ORIGIN AND EVOLUTION OF MULTI-BAND VARIABILITY IN THE RADIO SOURCE 4C 38.41

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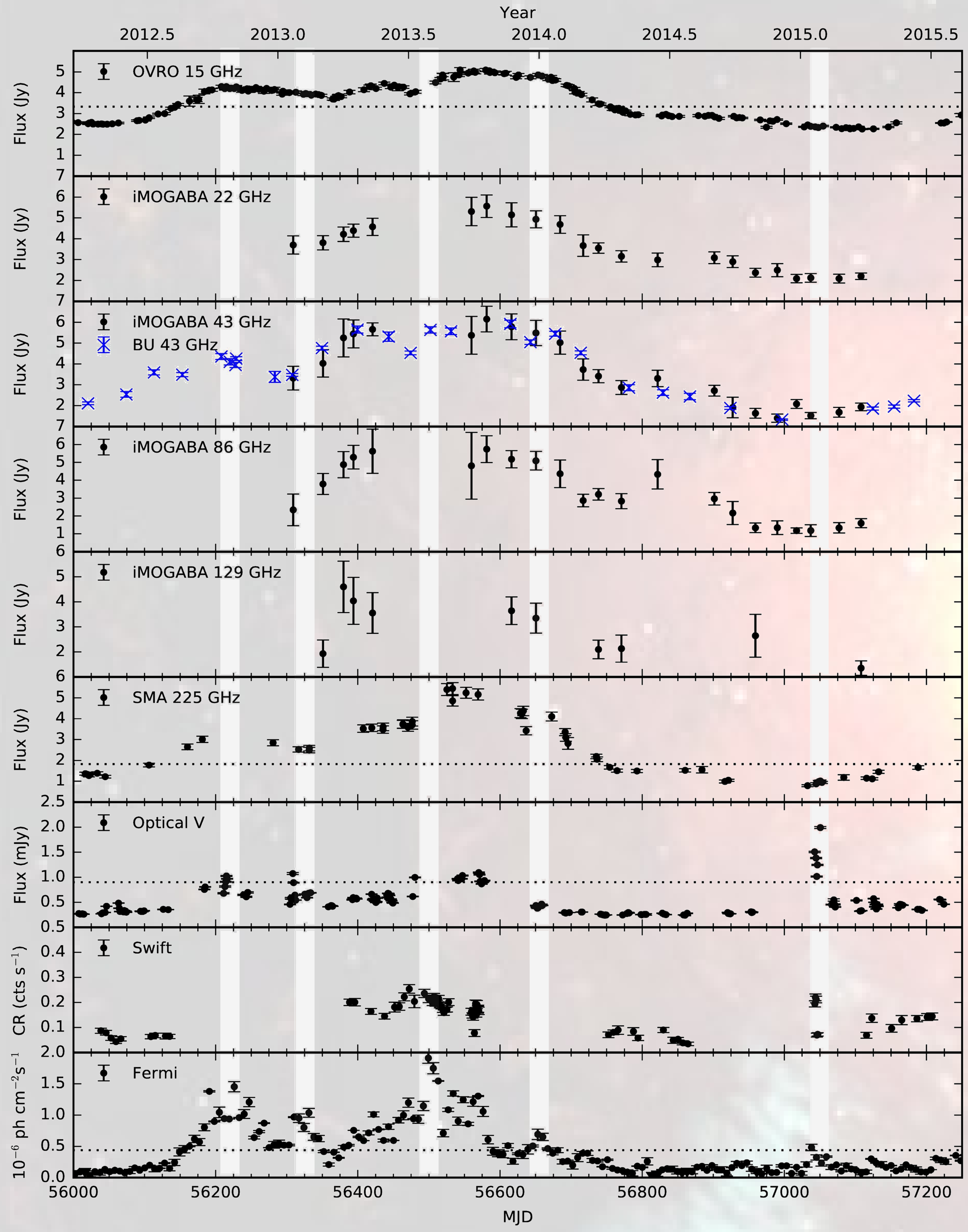
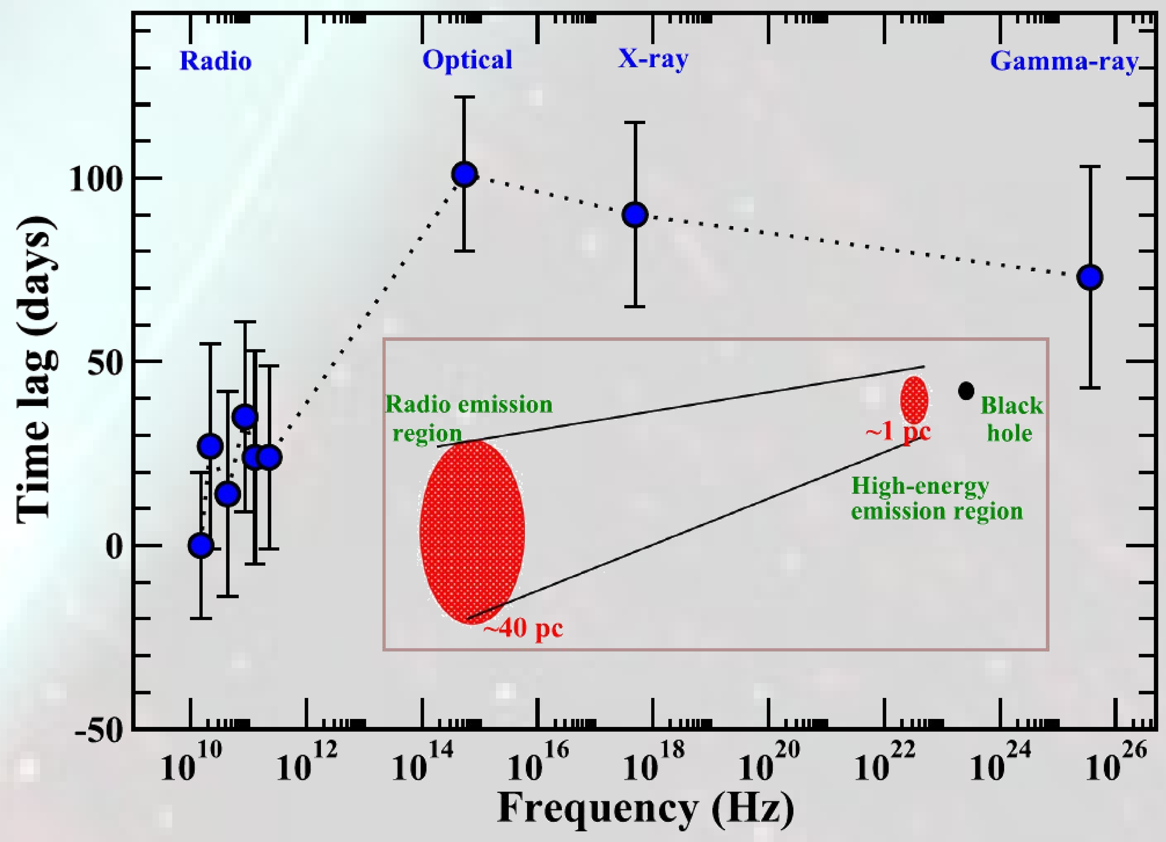
The flat spectrum radio quasar 4C 38.41 showed a significant increase of its radio flux density during the period 2012 March - 2015 August which correlates with gamma-ray flaring activity. Multi-frequency simultaneous VLBI observations were conducted as part of the interferometric monitoring of gamma-ray bright active galactic nuclei (iMOGABA) program and supplemented with additional monitoring observations at various bands across the electromagnetic spectrum. The epochs of the maxima for the two largest gamma-ray flares coincide with the ejection of two respective new VLBI components and the evolution of the physical properties seem to be in agreement with the shock-in-jet model. Derived synchrotron self absorption magnetic fields, of the order of 0.1 mG, do not seem to dramatically change during the flares, and are much smaller, by a factor 10,000, than the estimated equipartition magnetic fields, indicating that the source of the flare may be associated with a particle dominated emitting region.

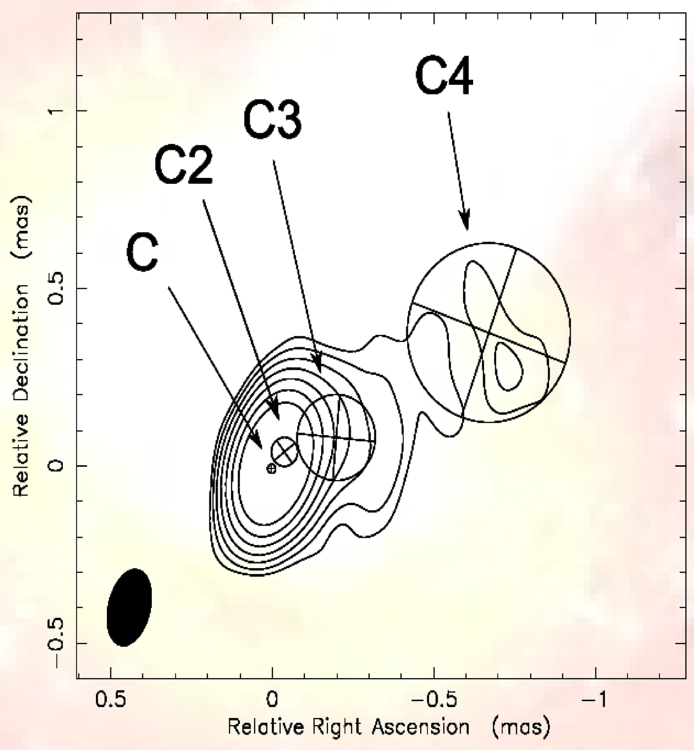
Light curve of 4C 38.41. Horizontal dotted lines show flux threshold (median+3rms in flux density). High flux densities, more than twice as large as usual, are observed in radio bands between MJD 56200 and MJD 56700. The associated optical, X-ray, and γ-ray fluxes seem to follow a similar trend, although for optical and X-rays, the poor sampling complicates the comparison. Moreover, a clear flux peak seen in these bands at MJD 57050 is not visible in any radio band.

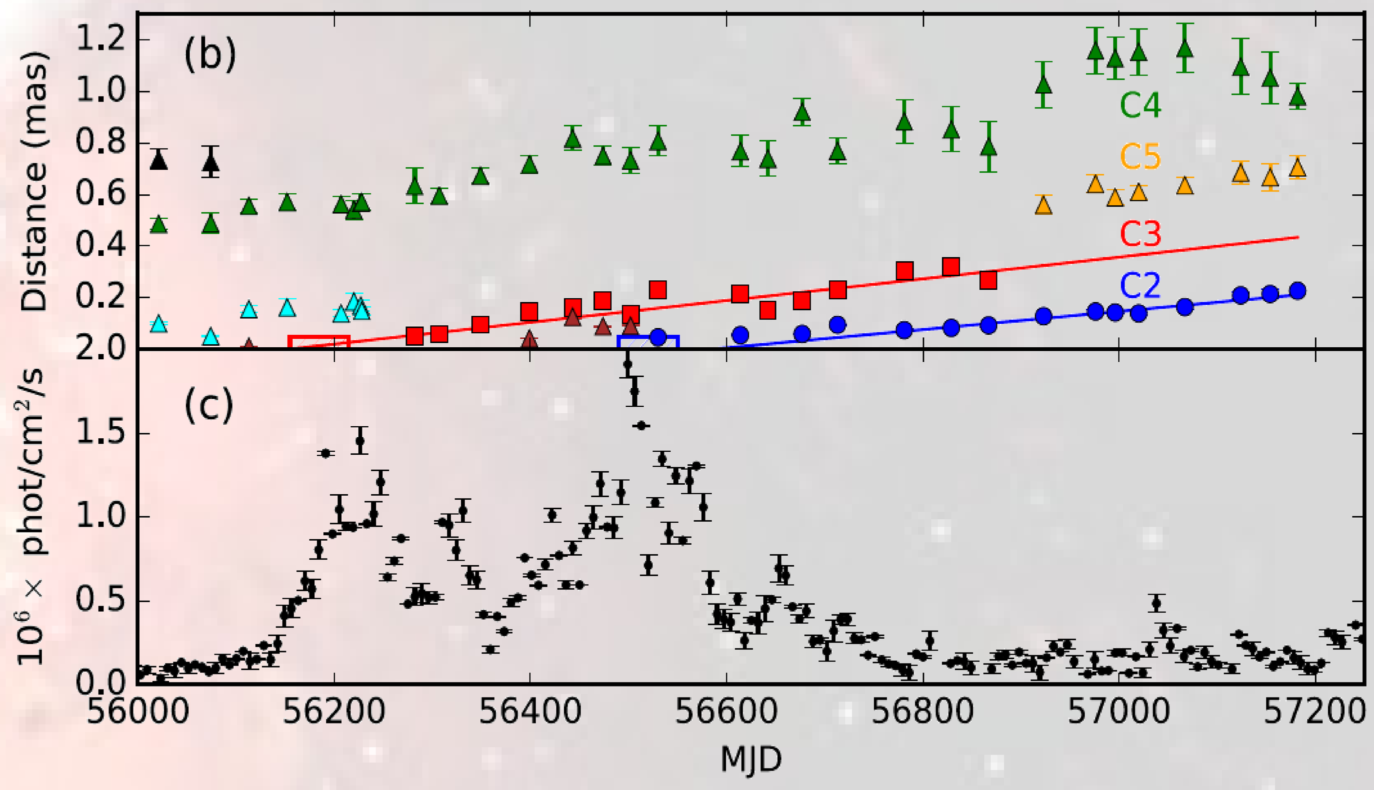


Cross-correlation analysis shows the flux in the different bands to be significantly correlated, with the possible exception of optical bands, where the correlation, while still present, is not statistically significant (<95%).

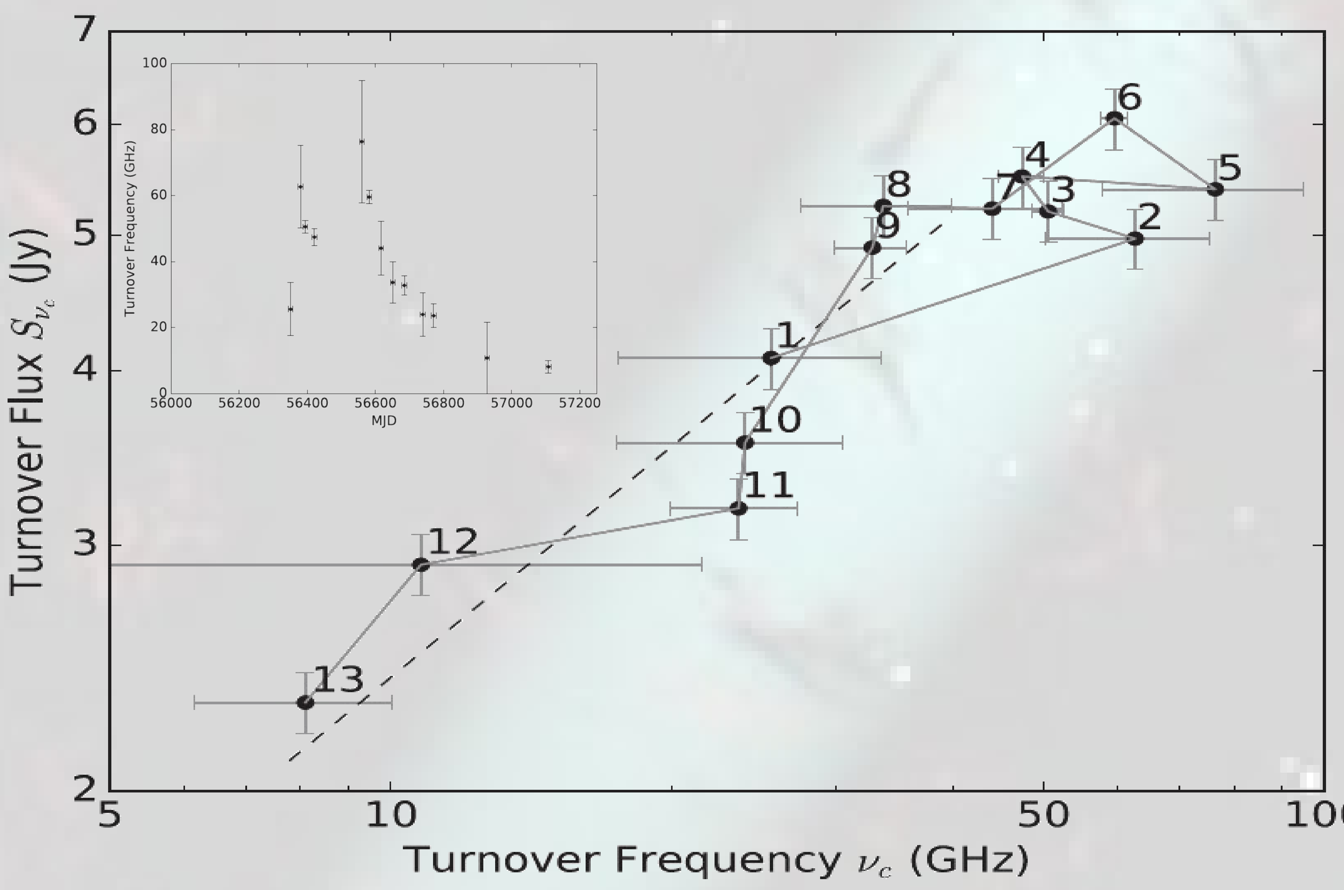
Analysis of the DCF suggests time lags smaller than the uncertainty in the peak of the DCF among radio frequencies, as well as among high energies (optical, X-rays, and γ-rays), whereas a time lag of about 70-90 days is found between radio and high-energy bands, suggesting that the emissions at high energies and in radio bands are produced in two different jet regions, with the γ-rays located at 1±13 pc and radio emission at 40±13 pc from the jet apex.



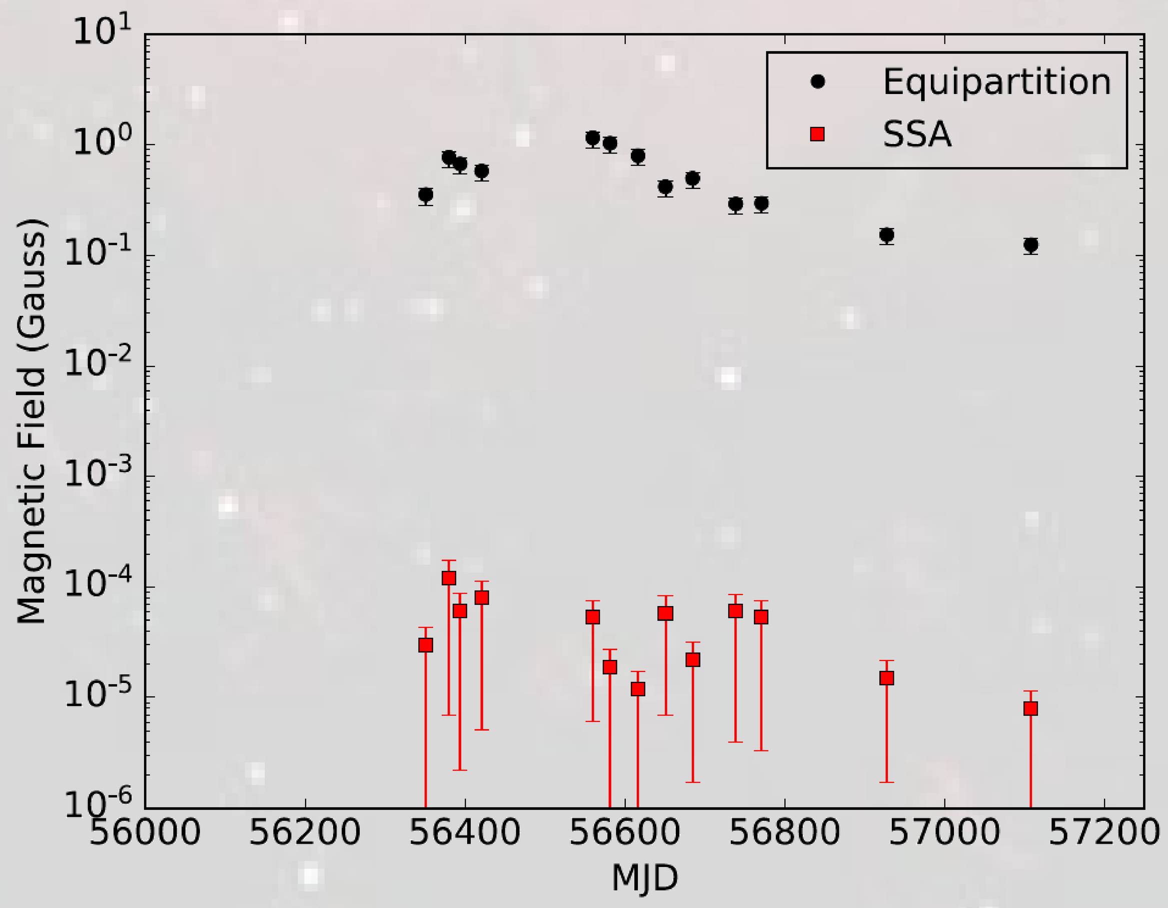




Resolved components by the BU 43 GHz VLBI data are found to be moving away from the core. Two of them, C2 and C3, with speeds of 10.2±0.8 and 11.7±1.6c, have extrapolated ejection epochs MJD=56520±30 and MJD=56185±30, respectively, which fall well within the epochs for which the largest γ-rays were observed. This seems to indicate that the γ-ray flaring is tightly associated with the ejection of these components. There are no radio structural changes associated with the dimmer γ-ray flares. The reported flaring activity in the source can simply be explained by radiative processes having a constant Doppler factor.



The turnover frequency shifts from few GHz to few tens of GHz after the more luminous, long-lived γ-ray flares occur. The evolution of the flare in the turnover frequency—turnover flux density plane shows an initial complicated pattern for the Compton and synchrotron losses stages due to the overlap of the effects from two interleaved flares, while the adiabatic loss stage is very clear, with a slope ϵ_{adiab}=0.6±0.1, in agreement with the shock-in-jet model in Marscher & Gear (1985).



The estimated magnetic field strength via synchrotron self-absorption considerations does not significantly vary over time and is of the order of 0.1mG, smaller by a factor 10^4 than the magnetic field strength estimated using equipartition arguments. These two findings suggest that the emitting region of the flares is particle dominated.

***Conclusions*:**

4C 38.41 showed an increase of its radio flux density correlated with γ-ray flares with radio enhancement following that of high energies by about 70-90 days.

This phenomena can be associated with the ejecta of new components from a particle dominated region, becoming visible as radiation reaches optically thin regions.

Follow-up of the components location, speed, flux density and turnover frequency show that emission is in agreement with the shock-in-jet model adiabatically expanding with a constant Doppler factor.

References:

Algaba et al. 2018a ApJ, 52, 30
Algaba et al. 2018b ApJ, 859, 128
Marscher & Gear 1985, ApJ, 298, 114