LOFT-e:

Localisation of Fast Transients with e-MERLIN

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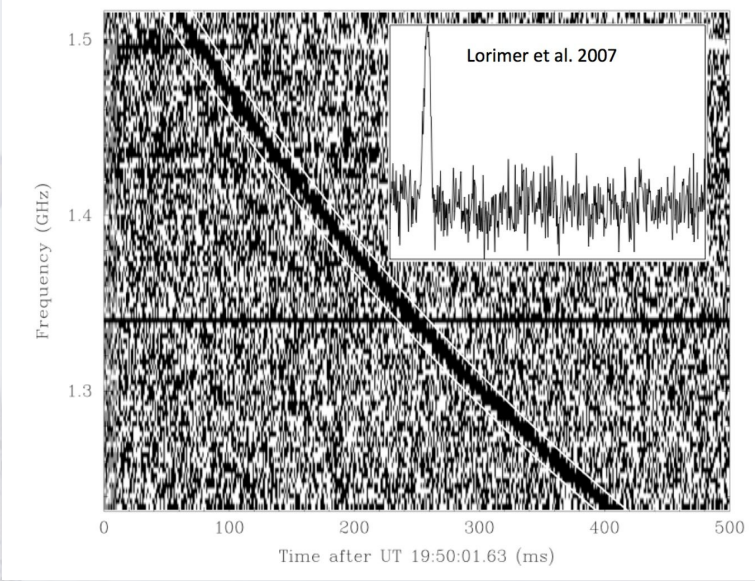
[2]MPIFR, Bonn

A commensal Fast Radio Burst detection and localisation system for e-MERLIN.

Fast Radio Bursts (FRBs)

Short, bright bursts of radio emission...

- First discovered in 2007[+] (Lorimer et al.)
- 17 published as of 2016[++] (Swin FRBcat)
- Intrinsic widths 0.5 - 15 ms[++]
- Large measured dispersion measures[++]
- Intrinsically brighter than pulsars



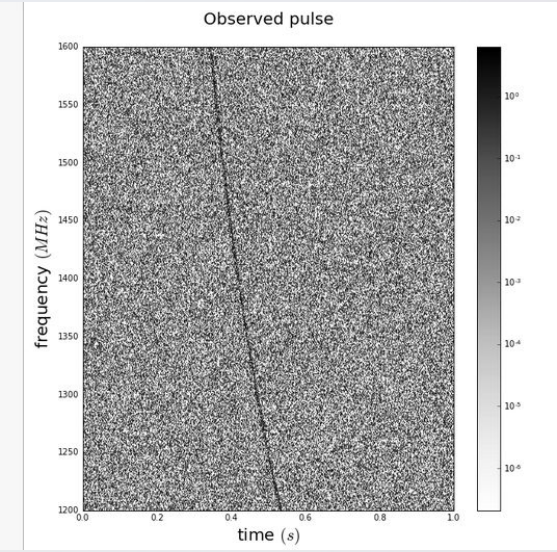
[+] Lorimer et al., 2007, arXiv: 0709.4301

[++] FRBcat Swinbourne FRB catalogue: http://www.astronomy.swin.edu.au/pulsar/frbcat/

Dispersion Measure (DM)

Free electrons disperse radio waves...

- Low frequencies arrive later



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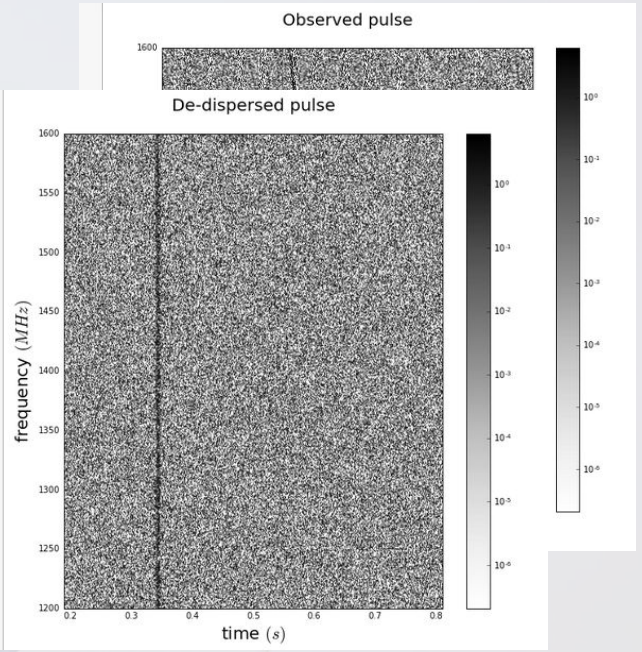

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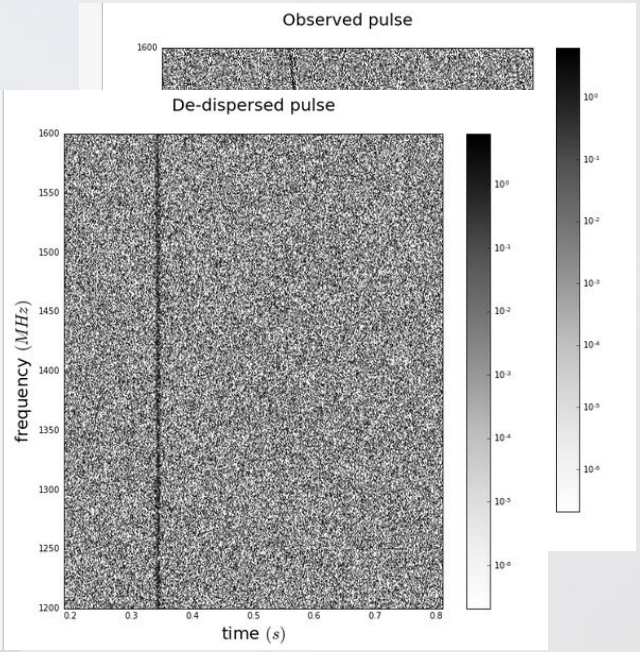
- DM characterises time sweep



$$DM = \int_0^d n_e \, dl$$

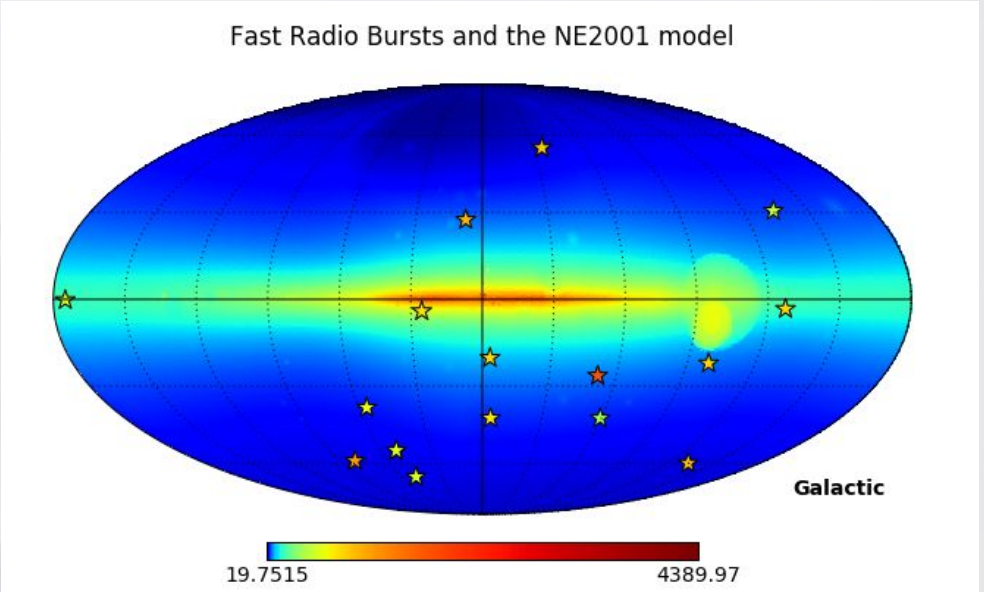
DM: the integrated electron density along the line of sight.[+]

[+] Lorimer & Kramer, Handbook of Pulsar Astronomy

FRB DMs

Pulsars have mapped the Milky Way's n_e[+]

- Combined DMs & independent distances
- DM may be used as distance estimator



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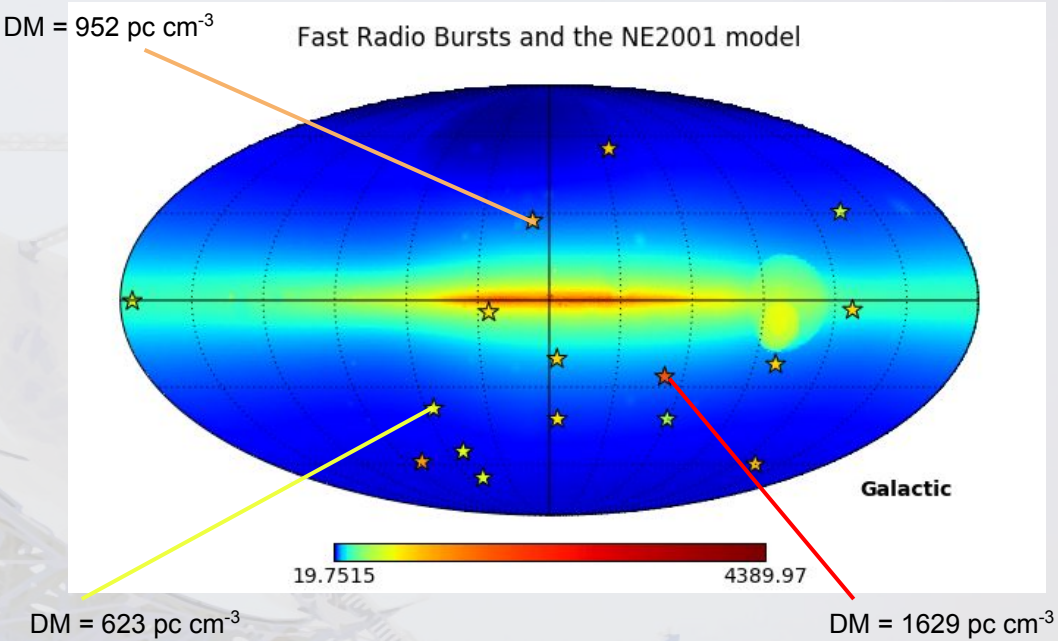
$$DM_{obs} = DM_{FRB} + DM_{MW}$$



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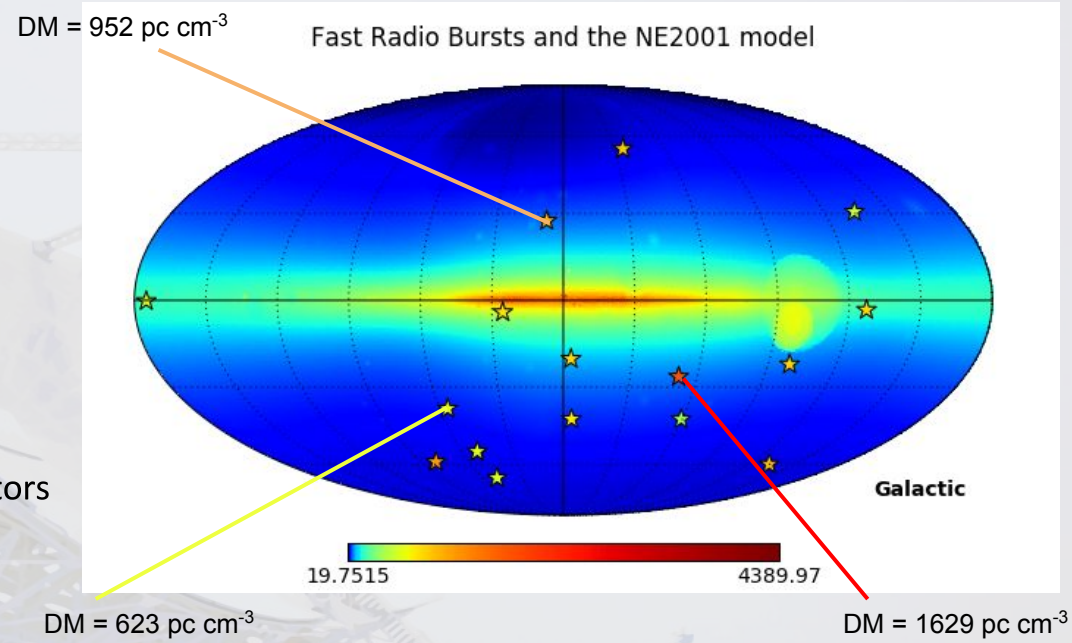

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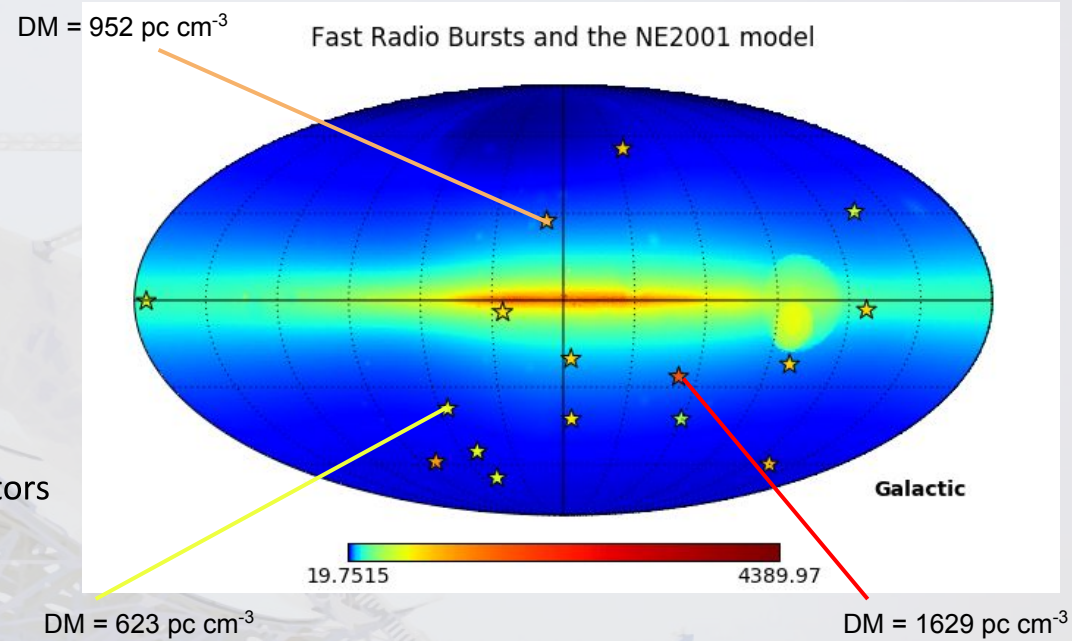

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- Some FRBs may even be at cosmological distances

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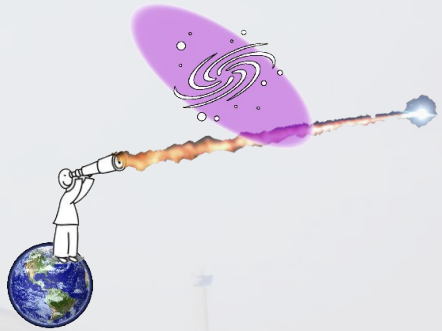
Bursting with excitement!

FRBs could be useful probes…

- Of cosmology [+]
- Of the IGM [+]
- Of galactic halos [++]



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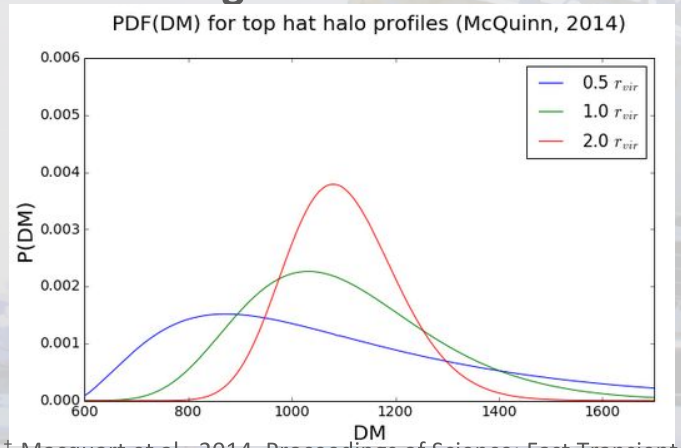

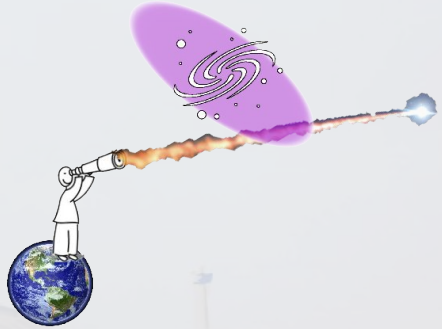

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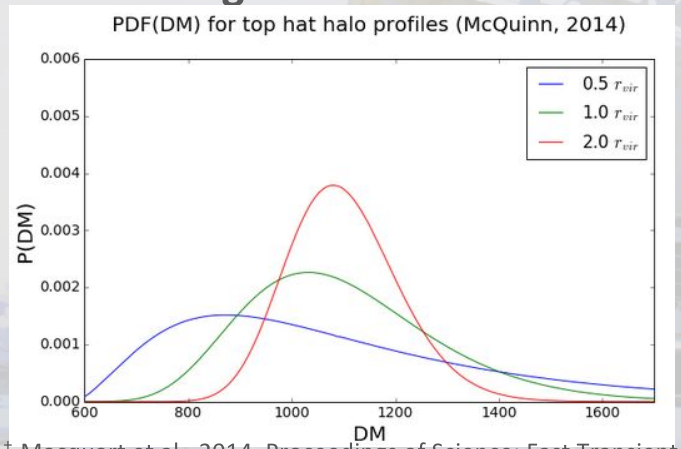

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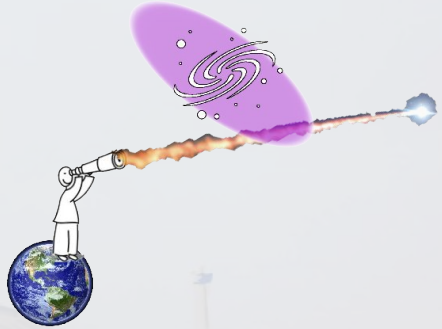

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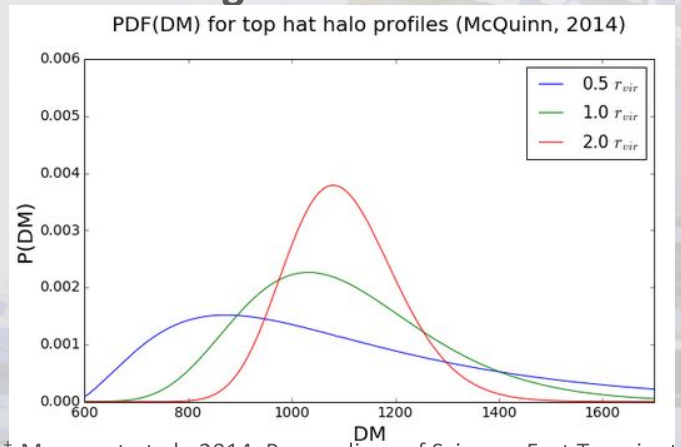
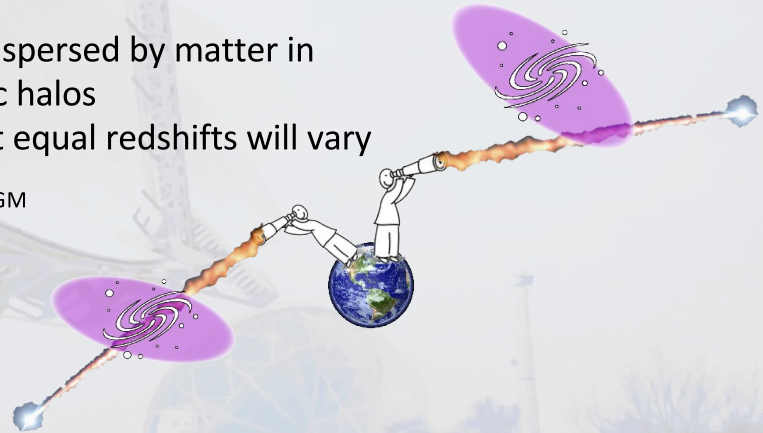


- FRBs dispersed by matter in galactic halos
- FRBs at equal redshifts will vary in DM_{IGM}



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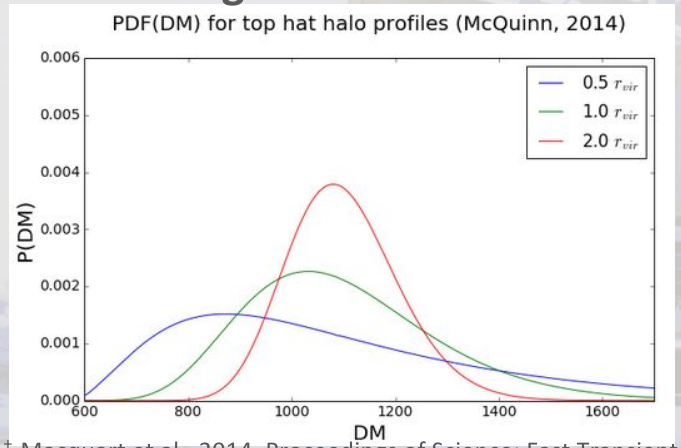

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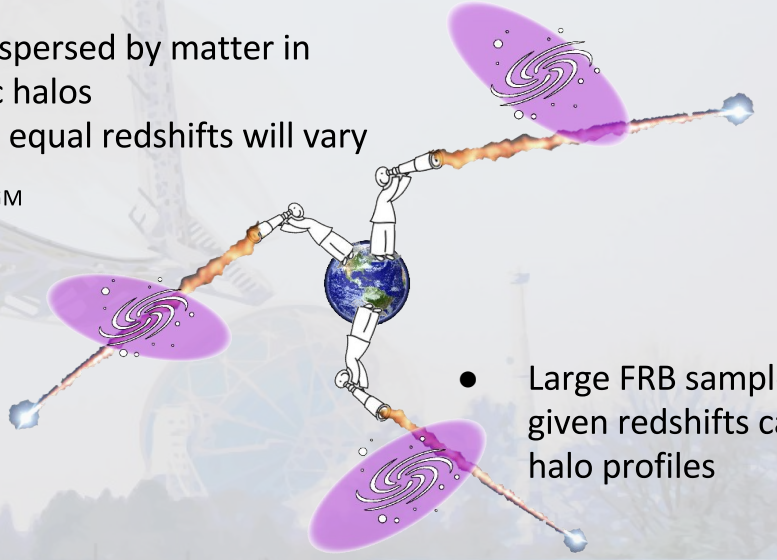

- Large FRB samples at given redshifts can probe halo profiles

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2016 has been eventful...

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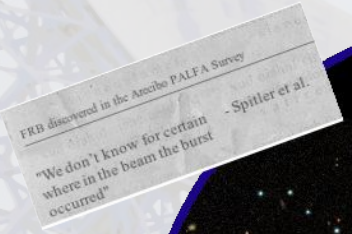
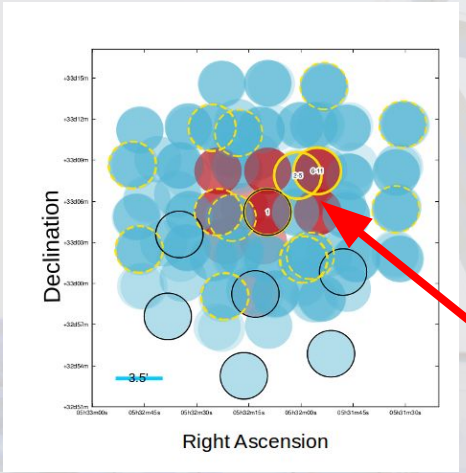
A Repeating Fast Radio Burst[+]

- FRB 121102 repeats unpredictably
- Localisation: Aricebo beam FWHM ~3.5'
- Beam overlap reduced uncertainty radius: ~3'





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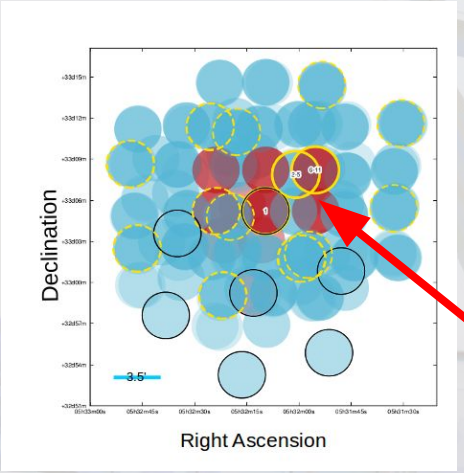

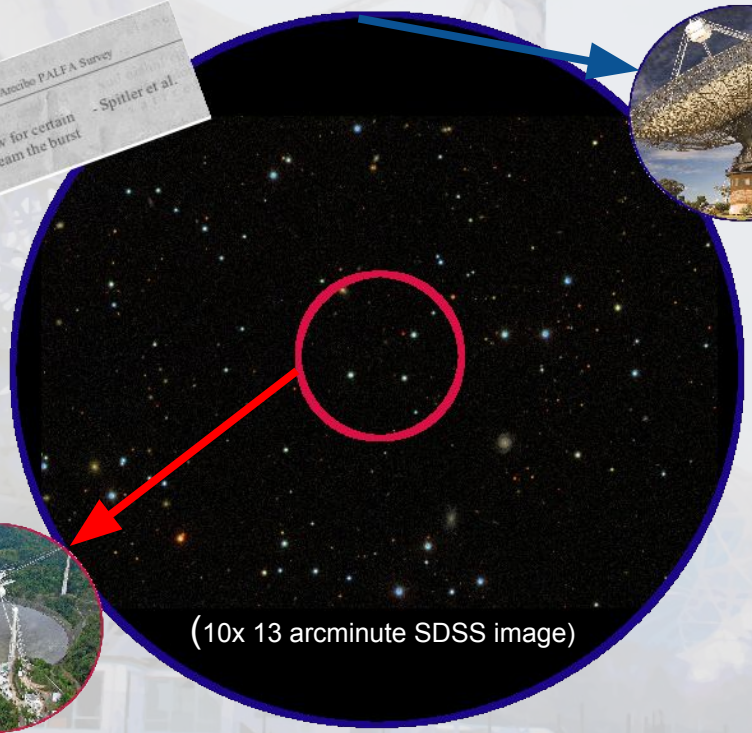

The Host Galaxy of a Fast Radio Burst[++]

- FRB 150418 detected in real-time
- Localisation: Parkes beam FWHM ~14.1'
- Possible fading afterglow detected 2 hrs later

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- Determine FRB nature(s): need accurate localisation
- Do exciting science: need distances ⇒ need localisation
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The equipment:

- 6x dishes 25-32m (+ Lovell)
- L-band (1.4 GHz) FOV: 30' (25m dishes)
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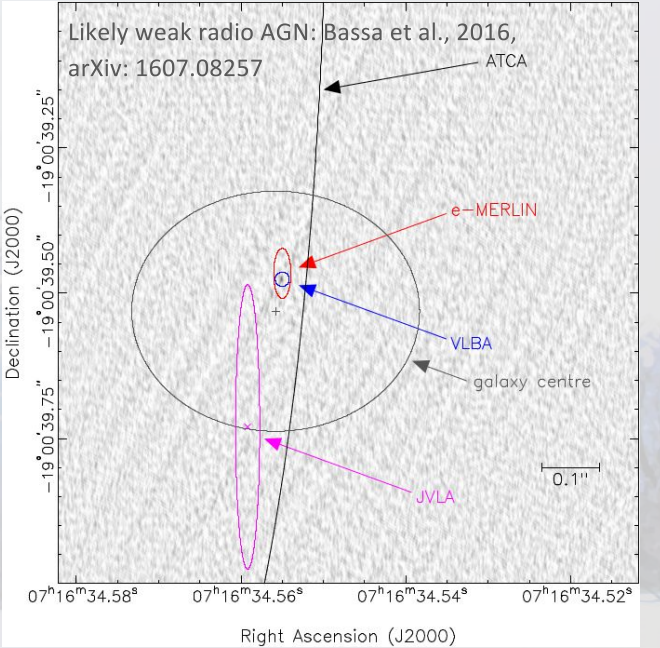

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Our goals:

- Real-time commensal observing system for e-MERLIN
- Anti-coincidence to probe lower S/N candidates
- Incoherent FRB detections trigger data dump
- Coherent beamforming for burst localisation

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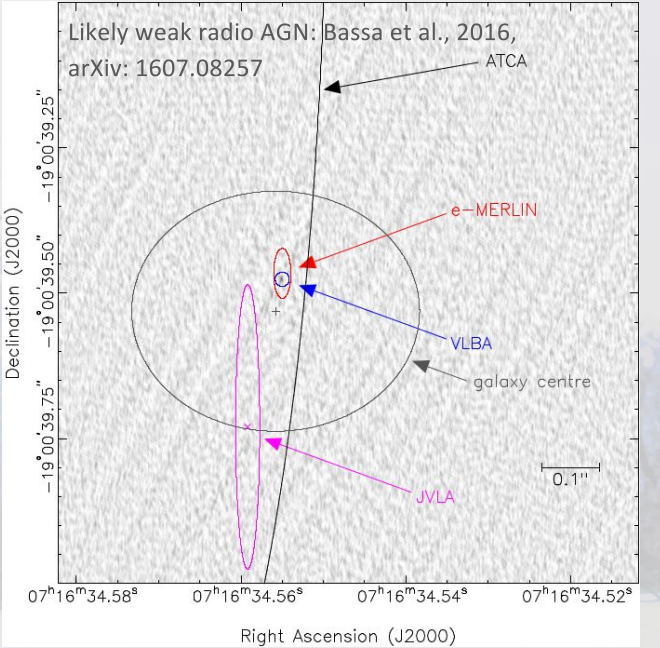

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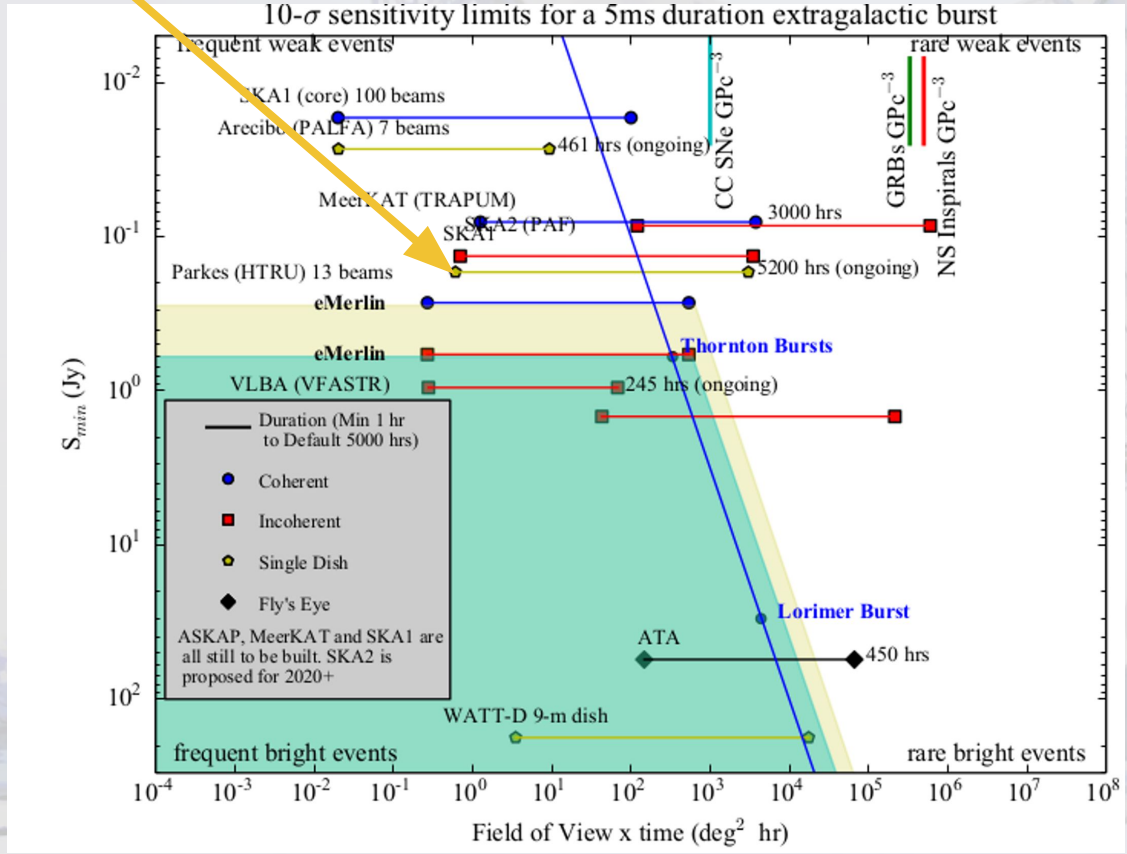

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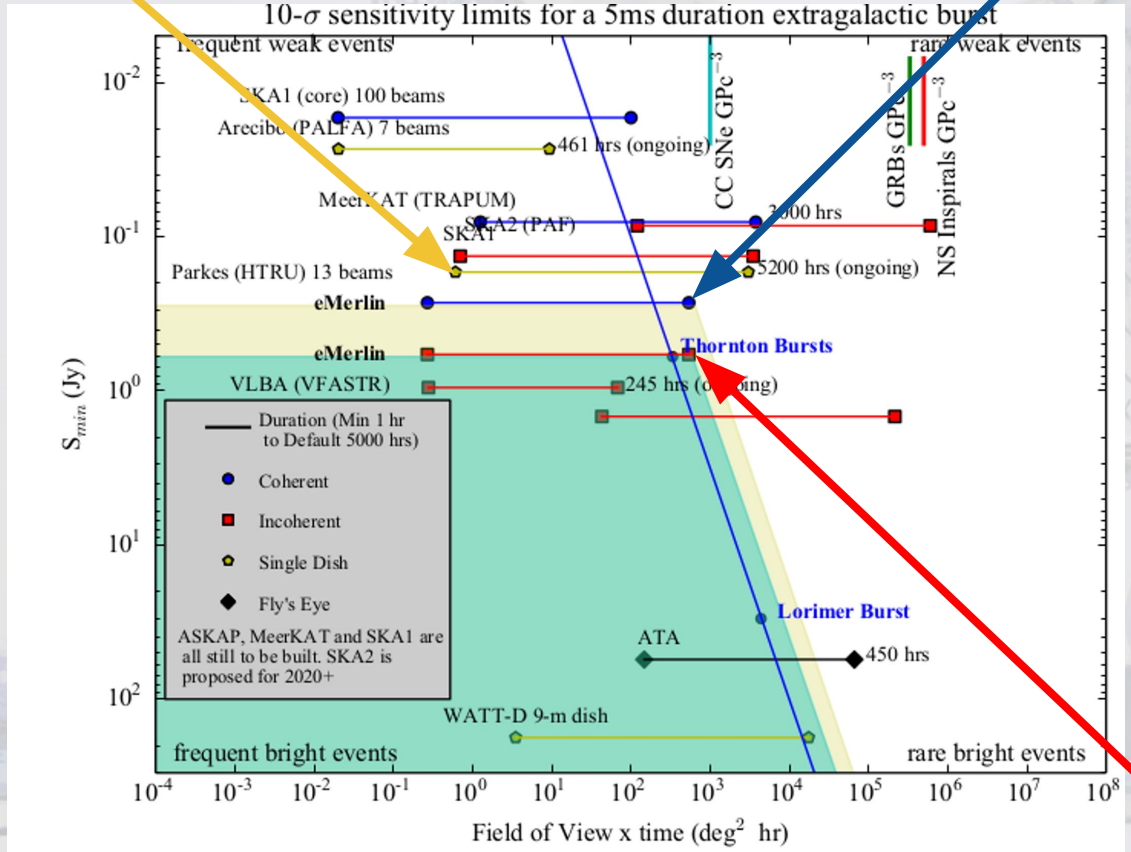

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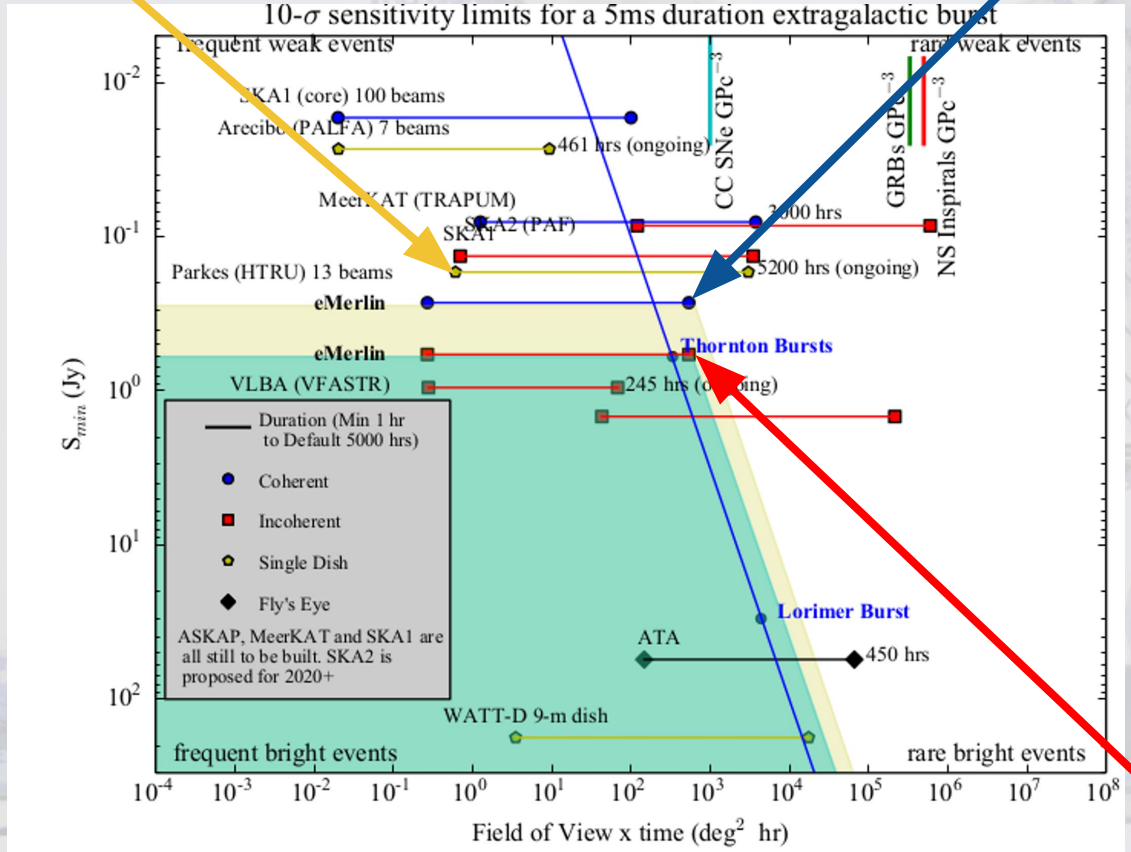

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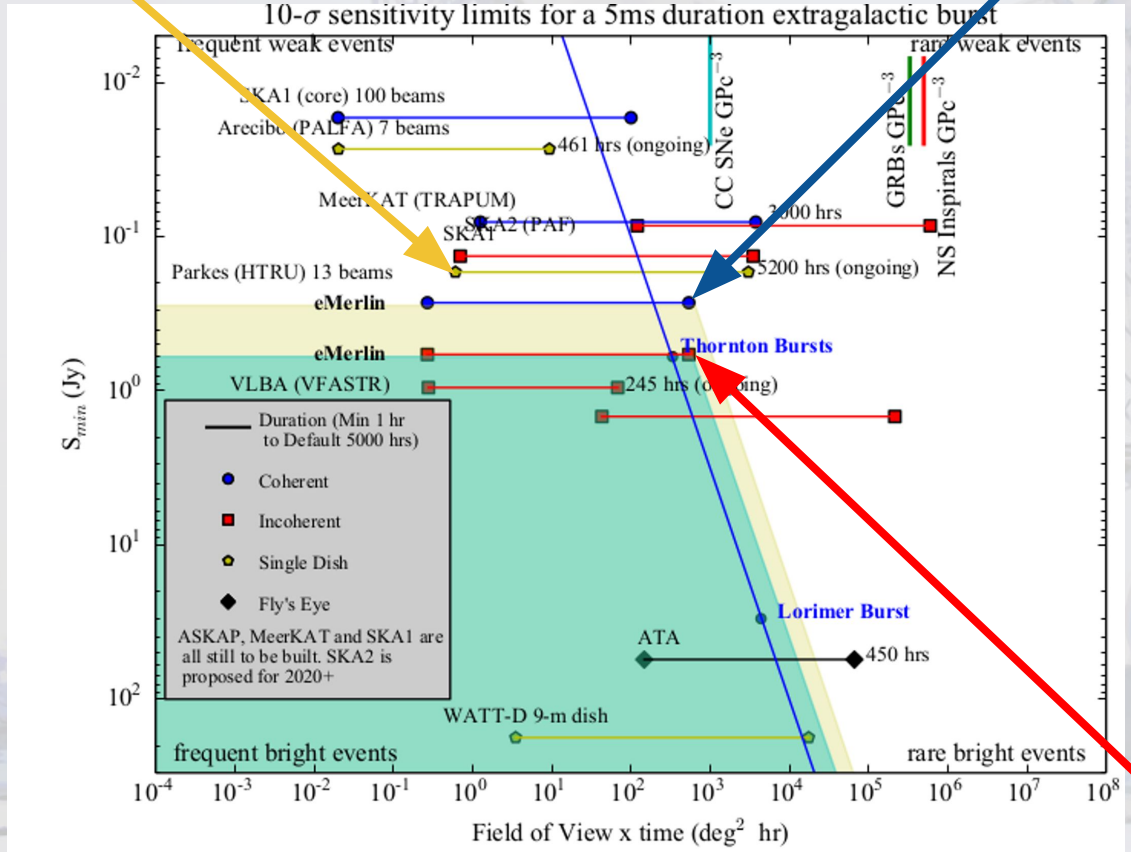

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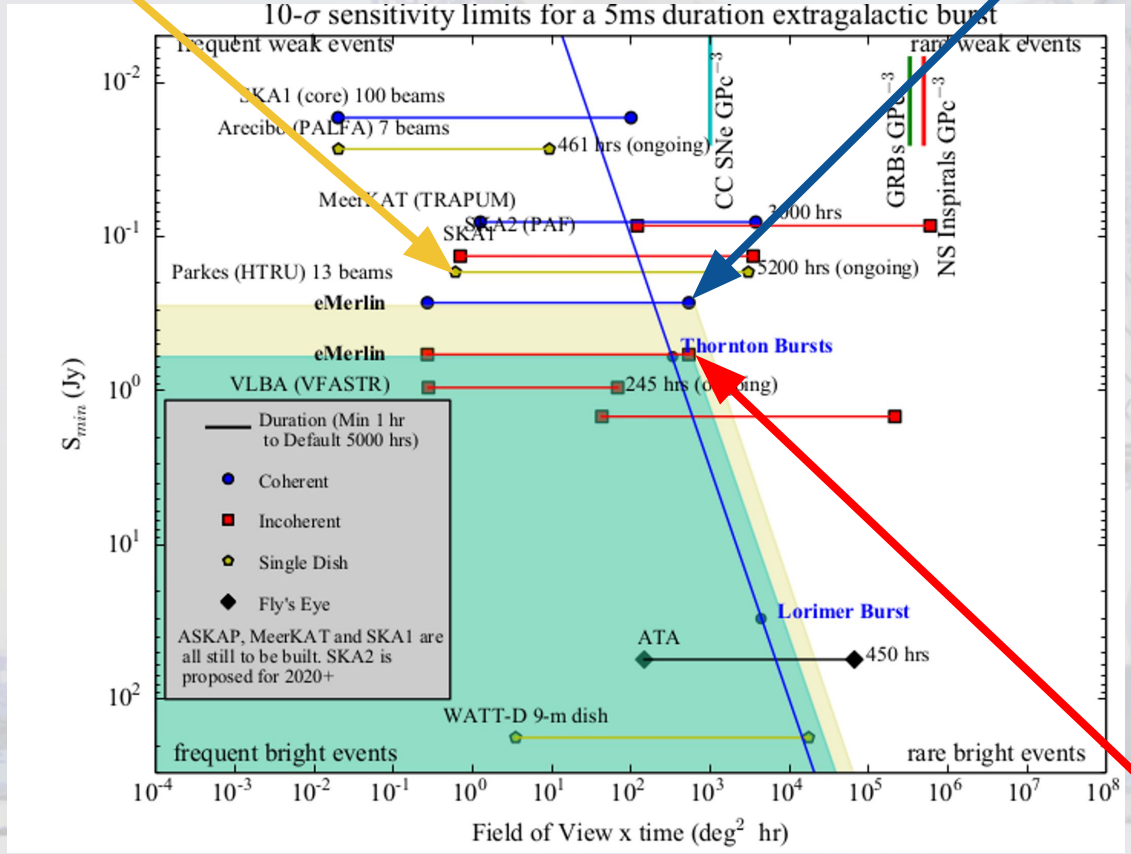

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We expect:

- ~ 1 FRB per 400 hrs

4(±4) FRBs per year (L-band) (w Lovell)

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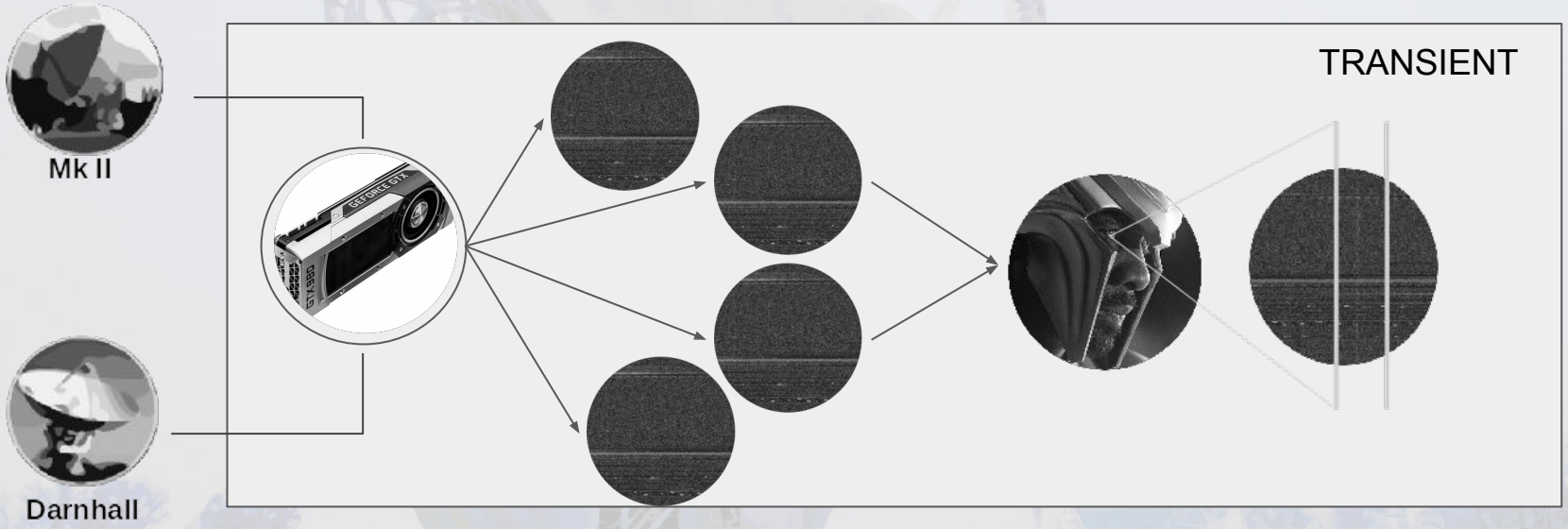
Our method

3 GPU machines:

- Transient
- Compute-0, 1



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Run commensally to regular observations

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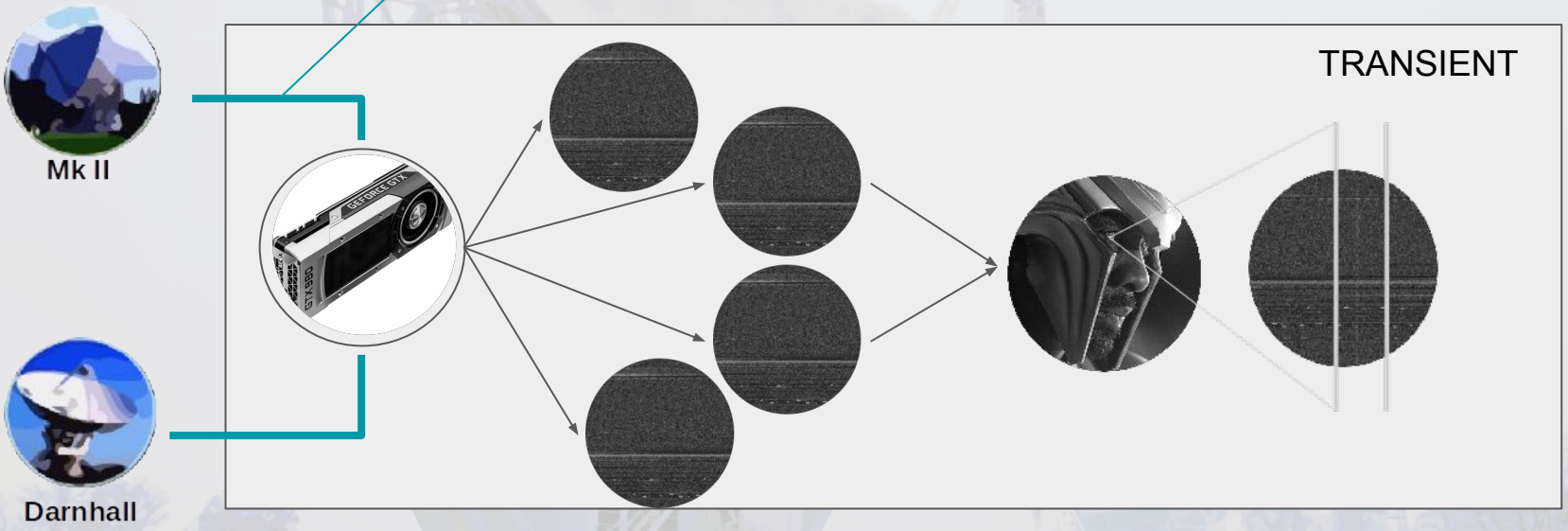

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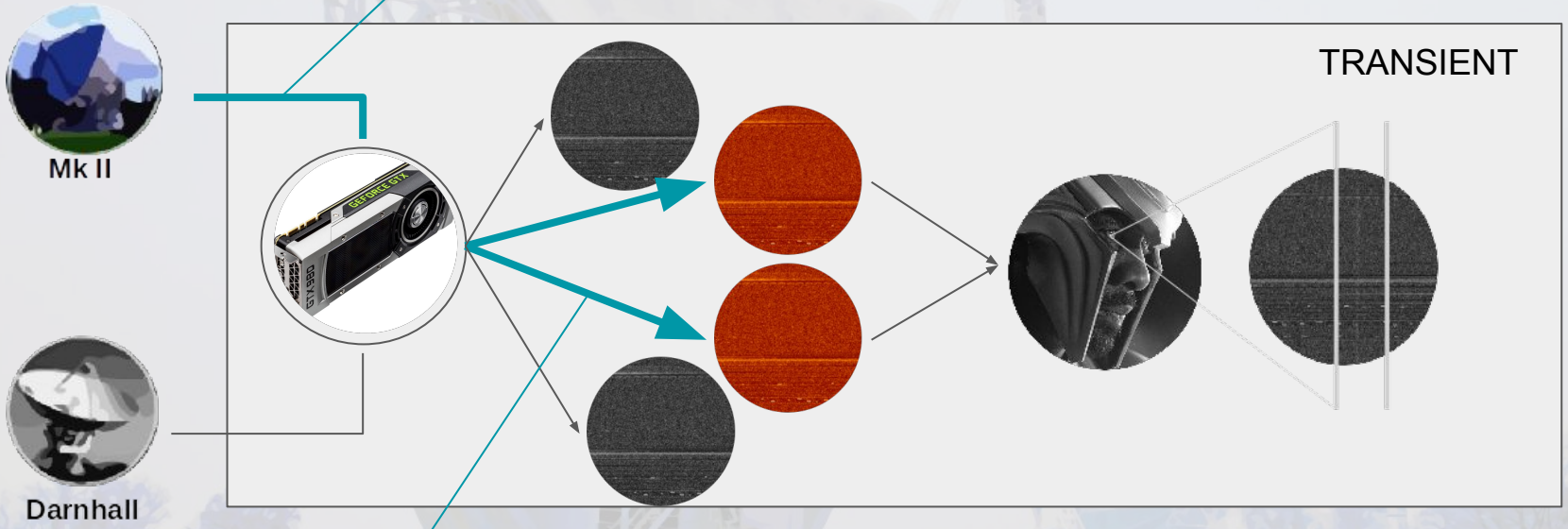

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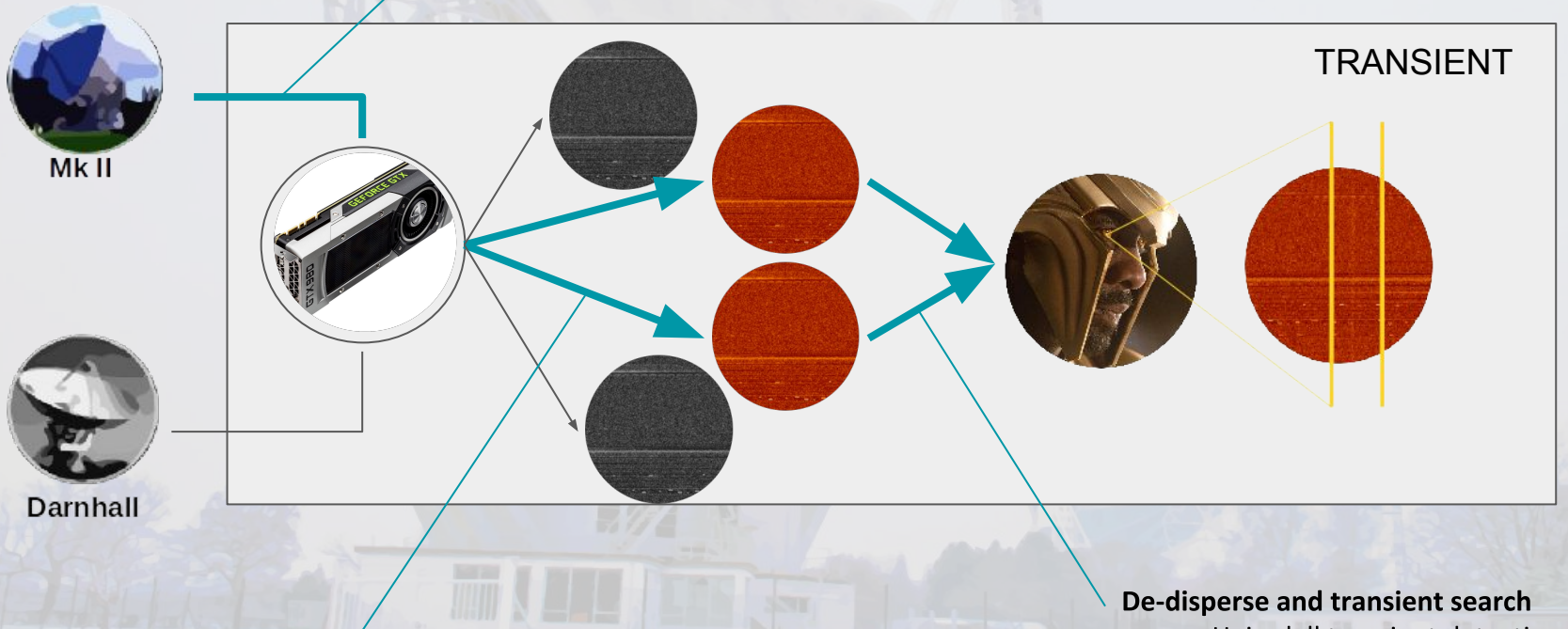

Process data in real time

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De-disperse and transient search

- Heimdall transient detection software
- Trial de-dispersions: 0-5000 pc cm^{-3}
- Identify candidates via matched filtering

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Data stored in ring buffer

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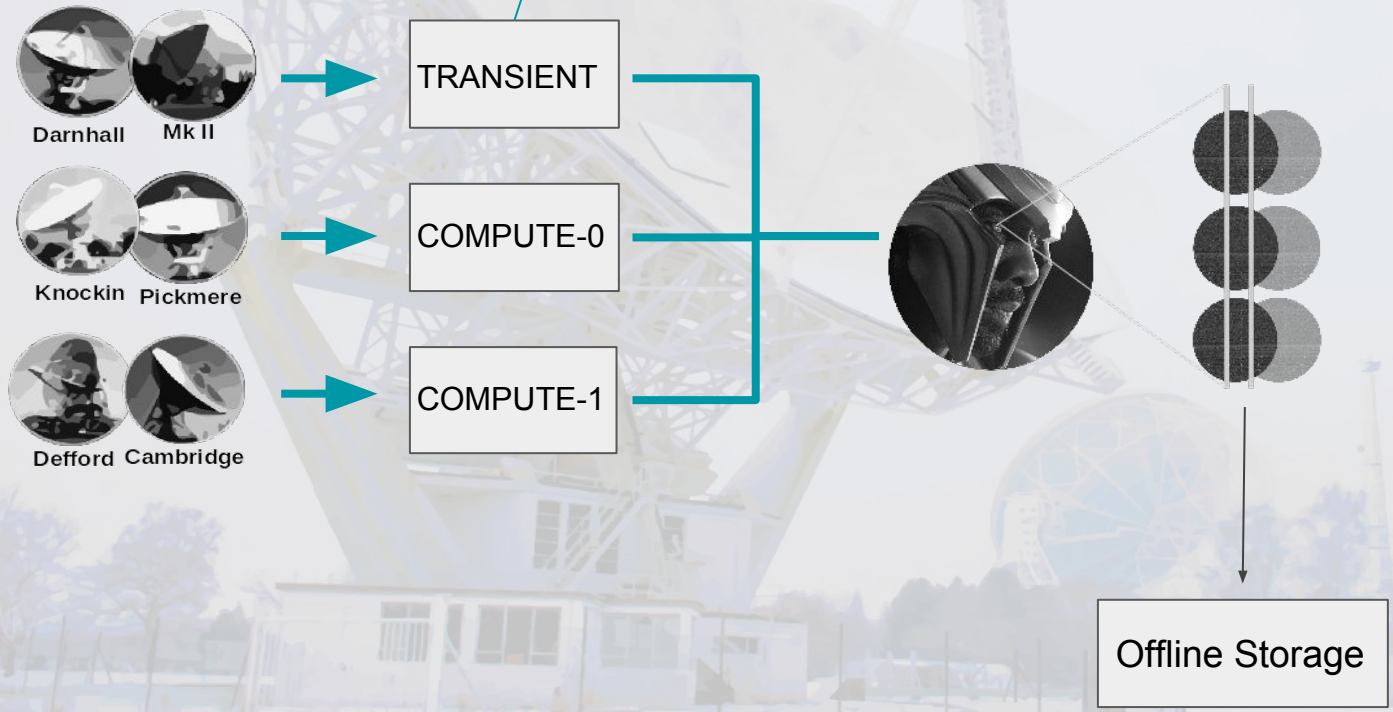
- De-disperse and transient search



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Mitigate RFI in real time

- Compare candidates in individual telescopes
- Anti-coincidence
- Discard local signals

TRANSIENT

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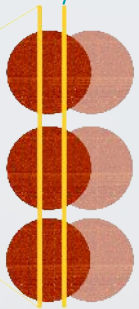
COMPUTE-1



Offline Storage

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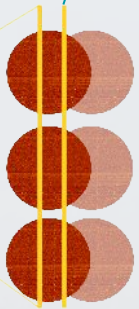

Trigger data dump

- Store good candidates offline
- Beamform
- Localise!

Offline Storage

Current status

- Receiving (vast) quantities of data
- Testing channelising software
- Testing anti-coincidencing
- Testing beamforming (insert image here)

Conclusion

Fast Radio Bursts (FRBs)

- Millisecond, extragalactic radio pulses
- Currently 17 in literature, all unlocalised
- Localised (i.e. redshift!) populations could probe galaxies, IGM, and cosmology

LOFT-e

- Commensal FRB detection and localisation system for e-MERLIN
- Expects 4(±4) localised FRBs per year (L-band)
  - We can also search other bands...
- Coming soon!