Gamma-ray emission of narrow-line Seyfert 1 galaxies.

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Introduction:

Narrow-line Seyfert 1 (NLS1) galaxies are a class of AGN characterized by a rather narrow width of Hβ Balmer emission line (FWHM <~ 2000 km/s), presence of a strong FeII bump and flux ratio [OIII]/Hβ < 3 (Osterbrock and Pogge, 1985; Pogge, 2000). The fraction of radio detected NLS1 in the FIRST survey is 7.1%, significantly lower than for broad-line Seyfert 1 AGN (10.2%, Zhou, 2006). There are however a few cases of very radio-loud NLS1 (RL-NLS1) with R > 10^3, flat radio spectrum and rapid variability, suggesting the presence of relativistic jets which point towards us, like those observed in blazars.

The Fermi/LAT detection of gamma-ray emission from the radio-loud NLS1 PMN 0948+0022 (Foschini et al., 2009a; Abdo, 2009a; Abdo, 2009b) and successively from 1H0323+342, PKS 1502+036 and PKS 2004-447 (Abdo, 2009c) definitively confirms the presence of jets closely aligned to the line of sight. The analysis with the synchrotron and inverse-Compton model, used to fit blazar's SED (Ghisellini and Tavecchio, 2009), provides a good fit of data and allows us to estimate the jet power which is in the range of quasars for the first two, and in the range of BL Lac objects for the remaining two RL-NLS1. However the black hole mass estimates for these objects are one or two order of magnitude smaller than for blazars, (10^6 – 10^8 M_{sun}) and the Eddington ratios are very high (up to 90% for 1H 0323+342), positioning the RL-NLS1 in a not yet populated zone in the EV1 plane (mass vs accretion rate, Boroson, 2002). Furthermore the width of the Hβ emission line is the narrowest among all type-1 AGNs. Finally, blazars are hosted in elliptical galaxies while Seyfert are likely to be found in spirals. Thus the RL-NLS1 constitute a new class of gamma-ray emitting AGN.

The RL-NLS1 sources have proven to be highly variable in their gamma-ray emission, this allows us to infer an upper limit for the size of the emitting blob which amounts to ~300 AU. The observed gamma-ray luminosity generated in such a small volume implies an optical depth for pair creation much greater than unity, which would finally inhibit the emission of gamma-rays unless relativistic effects are taken into account. The aim of this work is to measure the minimum gamma-ray variability timescale (τ_{min}) in order to estimate a lower limit for the relativistic Doppler factor (δ). This allows us to constrain the values for the bulk Lorentz factor and the angle between the jet axis and the line of sight.

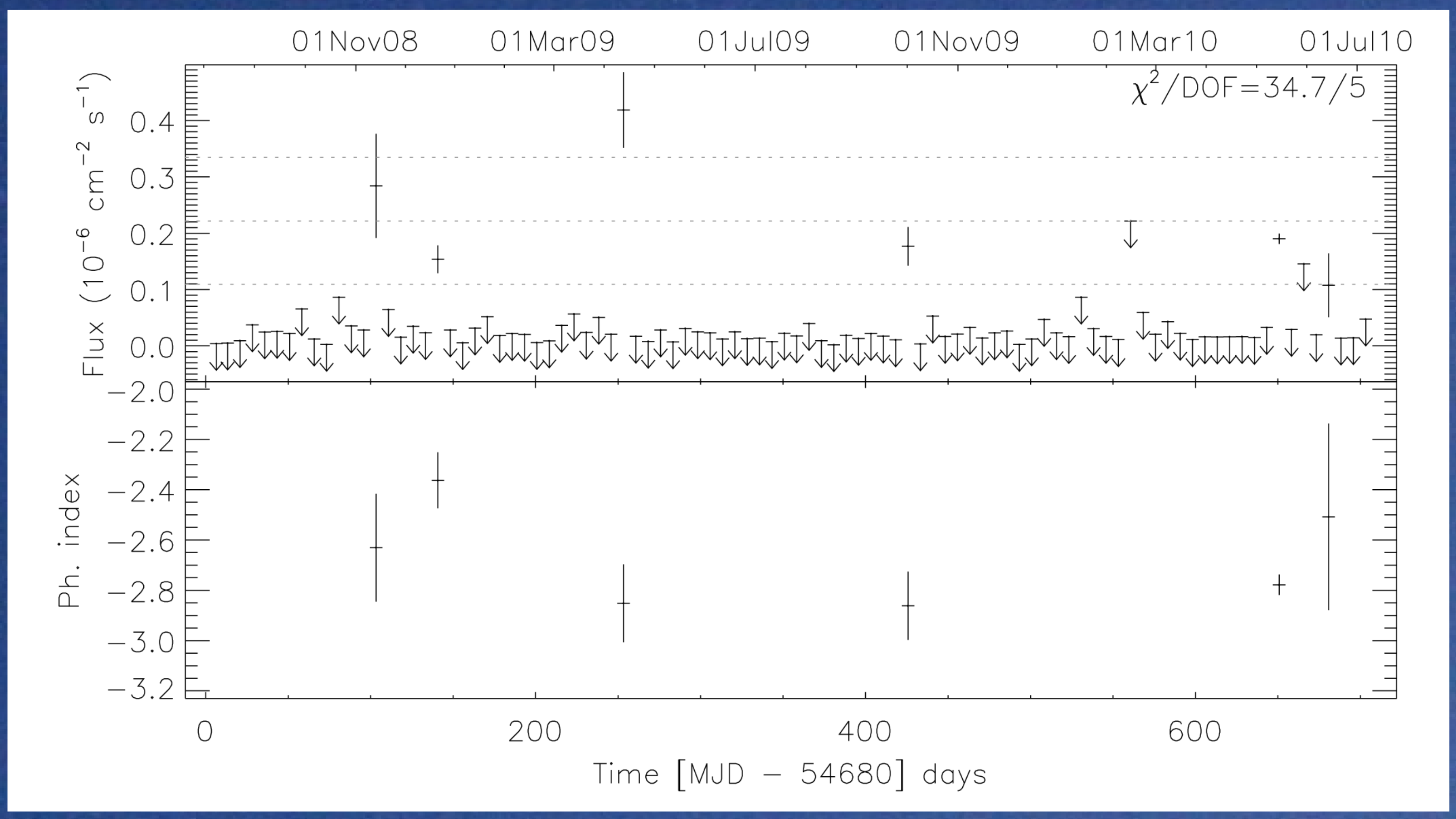
$$\delta \gtrsim \left[0.03\frac{\sigma_T}{c^2}\frac{D_L^2}{\tau_{min}}F_x\left(\frac{E_x E}{m^2c^4}\right)^{\alpha}(1+z)^{2\alpha}\right]^{1/(4+2\alpha)}$$

σ_T :Thomson cross section;
D_L: luminosity distance;
τ_{min} minimum e-folding time;
F_x: X-ray flux density;
α: X-ray spectral index;
Z: redshift;
E_x: target photon energy;
E: bullet photon energy;

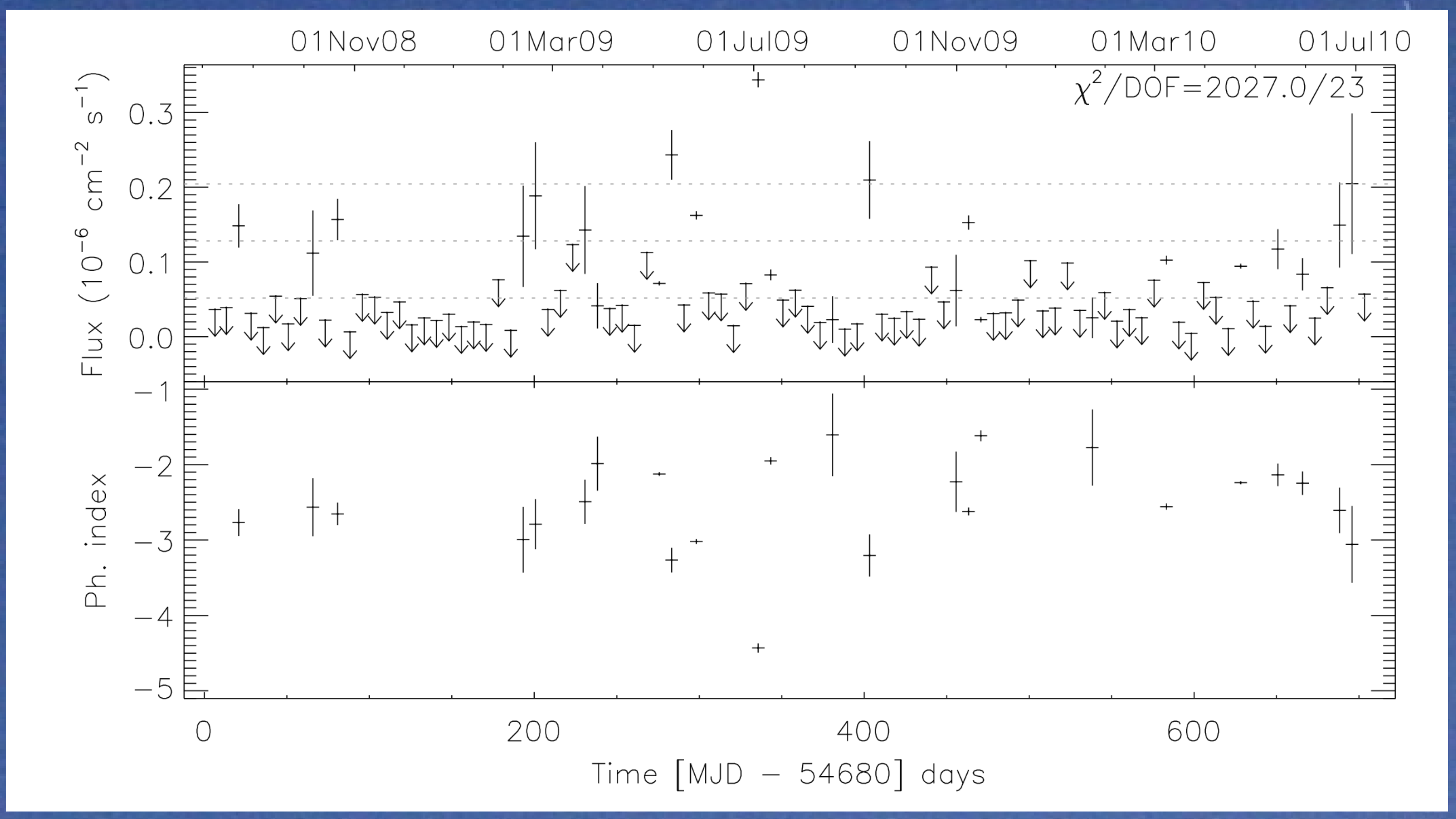
Data Analysis:

We extracted light curves spanning the period from aug-04-2008 to jul-10-2010 with time binnings ranging from ~5 hours to 30 days. Light curves with time binning of 7.5 days are shown in figures below (top panels, Y error bars are equal to 1σ errors). When the detection was not statistically significant we computed an upper limit. The lower panels show the spectral indices α ($F \propto E^{+\alpha}$) with their 1σ errors. A statistically significant variability is present, as is shown by a chi-squared test performed against the null hypotesis of constant flux (values of chi-squared and DOF in the upper right corner of top panels). The timescale variability is computed as the minimum e-folding time (among all time binnings) between points having TS>25 (except PKS 2004-447, TS>16) and a flux difference greater than √TS times the maximum error involved.

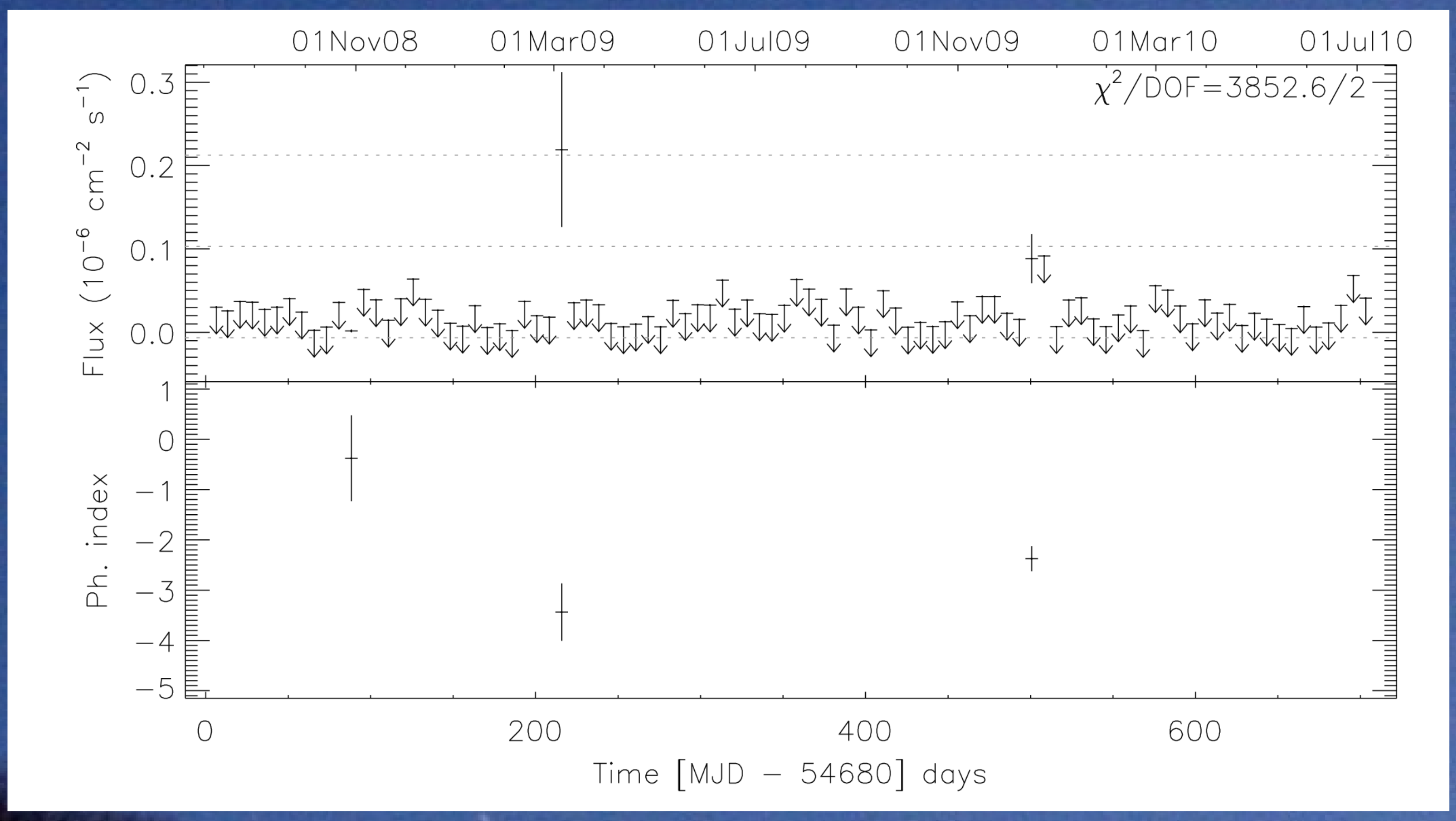
1H 0323+342



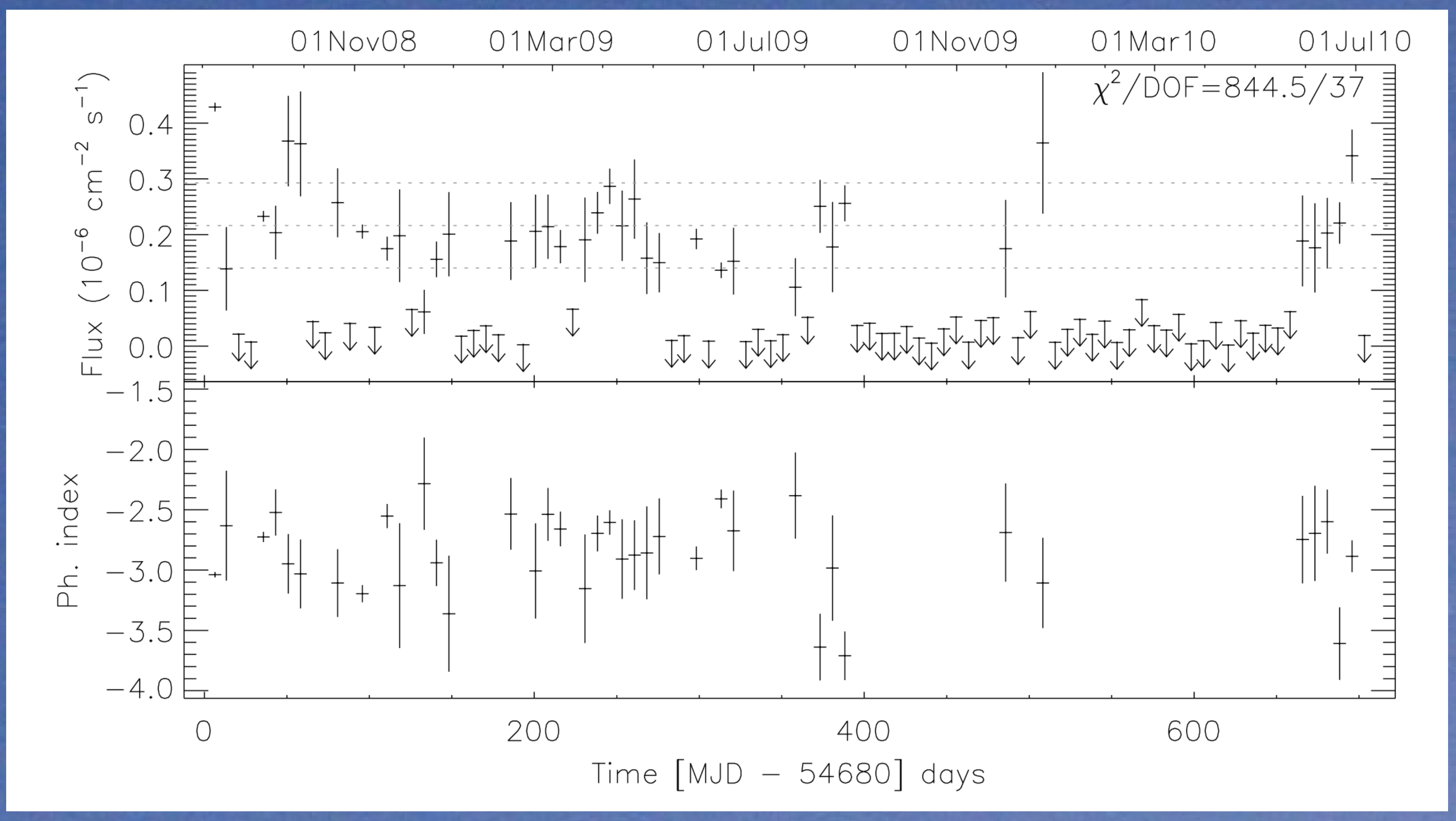
PKS 1502+036



PKS 2004-447



PMN J0948+0022



Results:

The results of this analysis are reported in Tab. 1. The relativistic Doppler factor allows to constrain the bulk Lorentz factor and the angle between the jet axis and the line of sight through the formulae shown on the right. The resulting lower limits for the bulk Lorentz factors are compatible with the values found independently in Abdo, 2009c by fitting the SED, and confirms the presence of relativistic bulk motion towards the observer.

$$\Gamma_{min} = \left[1-\left(\frac{\delta^2-1}{\delta^2+1}\right)^2\right]^{-1/2}$$

$$\theta_{max} = asin\left(\frac{1}{\delta}\right)$$

Source	z	D_L [Gpc]	Flux@1keV [μJy]	α	τ_{min}@1GeV [days]	$\Delta\tau_{min}$ [days]	δ_{min}	Γ_{min}	θ_{max} [deg]	R_{max} [AU]
PMN J0948+0022	0.59	3.40	0.96	0.7	1.70	0.85	2.9	1.6	20.2	535.7
1H 0323+342	0.06	0.27	3.40	1.0	0.67	0.59	1.5	1.1	42.8	159.6
PKS 1502+036	0.41	2.20	0.04	0.0	35.56	14.60	0.6	1.1	—	2836.0
PKS 2004-447	0.24	1.20	0.37	1.1	56.27	6.82	0.9	1.0	—	6764.0

Tab. 1: results of the analysis. Columns are: 1: source name, 2: redshift, 3: luminosity distance, 4: X-ray flux density, 5: X-ray spectral index, 6: minimum gamma-ray e-folding time, 7: associated error, 8: minimum relativistic Doppler factor, 9: minimum bulk Lorentz factor, 10: maximum angle between the jet axis and the line of sight, 11: minimum size of emitting region.

Since these sources may be sporadically active we expect that other sources may become detectable in the future. Thus we are currently monitoring the gamma-ray activity of a set of 29 sources to eventually enlarge the sample of gamma-ray detected RL-NLS1.

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