DMCalc: Tutorial

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A short intro to DM

- Pulsar signals are dispersed - Thanks to free electrons in ISM
- The delay is a strong function of frequency $\sim \nu^{-2}$
- Dispersion Measure (DM) is the integrated column density of electrons between pulsar and observer

$$DM = \int_0^d n_e dl \ \mathrm{pc\ cm^{-3}}$$

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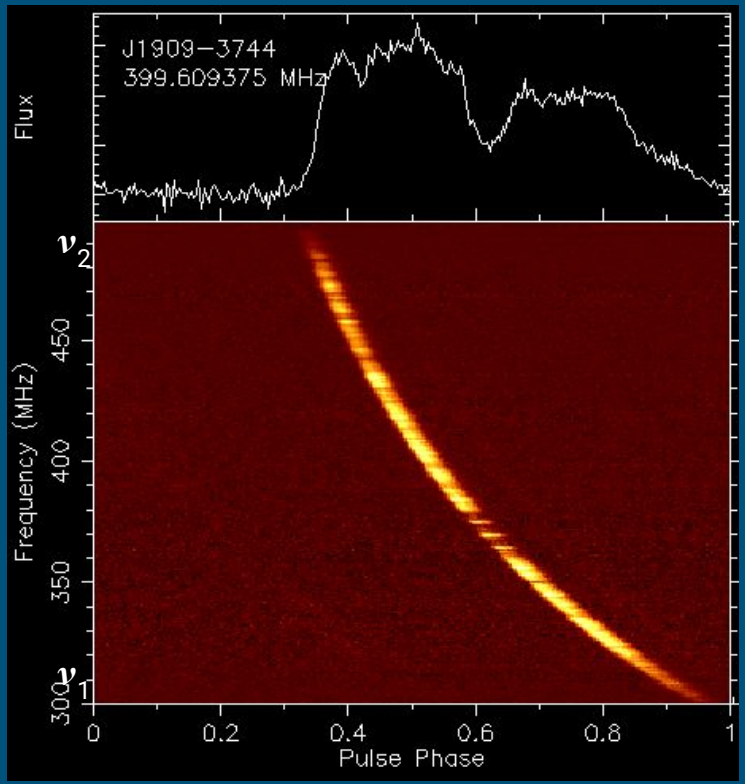
$$\Delta t = 4.15 \times 10^6 \times (\nu_1^{-2} - \nu_2^{-2}) \times DM(ms)$$

- DM - a measure of electron density



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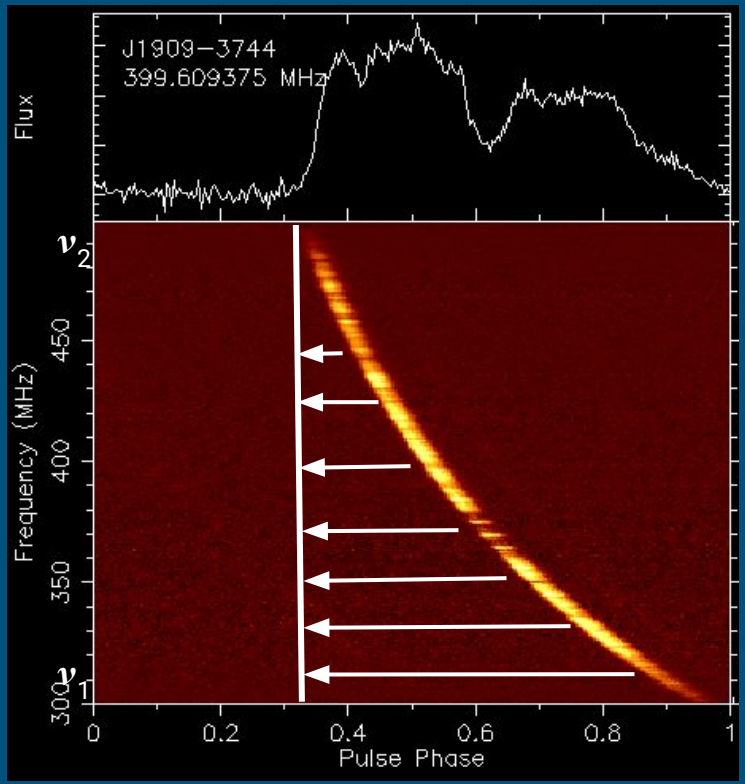

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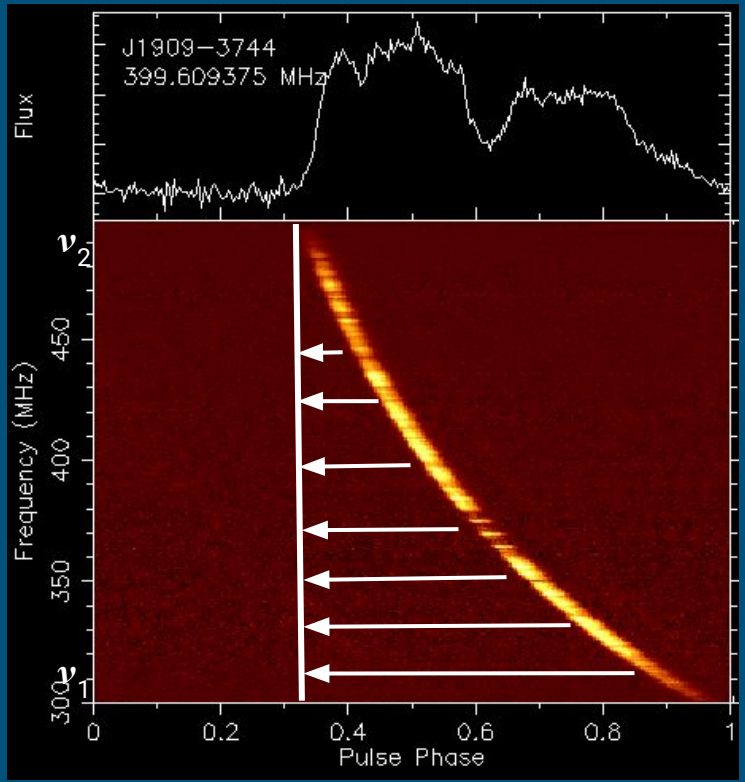

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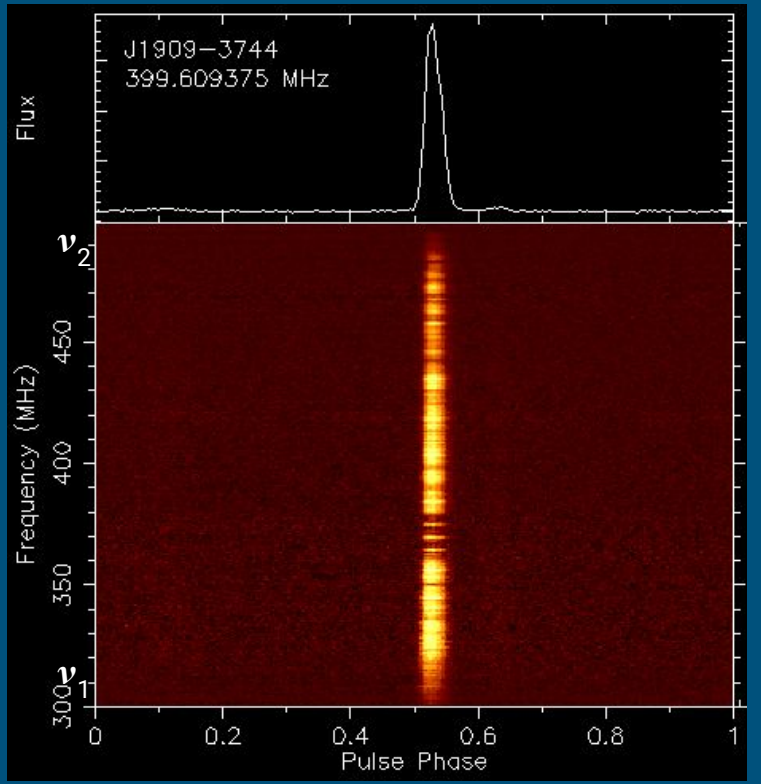
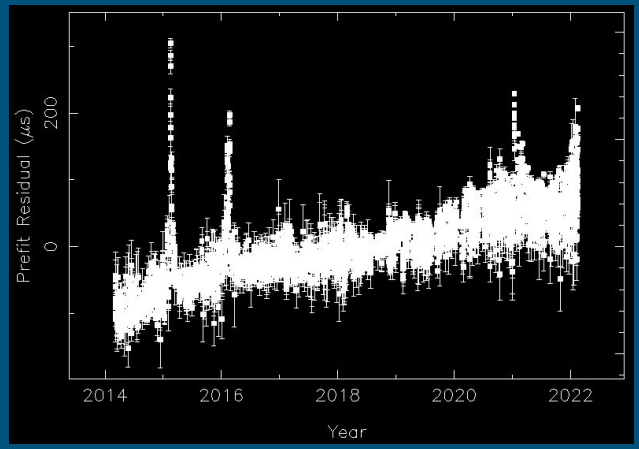
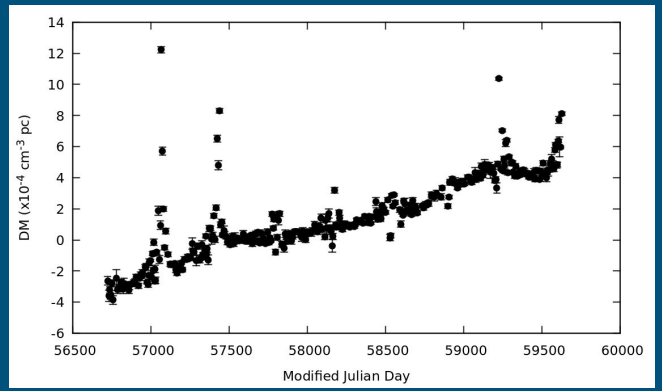


Why should we worry??

DM variations affecting ToAs

- LOFAR observations (120 - 190 MHz) of PSR J2145-0750
- ToAs follow DM variation very well
- Change in pulsar period (dP/dt) also show similar trend
- DM correction will help model the other pulsar parameters better
- And ultimately useful for PTAs to detect GWs





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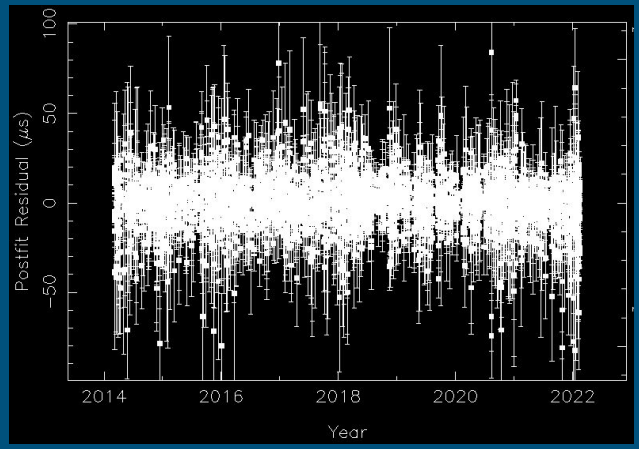
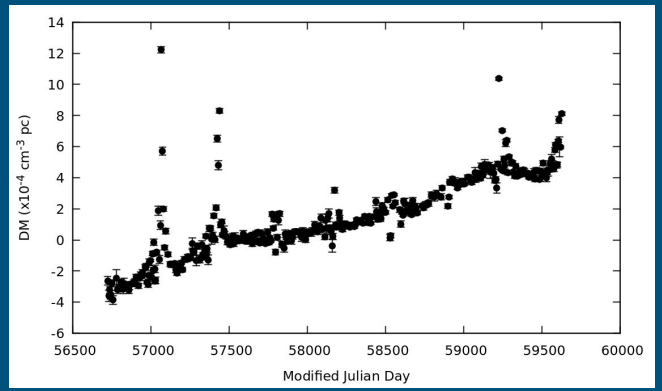
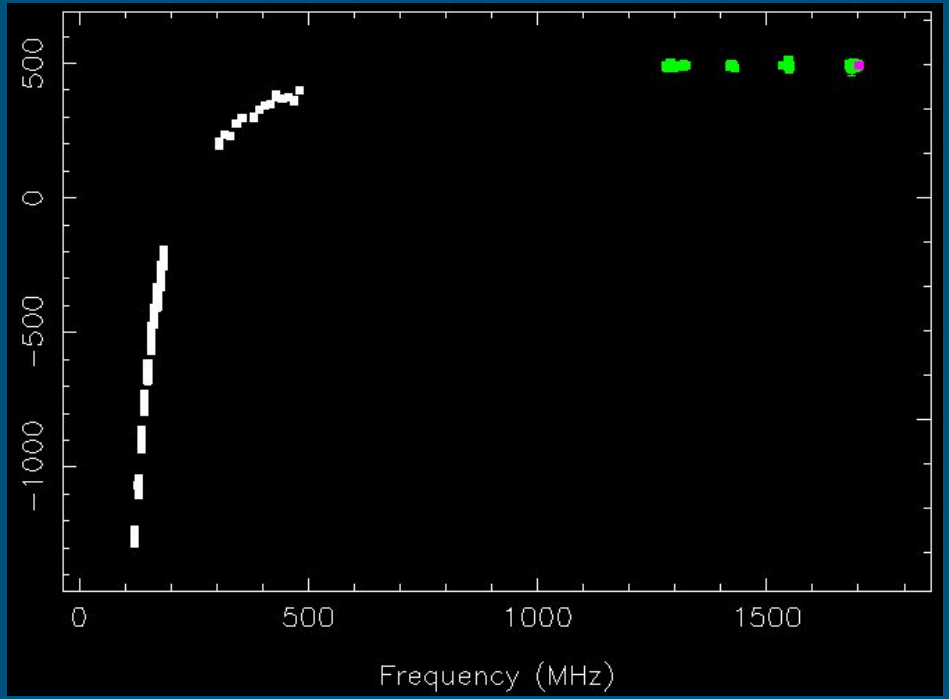




Lower frequency - better precision

- Since DM delay scales as ν^{-2} lower frequency wide-band receivers improve precision
- Combining different telescope's data across frequencies improves it further (plot shows data from LOFAR (120 - 190 MHz) - uGMRT (300 - 500 MHz) - NRT (1250 - 1750 MHz)
- Not all pulsars are visible below ~200 MHz – Importance of uGMRT bands



Different ways to measure DM

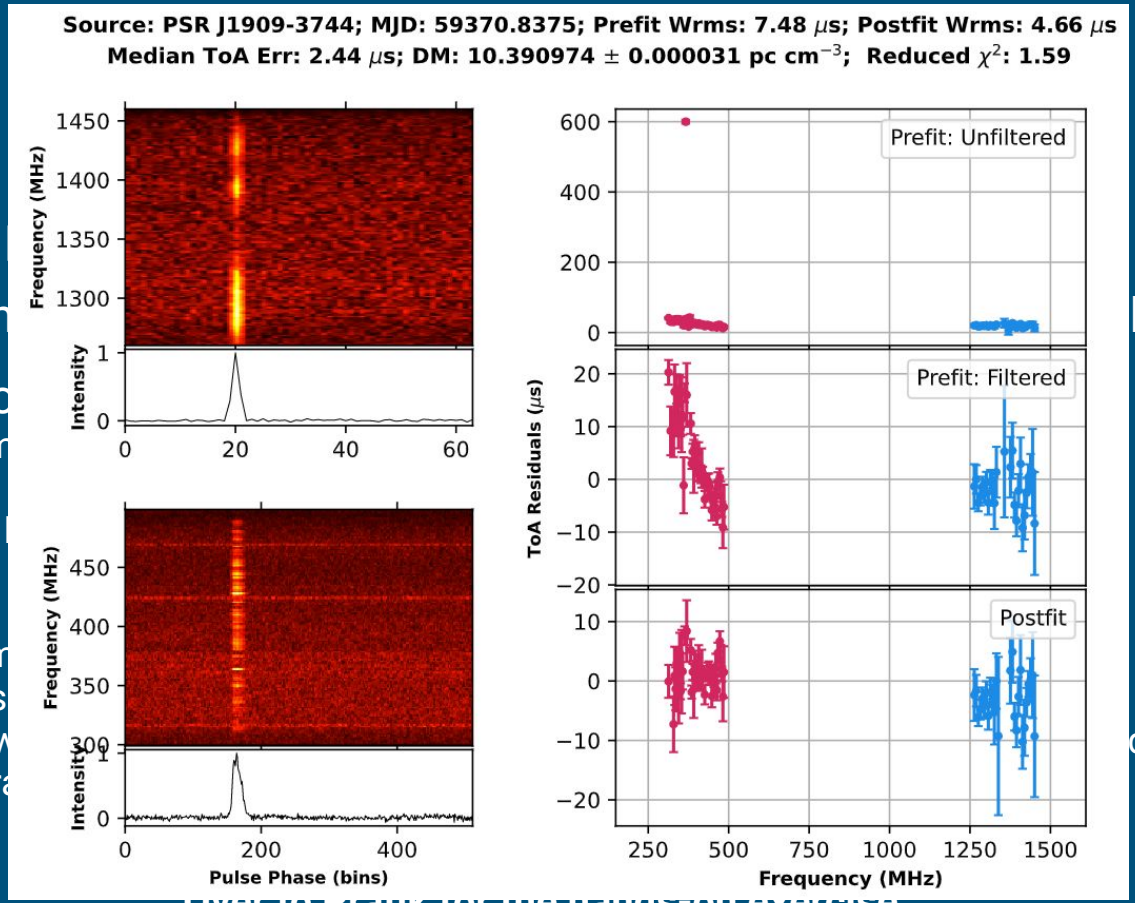
- Classically, Use 2-3 widely separated narrowband profiles
- Maximising the S/N - Not accurate as profiles are complex
- Narrowband timing - DM and its variation

With wide-band receivers:

- Use of frequency resolved templates (Liu et al. 2014; Tiburzi et al. 2019)
    - 2D templates
    - Improved accuracy
    - Takes care of intrinsic profile evolution
- Use of wide-band technique (Pennucci et al. 2019; Alam et al. 2021)
    - 2D templates
    - PCAs to model the profile evolution
    - One ToA/band/observation - reduces data volume for PTA analysis

DMCalc

- A Python
- Dependen kit-learn, etc.
- What it do
  - Find/m
  - Reject
  - Fit for
- Products
  - DM tim
  - Analys
  - ToAs w dent DM constra



Over to Pratik for the hands-on exercise...