Intraday Variability and the Local Interstellar Medium

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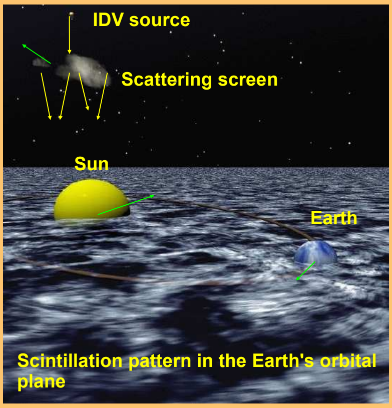
25% - 30% of blazars show **Intraday Variability** (IDV), few hours to few days long variations of their radio flux density (Heeschen et al., 1987; Witzel et al., 1986). If interpreted as being source intrinsic, the short variability time-scale would imply – through the light travel time argument – micro-arcsecond-scale sizes of the emitting regions, which would result in excessively large apparent brightness temperatures, in the range of 10^{16} – 10^{21} K. This is far in excess of the inverse-Compton limit of 10^{12} K (Kellerman & Pauliny-Toth, 1969). Theories explaining IDV with variations intrinsic to the quasar require excessively large Doppler boosting factors, special source geometries or coherent and collective plasma emission.

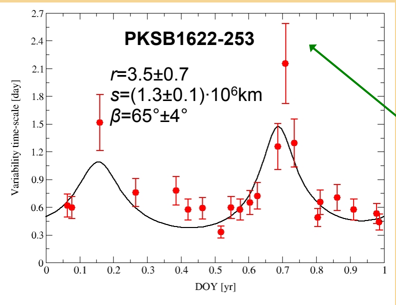
However, the source-extrinsic theory explains IDV as a propagation effect. In this interpretation, IDV is caused by interstellar scintillation (ISS) of radio waves in the turbulent ionized plasma of the Milky Way (e.g., Rickett, 2001). One of the most convincing arguments in favor of an extrinsic explanation is the so-called **annual modulation** of the IDV time-scale. The characteristic variability time-scale 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 time-scale of the IDV source (e.g. Dennett-Thorpe & de Bruyn, 2003).

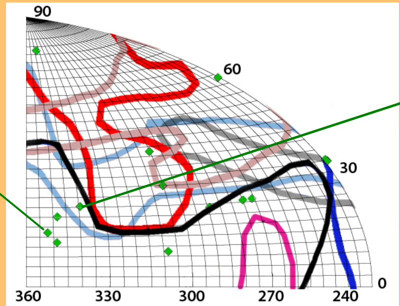
So far in every IDV source showing annual modulation, anisotropic annual modulation model was used to describe the seasonal variation of the time-scale. In the anisotropic model, the scintillation time-scale also depends on the ellipticity of the scintillation pattern and on the direction in which the relative velocity vector (between the Earth and the screen) "cuts through" this elliptical scintillation pattern. Thus, the fitted parameters obtained from the anisotropic scintillation model are the **velocity components of the scattering screen** (v_α and v_δ), the **scattering length-scale** (*s*, which depends on the screen distance and the scattering angle), the **angular ratio of the anisotropy** (*r*) and its **position angle** (β).

Recently, Redfield & Linsky (2008) published kinematical properties of the closest clouds within the Local Interstellar Medium (LISM). Linsky et al. (2008) investigated whether the reported cloud properties can explain the annual modulation pattern seen in three IDV sources. Here we follow their approach and study three IDV sources showing annual modulation. The time-scale measurements of PKS B1519-273 and PKS B1622-253 are from Carter et al. (2009). Those of J1128+5925 are our own (Gabányi et al., 2009).

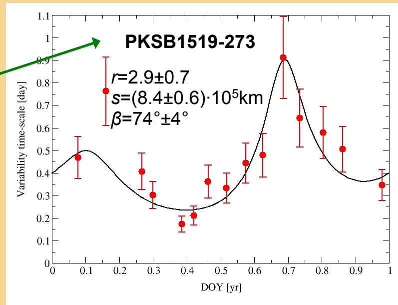


Sketch of the annual modulation model. Green arrows represent velocity vectors (Fuhrmann 2004, PhD thesis, Bonn Univ.).





Clouds in the LISM from Redfield & Linsky (2008). (Hammer projection of Galactic coordinates). Thick color lines represent cloud boundaries: blue for LIC, grey for Aur, light blue for Gem, red for NGP, salmon for Leo, magenta for Cet, black for G. Green symbols are IDV sources.



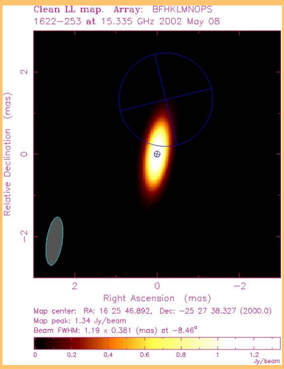
PKS B1622-253: According to the LISM model of Redfield & Linsky, the line of sight of the source traverses the G cloud and passes near to the Gem, Mic, NGP and Aql clouds. When fitting the annual modulation of the variability time-scale the lowest χ^2 value was obtained using the velocities of the Gem cloud, χ^2=1.8 (solid black line in the plot). For the velocities of the other clouds, either no stable fit could be achieved (G and Aql clouds), or χ^2>2 (Mic and NGP clouds). Close to the direction of the IDV source, the distance of the Gem cloud ≤ 64 pc. From the scattering length-scale obtained from the fit, this distance would imply a scattering source size of 0.13 mas.

The source is part of the MOJAVE (Lister et al., 2009) sample. According to the 15-GHz VLBI observation, the brightest feature can be best described by a circular Gaussian with 0.14 mas FWHM. This upper limit on the source size is in agreement with the above derived scattering size.

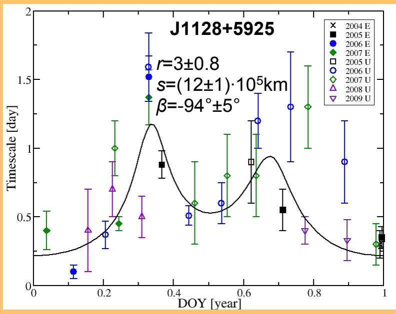
Both PKS B1622-253 and PKS B1519-273 were detected by the **Fermi Gamma-ray Space Telescope** (Abdo et al., 2010). This is not surprising since (i) compact blazars are preferably gamma-bright and (ii) ≈30% of compact blazars show IDV. Statistical analysis of a large sample is needed to investigate this in detail.

PKS B1519-273: It was one of the sources investigated by Linsky et al. (2008), but at that time, not enough time-scale measurements were available. According to the LISM model of Redfield & Linsky, the line of sight PKS B1519-273 traverses the G cloud and the Gem cloud and passes near to the NGP and Leo clouds. When fitting the annual modulation of the variability time-scale, the lowest χ^2 value was obtained using the velocities of the Gem cloud, χ^2=1.5 (solid black line in the plot). For the velocities of the other clouds, either no stable fit could be achieved (G cloud), or χ^2>>2 (Leo and NGP clouds). Toward the line of sight of the IDV source, the distance of the Gem cloud is ≤ 64 pc. From the scattering length-scale obtained from the fit, this distance would imply a scattering source size of 0.08 mas.

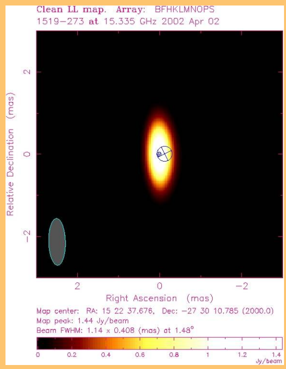
The source is part of the MOJAVE sample. The brightest feature can be best described by a circular Gaussian with 0.1 mas FWHM. This value is in agreement with the above derived scattering size.



Modelfit to the MOJAVE dataset of PKSB1622-253. The chosen epoch (2002 May) is the closest to the IDV time-scale measurements.



J1128+5925: Densely time-sampled **5 GHz flux-density monitoring observations** of the source were conducted with the Effelsberg 100-meter radio telescope (Germany) and the Urumqi 25-meter radio telescope (China) in more than thirty epochs during the last 4 years. According to the LISM model of Redfield & Linsky, the line of sight of the source traverses the LIC and passes near the NGP cloud. However, neither the velocity of the LIC, nor that of the NGP gives a stable fit to the time-scales. The best fit screen velocity components: v_α=1±4 km/s and v_δ =-11±2 km/s.



Modelfit to the MOJAVE dataset of PKSB1519-273. The chosen epoch (2002 May) is the closest to the IDV time-scale measurements.

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