THE TIME DELAY BETWEEN QSO 0957+561 A,B

J. PELT
Tartu Astrophysical Observatory
EE-2444 Toravere, Estonia

R. KAYSER
Hamburger Sternwarte
D-21029 Hamburg-Bergedorf, Germany

R. SCHILD
Harvard Smithsonian Center for Astrophysics
Cambdridge, MA 02138, U.S.A.

AND

D.J. THOMSON
AT&T Bell Laboratories
Murray Hill, NJ 07974, U.S.A.

We here present a short report about the application of a simple time delay estimator to the extensive data set compiled and partly observed by R. Schild, containing 707 A and B observations with corresponding error estimates from JD 244194 to JD 249169.

For our analyses we used a cross-sum type dispersion estimation statistic (for details see Pelt et al. 1994) to measure the dispersion around the combined data set $C_k, k = 1, \ldots, K$, where the B data are shifted by τ and corrected against the magnification b:

$$D^2 = \min_b \frac{\sum_{i=1}^{K-1} \sum_{j=i+1}^{K} S_{i,j} G_{i,j} (C_i - C_j)^2}{2 \sum_{i=1}^{K-1} \sum_{j=i+1}^{K} S_{i,j} G_{i,j}}$$

Here the *Smoothing Window* is defined as $S_{i,j} = 1$ for $|t_i - t_j| \leq \theta$ and otherwise $S_{i,j} = 0$. The statistic D^2 contains a free parameter θ. An absolutely parameter-free (high resolution) statistic can be obtained when $S_{i,j} = 1$ only for the pairs of (C_i, C_j) which occur neighboring in the combined data set. The *Selection Window* $G_{i,j} = 1$ is equal to one only for measurement pairs C_i, C_j for which C_i and C_j belong to different original series and zero otherwise. Consequently we take into account only relevant pairs.

M. Kafatos and Y. Kondo (eds.), Examining the Big Bang and Diffuse Background Radiations, 539–540.

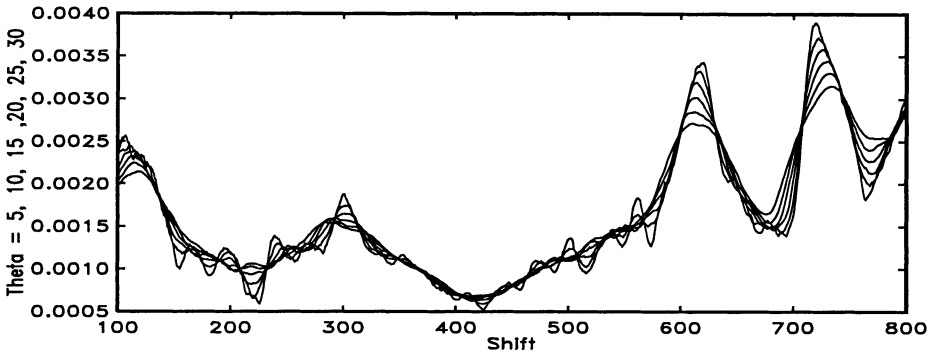

Figure 1. Smoothed dispersion spectra

An important statistic to describe the data is the *Data Window*, which counts the number of neighboring A,B pairs in the combined data set for different time delays τ. The minimum number for relevant pairs for the Vanderriest (1989) data occurred just for time delays near the 535 days (43 pairs for $\tau = 528, 534, 537$). For the extended data set there is a minimum of 155 pairs for time delays of 514 and 515 days. In the high resolution dispersion spectrum for the extended data set (with all pairs included) the strongest minimum occured at a delay of 515 days, which (again) coincides with the minimum of the *Data Window*. However, the spectrum with only A,B pairs included shows a minimum around 425 days.

We finally computed a series of spectra using smoothed estimators with different values of the resolution parameter $\theta = 5, 10, 15, 20, 25, 30$. For $\theta = 5, 10$ the absolute minimum occurred still around 425 days, but starting from $\theta = 15$ it moved to smaller values (414,416,412 and 413 days accordingly). From this follows that small shifts from 415 to 425 days must be attributed to the high frequency components of the A and B lightcurves. The convergence of the spectra is well illustrated on Fig. 1.

The application of the simple nonparametric delay estimation method to the extended data set shows clearly that time delay value around 415 days can not be ruled out. Contrarily to that, the feature around 535 days in the dispersion spectra is less pronounced than for the subsets analyzed earlier. Additional evidence of its spurious nature stems from the fact that the minimum in the *Data Window* for extended data set (515 days) shows itself also in the spectrum for which all the pairs are taken into account. However, this evidence for the delay of 415 days against the delay of 525 days can not be treated as final proof of its reality. Further analysis with use of refined statistical techniques is needed to solve the QSO 0957+561 controversy.

References

Vanderriest, C. et al. (1989) *A&A* **215**, 1
Pelt J. et al. (1994) *A&A* **286**, 775