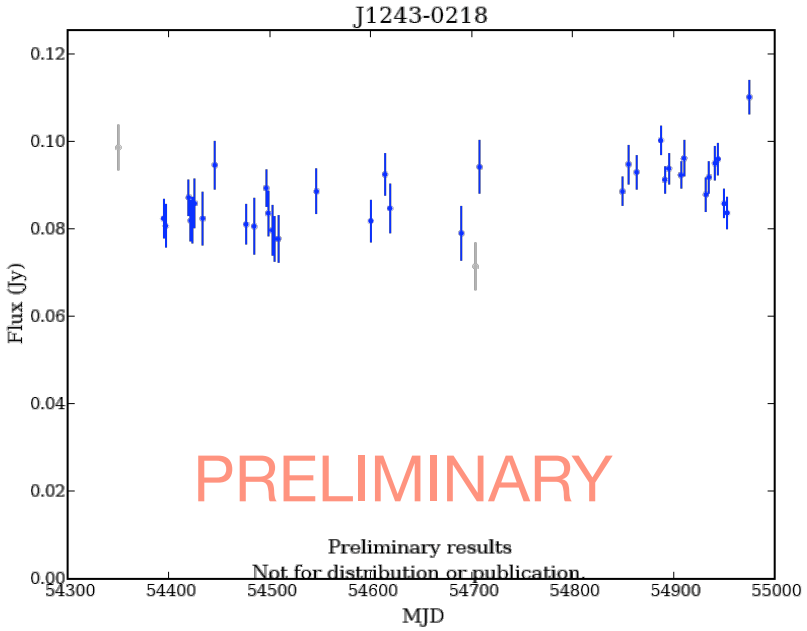

PRELIMINARY
86 GHz
F-GAMMA
data
Monte-Carlo evaluated probability density
r (Pearson product-moment correlation coefficient)
0
1
2
3
4
0
0.2
0.4
0.6
0.8
1

Conclusions

- Two years+ radio data, good sample overlap with *Fermi*-LAT AGN
- New *intrinsic modulation index* method
- Statistically significant correlation of radio and γ-ray flux densities using likelihood method with *simultaneous* data
- First 2 years data available very soon
  - http://www.astro.caltech.edu/ovroblazars
  - ~ weekly updates to begin shortly
  - RSS feed for updates

See also M. Giroletti's talk in the Extragalactic parallel session.

Extra Material


J1243-0218
Flux (Jy)
MJD
PRELIMINARY
Preliminary results
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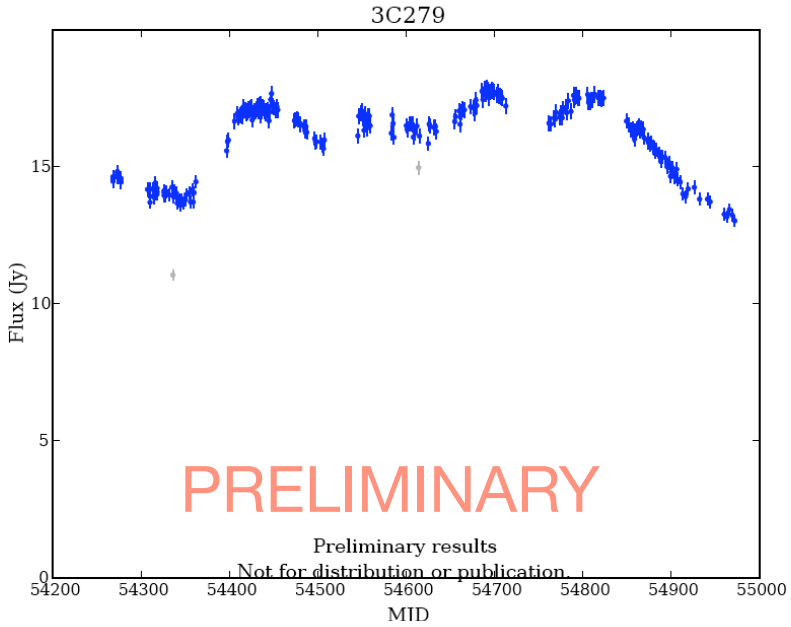
3C279
Flux (Jy)
MJD
PRELIMINARY
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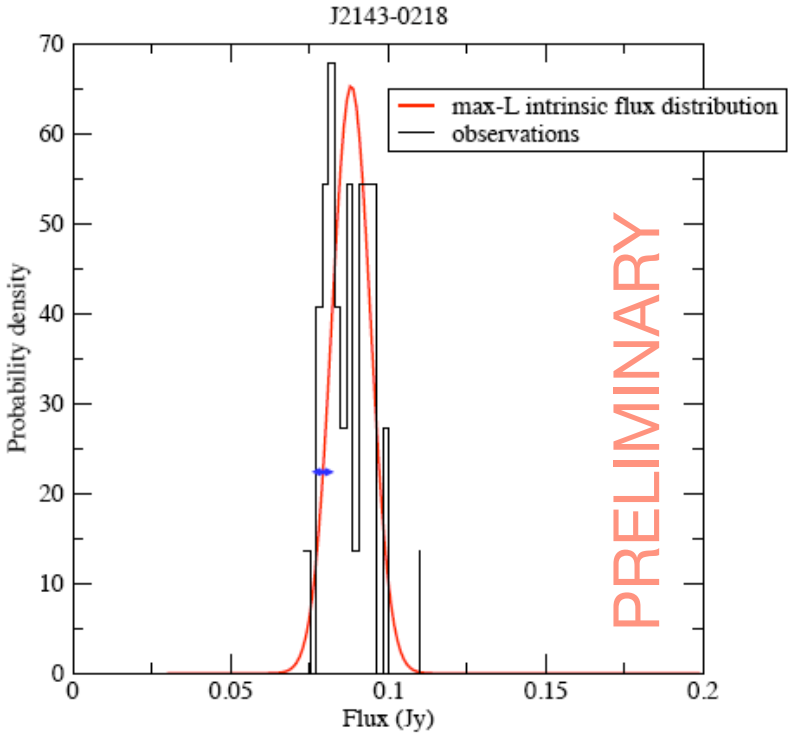
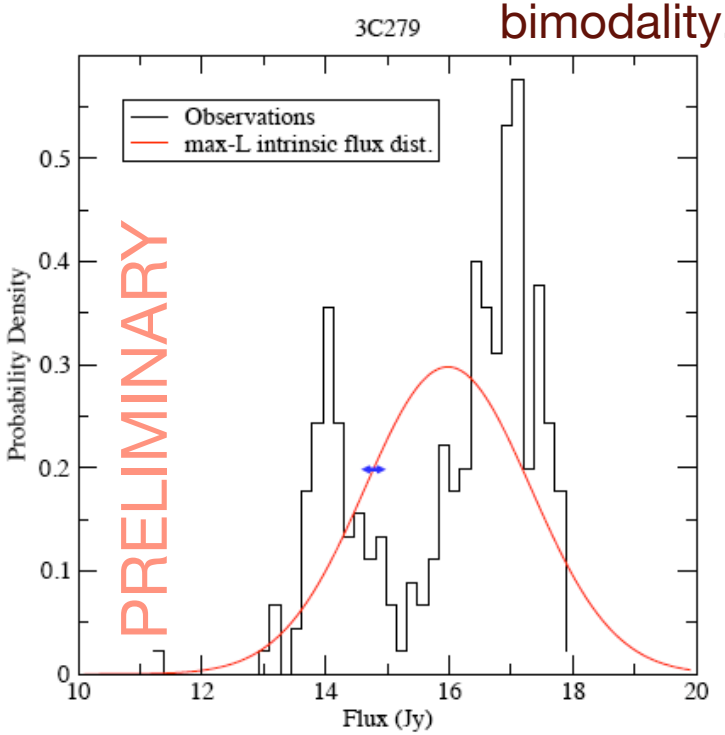

J2143-0218
max-L intrinsic flux distribution
observations
Probability density
Flux (Jy)
PRELIMINARY

bimodality!


3C279
Observations
max-L intrinsic flux dist.
Probability Density
Flux (Jy)
PRELIMINARY