PROCEEDINGS OF SCIENCE

Are Local Interstellar Clouds Responsible for Annual Modulation in IDV Sources?

K. É. Gabányi*,[ab] **T. P. Krichbaum,**[c], **N. Marchili,**[c] **and L. Fuhrmann**[c]

[a]*FÖMI Satellite Geodetic Observatory*
Budapest, P.O. Box 585 1592, Hungary
[b]*Hungarian Academy of Sciences, Research Group for Physical Geodesy and Geodynamics*
Budapest, Hungary
[c]*Max-Planck-Insitute für Radioastronomie*
Auf dem Hügel 69, Bonn 53121 Germany
E-mail: `gabanyik@sgo.fomi.hu`

Intraday Variability (IDV) is the short timescale flux-density variation observed usually at cm wavelengths in blazars. Source-extrinsic theory explains IDV as a propagation effect: it is caused by interstellar scintillation (ISS) of radio waves in the turbulent ionized plasma of the Milky Way. One of the most convincing arguments in favor of a source-extrinsic explanation is the so-called annual modulation of the IDV timescale. The characteristic variability timescale is inversely proportional to the relative velocity between the observer and the scattering medium. As the Earth orbits around the Sun, the observer's velocity (and thus the relative velocity vector between the observer and the scattering medium) undergoes a systematic seasonal cycle. This annual velocity variation is observed as an annual change in the variability timescale of the IDV source. Thus, the velocity of the scattering screen can in principle be deduced from the annual modulation curve. However, in practice the results obtained from the fit to the data are not unique. A viable approach is to use independent measurements of the scattering screens' velocity. These values can be obtained from published studies of the Local Interstellar Medium (LISM). In the following, we investigate whether LISM cloud velocities can be used to fit the observed annual modulation in three IDV sources.

10th European VLBI Network Symposium and EVN Users Meeting: VLBI and the new generation of radio arrays
September 20-24, 2010
Manchester Uk

---

*Speaker.

http://pos.sissa.it/

PoS(10th EVN Symposium)078

1. Introduction

Approximately 25-40% of blazars show the phenomenon called Intraday Variability (IDV, [1]), which is a fast variation of the flux density at cm wavelengths. Its timescale ranges from a few days to 20 minutes, the amplitude of the variation can be a few percents or as high as 100 %. The observed short variability timescales make it very difficult to explain IDV as source-intrinsic effect. If the variation originated from the source itself, using causality and the common light-travel time arguments, the short timescales would invoke source sizes in the range of μas, and consequently, very high brightness temperatures. Brightness temperature values in excess of the equipartition limit ($5\text{x}10^{10}$ K, [2]) are usually explained via relativistic beaming. However, in the case of IDV sources, the invoked Doppler factors are much higher than those derived from kinematic studies of features in the highly relativistic jets of blazars. But source-extrinsic theory interpreting IDV as a propagation effect usually can succesfully explain the short timescales. In this interpretation, IDV is caused by interstellar scintillation (ISS) of radio waves propagating through the turbulent ionized plasma of the Milky Way (e.g., [3]).

One of the most convincing arguments in favor of an extrinsic explanation is the so-called annual modulation of the IDV timescale. The characteristic variability timescale is inversely proportional to the relative velocity between the observer and the scattering medium. The observer's velocity (and so the relative velocity vector between the observer and scattering medium) undergoes a systematic annual modulation as the Earth orbits around the Sun. This annual velocity variation is observed as an annual change in the variability timescale of the IDV source (e.g. [4]). When modelling the annual cycle in an IDV source, the velocity of the scattering screen is one of the fit parameters. However, in practice, the velocity estimate is not unique. This problem can be overcome, if additional measurements exist - for example the IDV timescales and annual modualtion are also measured and fitted at other frequencies [5]. Another possible approach is to obtain independent velocity measurements of nearby ionized interstellar clouds which can constrain the annual modulation model. [6] used high resolution LISM observational data to study the kinematical properties of the closest ($\lesssim 17$ pc) clouds in the LISM. They identified and derived velocity vectors for 15 local clouds. These very nearby clouds may be responsible for the variability in the fastest IDV sources (e.g., [5] and references therein). [7] used this data to study three IDV sources, which were reported to show annual modulation. For each source, the line of sight appears to pass through or very near to at least two clouds. The authors obtained very good fits to the annual cycles using the velocities of near-by LISM clouds. We followed their approach and studied three IDV sources showing annual modulation.

2. Observations and data reduction

The quasar B1519-273 was originally studied by [7], and the authors used the timescale measurements of [8]. Since the publication of the [7] paper, results of more extensive observational campaign of B1519-273 and fits of its annual modulation cycle were published by [9]. Together with B1622-253, B1519-273 was monitored by [9] using the University of Tasmania 30-m radio telescope near Ceduna (South Australia) between 2002 and 2004 at 6.7 GHz. In the following, we use their timescale measurements.

Since December 2004, J1128+5925 has been regularly monitored by our team [10] in more than 30 densely time-sampled flux-density monitoring observations with the Effelsberg 100-meter (MPIfR, Germany) and the Urumqi 25-meter (PR China) radio telescopes at 5 GHz. These observations were summarized in previous papers ([11] and references therein). Regarding the observational techniques and data reduction steps we refer to [12], as well as [13] and [14].

3. The anisotropic annual modulation model

In all IDV sources, where annual modulation of the variability timescale was observed, the fit to the observations required to introduce anisotropic scintillation. In this scenario the variability timescale depends on the following parameters: the velocity of the scattering screen, the scintillation length-scale (the product of the scattering size and the screen distance, s), the ellipticity of the scintillation pattern (r) and the direction in which the relative velocity vector "cuts through" the elliptical scintillation pattern. Following [5], an analytic expression of the IDV timescale ($t\,(T)$) for the anisotropic annual modulation is given by the following equation: $t\,(T) = \frac{s\sqrt{r}}{\sqrt{\mathrm{v}(T)^2+(r^2-1)(\mathbf{v}(T)\times\mathbf{S})^2}}$, where $\mathbf{v}\,(T)$ is the relative velocity between the scintillation screen ($\mathbf{v}_{\mathrm{screen}}$) and the observer (the Earth, $\mathbf{v}_{\oplus}$), $\mathbf{v}\,(T) = \mathbf{v}_{\oplus}\,(T) - \mathbf{v}_{\mathrm{screen}}$ (in the plane of the sky). As the Earth orbits around the Sun, $\mathbf{v}_{\oplus}\,(T)$ (and consequently $\mathbf{v}\,(T)$ as well) varies annually. v denotes the absolute value of $\mathbf{v}$. $\mathbf{S}$ is the unit vector defining the orientation of the elliptical scintillation pattern. When fitting the model, we derive the velocity of the scattering screen in right ascension (v_{α}) and in declination (v_{δ}) direction.[1]

4. Results

According to [6], the line of sight of B1519-273 traverses the "G cloud" and the "Gem cloud", and it passes near to the "NGP" (20°) and "Leo cloud" ($\lesssim 5^{\circ}$). B1622-253 and B1519-273 are located very close on the sky, thus their LISM environments are almost the same. The line of sight of B1622-253 traverses the "G cloud", and passes near the "Gem" ($\sim 10^{\circ}$), "Mic" ($\sim 20^{\circ}$), "NGP" ($\sim 20^{\circ}$) and "Aql clouds" ($\sim 17^{\circ}$).(Distance values given in parenthesis are estimates based upon the figures in [6].) For each source, we tried to fit the variability timescales using velocities of all these clouds. The best fits (lowest reduced χ^2 1.6 and 1.9 for B1519-273 and B1622-253, respectively) were obtained in both cases by using the velocity of the "Gem cloud". (The parameters of the fit, and the annual modulation plots are given in the accompanying attachement.) The ratio and angles of anisotropy of the two fits are very similar strenghtening the hypothesis that the same scattering material is responsible for the IDV in both sources. Both sources are part of the MOJAVE survey [15]. Gaussian modelfits to the visbilities of the MOJAVE data revealed that the ratio of the size of the cores of the two sources are identical to the ratio of the scattering length-scale. Thus, the smaller scintillating source size is repsonsible for the shorter timescale of B1519-273.

For J1128+5925, we did not find any nearby ($\lesssim 20^{\circ}$) LISM cloud among those identified by [6], whose velocity would provide a good fit to the annual modulation of the variability timescale.

---

[1] In their paper, [9] derived the velocity vector components of the scattering screen with respect to the LSR. In the following, where we reference their annual modulation parameters, we transformed their original velocity values to be in accordance with ours (which is given with respect to the solar system barycenter).

Acknowledgments

This paper made use of data obtained with the 100-meter Effelsberg radio telescope of the Max-Planck-Institut für Radioastronomie (Bonn, Germany) and the 25-meter Urumqi Observatory of the National Astronomical Observatories (NAOC) of the Chinese Academy of Sciences (CAS). This research has made use of data from the MOJAVE database that is maintained by the MOJAVE team. This work was supported by the Hungarian Scientific Research Fund (OTKA, grant No. K72515) and it may or may not have been supported by the Hungarian Space Office of the National Office for Research and Technology (URK09314).

References

[1] D. S. Heeschen, T. P. Krichbaum, T. Schalinski, A. Witzel, *Rapid variability of extragalactic radio sources*, *AJ* **94** (1987)

[2] A. C. S. Readhead, *Equipartition brightness temperature and the inverse Compton catastrophe*, *ApJ* **426** (1994)

[3] B. J. Rickett, *Radio Sources and Scintillation, Astrophysics and Space Science* **278** (2001)

[4] J. Dennett-Thorpe & A. G. de Bruyn, *Interstellar scintillation as the origin of the rapid radio variability of the quasar J1819+3845, A&A* **404** (2003)

[5] H. Bignall et al., *Rapid interstellar scintillation of PKS B1257-326: Two-Station Pattern Time Delays and Constraints on Scattering and Microarcsecond Source Structure*, *ApJ* **652** (2006)

[6] S. Redfield, & J. L. Linsky, *The Structure of the Local Interstellar Medium. IV. Dynamics, Morphology, Physical Properties, and Implications of Cloud-Cloud Interactions*, *ApJ* **673** (2008)

[7] J. L. Linsky et al., *The Origin of Radio Scintillation in the Local Interstellar Medium*, *ApJ* **675** (2008)

[8] D. L. Jauncey et al., *Interstellar Scintillation and Annual Cycles in the BL Lac Source PKS 1519-273, Astrophysics and Space Science* **288** (2003)

[9] S. J. B. Carter et al., *Annual Cycles in the Interstellar Scintillation Timescales of PKS B1519-273 and PKS B1622-253*, *MNRAS* **396** (2009)

[10] N. Marchili et al., *Observations of IntraDay Variable sources with the Effelsberg and Urumqi Radio Telescopes*, in proceedings of *Dynamic2007,* `PoS(Dynamic2007)019`

[11] K. É. Gabányi et al., *High resolution studies of the IDV quasar J1128+592*, *Journal of Physics Conference Series*, **218** (2010)

[12] K.É. Gabányi, et al., *The IDV source J 1128+5925, a new candidate for annual modulation?, A&A* **470** (2007)

[13] L. Fuhrmann et al., *Testing the inverse-Compton catastrophe scenario in the intra-day variable blazar S5 0716+71. III. Rapid and correlated flux density variability from radio to sub-mm bands, A&A* **490** (2008)

[14] N. Marchili, *Variability studies of a sample of IntraDay Variable sources*, Ph.D. thesis, Max-Planck-Institut für Radioastronomie (2009)

[15] M. Lister et al., *MOJAVE: Monitoring of Jets in Active Galactic Nuclei with VLBA Experiments. VI. Kinematics Analysis of a Complete Sample of Blazar Jets, AJ* **138** (2009)