Counting FRBs

Finding & Understanding Fast Radio Bursts

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ICRAR

International Centre for Radio Astronomy Research

Counting Fast Radio Bursts

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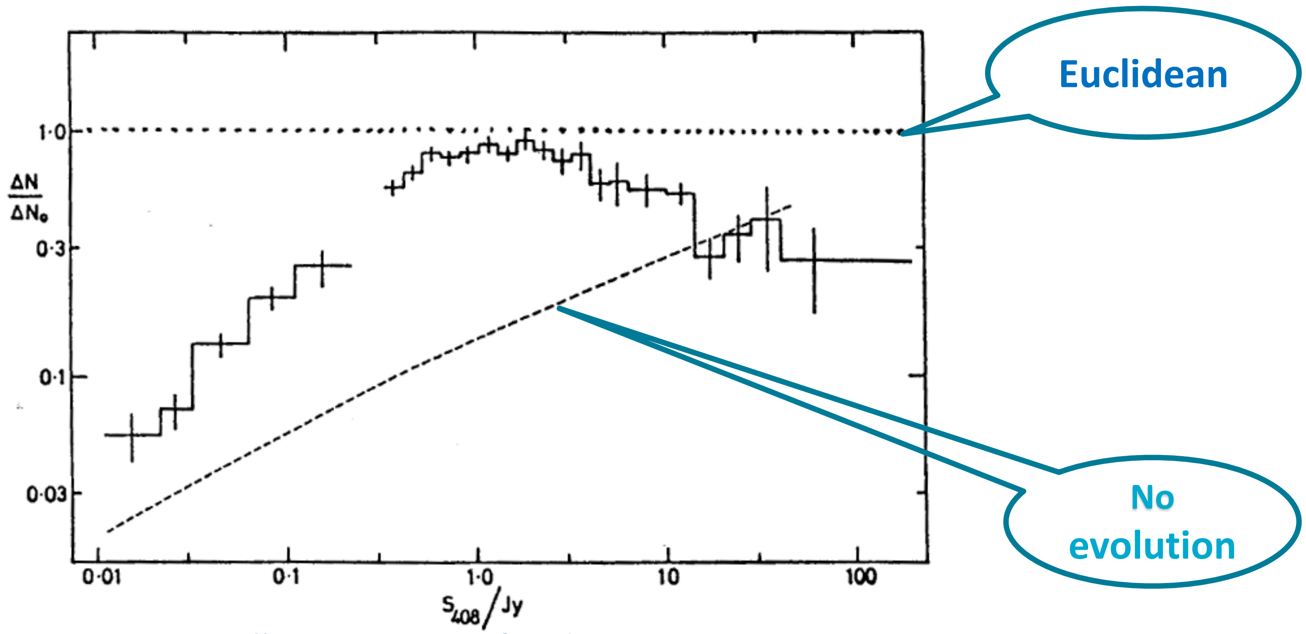
Counting AGN
the Log N - Log S or source counts

- Why they have been so important (and controversial)
- What can we learn from many decades of research
- The crucial role of the radio luminosity function



Wall 1981 Counts of Radio AGN.
Differential normalised

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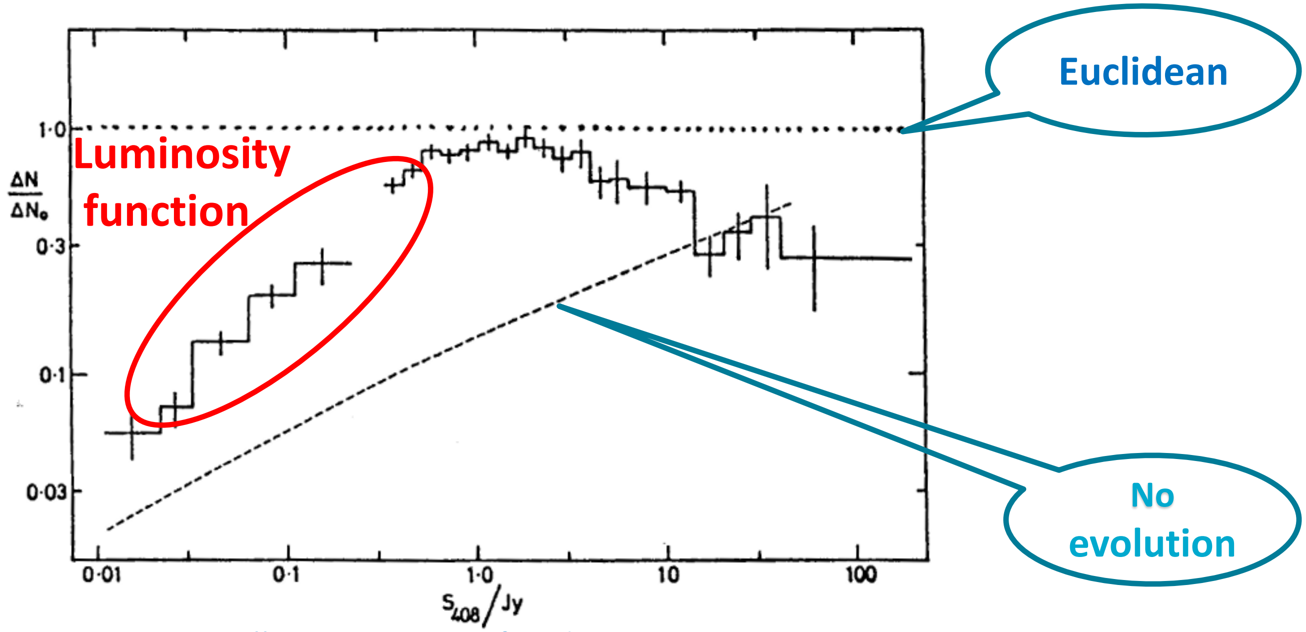

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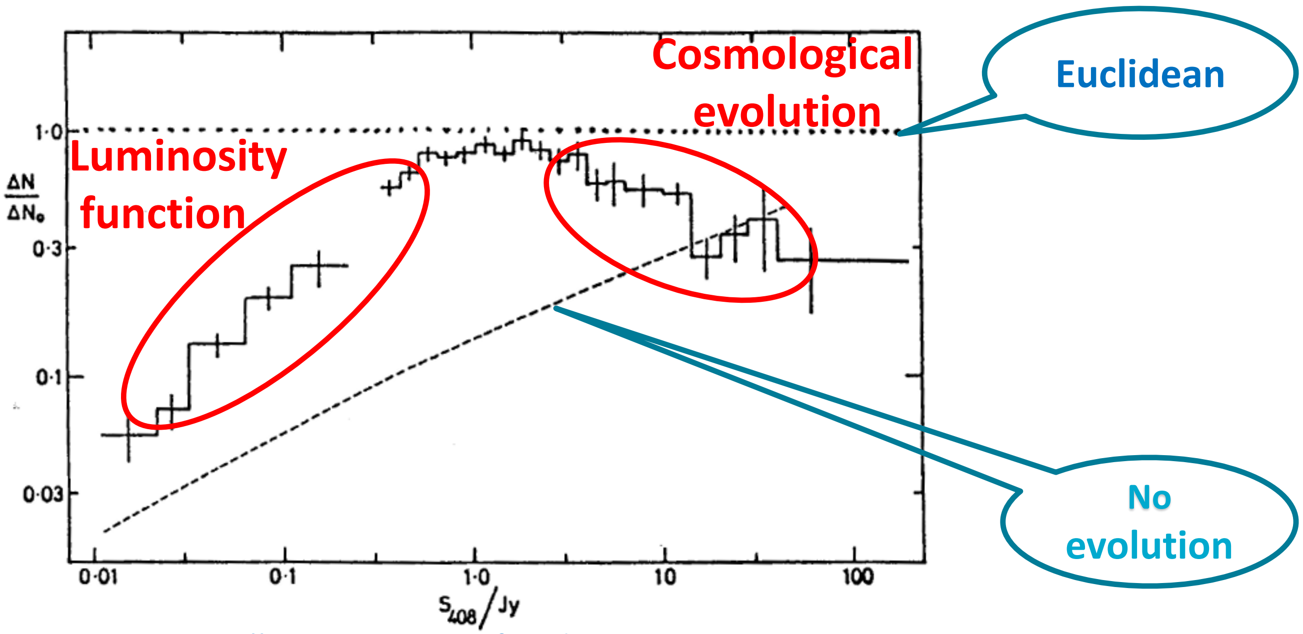

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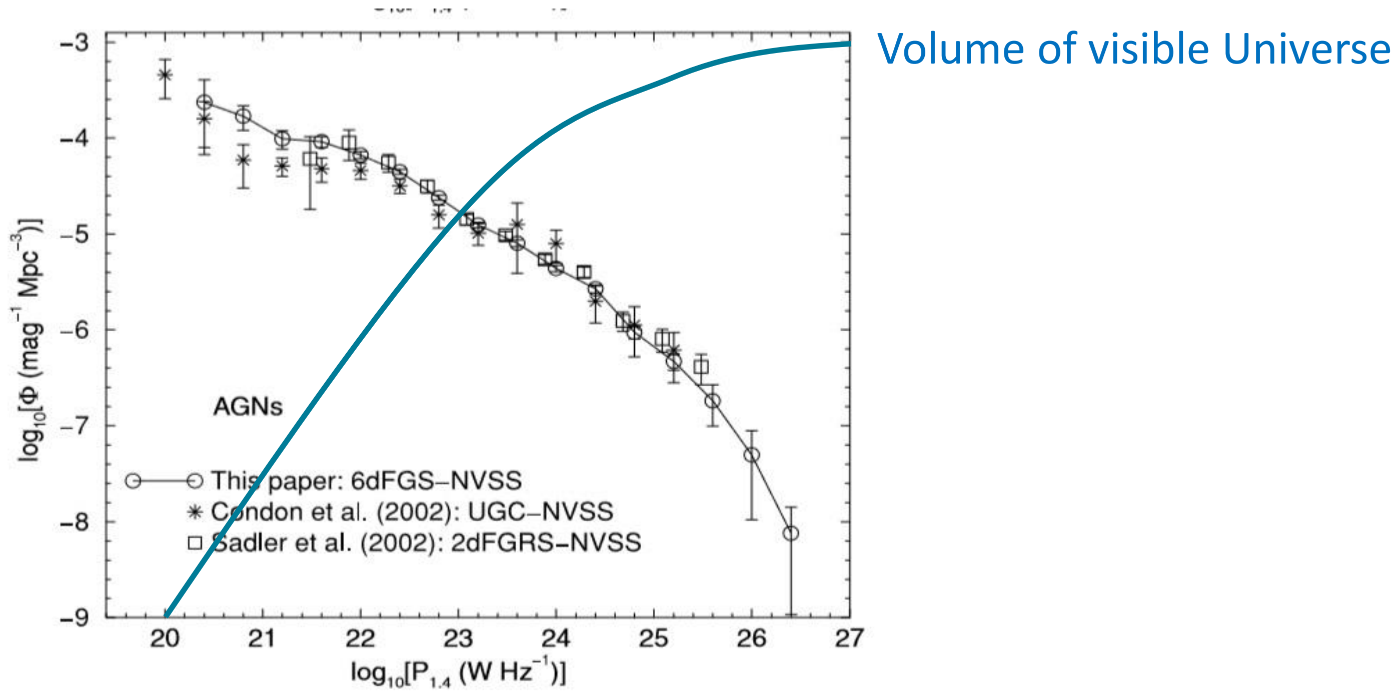
Why use source counts – event rates?

- Providing you have a well defined sample you do not need precise knowledge of the distance
- Sample has to have known completeness
- The shape of the rate distribution depends on the evolution of the luminosity function and this is a clue to the progenitor population
- The shape of the rate distribution is crucial for planning new instruments and observing strategy
  - Coherent (with small FoV) or incoherent (with large FoV)
  - FoV v sensitivity
- Use techniques like the maximum likelihood estimators
- Include time (rate and fluence) as well as space curvature terms

The Radio Luminosity Function and why it matters

- FRBs have a very broad luminosity function > 10^4
  - ➢ this dominates the statistical properties of the population (not the distance)
- The increasing volume visible at higher luminosity can cancels the decreasing source density – critical luminosity function (von Hoerner (1973)
- There may or may not be a Hubble relation



Flux density distribution v redshift

- showing effect of the luminosity function

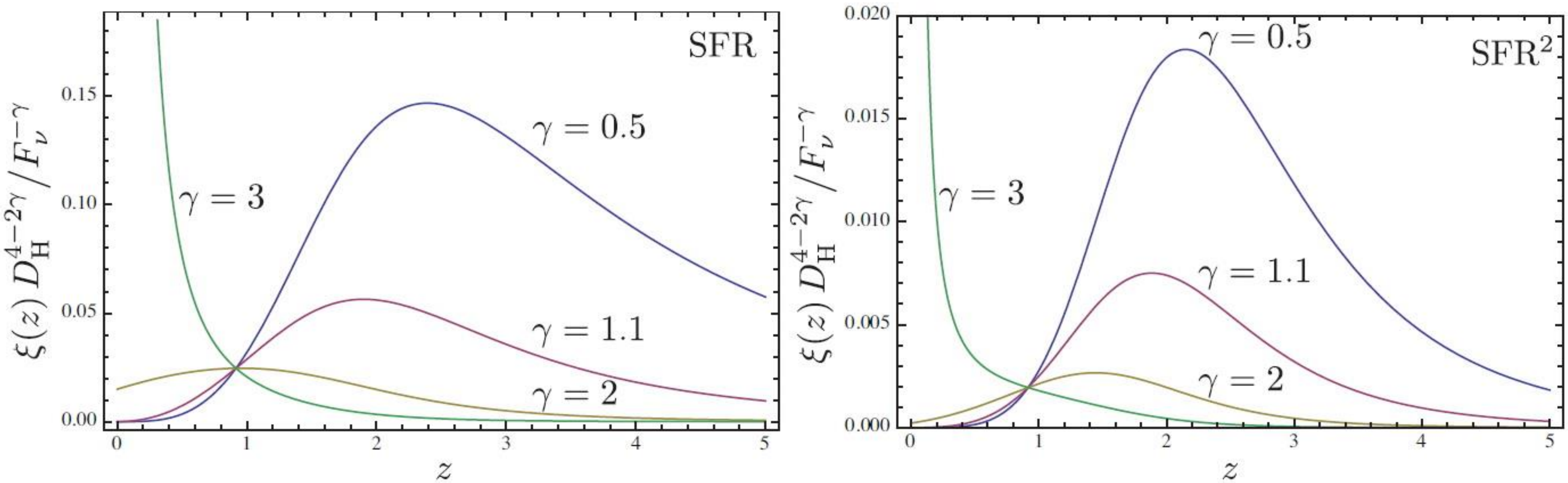


Figure 6. The differential redshift and flux density distribution of eq. (30) for a variety of γ indices for $\alpha = 1$ and for abundance evolution scenarios that scale either (left) linearly or (right) quadratically with the SFR. The plot is normalised by the constant $F_\nu^{-\gamma} D_H^{4-2\gamma}$ for plotting purposes.

Problems with existing FRB catalogues

- Discovery bias – winners curse
  - Should exclude Lorimer
- Beam location uncertainty (because single event)
  - Both fluence estimate and search area are wrong
  - Statistical correction possible but depends on count slope and beam shape
- Multiple beam detections
  - Strong bias introduced if the catalogue has a mixture of corrected and uncorrected fluences

Parkes considerations

Macquart & Ekers 2017

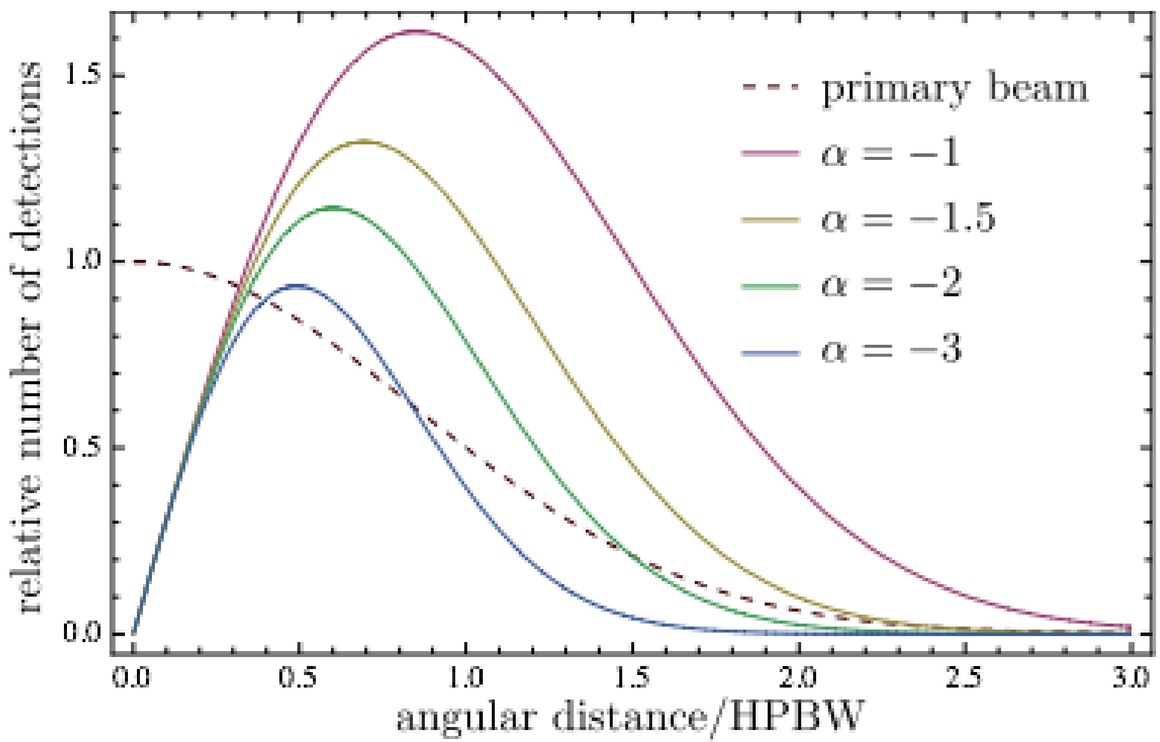
Parkes event rate hard to interpret

True completeness fluence depends on beam correction

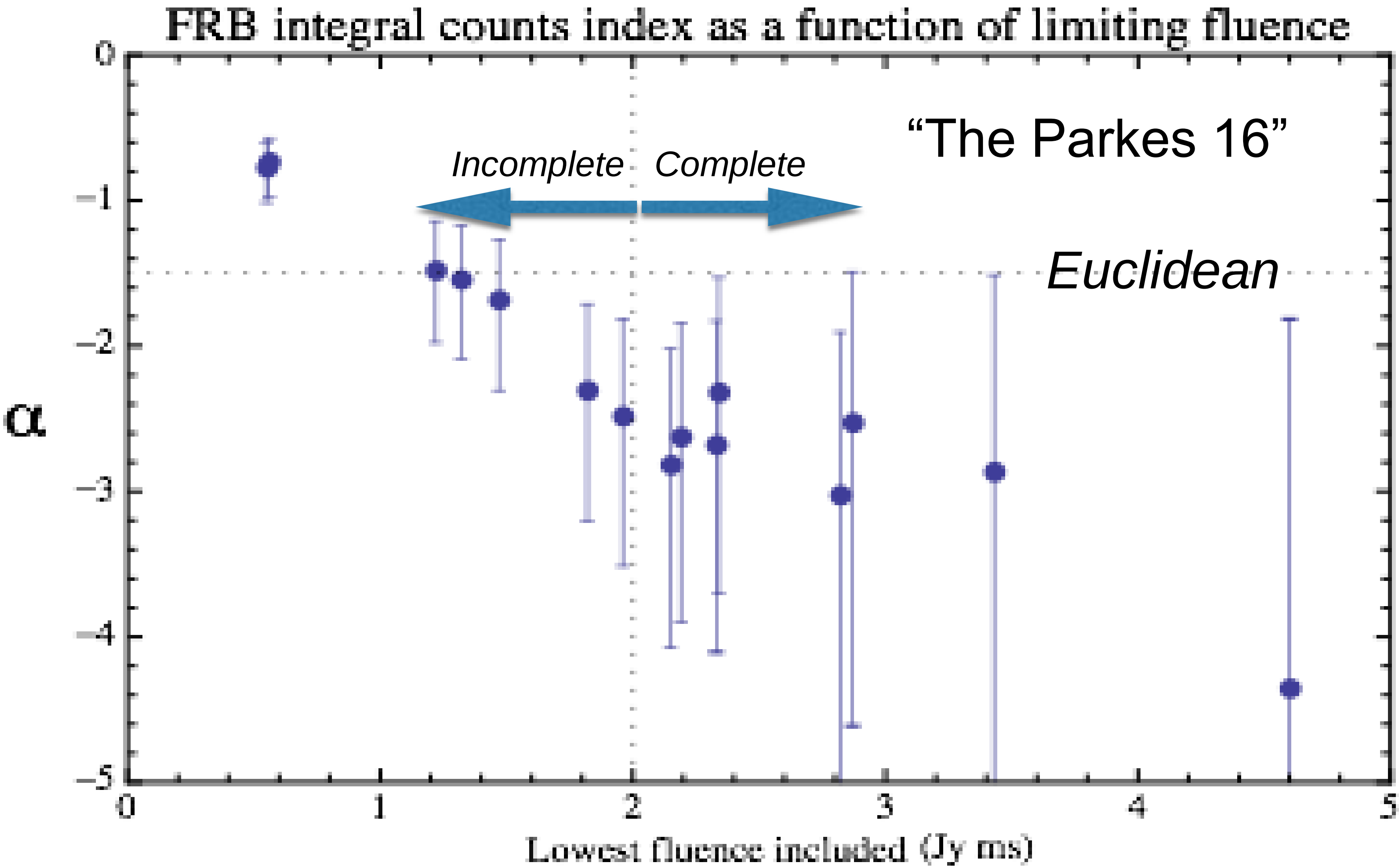
True rate depends on source counts slope:

$$R = \frac{\pi\theta_b^2}{\alpha \log 2} K S^{-\alpha}$$

$$N(>S) \propto S^{\alpha}$$

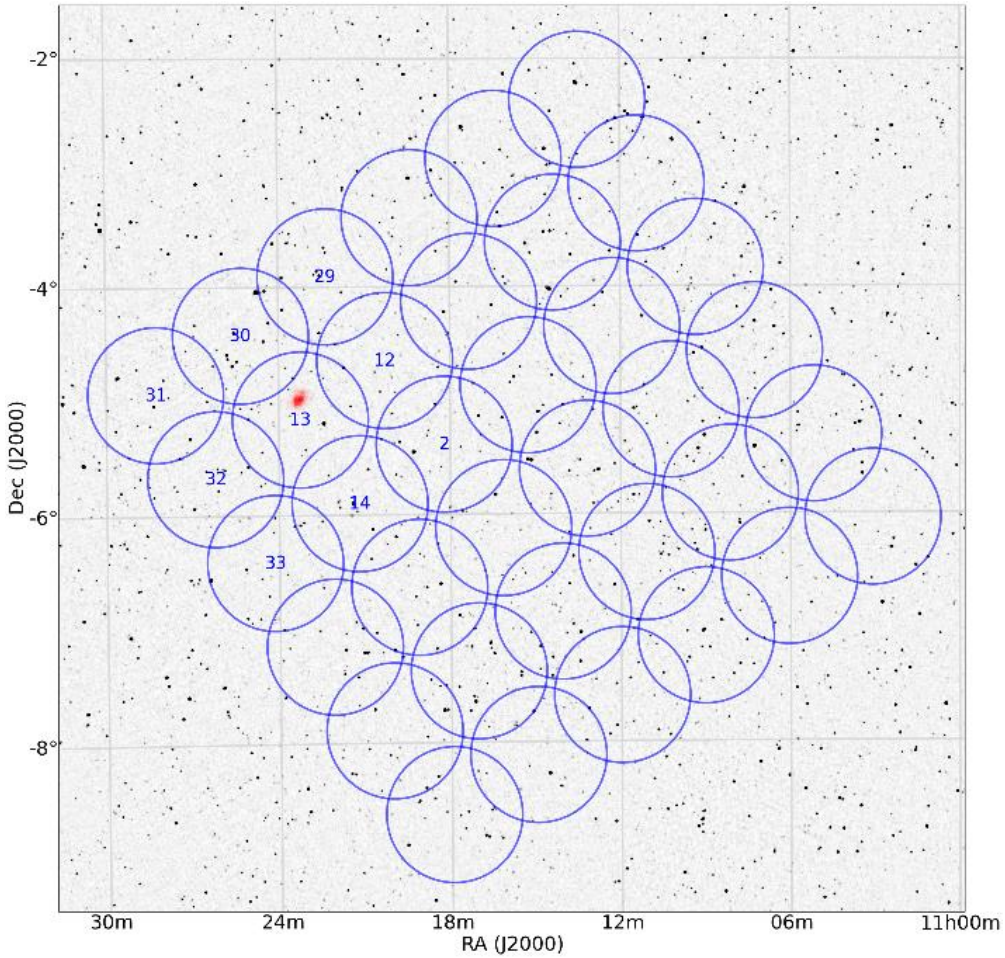


Parkes source counts
Maximum likelihood analysis



The ASKAP FRBs - no beam location uncertainty

- PAF localisation
- V/Vmax = 0.59
- Implies alpha=-2.2.



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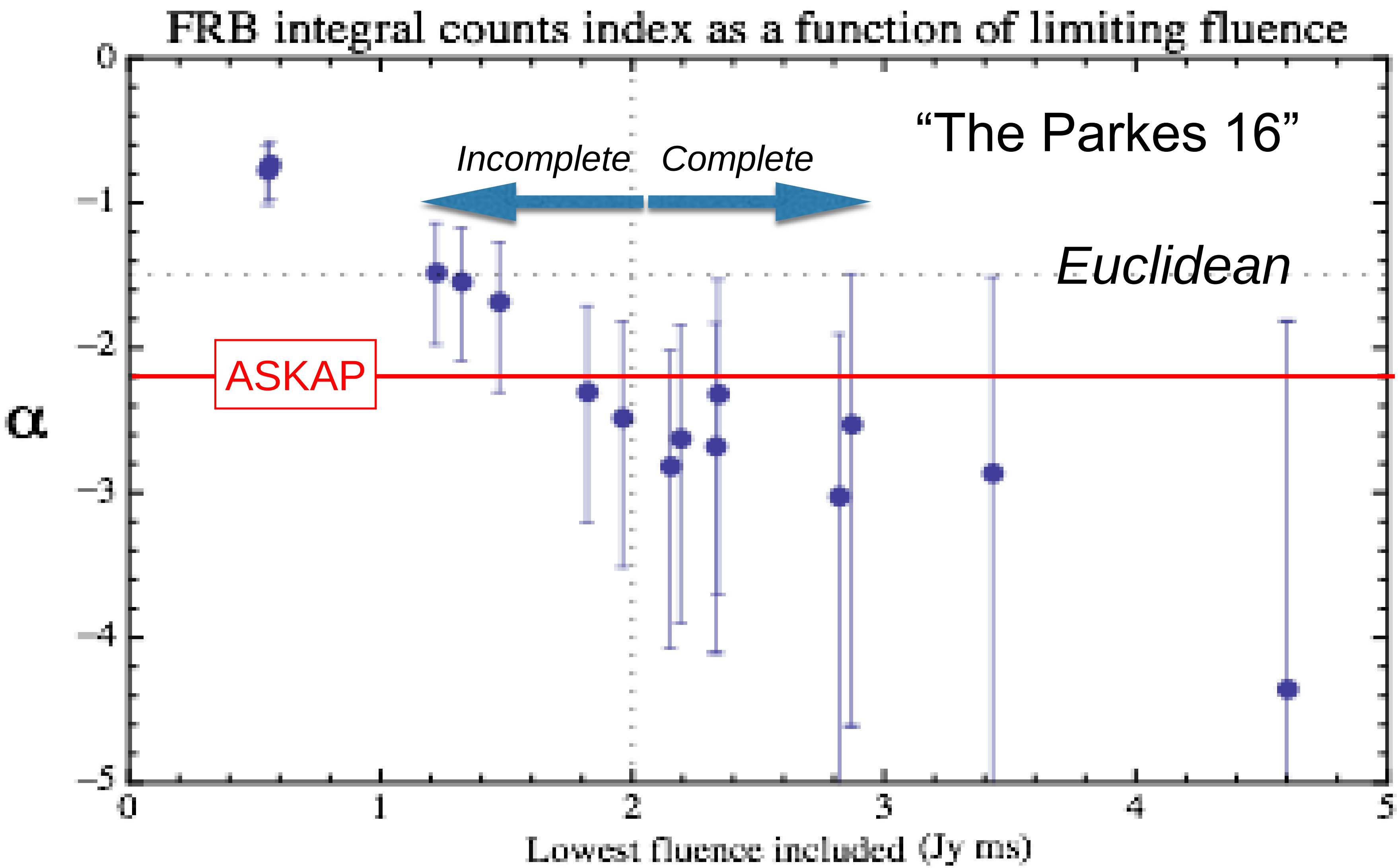

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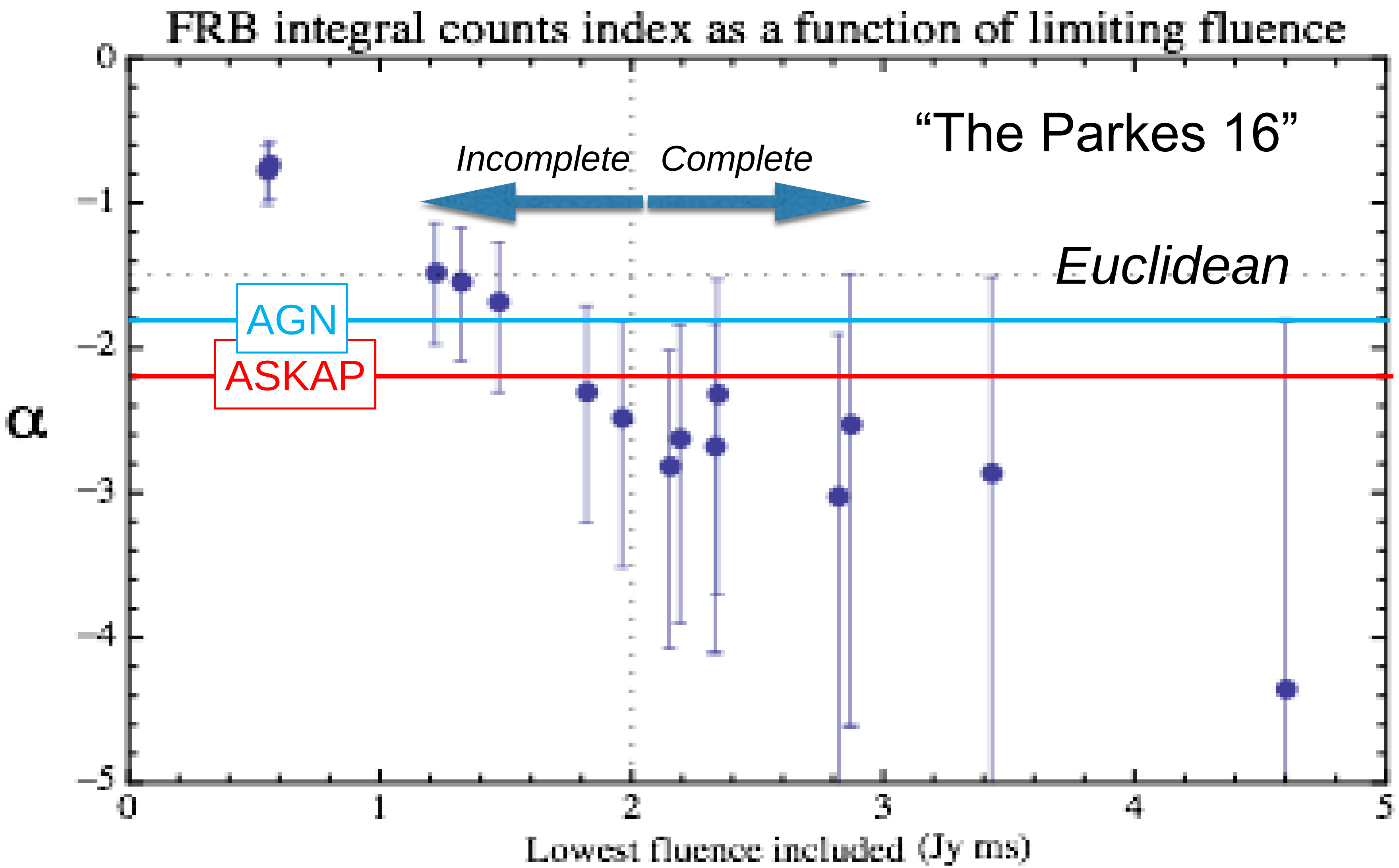
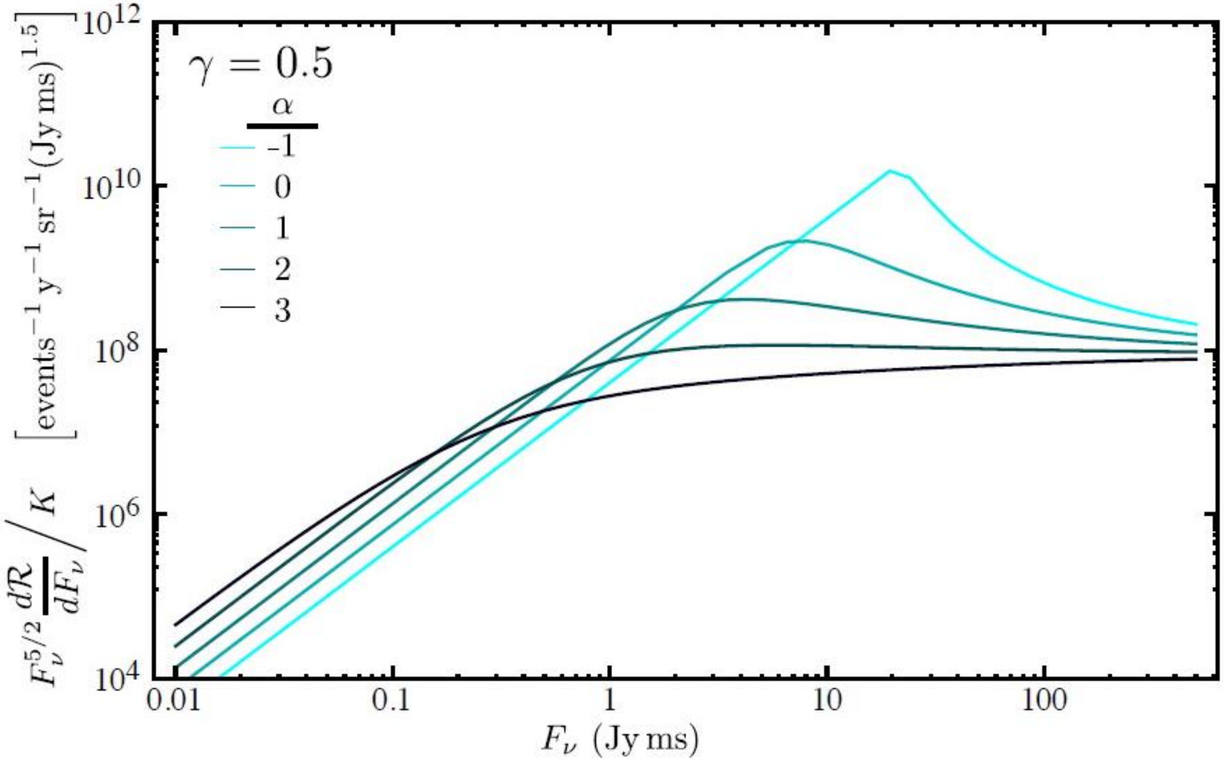


FRB rate counts

- Macquart & Ekers (2018)
  - – theoretical framework to interpret counts and DM distributions
- Extremely flat luminosity function
- Strong evolution: $SFR^2 = (1+z)^{5.6}$



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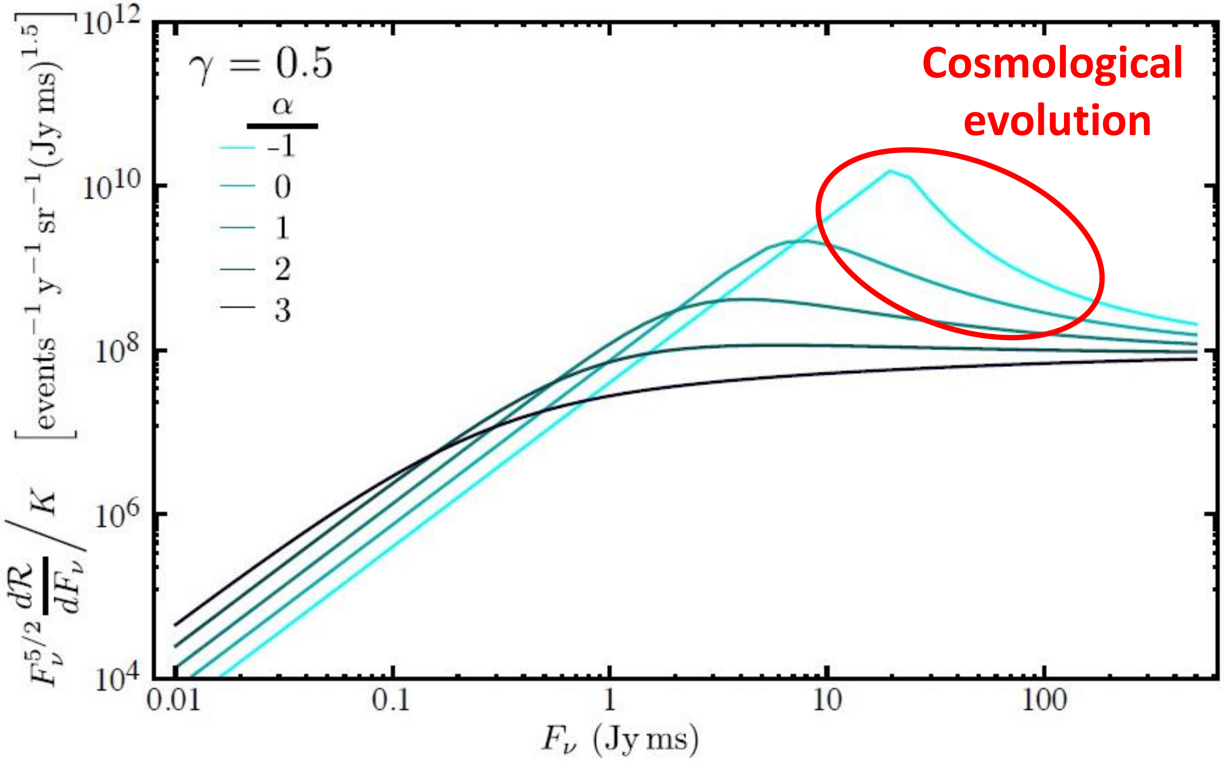
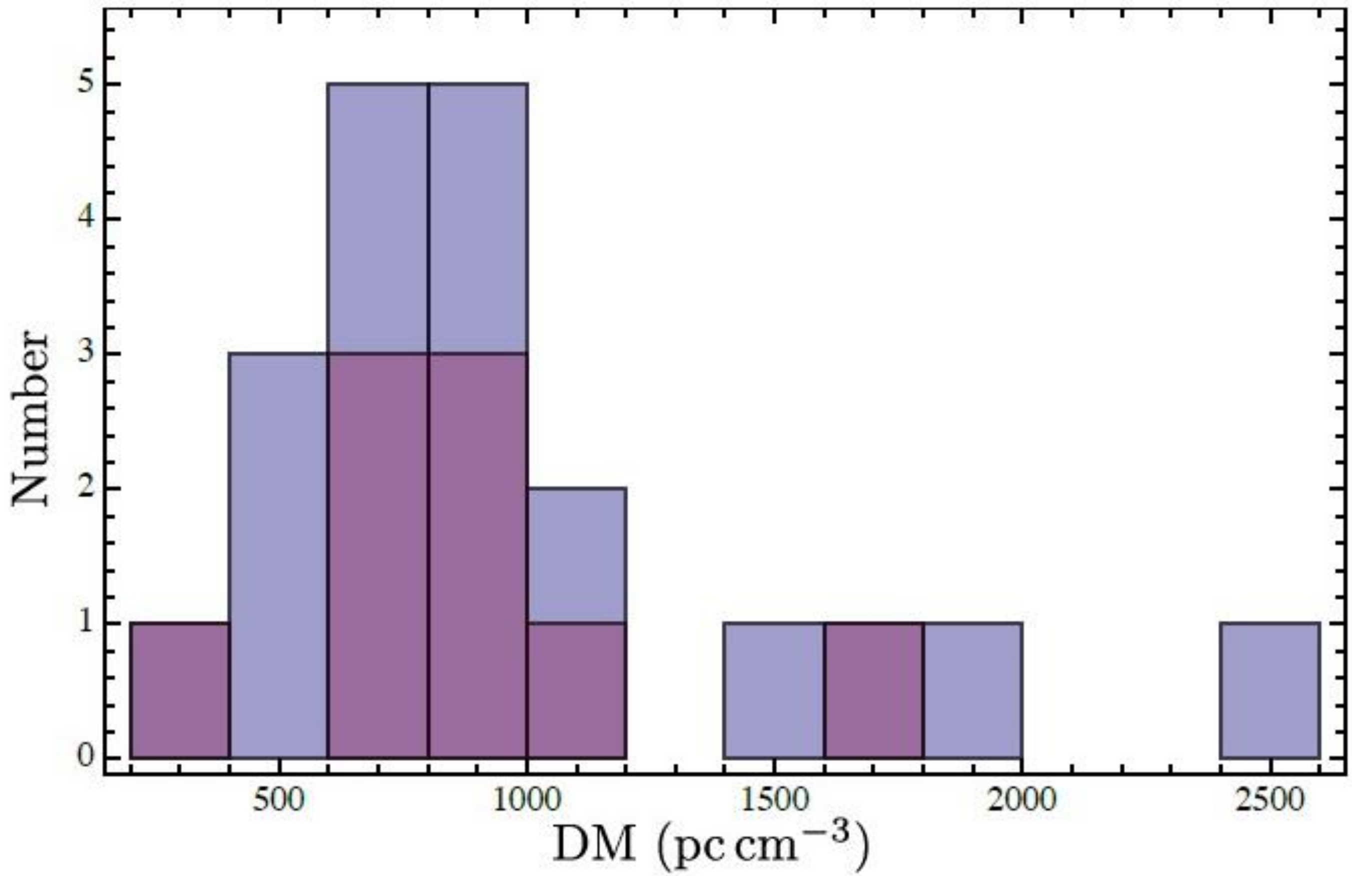


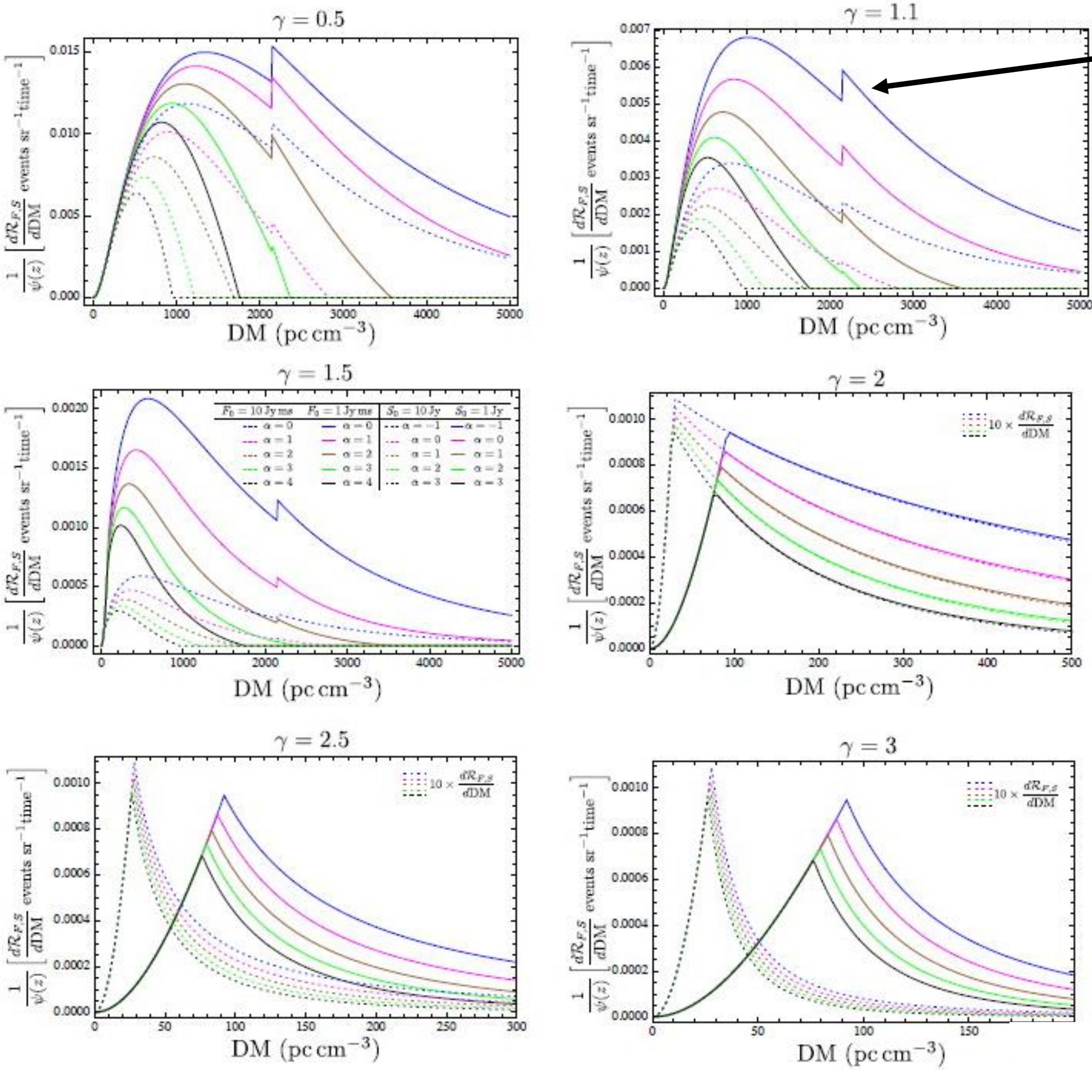
Parkes FRB DM distribution

- Petroff et al 2016: full sample >2Jy ms completeness
- Excluding Lorimer

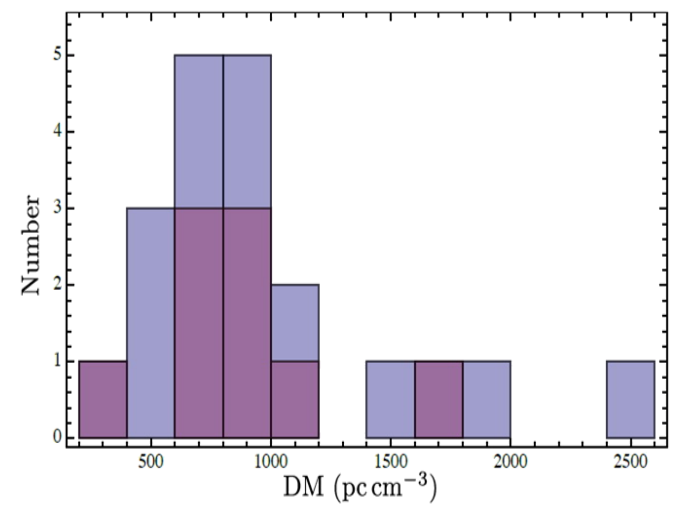


Model FRB DM distribution

He reionisation!



convert *z* into *DM* using an (oversimplified) model of the IGM, but including He reionization:



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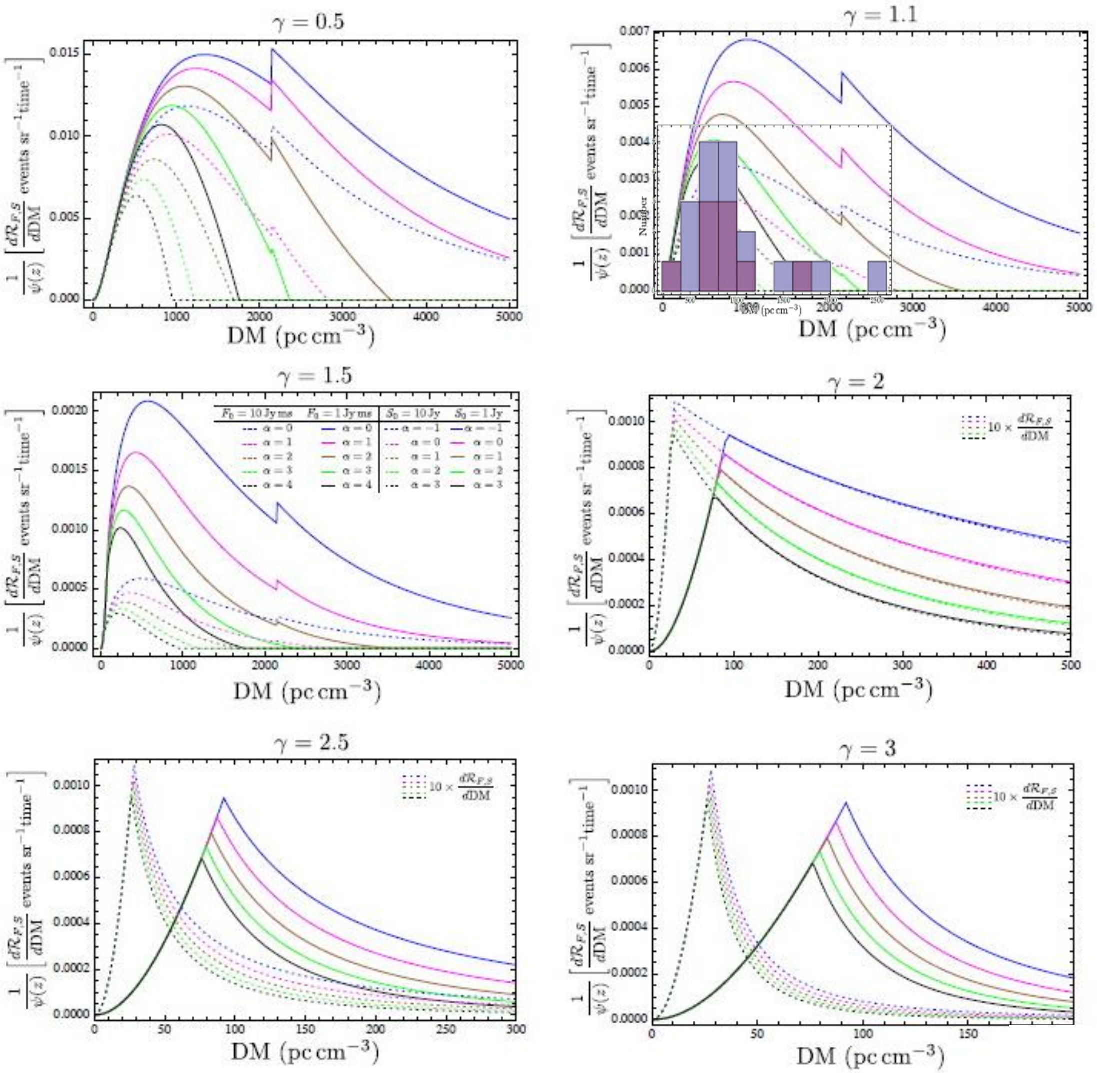

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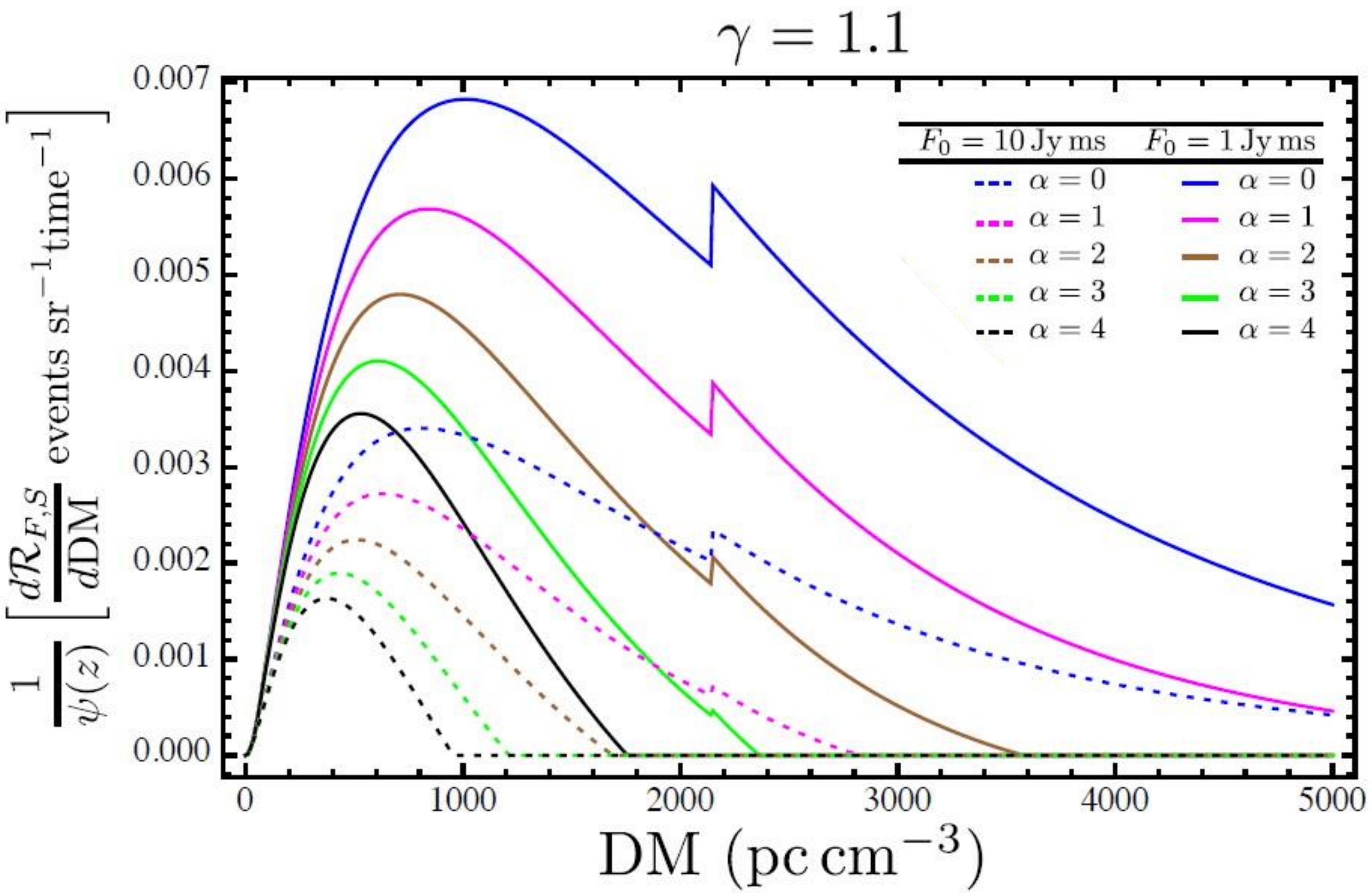

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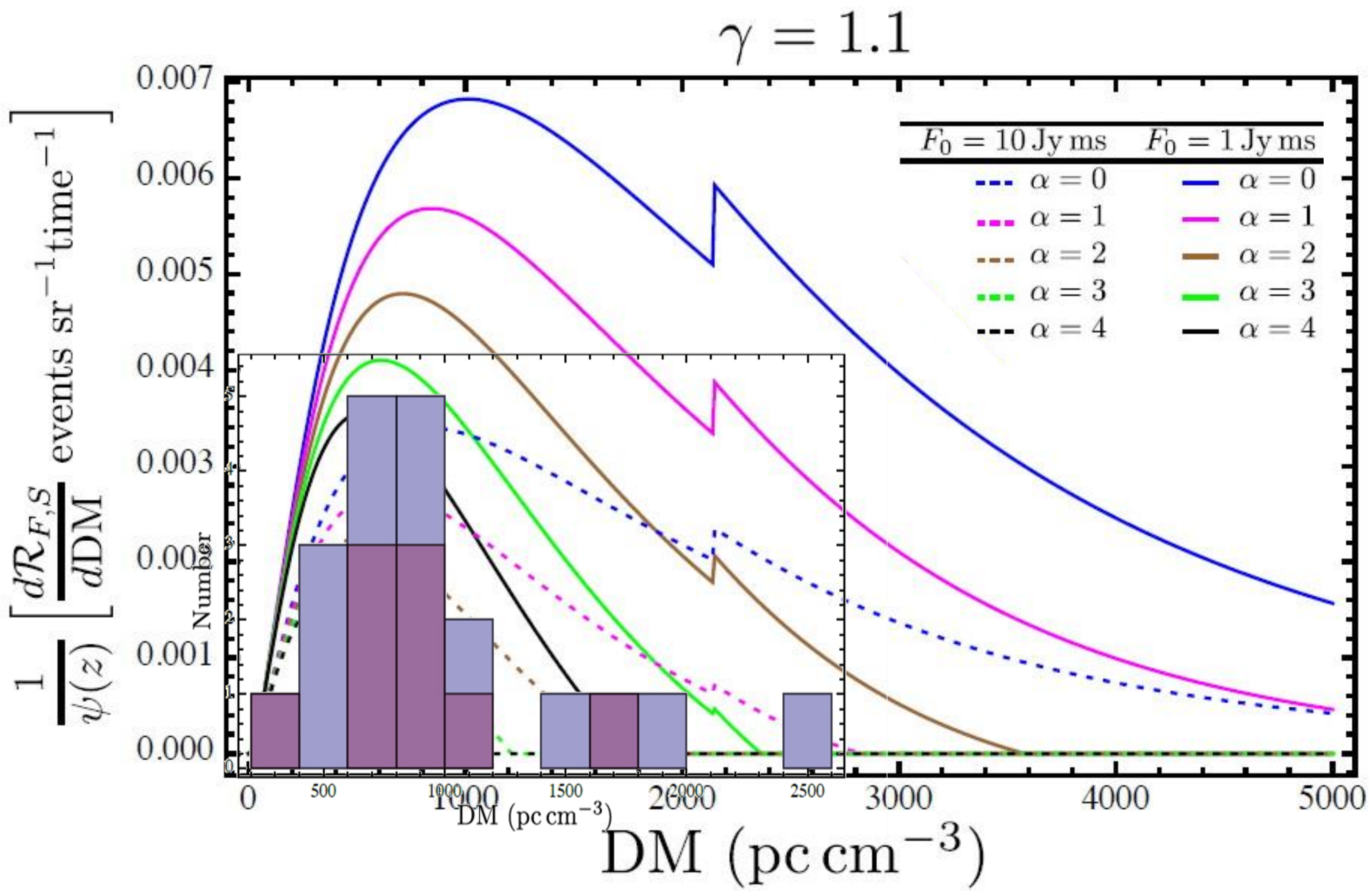

Conclusions

- FRBs have a very broad luminosity function
  - X 10^4 and this dominates the statistical properties of the population
- The high fluence end of the distribution is most sensitive to evolution and distribution on cosmological scales
  - Strong motivation for large FoV surveys rather then high sensitivity surveys
  - The statistics for high fluence transients improves with time
    - This is very different to counts of non-transient sources
- There may not be a Hubble relation for FRBs
- The Parkes FRB steep source counts require very strong evolution
  - Eg (star formation rate)^2 or following the AGN $(1+z)^6$
- An exponential scattering tail cannot change the broad luminosity function
- FRB DM distributions as a function of fluence is an extremely powerful probe