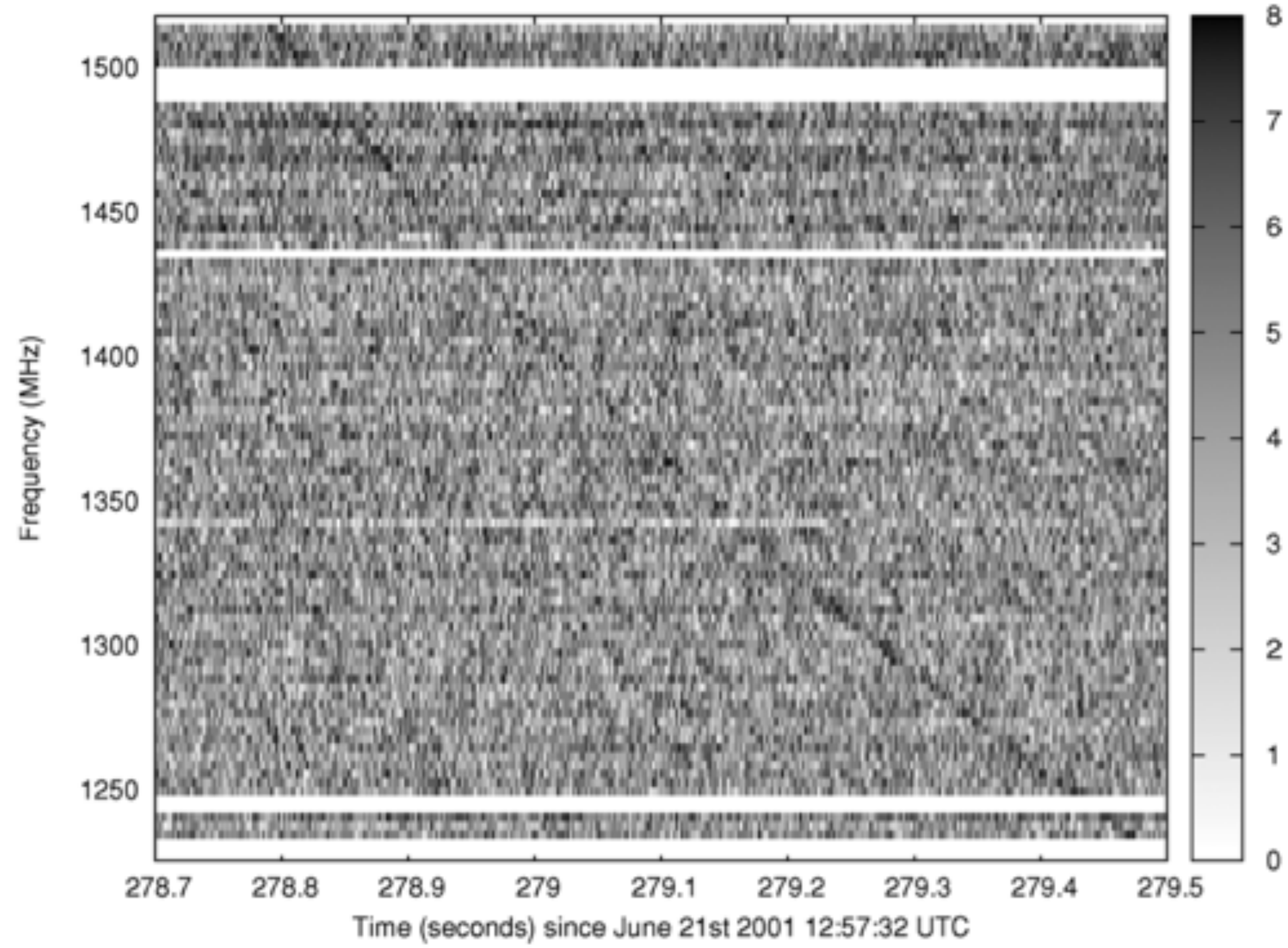
A Galactic Origin for the Fast Radio Burst FRB010621



Keane et al. 2012

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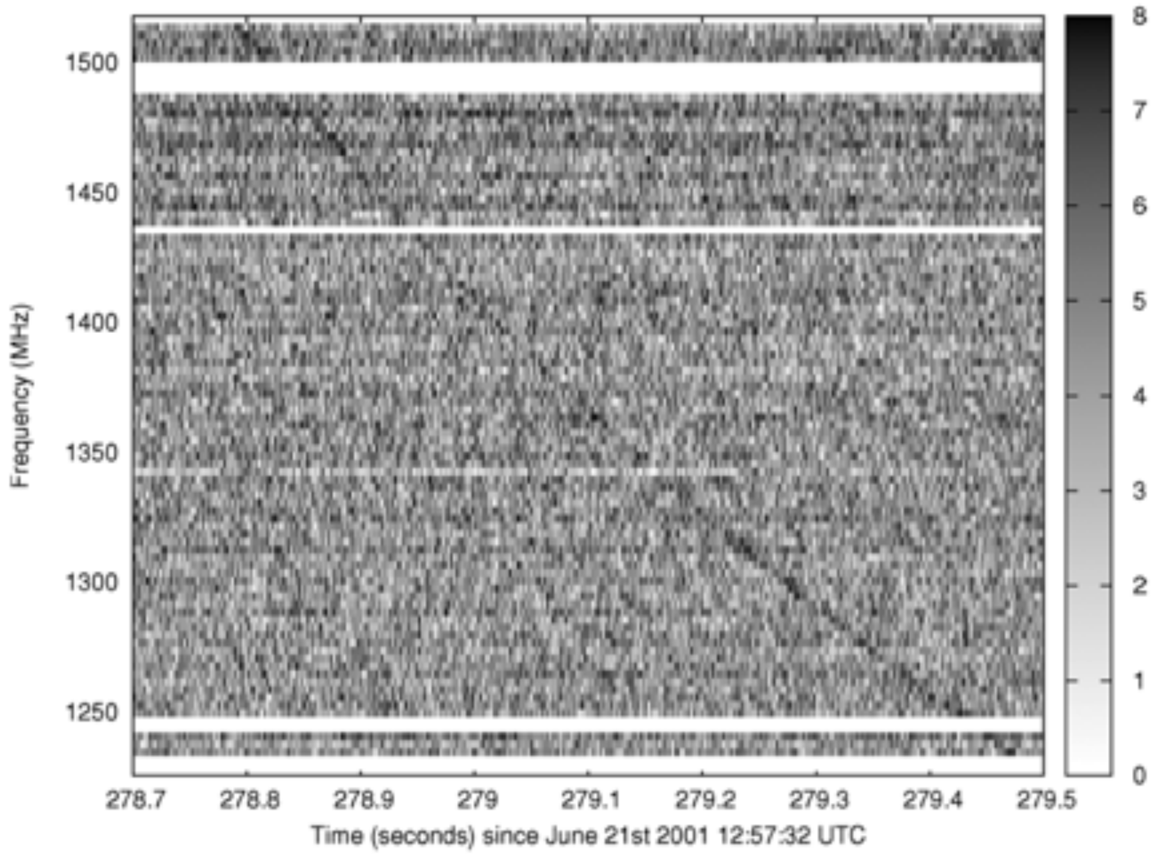
Motivation

- FRBs: bright, non-repeating, highly dispersed, non-scatter-broadened* radio pulses
- distances uncertain to within a factor of $\approx 10^8$
- labyrinth of explanations
  - Galactic: unusual neutron stars, annihilating mini-black holes, flare stars, ...
  - Extragalactic: annihilating black holes, neutron star mergers, stellar/SNR collision, magnetar bursts, GRBs, “blitzars”, cosmic strings, ...
- burst of publications
  - $\approx$ 70 papers on ADS since 2012 ($\approx$ 30 in 2014)
- race is on for $N_{detections} > N_{theories}$
- critically examine distance constraints for an FRB near Galactic plane

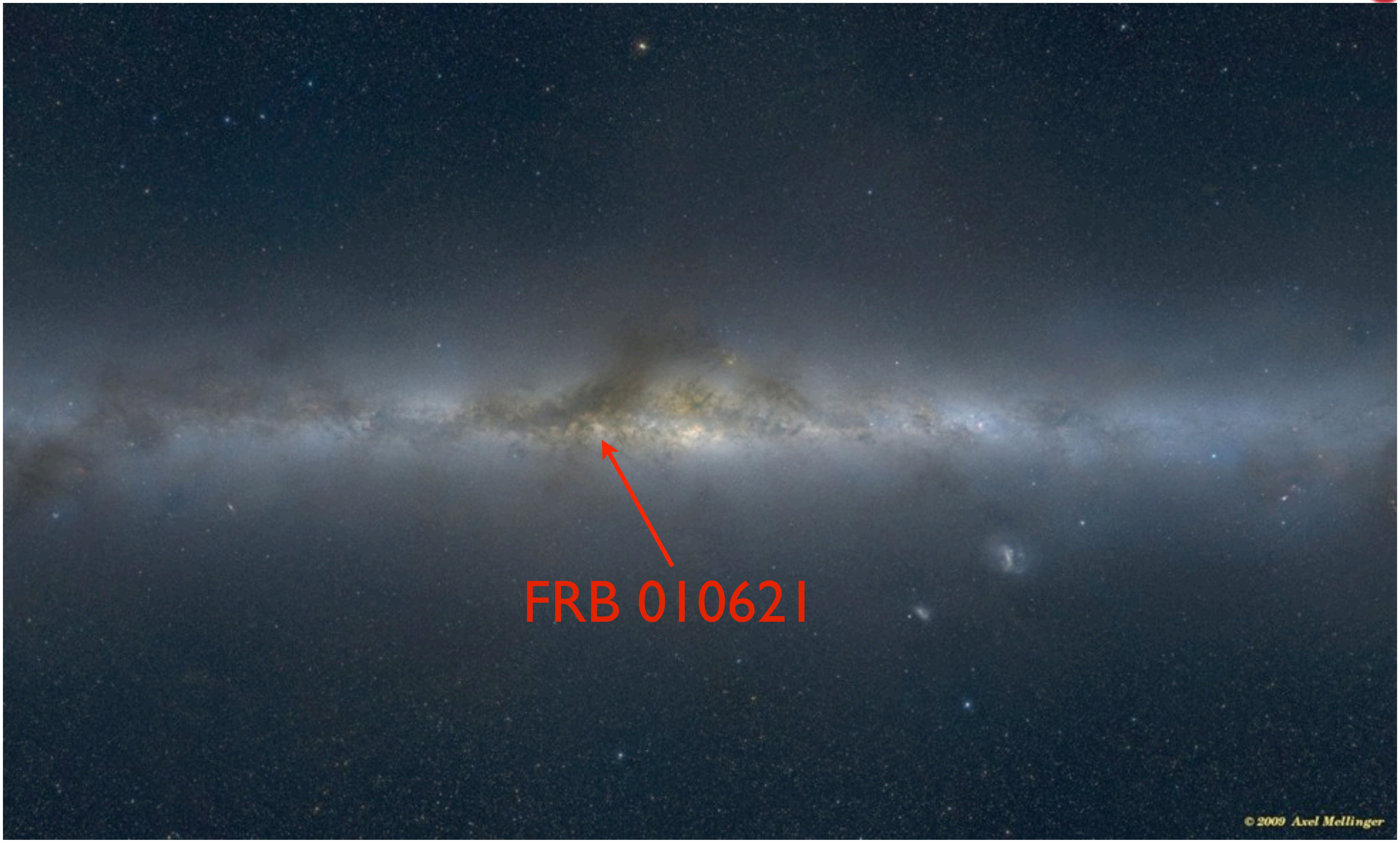
FRB 010621

- discovered in one 14′ beam at Parkes
- RFI, 'perytons' ruled out
- low Galactic latitude: (25.43°, -4.00°)
- peak flux density: 360 - 510 mJy
- scatter broadening < 3 ms
- dispersion measure: $\int n_e(l)dl = 746 \pm 1$ cm^{-3} pc
- DM from NE2001 model: 533 cm^{-3} pc
  - 8 pulsars within 2° of FRB; all DM < 390 cm^{-3} pc
- if excess DM extragalactic, $D \approx 500h^{-1}$ Mpc
- can DM be fully attributed to electrons in Galaxy?

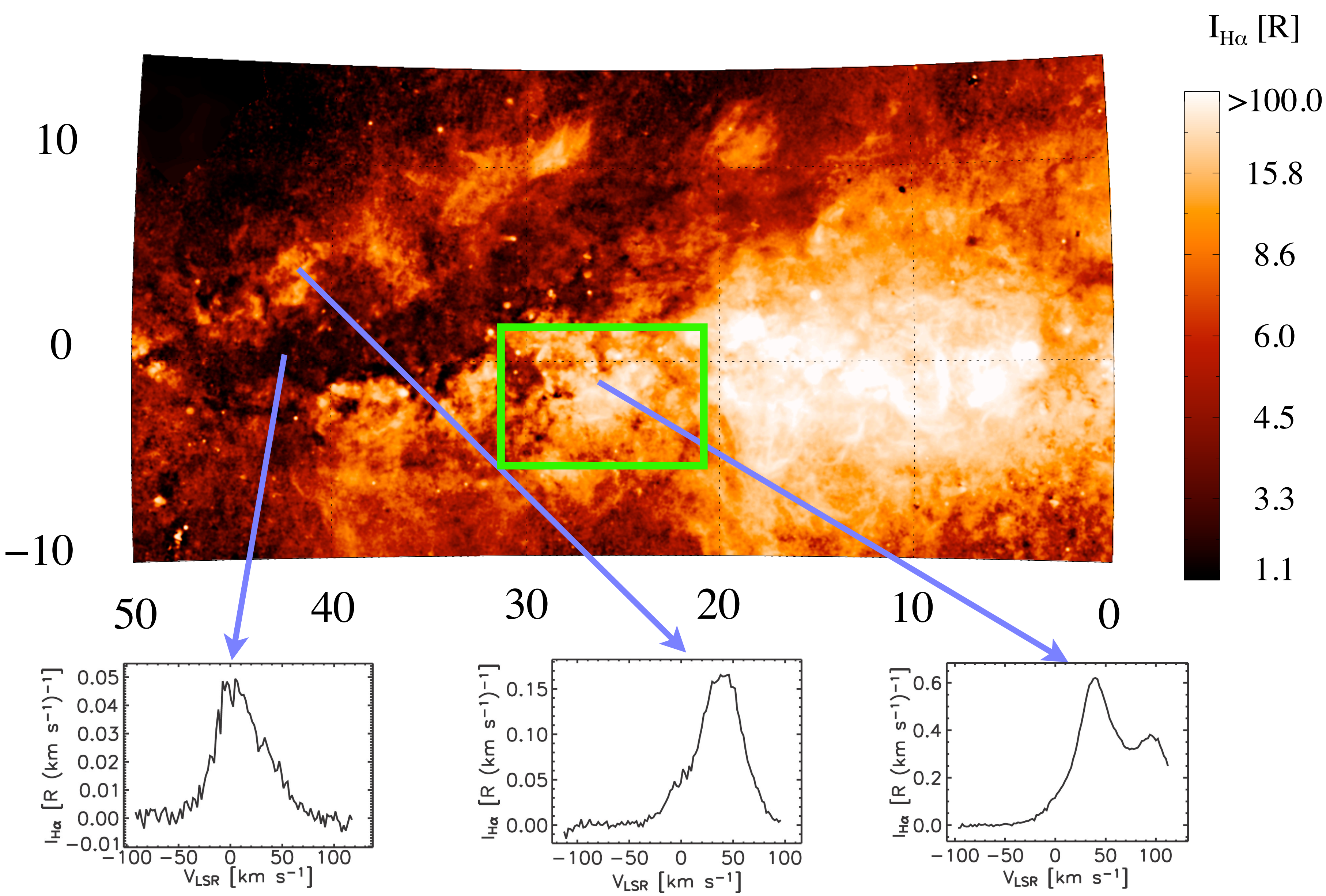


Keane et al. 2012

“Scutum Star Cloud”



Optical Window into Inner Galaxy



Hα Spectra

- WHAM: All-sky, velocity-resolved optical emission line survey of diffuse ionised gas
- *Independent* measure of electron content along line of sight to FRB
- Hα emission seen out to high radial velocities; inferred $D_\odot \sim 7$ kpc
- Line ratio Hβ/Hα quantifies attenuation by dust: $A_V \sim 3$ mag

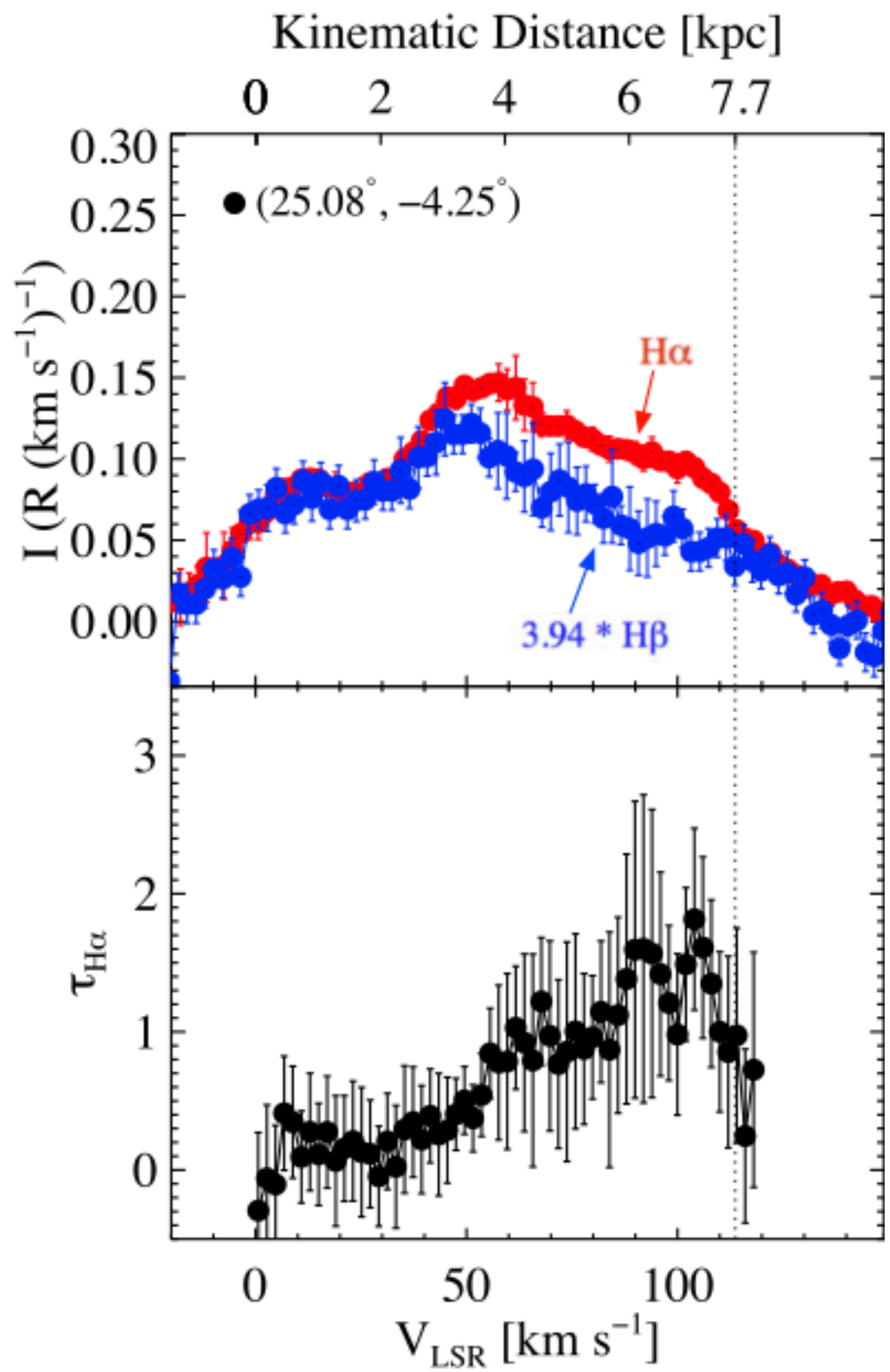
Emission Measure

- average spectrum over 1° circular beam
- 85% chance FRB010621 in WHAM beam toward (25.08°, -4.25°)
- v_{LSR} related to kinematic distance
- $I_{H\beta}/I_{H\alpha}$ implies $\tau_{H\alpha} \approx 2$
- EM related simply to $I_{H\alpha}$

$$\mathrm{EM} \equiv \int_0^\infty n_e(l)^2 \mathrm{d}l = 2.75 T_4^{0.9} I_{H\alpha}$$

- extinction-corrected EM:

276 ± 24 cm^{-6} pc [foreground dust screen; e^{τ}]
86 ± 7 cm^{-6} pc [dust well mixed; $\tau/(1-e^{\tau})$]



Model for EM & DM

- assume e^- reside in clouds with mean density n_0
- clouds occupy a fraction of line-of-sight distance f $(0 < f < 1)$
- heliocentric distance to FRB: D_p
- heliocentric distance over which e^- contribute to $I_{\mathrm{H}\alpha}$: $D_{\mathrm{H}\alpha}$

$$\mathrm{DM} = n_0 f D_\mathrm{p} \qquad \mathrm{EM} = n_0^2 f D_{\mathrm{H}\alpha}$$

$$D_\mathrm{p} = \frac{\mathrm{DM}}{\sqrt{\mathrm{EM}}} \frac{\sqrt{D_{\mathrm{H}\alpha}}}{\sqrt{f}} = 13.6 \frac{\sqrt{D_{\mathrm{H}\alpha}^{10}}}{\sqrt{f_{0.1}}} \mathrm{kpc}$$

$\mathrm{DM} = 746\ \mathrm{cm}^{-3}\ \mathrm{pc}$

$\mathrm{EM} = 276\ \mathrm{cm}^{-6}\ \mathrm{pc}$

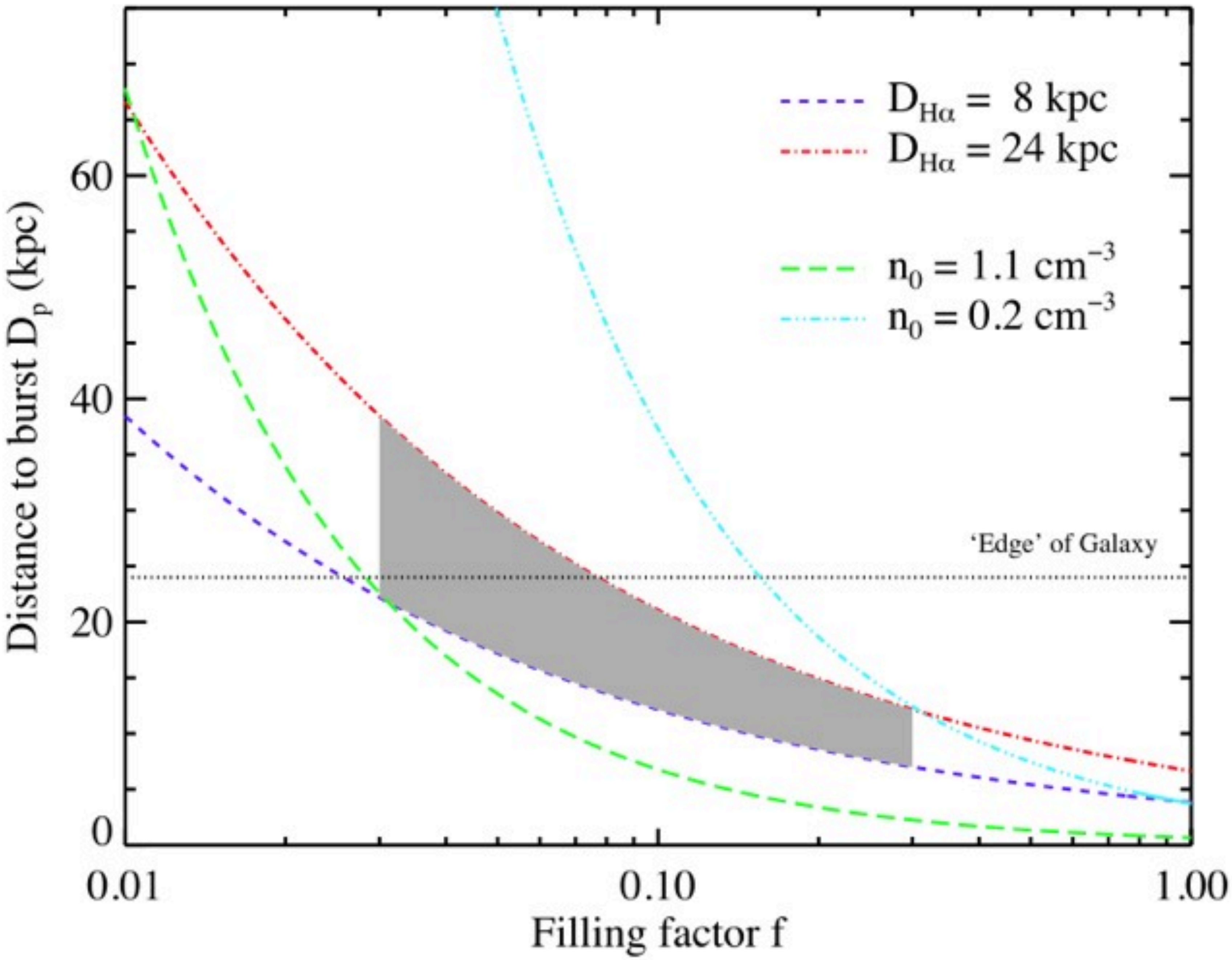
$D_{\mathrm{H}\alpha}^{10} = D_{\mathrm{H}\alpha} / 10\ \mathrm{kpc}$

$f_{0.1} = f / 0.1$

- $8\ \mathrm{kpc} < D_{\mathrm{H}\alpha} < 24\ \mathrm{kpc}$ (from Hα spectra, MW geometry)
- $0.03 < f < 0.3$ (from DM/EM toward pulsars of known distance)

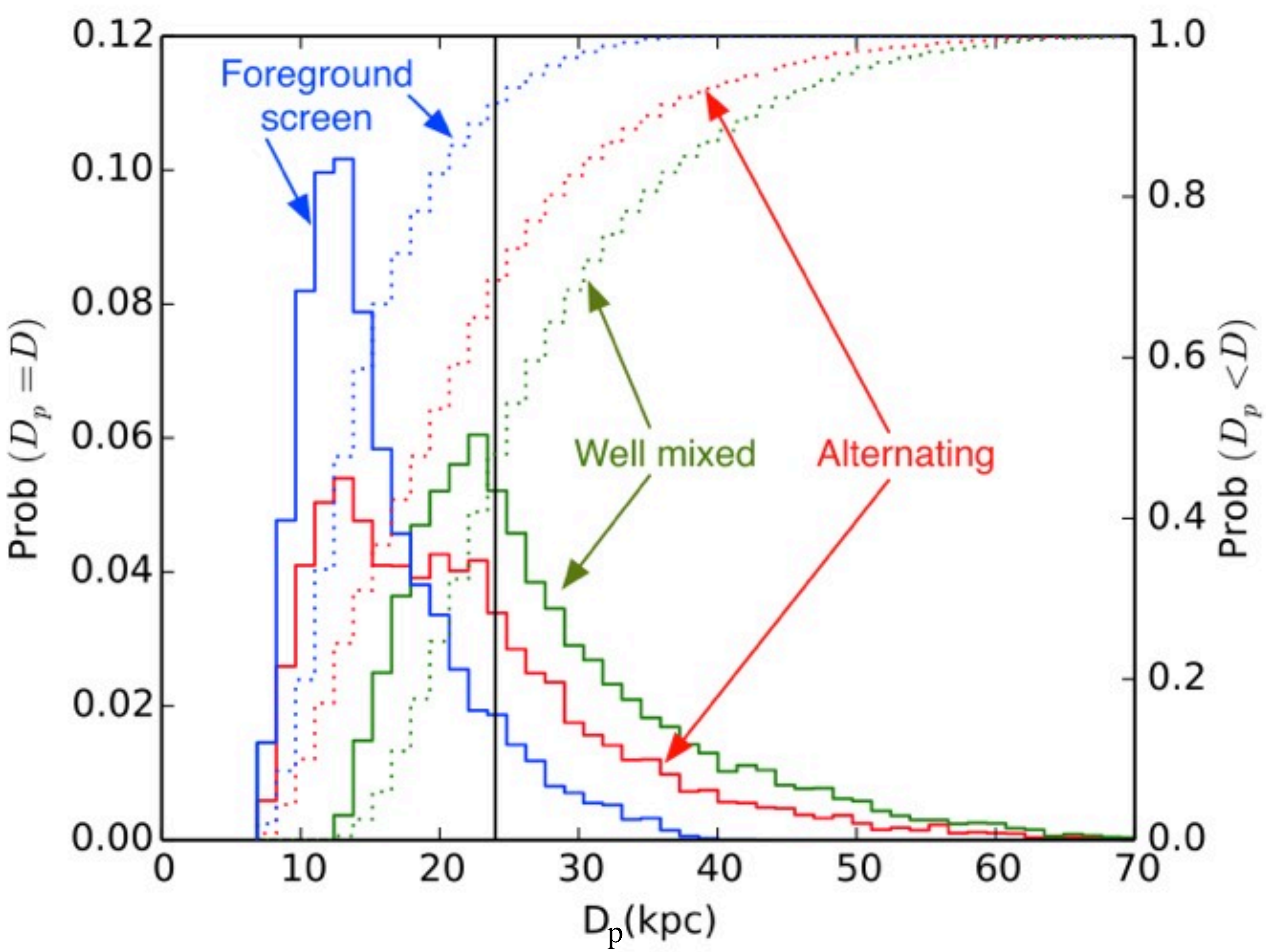
Reynolds 1991; Berkhuijsen et al. 2006; Gaensler et al. 2008

Estimating D_p



- assume uniform prior distribution for f and $D_{H\alpha}$
- select value for EM (foreground screen/well-mixed)
- create Monte Carlo realizations using priors
- calculate posterior probability distribution for D_p

Estimating D_p



- probability D_p < 24 kpc
  foreground: 90%
  'alternating': 68%
  well-mixed: 45%

- if foreground screen, most likely distance: $D_p = 14 \pm 6$ kpc

- predicted scatter broadening at 20 kpc is ≈ 2 ms (< 3 ms ✔)
  Cordes & Rickett 1998

- (for all models, D_p < 50 kpc with probability > 95%)

Caveats

- dust correction
  - $\tau_{H\alpha}$ increases sharply at 3-4 kpc
  - $\rightarrow$ foreground model more likely
- assumptions for model of ISM
  - f, n_0 constant with l (z-height)
  - no HII regions along line of sight

$\rightarrow$ difficult to estimate precise distance D_p

http://hasif-sharif.blogspot.co.uk

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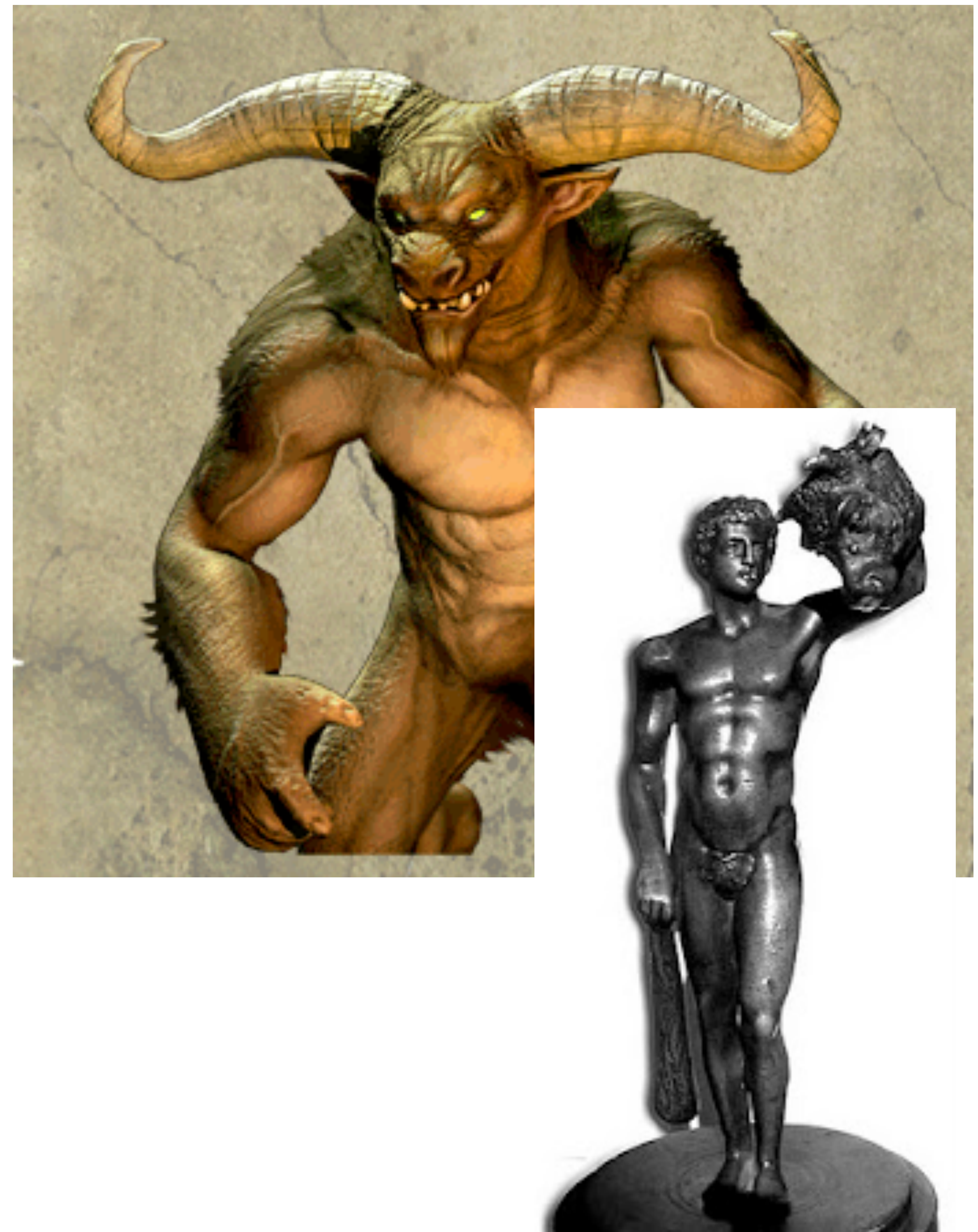
$\rightarrow$ difficult to estimate precise distance D_p

$\rightarrow$ easier to place upper limit on D_p



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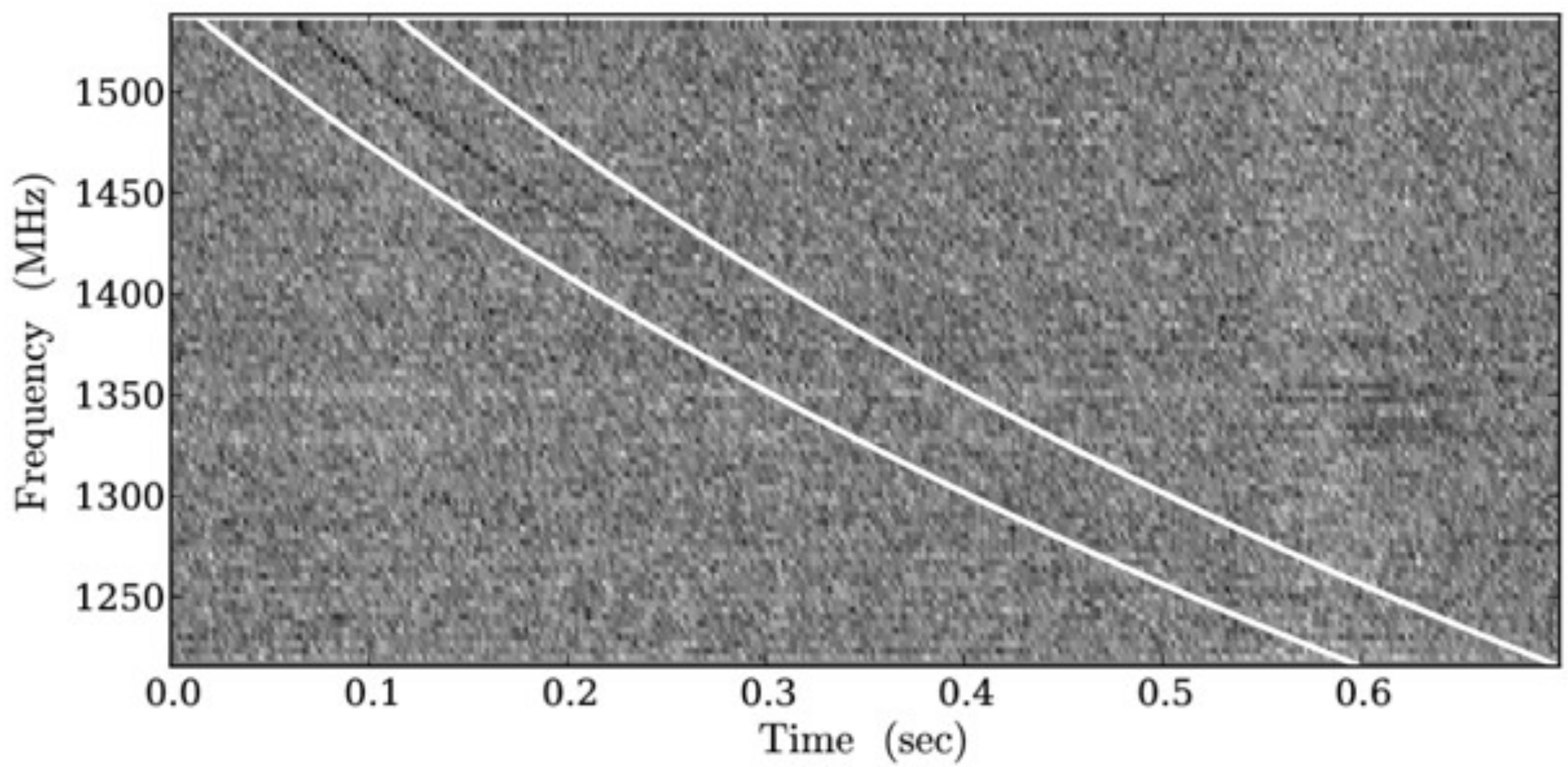
Arecibo FRB 121102

- discovered in one 3.5′ beam at Arecibo
- dispersion measure: 557 ± 3 cm^{-3} pc
- DM from NE2001 model: 188 cm^{-3} pc
- in Galactic plane toward anti-centre: (174.95°, -0.22°)
  → no velocity-distance relation
  → accurate extinction-corrected EM challenging



Spitler et al. 2014 (arXiv:1404.2934)

Summary

- at least one member of the FRB 'class' of objects is Galactic
  - 90% probability that $D_\odot < 24$ kpc
  - read more at arXiv:1401.0268; MNRAS
- high Galactic latitude members of FRB class are likely to be extragalactic
  - hard to say if low-*b* Arecibo FRB is Galactic
- serious consideration should be given to Galactic origin ideas
  - pulsar with unusual pulse-amplitude distribution?
  - annihilating mini (cometary-mass) black hole?
  - coronal emission from flare stars?
  - ?

e.g., Keane et al. 2012;
Loeb et al. 2014;
Luan & Goldreich 2014; etc.

- need more detections (2 out of ~~7~~ 14 in Galactic plane)
- stay tuned to afternoon post-coffee talks today!