A population model for Fast Radio Bursts

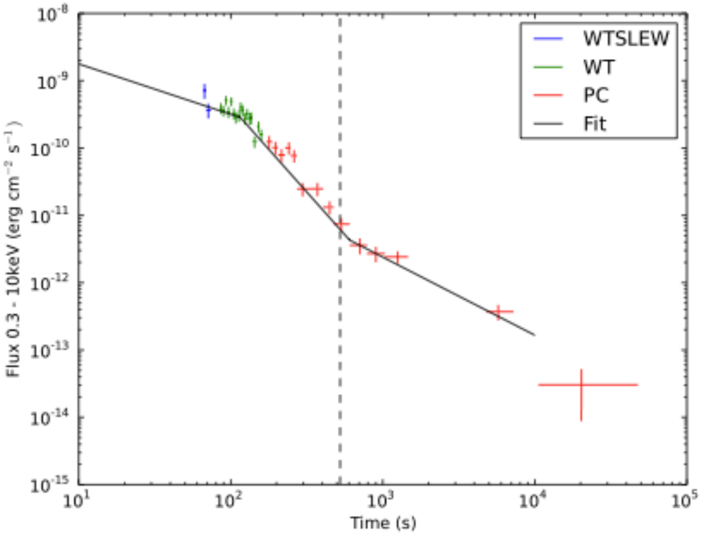
Keith Bannister
Bolton Fellow
CSIRO Astronomy & Space Science
keith.bannister@csiro.au

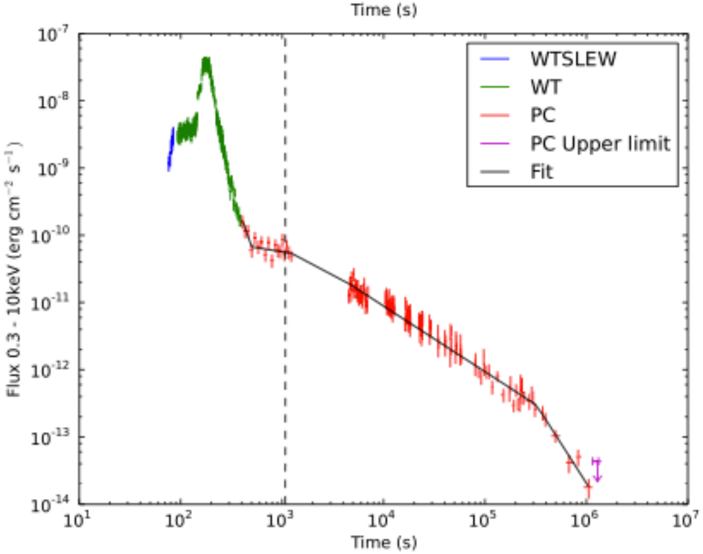
In collaboration with Benjamin Pope (Cambridge)

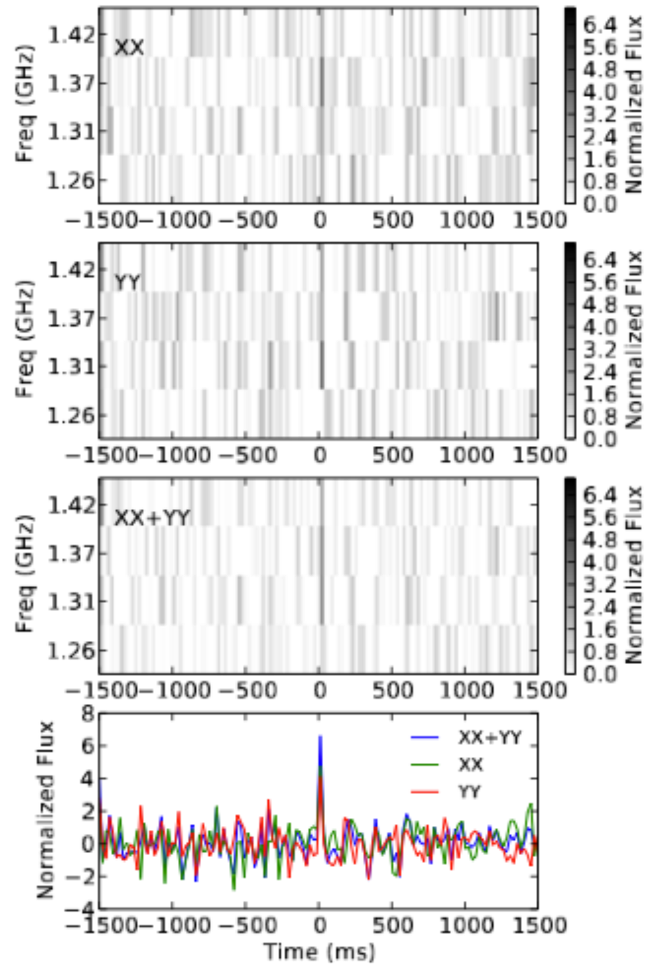
Outline

- An archival burst
- Statistics in 2 plots:
  - Number vs DM (or z?)
  - Number vs luminosity
- Some thoughts on a population model
- An aside: Keane burst is (probably) Galactic
- Conclusions

FRBs after (L)GRBs?

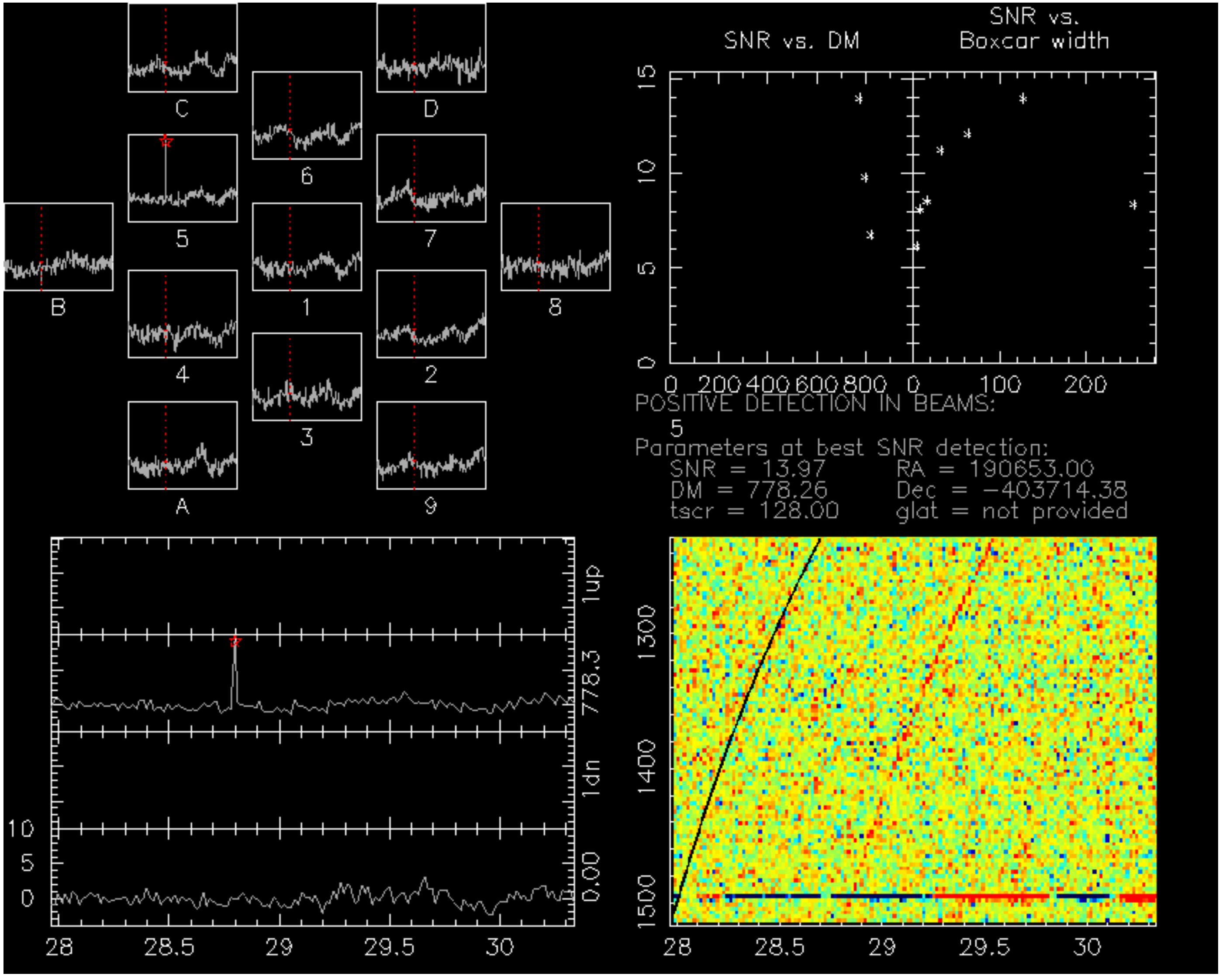






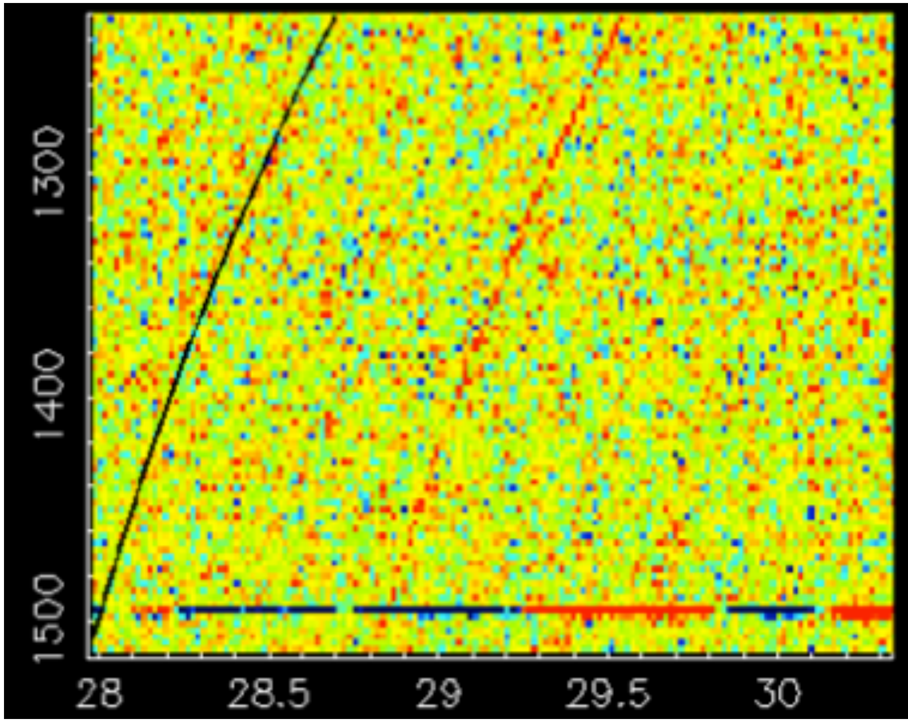
Bannister+ 12

Archival burst - FRB010125



Archival burst - FRB010125

- Parkes mid-latitude survey
- DM: 790 pc/cm3
- Excess DM: 680 pc/cm3
- Peak flux dens.: 300 mJy
- S/N: 14
- Width: 9.4 ms
- b = -20 deg



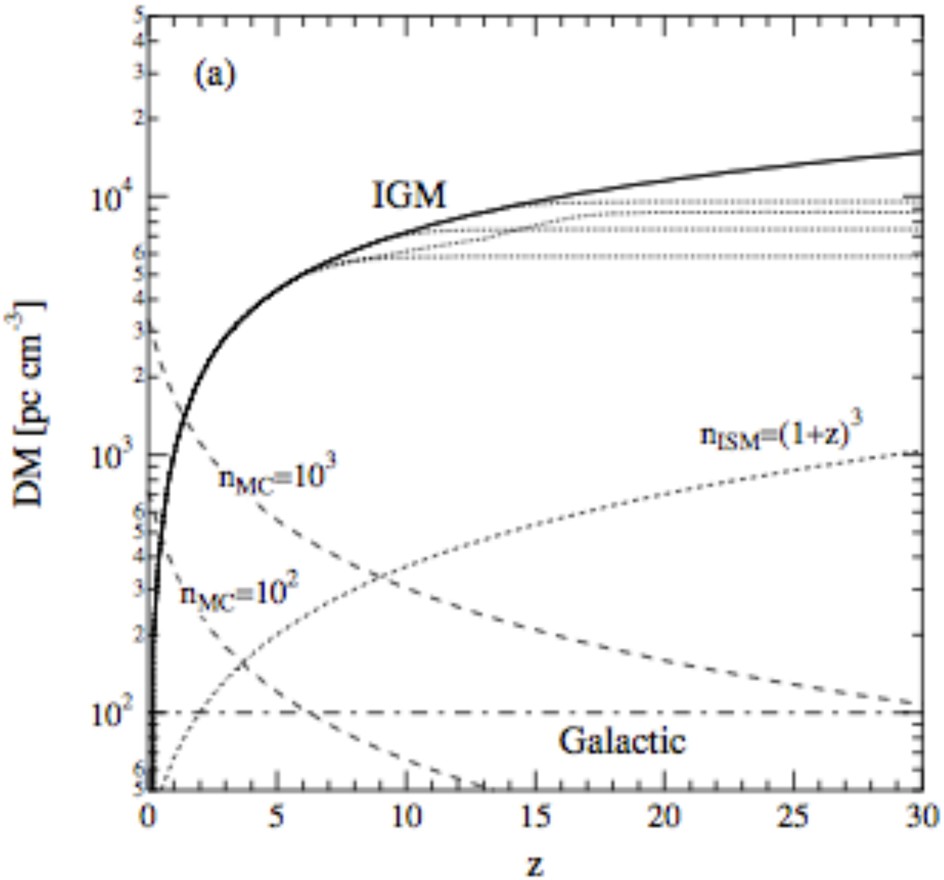
Can we constrain the physical properties of FRBs?

Even with so many uncertainties?

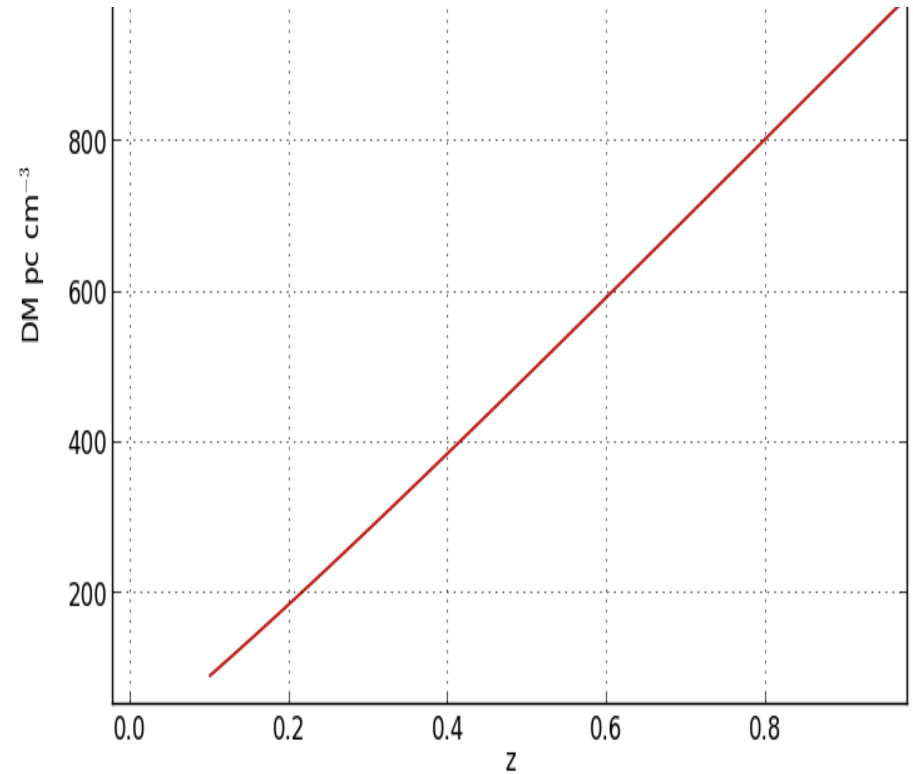
Some questions

- Assume isotropic, extragalactic
  - I'm drinking the kool-aid (sorry Ron)
- Are they standard candles?
- Is the host DM significant?
- Does the comoving volume rate change with redshift?
  - E.g.Does the rate track the star formation rate density, which is higher at z=1 than z=0.

Step 1: Assume excess DM is from the IGM



Inoue 04



Step 2 - Assumptions

- Assume the observed flux density = the true flux density (Here be dragons)
- Host DM = 0
- Comoving volume rate : $\rho_0 z^\delta$
- Integrate up this equation:

$$N(z, L) = \rho(z)\Omega(S, S_0)N(L)dL\,dV\,c$$

$$= \rho_0 z^\delta \Omega(S, S_0)L^{-\alpha} dL\,dV\,c \qquad L_{min} < L < L_{max}$$

Step3: Assume a form for the **intrinsic** luminosity function

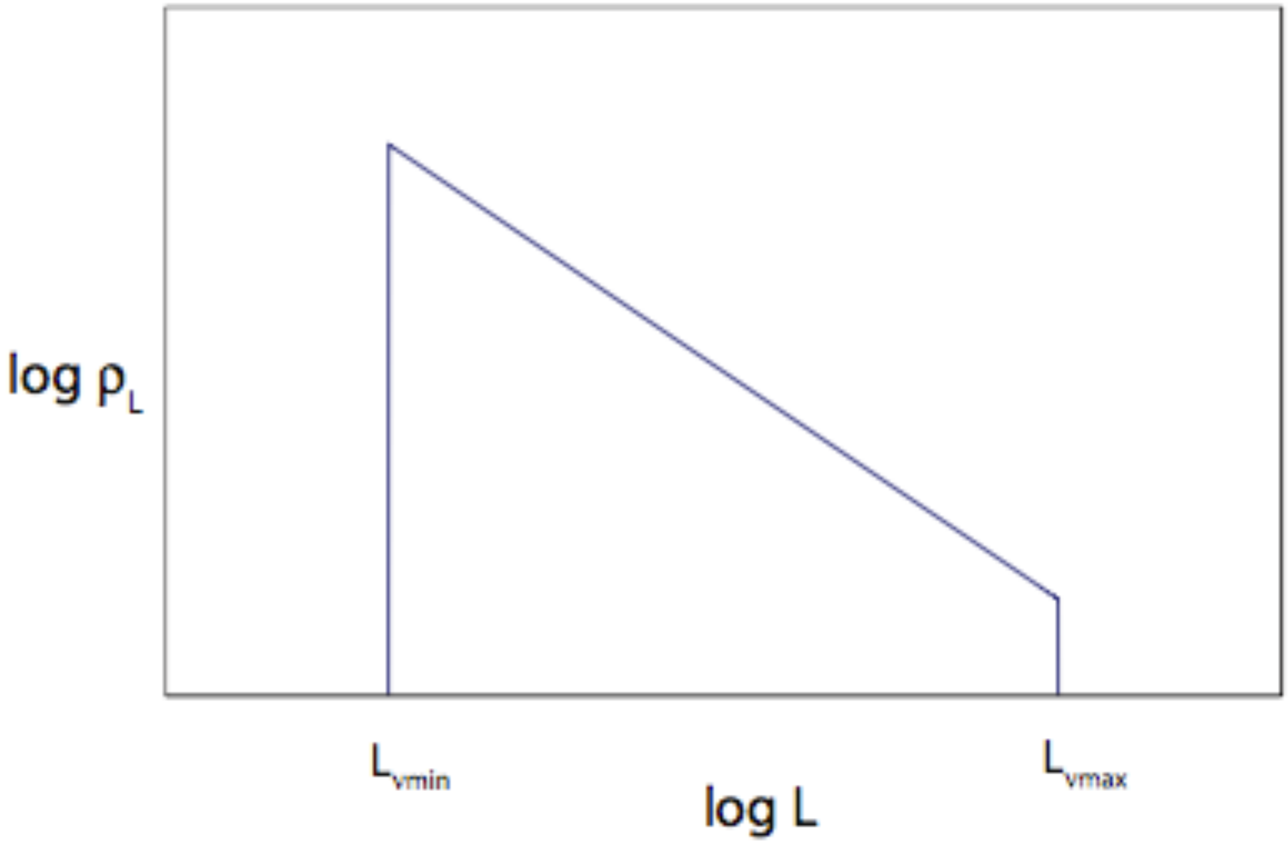
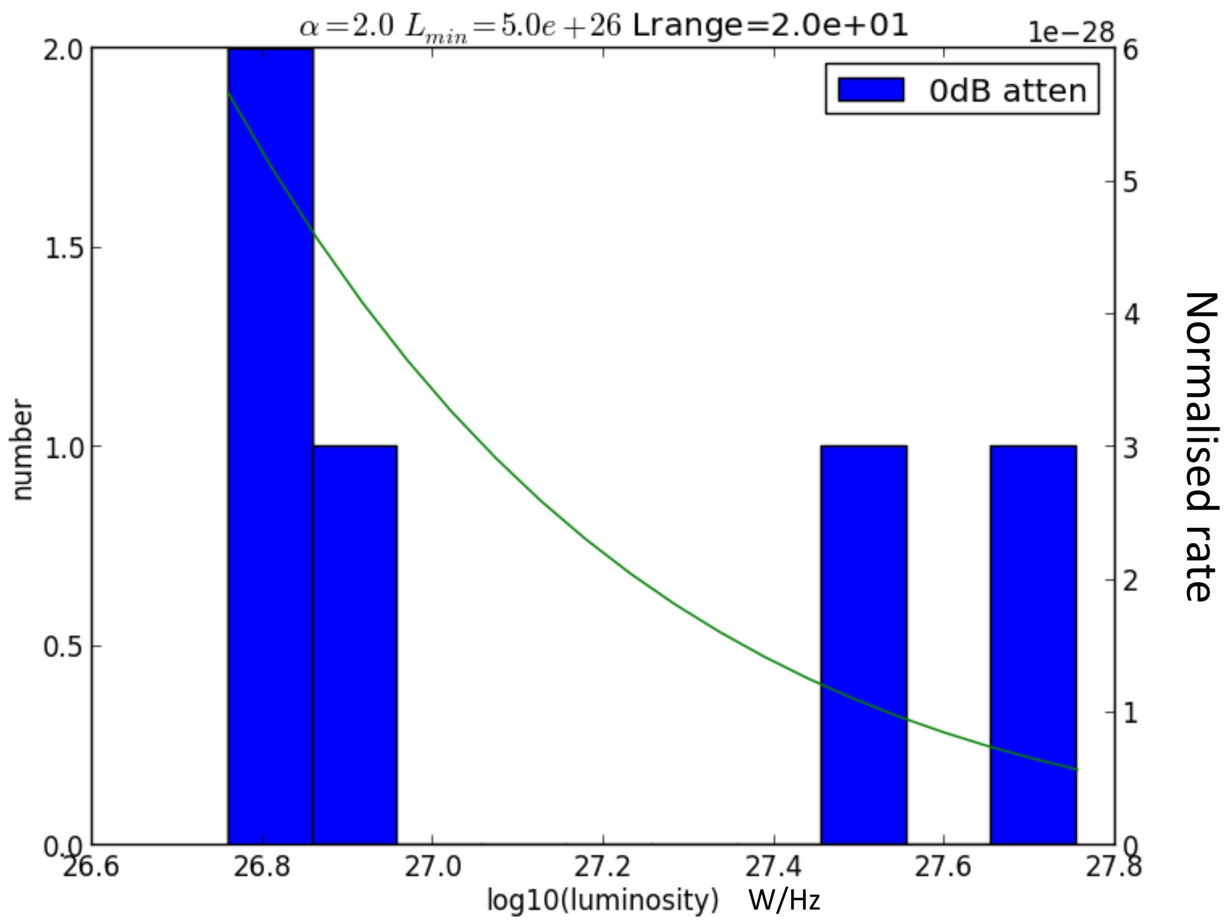


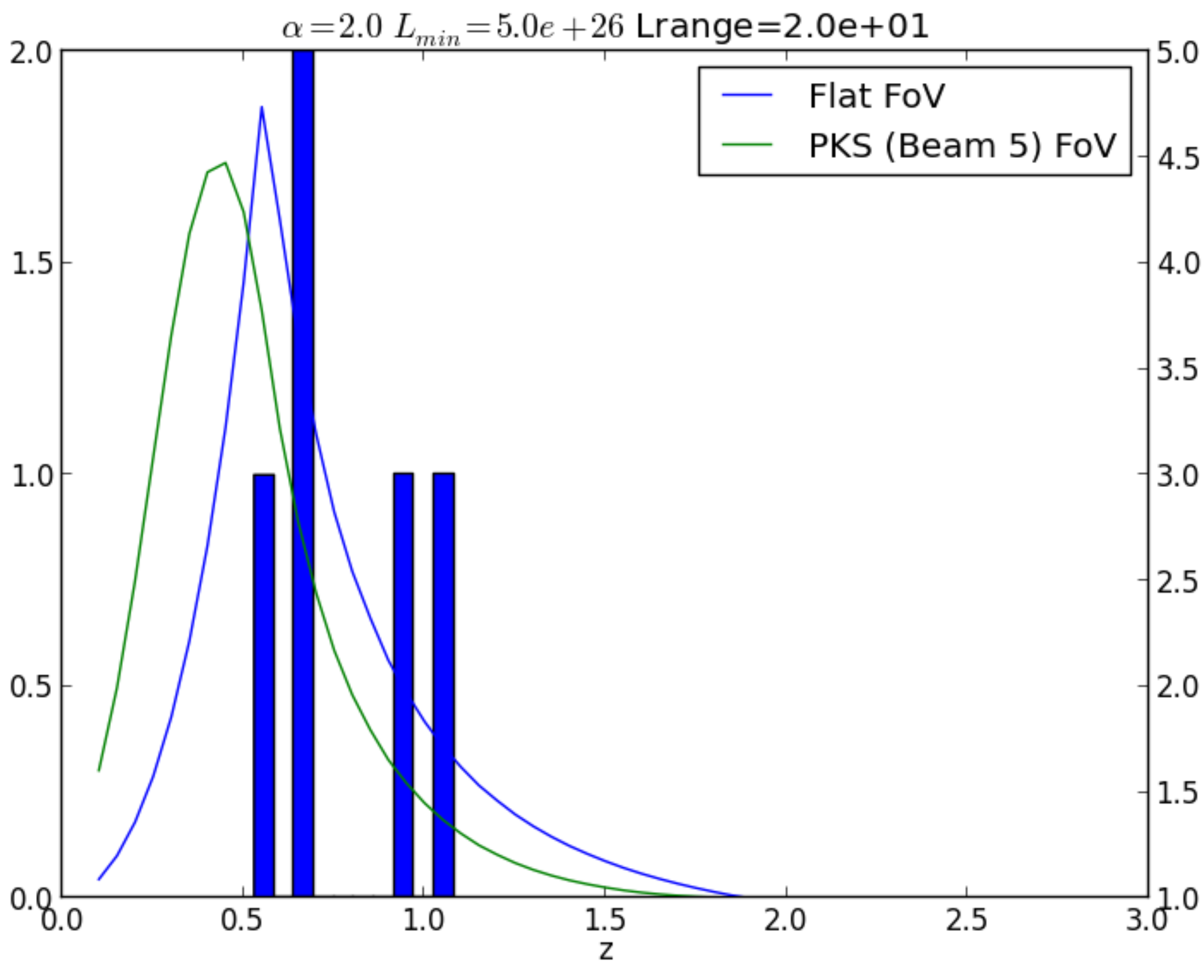
Figure 1. Generic luminosity distribution considered in the text. (A color version of this figure is available in the online journal.)

Macquart 11

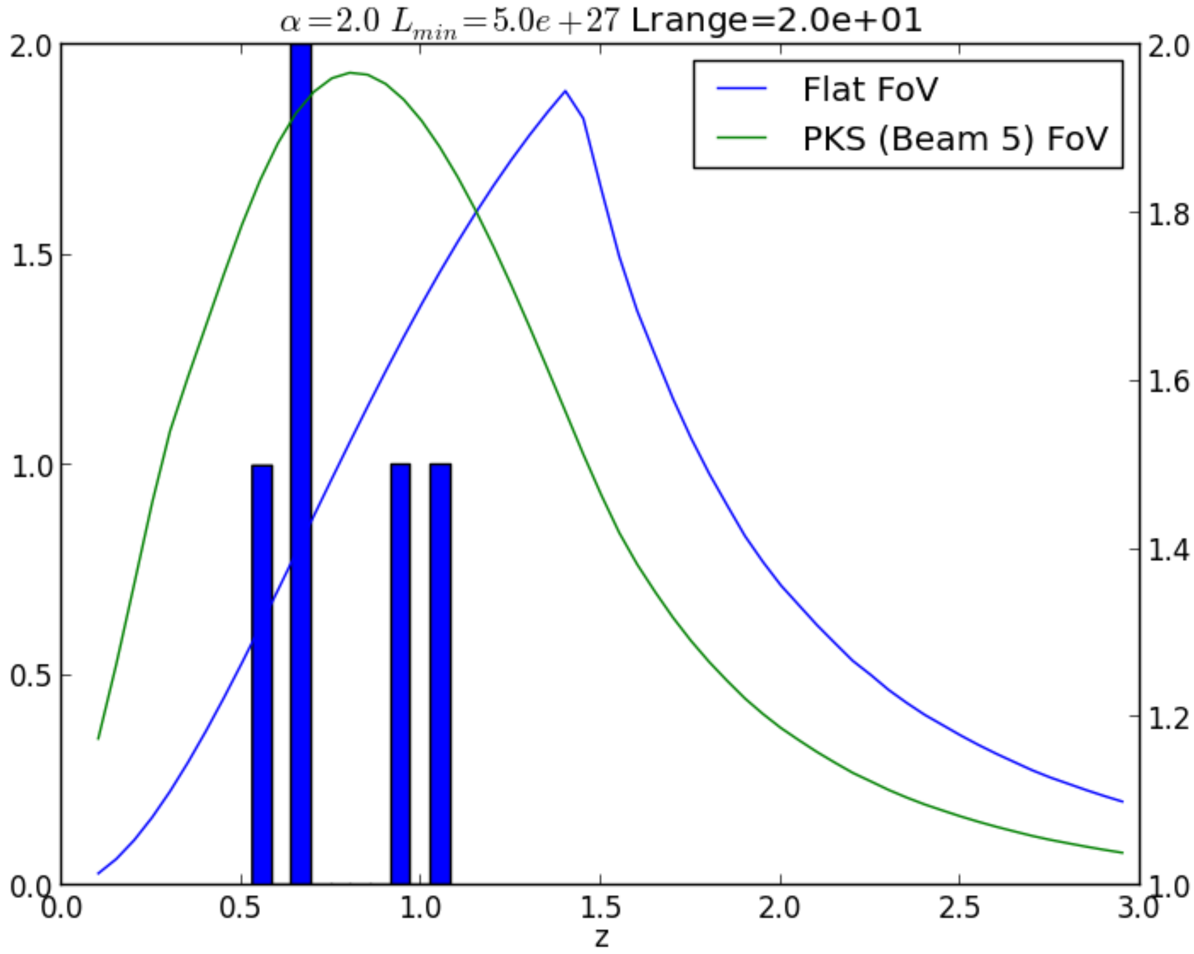
Step 4: **Observed** Luminosity Function



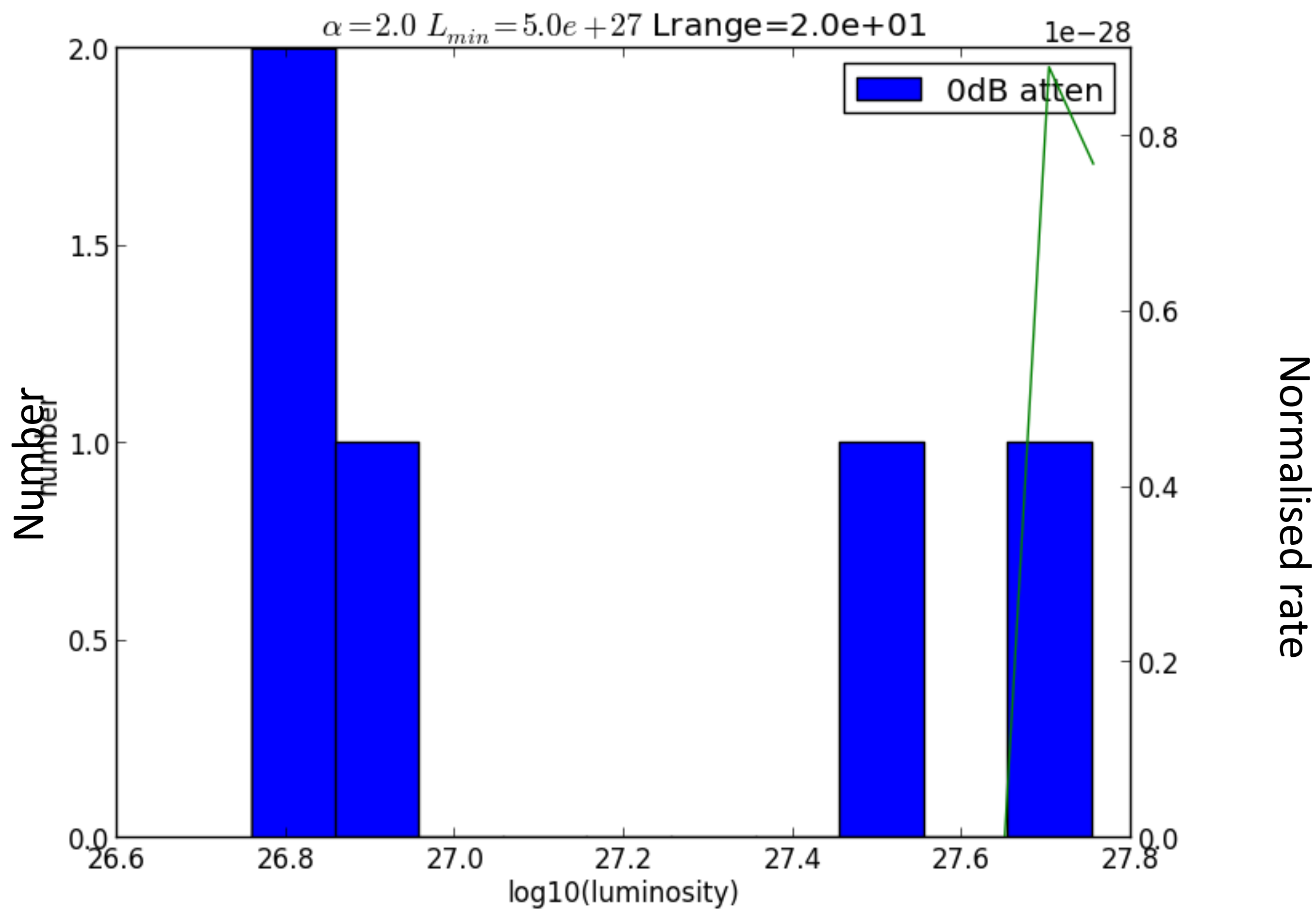
But the number vs redshift peaks too early



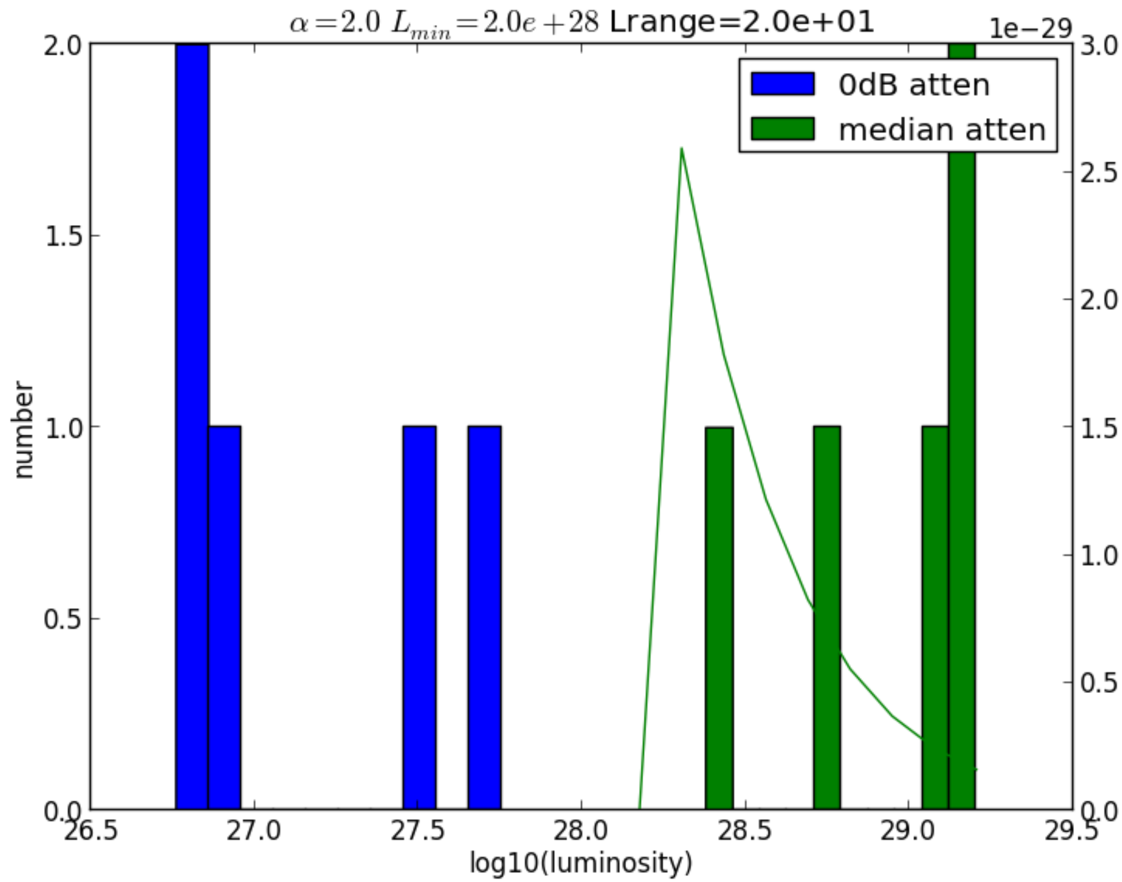
To fix that – raise the luminosity



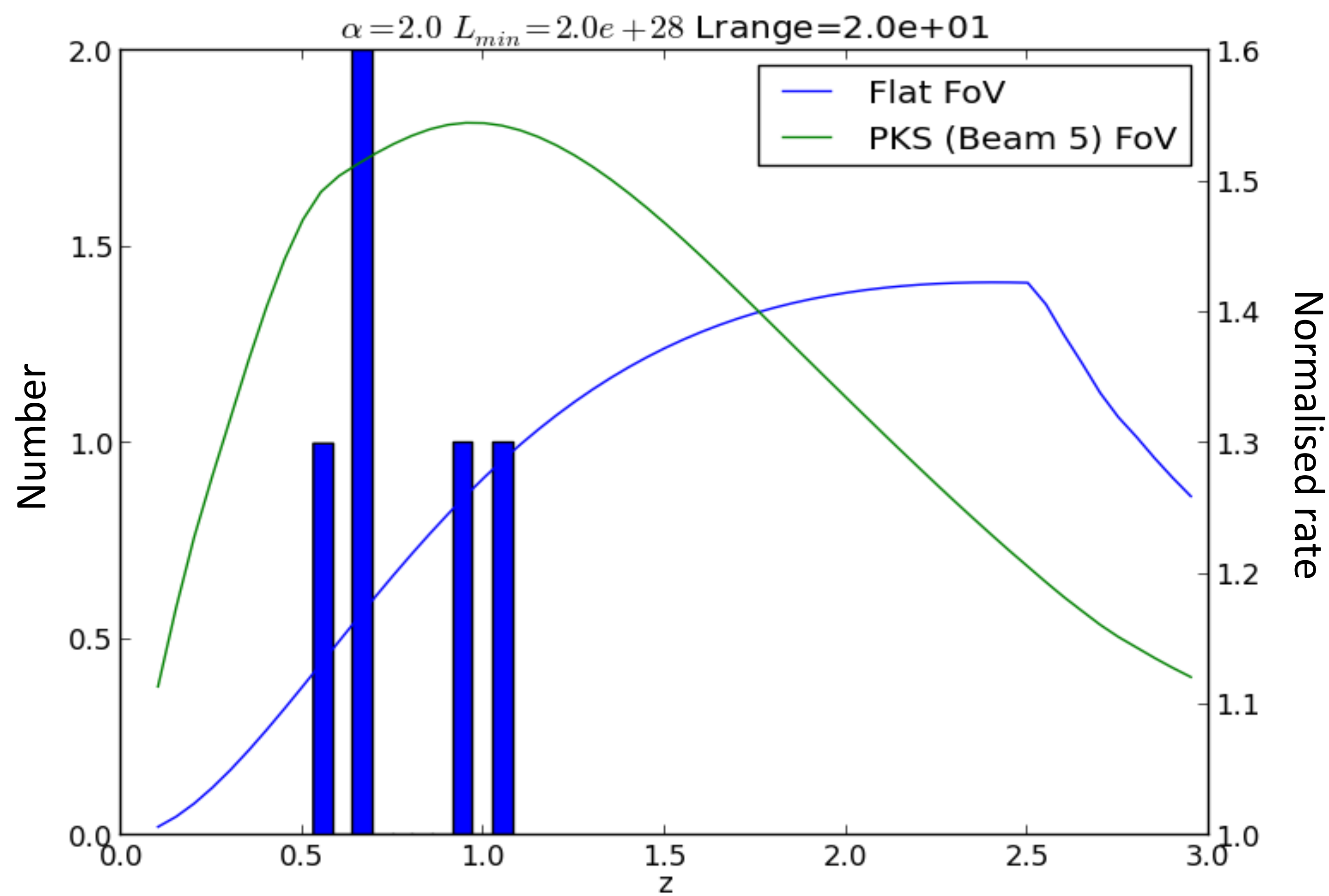
But that makes the luminosity function infeasible



But really – measured flux attenuated by the beam – so we can increase the luminosity!

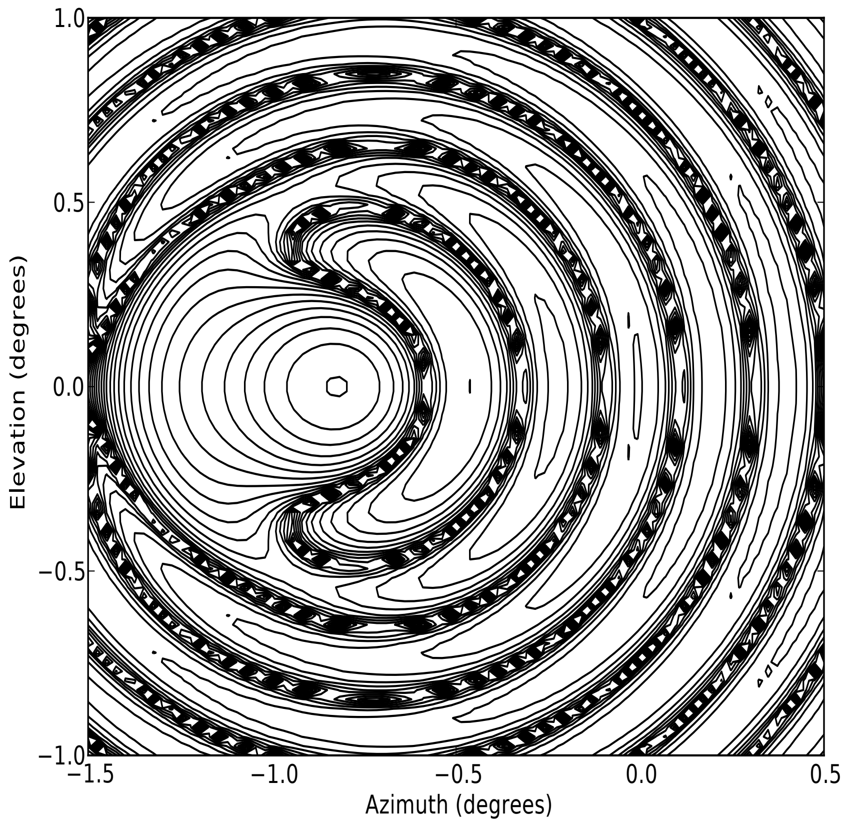


But then – you expect the same number of events at z=0.7 as z=1.6 (which we don't see)

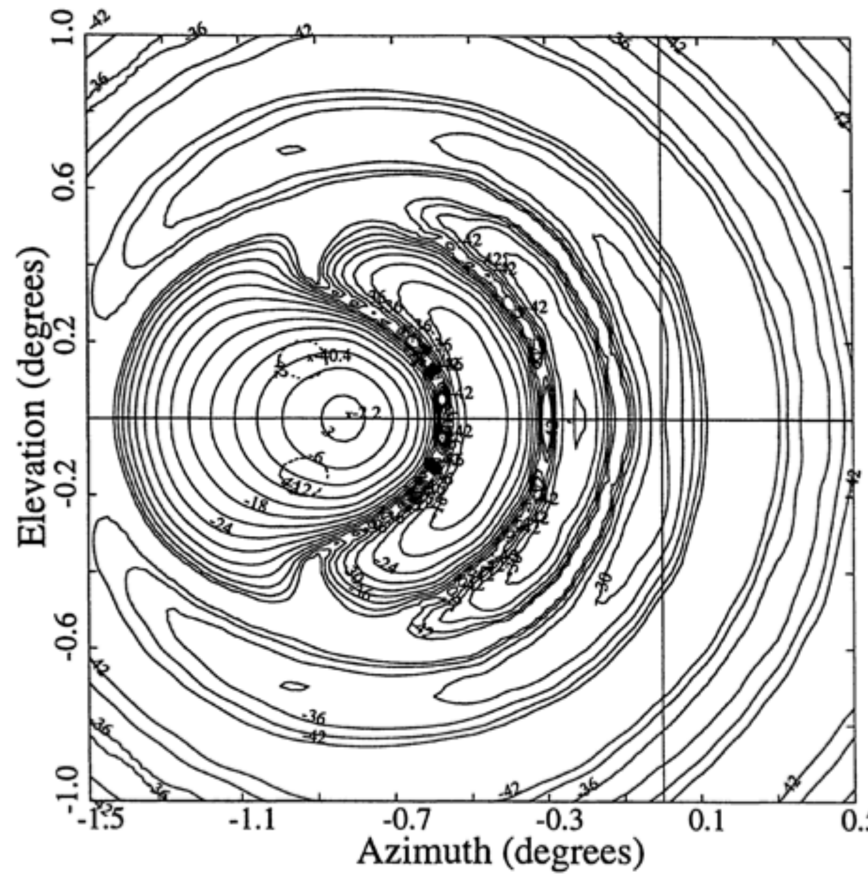


Really, you want to Monte-Carlo that puppy up

Parkes beam model

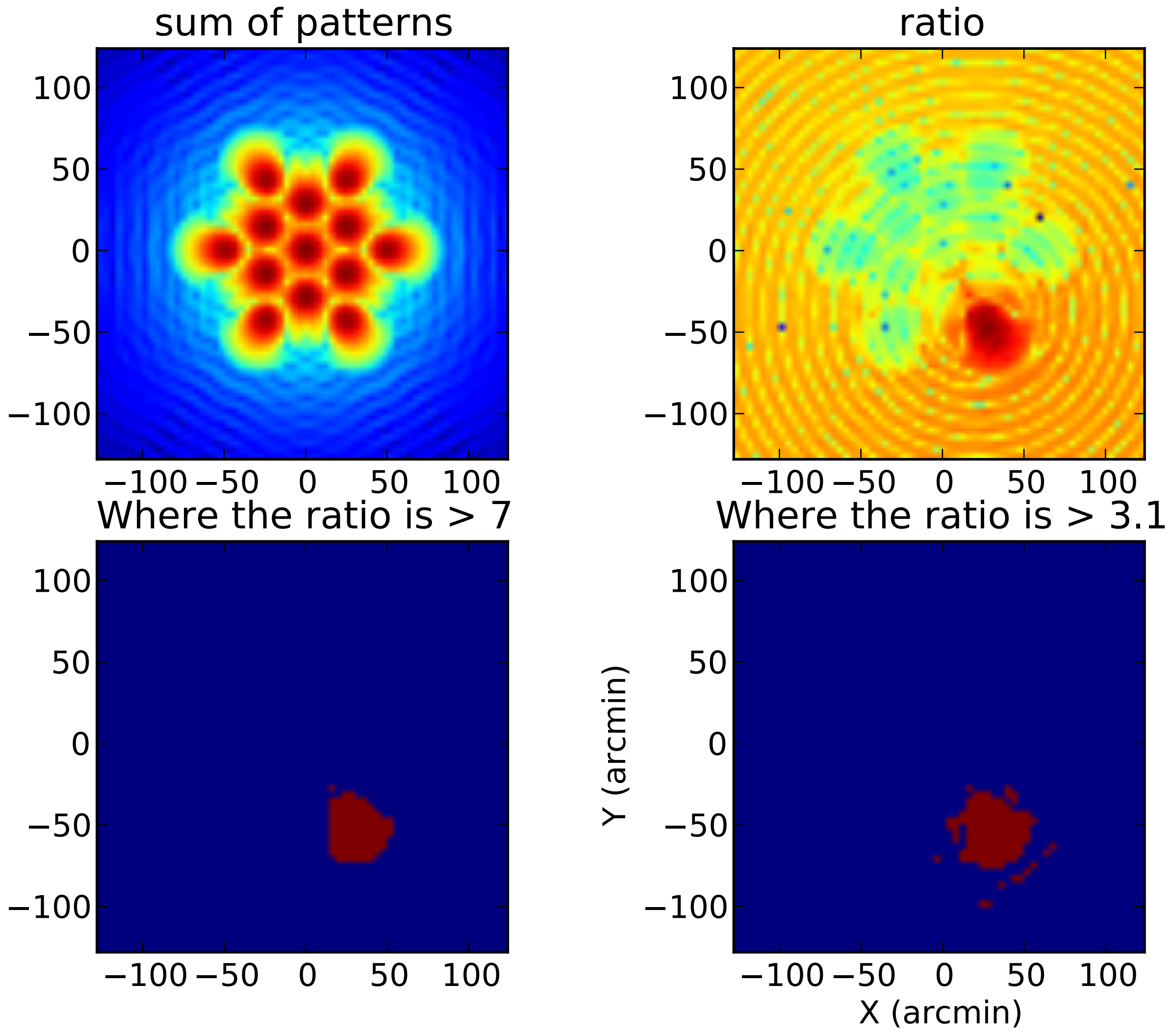


Gaussian -12dB taper, 2.4m blockage

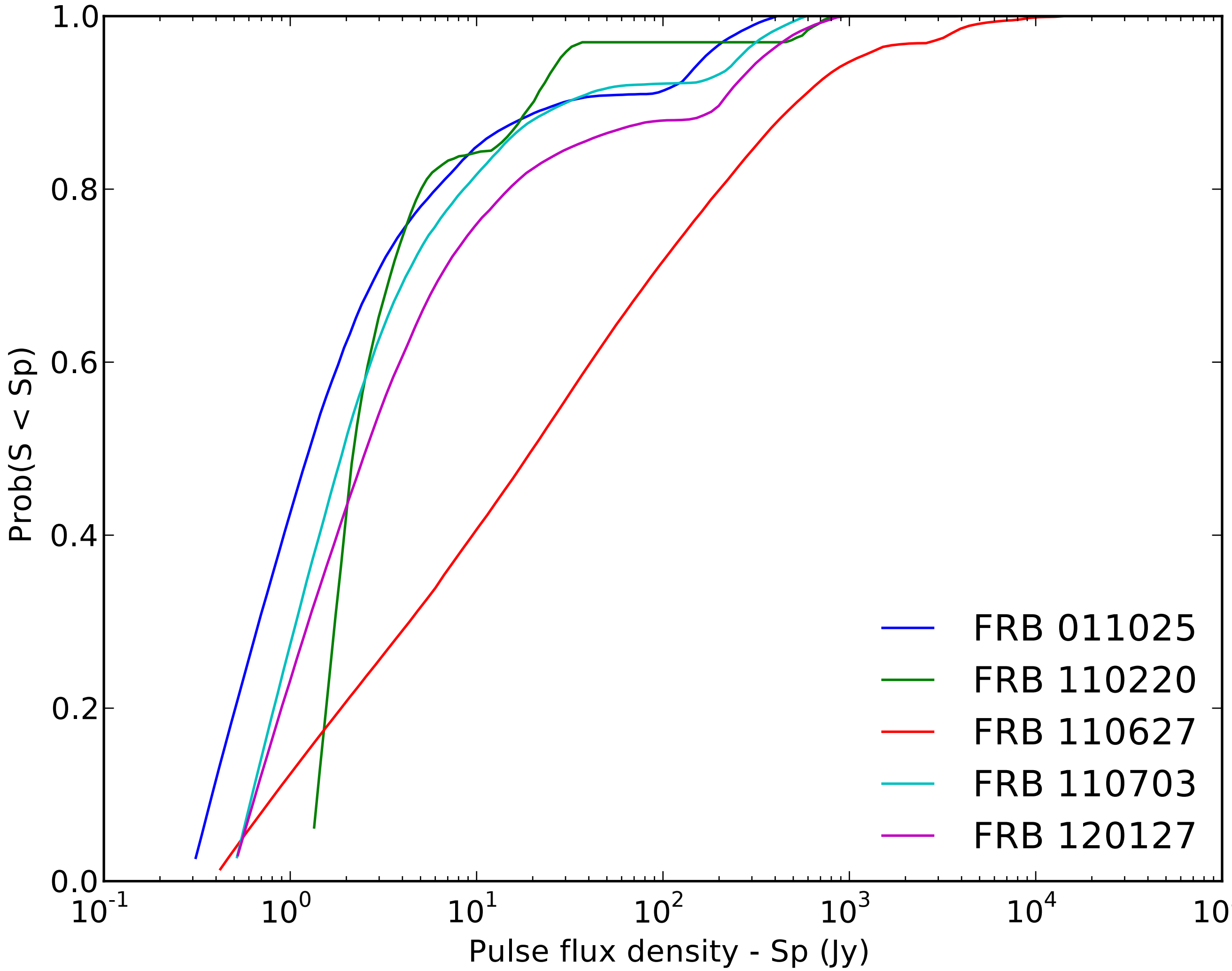


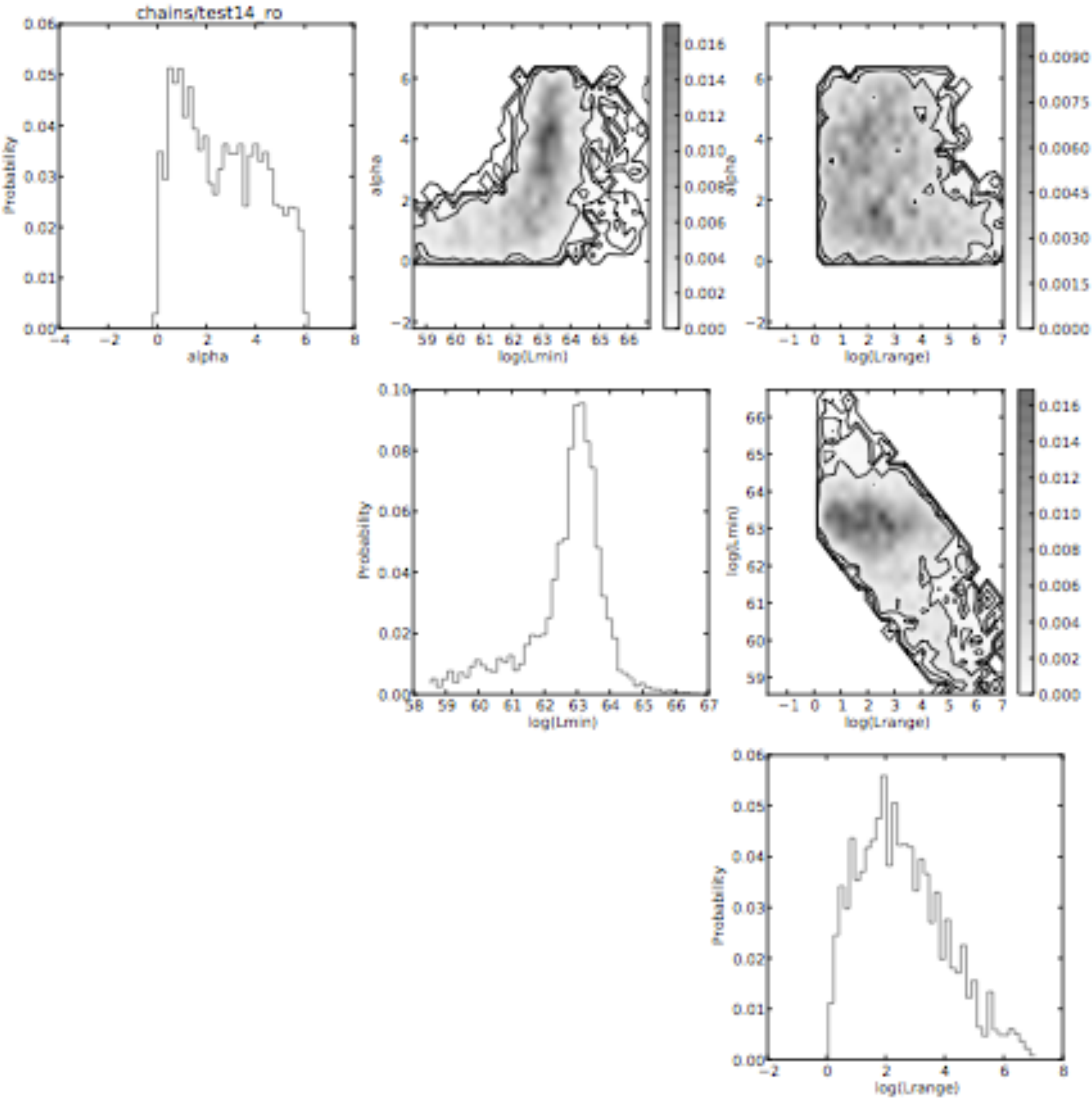
Staveley-Smith+ 96

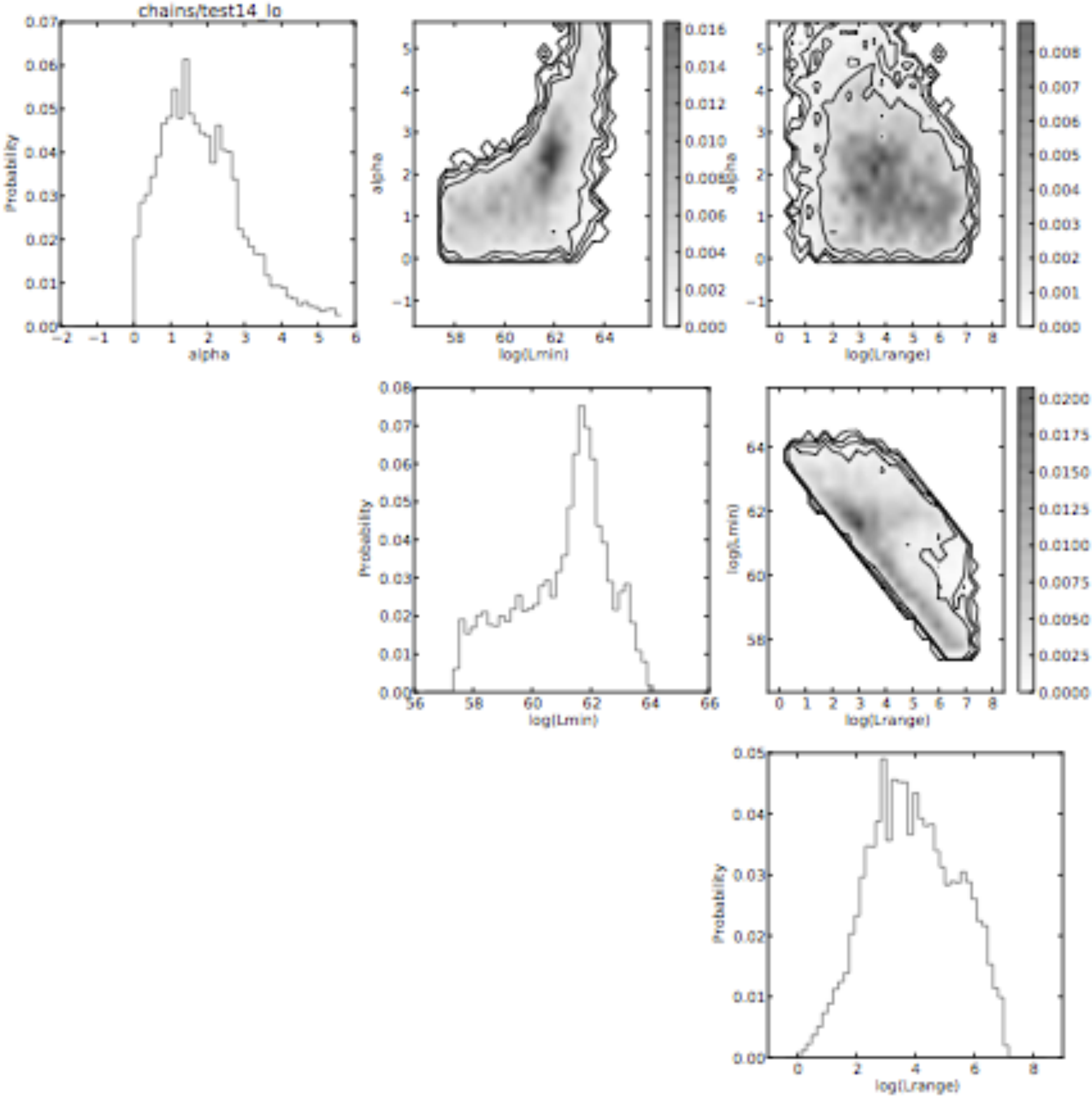
Constraining the flux density



Prior on the flux density




chains/test14_ro
Probability
alpha
log(Lmin)
log(Lrange)


chains/test14_lo
Probability
alpha
log(Lmin)
log(Lrange)

Problem: Number vs z and luminosity function don't agree

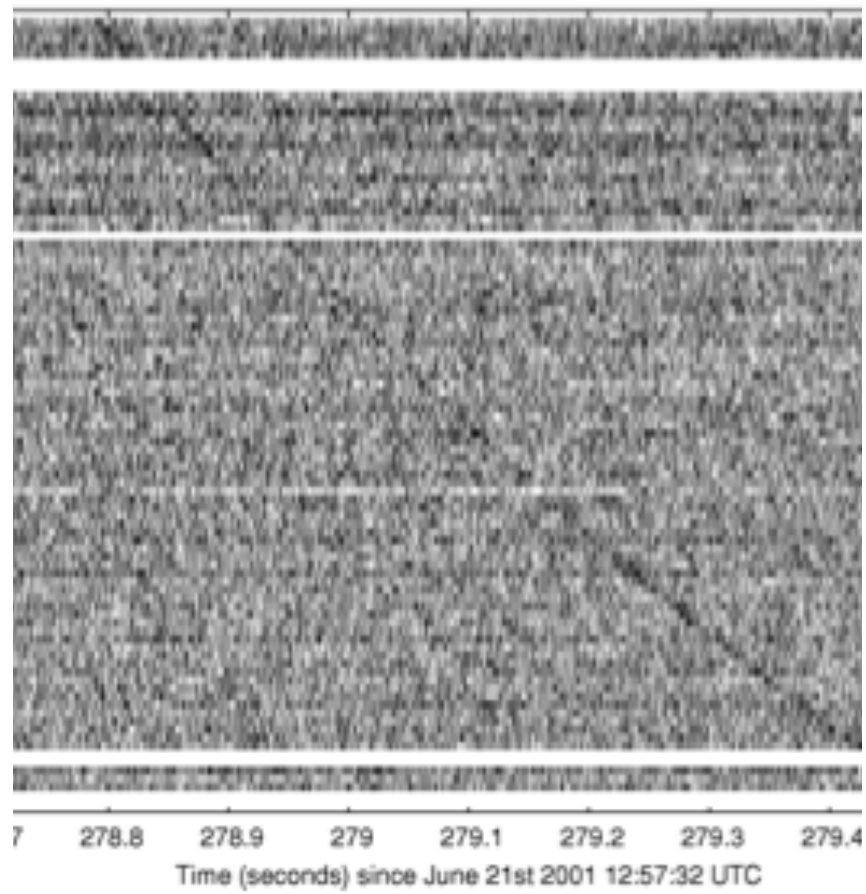
- Lmin is different by a factor of about 5.
- Solutions:
  - Host DM is significant
  - Comoving volume rate evolves dramatically (Star formation rate?)
- Or:
  - Intergalactic DM models are way off
  - They're not extragalactic
  - Luminosity function isn't a cutoff power law

Hα/Hβ observations of the Keane burst

In collaboration with Greg Madsen

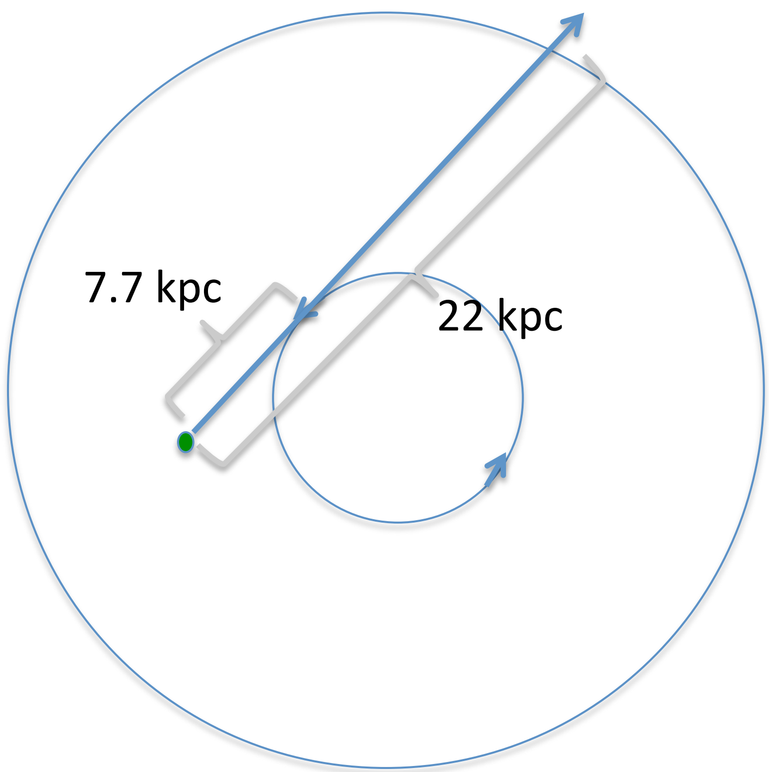
The ‘Keane’ burst

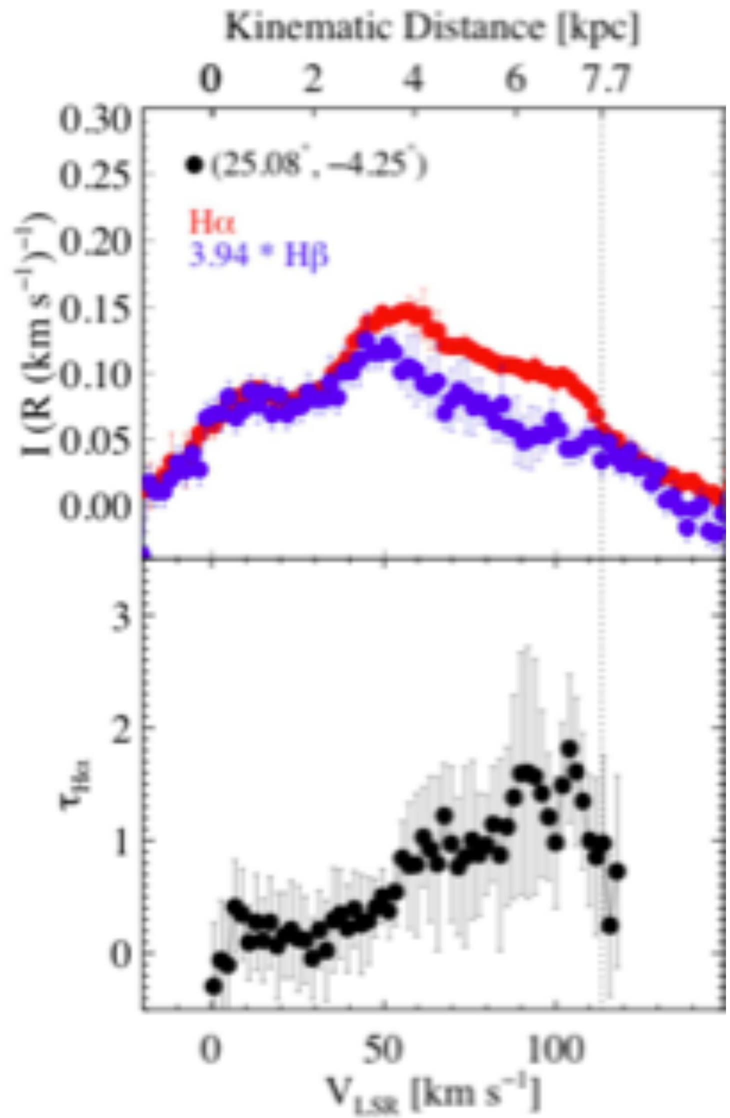
- DM = 746 pc/cm3
- l = 25 deg
- b = -4 deg
- The location of the Scutum Star ‘Cloud’
  - Low extinction window in the Milky Way



Keane+ 2012

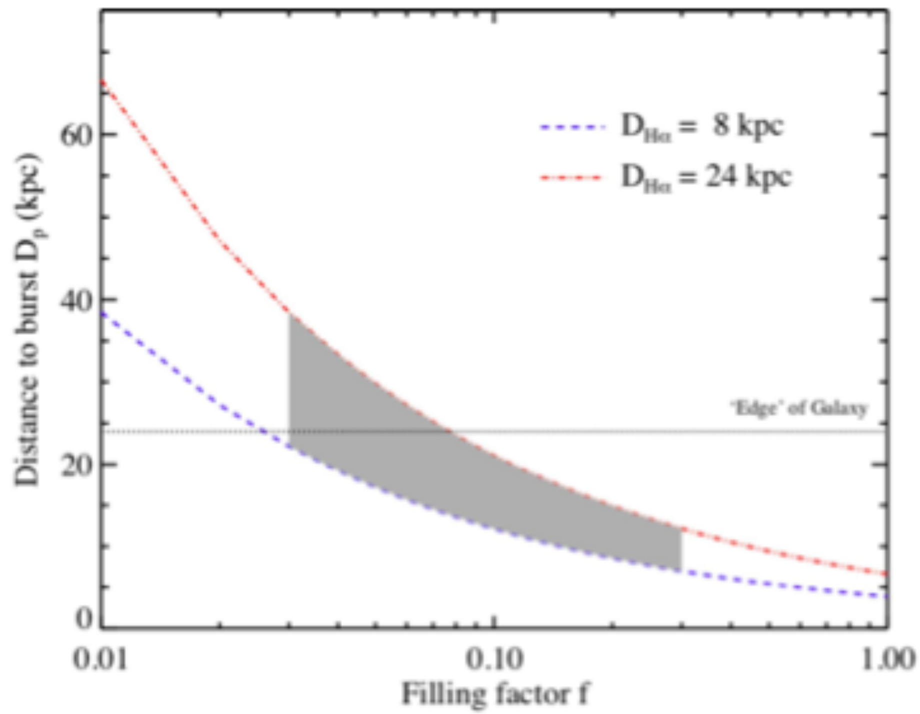
WHAM Hα/Hβ observations



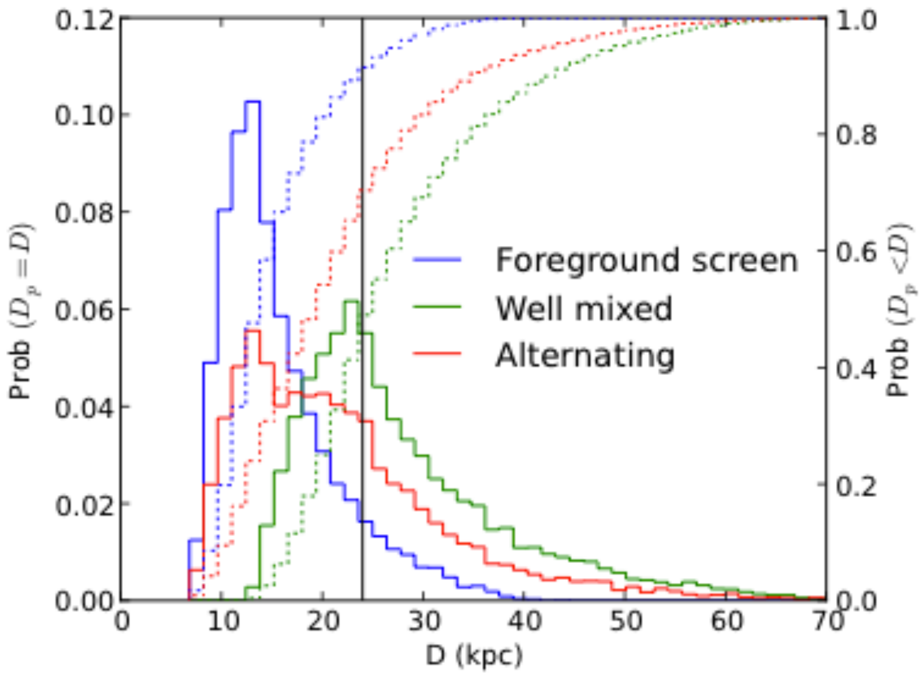


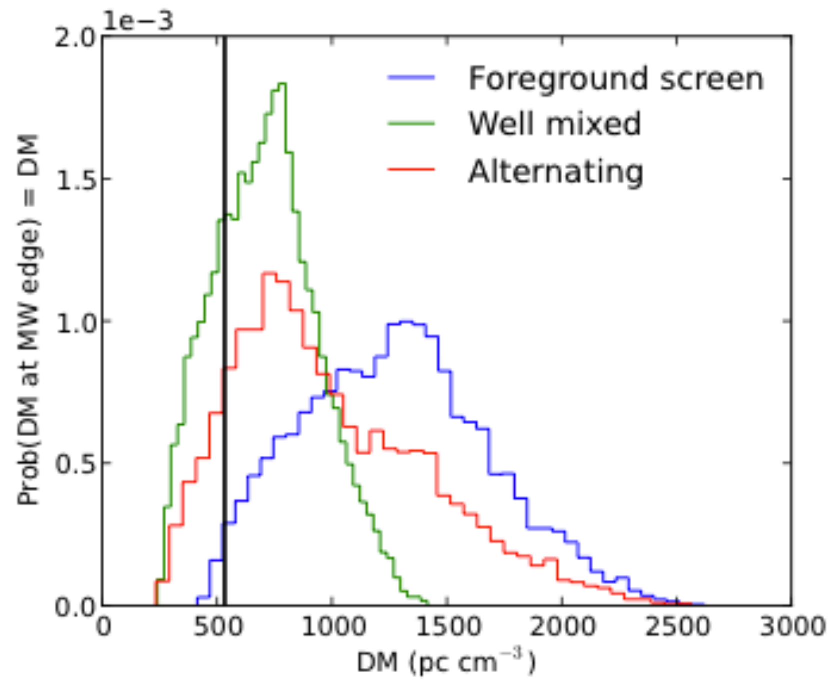
Constraining the distance

- We measure an extinction-corrected EM
- $I_{H\alpha}$ = 276 pc/cm^6
- Assume $D_p = \frac{\mathrm{DM}}{\sqrt{\mathrm{EM}}} \frac{\sqrt{D_{H\alpha}}}{\sqrt{f}}.$
- Hα photons must be coming from > 8kpc and < 22 kpc
- Monte Carlo the unknown Hα distance ($D_{H\alpha}$) and filling factor (f)



Monte Carlo (that puppy up) Results





Results

- Assuming most likely dust extinction model (Foreground screen)
  - Pulse is galactic ($D < 22$ kpc) with 90 % confidence
  - $D = 14 \pm 6$ kpc
  - DM to edge of the Milky Way along this line of sight:
    - 1200 ± 400 pc cm^{-3}
    - NE 2001: 533 pc cm^{-3}

Conclusions

- We don’t know much about FRBs
- But we can make some semi-informed guesses
- More detections will steadily provide better constraints, even with just the current technology
- Other wavelengths are useful at constraining progenitor(s)