Triggered VLBI with CHIME/FRB

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NEROC Symposium Series
20191101
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Fast Radio Bursts

Brief (~1 ms)
Extragalactic
Non repeating

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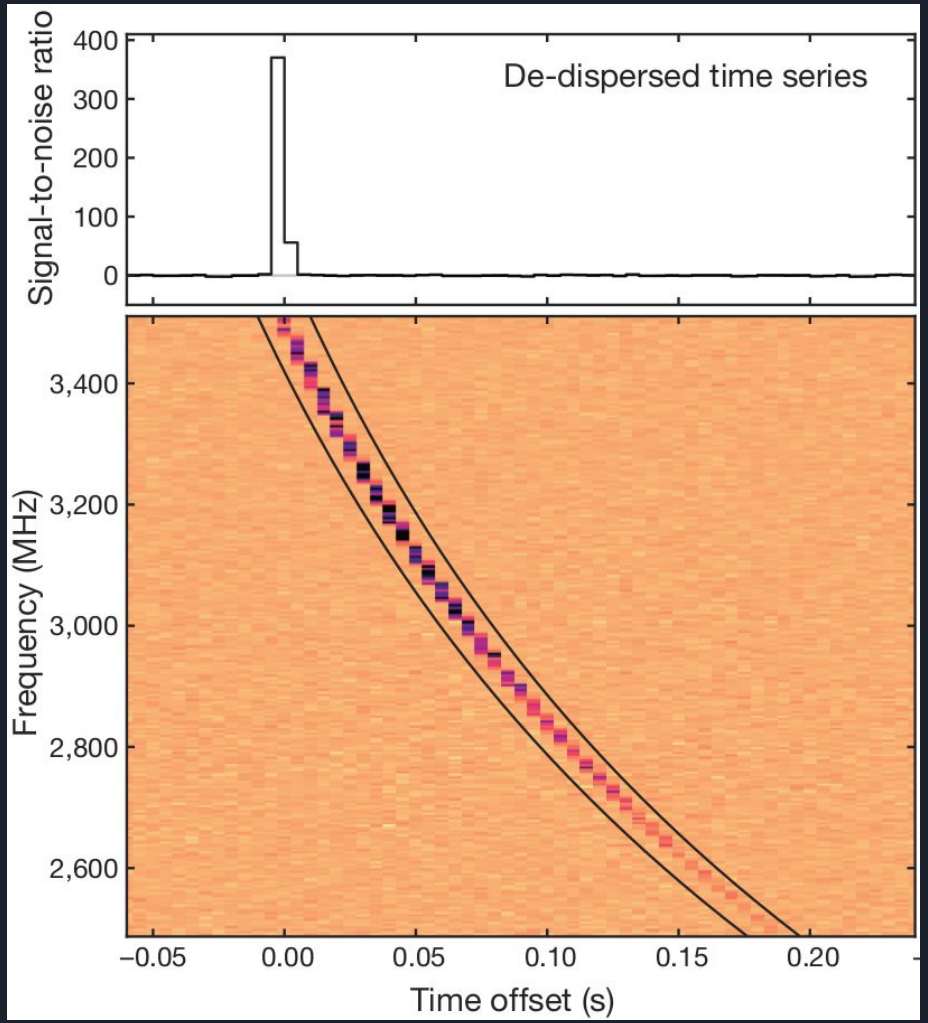
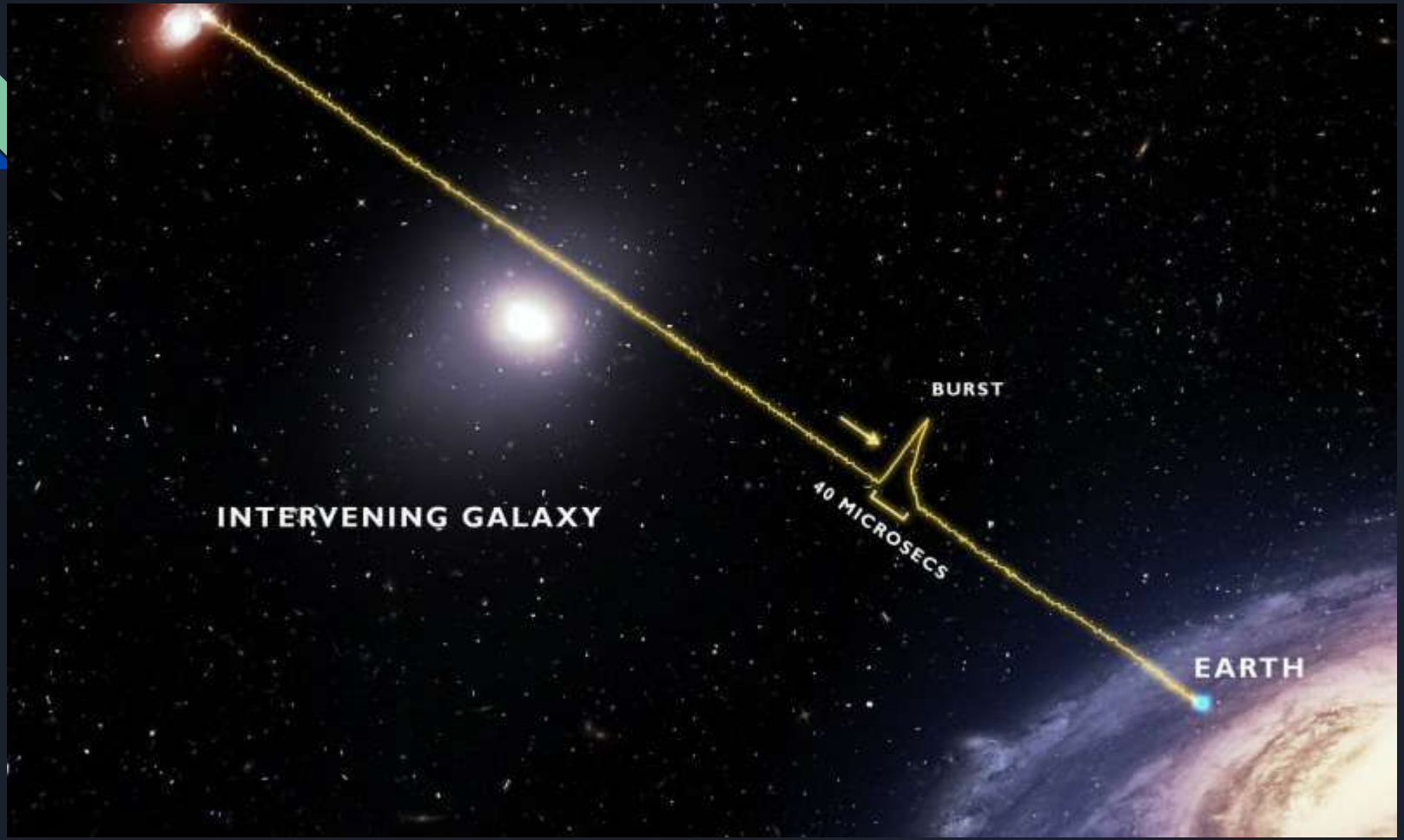
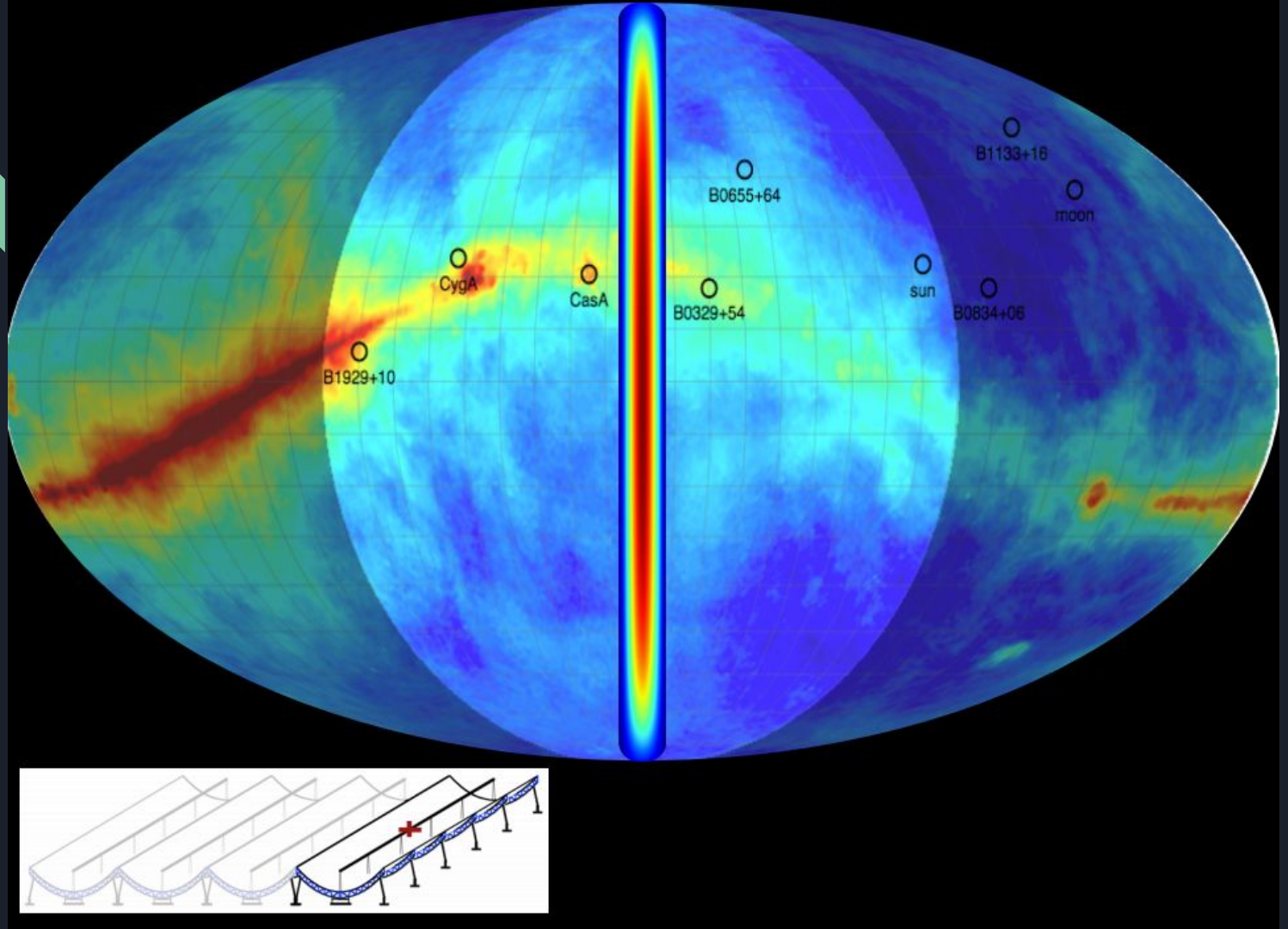
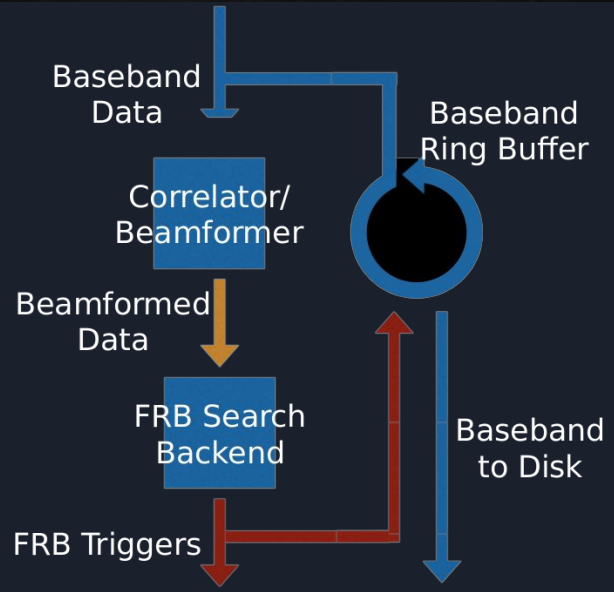


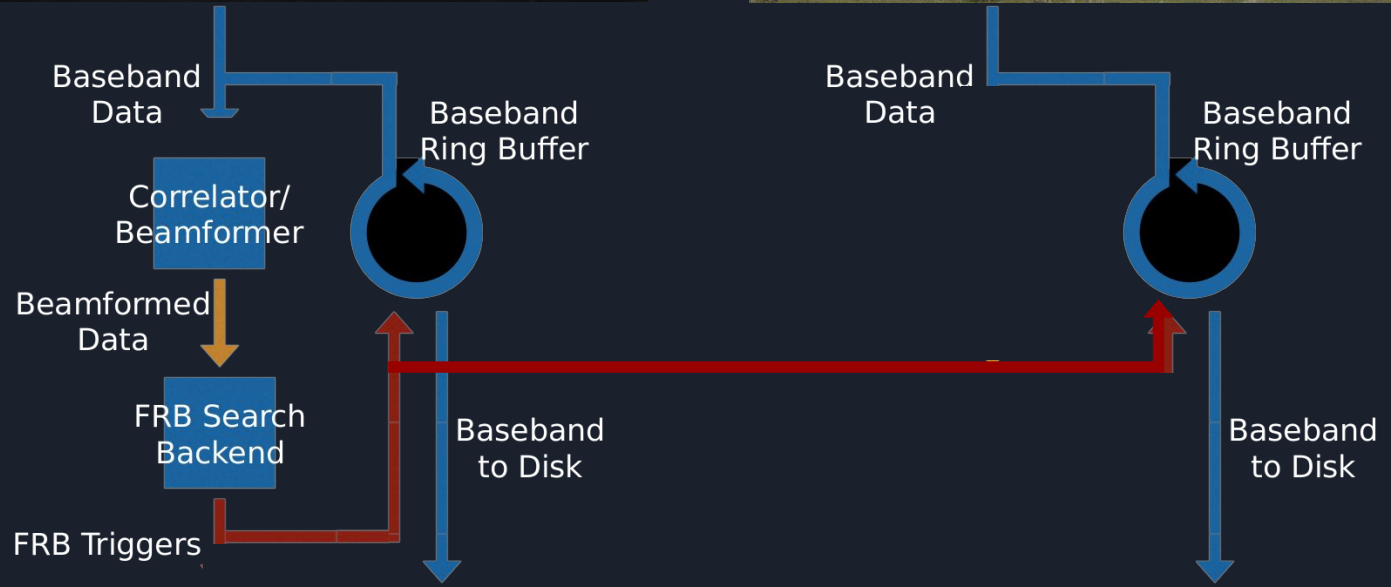

BURST
INTERVENING GALAXY
40 MICROSECS
EARTH


B1133+16
B0655+64
moon
CygA
CasA
sun
B0329+54
B0834+06
B1929+10

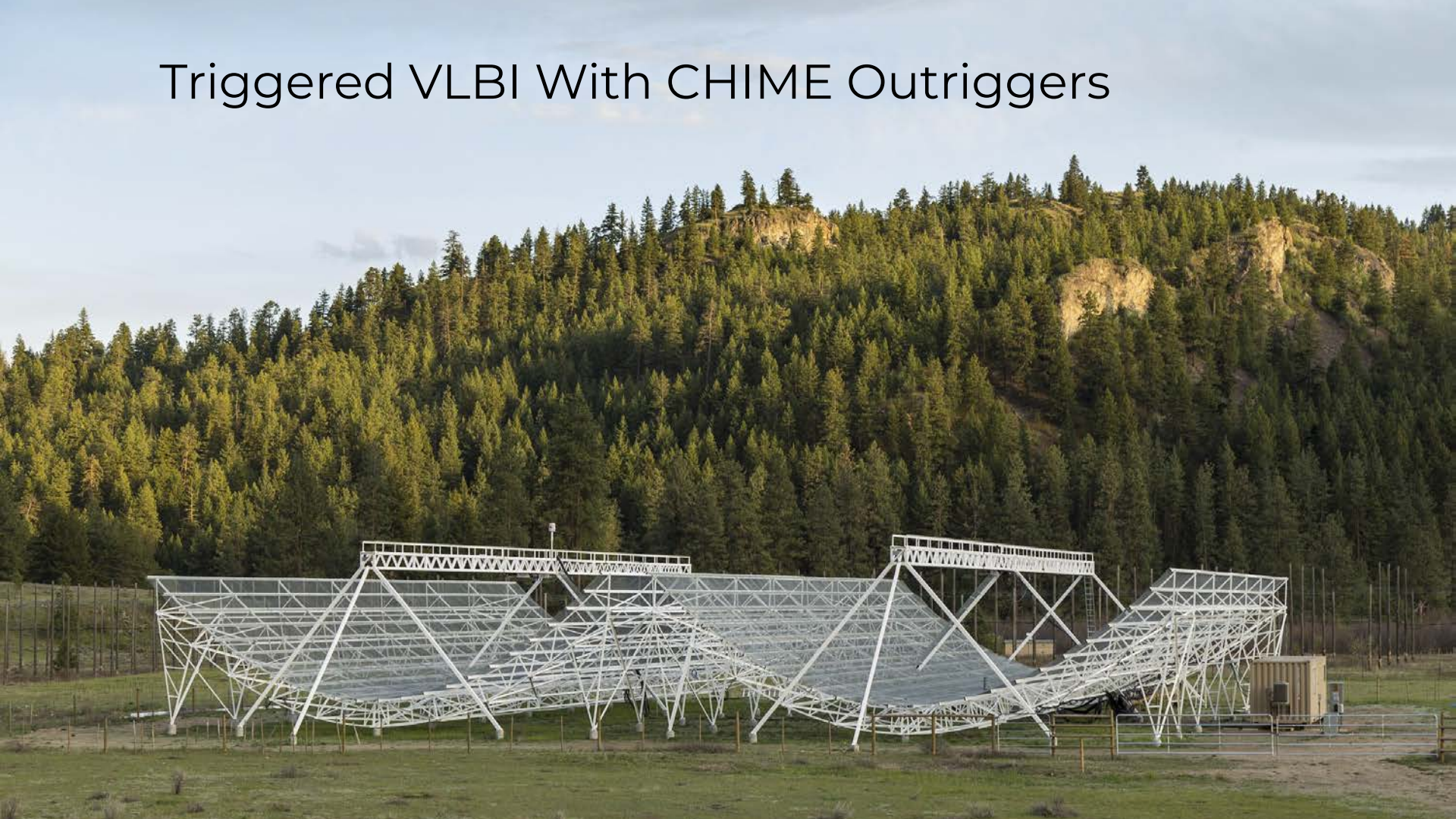
CHIME/FRB Detection Pipeline



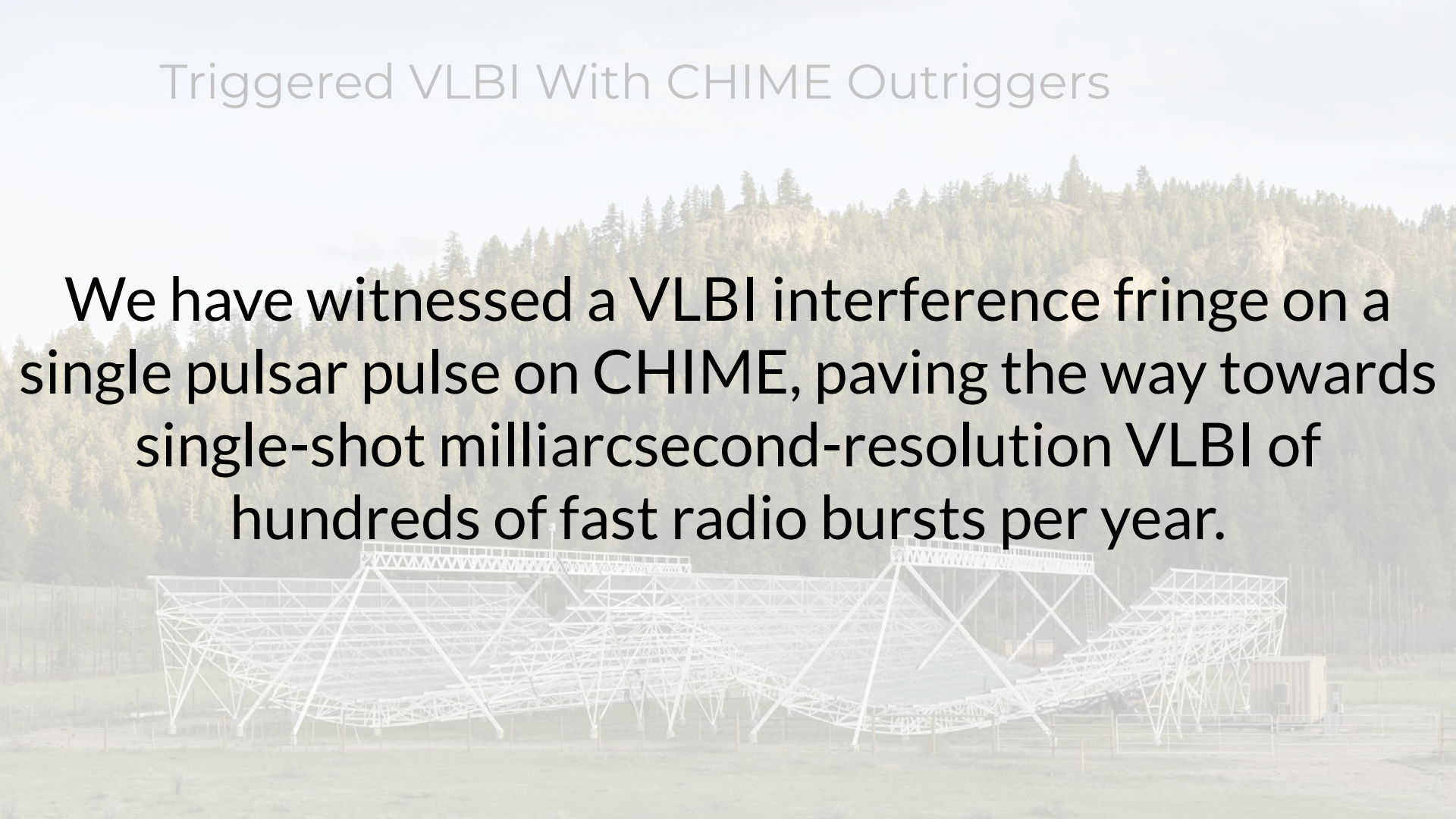
VLBI Detection Pipeline



Triggered VLBI With CHIME Outriggers

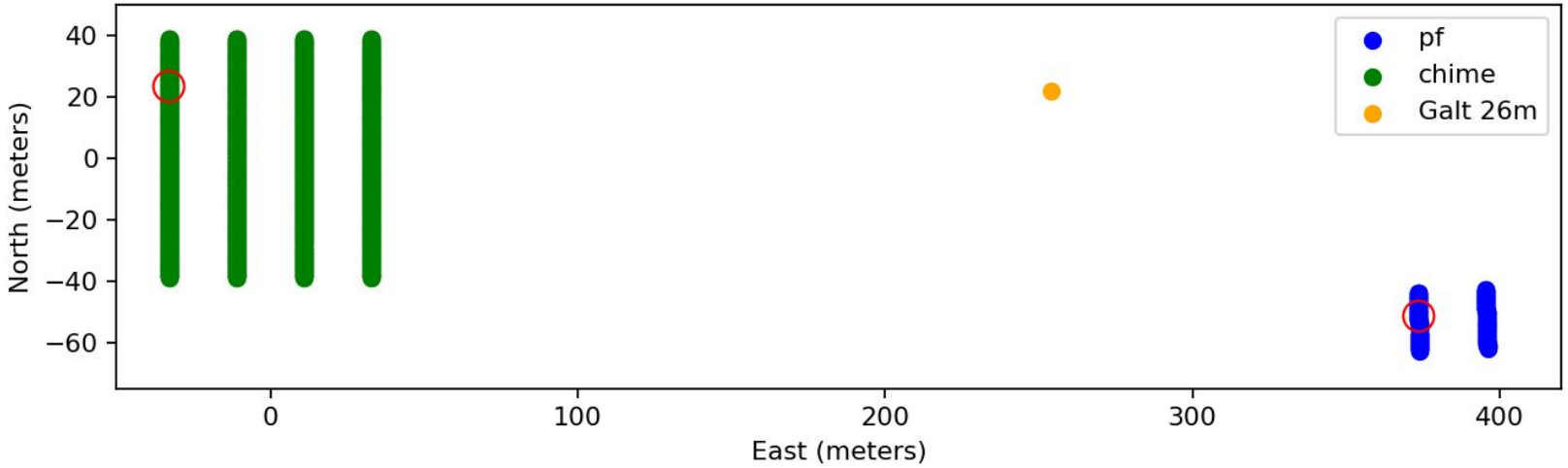


Triggered VLBI With CHIME Outriggers

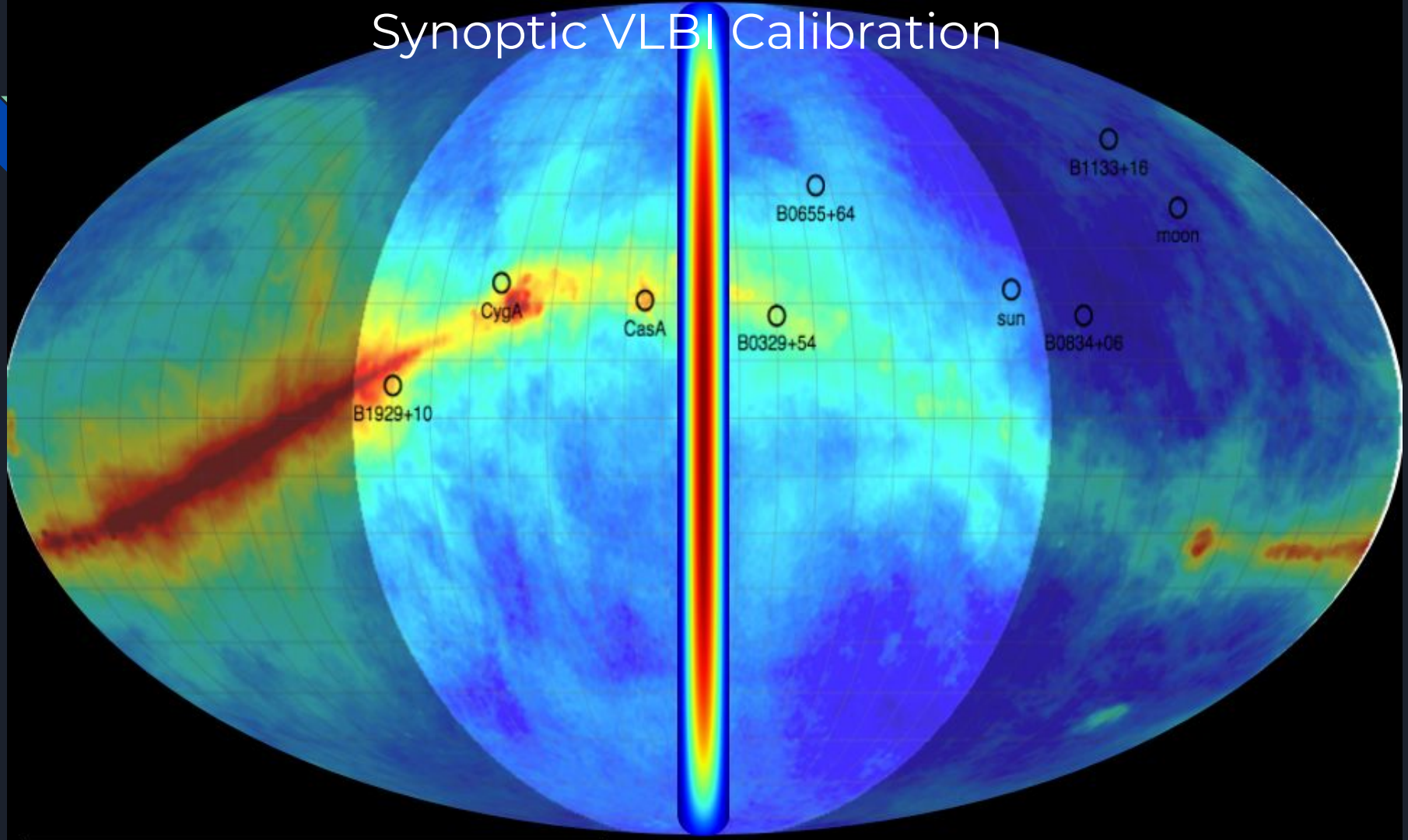


We have witnessed a VLBI interference fringe on a single pulsar pulse on CHIME, paving the way towards single-shot milliarcsecond-resolution VLBI of hundreds of fast radio bursts per year.

“VL”BI With CHIME and CHIME Pathfinder



Synoptic VLBI Calibration



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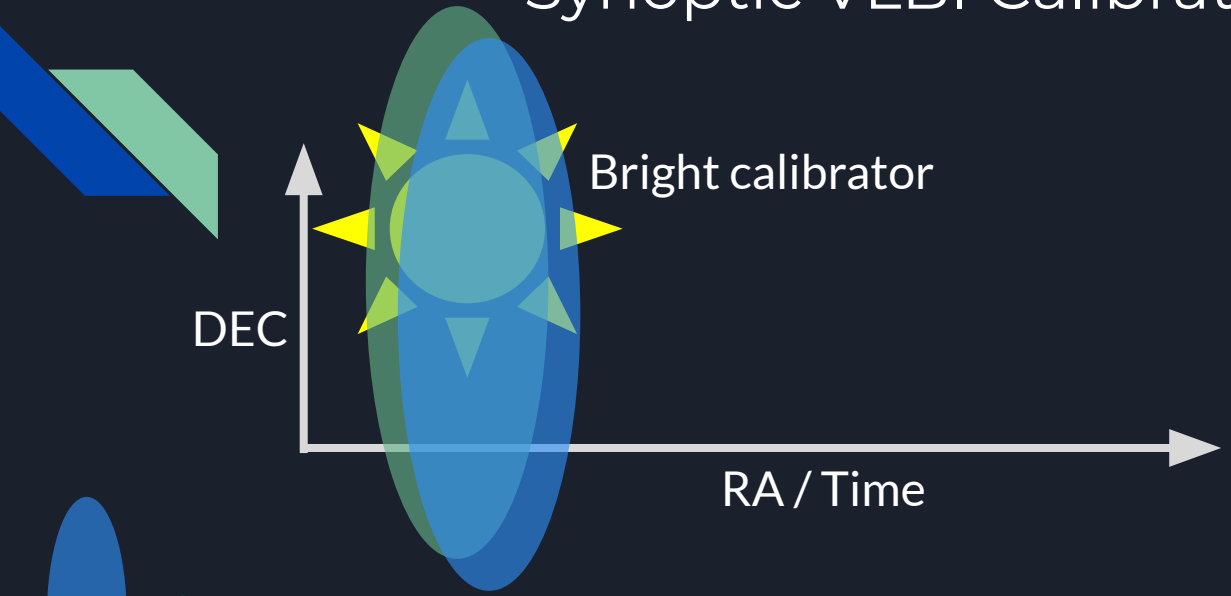


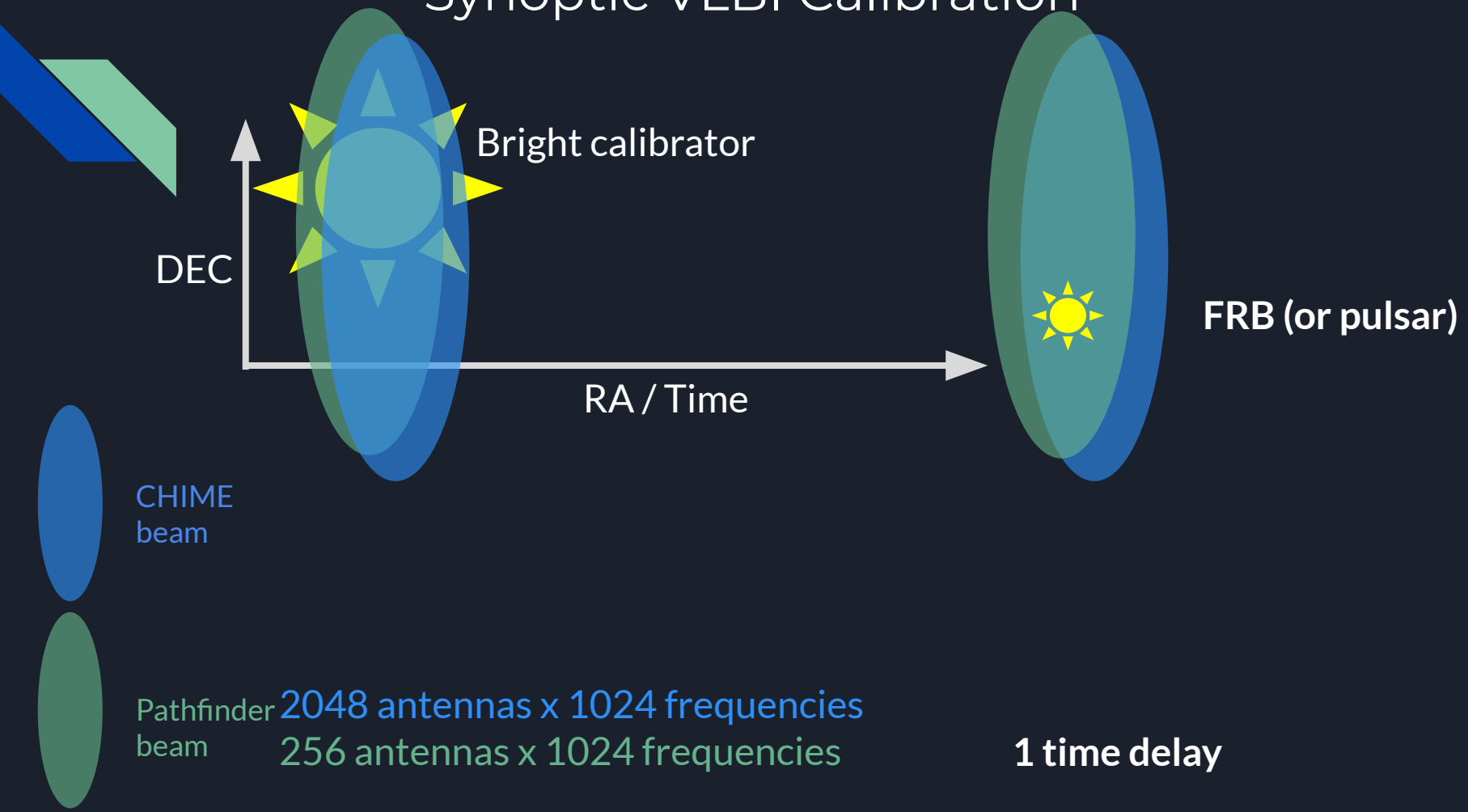
CHIME beam

Pathfinder beam

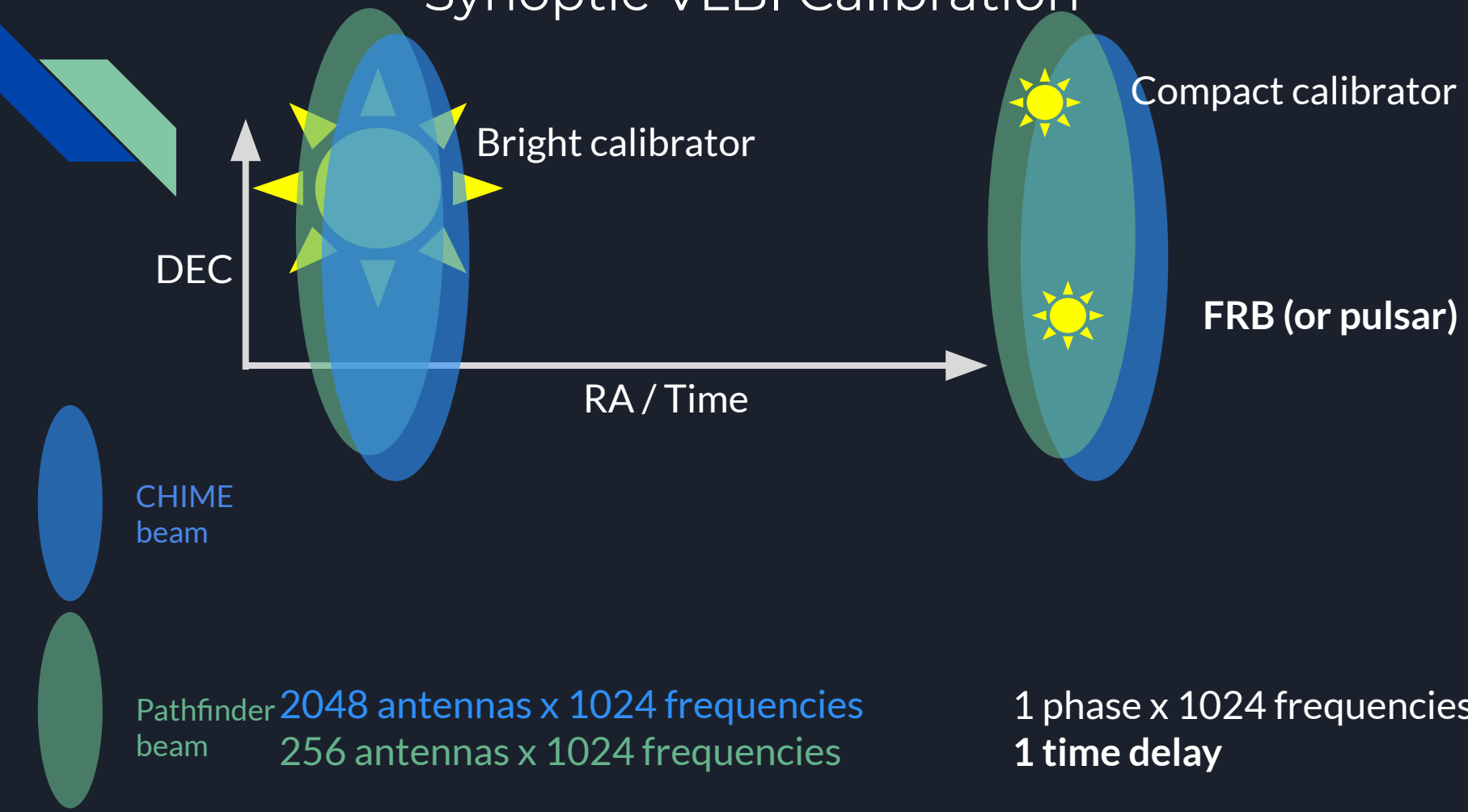
2048 antennas x 1024 frequencies

256 antennas x 1024 frequencies

Synoptic VLBI Calibration



Synoptic VLBI Calibration



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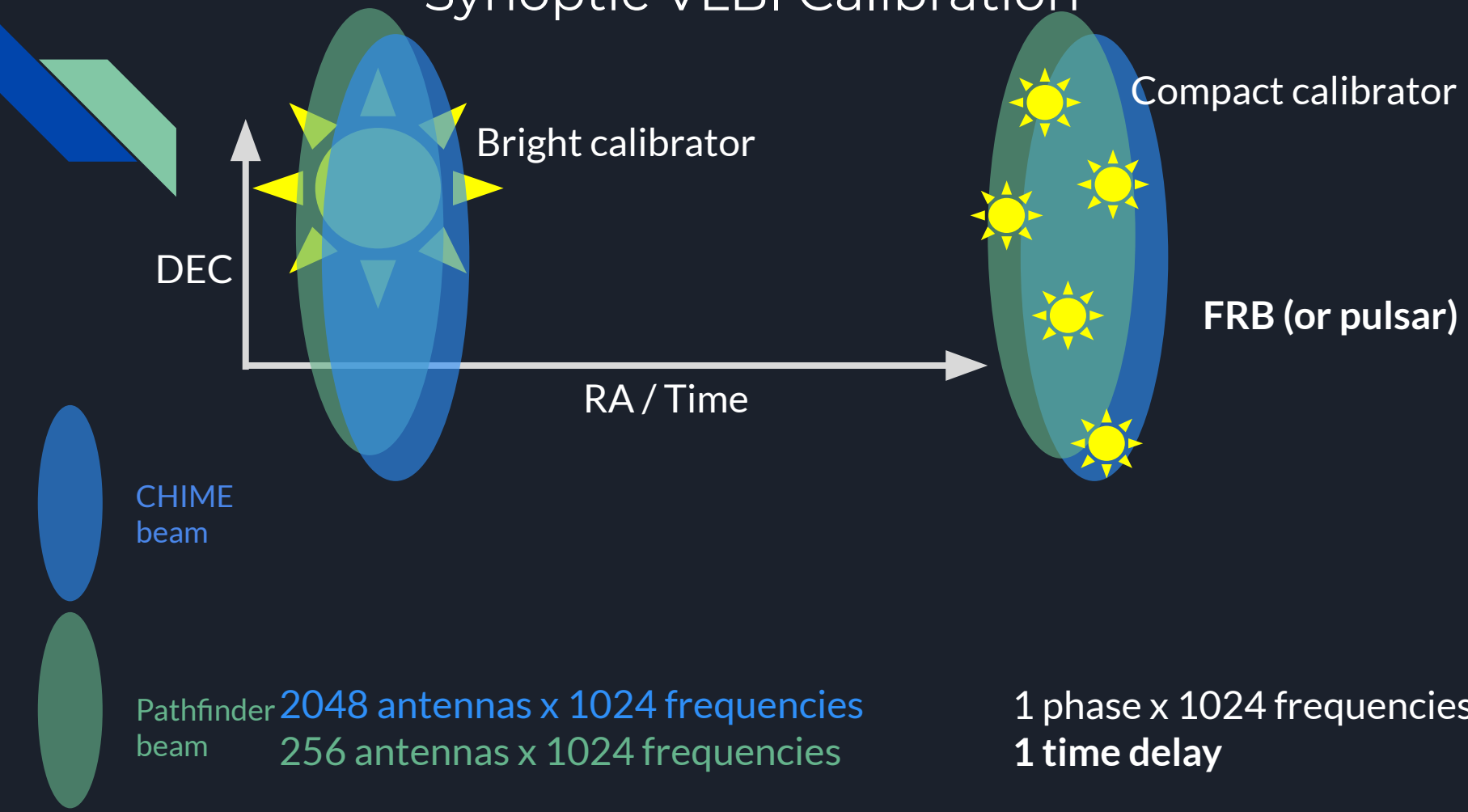

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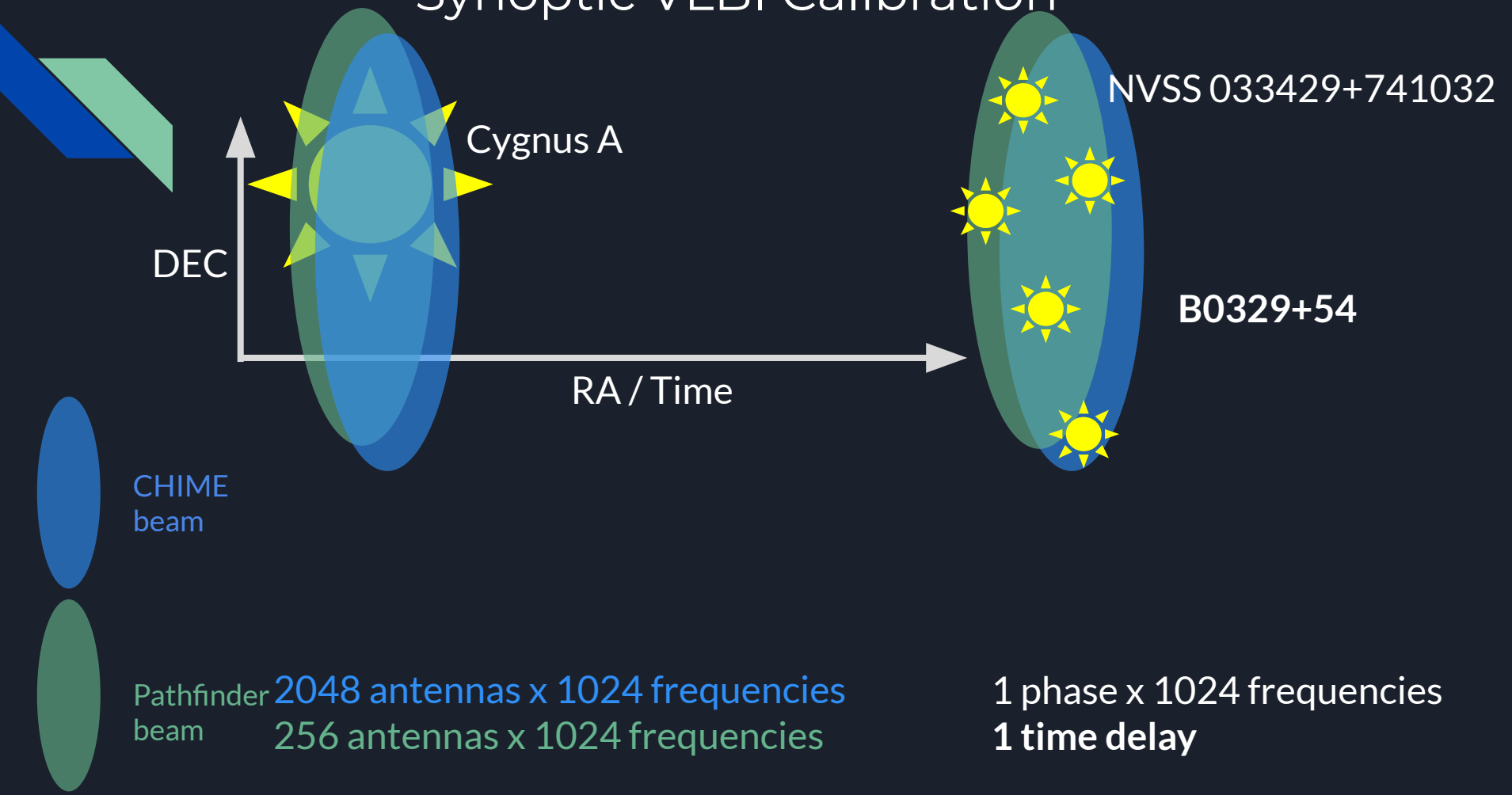
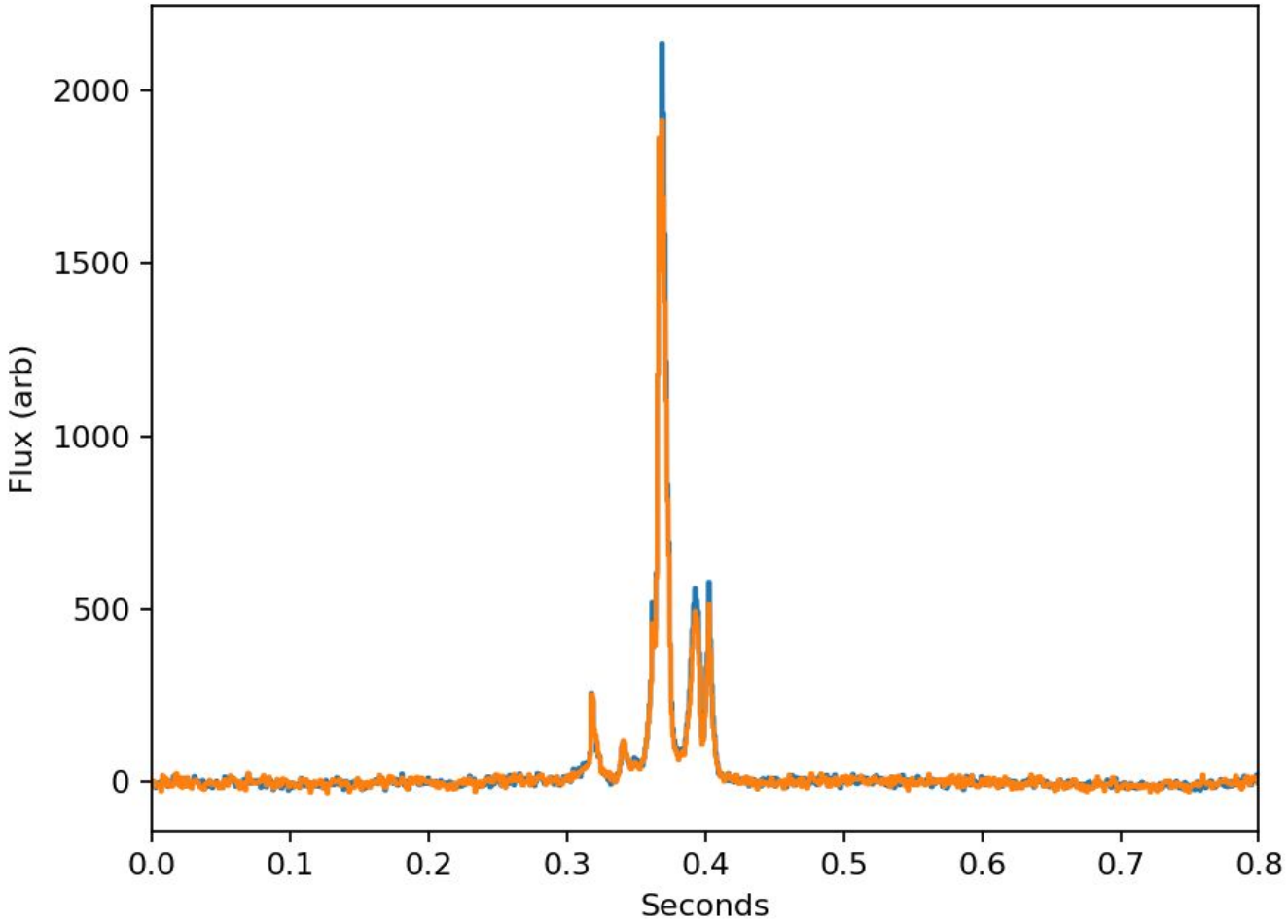
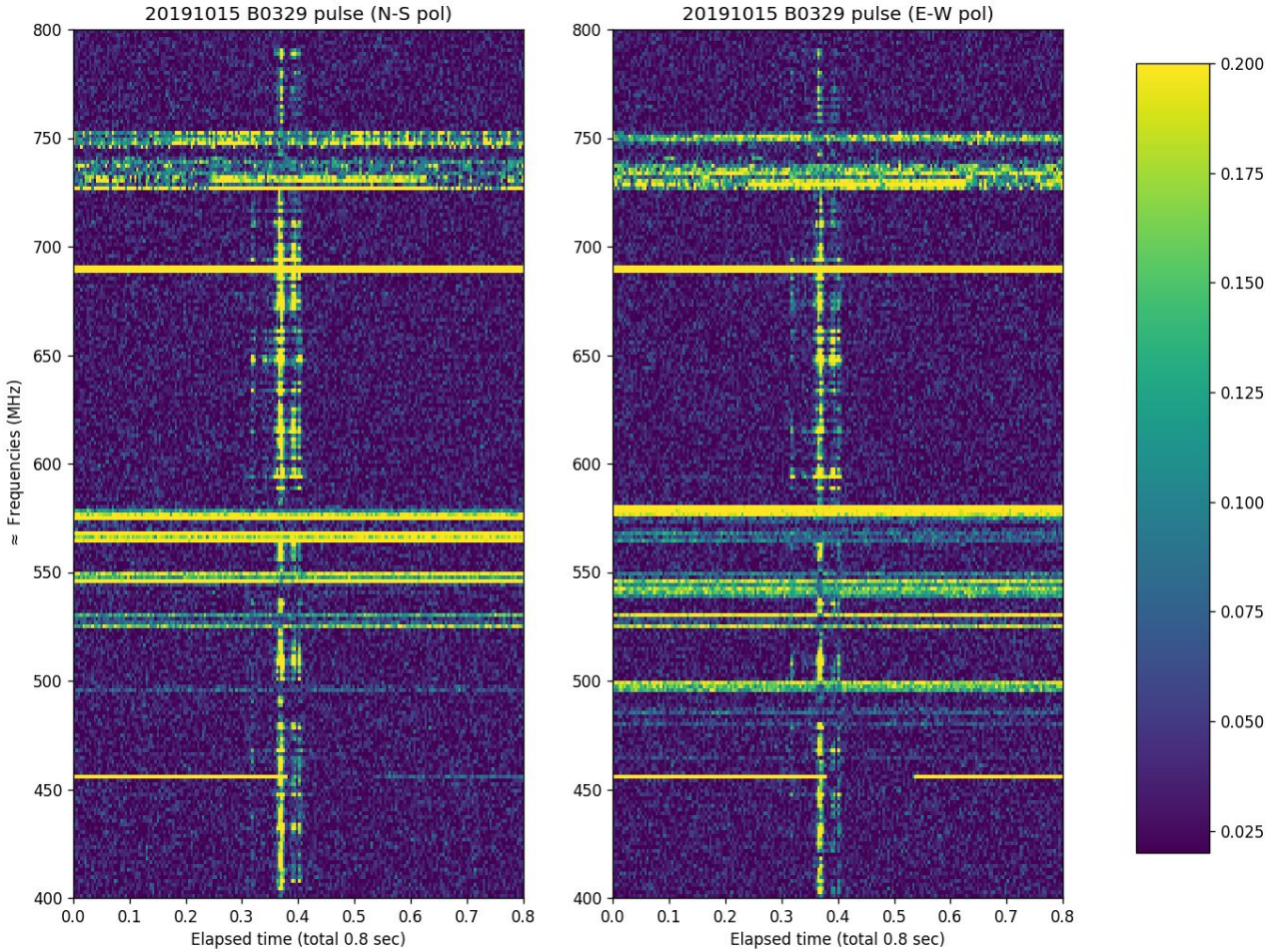
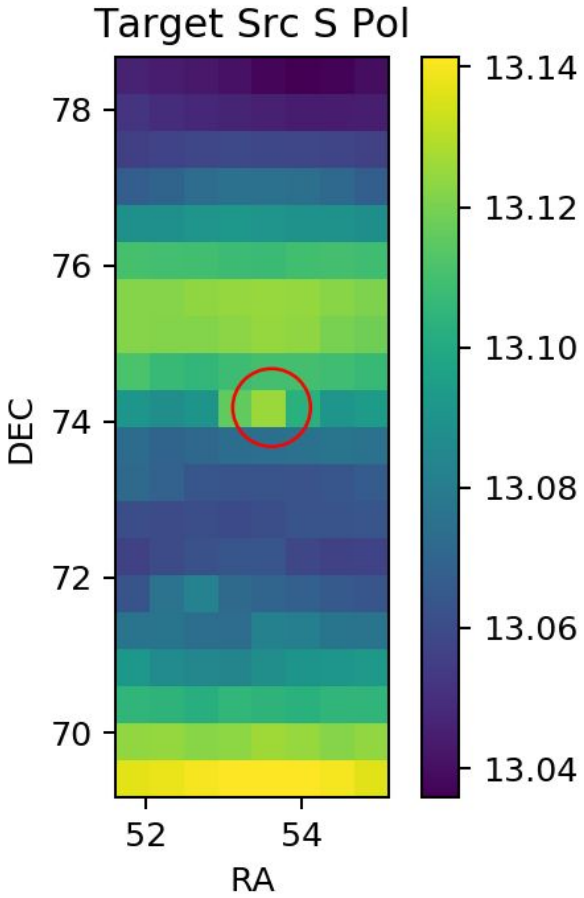
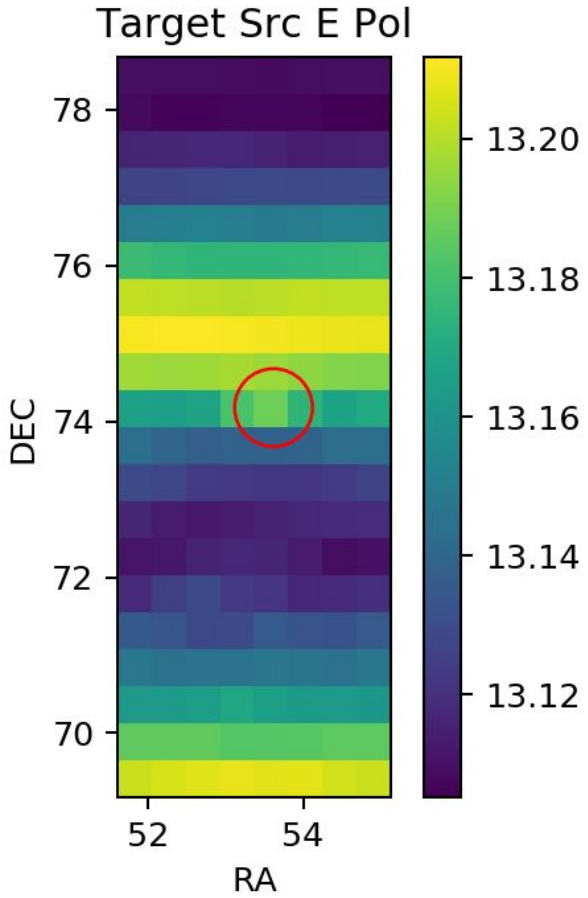
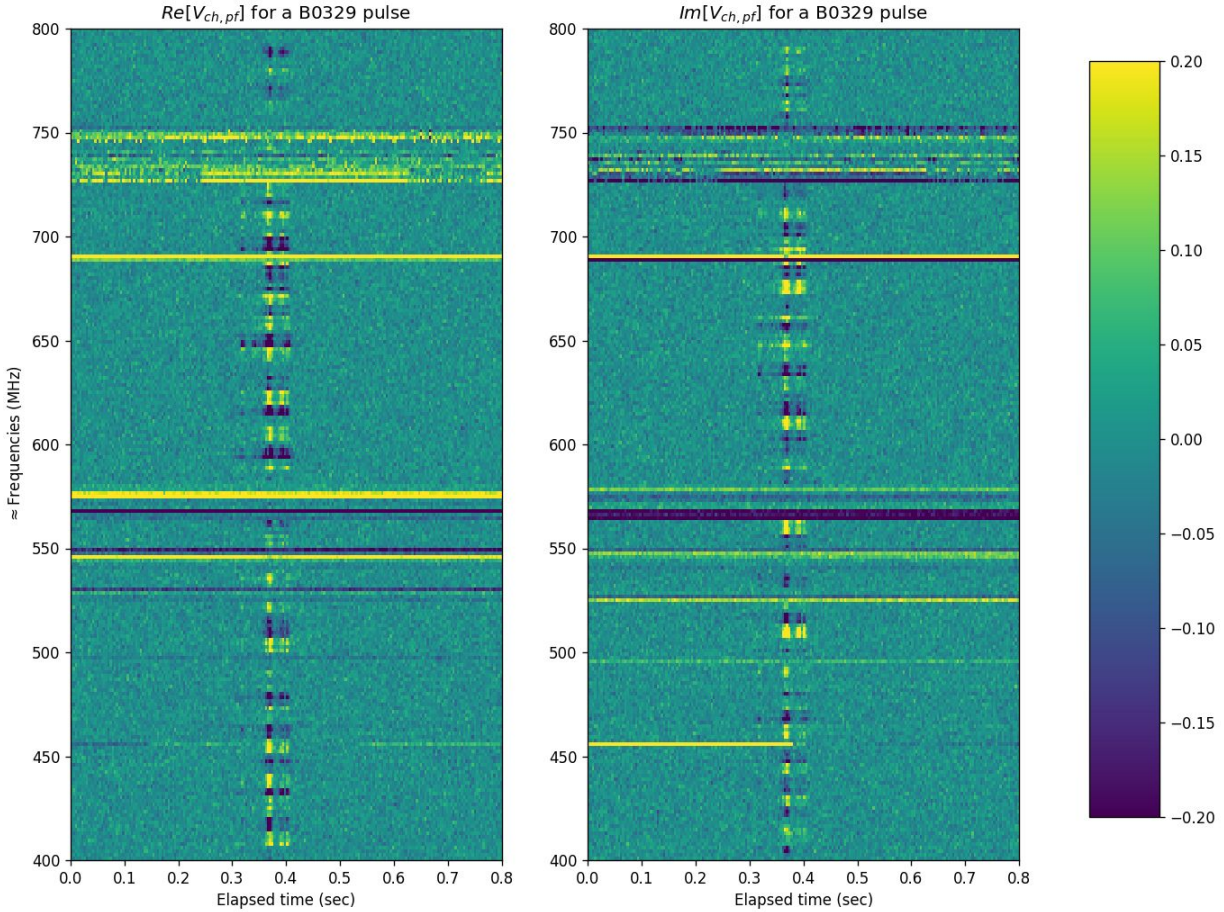


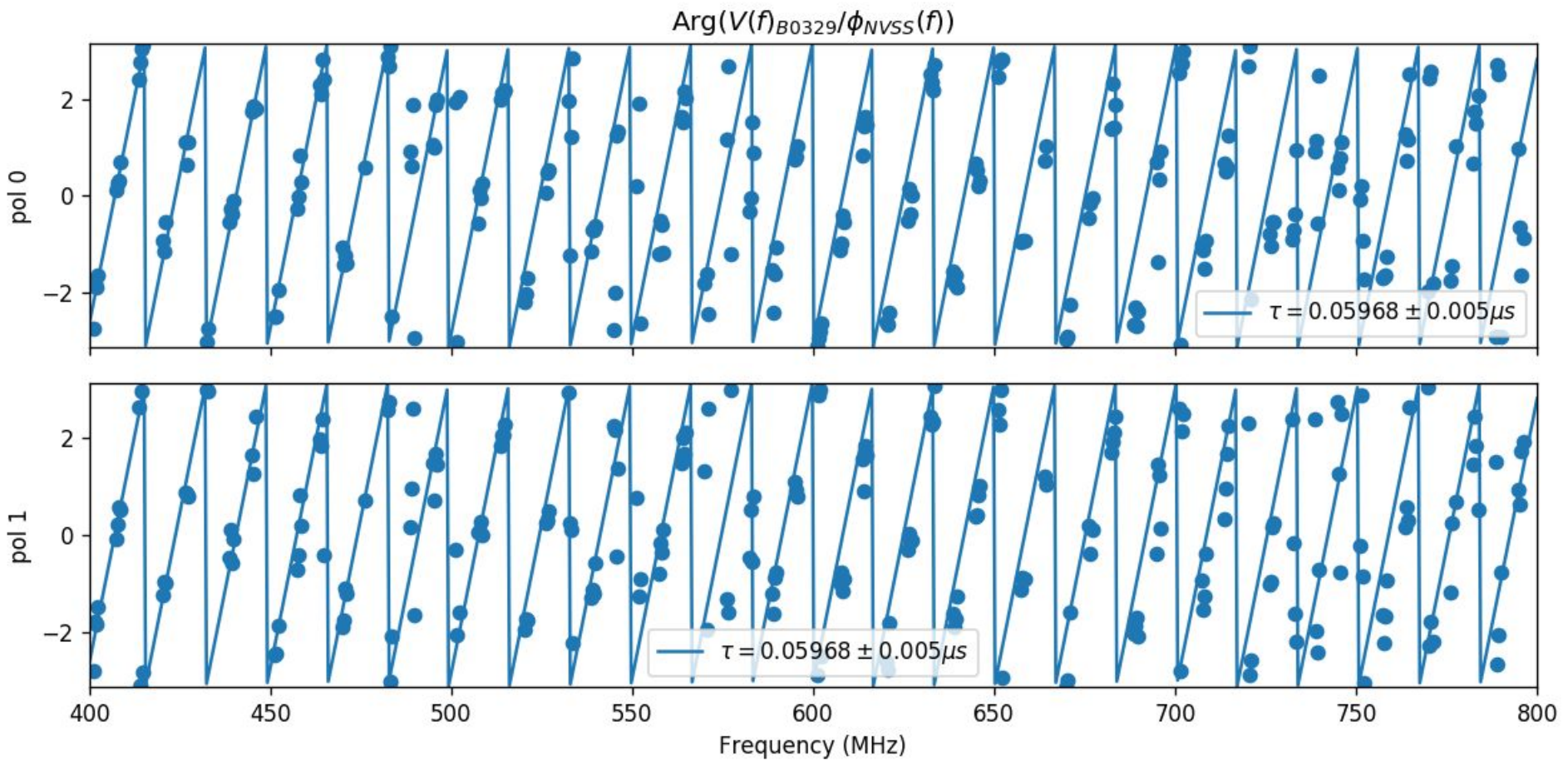

2000
1500
1000
500
0
Flux (arb)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Seconds


20191015 B0329 pulse (N-S pol)
20191015 B0329 pulse (E-W pol)
≈ Frequencies (MHz)
800
750
700
650
600
550
500
450
400
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Elapsed time (total 0.8 sec)
0.200
0.175
0.150
0.125
0.100
0.075
0.050
0.025


Target Src S Pol
78
76
74
72
70
DEC
52
54
RA
13.14
13.12
13.10
13.08
13.06
13.04


Target Src E Pol
78
76
74
72
70
DEC
52
54
RA
13.20
13.18
13.16
13.14
13.12


$Re[V_{ch,pf}]$ for a B0329 pulse
$Im[V_{ch,pf}]$ for a B0329 pulse
≈ Frequencies (MHz)
Elapsed time (sec)
Elapsed time (sec)
800
750
700
650
600
550
500
450
400
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.20
0.15
0.10
0.05
0.00
−0.05
−0.10
−0.15
−0.20


$\mathrm{Arg}(V(f)_{B0329}/\phi_{NVSS}(f))$
pol 0
pol 1
2
0
−2
$\tau = 0.05968 \pm 0.005\mu s$
$\tau = 0.05968 \pm 0.005\mu s$
400
450
500
550
600
650
700
750
800
Frequency (MHz)

Fast Radio Bursts Outlook

Localization → Arcminute present → Arcsecond → Milliarcsecond in development

What are they?

- Giant pulses from distant pulsars?
- AGN outbursts?
- White Dwarf-Neutron Star mergers?
- Shock Waves from Young Magnetars?
- Cosmic String Cusps?

Use FRBs to probe…

- Missing Baryons?
- Primordial Magnetic Fields?
- Matter Power Spectrum?
- Primordial Black Holes?
- H0?

Yale

Massachusetts
Institute of
Technology

Fast Radio Bursts

Are FRBs...

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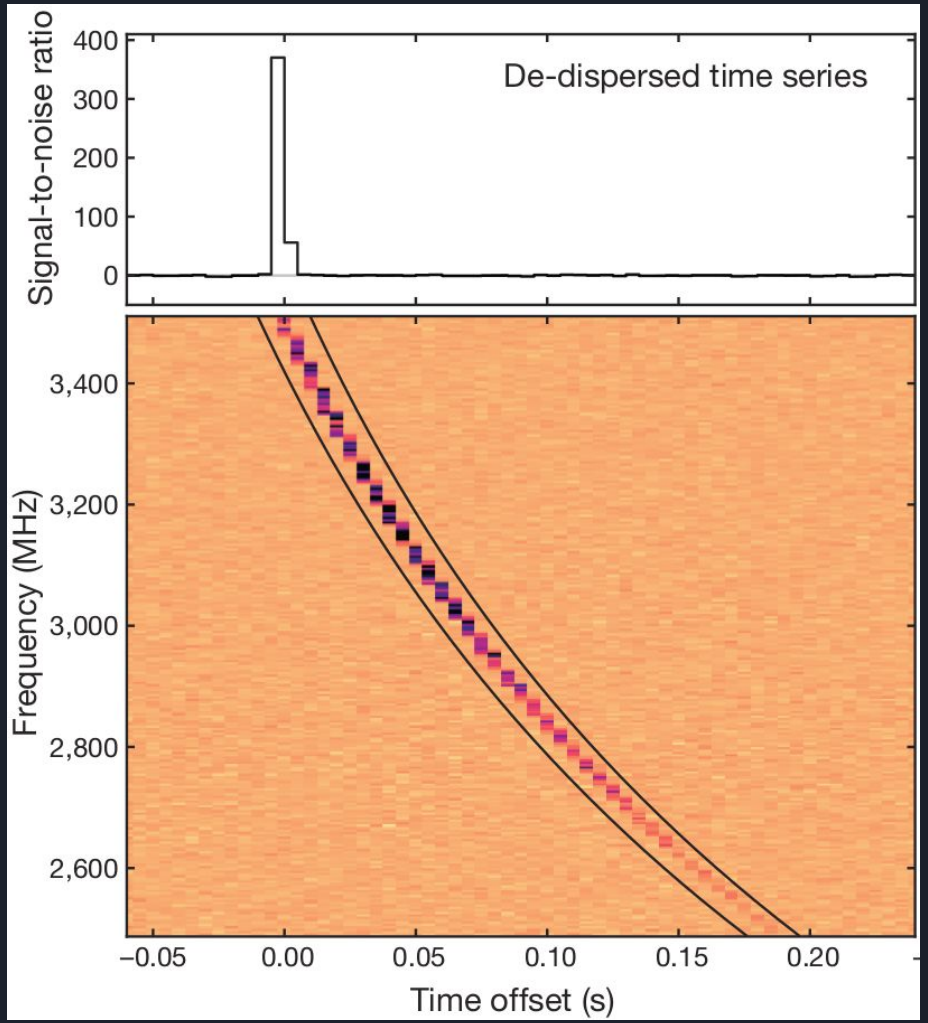

Parameter	Full CHIME	Pathfinder
Structure	Four 20 × 100 m cylinders	Two 20 × 37 m cylinders
Number of feeds per cylinder	256	64
Feed spacing	30 cm	30 cm
Frequency range	400 MHz - 800 MHz	400 MHz - 800 MHz
E-W Field of View	$2.6° - 1.3°$	$2.6° - 1.3°$
N-S Field of View	90°	90°
Synthesized beam size	$0.4° - 0.2°$	$1.4° - 0.7°$
Receiver noise temperature	$\lesssim 50$ K	$\lesssim 50$ K

Networking Details

CHIME Pathfinder:

1024 frequencies x 256 inputs x 800 MHz

MIT Triggered Baseband Recorder:

256 frequencies x 256 inputs x 800 MHz over 8x10G QSFP+ links

4 x NICs (Silicom PE 31640G2QI71/QX4)

1 TB RAM - 40 seconds of data