

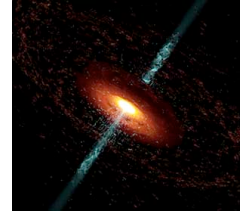
# Flux Density Monitoring with the SMA

Mark A. Gurwell





# A Unique Resource



## I. The SMA Calibrator Database

*What is it, and what is it used for?*

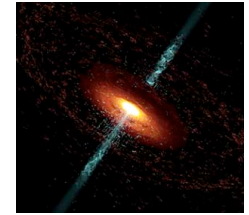
## II. Blazar Observations and Multi-Wavelength Campaigns

*A few examples*

## III. Independent Programs



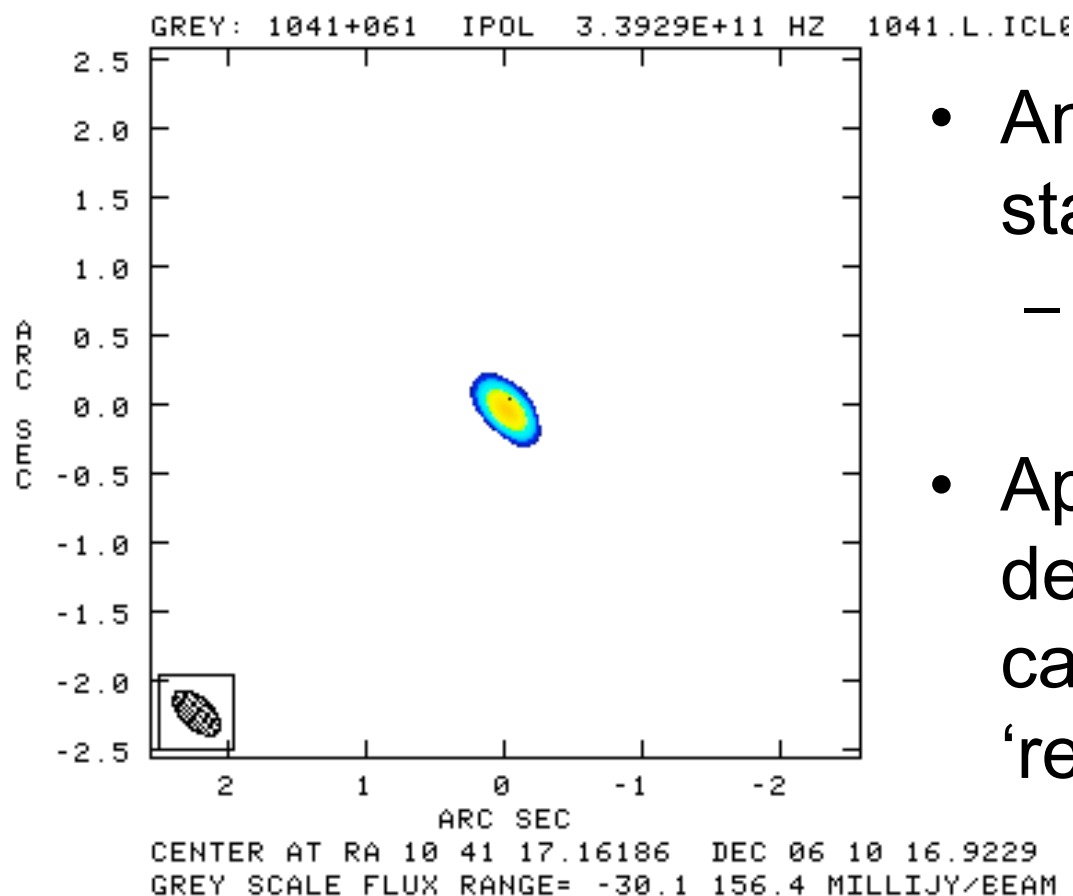
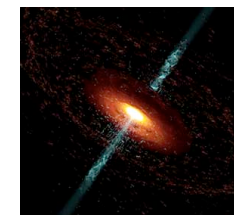
# I. What is the Calibrator Database?



- available, relatively bright sources
  - effectively point sources at resolutions offered by the SMA (sizes  $\ll 100$  mas)
- nearly exclusively quasars
  - flux densities from 100 mJy to  $>40$  Jy at 1.3 mm
- used to calibrate science observations
  - Phase gains ('seeing')
  - Amplitude gains ('approximate flux scale')



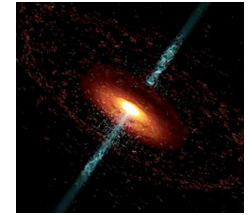
# Quasars as Calibrators



- Analogous to guide stars in adaptive optics
  - Timescales generally significantly longer
- Apply corrections determined on calibrator to target to 'remove atmosphere'



# Rationale for the Database



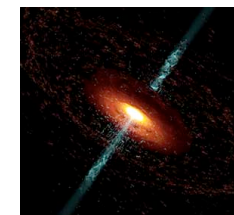
- Positions of quasars (very) well known
  - VLA, VLBA positions used, typical  $\Delta \sim$  few mas
- Flux densities are variable
  - Often by large factors
  - Timescales of  $< 1$  day through years
- Unlike stock market, past performance is (somewhat) indicative of future value
  - Strong quasars usually strong, but still uncertain

**Desirable to (accurately) track calibrator flux densities for planning, executing and calibrating science observations**





# SMA Calibrator Database



SMA Observer Center: Submillimeter Calibrator List - Mozilla Firefox <2>

File Edit View History Bookmarks Tools Help

## SMA Observer Center

Home  
Proposing  
Preparing to Observe  
After Observing  
Tools  
Specs  
Contact Us  
Log In

### Submillimeter Calibrator List

Compiled by Mark Gurwell, Tue Apr 14 14:32:03 2009.

To sort the list by distance from a source, enter the source position (J2000):  
(please use only integers in these fields)

Source RA:  h  m  s  
Source Dec:  d  m  s

**Highlights** indicate sources with  
3mm Flux > 4 Jy  
1mm Flux > 2 Jy  
850 $\mu$ m Flux > 2 Jy

Click [here](#) to scroll down to plots.

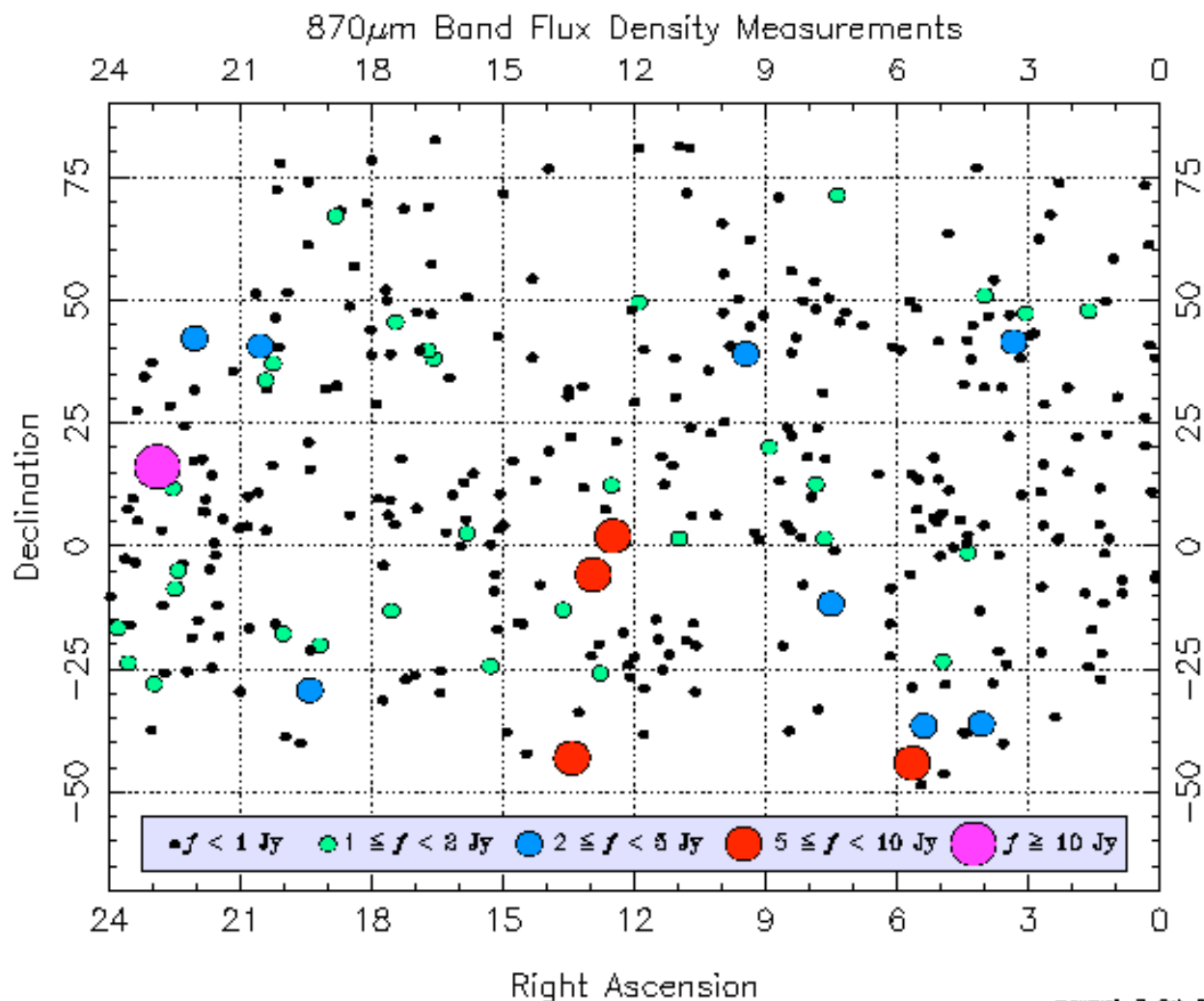
Source Name	J2000 Coordinates (from VLA)		Band	Last Obs. Date	Obs.	Flux Density (Jy) 30.0 day avg	Light Curves	
common	IAU (J2000)	RA	Dec					
atca cal	0004-476	00:04:35.640	-47:36:19.73	3mm	18 May 2007	ATCA	0.88 $\pm$ 0.08	<a href="#">plot</a> / <a href="#">data</a>
..	0005+383	00:05:57.1754	+38:20:15.148	3mm	12 Feb 2004	OVRO MMA	0.65 $\pm$ 0.03	<a href="#">plot</a> / <a href="#">data</a>
				1mm	01 Dec 2008	SMA	0.36 $\pm$ 0.03	
				850 $\mu$ m	11 Nov 2008	SMA	0.22 $\pm$ 0.06	
..	0006-063	00:06:13.8928	-06:23:35.335	3mm	20 May 2007	ATCA	1.56 $\pm$ 0.08	<a href="#">plot</a> / <a href="#">data</a>
				1mm	16 Jan 2009	SMA	0.95 $\pm$ 0.08	
				850 $\mu$ m	20 Nov 2008	SMA	0.56 $\pm$ 0.05	
..	0010+109	00:10:31.0058	+10:58:29.504	3mm	12 Feb 2004	OVRO MMA	2.41 $\pm$ 0.10	<a href="#">plot</a> / <a href="#">data</a>
				1mm	16 Dec 2008	SMA	0.51 $\pm$ 0.03	
				850 $\mu$ m	19 Oct 2008	SMA	0.86 $\pm$ 0.08	
..	0010+174	00:10:33.9906	+17:24:18.761	3mm	12 Feb 2004	OVRO MMA	0.36 $\pm$ 0.03	<a href="#">plot</a> / <a href="#">data</a>
				1mm	15 Mar 2002	OVRO MMA	0.39 $\pm$ 0.17	
..	0012-399	00:12:59.9080	-39:54:25.836	3mm	18 May 2007	ATCA	0.43 $\pm$ 0.04	<a href="#">plot</a> / <a href="#">data</a>
				3mm	12 Feb 2004	OVRO MMA	0.61 $\pm$ 0.03	
..	0013+408	00:13:31.1302	+40:51:37.144	1mm	09 Dec 2008	SMA	0.64 $\pm$ 0.04	<a href="#">plot</a> / <a href="#">data</a>
				850 $\mu$ m	22 Oct 2008	SMA	0.43 $\pm$ 0.07	
				3mm	12 Feb 2004	OVRO MMA	0.45 $\pm$ 0.03	
..	0014+612	00:14:48.8154	+61:17:43.852	1mm	09 Dec 2008	SMA	0.20 $\pm$ 0.04	<a href="#">plot</a> / <a href="#">data</a>
				850 $\mu$ m	22 Oct 2007	SMA	0.19 $\pm$ 0.05	

Done

- Data on >400 quasars
- Flux history accessible online
- 1.35 mm, 1.1 mm and 850  $\mu$ m SMA measurements
- Flux scale tied to solar system 'primary' calibrators (Uranus, Neptune, Mars, Titan, Ganymede, Callisto)



# Sky Distribution

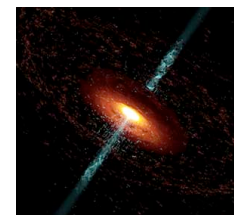


Most  $< 1$  Jy  
Typically  $< 30$   
above 2 Jy  
 $F_{\nu} \propto \nu^{-(0.5 \pm 0.4)}$

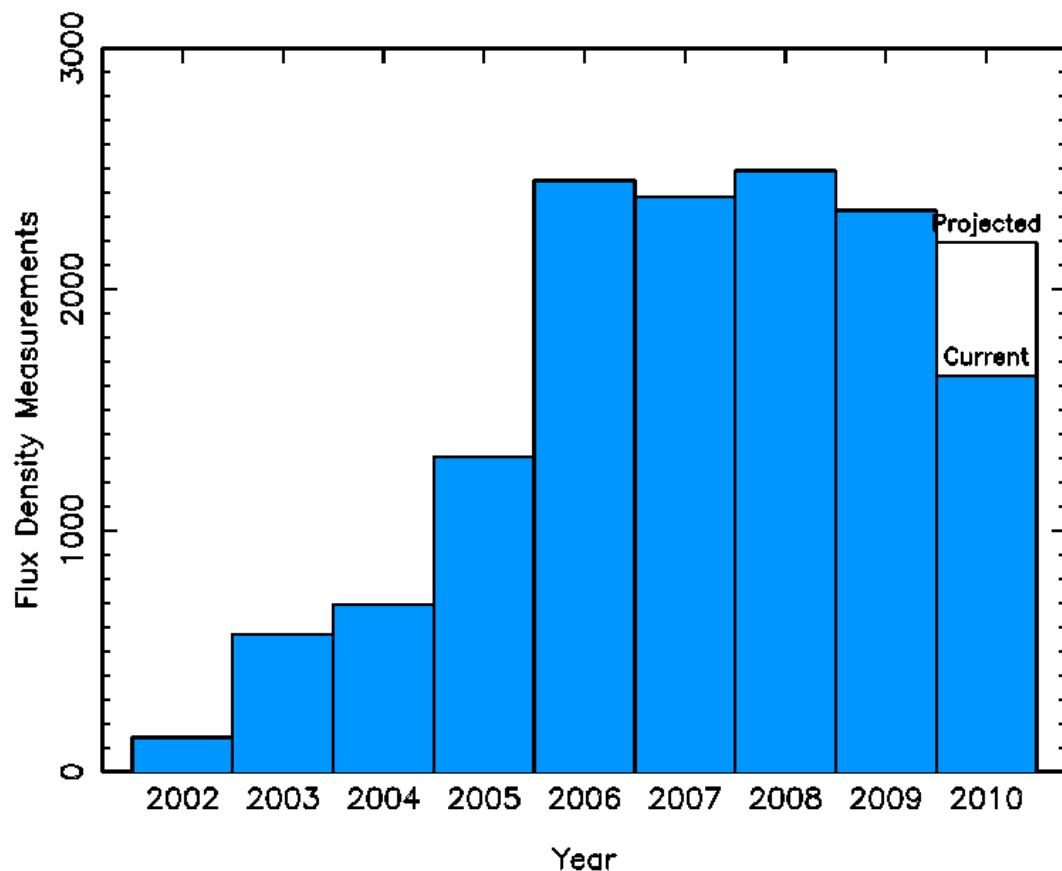
mgurwell 7-Oct-2010



# Size and Growth of Database



SMA Calibrator Database

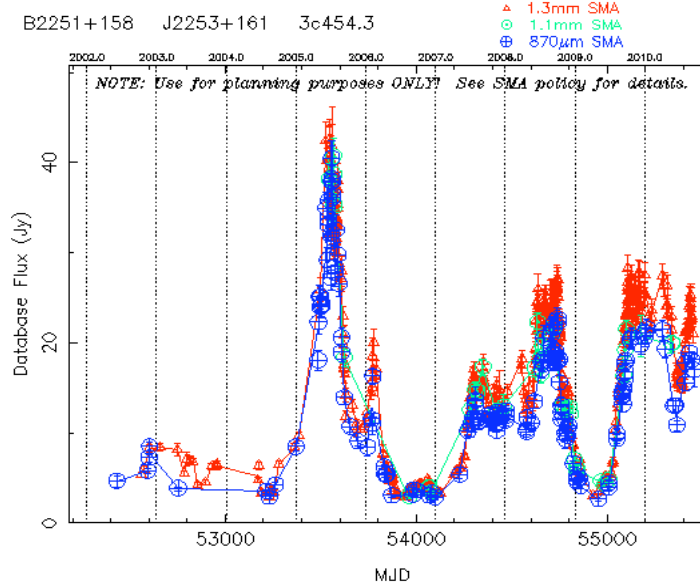
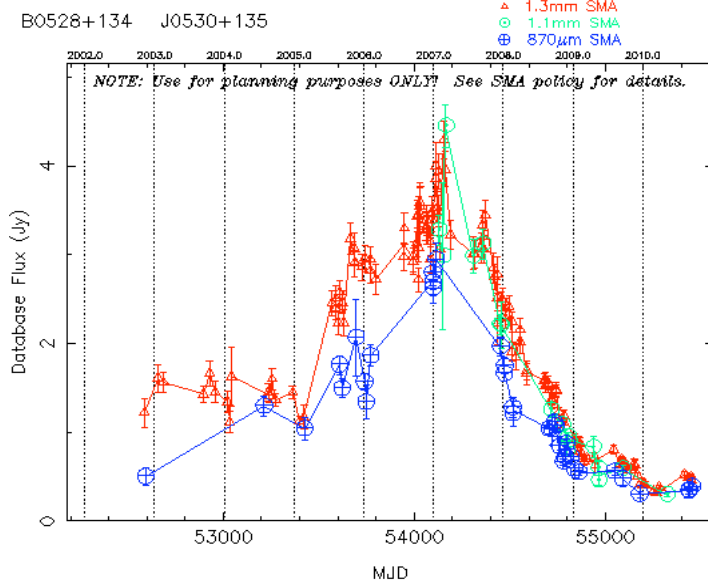
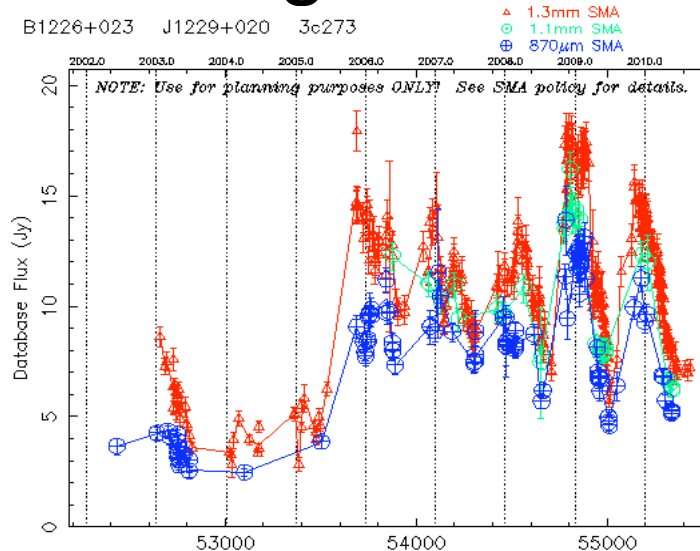
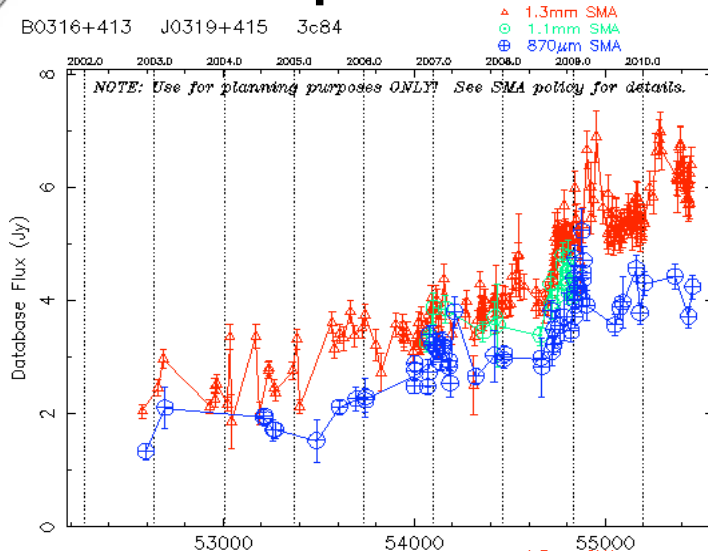
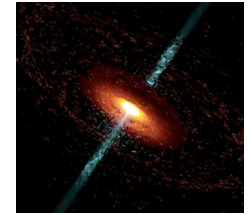


- Over 14000 measurements
- Adding ~2400/yr
- From regular science tracks and dedicated 'flux' and baseline calibration observations



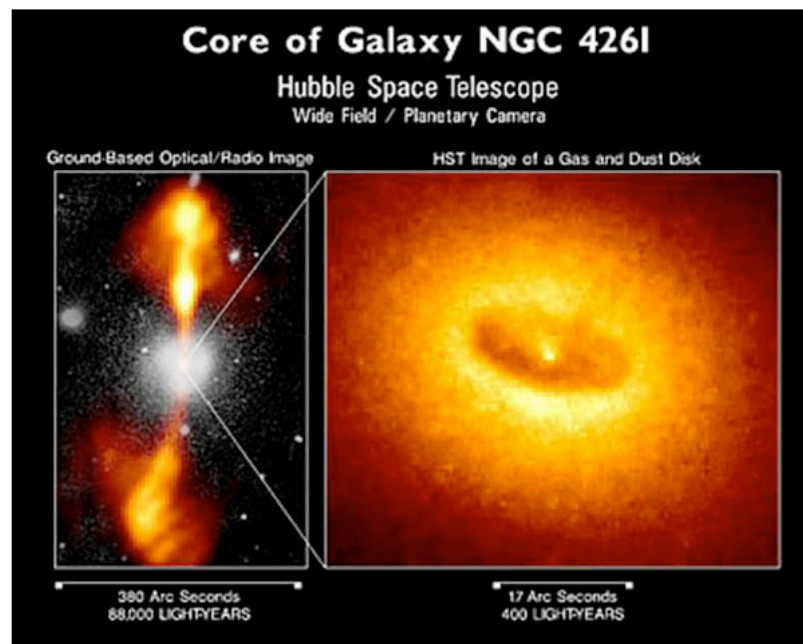
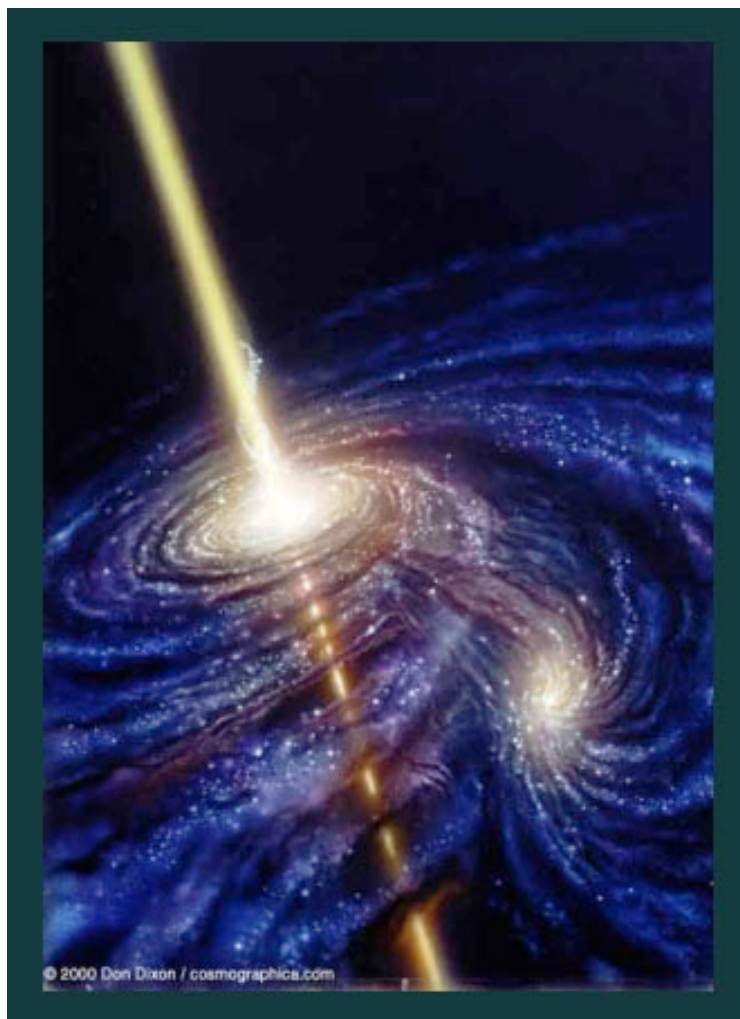
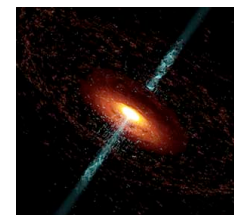


# Example MM/SubMM Light Curves





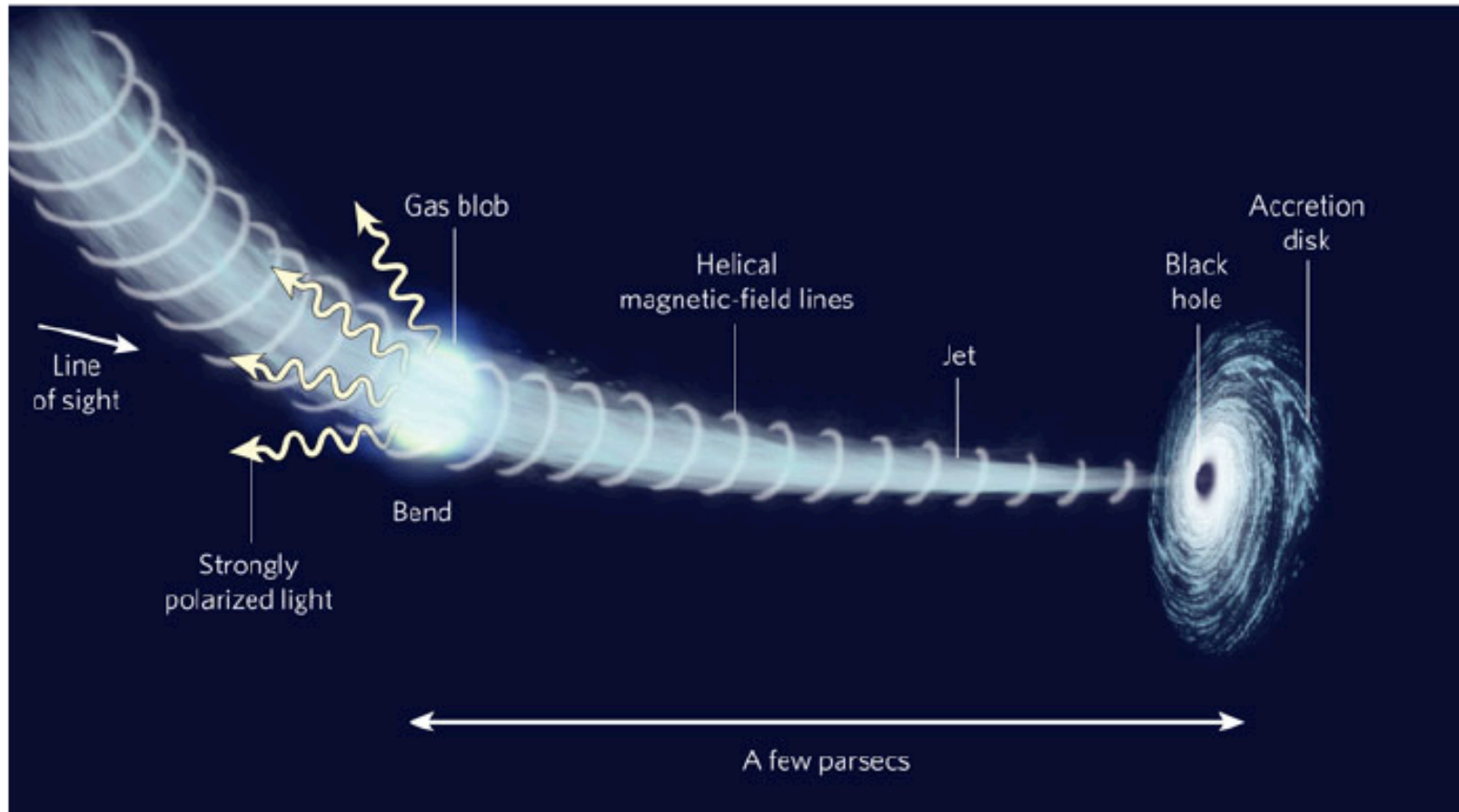
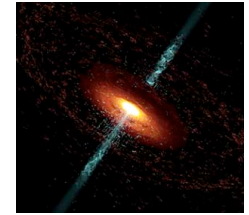
## II. Blazar/AGN Observations



**Figure 5:** Active galaxy NGC 4261 at radio and optical wavelengths.

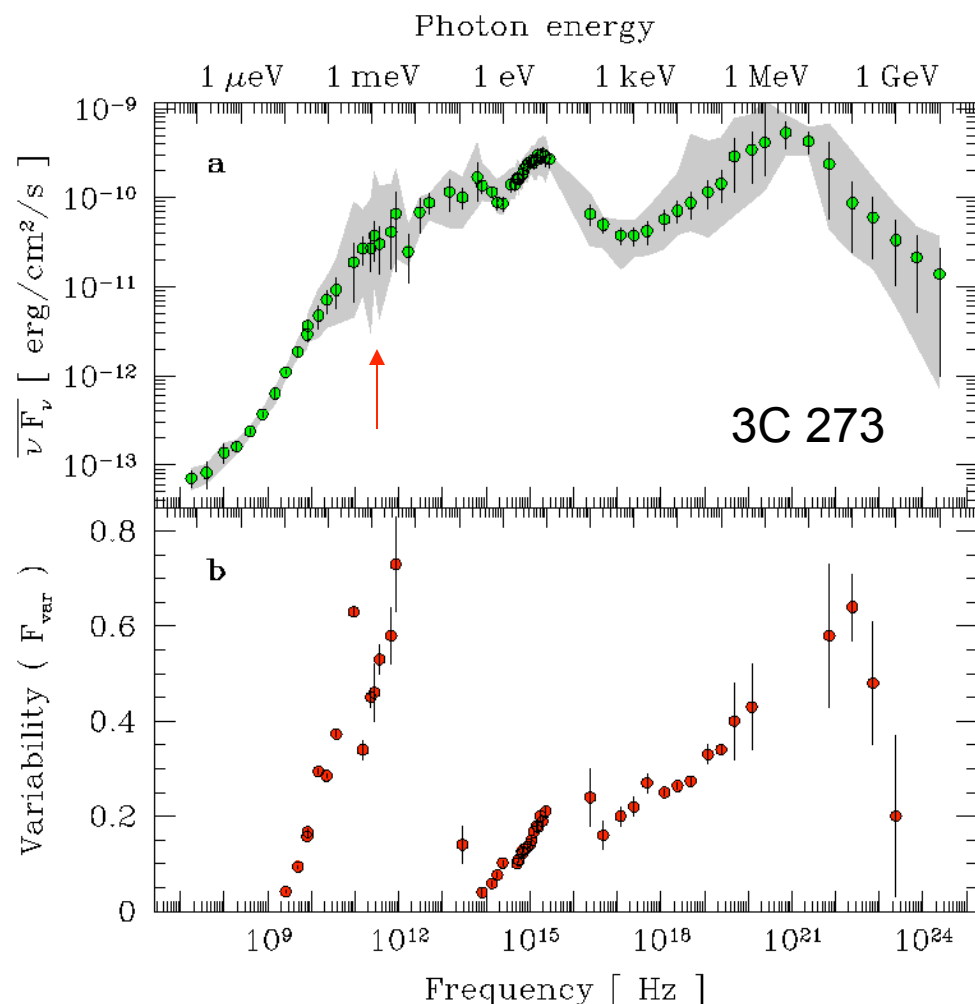


# Blazar Model





# Quasar/blazar SEDs



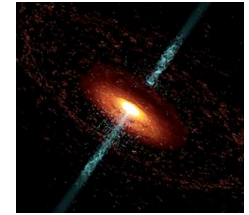
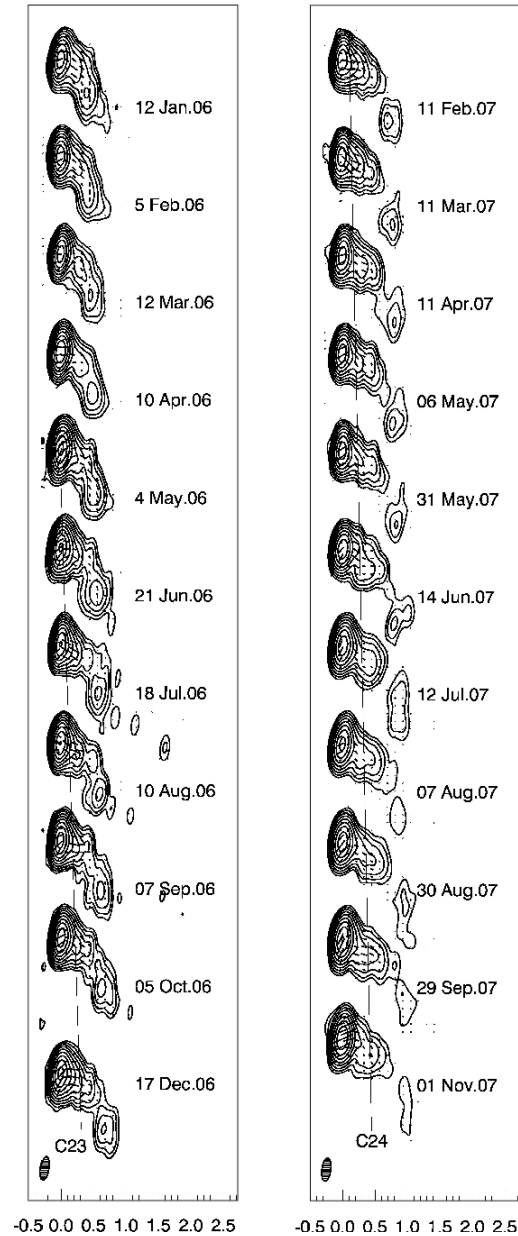
- Quasar/blazar emission
  - bimodal SED
  - Low peak synchrotron, high peak inverse Compton scattering
- Flare time delay related to relative location of emitting regions
- submm is closest band usable from ground for low end of synchrotron peak



# 3C279 - Radio Flare

VLBA monitoring of 3C279

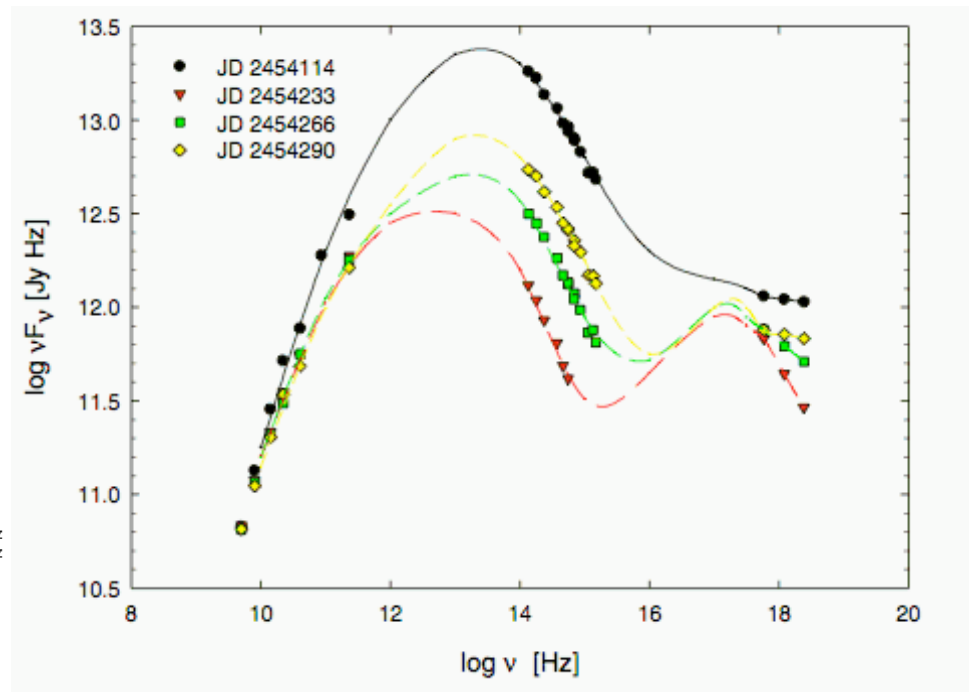
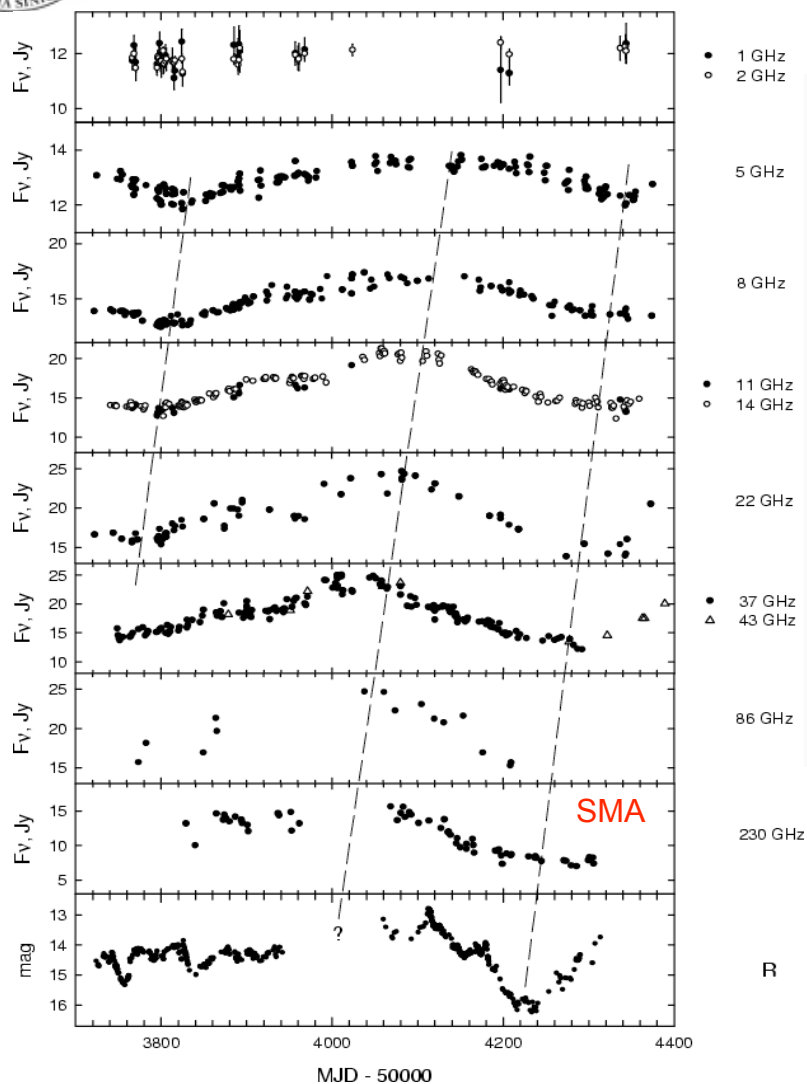
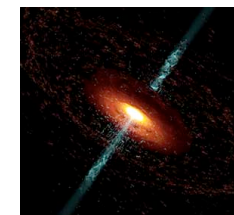
2006-2007 superluminal ejection  
along jet axis captured







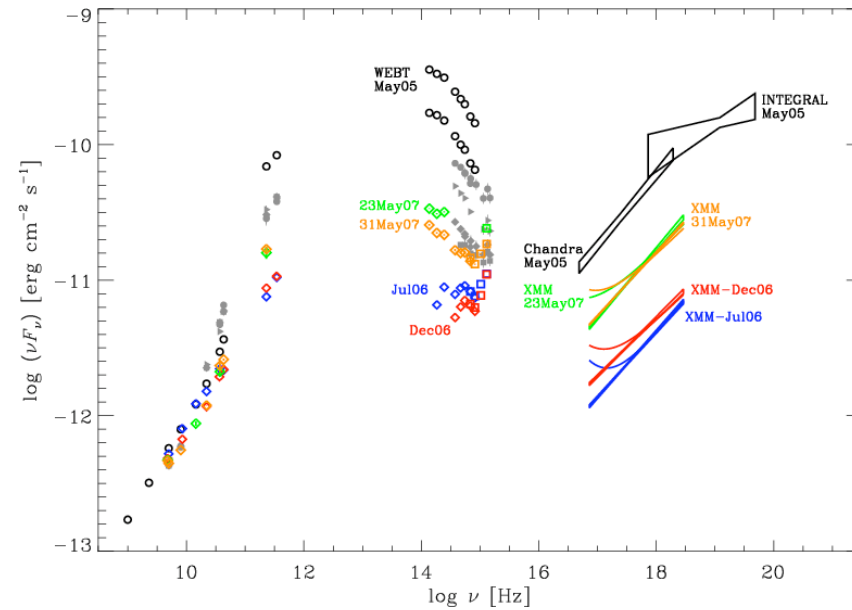
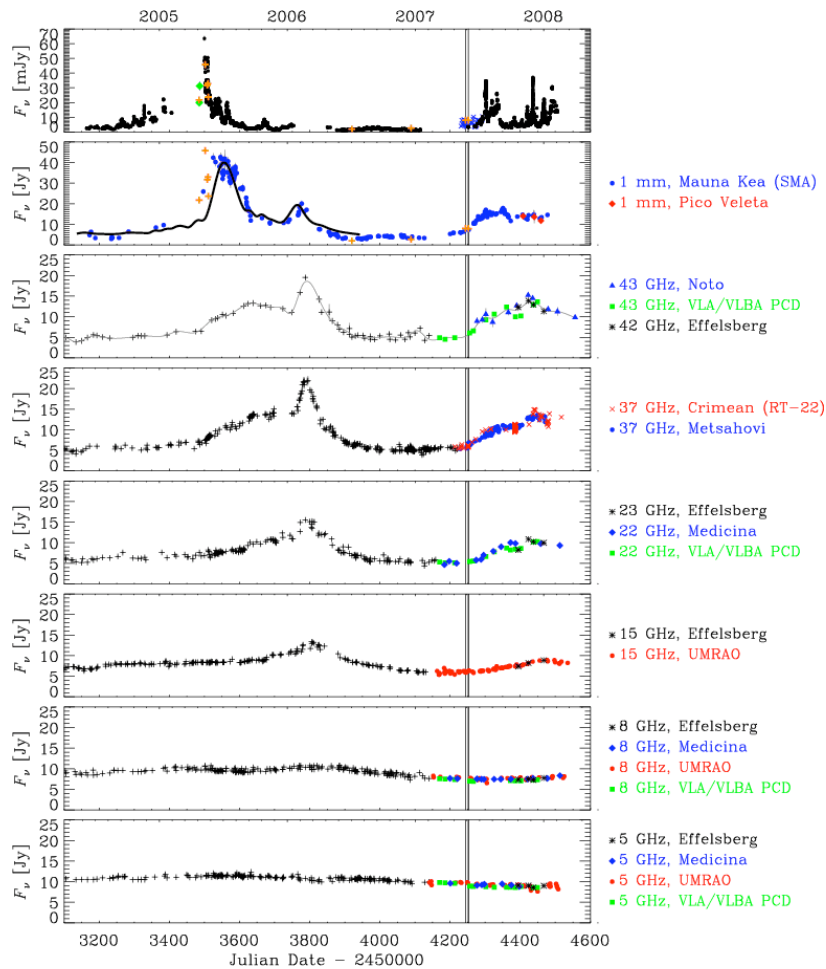
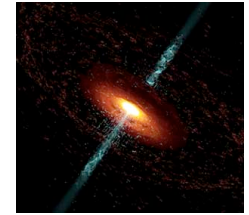
# 3C279 - Flare Propagation



Larionov et al 2008



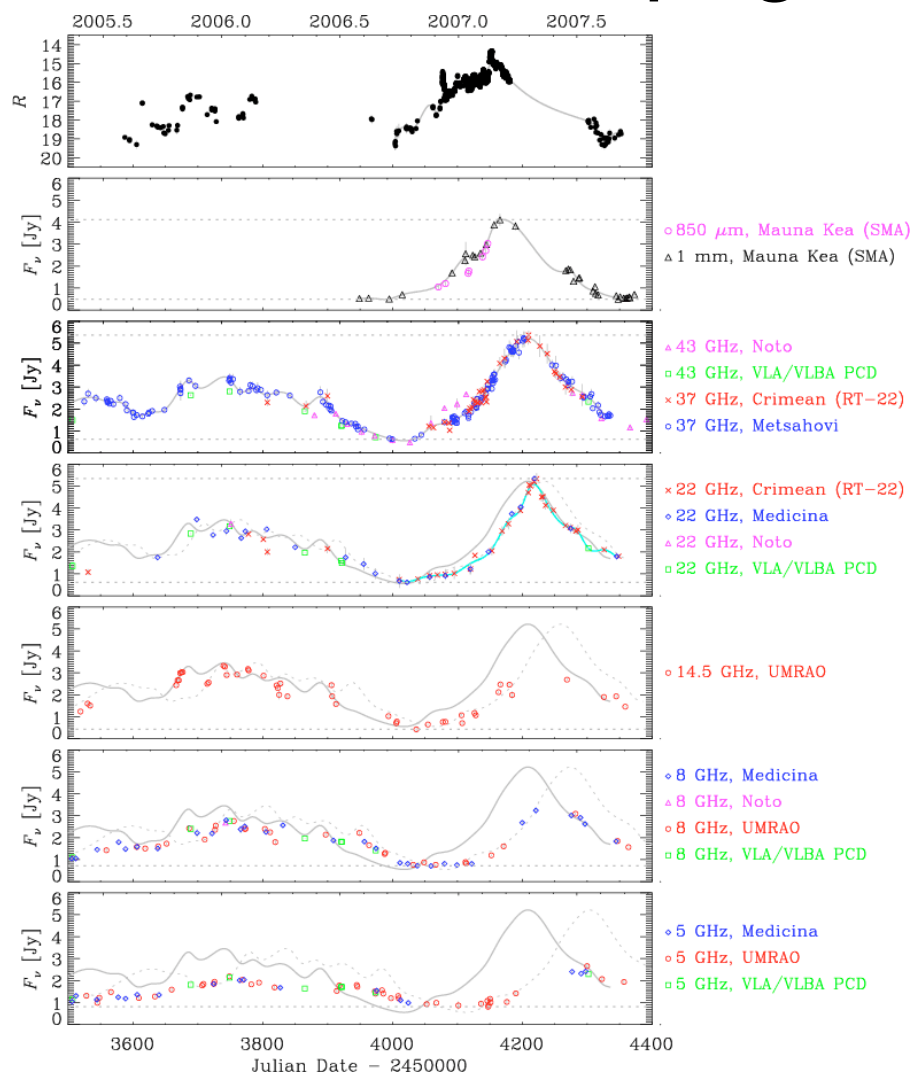
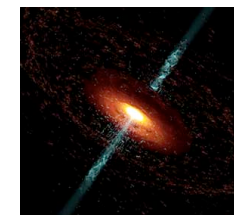
# 3C454.3 Flare Propagation



Raiteri et al 2008A.



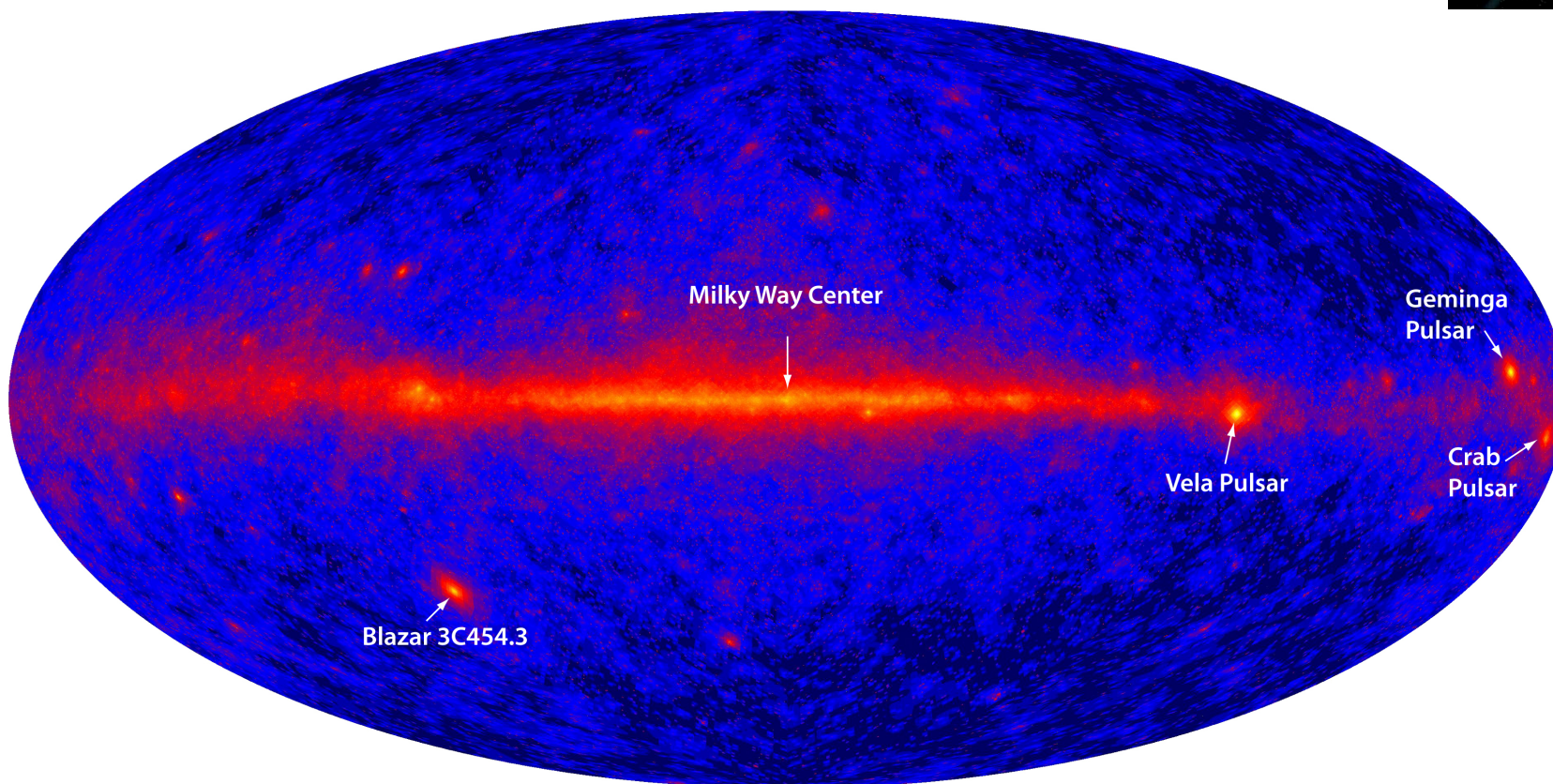
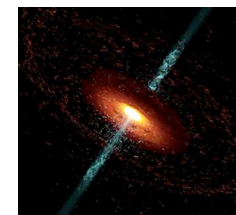
# 0235+164 Flare Propagation



Raiteri et al 2008B



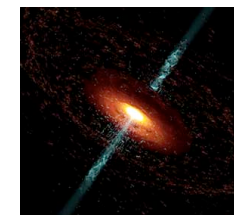
# Blazars Blazing



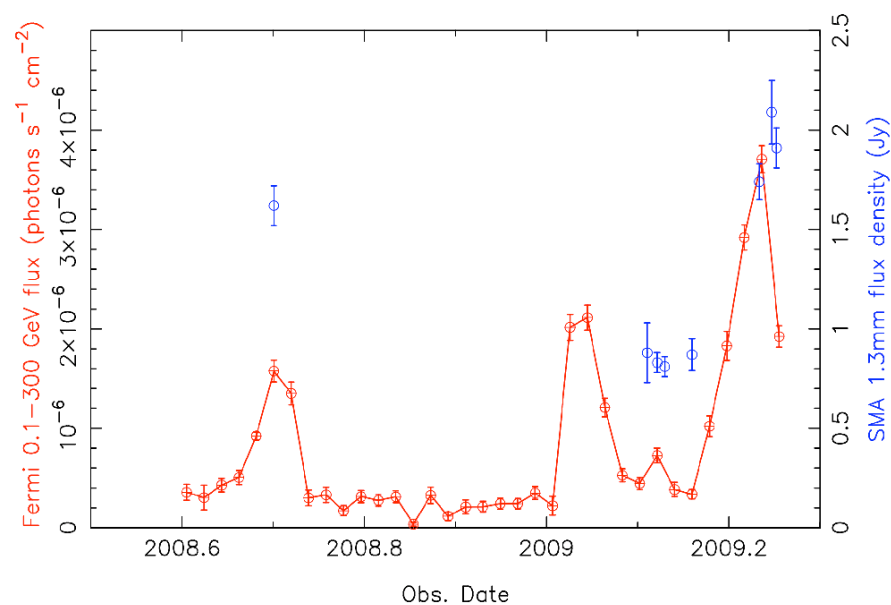
## The Gamma Ray Sky - Fermi



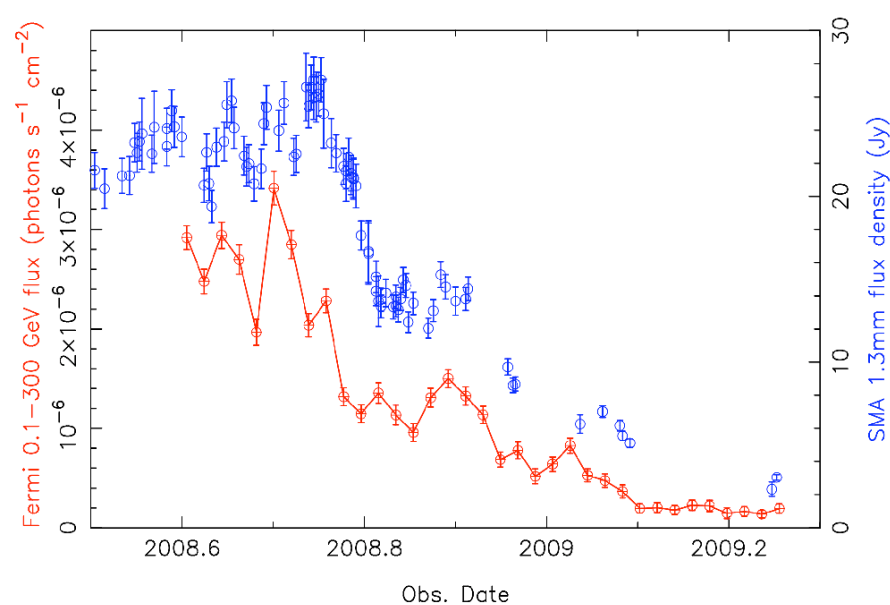
# Gamma-ray/mm/submm correlation



B1510-089 – SMA/Fermi



3C454.3 – SMA/Fermi

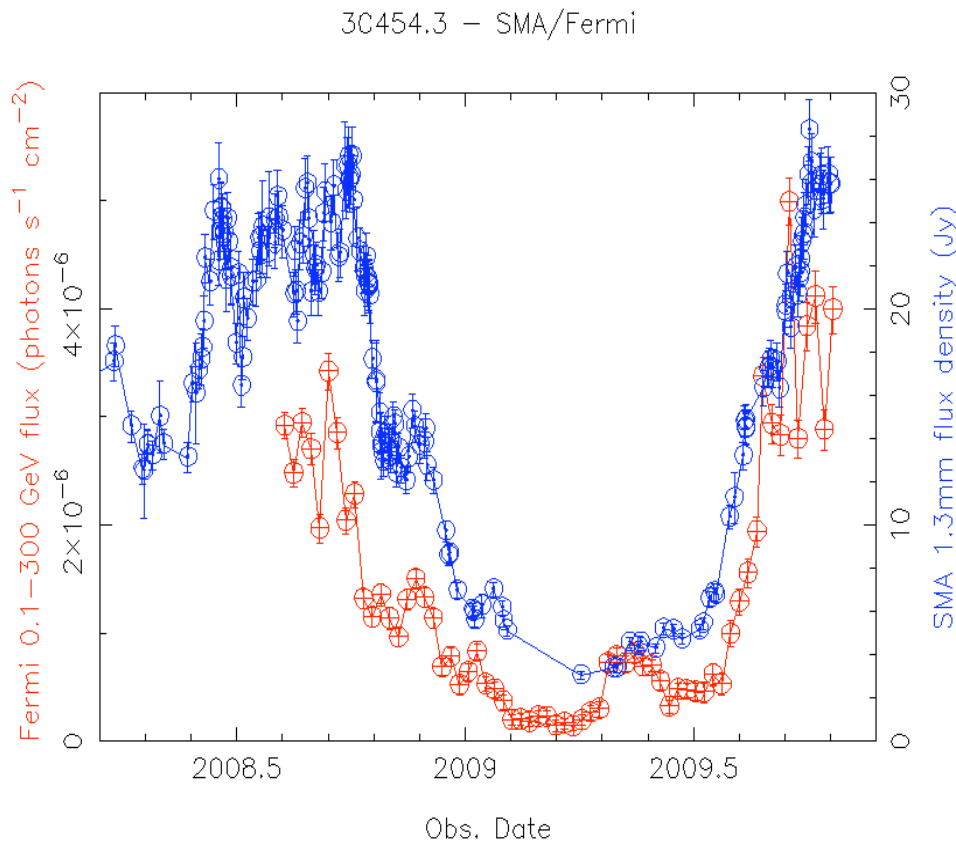
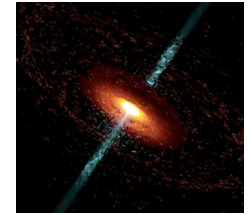


Wehrle et al (ongoing)





# Gamma Ray/MM Correlation II



A screenshot of a Mozilla Firefox browser window displaying an email from ATel #2150. The email subject is "Strong Millimeter-Band Flaring of 3C454.3 Underway". The sender is Mark A. Gurwell from the Harvard-Smithsonian Center for Astrophysics. The email contains a detailed report on the quasar's activity, including a table of related ATel events and a list of subjects.

**ATel #2150: Strong Millimeter-Band Flaring of 3C454.3 Underway**

for reporting and commenting on new astronomical observations  
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Present Time: 29 Oct 2009; 18:00 UT

[ Previous | Next | ADS ]

**Strong Millimeter-Band Flaring of 3C454.3 Underway**

ATel #2150; **Mark A. Gurwell (Harvard-Smithsonian Center for Astrophysics, MA, USA)**  
 on **6 Aug 2009; 14:17 UT**  
 Distributed as an Instant Email Notice (Request for Observations)  
 Password Certification: Mark A. Gurwell (mgurwell@cfa.harvard.edu)

**Subjects: Millimeter, Sub-Millimeter, Request for Observations, AGN, Quasars**  
**Referred to by ATel #: 2155, 2181, 2200, 2223**

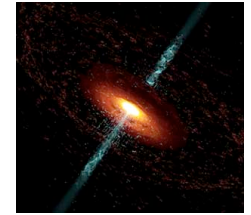
The Submillimeter Array (SMA) performs ongoing flux density monitoring of quasars that are typically bright in the mm/submm bands, in order to optimally choose quasars for use as interferometric calibration sources. Through this monitoring effort, we report that the quasar 3C454.3 (J2253+161) is currently flaring strongly at millimeter wavelengths.

After reaching 1.3 mm band flux densities of 27 +/- 1.8 Jy on October 3 2008, the quasar showed a substantial long term drop in intensity, reaching a measured nadir of 3 +/- 0.2 Jy on April 3, 2009 (though observations in 2009 are particularly sparse prior to May, and it is possible that the source dipped below 3 Jy during this time). We note that this drop in millimeter flux density is strongly correlated with a drop in the gamma ray intensity as measured by the Fermi Large Area Telescope (LAT) monitoring program (see [http://fermi.gsfc.nasa.gov/ssc/data/access/lat/msl\\_lcr/](http://fermi.gsfc.nasa.gov/ssc/data/access/lat/msl_lcr/)).

Since April, 3C454.3 has been steadily increasing in 1.3 mm band flux density, nearly doubling by July 10 (to 5.4 +/- 0.3 Jy), equivalent to a growth rate of about 4.3% per week. However, monitoring observations over the past 25 days show a dramatic increase in the rate of brightening. On August 3, the flux density was measured to be 10.3 +/- 0.6 Jy, and on August 4 the flux density had grown to 11.3 +/- 1.1 Jy, equivalent to a growth rate of 21.2% per week; this is over 5

**Related**

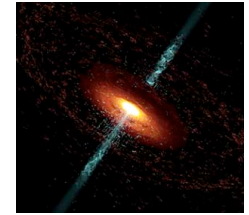
- 2223 [Strong Millimeter-Band Flaring of 3C454.3 Continues](#)
- 2201 [Optical behavior of 3C 454.3 in the current flaring state](#)
- 2200 [Fermi LAT detection of GeV flares from 3C454.3 and 3C273](#)
- 2182 [Discovery of a ~205 Hz X-ray pulsar in the globular cluster NGC 6440](#)
- 2181 [Optical and IR flare of 3C 454.3](#)
- 2180 [NGC 6440 active again](#)
- 2168 [Fermi LAT detection of a GeV flare from 3C 273](#)
- 2155 [Optical and IR flare of blazars 3C 454.3 and 3C 279](#)
- 2154 [Fermi LAT and INTEGRAL detection of increasing high-energy activity of blazar 3C279](#)
- 2150 [Strong Millimeter-Band](#)



- Currently 16 publications using general SMA flux density monitoring results
- Many more in progress as Fermi observation baseline increases and more flaring sources are discovered



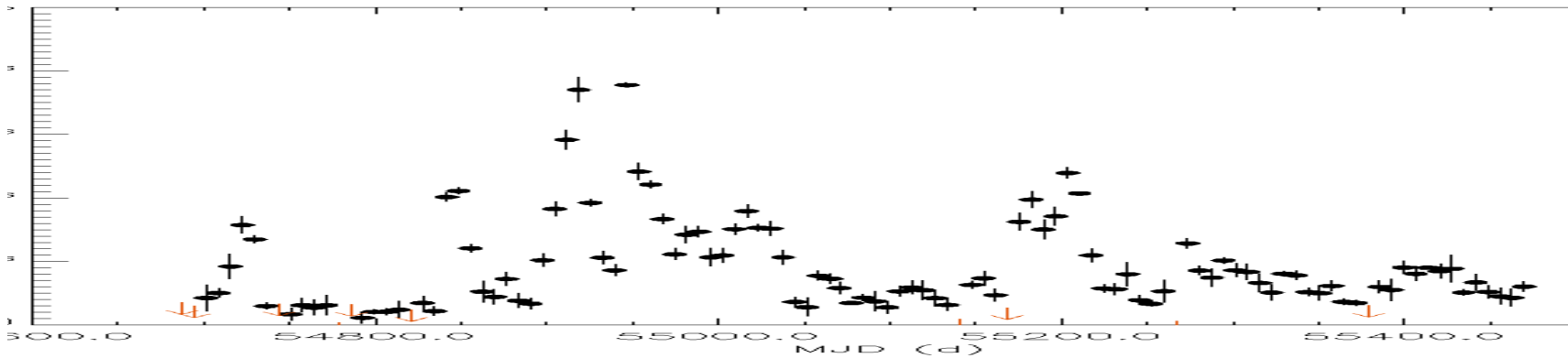
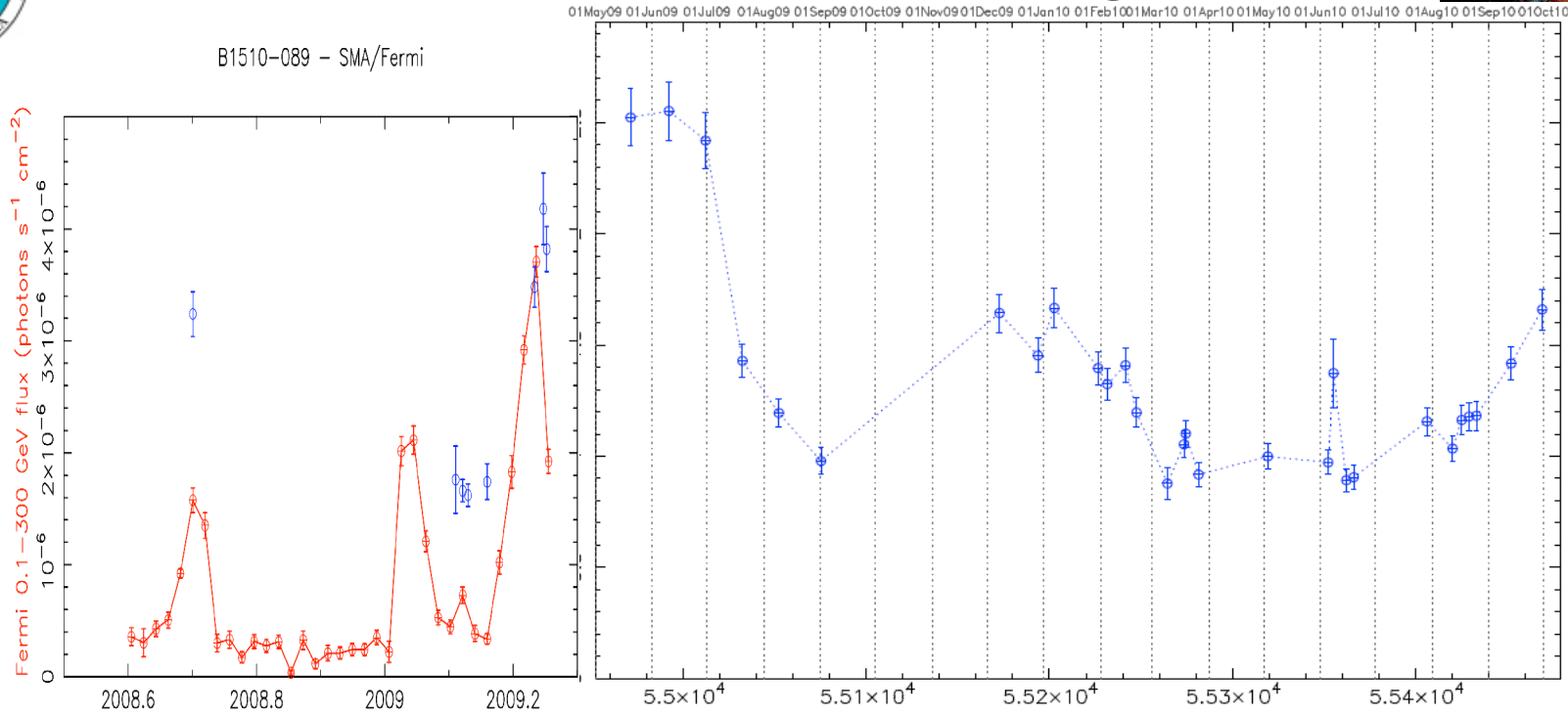
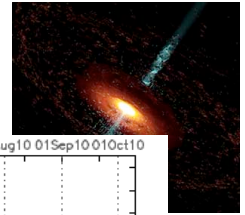
## III. Independent Programs



- General flux monitoring not sampled enough in some cases, or not at all in others
- Several proposals accepted for monitoring of specific sources with a regular cadence, with impacts on scheduling
  - Ann Wehrle, Fermi LAT Bright Source catalog
  - Ian McHardy, M81\*
  - Aneta Siemiginowska, FSRQs

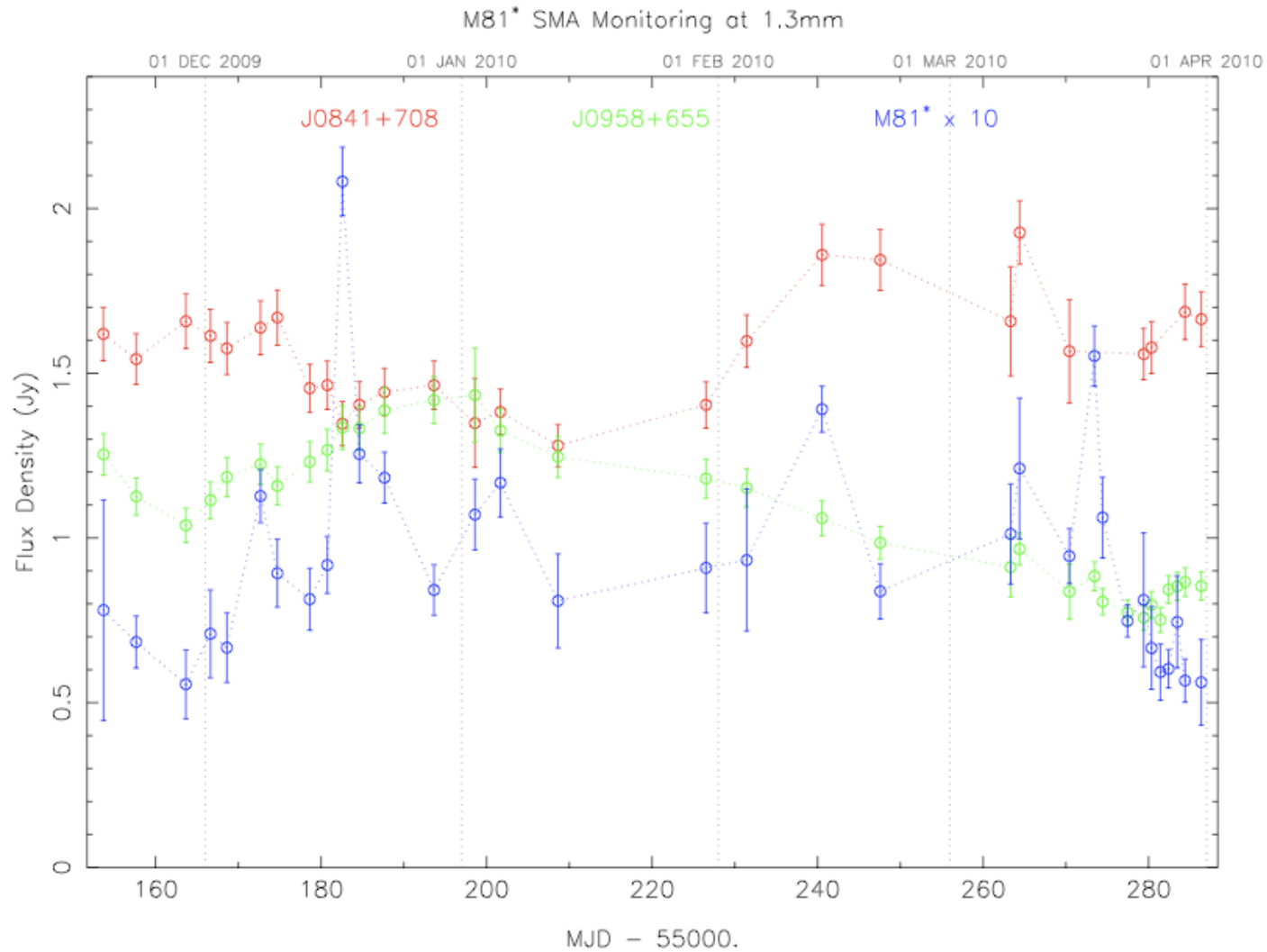
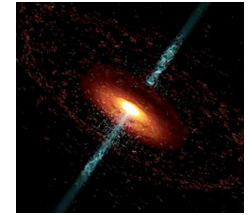


# Improved Time Sampling





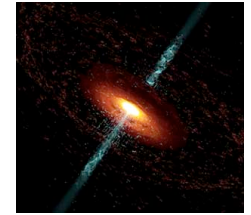
# M81\* Monitoring







# Summary



- SMA Calibrator Database is a nearly unique, accessible resource for the mm/submm flux density history of several hundred quasars
- The SMA data occupy the highest frequency band easily available from the ground for the synchrotron peak in blazars, providing critical information on the shape of the SED of these sources and the location of the emitting regions



END

