Covariances Between ISM and Timing Parameters in Millisecond Pulsars

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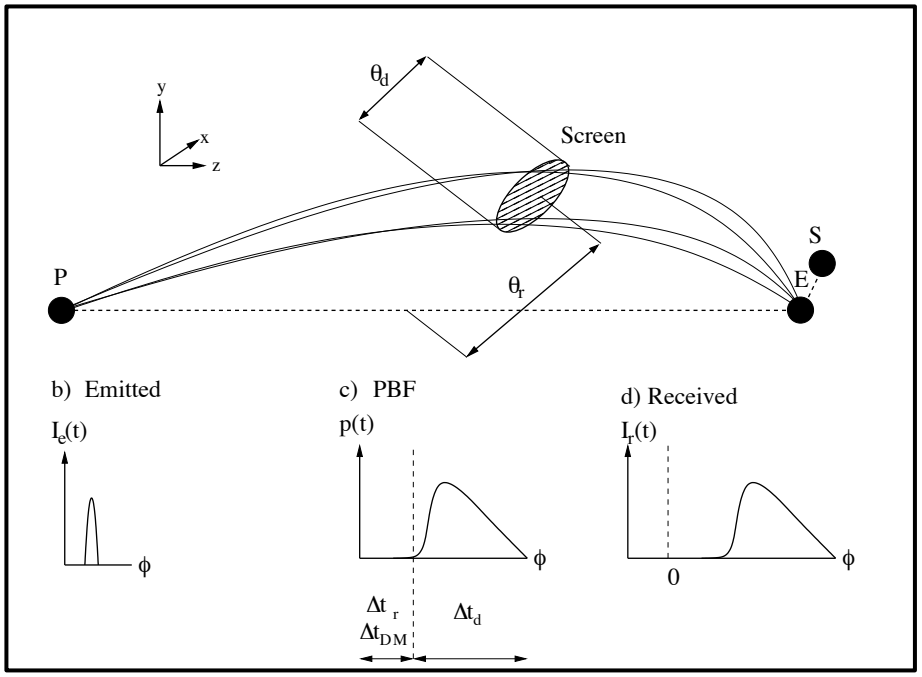
Refractive effects in the ISM



From Shannon 2011 (PhD Dissertation)

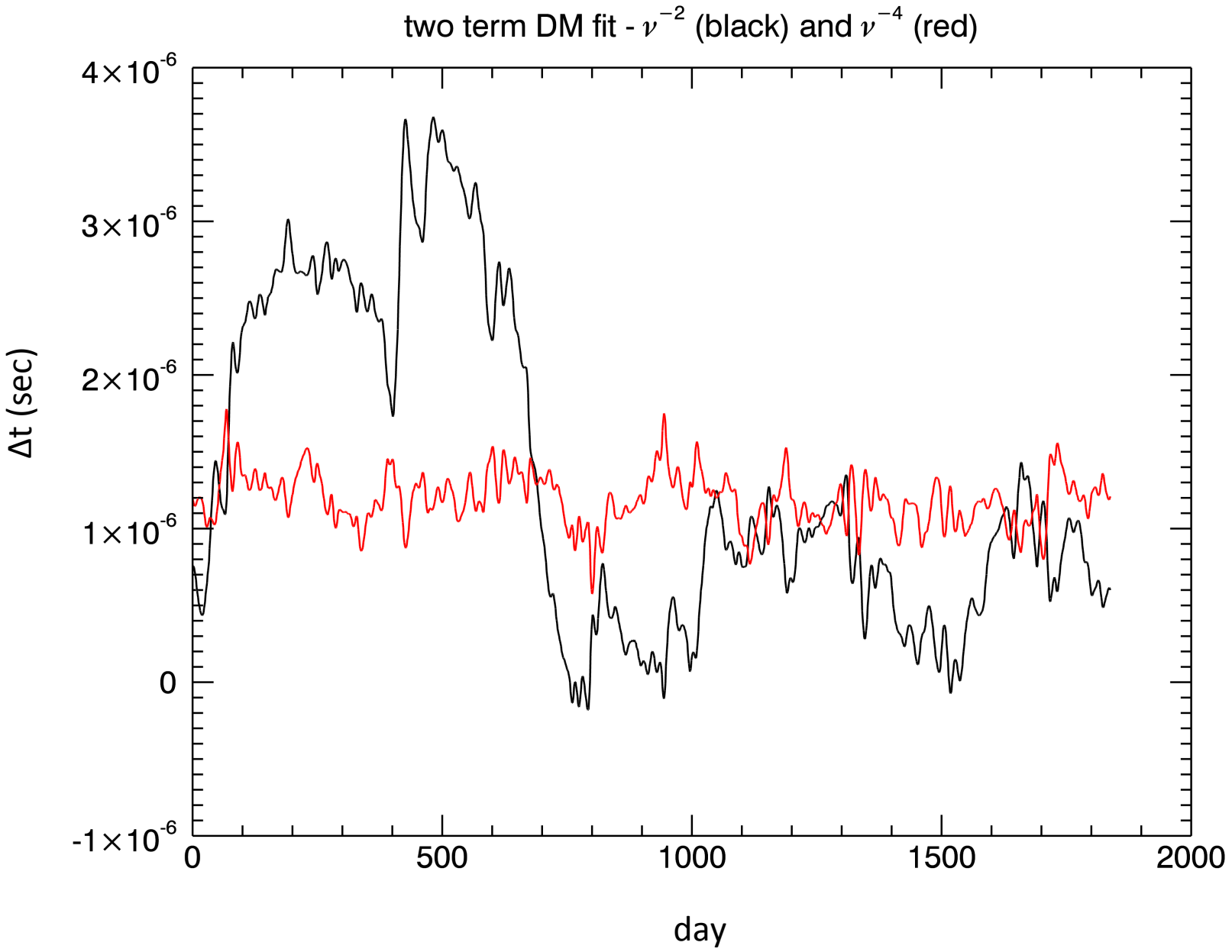
- Time delay due to angle-of-arrival θ is $\propto \theta^2$
- Frequency dependence: $\theta \propto \nu^{-2}$
- $\Delta t_{AOA} \propto \nu^{-4}$
- Here we assume Kolmogorov power spectrum for (isotropic) spatial fluctuations in refractive screen
- Focus here on refractive effects – time delays due to diffraction as well
- Result – varying DM as well as refractive component

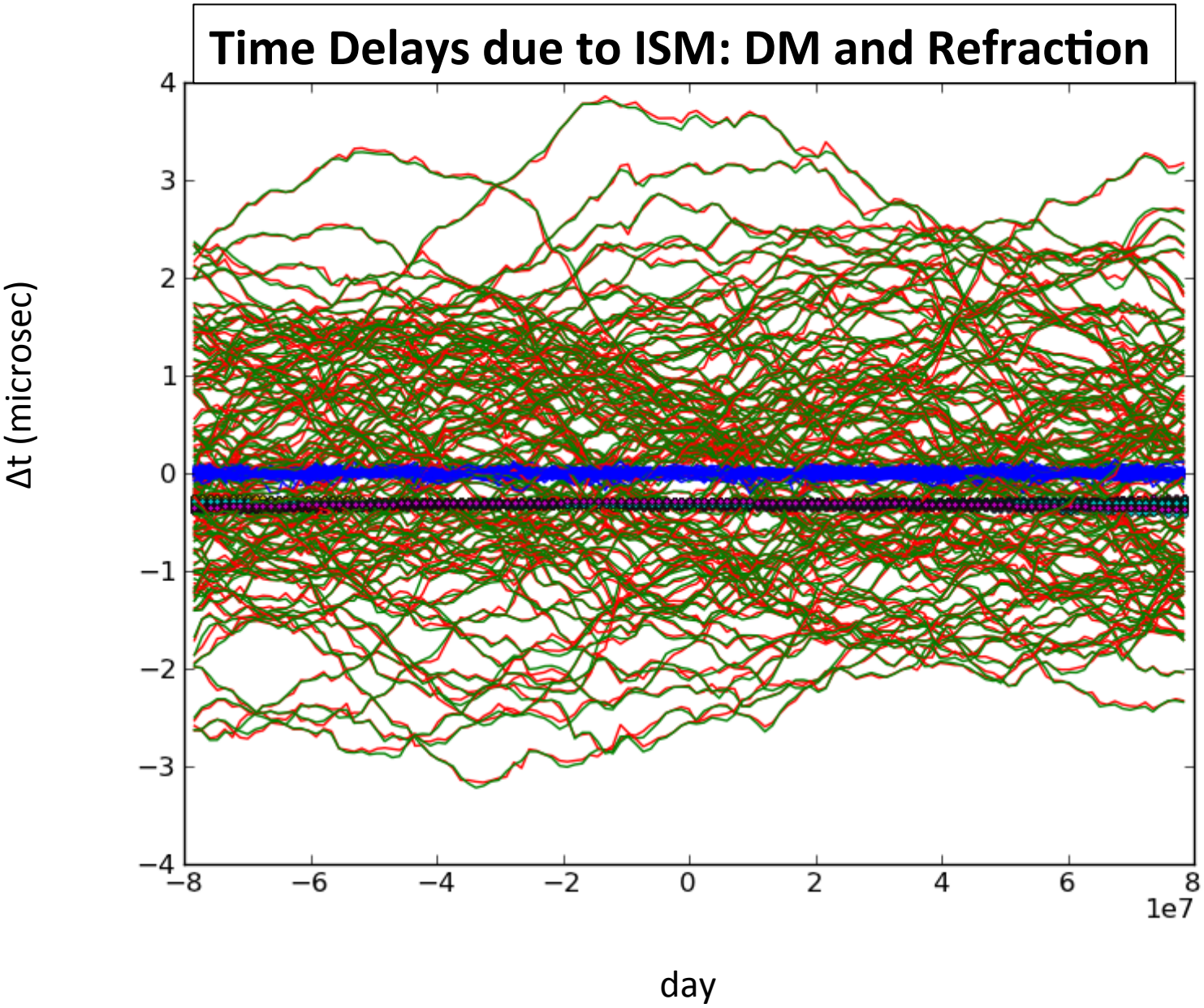
Model for timing residuals

- N_{days} = 128 (about every 2 weeks over 5 yr)
- Linear least squares – no iterations

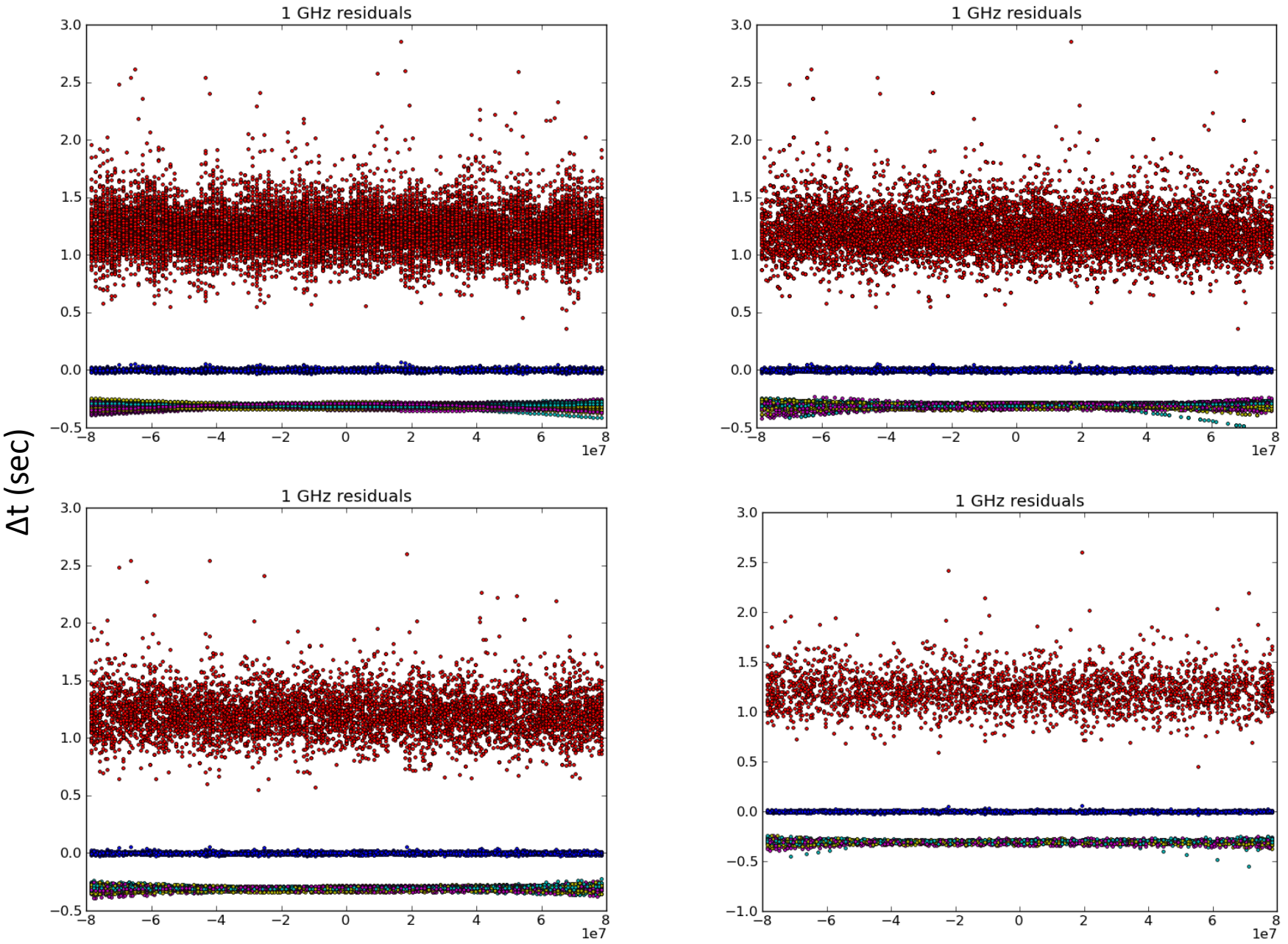
$$\Delta_t(\nu) = A + Bt_i + C{t_i}^2 + \frac{DM(t_i)}{\nu^2}$$

- DM at each time is a separate parameter for the model – 131 parameters total
- Time cadence is varied to be more and more "Poisson" -like

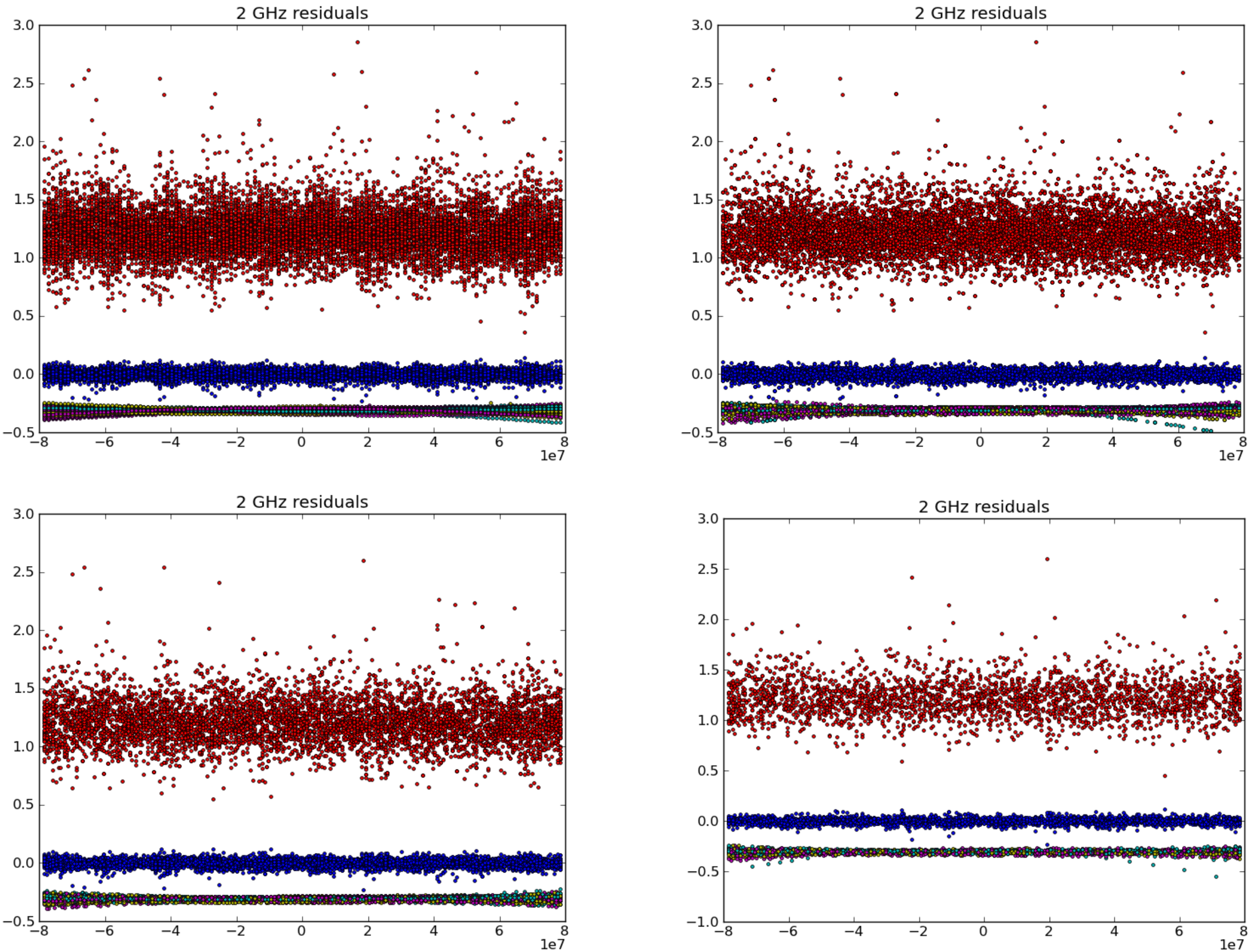

two term DM fit - ν^{-2} (black) and ν^{-4} (red)
4×10-6
3×10-6
2×10-6
1×10-6
0
-1×10-6
Δt (sec)
0
500
1000
1500
2000
day


Time Delays due to ISM: DM and Refraction
Δt (microsec)
4
3
2
1
0
−1
−2
−3
−4
−8
−6
−4
−2
0
2
4
6
8
1e7
day

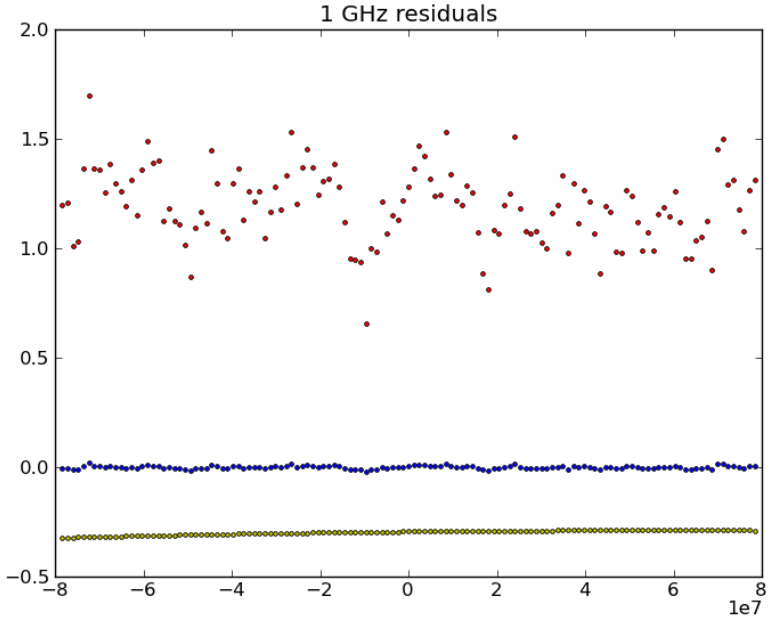
Residuals after DM term removed: 1GHz

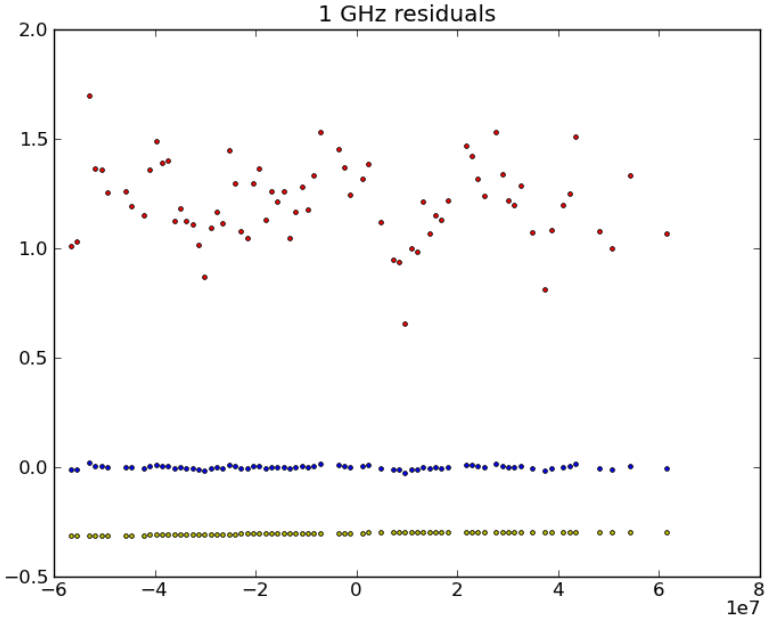


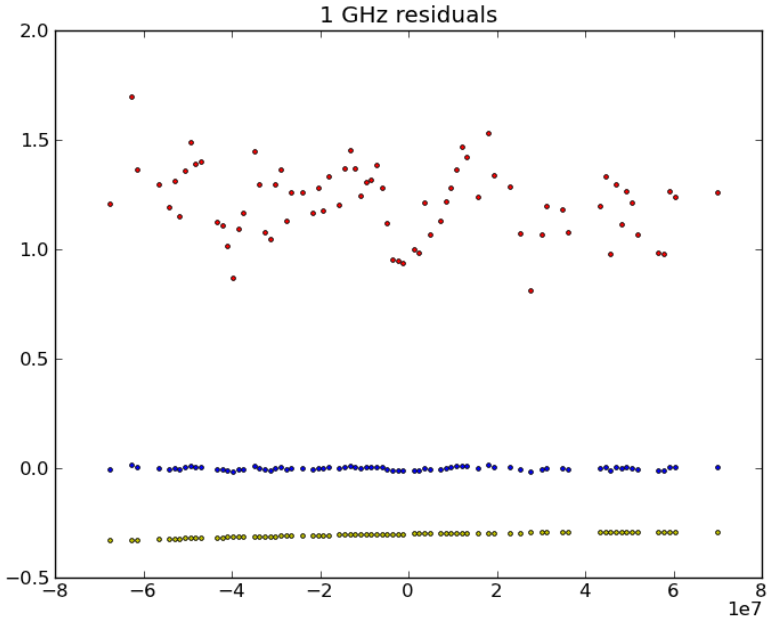
Residuals after DM term removed: 2GHz



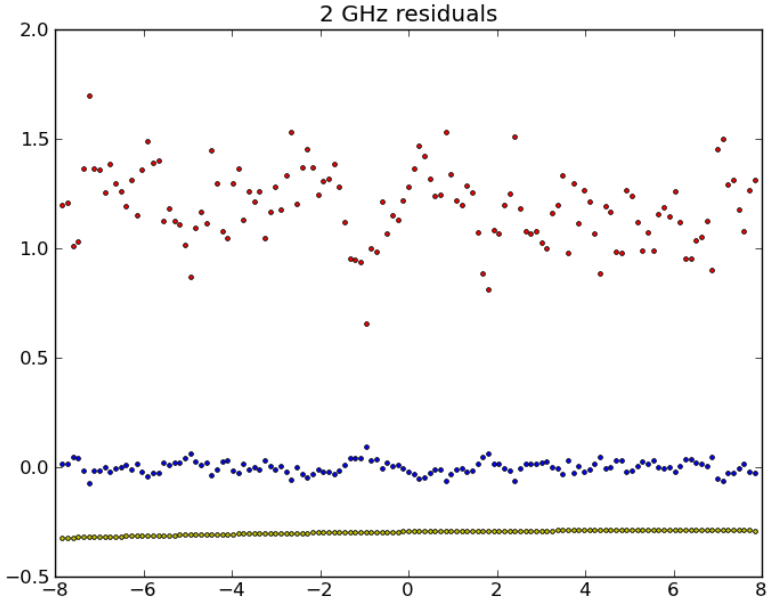
Single iteration residuals after DM term removed: 1 GHz

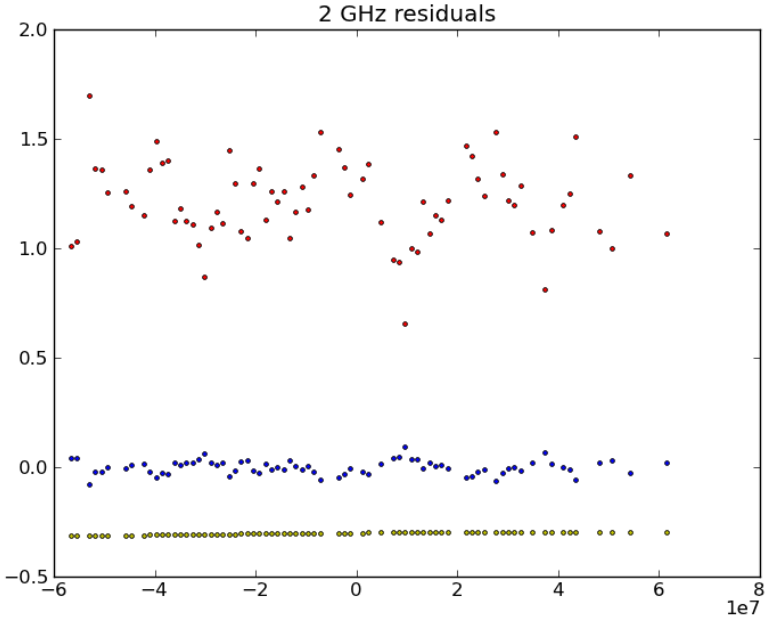


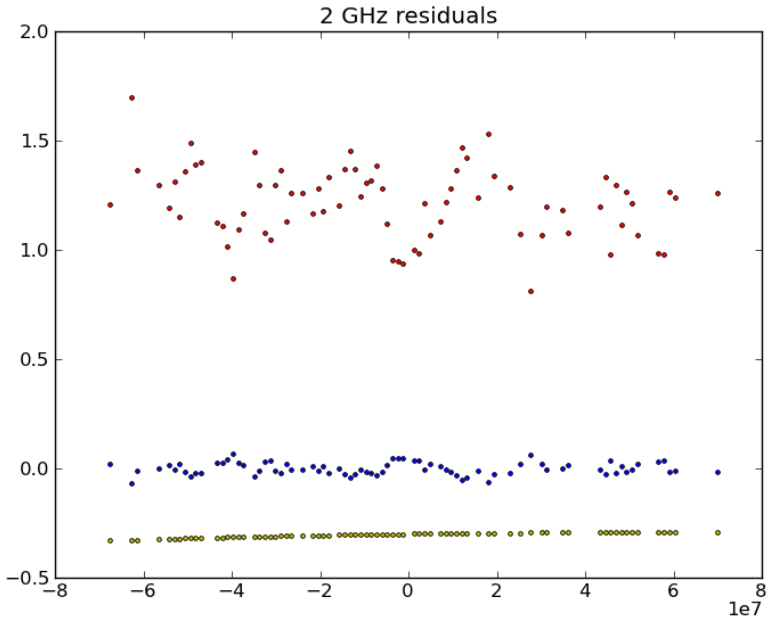




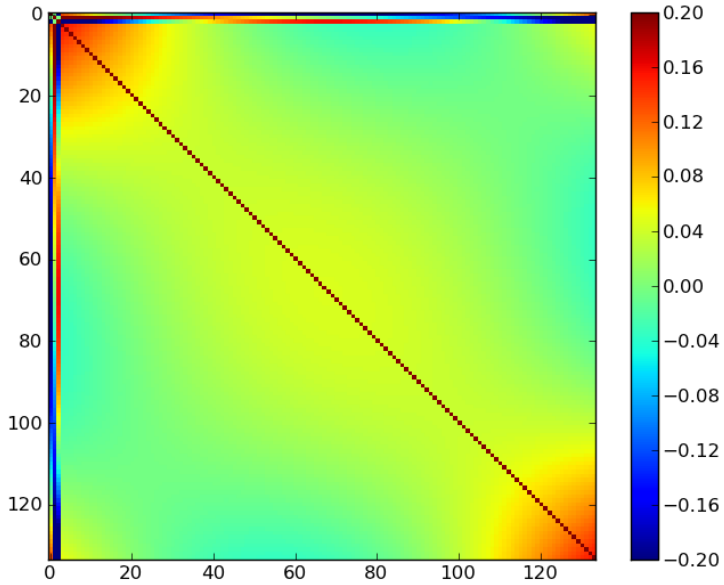
Single iteration residuals after DM term removed: 2 GHz

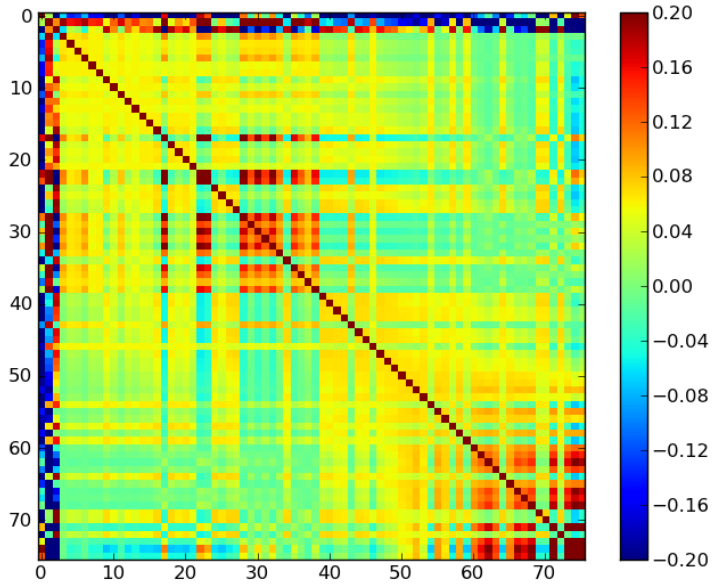


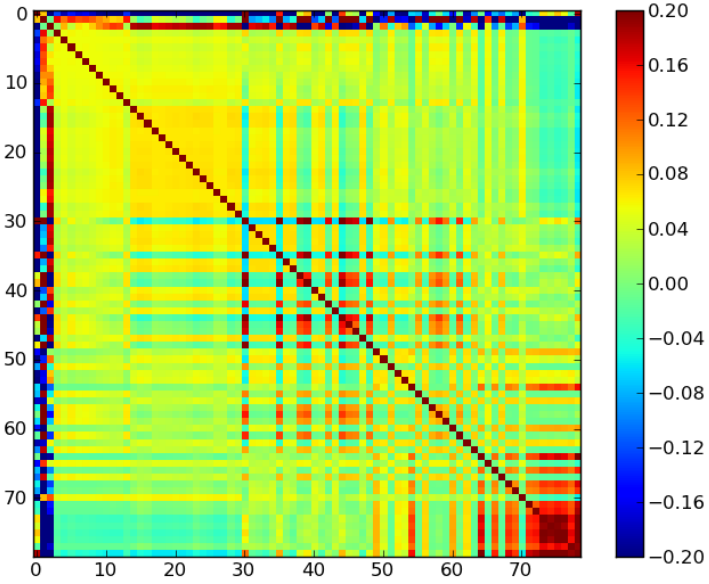




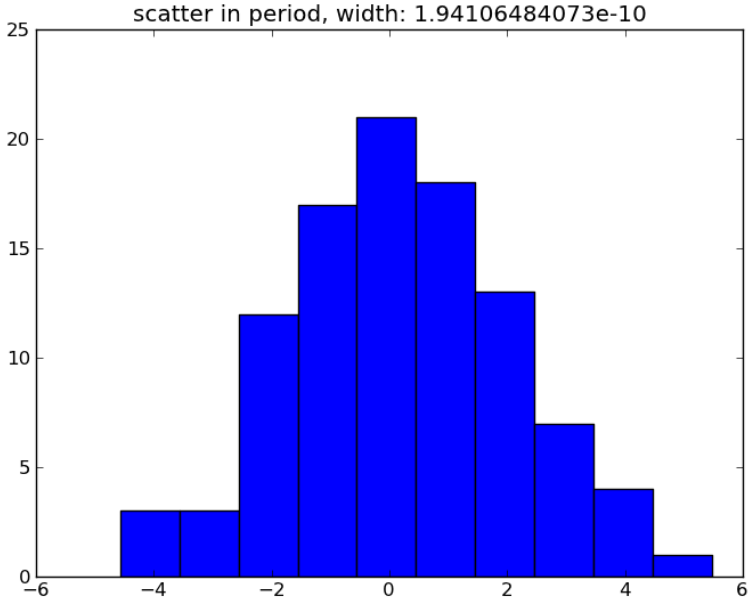
Covariance Matrix of Model Parameters

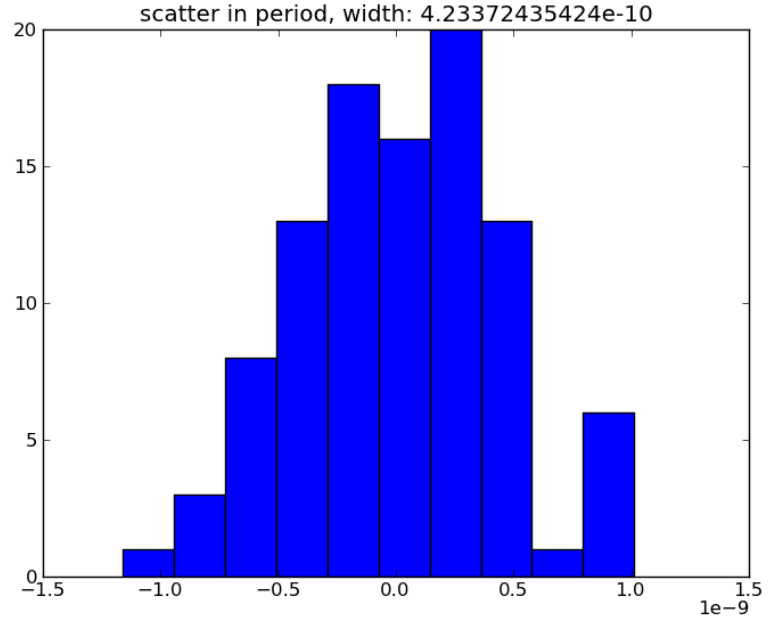


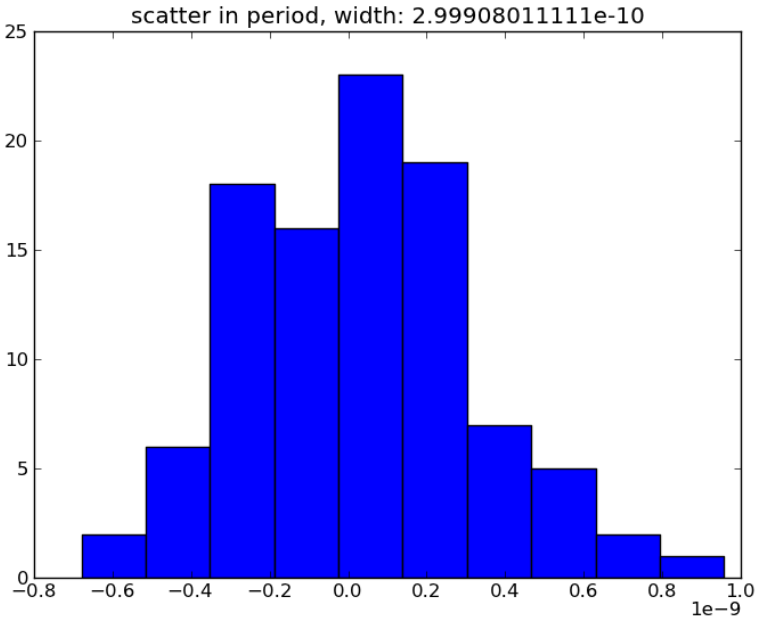




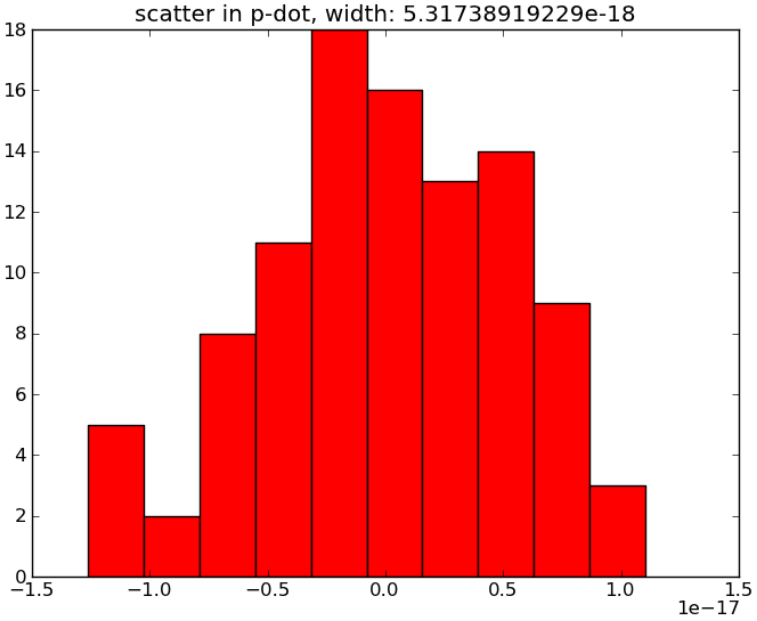
Scatter in B Parameter

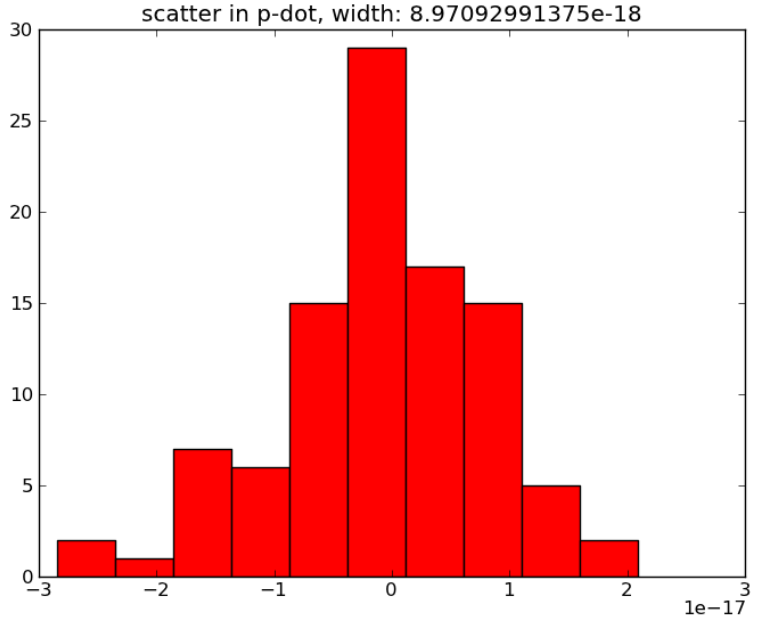


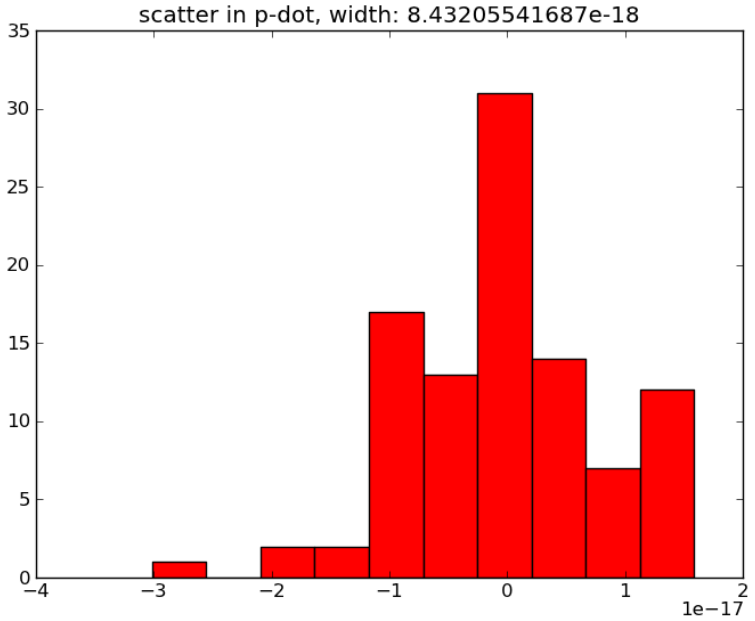




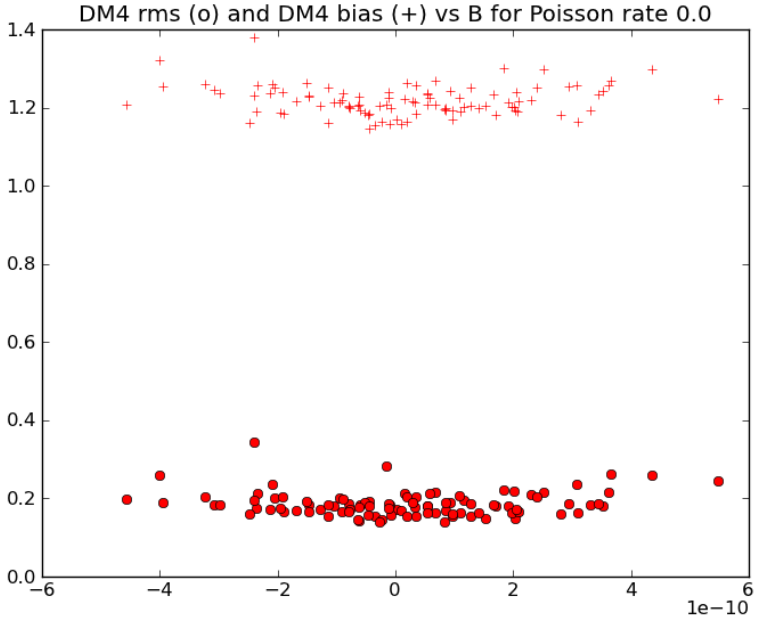
Scatter in C Parameter

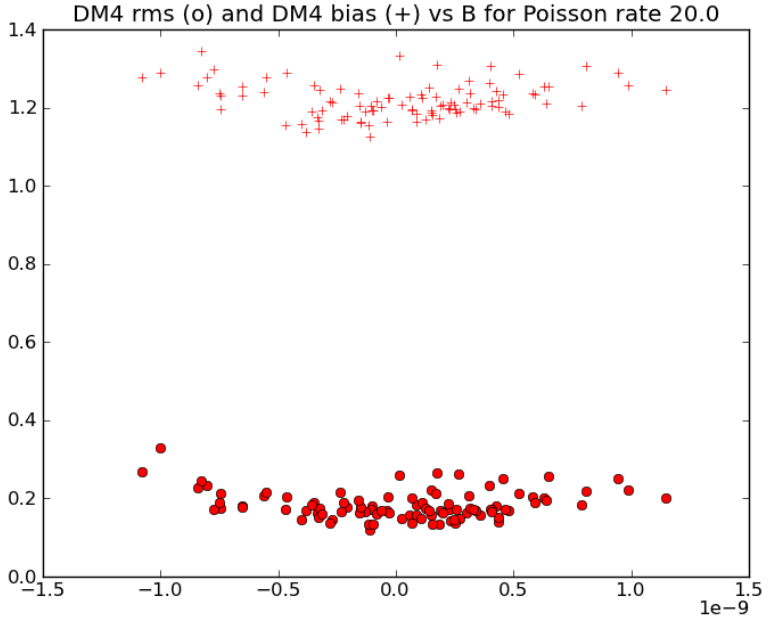


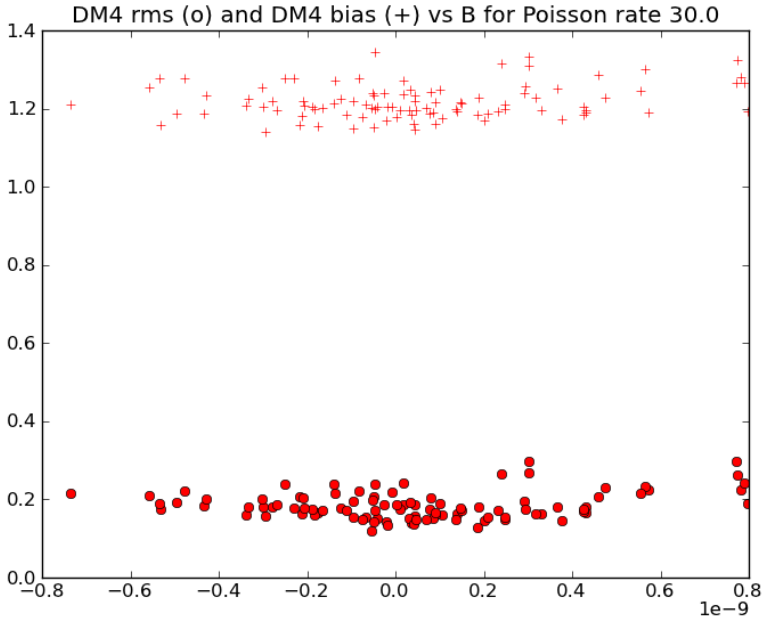




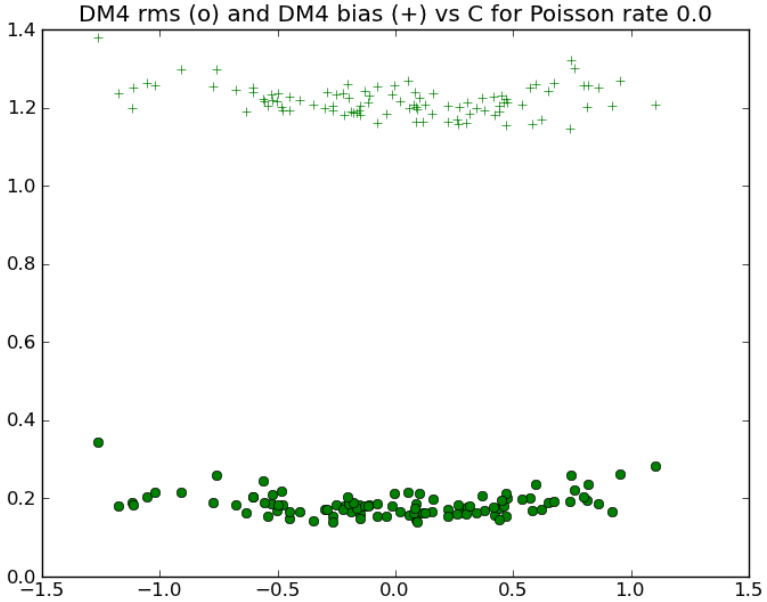
Scatter in Refractive Time Delay

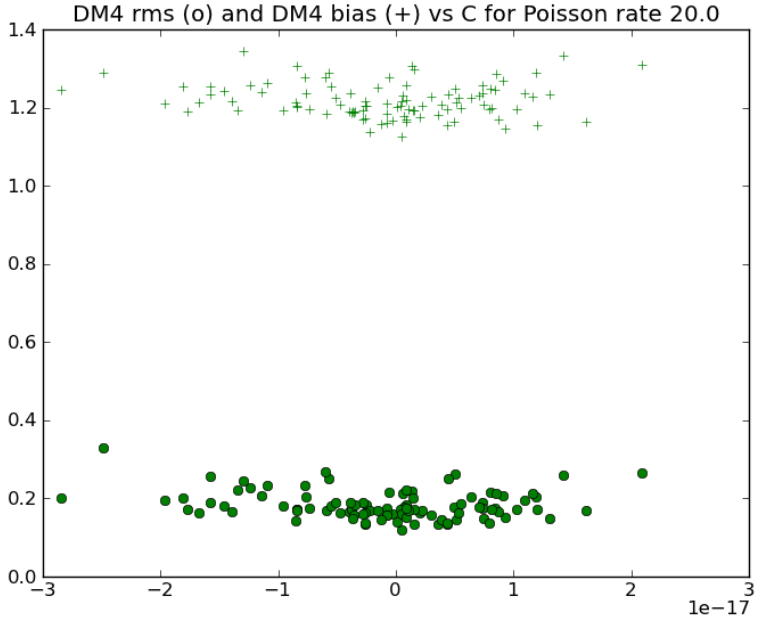


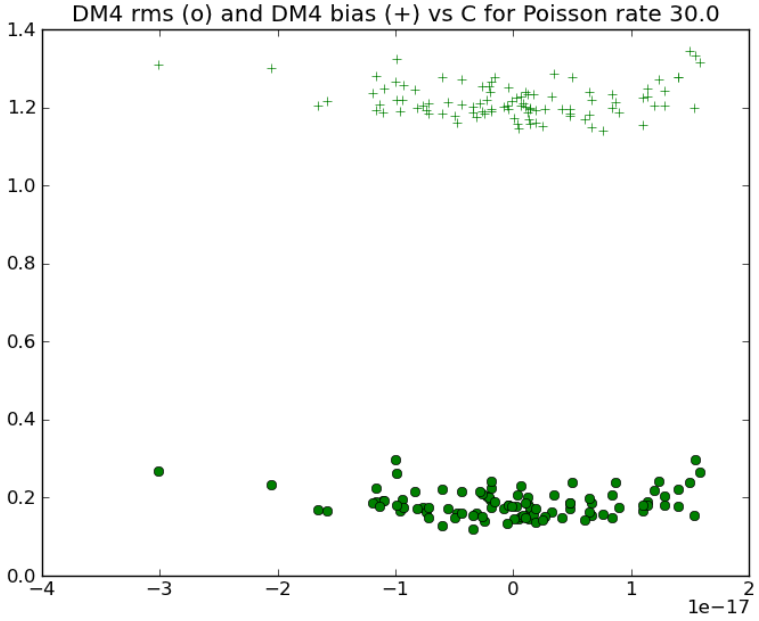




Scatter in Refractive Time Delay







Towards modeling the ISM beyond DM

- Beyond Kolmogorov fluctuation spectrum
- Introduction of anisotropies
- as timing residuals approach 10ns, explicit modeling of refractive and diffractive effects should be employed in addition to DM variations