





# OVRO 40m blazar monitoring program

Rodrigo Reeves, UdeC, Chile  
on behalf of the OVRO 40m blazar group  
ICTS, Bangalore, India  
October 15th, 2015

*Mon. Not. R. astr. Soc. (1974) 167, Short Communication, 31P–35P.*  
THE MORPHOLOGY OF EXTRAGALACTIC RADIO  
SOURCES OF HIGH AND LOW LUMINOSITY

*B. L. Fanaroff and J. M. Riley*





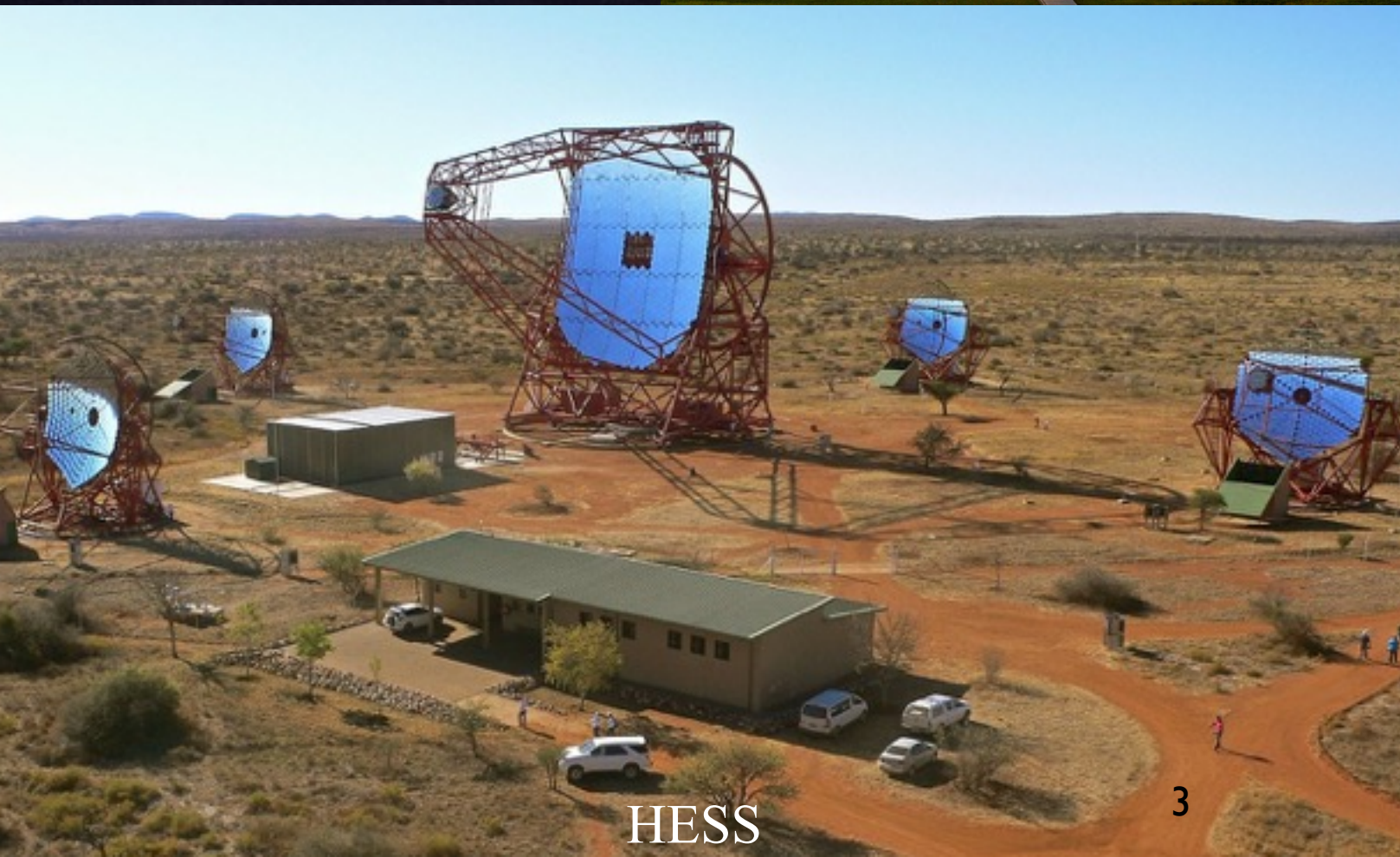
40 m Telescope OVRO



Fermi-GST Launch



MAGIC



HESS



VERITAS



CTA - artist's impression



# OVRO 40m Collaboration

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In partnership with  
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L. Furhmann

T. Krichbaum

I. Myserlis



# AGN blazar emission models

Mkn 421, Abdo et al, *ApJ*, 736, 131 (2011)

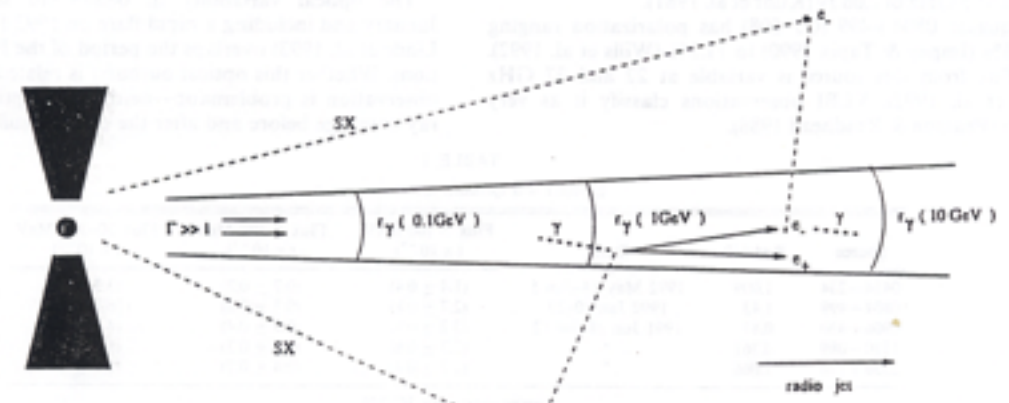
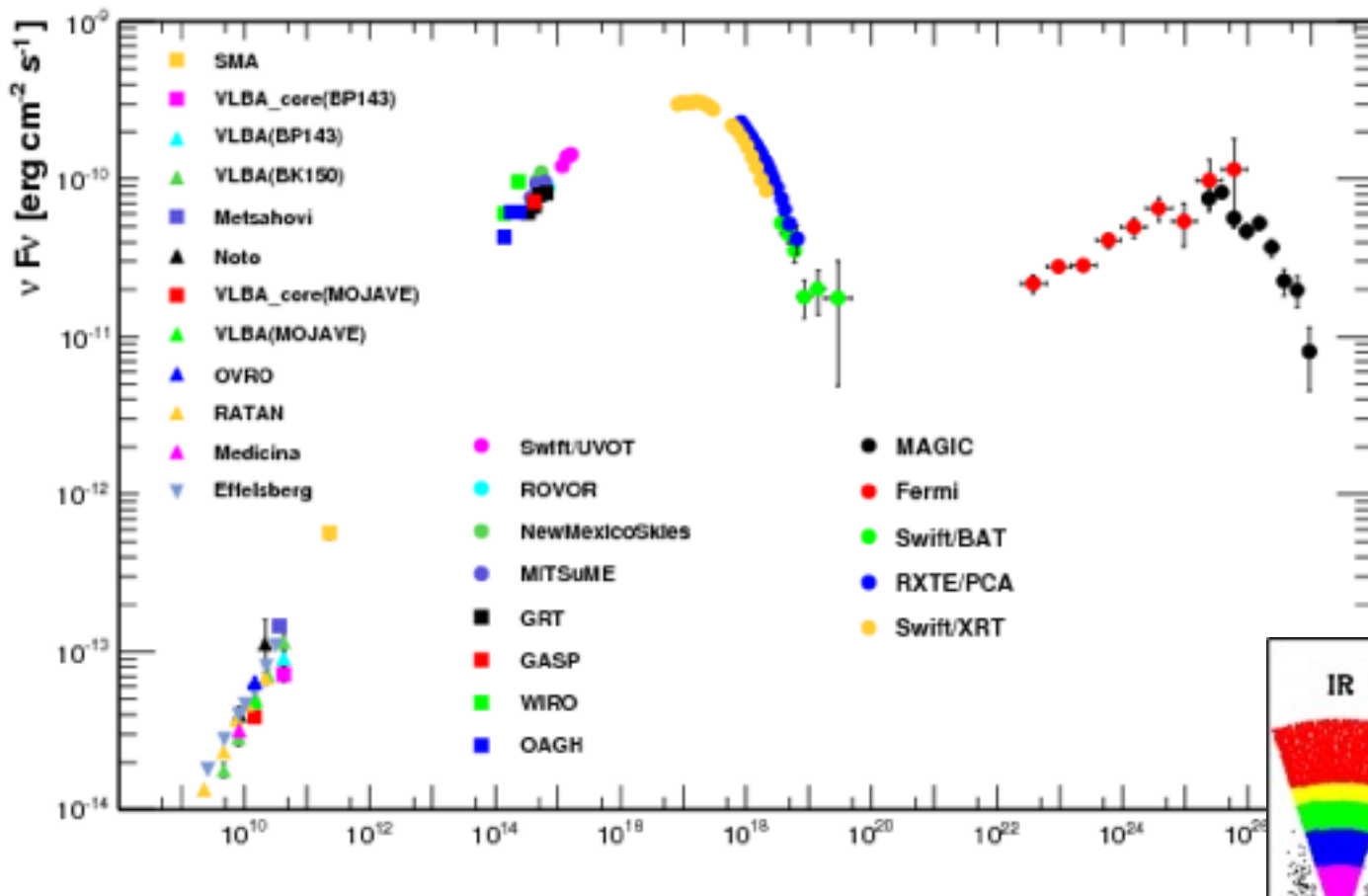
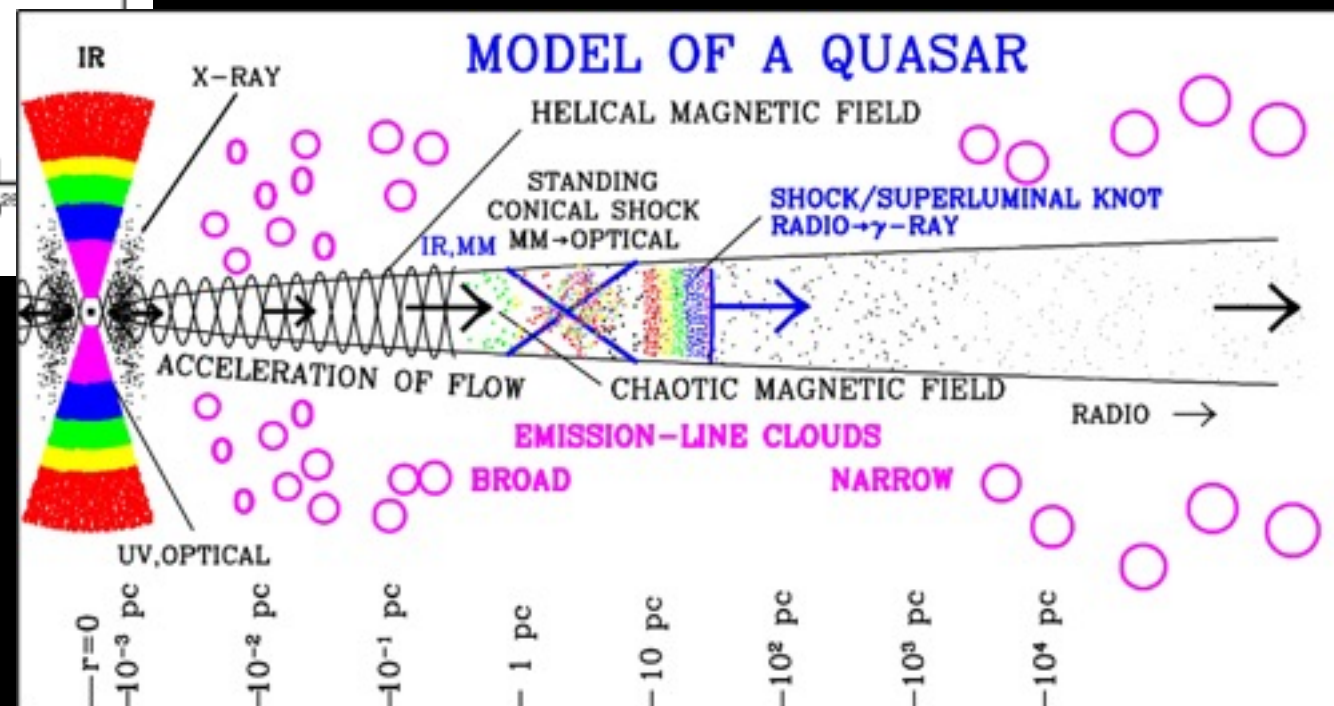


FIG. 6.—Schematic representation of the pair cascade model. A relativistic jet is formed parallel to the spin of a massive black hole orbited by a thick accretion disk. Soft X-ray photons denoted SX emitted near the black hole may be Thomson-scattered into the jet. There they can both combine with  $\gamma$ -rays to form electrons and positrons and be inverse Compton scattered by electrons and positrons to form  $\gamma$ -rays. In this way a pair cascade can develop. Also shown are the  $\gamma$ -spheres for  $\gamma = 0.1, 1, 10$  GeV.

Blandford & Levinson, 1995, *ApJ*, 441, 798

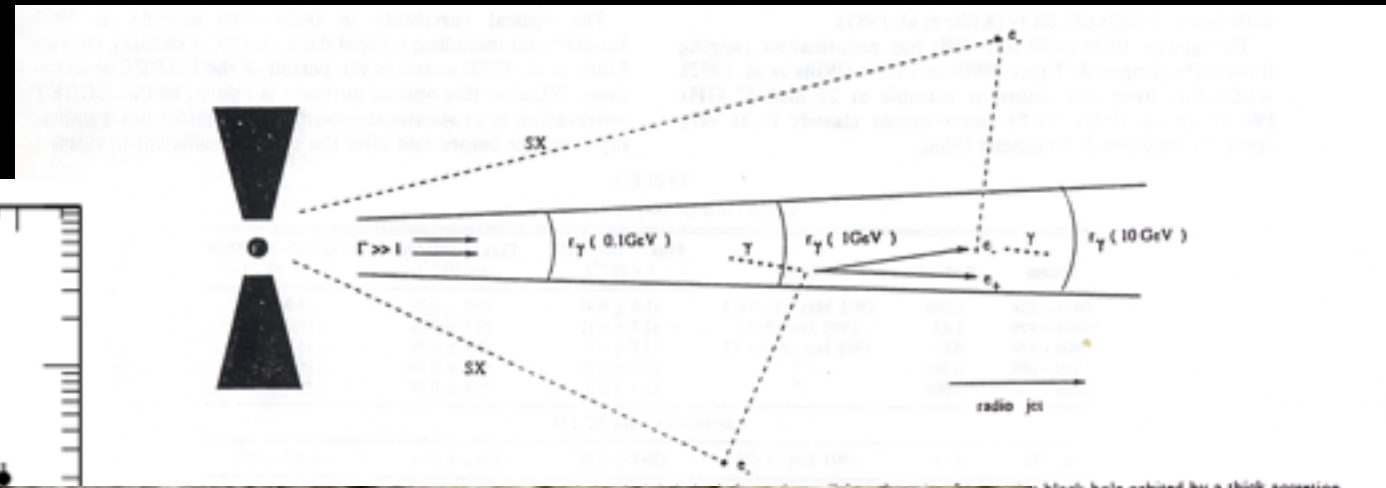
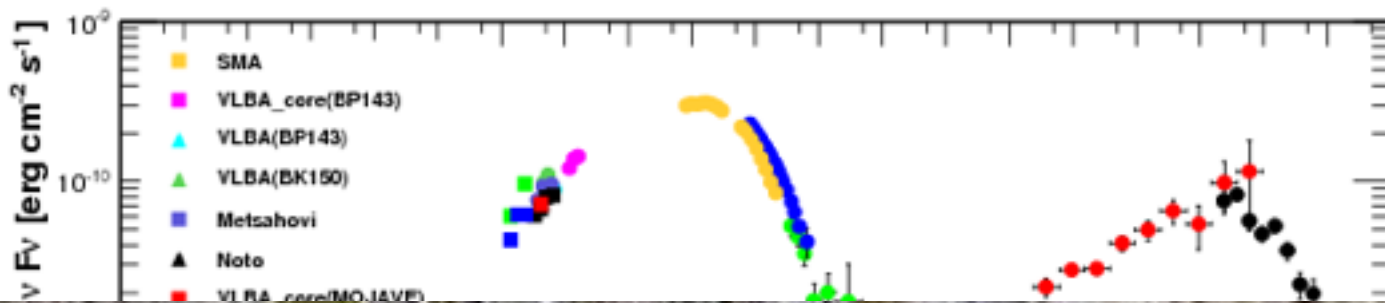


<https://www.bu.edu/blazars/research.html>



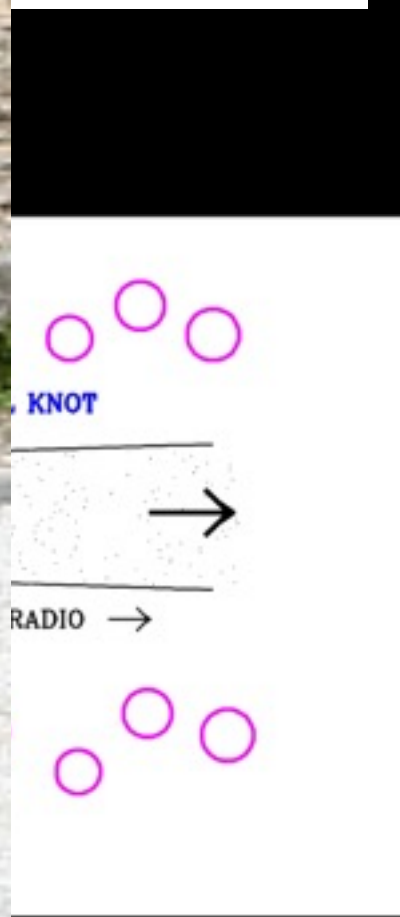
# AGN blazar emission models

Mkn 421, Abdo et al, *ApJ*, 736, 131 (2011)



the black hole orbited by a thick accretion disk. The electrons and positrons combine with  $\gamma$ -rays to form electrons and positrons. Also shown are the  $\gamma$ -spheres for the different components.

Abdo et al., 1995, *ApJ*, 441, 798

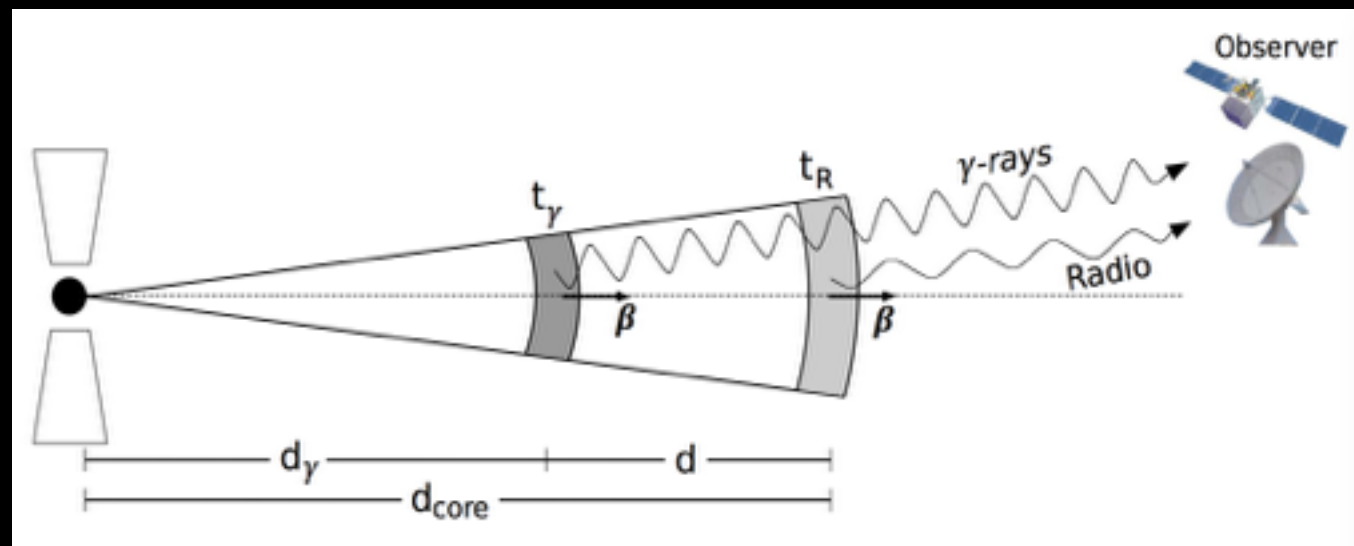


[ch.html](#)



# Our goals:

- Determine the sites of VHE and gamma ray emission relative to the radio emission regions



- Monitor all the bright quasars north of dec -20deg and the most studied AGN and micro quasars biweekly
- Collaborate with community for multiband characterization of blazar emission

# OVRO 40m Blazar monitoring program

- Dedicated telescope for blazar monitoring
- 1800+ sources twice a week
- Catalog from CGRaBS + 1/2/3FGL  
+ VERITAS, MAGIC and HESS
- Total power receiver [2008-2014]  
Rx@15 GHz, BW 3 GHz
- Spectropolarimeter [2014- ? ]  
[13-18] GHz, df 40 KHz, dual-pol

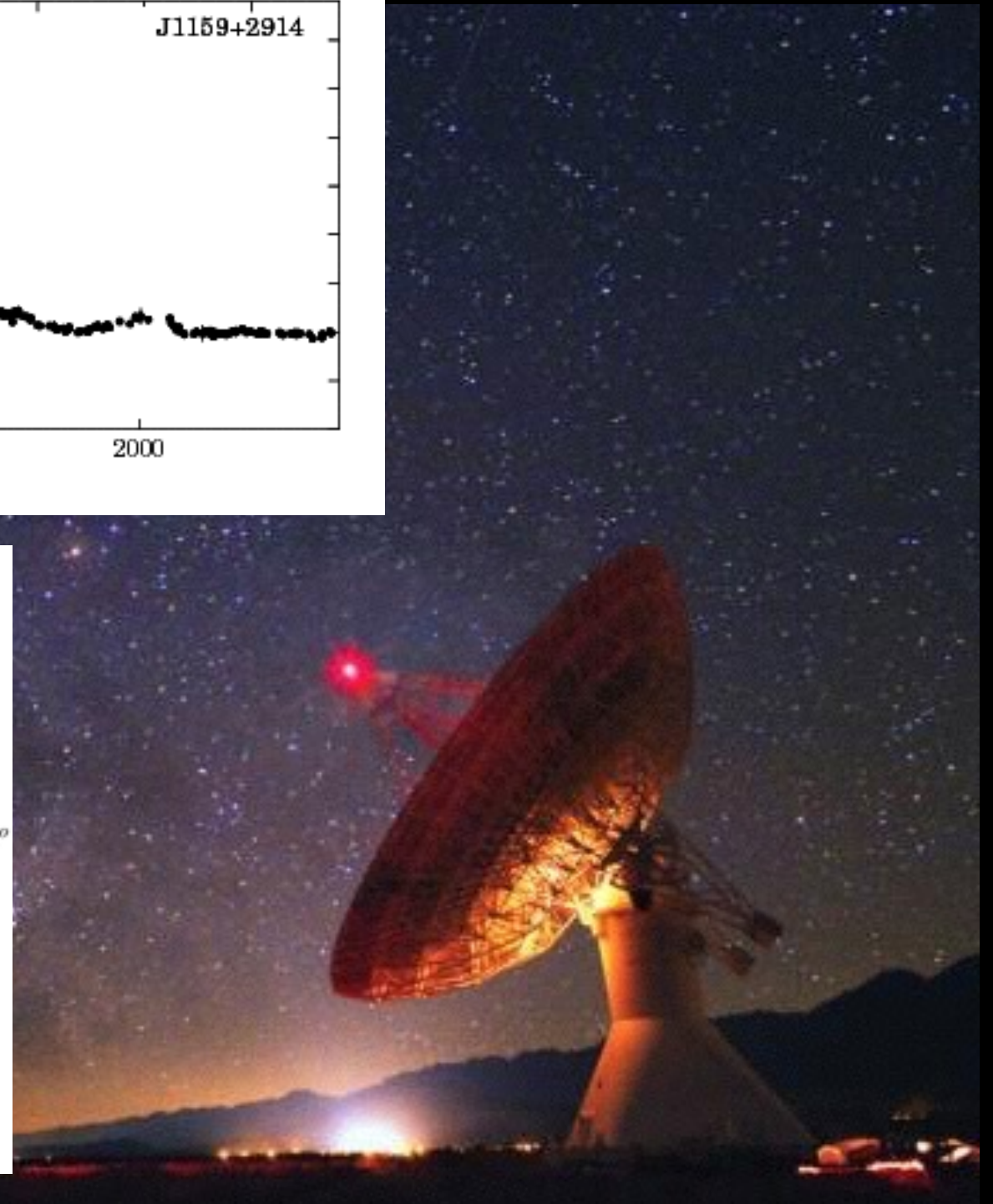
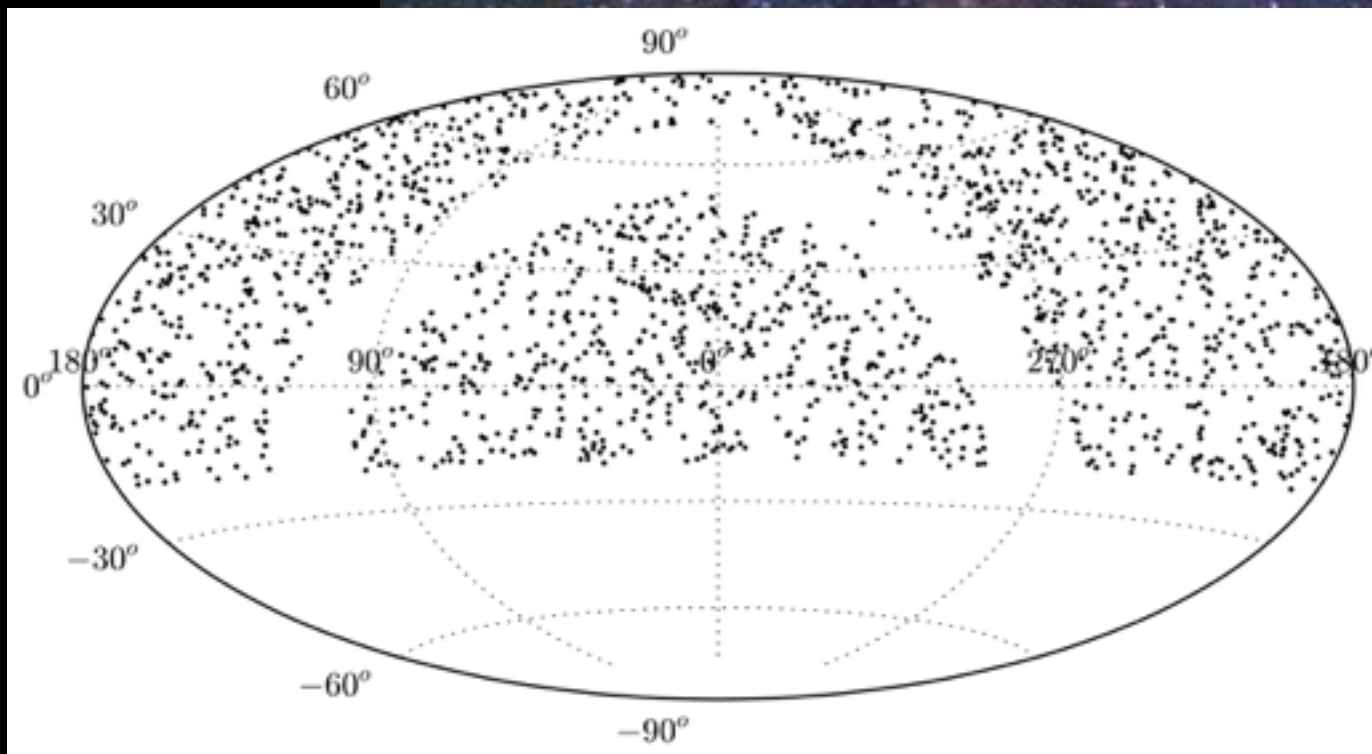
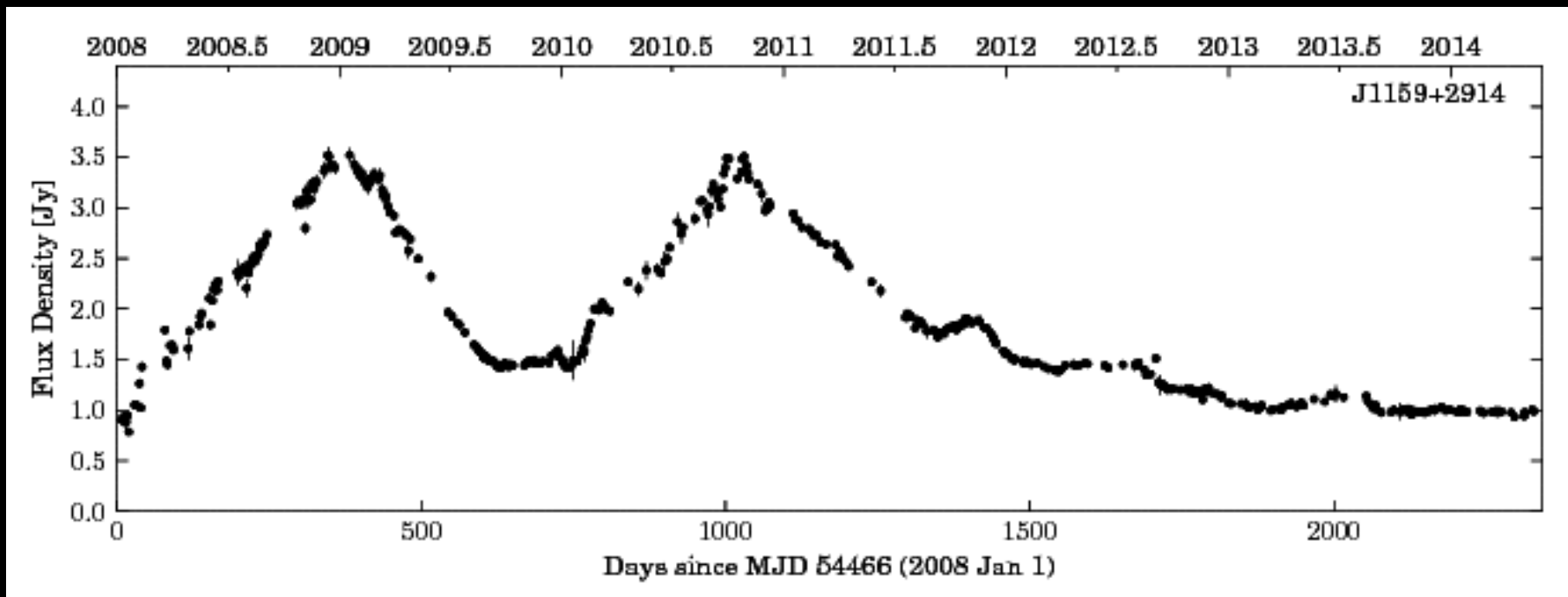


The OVRO 40 m telescope at night  
by Joseph Richards



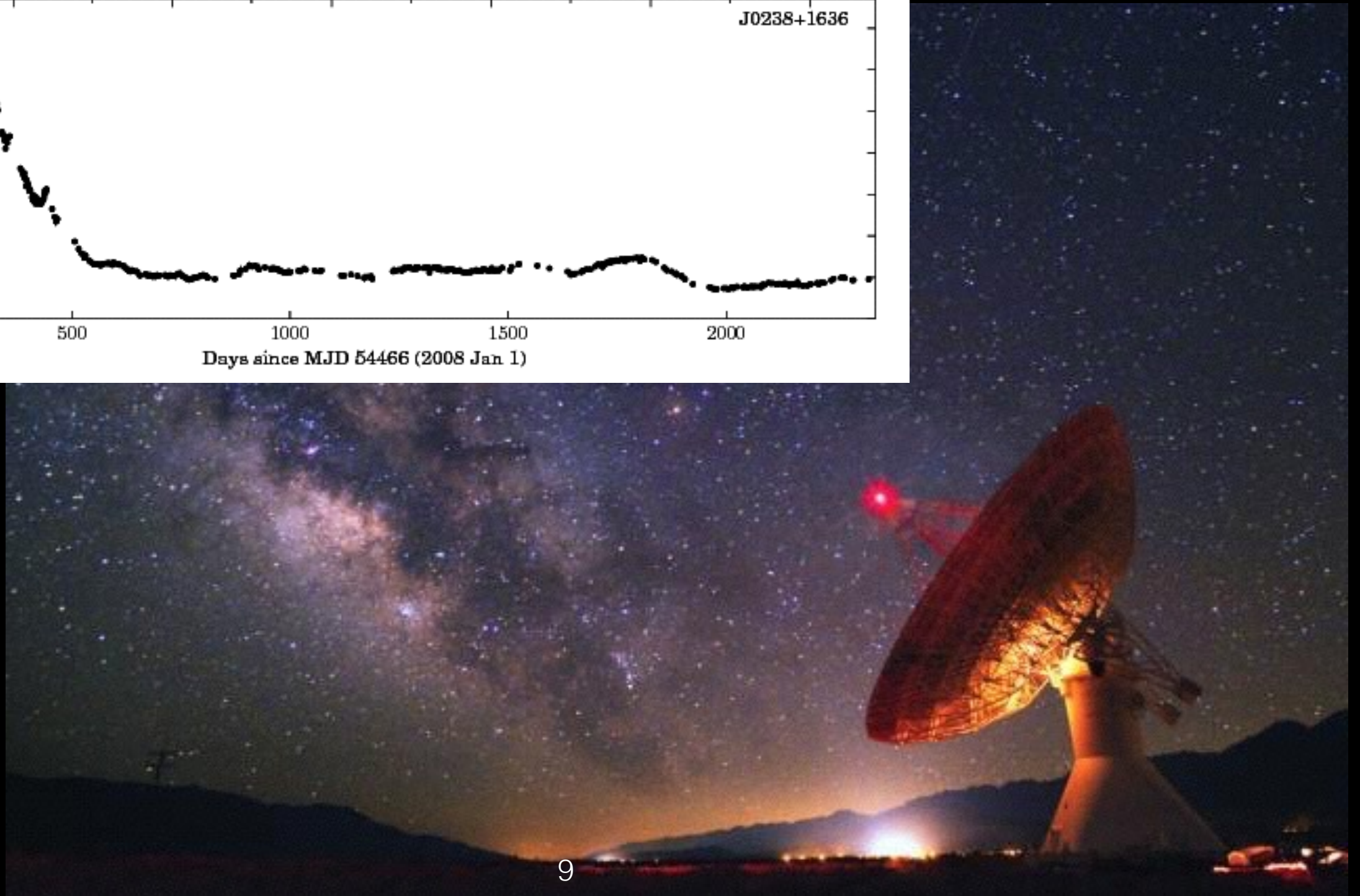
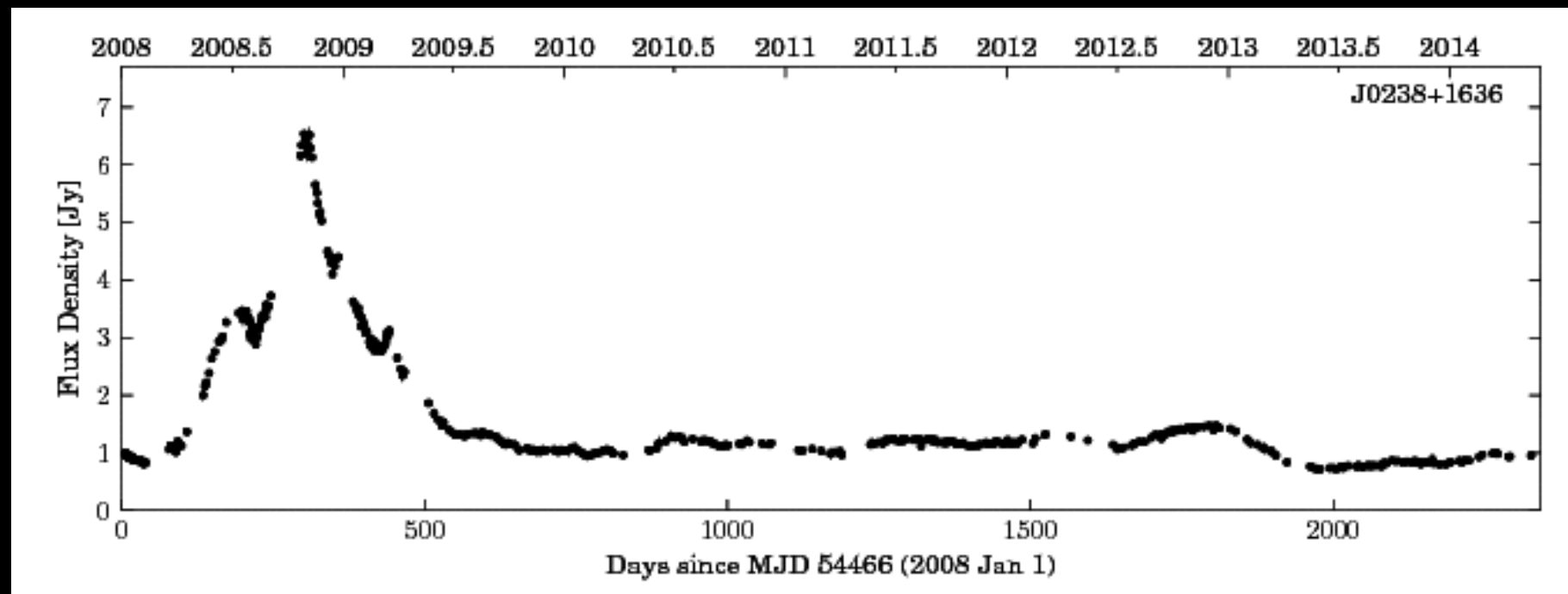
# Owens Valley Radio Observatory

## OVRO - 40m telescope



# Owens Valley Radio Observatory

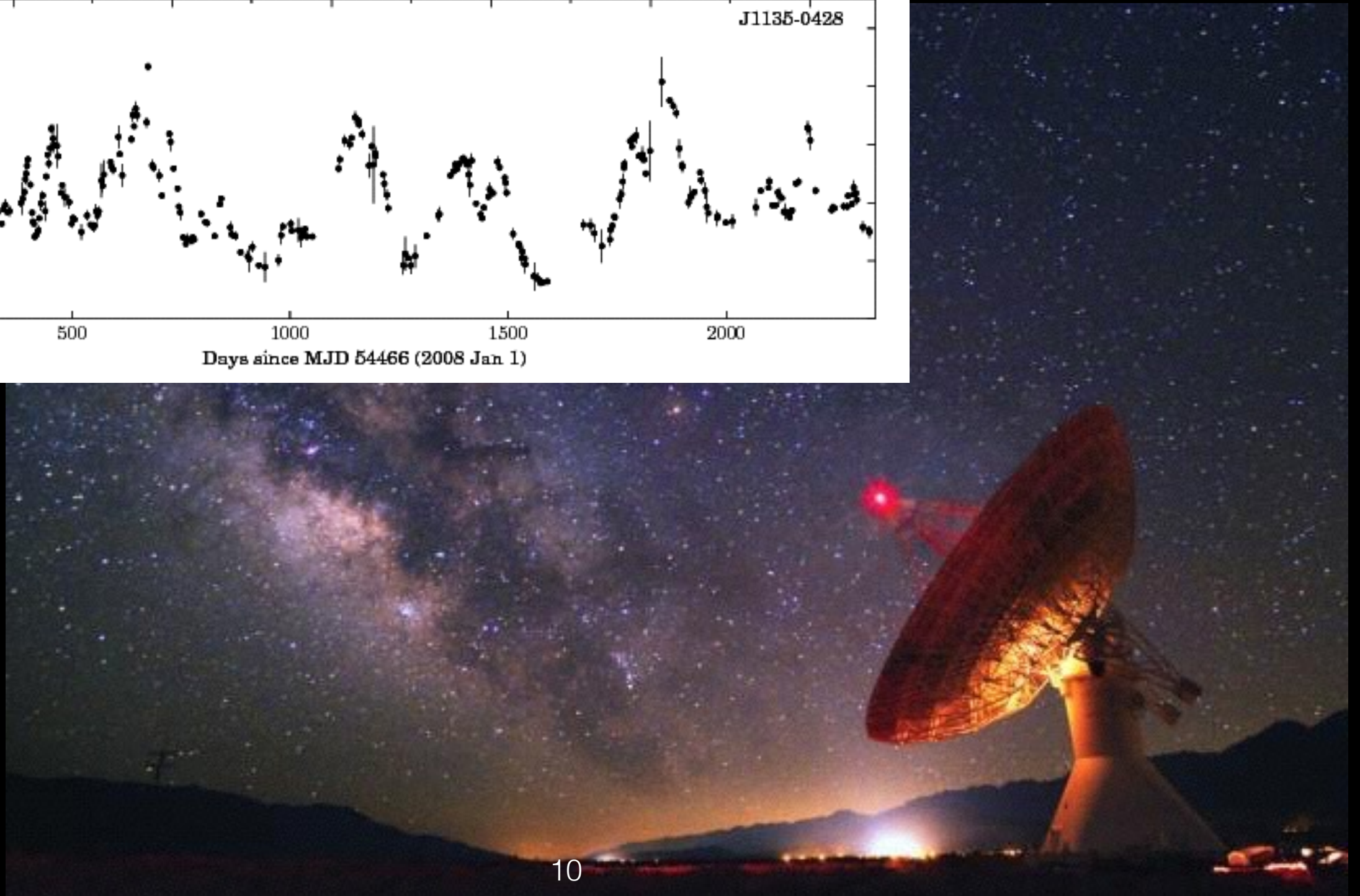
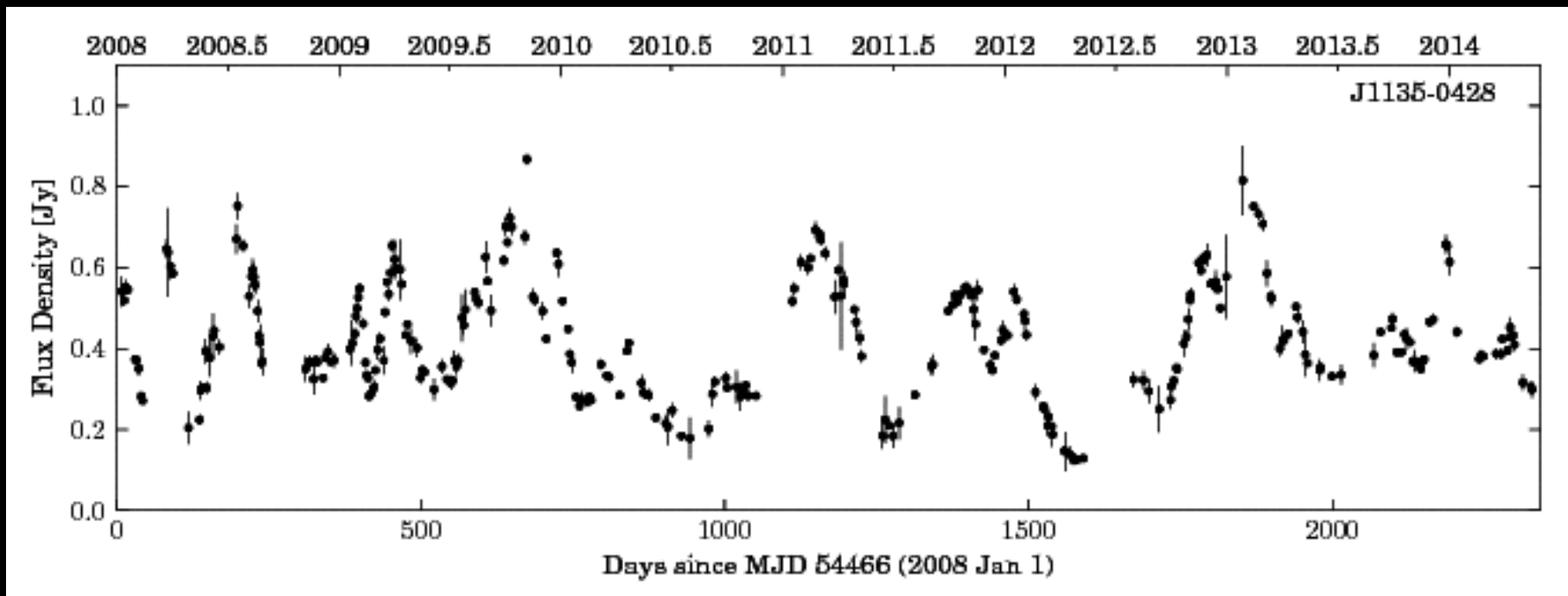
## OVRO - 40m telescope





# Owens Valley Radio Observatory

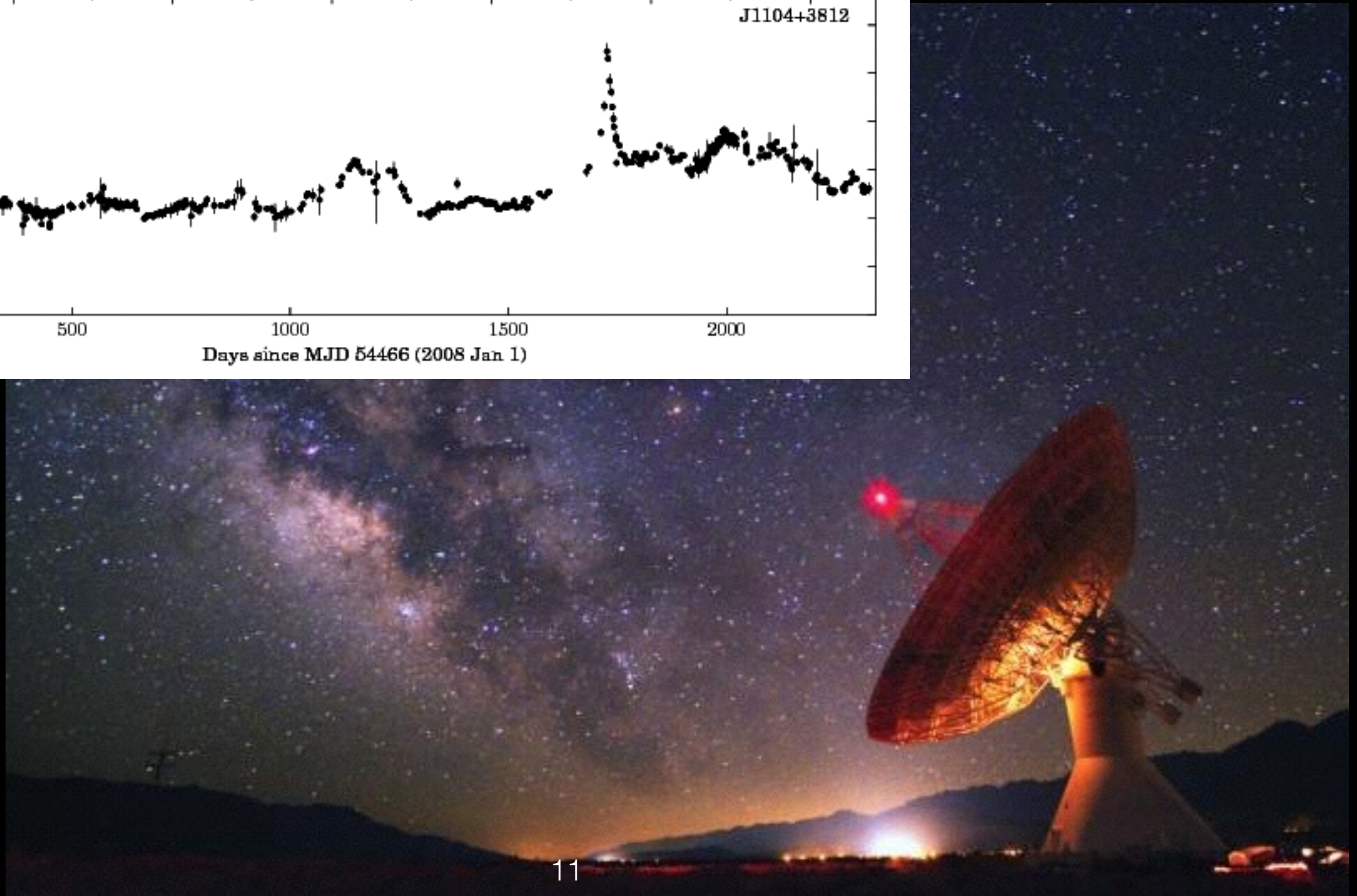
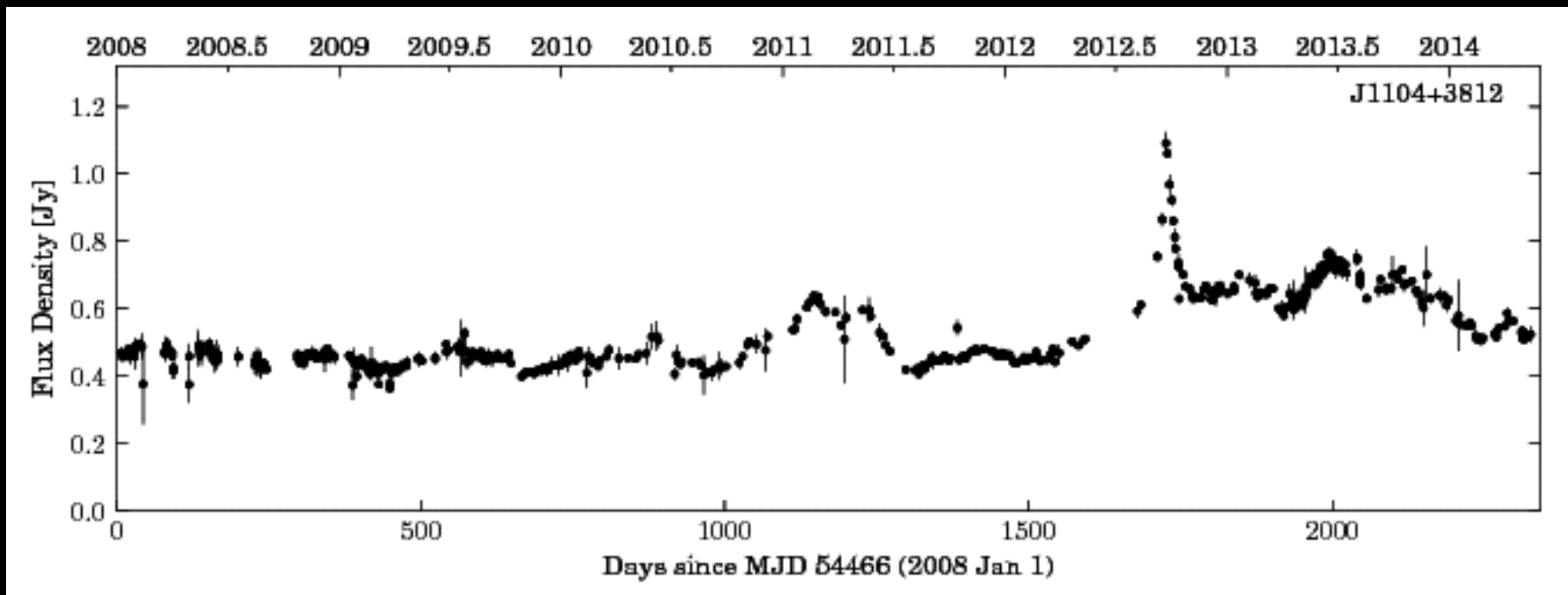
## OVRO - 40m telescope





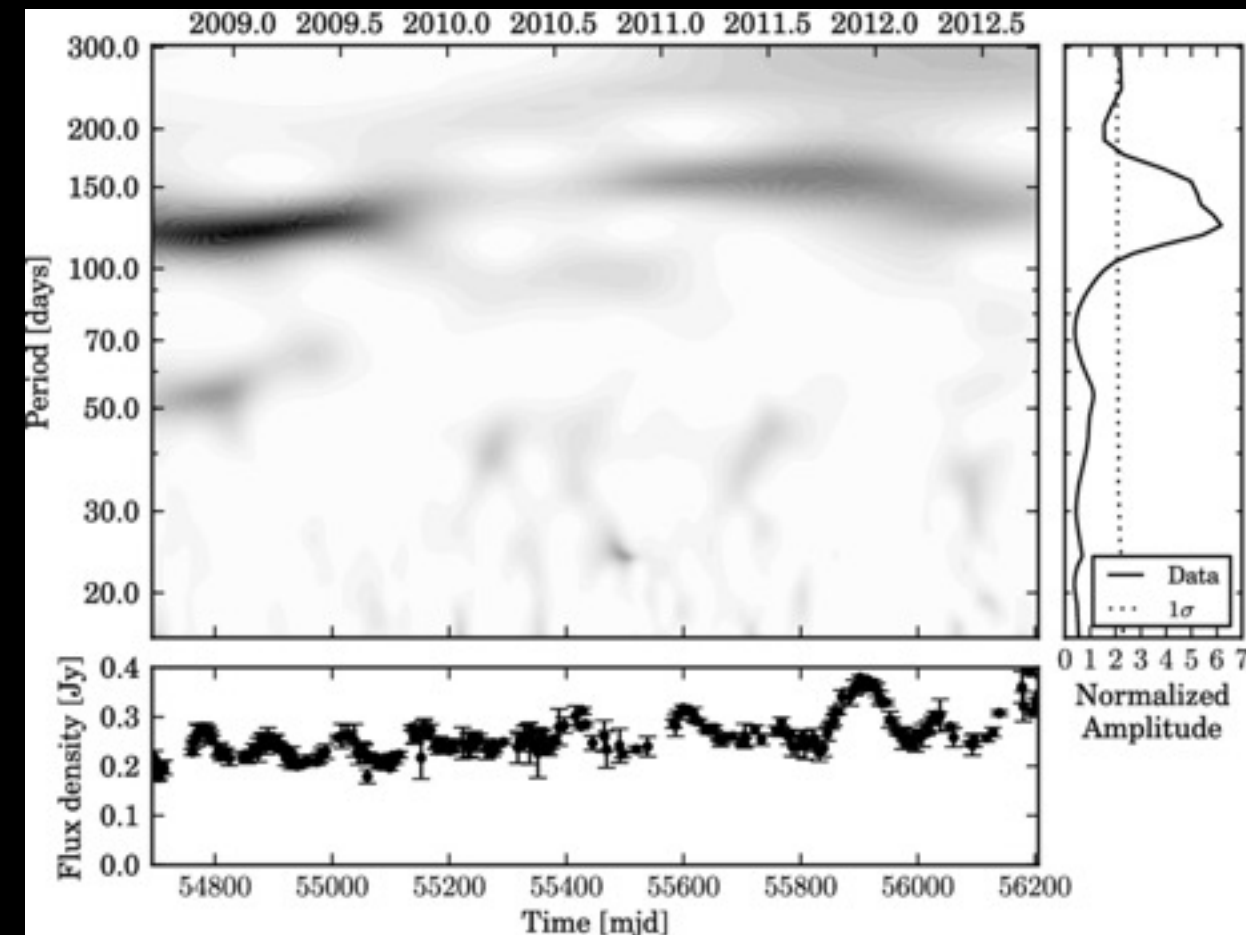
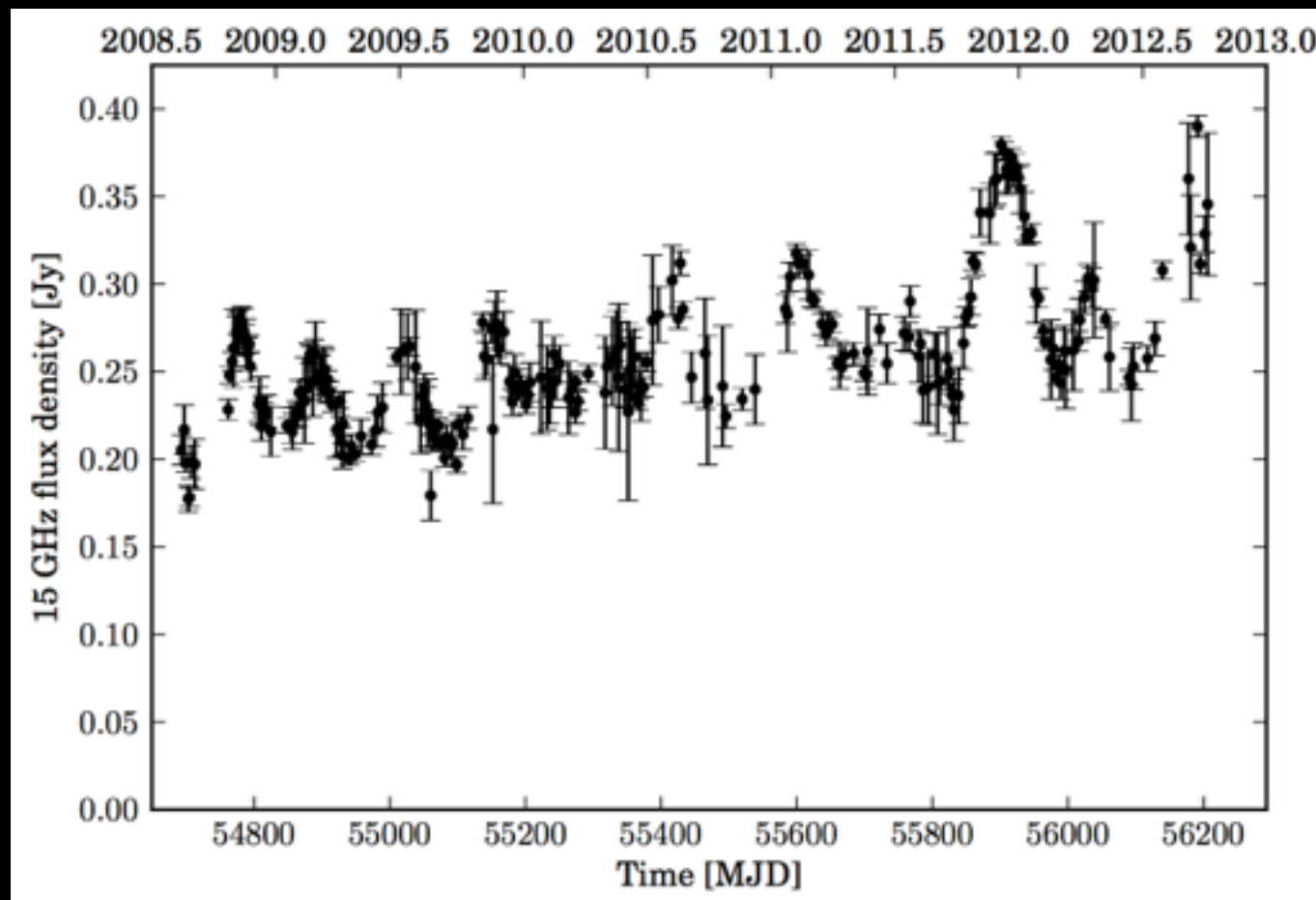
# Owens Valley Radio Observatory

## OVRO - 40m telescope





# A QPO in J1359+4011



Period of 120 -> 150 days

Span of 4 yrs

25% flux modulation

WWZ with Morlet base function

King et al. (2013)

2.8 sigma sig.

Montecarlo evaluation

# OVRO - Fermi lightcurve correlations and statistical analysis

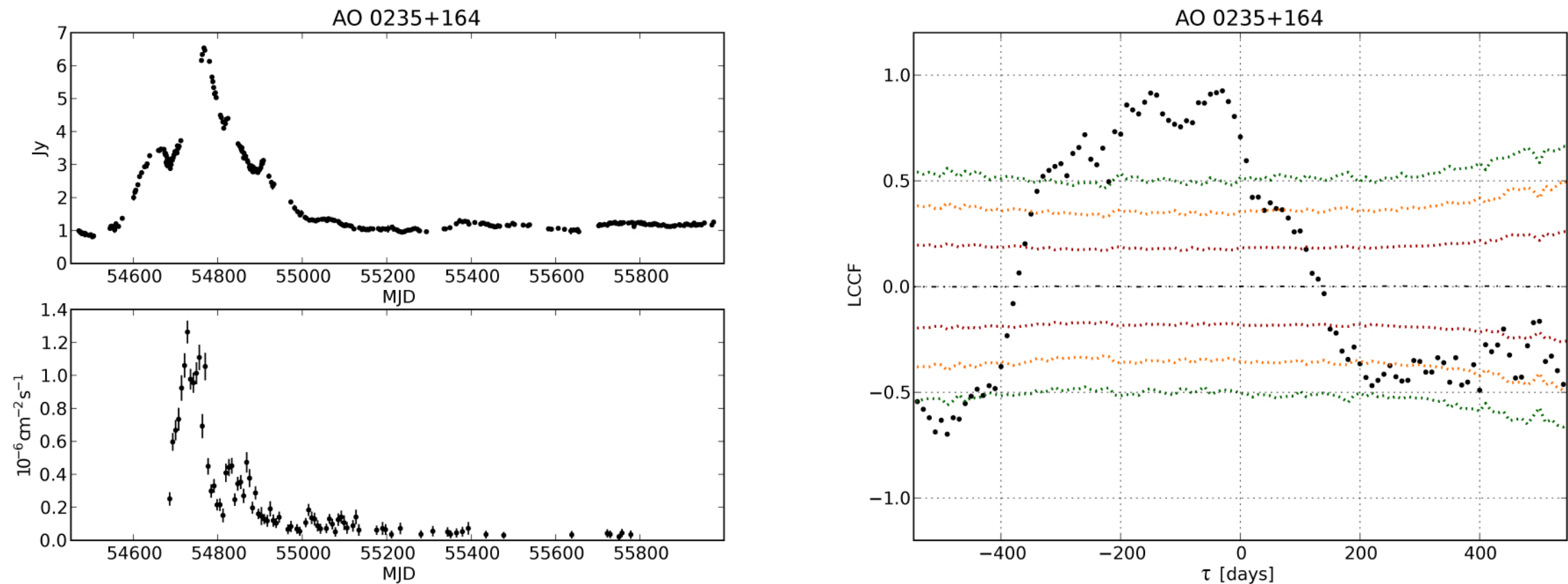


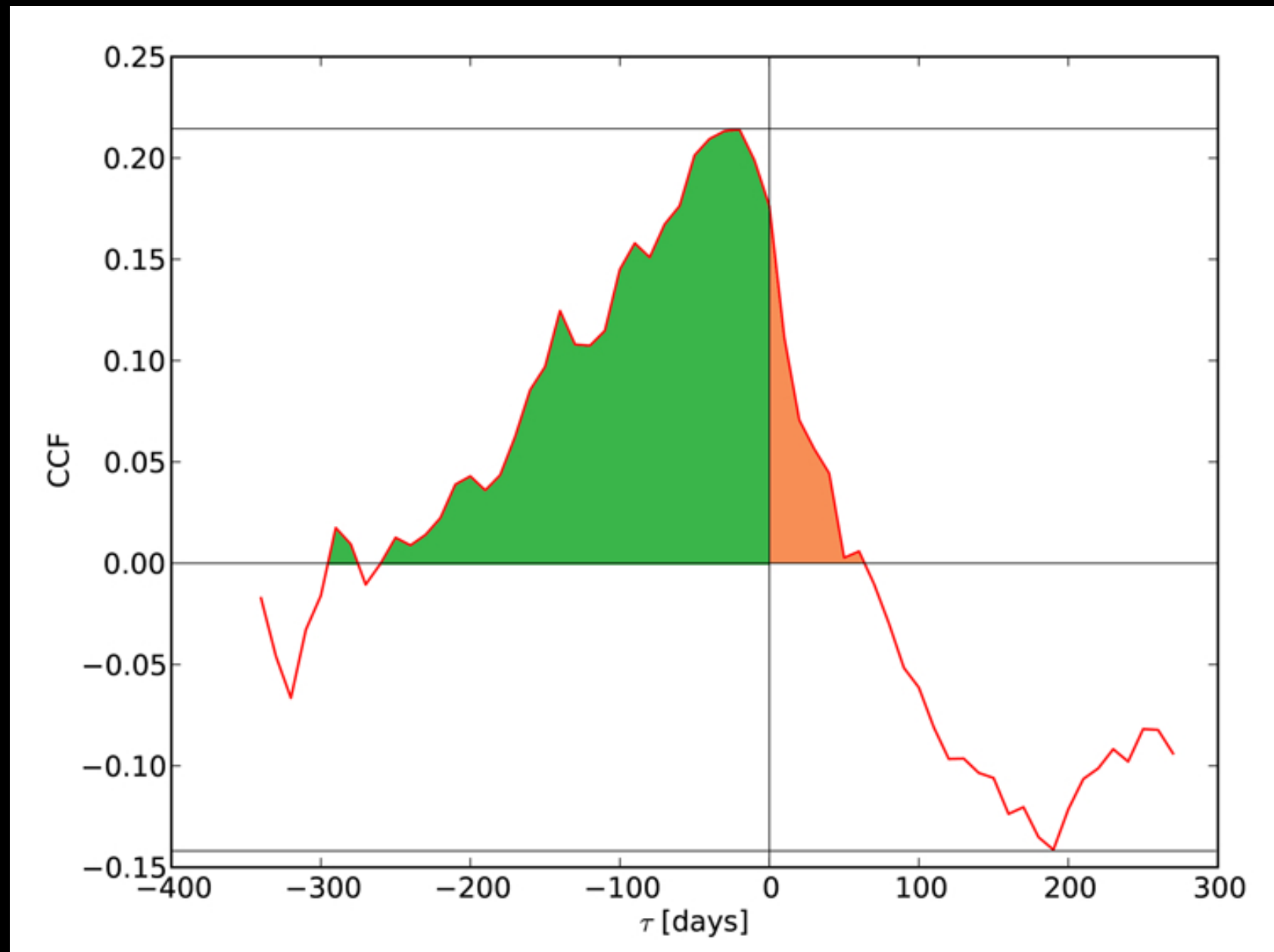
Figure 1: Radio (*top left*) and  $\gamma$ -ray (*bottom left*) light curves of AO 0235+164 and the cross-correlation of the two (*right*). The green line in the right panel shows the  $3\sigma$  significance level.

| Source                                     | $d$<br>[pc] |
|--------------------------------------------|-------------|
| AO 0235+164, $\tau = -150 \pm 8 \text{ d}$ | $37 \pm 23$ |
| AO 0235+164, $\tau = -30 \pm 9 \text{ d}$  | $8 \pm 5$   |

Max-Moerbeck et al (2014)

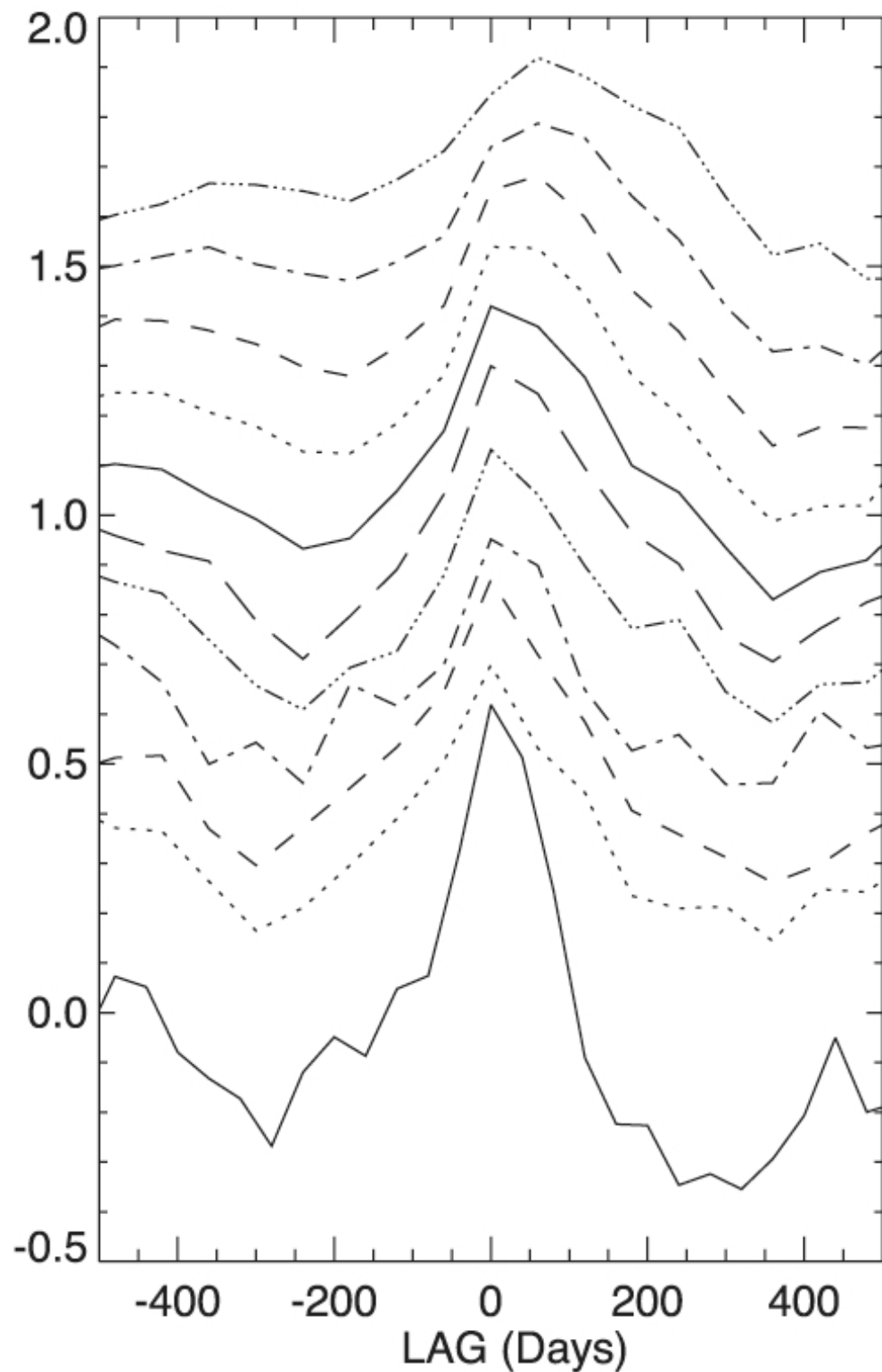


# OVRO / Fermi lightcurve correlation stacking

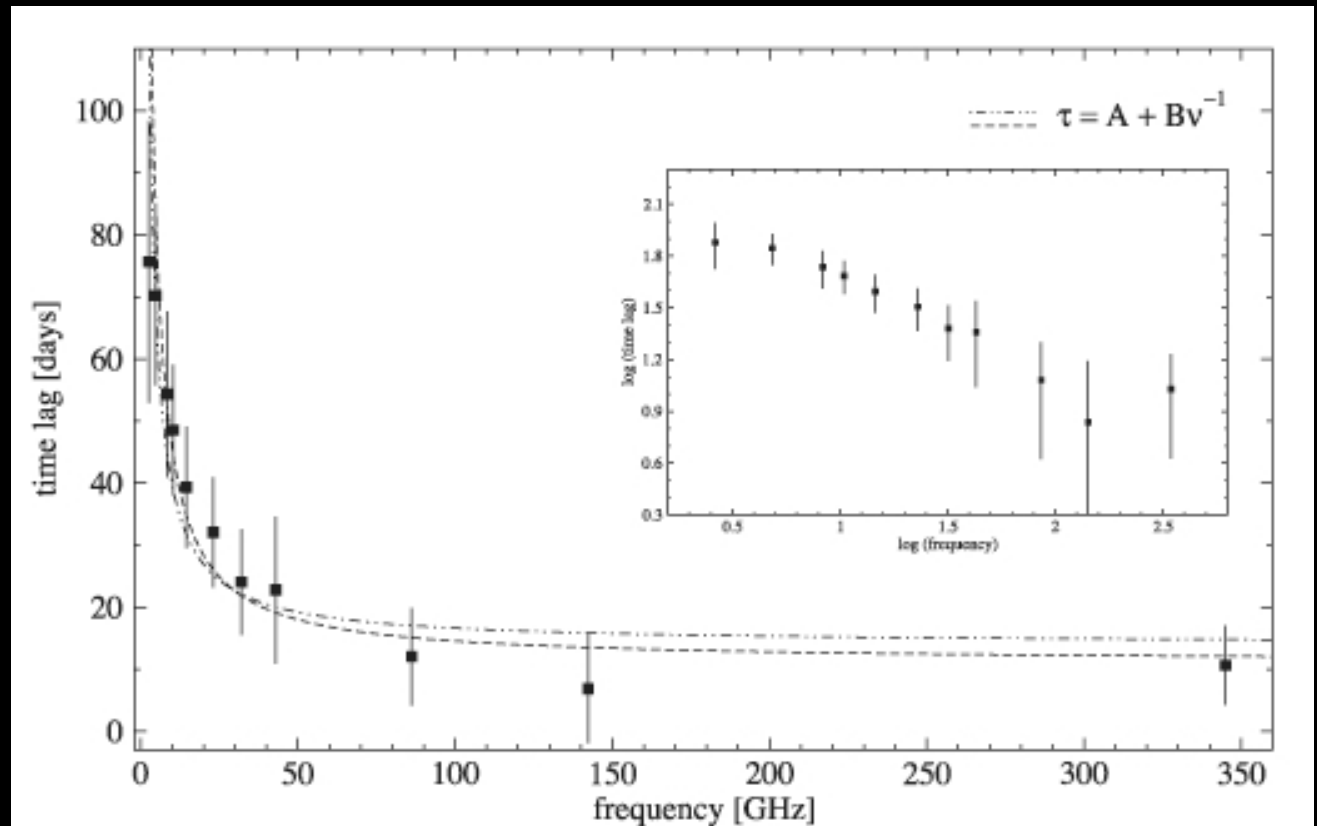


Made with 41 sources from Max-Moerbeck et al (2014)

# Frequency dependent flare delays from F-GAMMA: signature of SSA?



**Figure 4.** Stacked radio/ $\gamma$ -ray DCCFs (source frame) across all radio bands. From top to bottom are shown:  $\gamma$ -ray versus 110, 60, 36, 28, 20, 13, 9, 7, 3, 2 and 0.8 mm wavelength. For better illustration, the 2 mm/ $\gamma$ -ray DCCF has been displaced along the y-axis by 0.35 and the longer radio wavelength ones each by an additional shift of 0.15. Since time values are redshift corrected, fewer data points contribute to the stacked DCCF at large lags which increases the sensitivity to chance correlations (such as the peaks at lags  $-450$  and  $+450$  d).



**Figure 5.** Stacked radio/ $\gamma$ -ray time lags (source frame) versus frequency. Positive lags denote  $\gamma$ -ray leading. A clear trend of decreasing lags towards higher frequencies is evident. The lines represent least-squares fits of the form  $\tau_{r,\gamma}(\nu) = A + B\nu^{-1}$  to all lags (dash-dotted line) as well as omitting the lag of the lowest radio frequency (dashed line). For the former case, the fit parameters  $A$  and  $B$  are 14.1 and 257.4, respectively. The inset displays the data in a logarithmic representation.

Fuhrmann et al. (2013)





#### **Publications January 2014 – June 2015:**

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# Summary

- High cadence,  $> 7\text{yr}$  dataset available to public
- Our statistical approach deals with the red noise problem, so our significance levels are physically meaningful
- Demonstration that radio flares lag the gamma-ray flares. Will improve dramatically with increasing timebase because of better constraints on slopes
- Blazar spectral-polarimetry coming very soon

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## OVRO 40m Telescope

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### Monitoring of *Fermi* Blazars

In 2007, the 40 M Telescope at the Owens Valley Radio Observatory (OVRO) embarked on a new research campaign. In support of the *Fermi* Gamma-ray Space Telescope, launched in 2008, the OVRO 40 M Telescope is monitoring more than 1800 blazars about twice per week.

Our paper, [Blazars in the \*Fermi\* Era: The OVRO 40-Meter Telescope Monitoring Program](#), describes our observing program in detail and presents results from 2008 and 2009. Extended analysis on the differences of radio and gamma-ray selected samples using data between 2008 and 2011 is presented in [Connecting radio variability to the characteristics of gamma-ray blazars](#). Other OVRO publications are listed on the [OVRO 40m Papers](#) page.

The 40 M measurements at 15 GHz are being compared to the *Fermi* gamma-ray measurements of the same sources. By looking for correlations in the variability, we are gaining a new understanding of the emission mechanisms at the hearts of Active Galactic Nuclei.

Reduced data for our core sample, the 1158 [CGRaBS](#) ([Healey et al. 2008](#)) north of  $-20^\circ$  declination, are available to the public. [The data can be obtained here](#). Use the user name *guest* and a blank password for access.

List of all AGN monitored at OVRO can be found [here](#). If you wish to obtain data for a source not listed on our [data](#) page, please [contact us via email](#).

The OVRO 40 M Telescope *Fermi* Blazar Monitoring Program is supported by NASA under awards NNX08AW31G and NNX11A043G, and by the NSF under awards AST-0808050 and AST-1109911.

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