LETTERS TO PROGRESS IN PHYSICS

Solar-Time or Sidereal-Time Dependent? The Diurnal Variation in the Anisotropy of Diffusion Patterns Observed by J. Dai (2014, Nat. Sci.)

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In this correspondence an additional analysis is reported about the anisotropic diffusion patterns of a toluidine blue colloid solution in water measured by J. Dai (*Nat. Sci.*, 2014, v. 6 (2), 54–58). In the previous analysis (Scholkmann, *Prog. in Phys.*, 2014, v. 10 (4), 232–235) it could be shown that the anisotropy data contain a diurnal and annual periodicity. This novel analysis investigated whether this periodicity is also present when the data were analyzed according to the sidereal time. The analysis revealed that the daily periodicity is present in the data scaled with the solar as well the sidereal time. When using solar time an oscillation with a diurnal period appears, when using sidereal time the oscillation is semidiurnal. In addition, the novel analysis revealed that the data of the maximum diffusion trend show a quantization of unknown origin.

Recently in this journal (v. 10 (4), [1]), I present a reanalysis of the data of J. Dai [2] that investigated fluctuations in anisotropic diffusion patterns of a toluidine blue colloid solution in water. It could be shown that the fluctuation of anisotropy, i.e. the maximum diffusion trend (MDT), clearly exhibits a diurnal and annual periodicity. Responding to this article, Prof. R. Cahill (Flinders University, Adelaide, Australia) suggested that it would be interesting to analyse if the observed periodicity is associated with the solar or the sidereal time (i. e. the time based on the Earth's rotation with respect to the fixed stars). In order to investigate this issue, the following new analysis was performed: (i) The time information given in the data of Dai was converted from the local solar time to the local sidereal time using the information of the location where the experiment was conducted (Wuhan City, China, latitude: N $\sim$ 30°35′35.1168″, longitude: E $\sim$ 114°18′18.6192″). (2) The data were analyzed by calculating the median and the median absolute deviation (MAD) for every hourly time interval (24 in total). (3) The function $f(\mathrm{MDT}) = \alpha_0 + \alpha_1 \cos(\mathrm{MDT}\ \omega)$ (with the free parameters α_0, α_1 and ω) was fitted to the daily grouped data using the Trust-Region-Reflective Least Squares Algorithm. For the fitting, the MAD values were taken into account to increase the precision of the fit (which is an improvement to the fitting approach used in the previous analysis [2]).

The individual MDT values plotted against the solar time and sidereal time are shown in Figure 1(a) and (e), respectively. Fitting the periodic (sinusoidal) function to the MDT data showed that the fit functions differ depending on the time scaling (solar vs. sidereal) used. When using the solar time the best fit is a function with a diurnal periodicity (see Figure 1(b)) whereas when using the sidereal time the best fit has a semidiurnal periodicity (See Figure 1(f)). The goodness-of-fit (quantified by the squared Pearson correlation coefficient, r^2, and the root-mean-square error, RMSE) for both cases were: (i) MDT data with solar time: $r^2 = 0.5028$, RMSE = 3.191, and (ii) MDT data with sidereal time: $r^2 = 0.4838$, RMSE = 3.04. A visualization of the r^2 and RMSE values for both cases is shown in Figure 1(d) and Figure 1(h). To visualize the density distribution of the MDT values the density at each point of the grid was calculated as $1/z$ with z the sum of squared distance from each point. For this the Matlab function "DataDensityPlot" written by M. McLean was used. The density plots are shown in Figure1(c) and Figure 1(g).

From this new analysis results we can conclude that (i) in both cases (solar and sidereal time scaling) the MDT data show a periodicity, (ii) the periodicity has a frequency depending on the time scaling: diurnal for solar time (oscillation maximum: at approx. 0.00 a.m.) and semidiurnal for sidereal time (oscillation maxima: at approx. 0.00 a.m. and 12.00–1.00 p.m.), (iii) the goodness-of-fit of the fitted function for both data sets (MDT vs. solar or sidereal time) is similar. The correlation is higher for the solar time scaling but the RMSE value lower for the sidereal time scaling. This can be interpreted as meaning that the MDT values contain an oscillation correlated with the solar as well as with the sidereal time. A related observation was obtained by Shnoll who found a solar and sidereal oscillation in the similarity of histograms of radioactive decay of ^{239}Pu [3, 4].

The detected oscillations indicate that there is possibly cosmophysical factor influencing the diffusion process. This factor might be influencing the process from a preferred direction in space such as determined for example by Miller (right ascension, $\alpha = 4^{\mathrm{hr}}\ 54^{\mathrm{min}}$, declination, $\delta = -70°\ 33'$ [5]; $\alpha = 4^{\mathrm{hr}}\ 56^{\mathrm{min}}$, $\delta = -70°\ 33'$ [6]), Cahill ($\alpha = 4.92^{\mathrm{hr}}$, $\delta = -75.0°$) [7], Múnera et al. ($\alpha = 16^{\mathrm{hr}}\ 40^{\mathrm{min}}$, $\delta = -75°$ [8]; $\alpha = 5^{\mathrm{hr}}\ 24^{\mathrm{min}}$, $\delta = +79°$ [9]), and Baurov ($\alpha = 19^{\mathrm{hr}}\ 32^{\mathrm{min}} \pm 40^{\mathrm{min}}$, $\delta = 36° \pm 10°$) [10].*

*The value for the right ascension is originally given by Baurov as α =

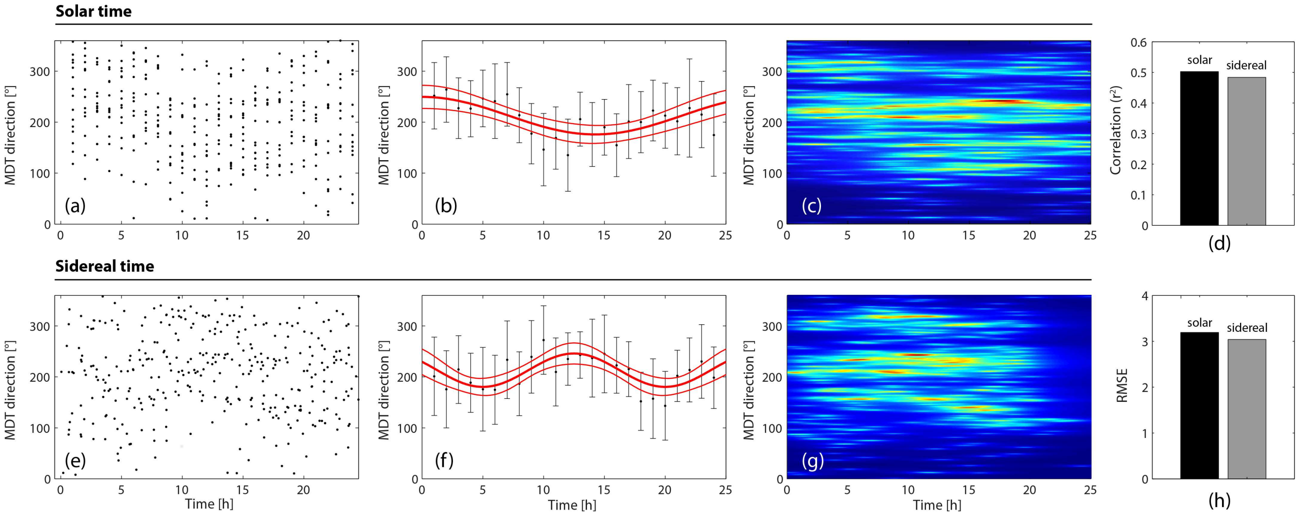

Fig. 1: Raw data plotted against solar (a) or sidereal (e) time. Fitted sinusoidal function to the MDT scaled using the solar (b) or sidereal (f) time. Density plot of the MDT values plotted against solar (c) or sidereal (g) time. The values for the correlation and RMSE value of the fit are shown in (d) and (h).

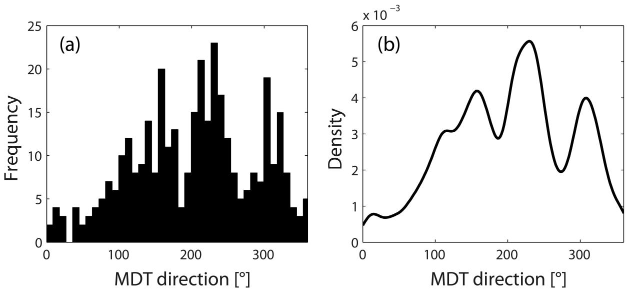

Fig. 2: (a) Histogram and Kernal density (b) of the MDT values.

As an additional analysis the characteristics of the distribution of the MDT from all 15 days were investigated by computing the histogram (number of bins: 40) and the Kernal density according to the method of Shimazaki & Shinomoto [5]. This analysis revealed an interesting pattern: the occurrence of MDT values shows three distinct peaks. The strongest peak is at 230°, the second at 158° and the third at 303° (see Figure 2). This quantization of diffusion anisotropy is another interesting feature of Dai's data that awaits explanation.

In conclusion, the new analysis performed shows novel features of the MDT data of Dai. Further MDT measurements and investigations into the cause of the observed effects would be an interesting next step in this area of research.

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293° ± 10° and was converted to $\alpha = 19^{\text{hr}}\ 32^{\text{min}}$ by the author using the equality 360° = 24 h.

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