Recipes for the statistical properties of Fast Radio Bursts

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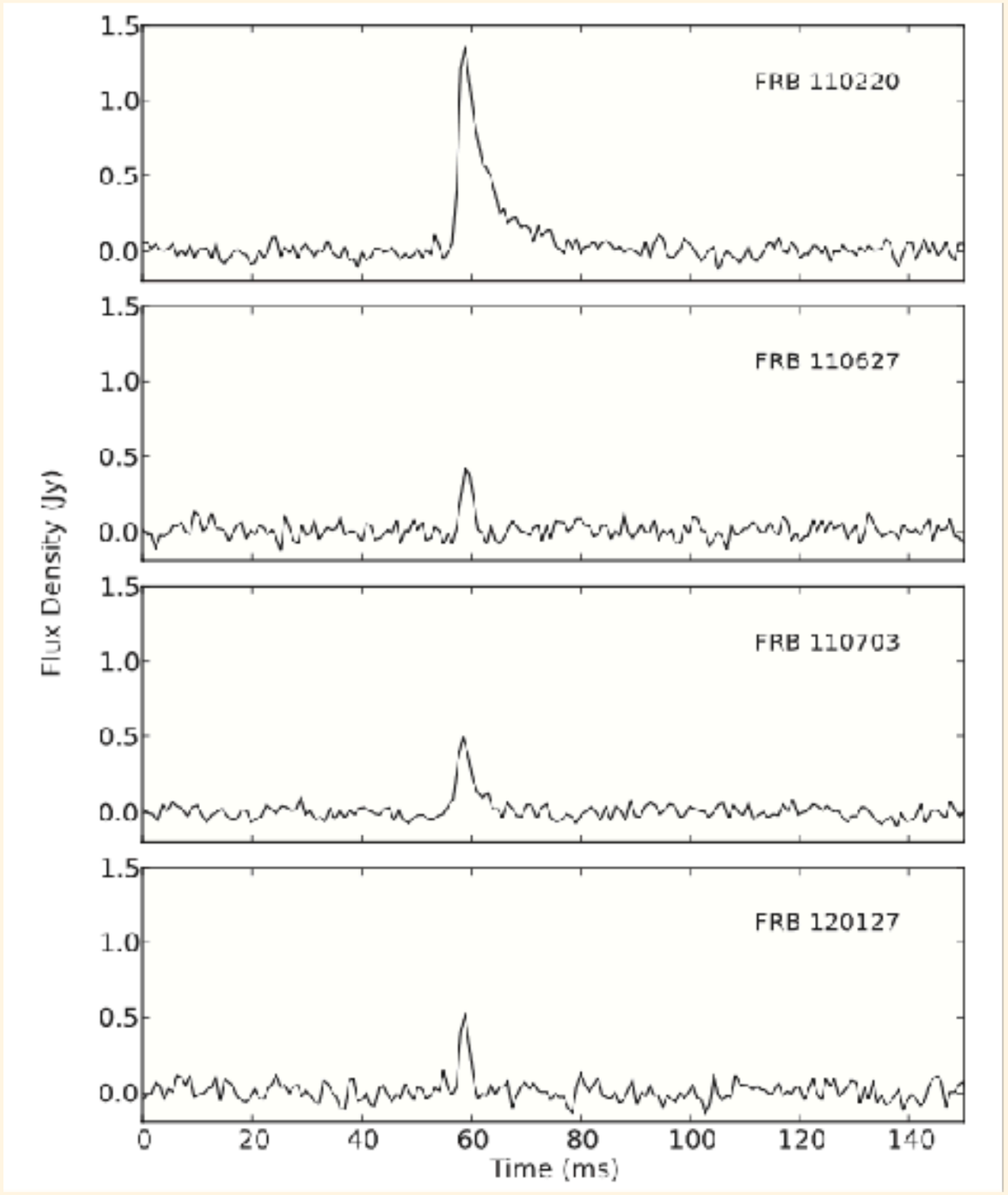
based on arXiv:1801.06578, accepted by ApJ

Fast Radio Bursts

- Transient events in radio bands (~ 1 GHz) with a few milli-sec durations.
- First discovered in 2007 by Lorimer et al.
- Currently ~ 30 events are known.
  - ~ 20 discovered by the Parkes radio telescope

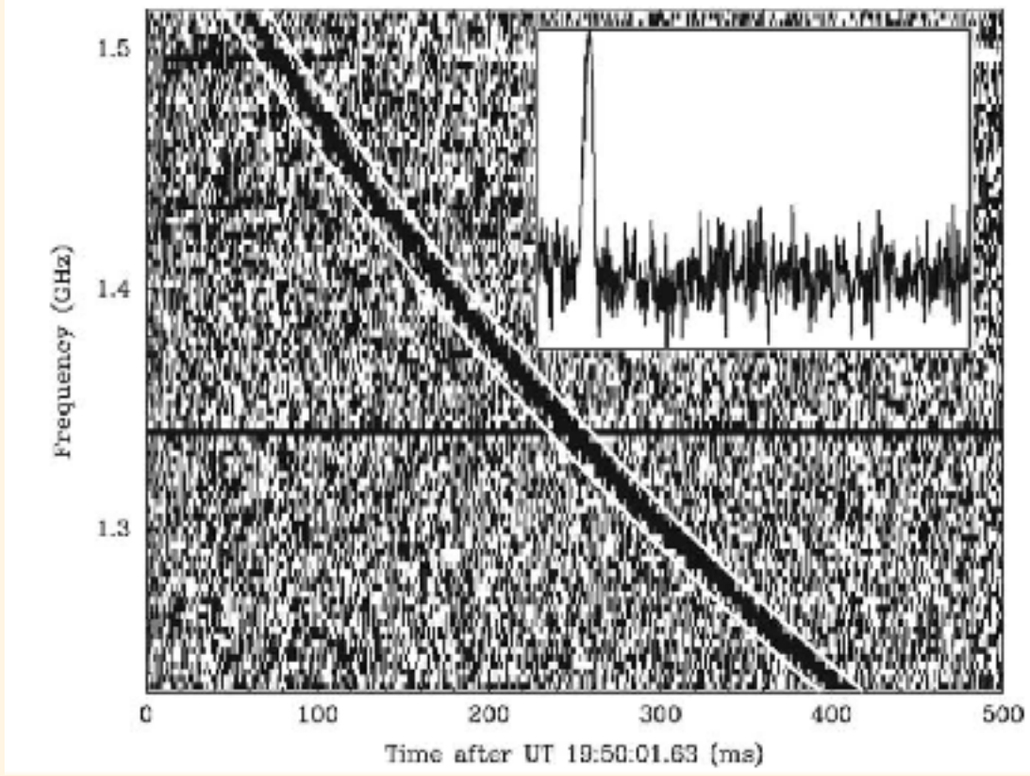
Caption: CSIRO's Parkes radio telescope. Credit: David McClenaghan, CSIRO



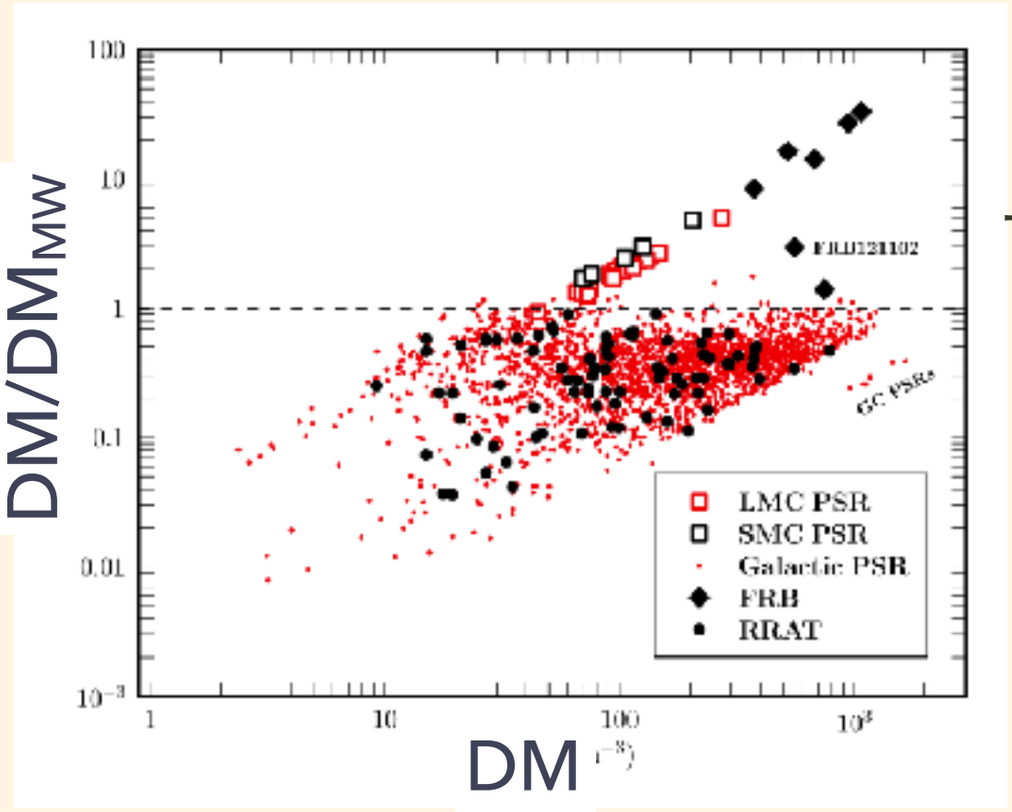
Thornton et al. (2013)

Dispersion measures of FRBs

- The dispersion measures (DMs) exceed the expected MW contribution.
  - DM
    - = delay of pulse arrival time as a function of ν
      - = free electron column density along the line of sight
- If the DMs arise from the IGM, FRBs reside at z ~ 0.3-1.5.
  - FRBs may enable us to observed the IGM.



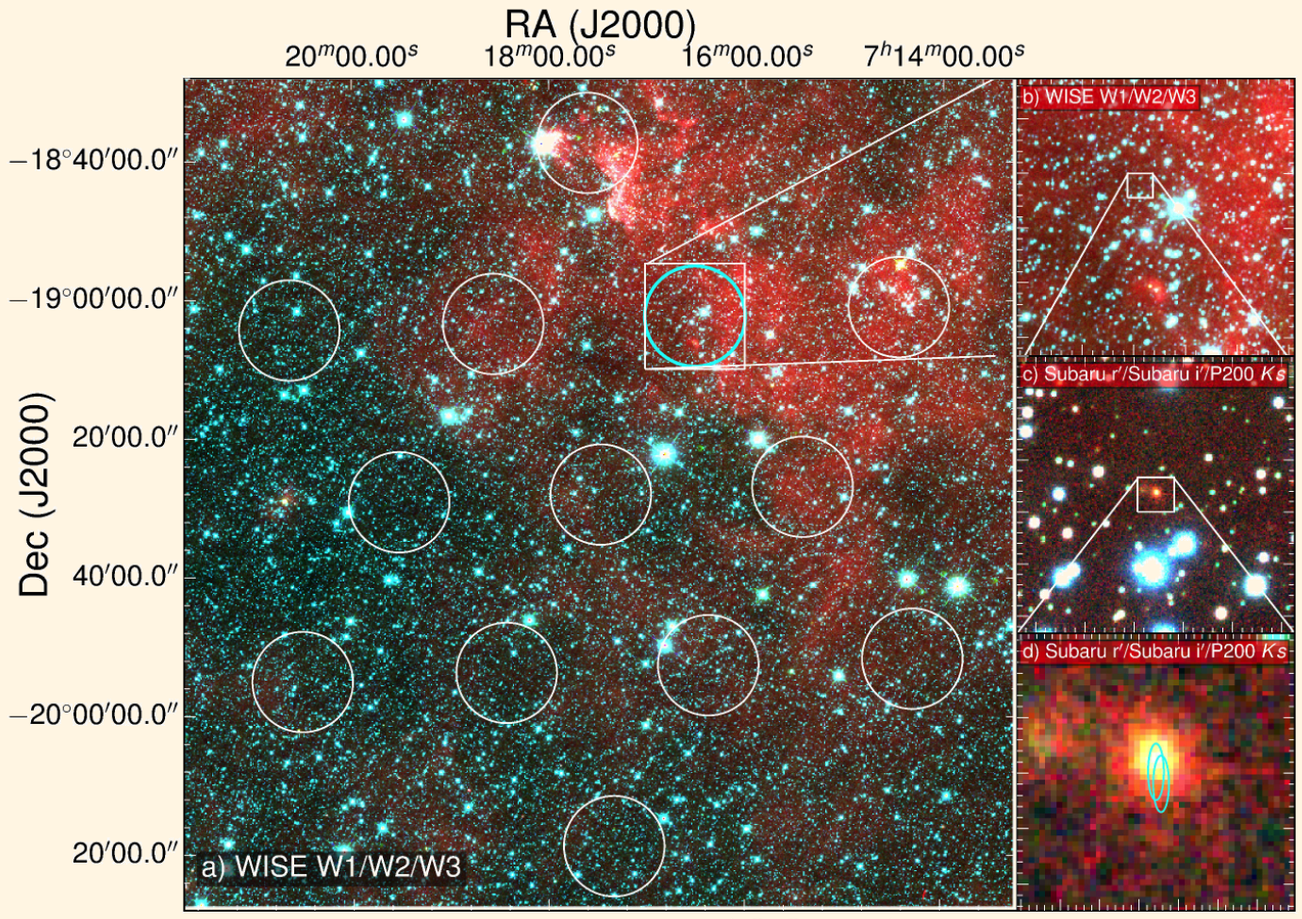
Lorimer+ (2007)



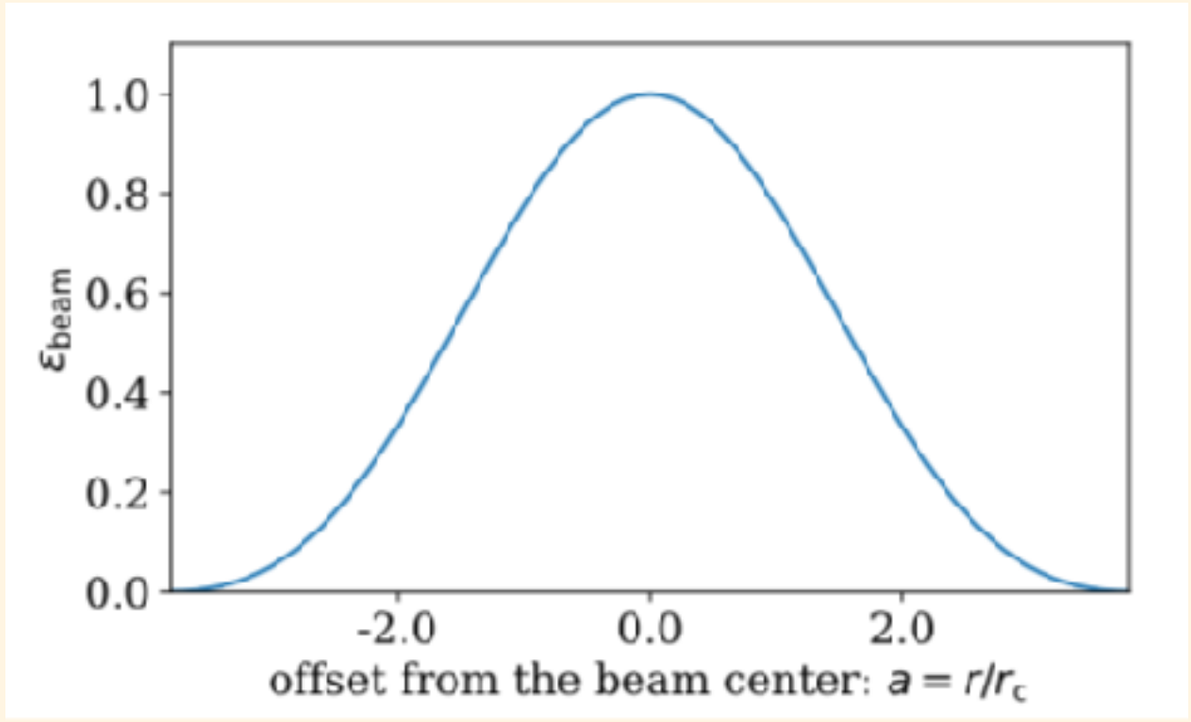
Spitler+ (2014)

Location and flux of FRBs

- The Parkes multi-beam receiver has 13 beams.
  - The only information about the location is the beam pointing.
  - ~ 14 arcmin in FWHM
- Efficiency of a radio receiver varies within it's beam.
  - Position of an FRB within the beam is not known.
  - Lower limits only.
- Exception
  - FRB 121102: the repeating FRB detected by Arecibo



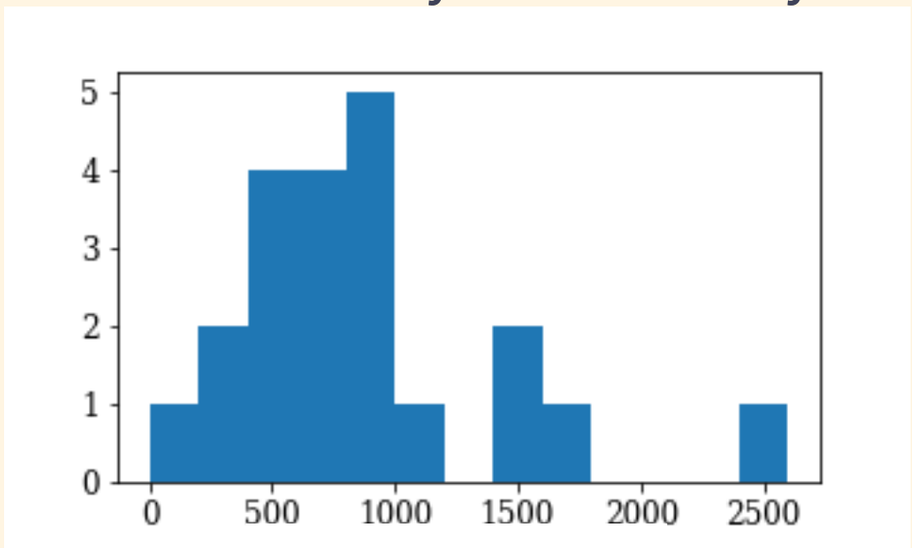
Keane+ (2016)

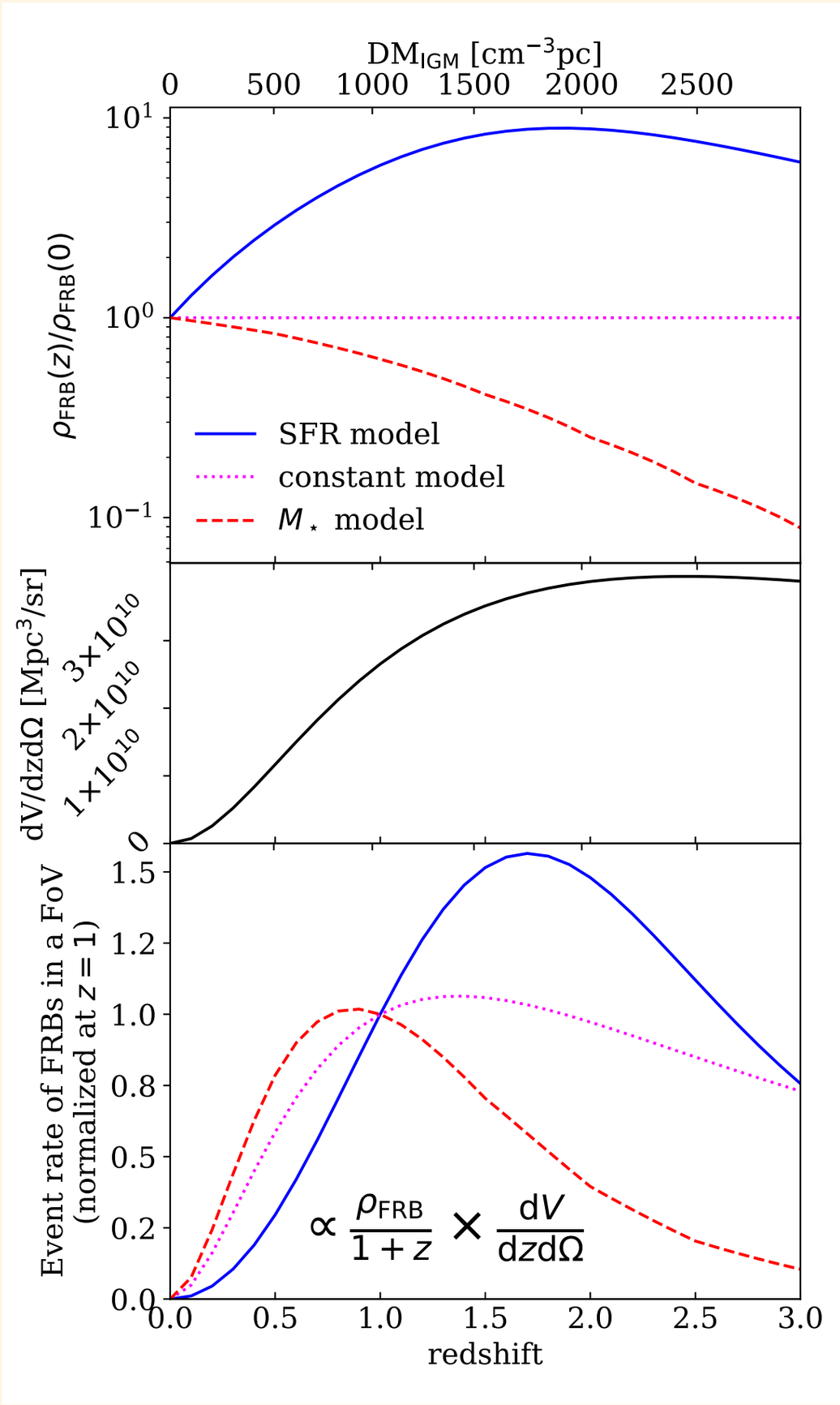


DM distribution of cosmological FRBs

Cosmic FRB history and the DM distribution

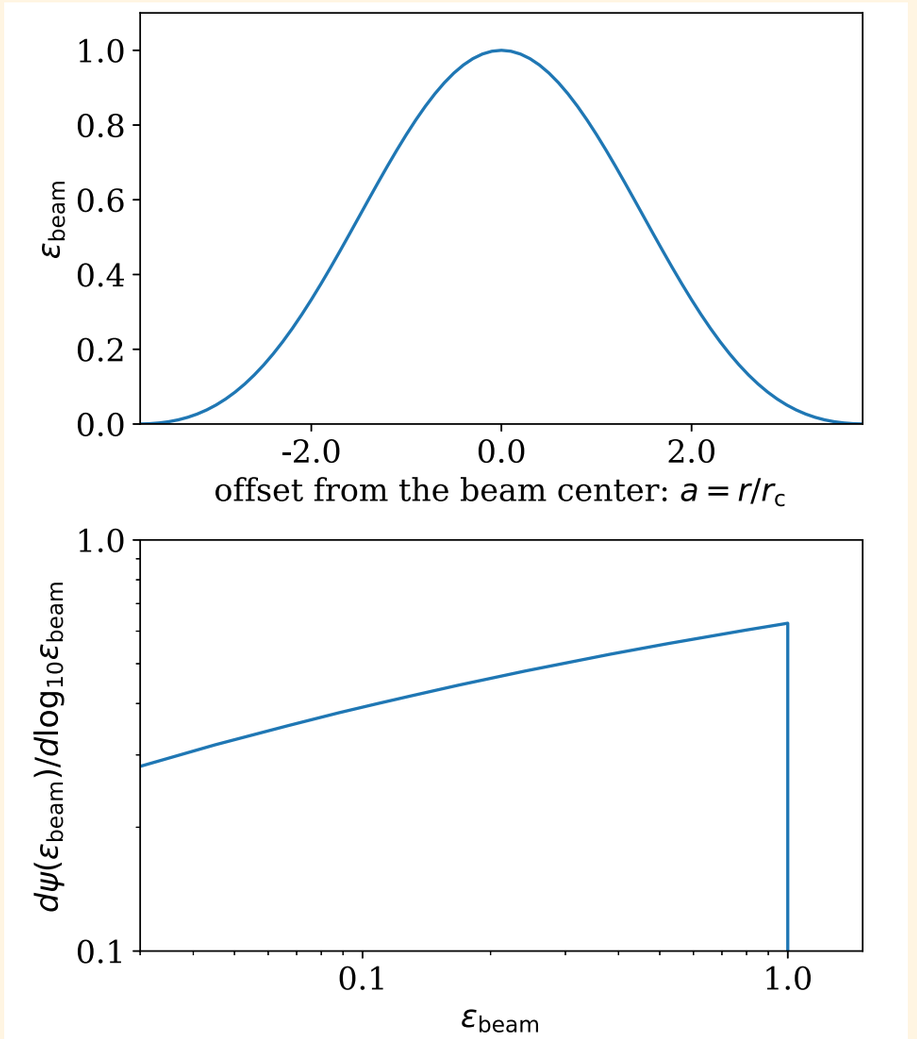
- If FRBs originate at cosmological distances, DM distribution ~ redshift distribution.
  - important clue to the cosmic FRB rate history.
  - In the cases:
    - $\rho_{FRB} \propto SFR$
    - $\rho_{FRB} \propto M_{\star}$
- The DM distribution is similar below DM ~ 1000 (or z ~ 1).
  - Dramatically different beyond that.

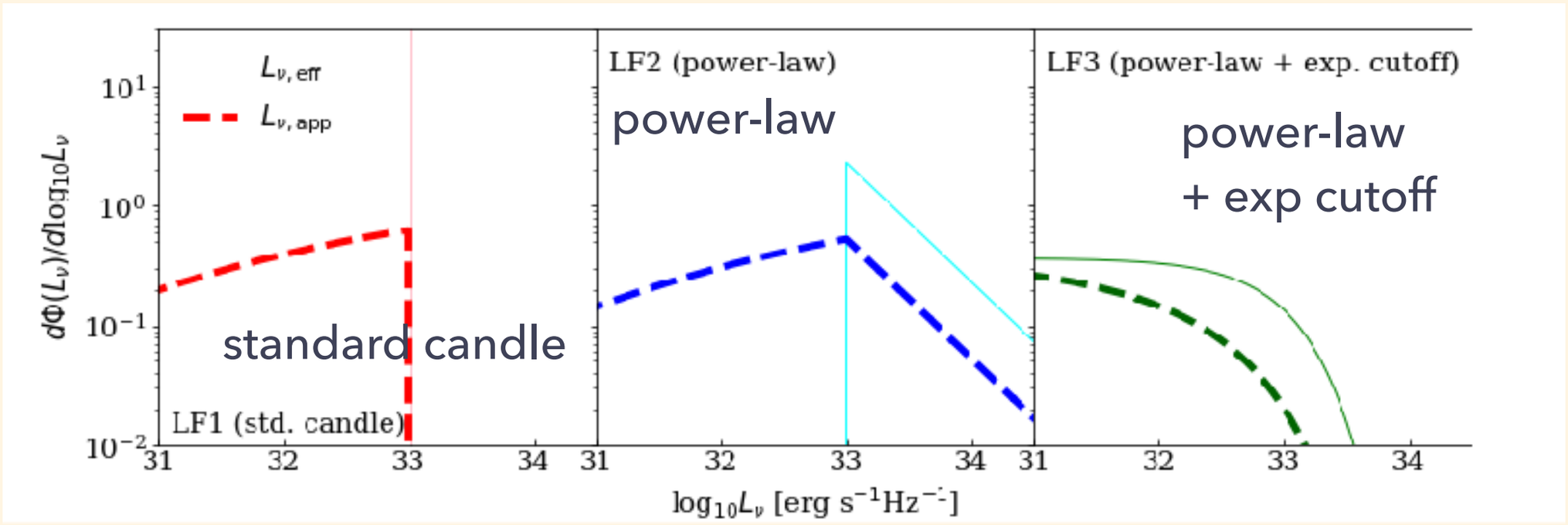




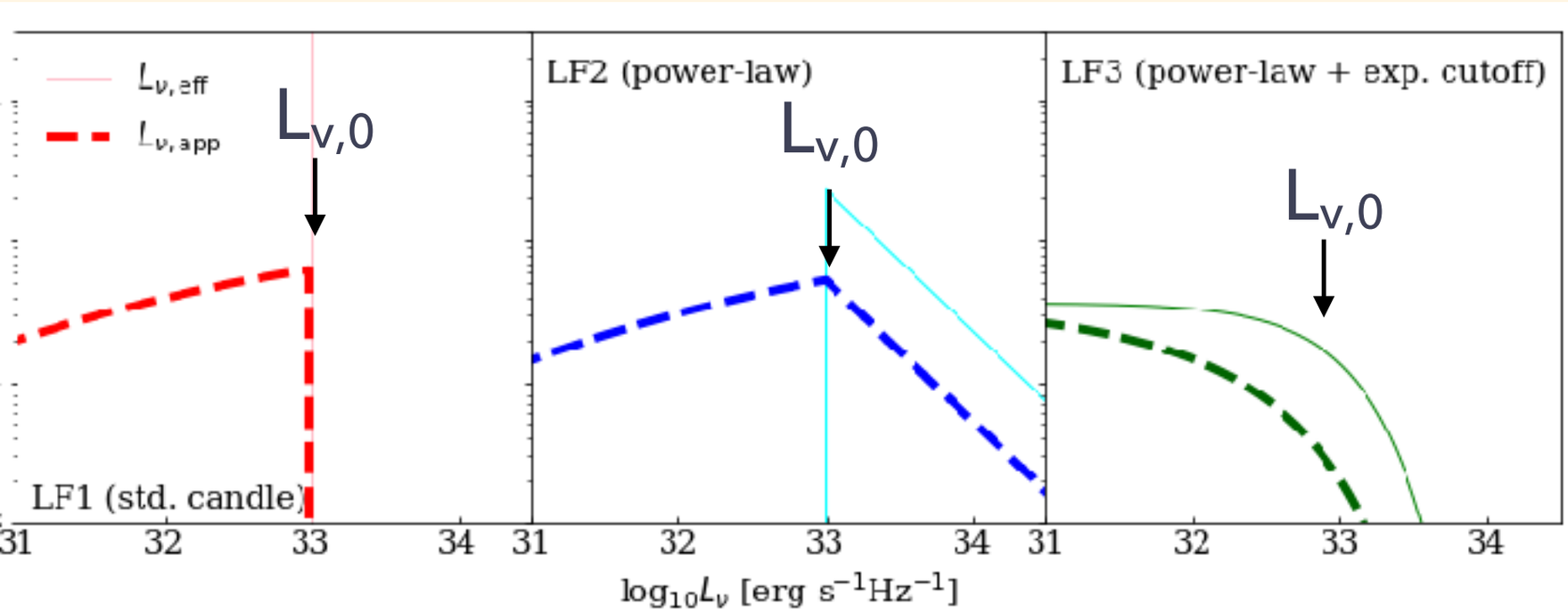
FRB luminosity function and beam efficiency pattern

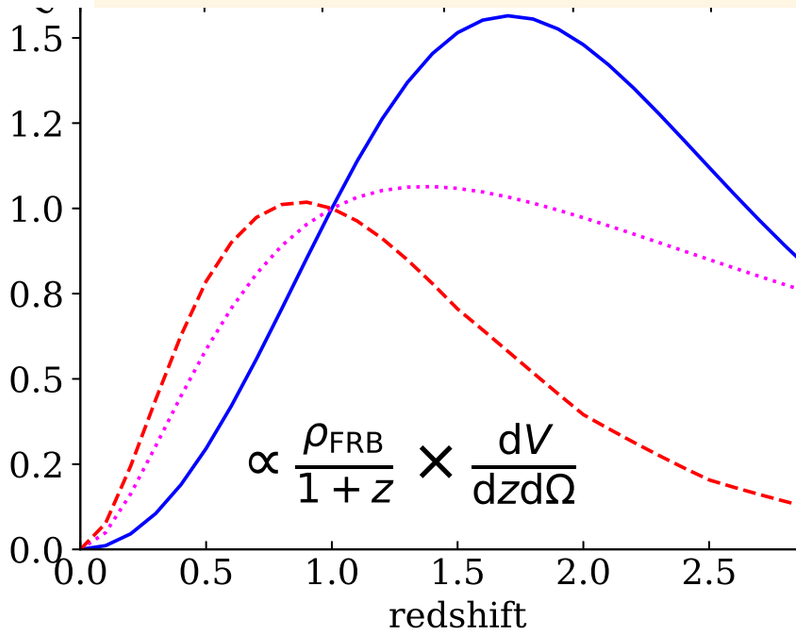
- The DM distribution depends also on the luminosity function (LF) of FRBs
- Receiver efficiency follows a certain probability distribution function (PDF).
- FRB LF is effectively convolved with the receiver efficiency PDF.
  - $F_{\nu,app} \equiv \varepsilon_{beam} F_\nu$
  - $L_{\nu,app} \equiv 4\pi d_L^2 F_{\nu,app} = 4\varepsilon_{beam}\pi d_L^2 F_\nu$
- detection limit: $F_{\nu,app} > 0.4$ [Jy]

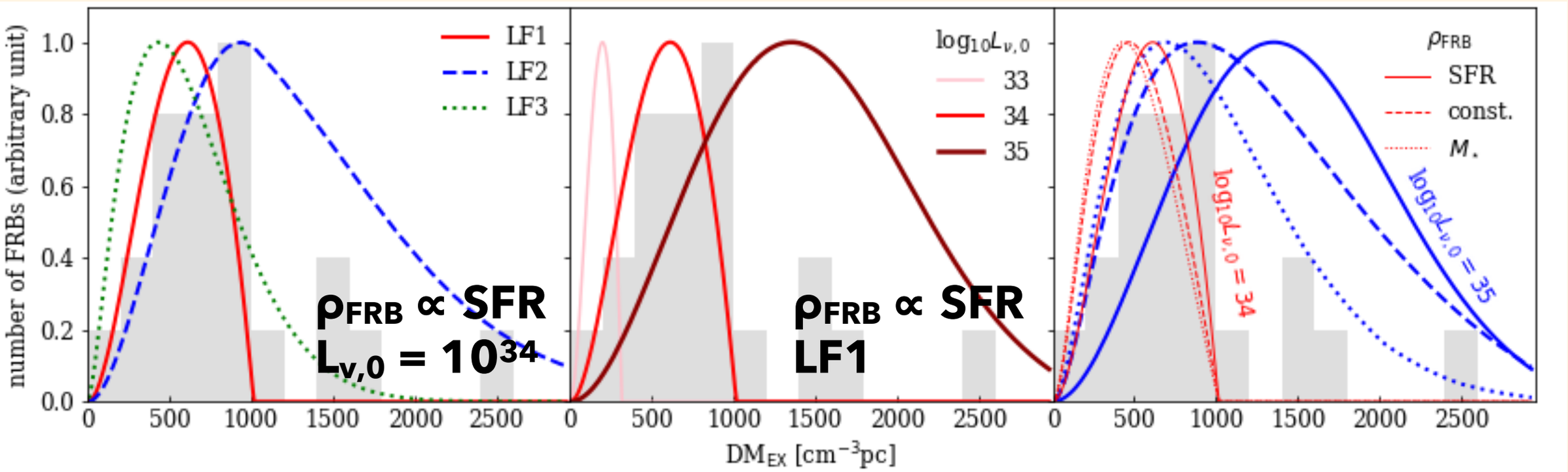




ρ_{FRB}, FRB LF, & DM distribution

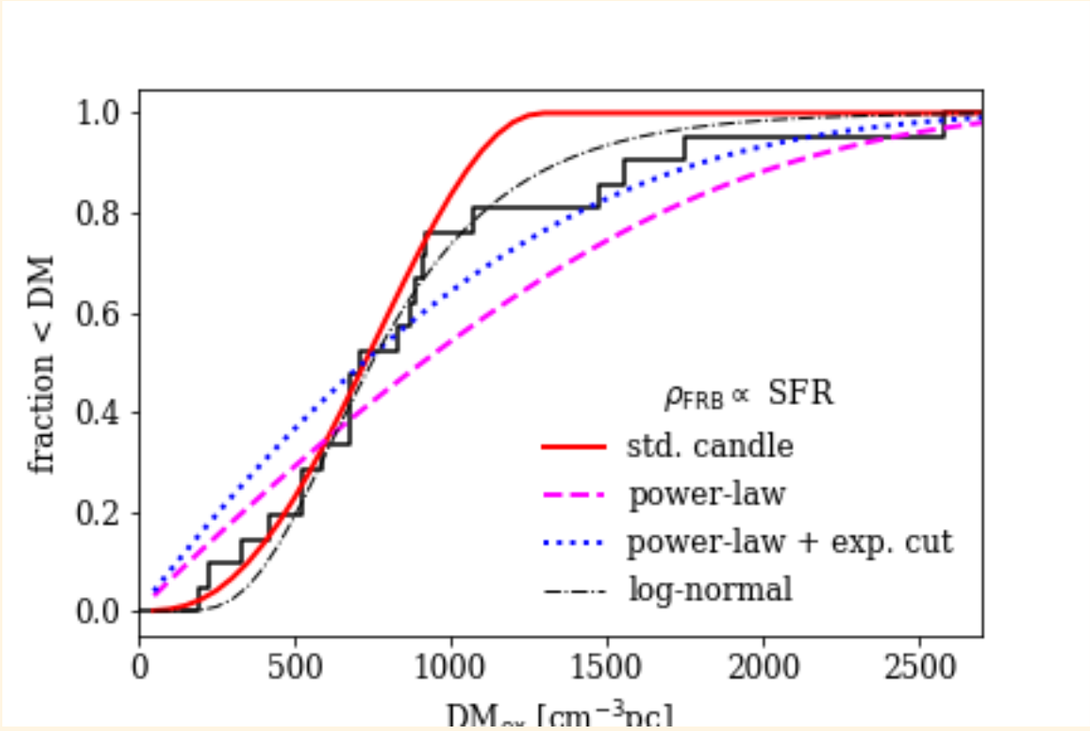


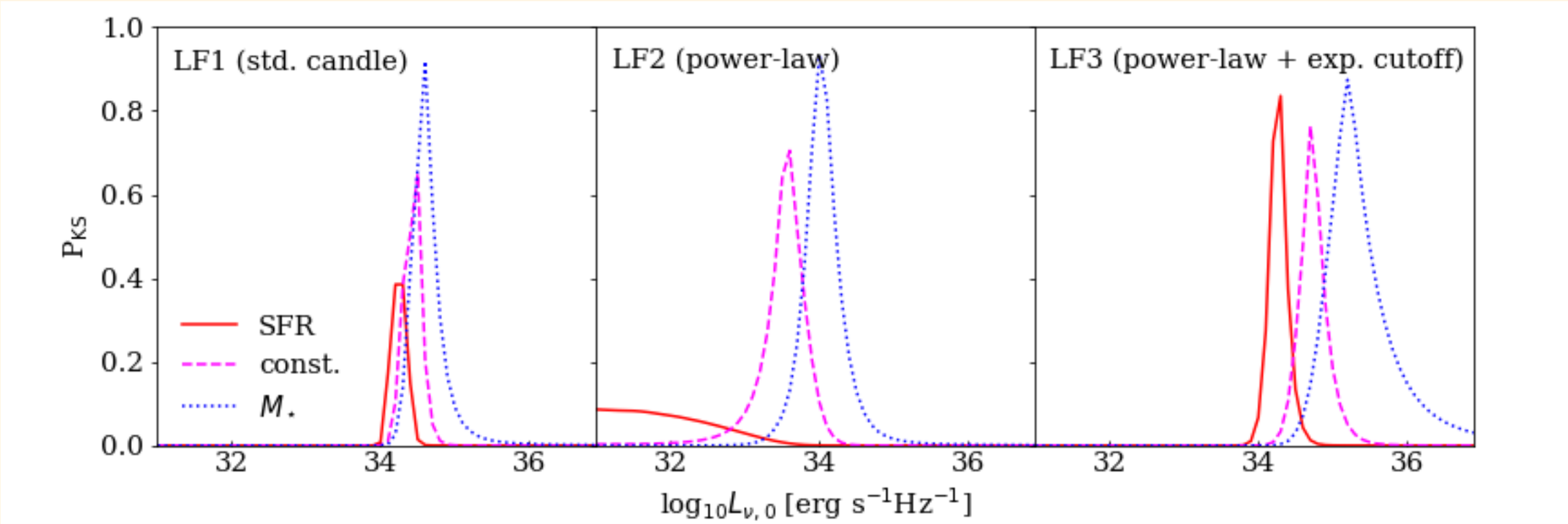




DM distribution of Cosmological FRBs

- LF and ρ_{FRB} are largely degenerated.
- LF2 (power-law) can not reproduce the DM distribution if $\rho_{FRB} \propto$ SFR.
- LF needs bright-end cutoff around $\log L_{\nu,0}$ [erg s^{-1}Hz^{-1}] ~ 34.

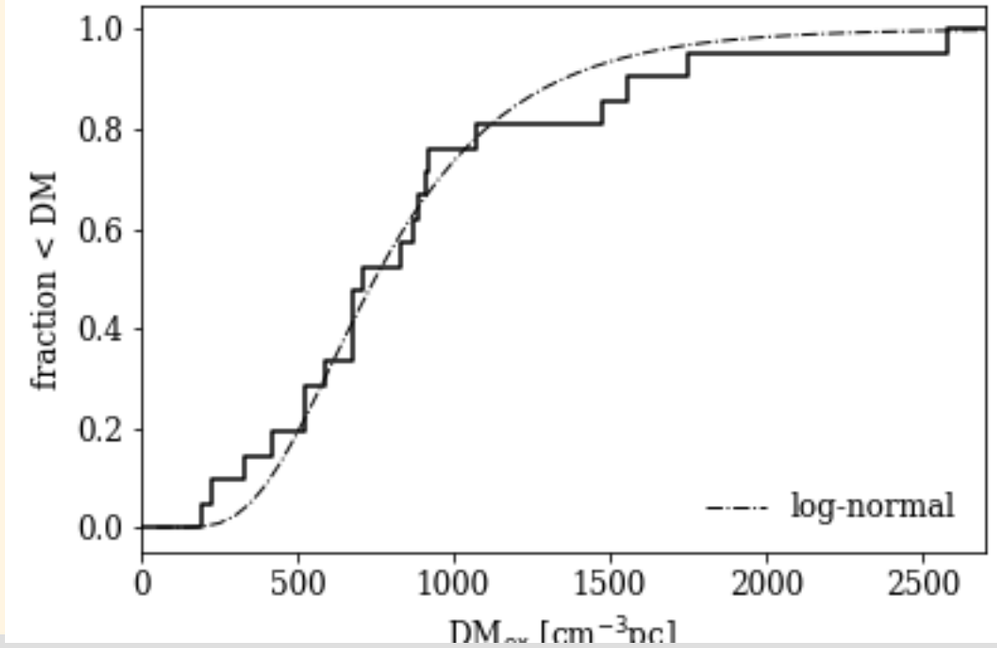


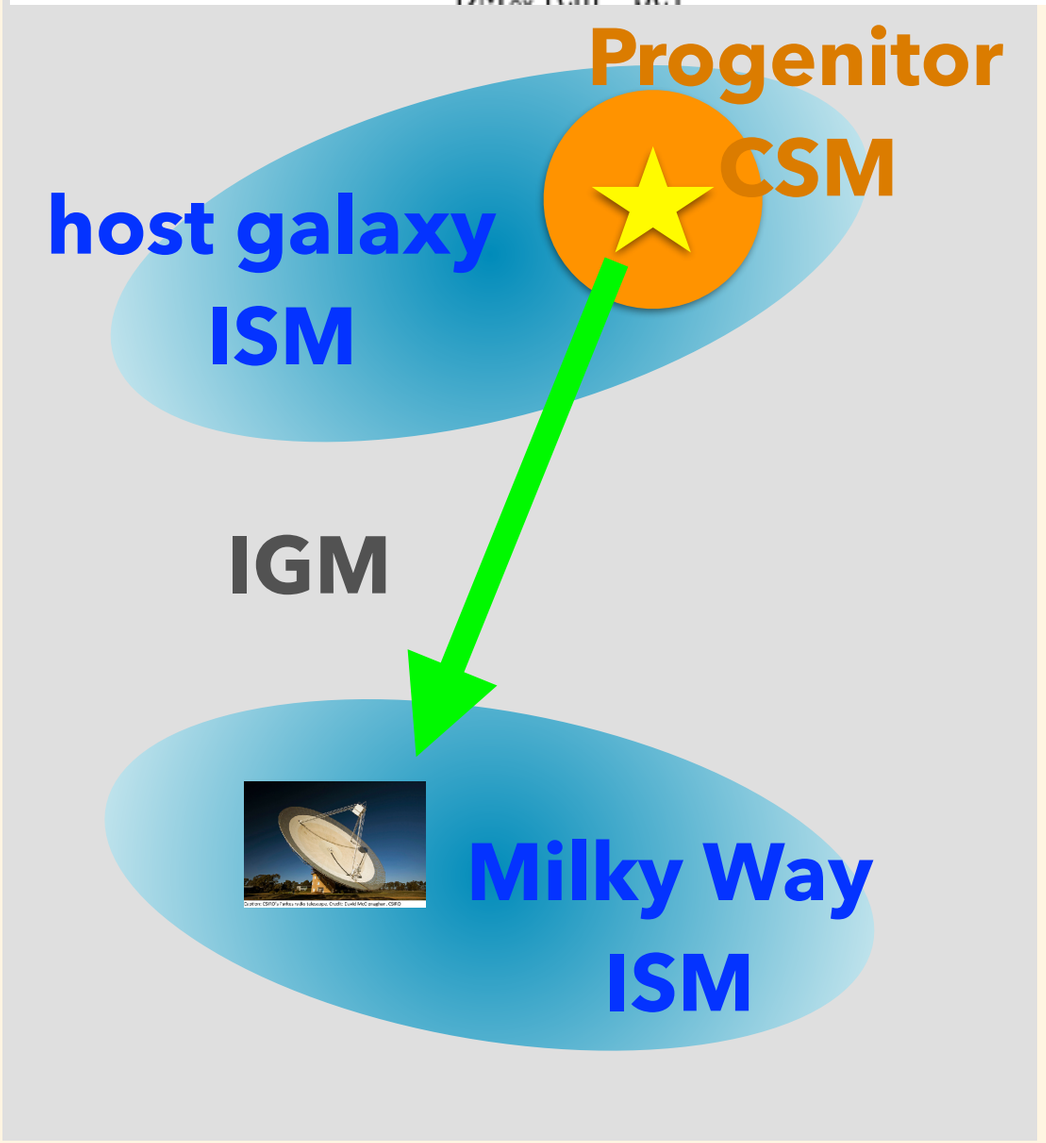


Cosmological
or
Local

Are FRBs cosmological or local?

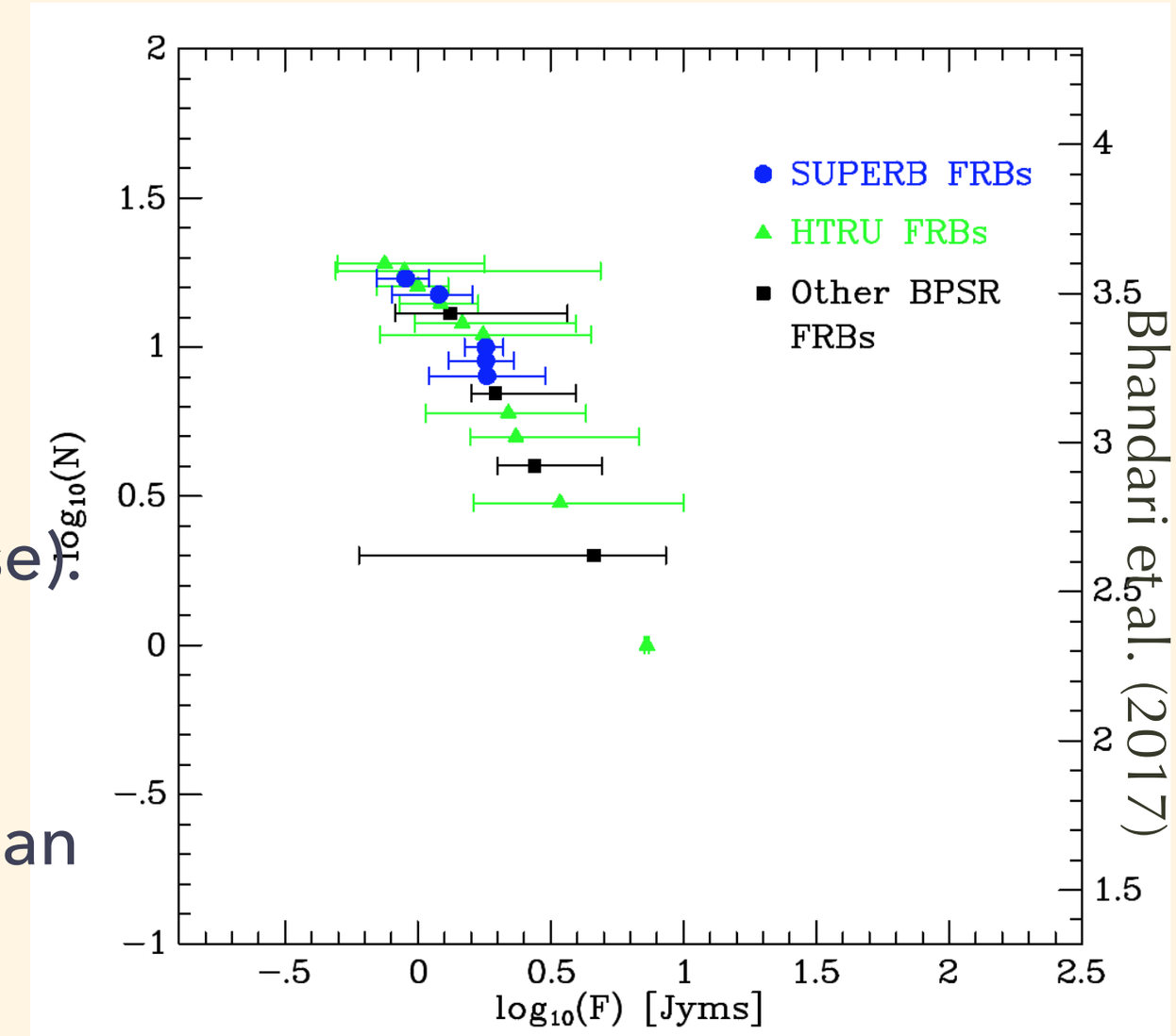
- DM from the IGM
  - ~ 1000 × z [cm^{-3}pc]
- DM do not necessarily arise solely from the IGM
  - host galaxy ISM
  - supernova remnant
  - HII region
- If the IGM is not the dominant DM component, FRBs might be at lower redshifts.

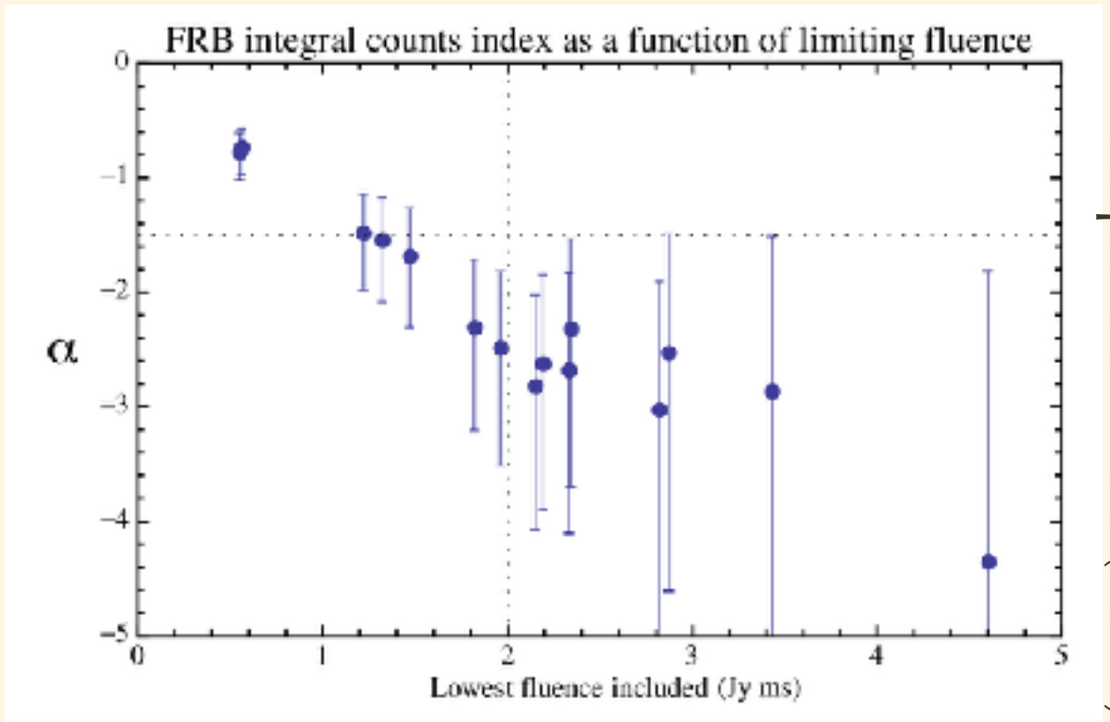




The logN-logS distribution

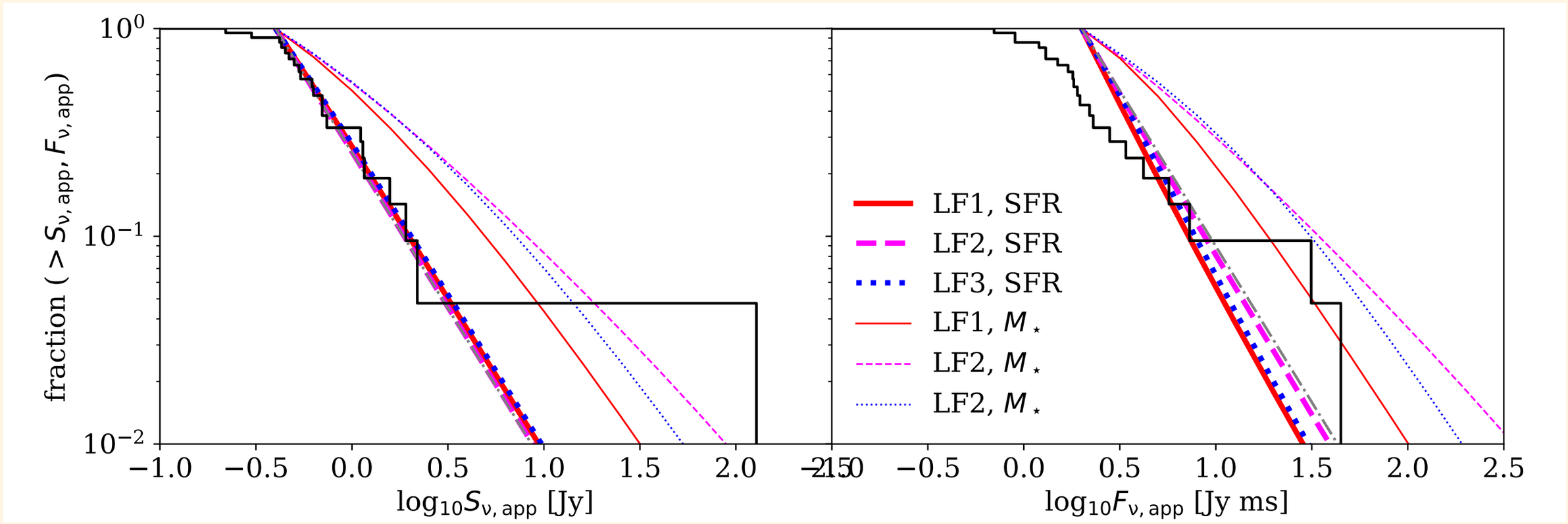
- The power-law slope = -1.5 in the Euclidean space (e.g., local universe).
- Cosmological effects modify the slope.
- The fluence distribution is flatter than the Euclidean (Vedantham et al. 2016).
  - affected by the incompleteness
    - steeper in the bright-end
    - completeness limit ~ 2 [Jy ms]
      - ~ 50% of the sample
- The S/N distribution agrees with the Euclidean.





The logN-logS distribution

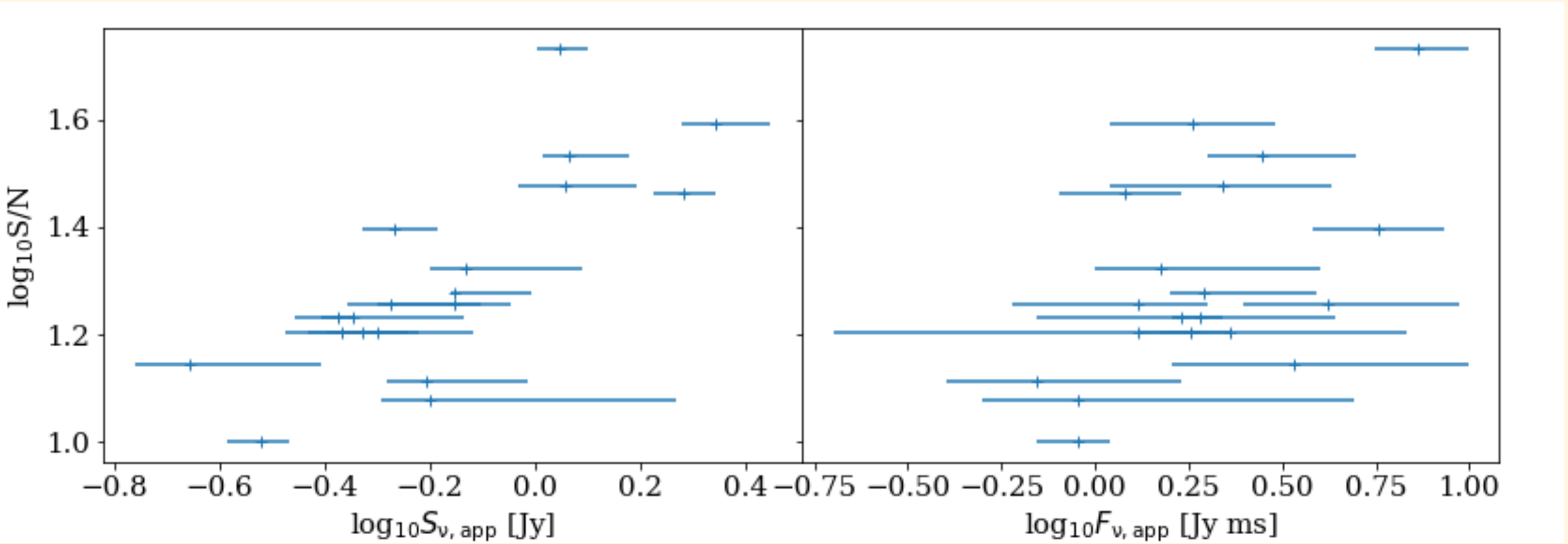
- S_ν distribution
  - When $\rho_{FRB} \propto$ SFR:
    - consistent with the Euclidean & obs.
  - When $\rho_{FRB} \propto M_\star$:
    - flatter than observed
    - close to the limit by the CHIME pathfinder (Amiri et al. 2017)
- F_ν distribution: steeper than the S_ν distribution & the Euclidean



Discussion

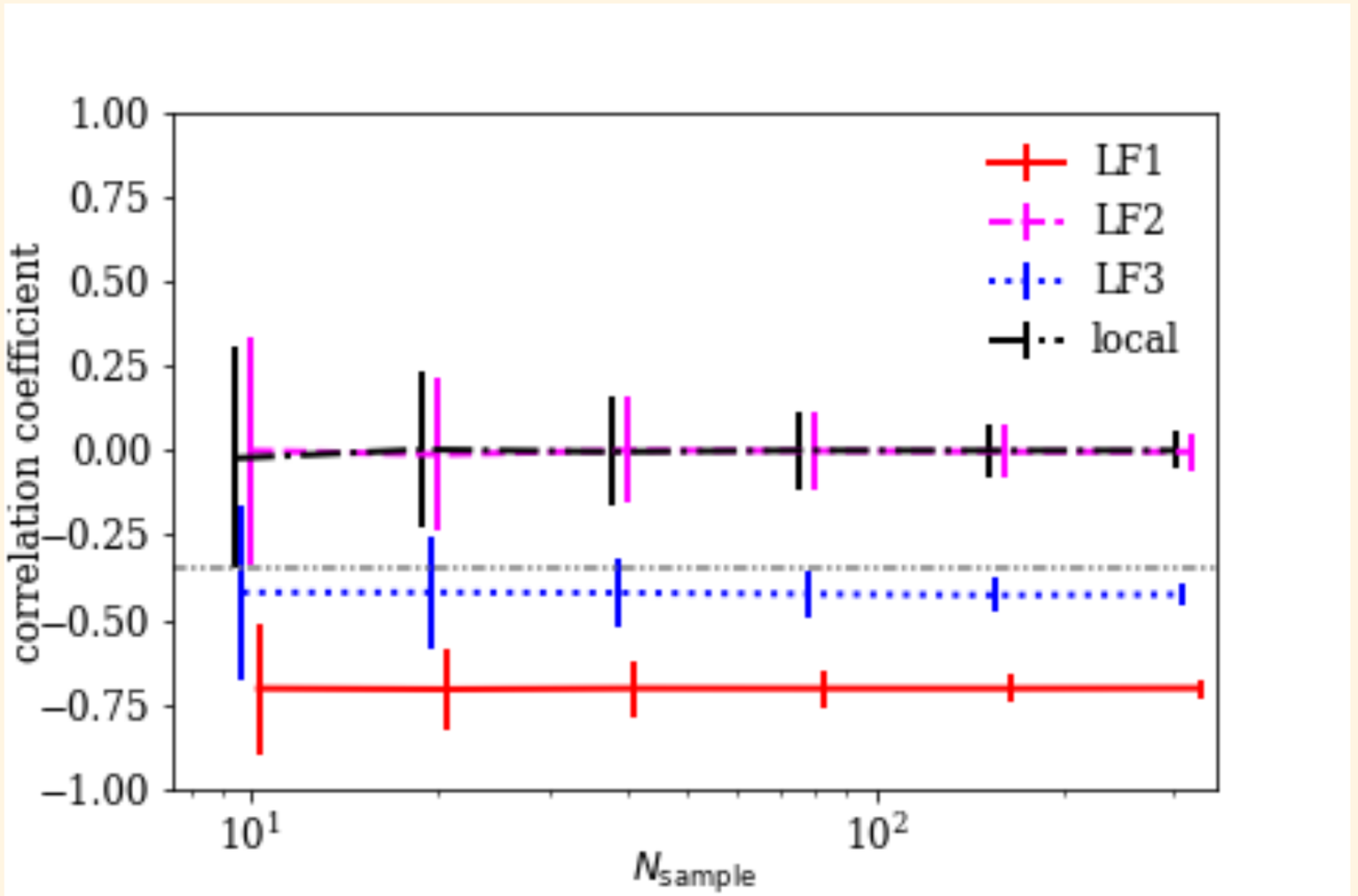
Flux, Fluence, and S/N

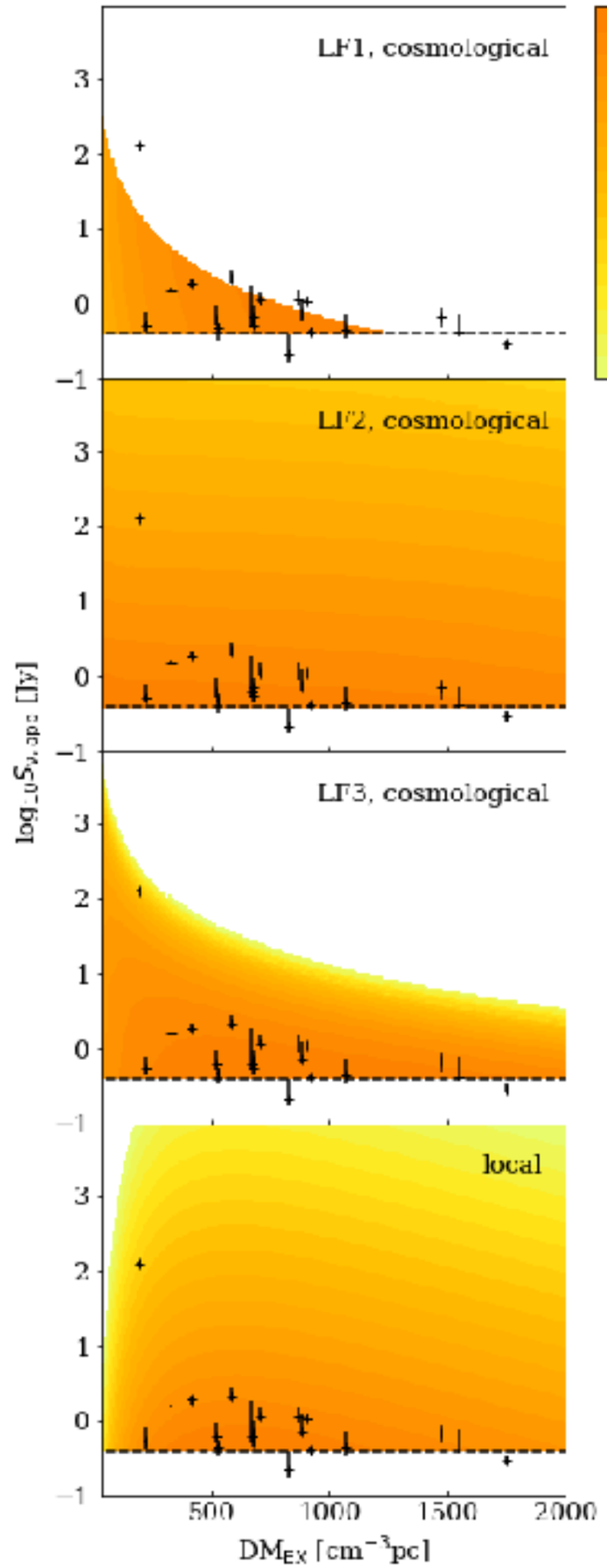
- The faint end of the F_ν distribution is affected by a complicated incompleteness.
  - The S_ν distribution is sharply cut.
- S/N of FRB detections is determined by S_ν rather than F_ν.
- Better constraint might be obtained by using S_ν instead of F_ν.



DM-flux correlation

- The S_ν distribution of cosmological FRBs is similar to the Euclidean when $\rho_{FRB} \propto SFR$.
- The correlation between DM and S_ν is a clue.
  - potentially provides better constraint than the logN-logS distributions.





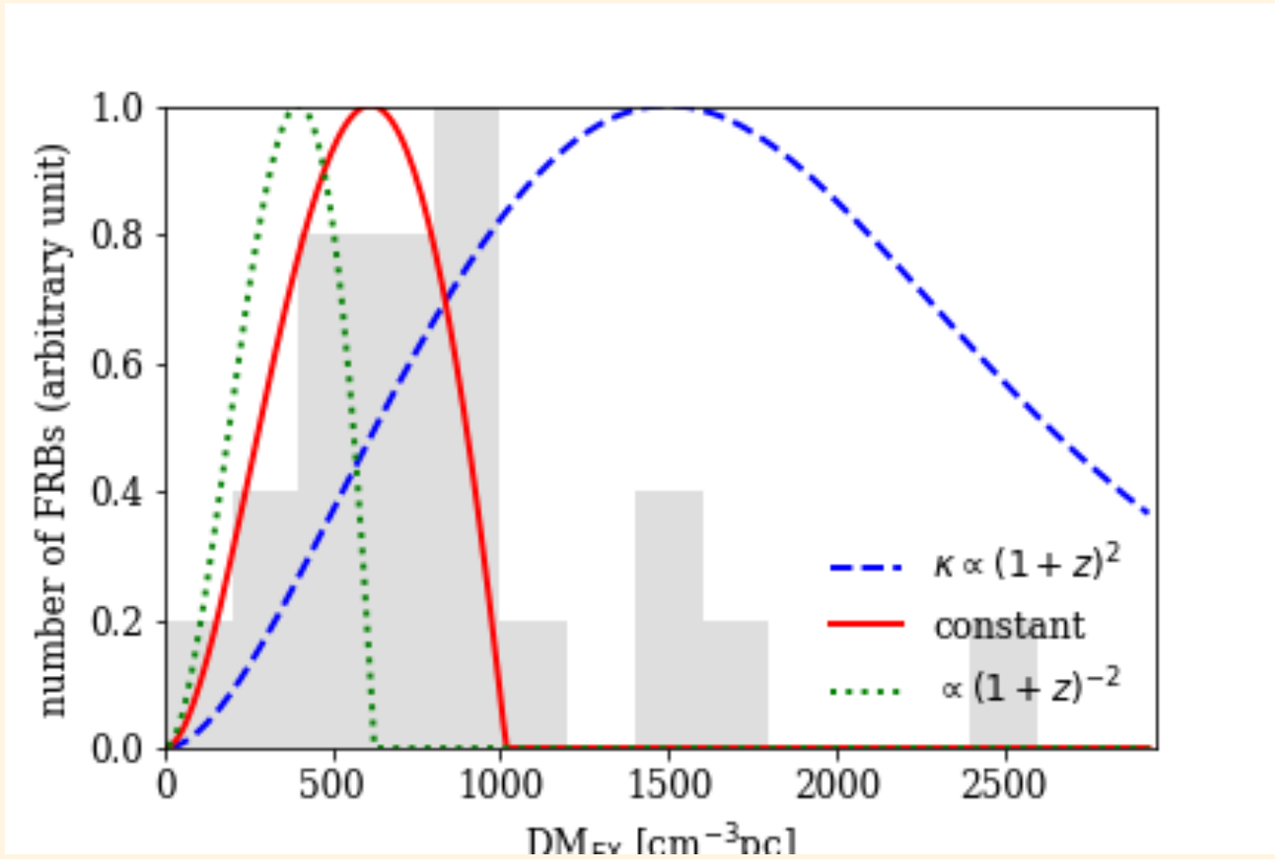
K-correction

- Constant L_v as a function of v is assumed in the discussion above.
  - SED of FRBs is largely degenerated with ρ_{FRB}.
- Observations in different frequency band are essential.

LF1

$\rho_{FRB} \propto SFR$

$L_{v,0} = 10^{34}$



Summary

- The large DMs of FRBs suggest they are at cosmological distances.
- Even the single messenger studies can constrain the nature of FRBs.
    - FRBs look really interesting.
- Many of the current limitations are peculiar to (single dish) radio telescopes.
    - Discovery of other messengers will revolutionize our understanding of FRBs.
- The Alerts will be public since April 2018.