

ASSOCIATING FAST RADIO BURSTS TO THEIR HOST GALAXIES

Tarraneh Eftekhari

Edo Berger

arXiv: 1705.02998

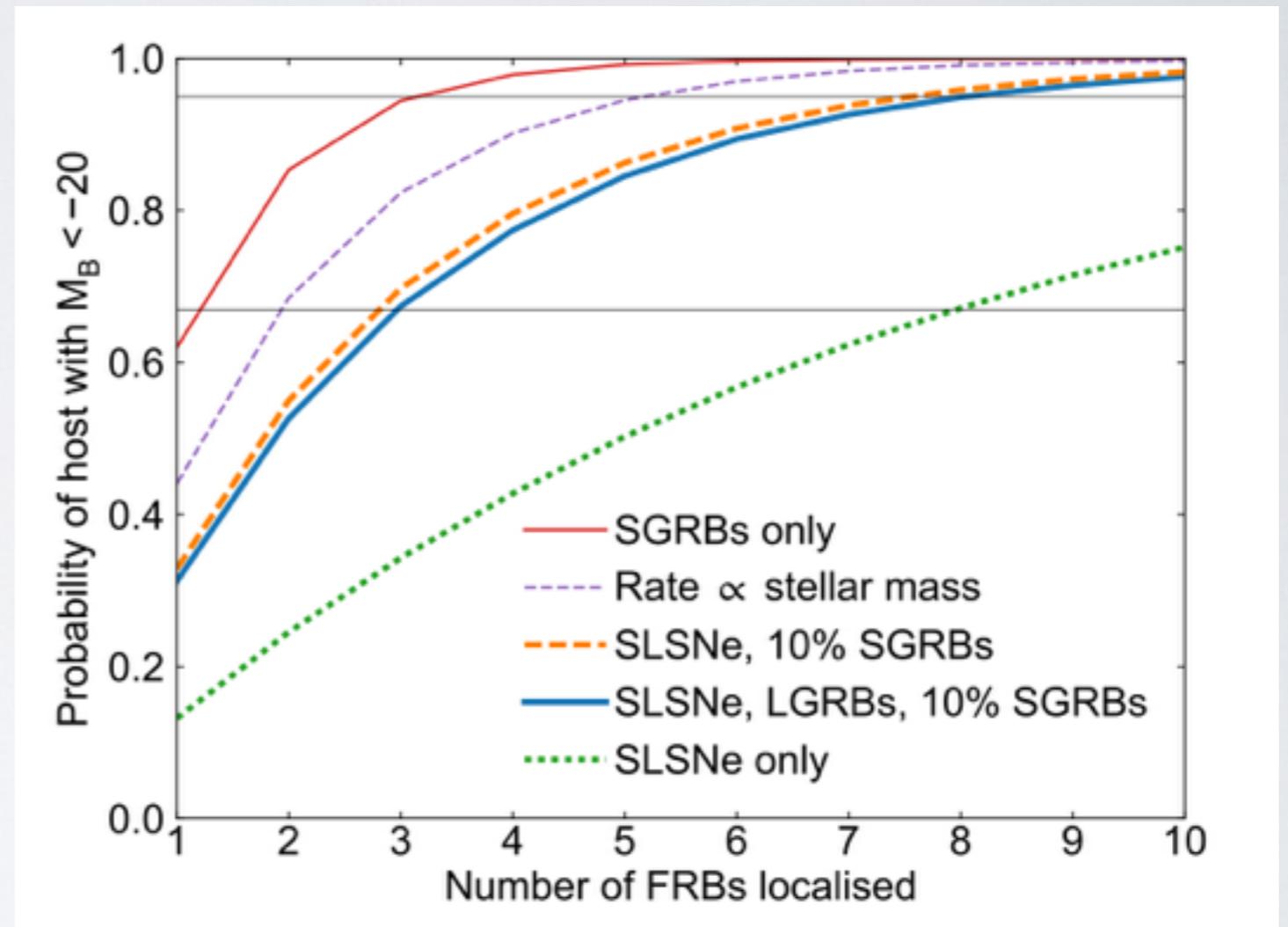
Harvard-Smithsonian Center for Astrophysics

June 13, 2017



LOCALIZING FAST RADIO BURSTS

- Critical for constraining progenitor models, host demographics and **distance scale**
- Formation channels can be tested with **less than 10 localizations**

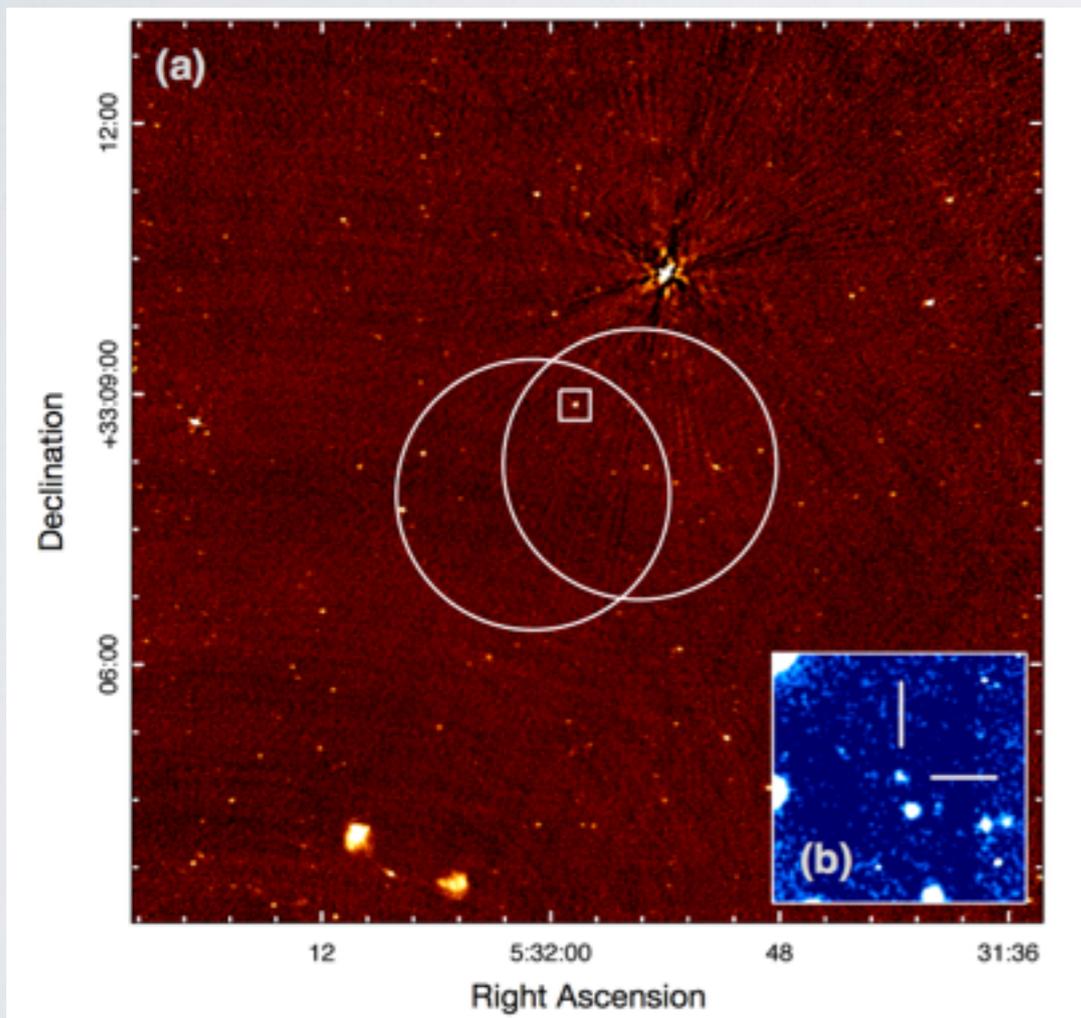


Nicholl et al. 2017

Can rule out SGRBs and other channels that trace cosmic stellar mass or star formation rate with ~ 10 localizations in $0.5 L^*$ galaxies

How robustly can we claim an association?

- Probability of a **chance coincidence**: (assuming Poisson distribution of galaxies)



$$P_{cc} = 1 - e^{-\pi R^2 \sigma(\leq m)}$$

Effective radius

Number of galaxies
above some limiting
magnitude m

How robustly can we claim an association?

- Parameterizing the effective localization radius:

$$R = \max[2R_{\text{FRB}}, \sqrt{R_0^2 + 4R_h^2}]$$

Galaxy offset

Half-light radius

How robustly can we claim an association?

- Parameterizing the effective localization radius:

$$R = \max[2R_{\text{FRB}}, \sqrt{R_0^2 + 4R_h^2}]$$

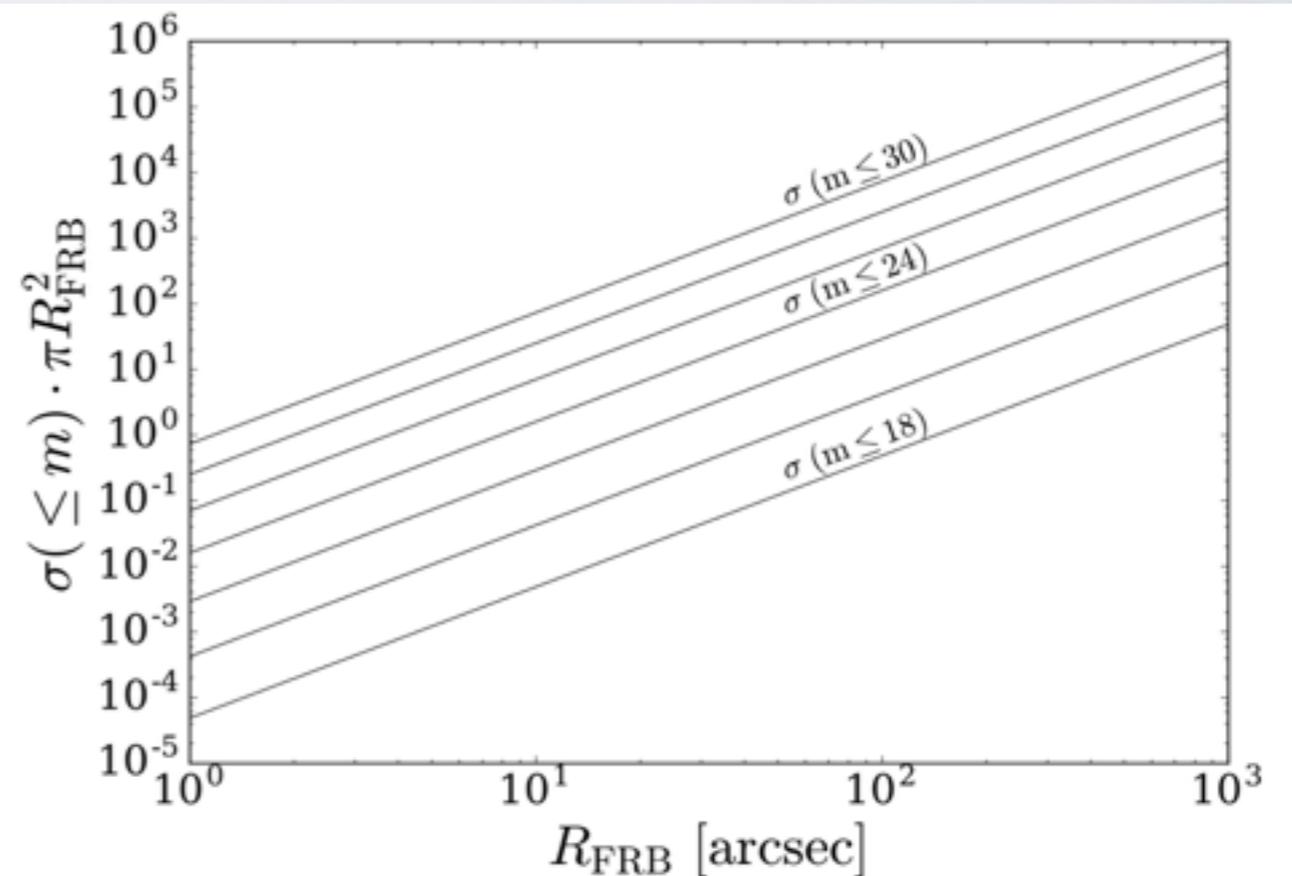
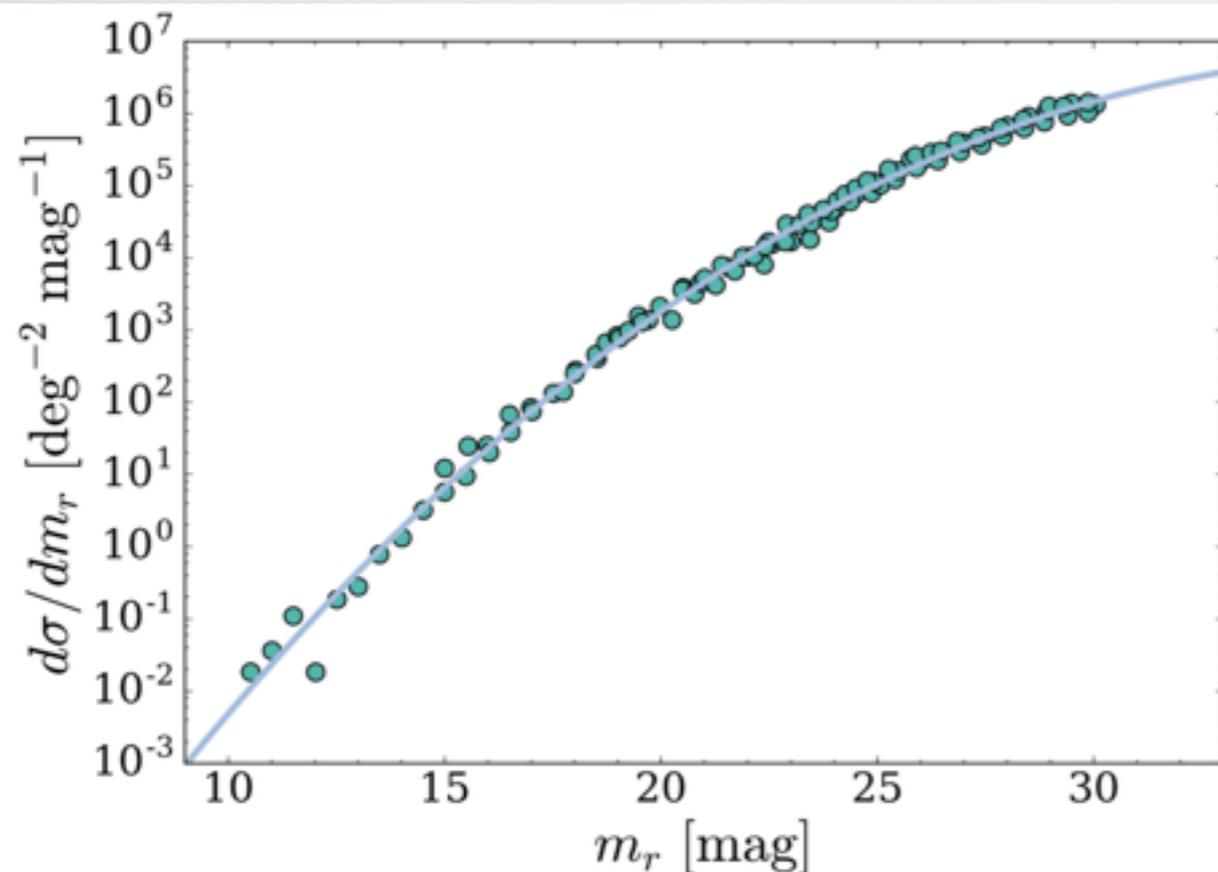
Galaxy offset Half-light radius

Adopt R_0 and R_h from SLSNe and LGRBs
(Lunnan et al. 2015; Blanchard et al. 2015)

For $R_{\text{FRB}} \lesssim 0.3''$ relevant scales are galaxy offset or half-light radius

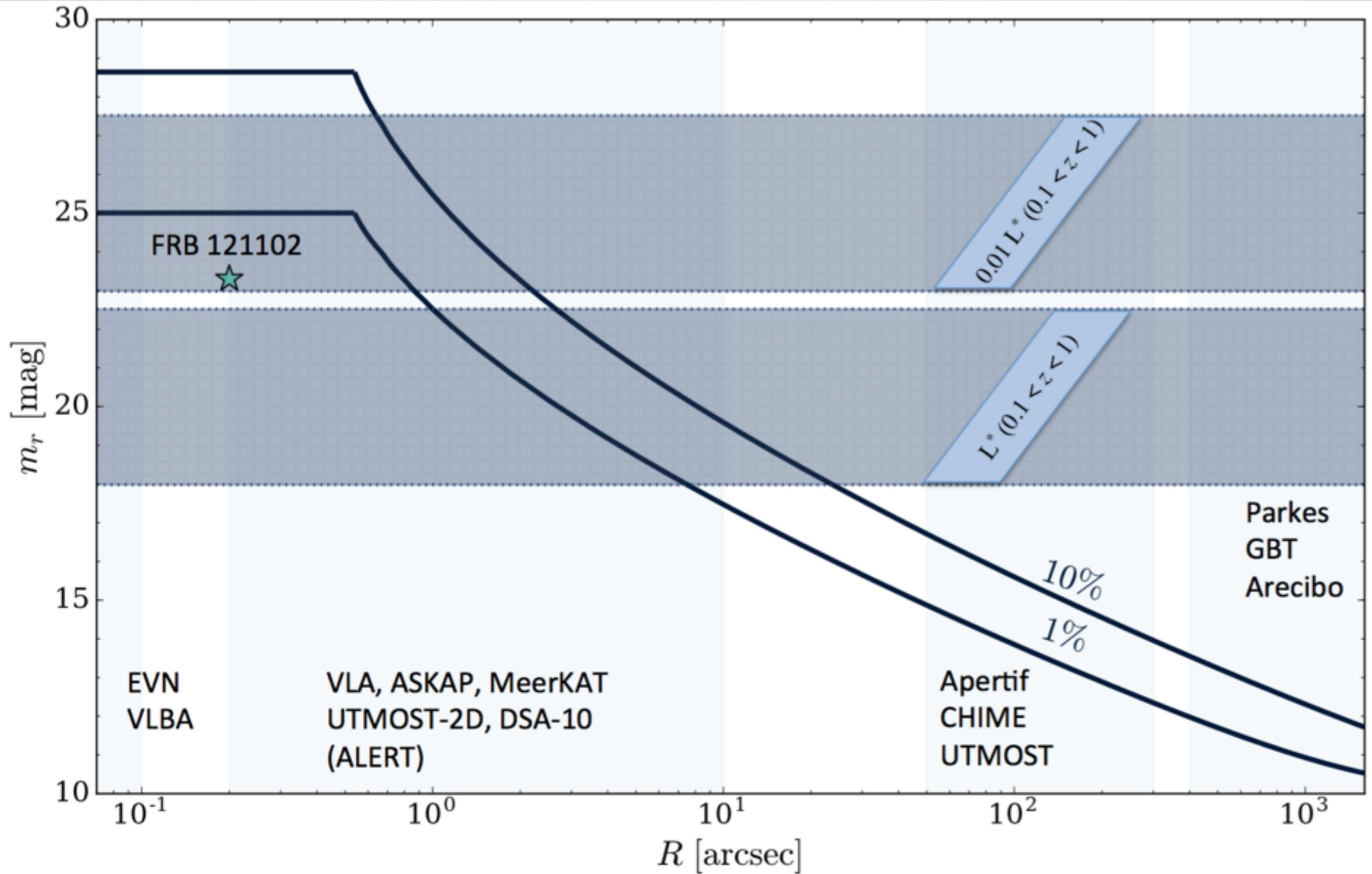
Using galaxy number counts to determine number of galaxies within a localization region

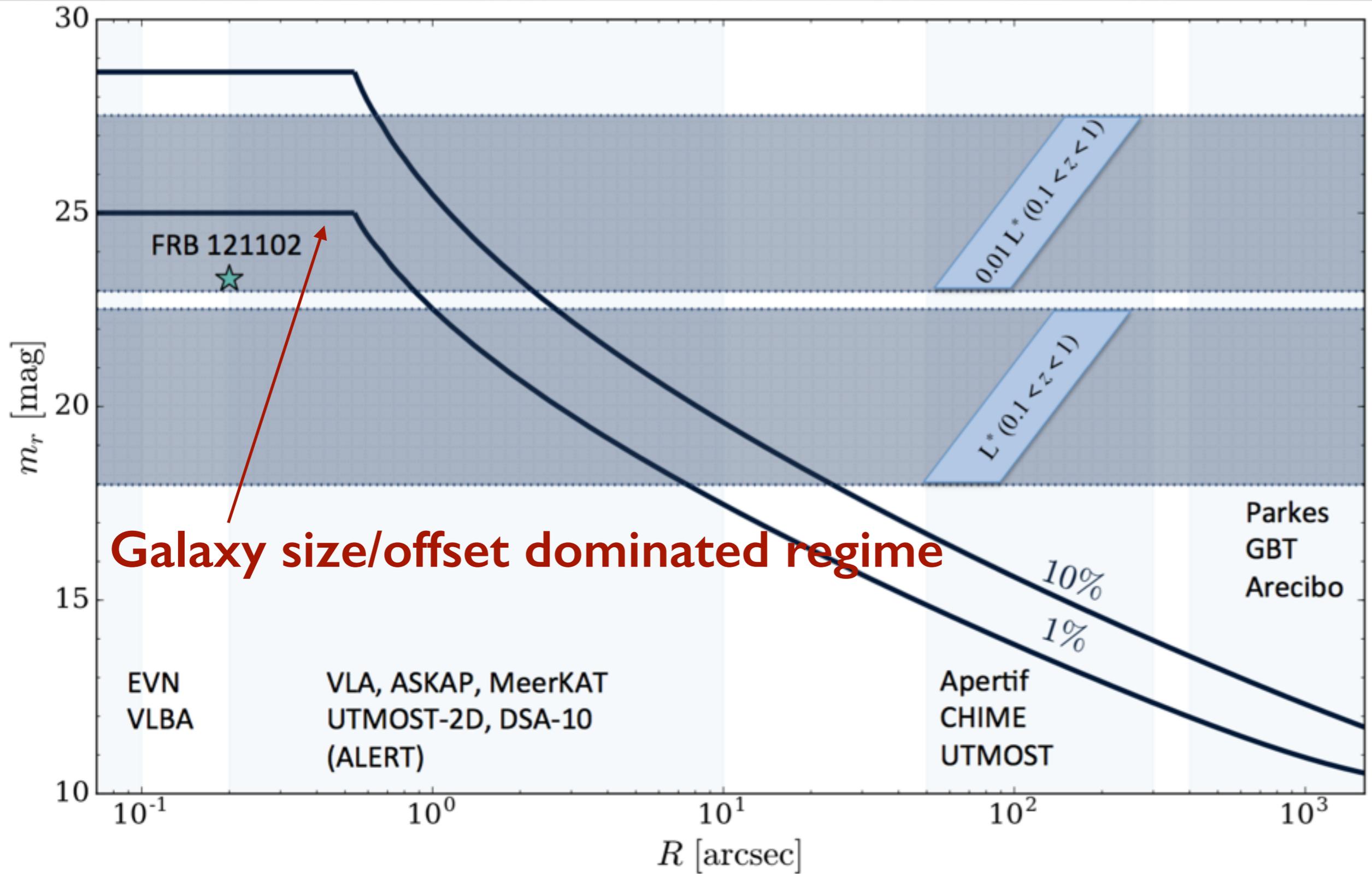
$$P_{\text{cc}} = 1 - e^{-\pi R^2 \sigma(\leq m)}$$



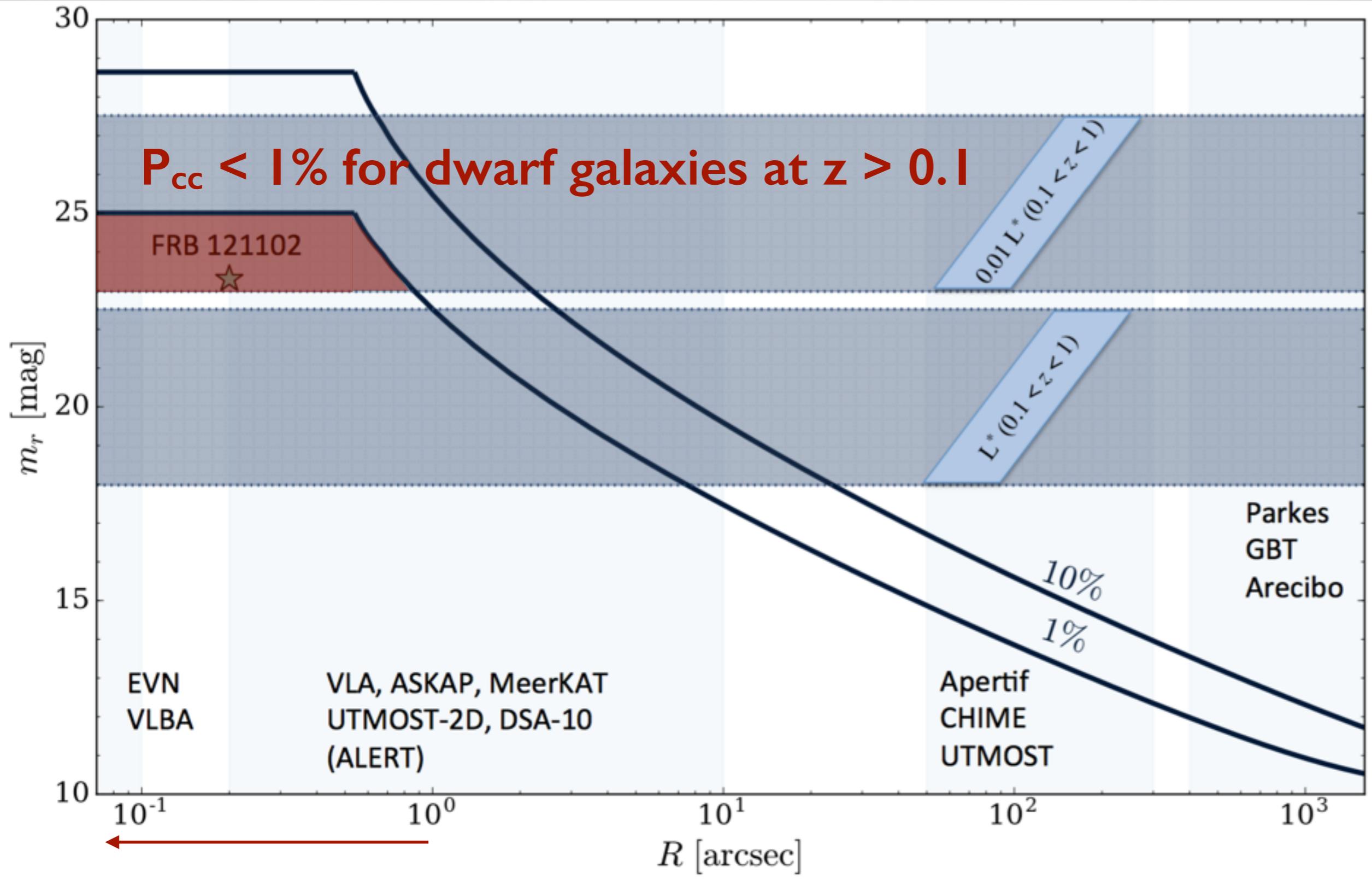
Eftekhari and Berger 2017

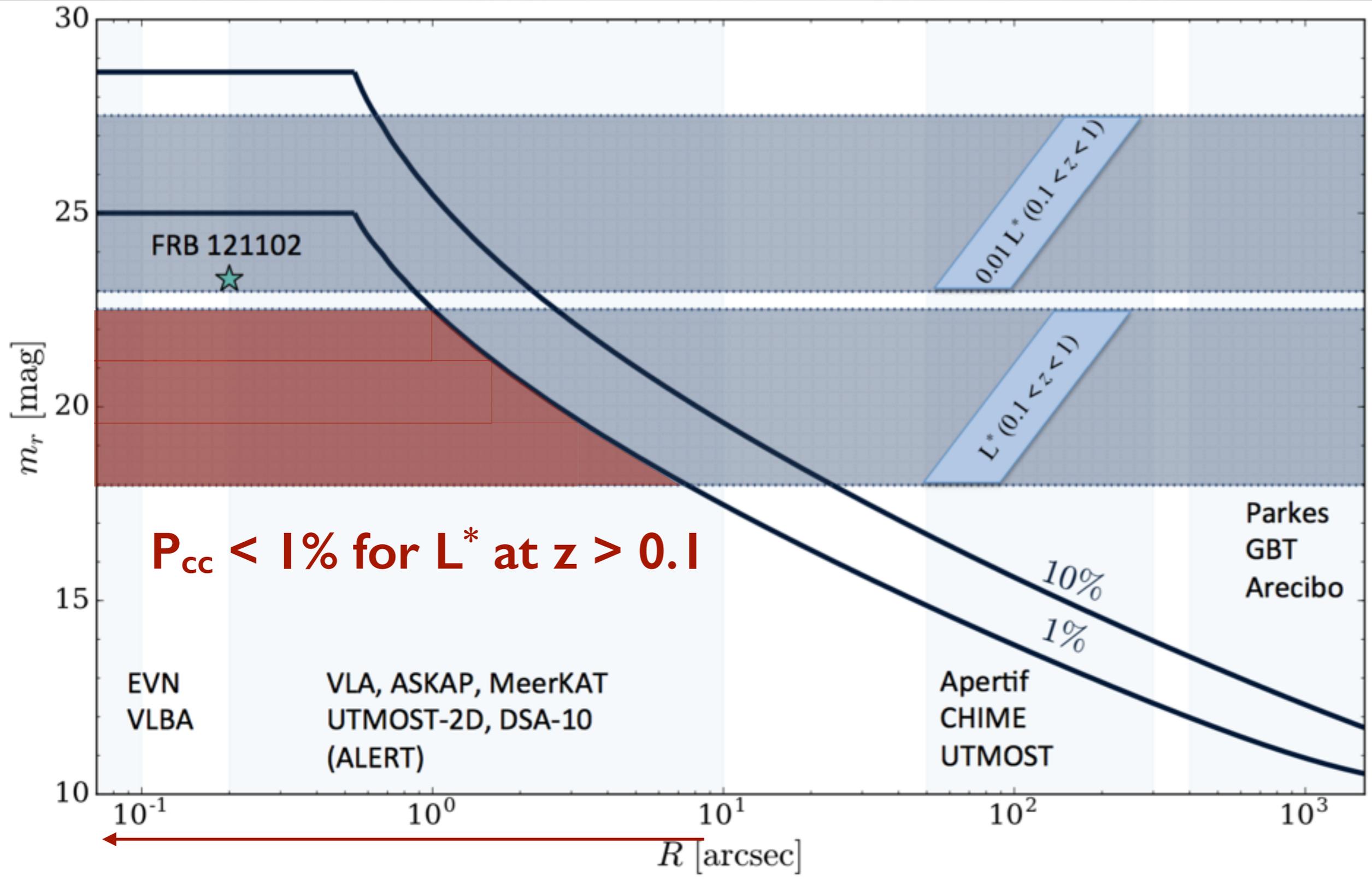
Galaxy number counts from Driver et al. 2016 — GAMA, HST, COSMOS





Galaxy size/offset dominated regime





Constraining the redshift with the DM

- Number counts alone are insensitive to redshift information
- DM can be used to constrain redshift and discard galaxies above redshift range of interest

Constraining the redshift with the DM

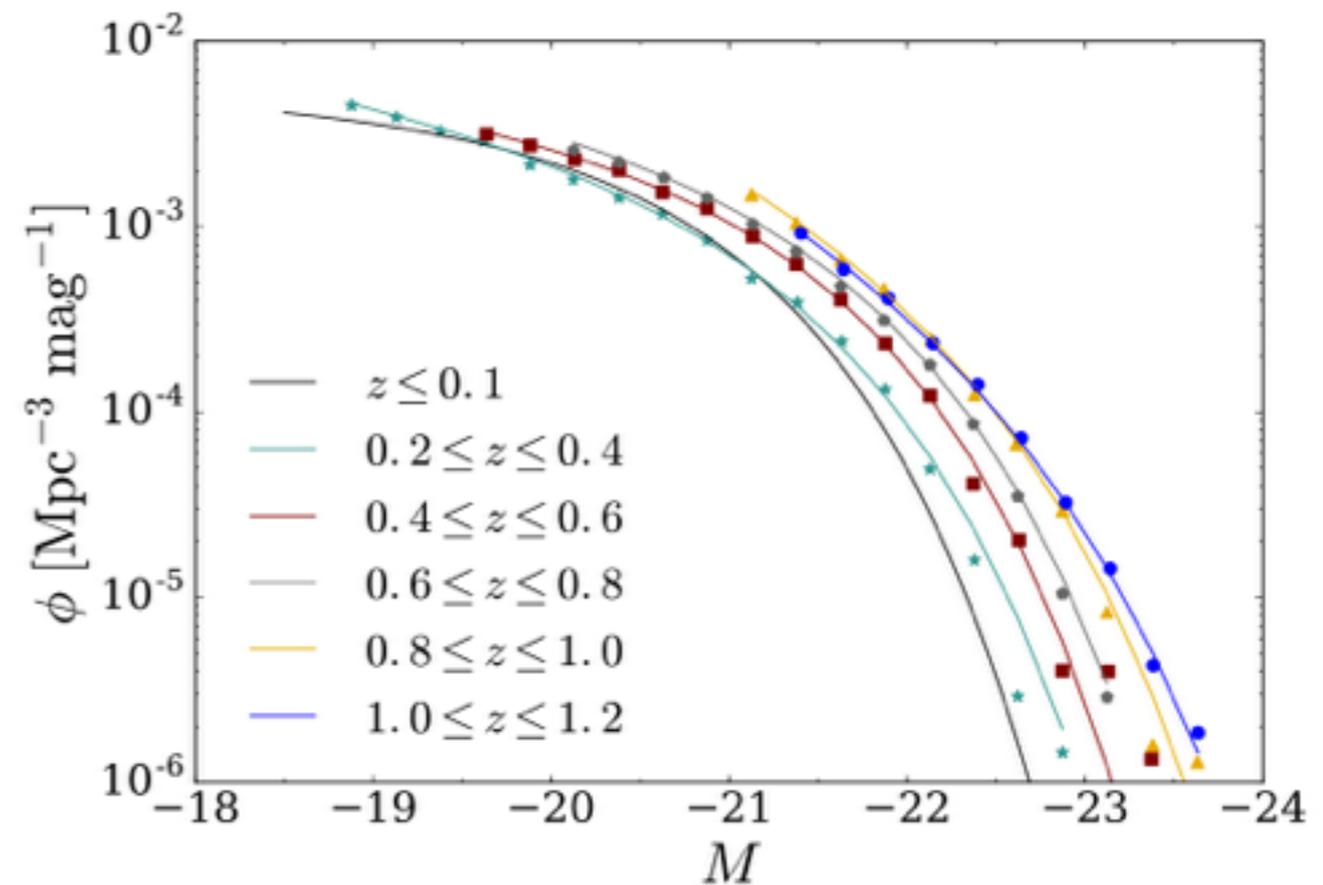
- Number counts alone are insensitive to redshift information
- DM can be used to constrain redshift and discard galaxies above redshift range of interest

Eftekhari and Berger 2017

$$P_{cc} = 1 - e^{-f_A \Sigma(\leq M) V_C(\leq z)}$$

Number density of galaxies above a limiting absolute mag

Comoving volume out to redshift z



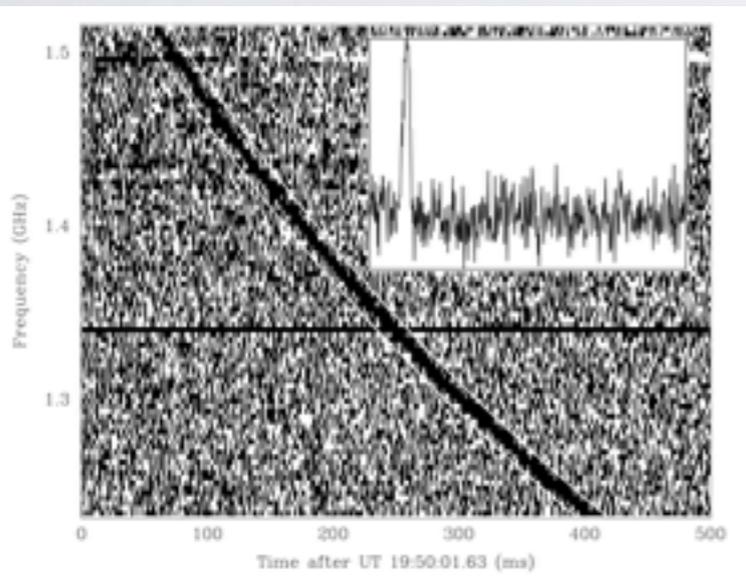
Luminosity functions from Blanton et al. 2003 and Beare et al. 2015

Constraining the redshift with the DM

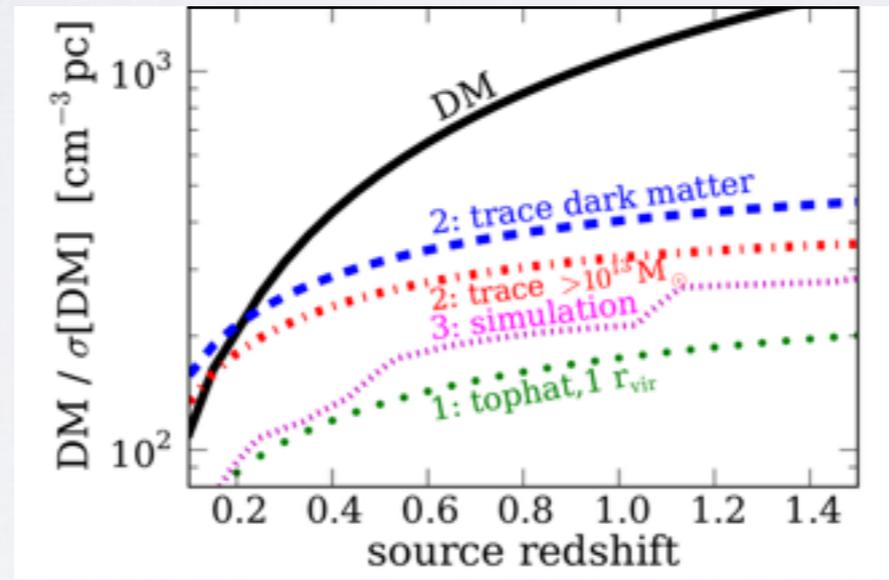
- Inhomogeneities introduce some uncertainty in DM- z relation

Constraining the redshift with the DM

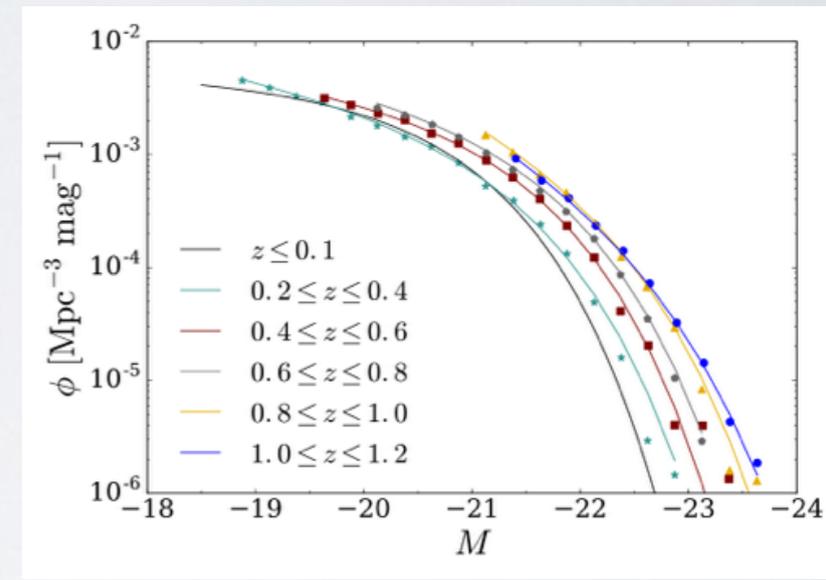
- Inhomogeneities introduce some uncertainty in DM-z relation



Lorimer et al. 2007



McQuinn 2014

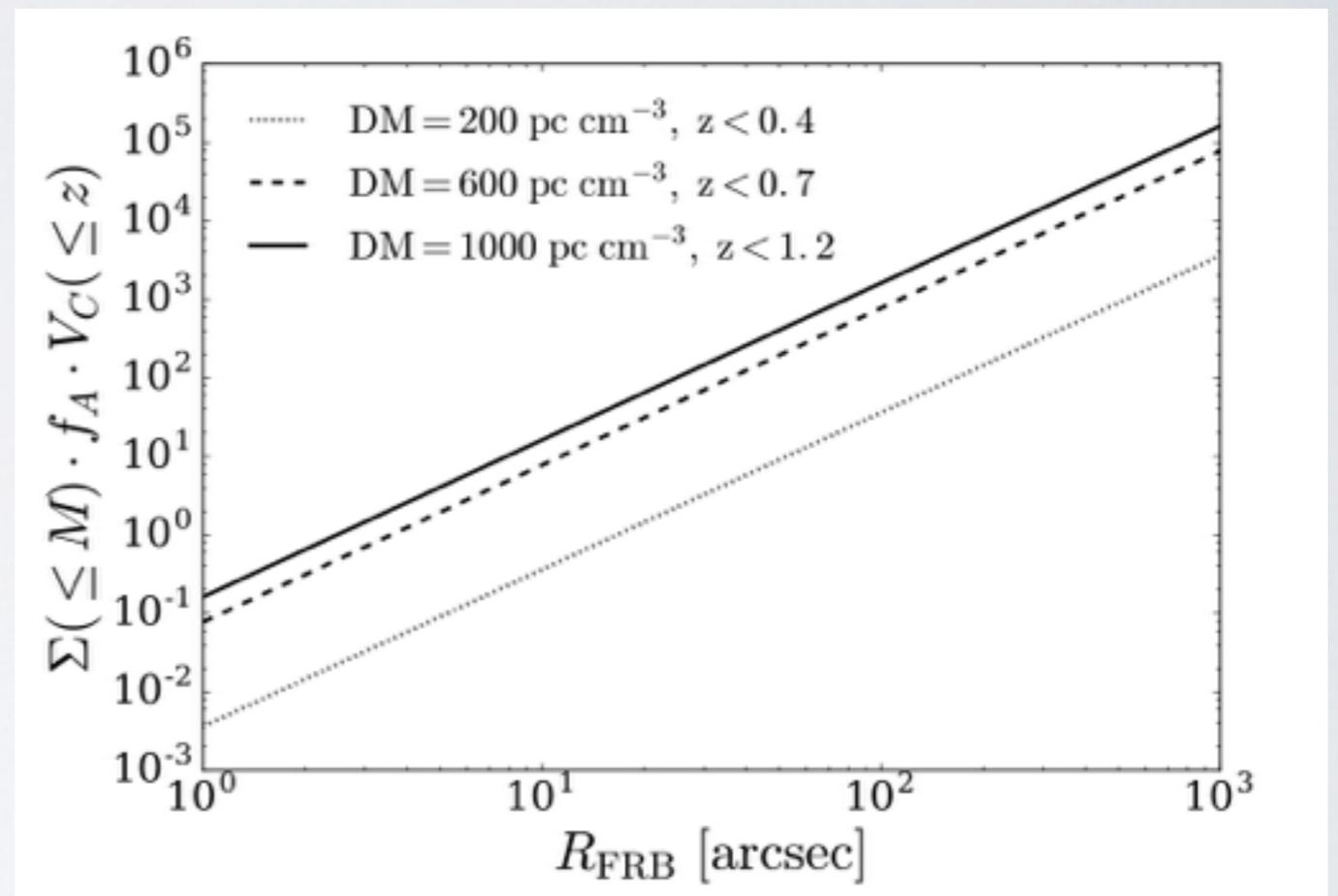


Eftekhari and Berger 2017

Most conservative estimate of z_{max} when baryons trace dark matter halos (assuming NFW profiles)

Improving the association likelihood

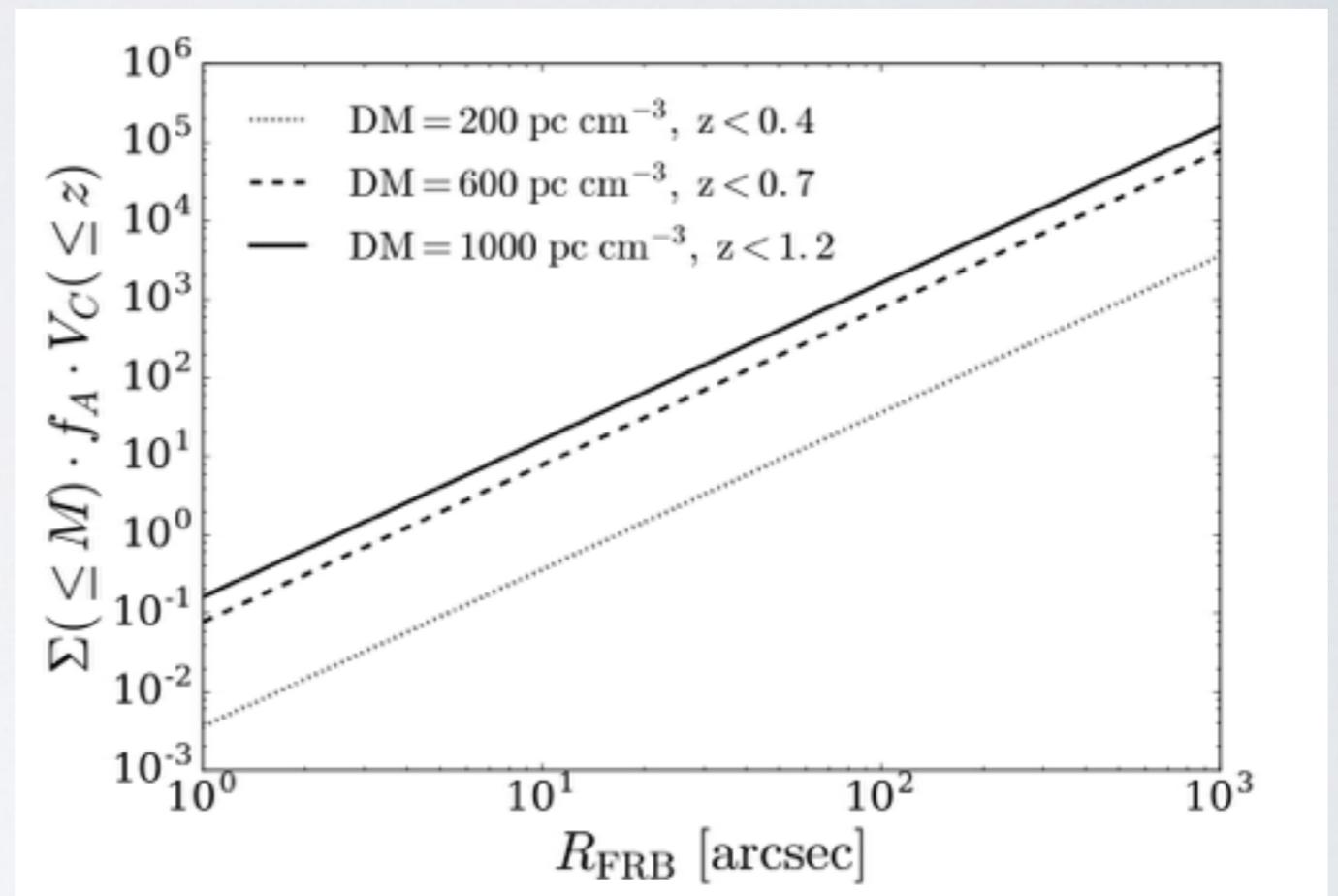
- **Factor of 2 fewer galaxies** at **high redshifts** ($z \sim 1.2$) compared to number counts scenario
- **Factor of 10 fewer galaxies** at low redshifts ($z \sim 0.4$)



Eftekhari and Berger 2017

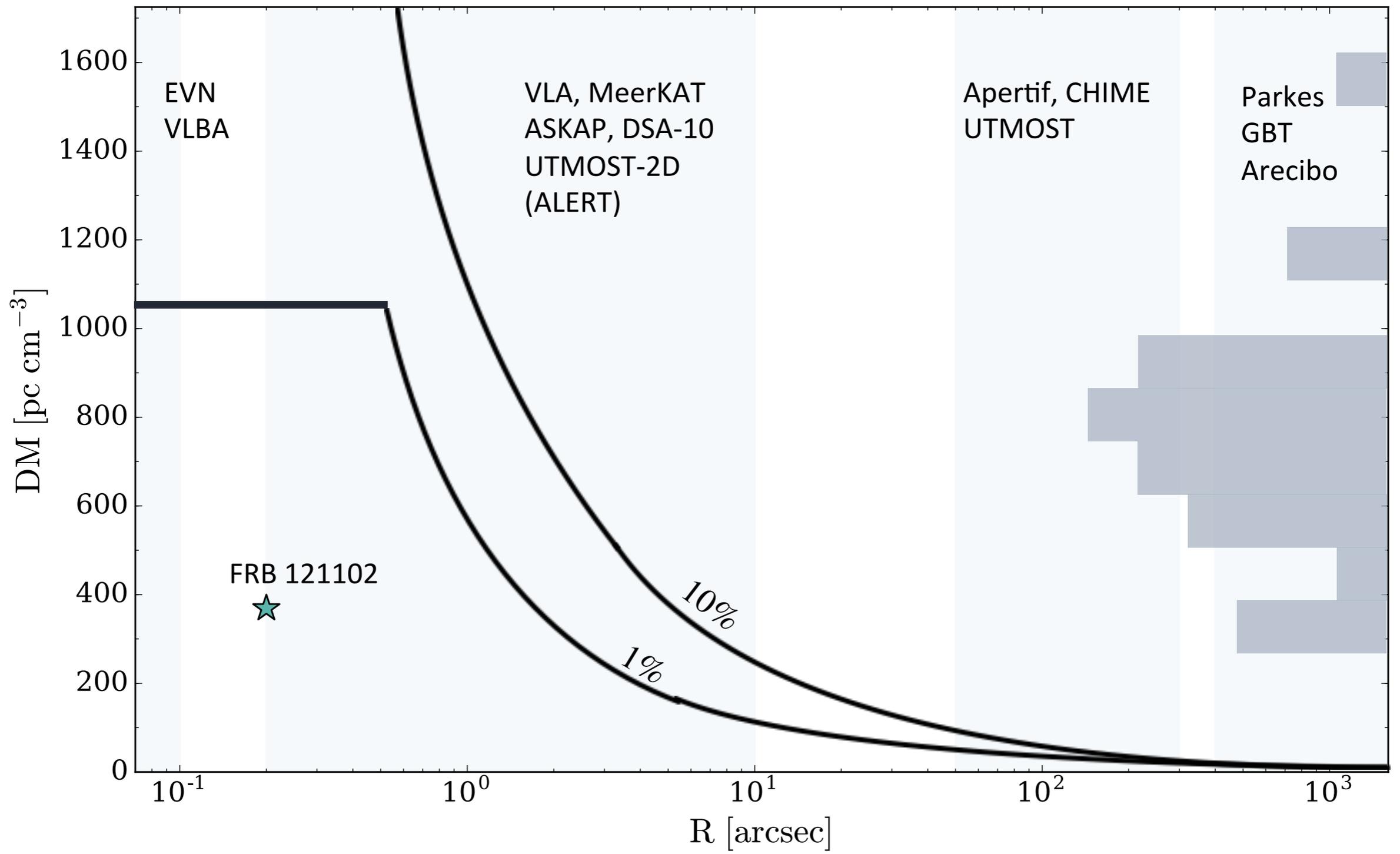
Improving the association likelihood

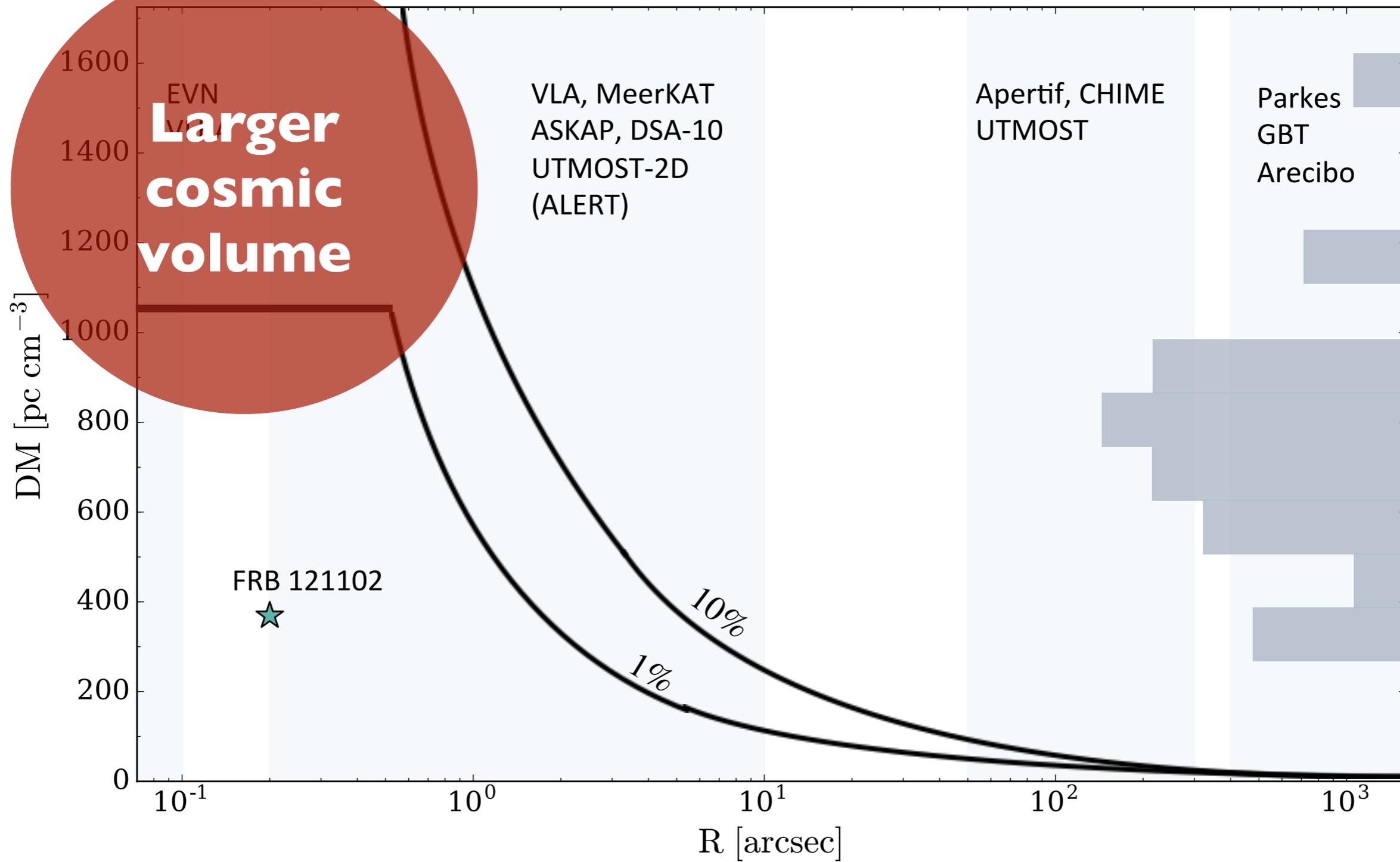
- **Factor of 2 fewer galaxies** at **high redshifts** ($z \sim 1.2$) compared to number counts scenario
- **Factor of 10 fewer galaxies** at low redshifts ($z \sim 0.4$)



Eftekhari and Berger 2017

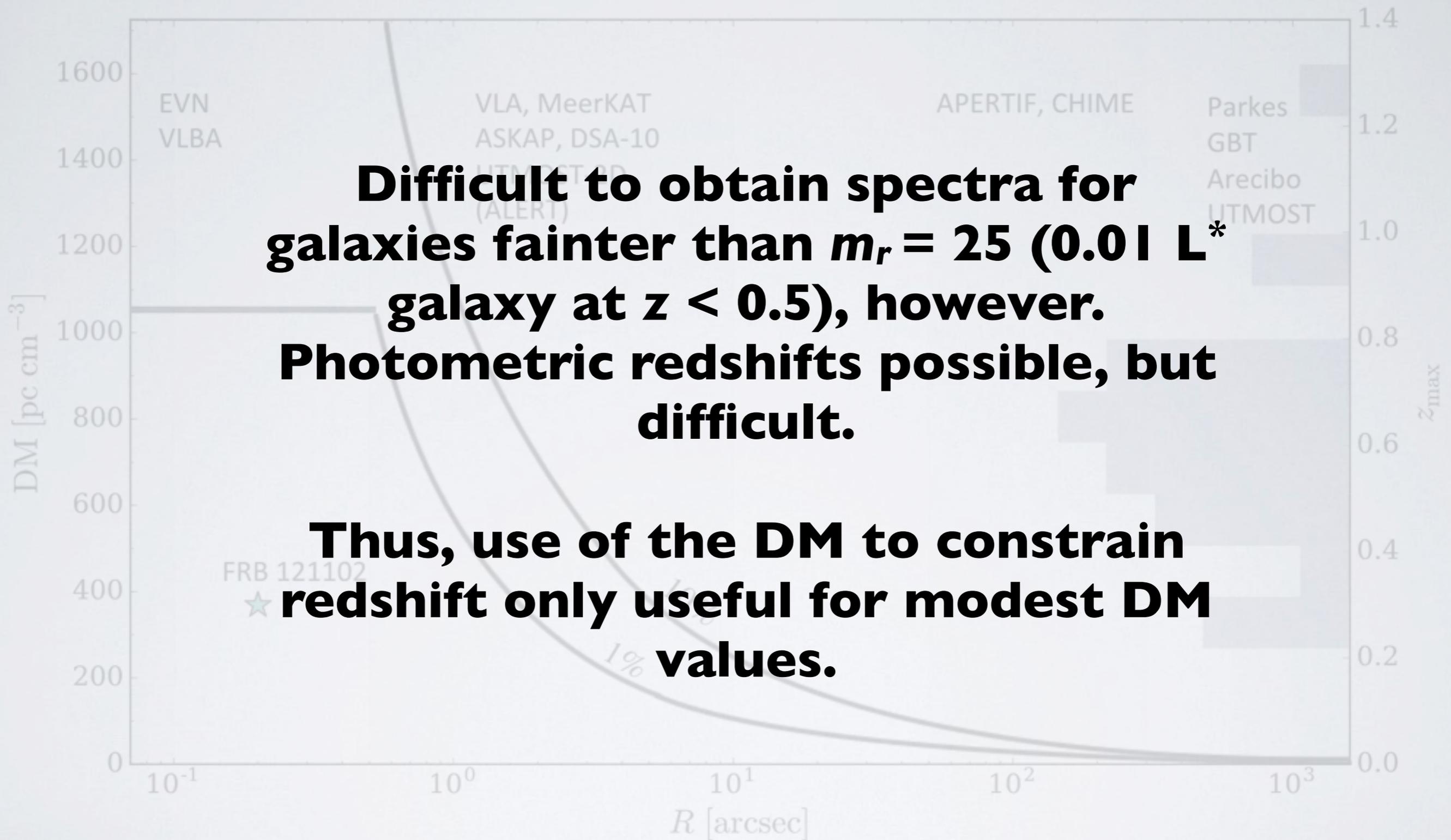
Allows for robust associations even with poorer localizations





Difficult to obtain spectra for galaxies fainter than $m_r = 25$ ($0.01 L^*$ galaxy at $z < 0.5$), however. Photometric redshifts possible, but difficult.

Thus, use of the DM to constrain redshift only useful for modest DM values.

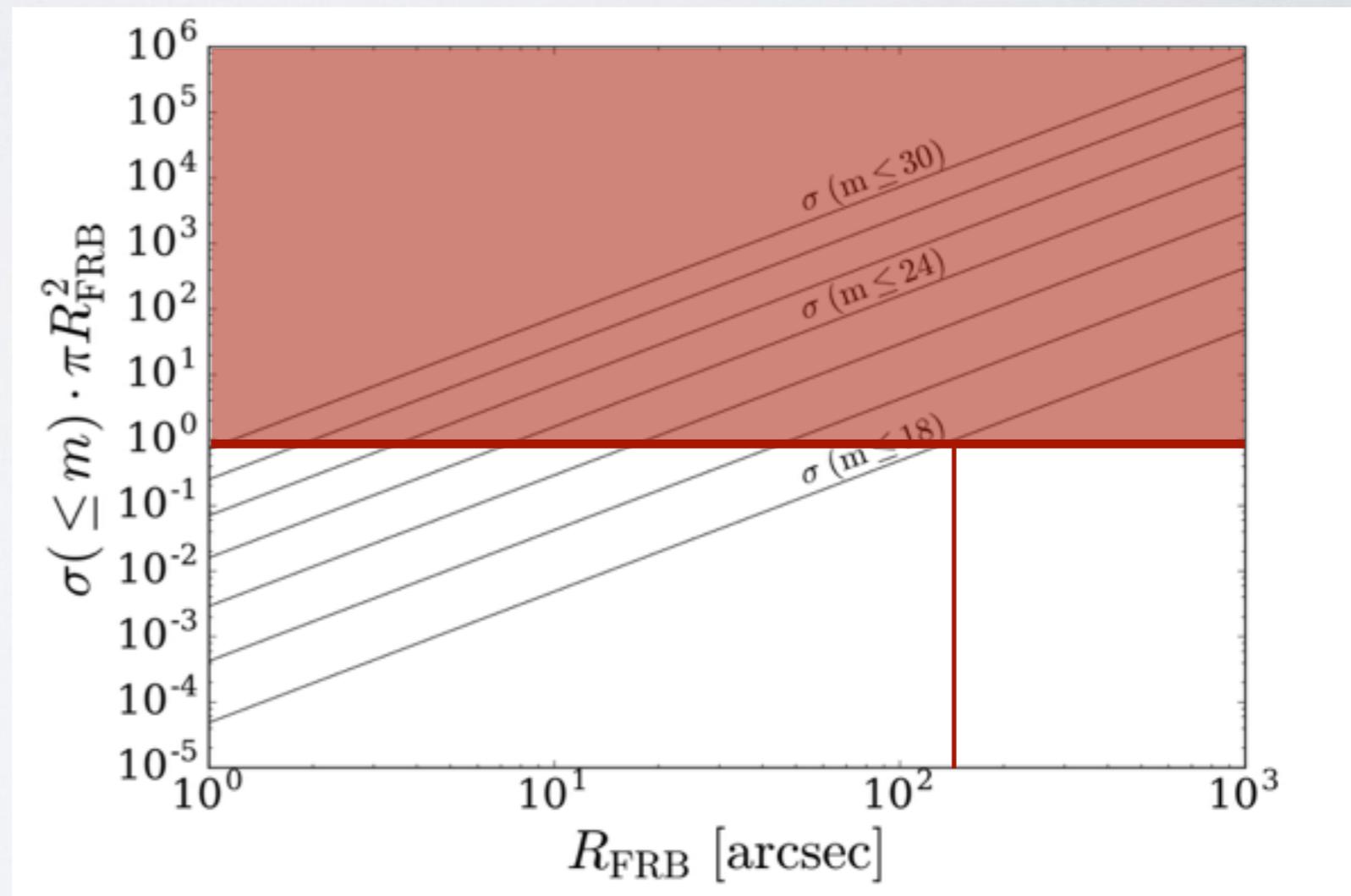


Characterizing the host galaxy in the absence of a robust association

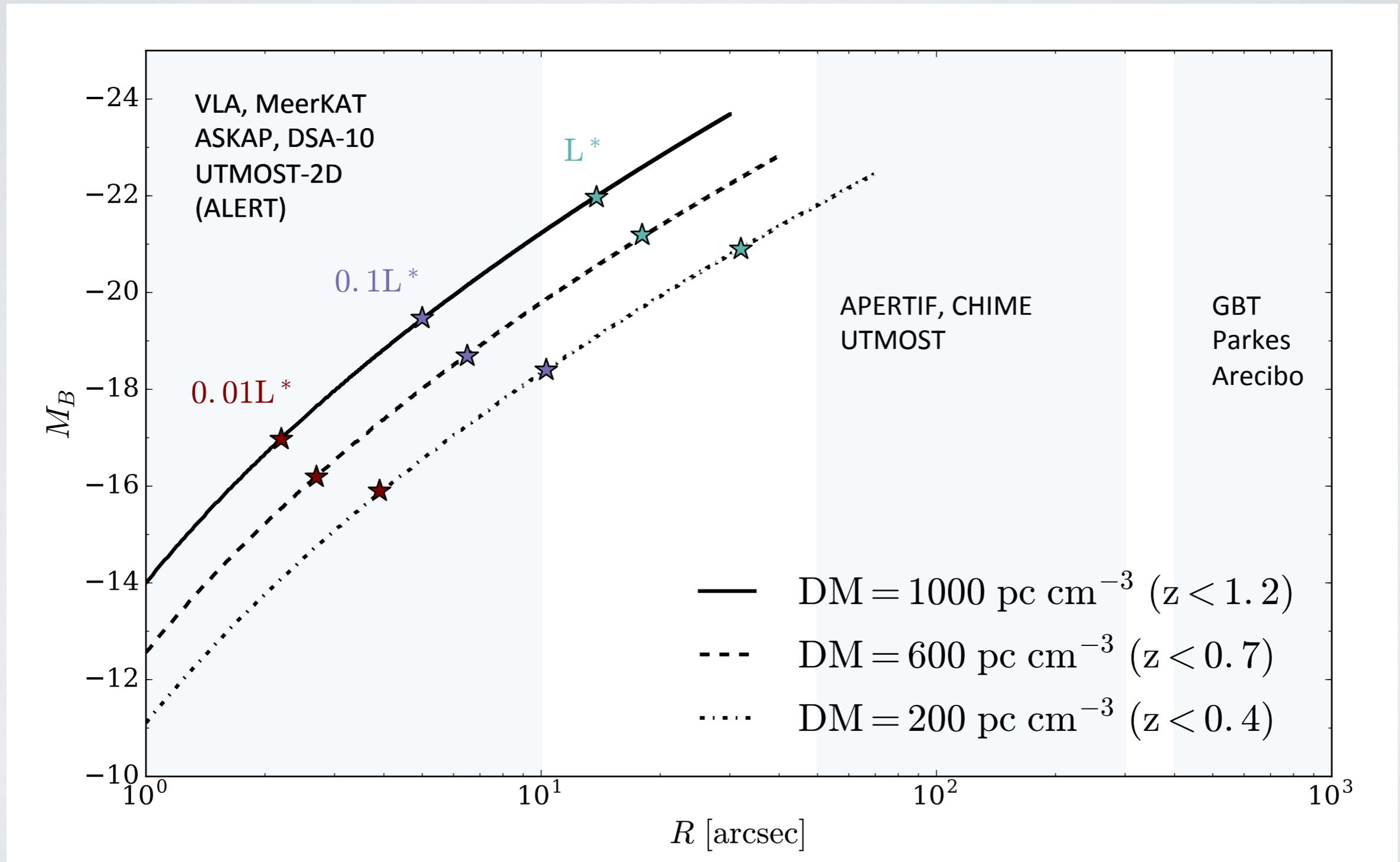
- Determine apparent magnitude corresponding to a single galaxy within the field as a function of localization region

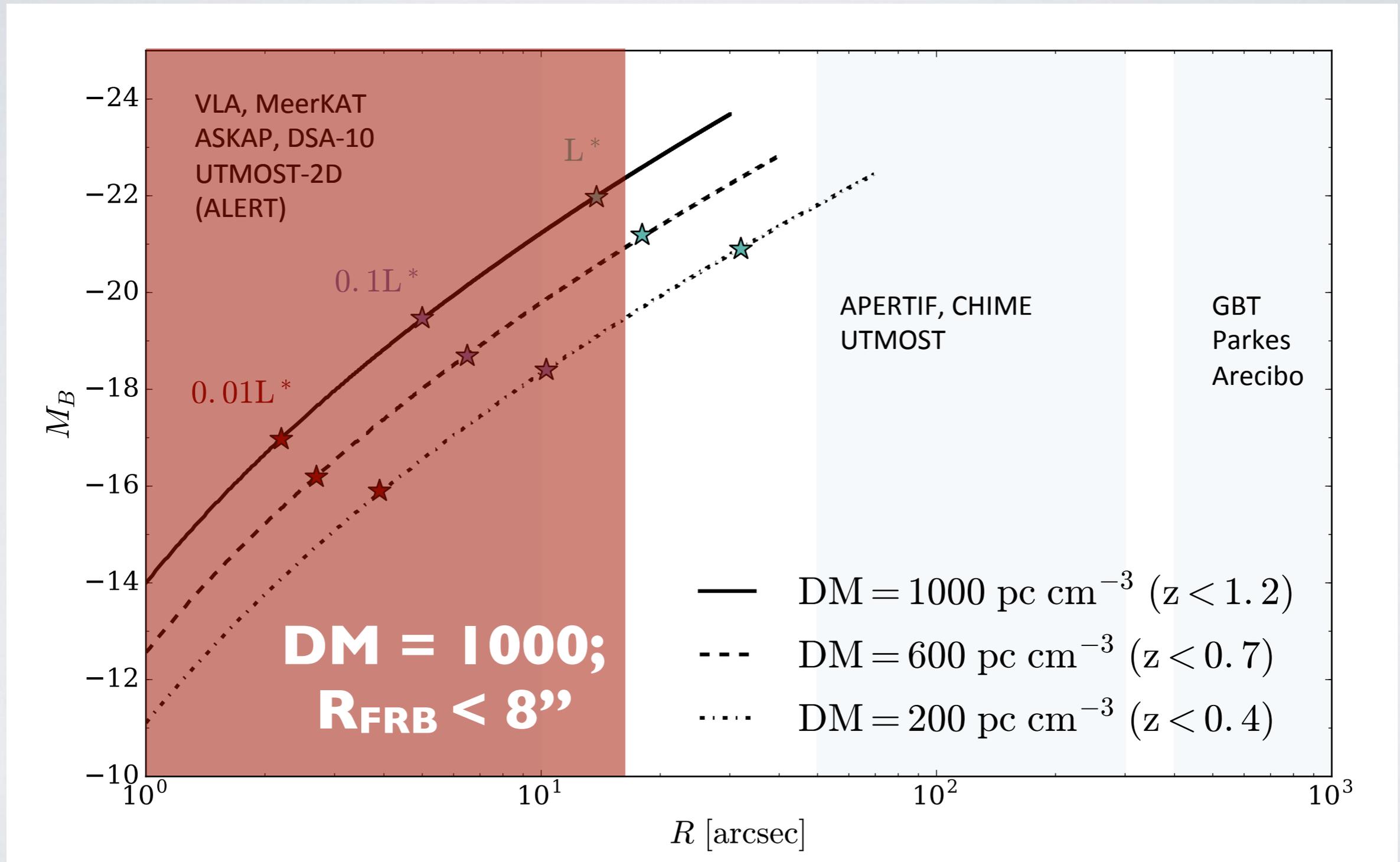
Cannot make a robust association...

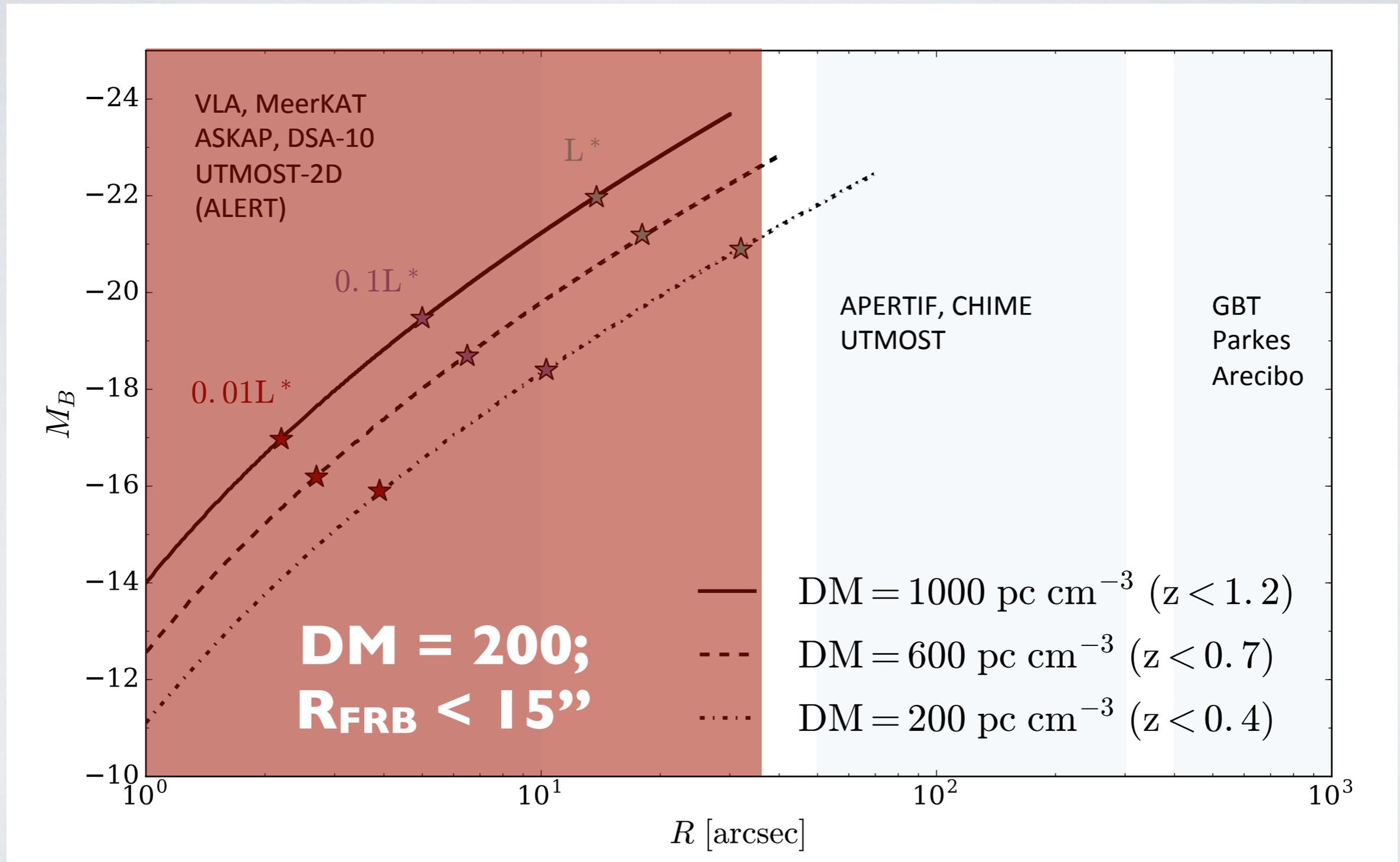
...but can place constraint on **maximum luminosity of the host.**

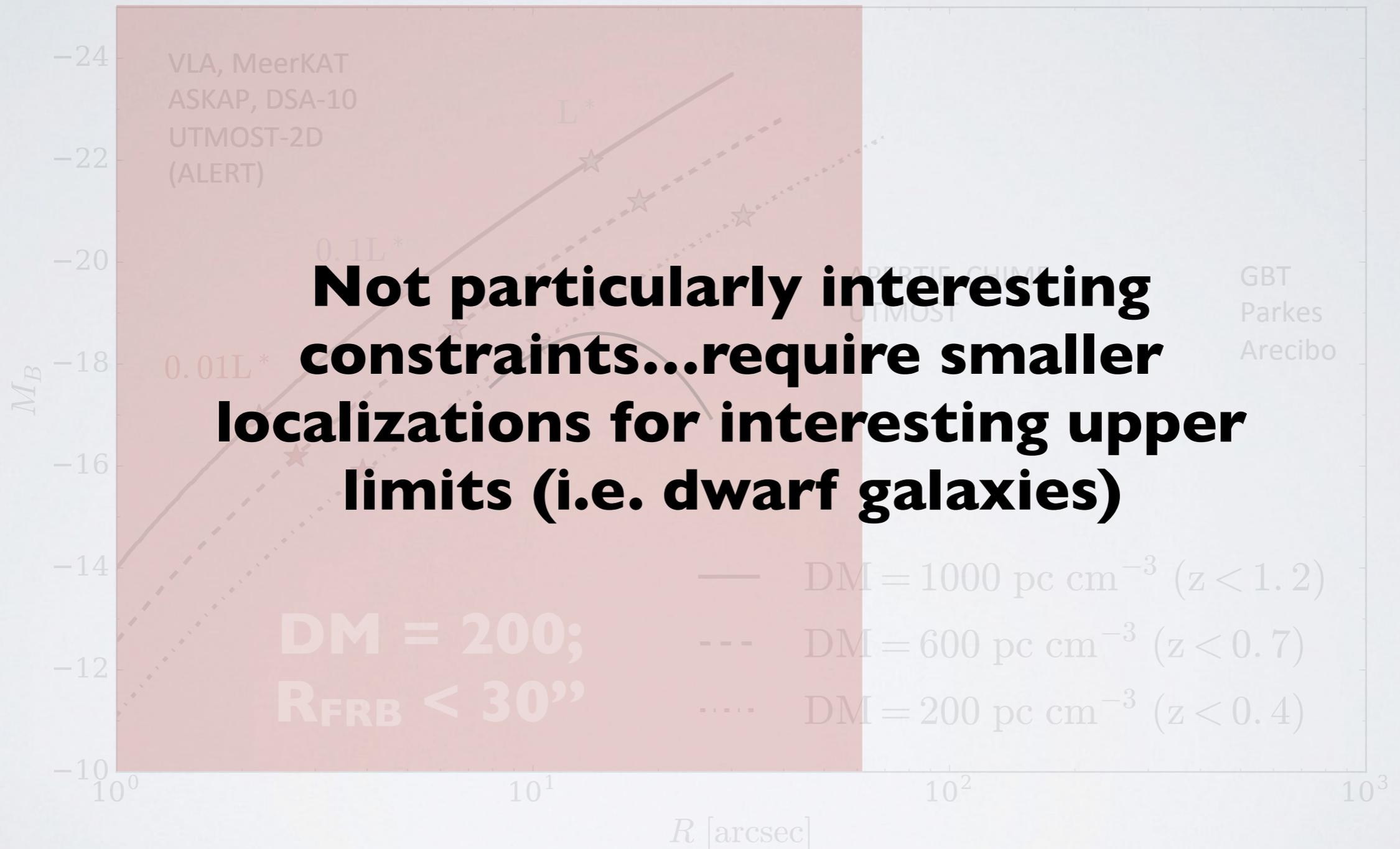


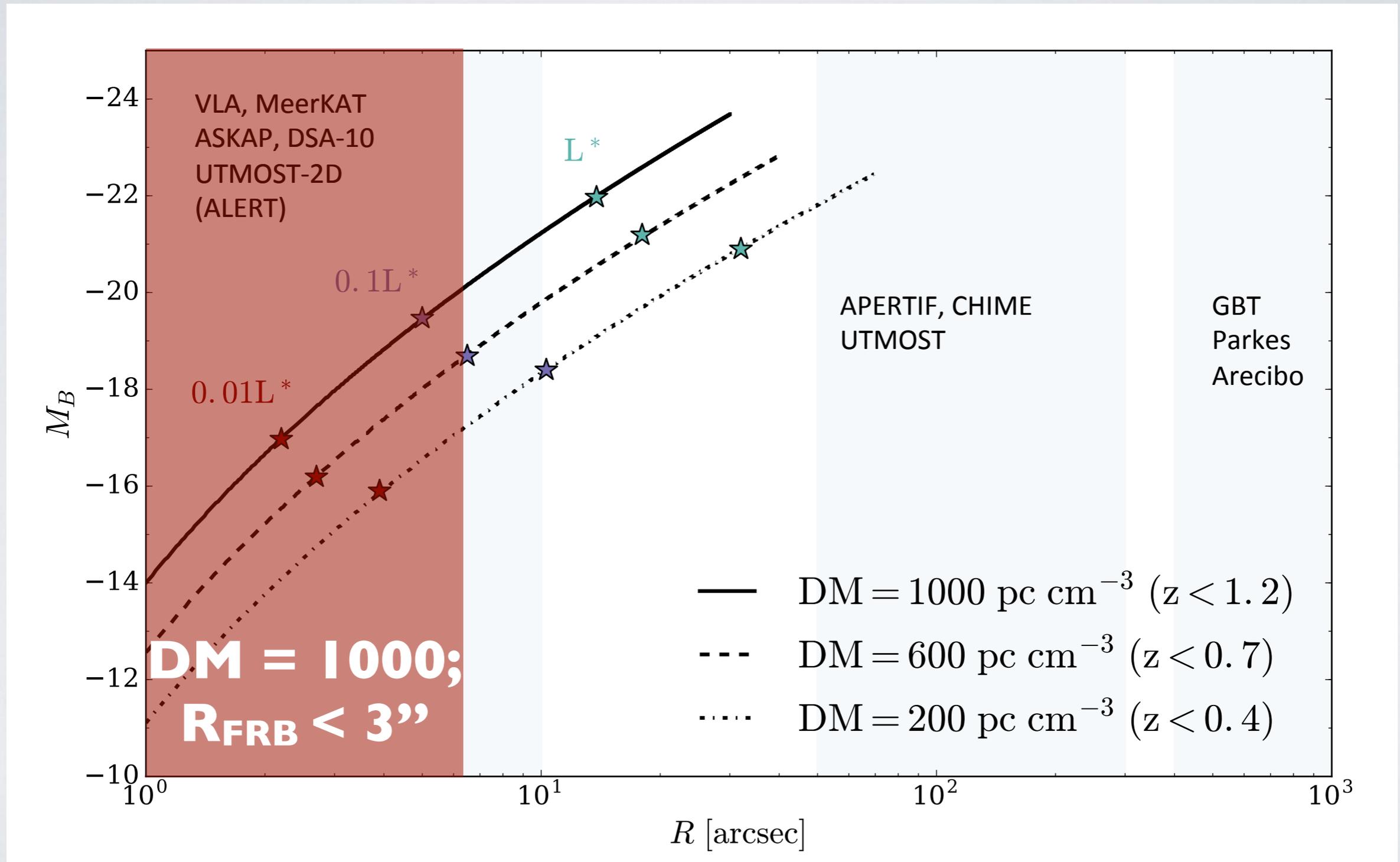
Observed DM \longrightarrow Add uncertainty \longrightarrow Z_{max} \longrightarrow Luminosity of galaxy at Z_{max}

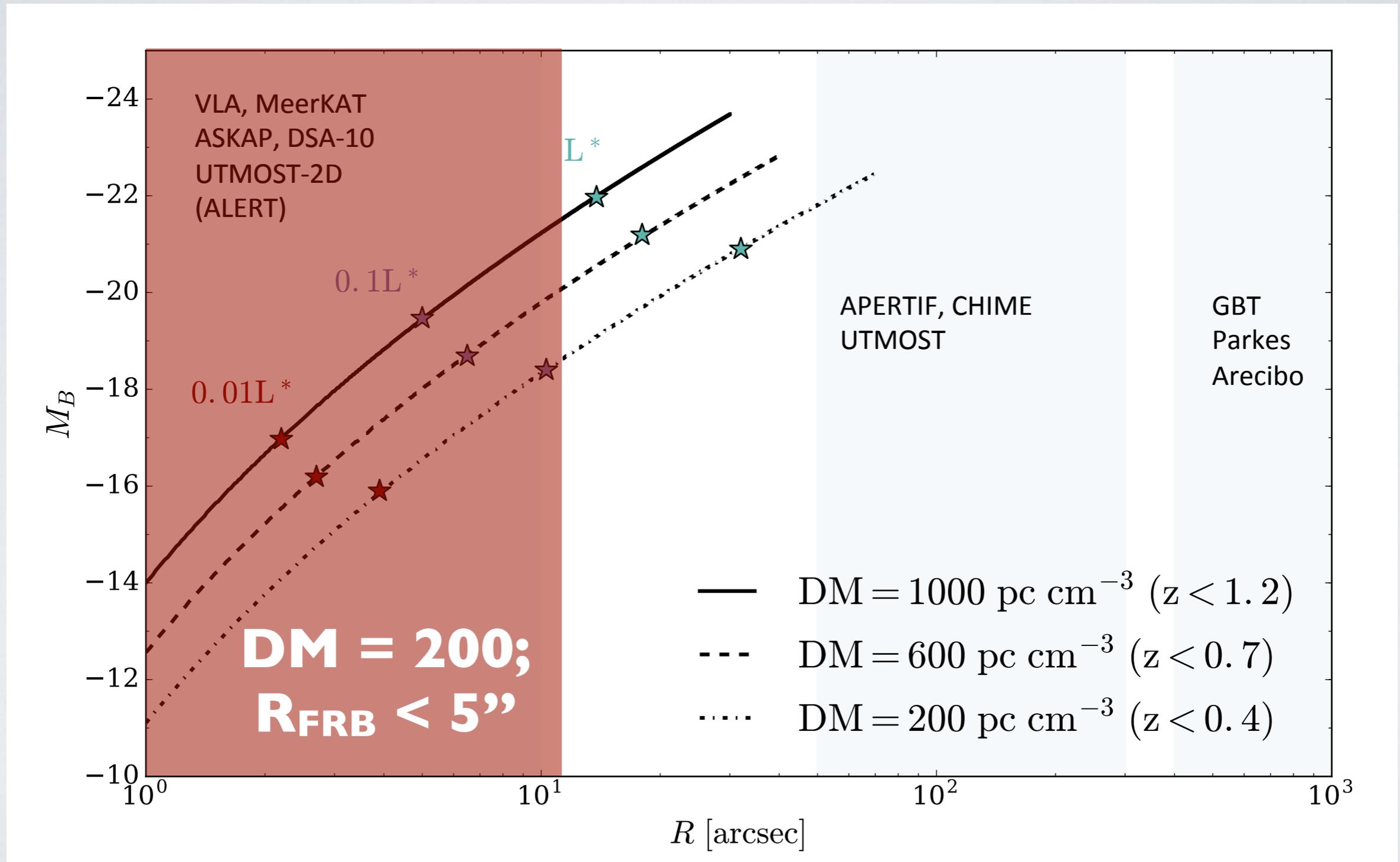


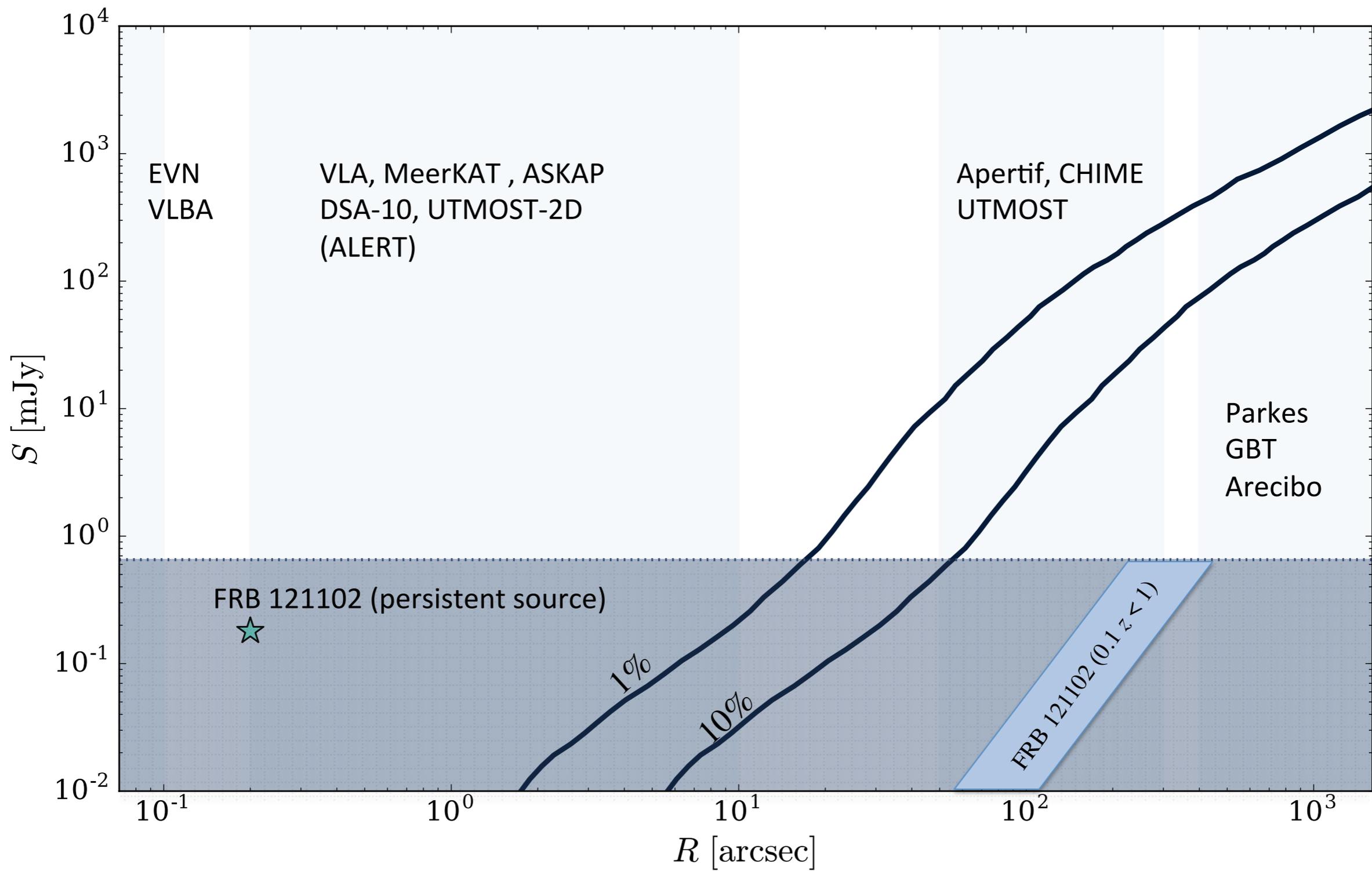












SUMMARY

- Require **sub-arcsecond localizations** for galaxies fainter than $m_r = 25$ for $P_{cc} < 1\%$ (as in the case of FRB 121102)
→ 0.01 L^* galaxies at $z < 0.5$ or L^* galaxies at $z < 1.5$
- Use of DM to constrain redshift only useful for low DM values, where it reduces the number of galaxies significantly, and where spectroscopic redshifts can be obtained
- Can place interesting upper limits on the luminosity of the host even in the absence of a robust association, but this still requires positions of a few arcsec
- **Few localizations with $< 2-3''$ will allow for constraints on FRB formation channel**