

KIYOSHI MASUI

HUNTING FOR FAST RADIO BURSTS WITH DIGITAL TELESCOPES

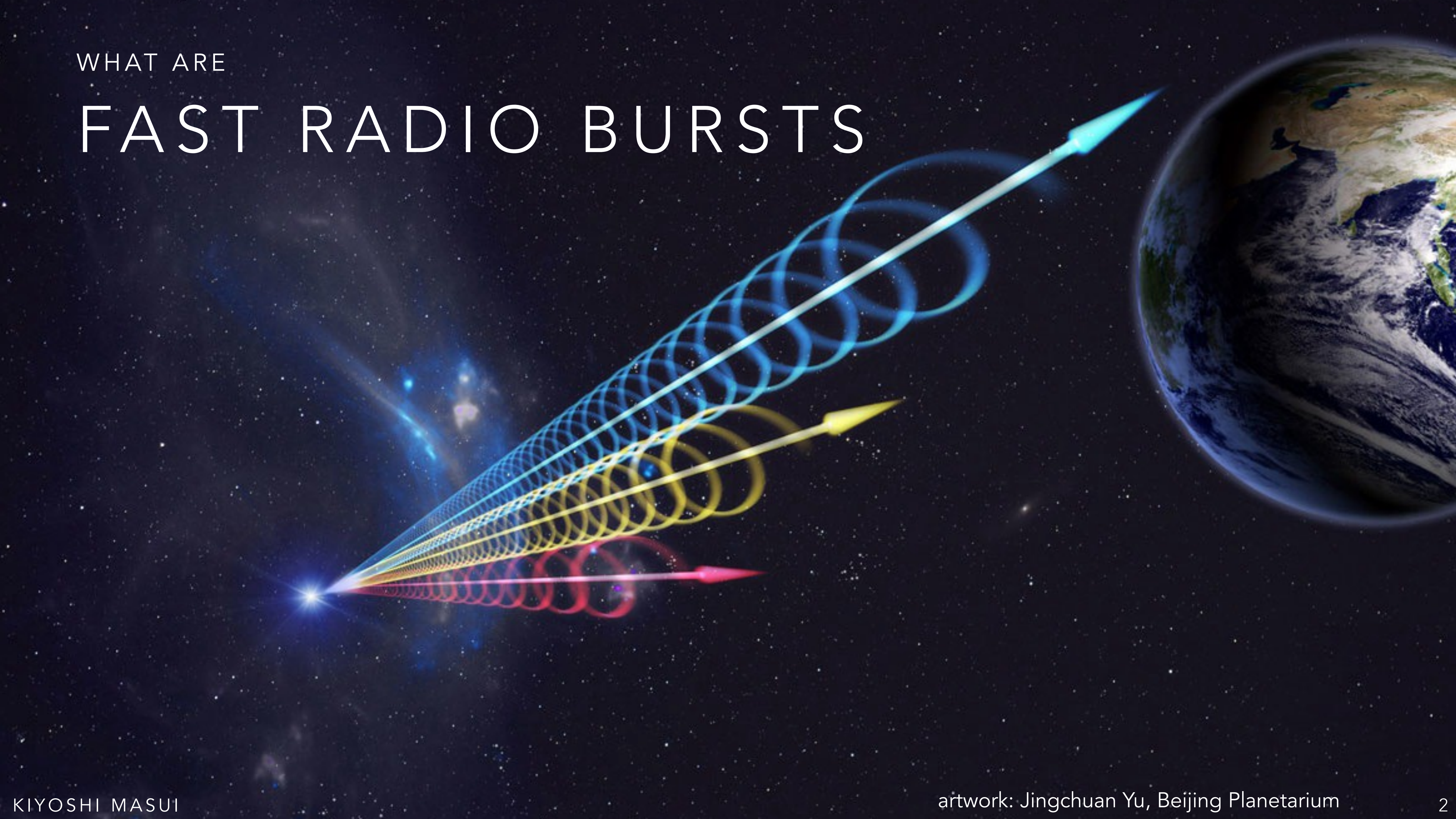
NATIONAL ACADEMIES OF SCIENCES, CORF MEETING
MAY 29, 2024



**Masui Synoptic
Radio Lab**

WHAT ARE

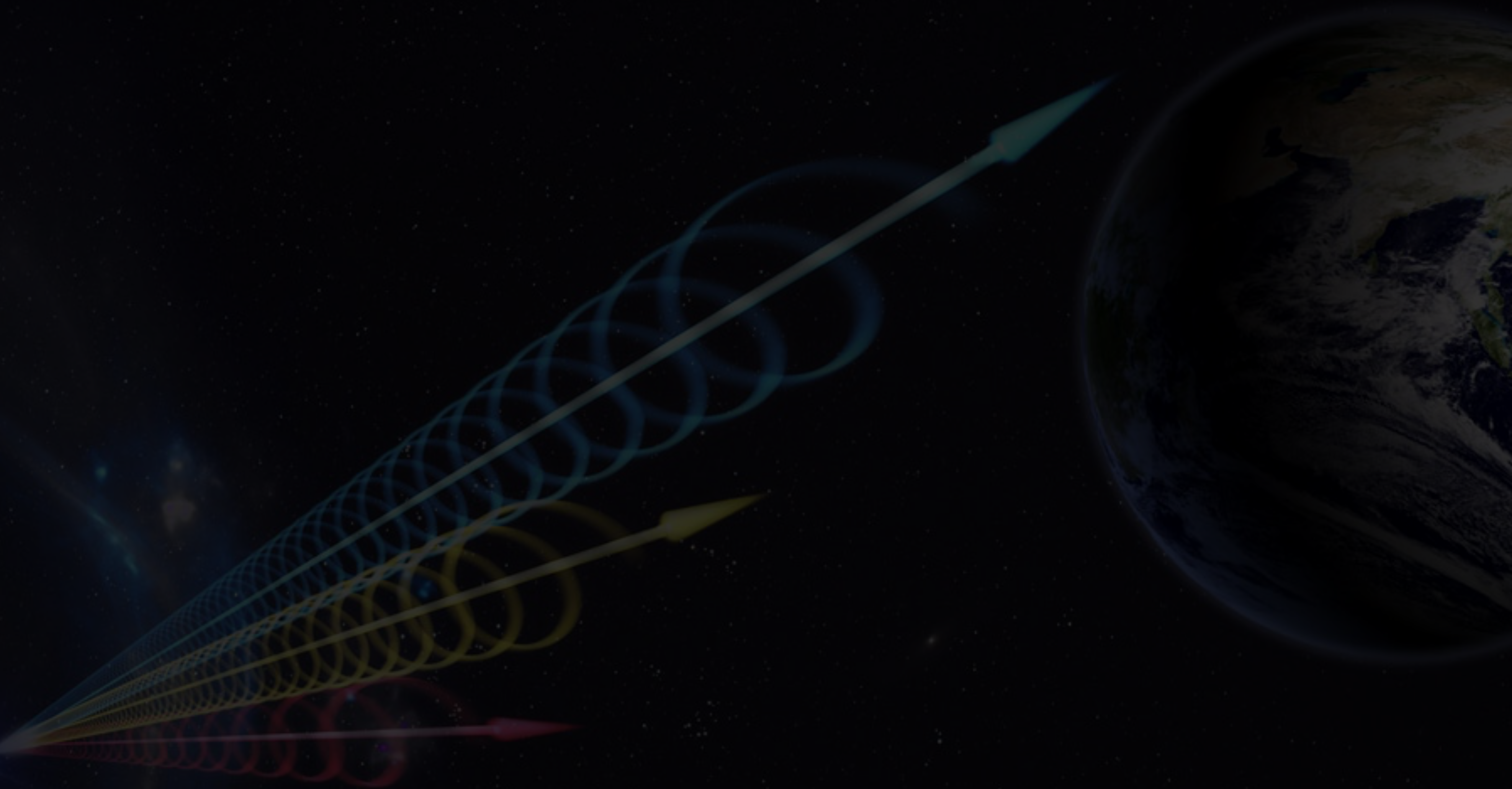
FAST RADIO BURSTS



FAST

RADIO

BURSTS

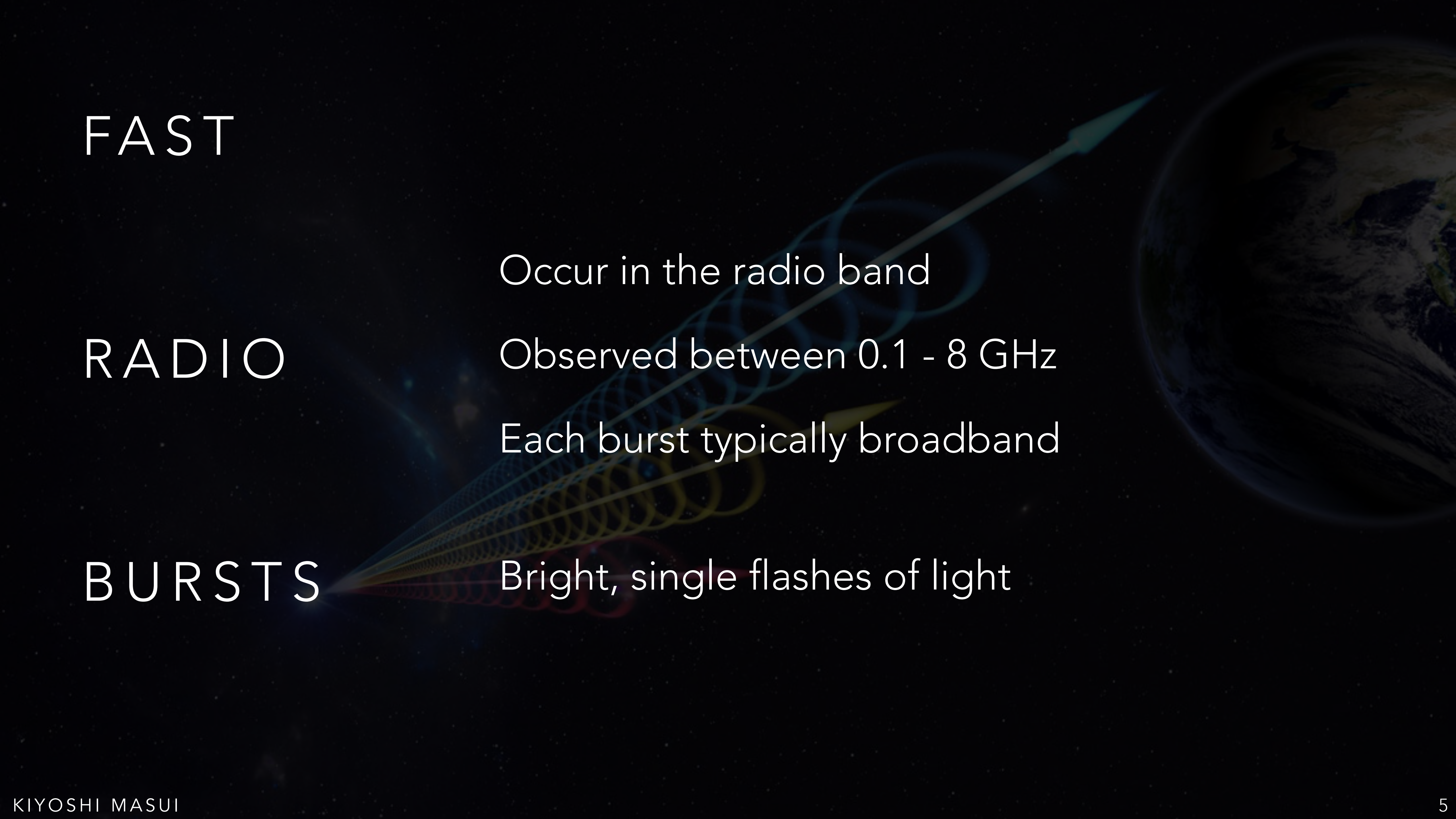


FAST

RADIO

BURSTS

Bright, single flashes of light



FAST

RADIO

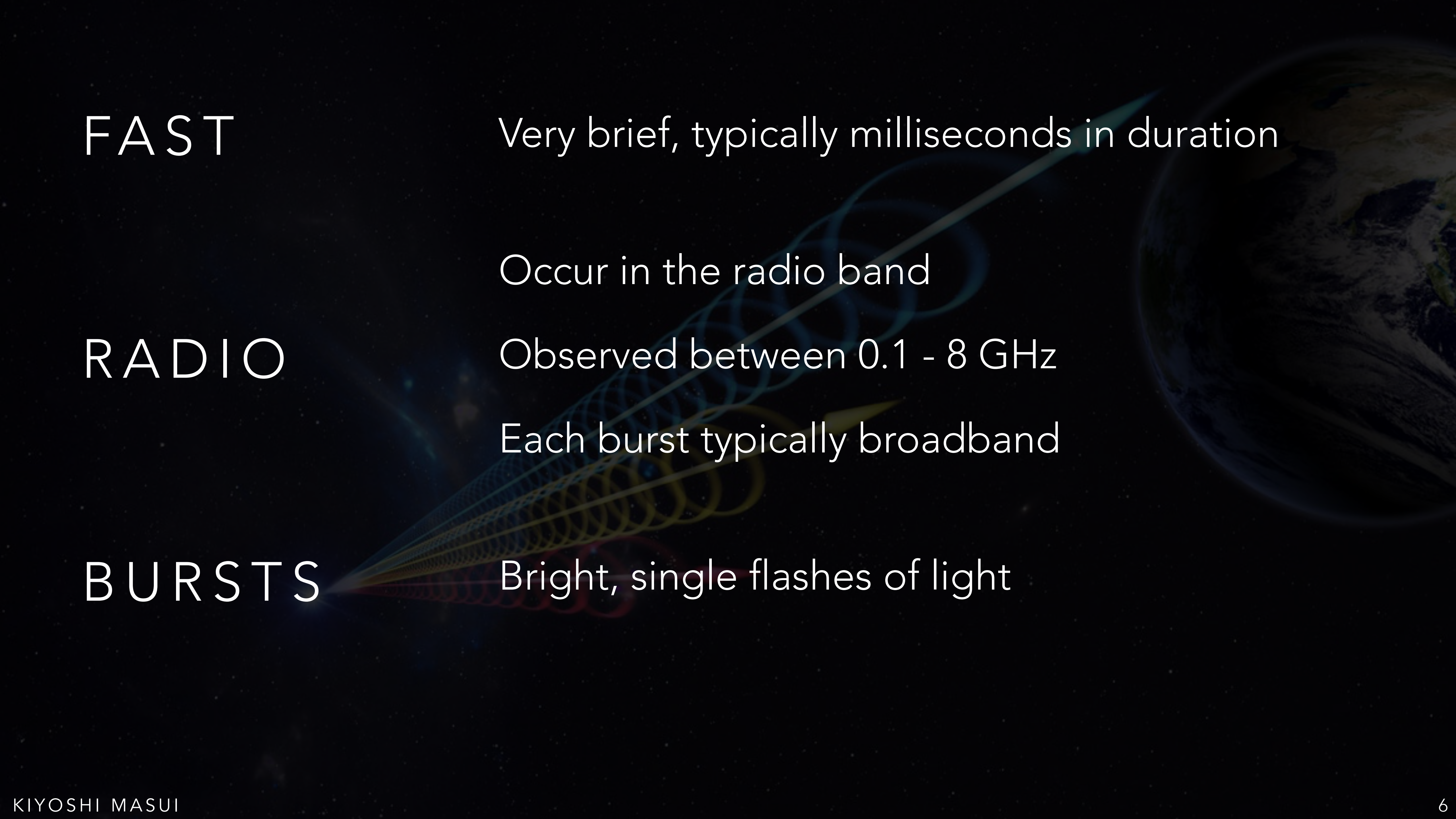
Occur in the radio band

Observed between 0.1 - 8 GHz

Each burst typically broadband

BURSTS

Bright, single flashes of light



FAST

Very brief, typically milliseconds in duration

RADIO

Occur in the radio band

Observed between 0.1 - 8 GHz

Each burst typically broadband

BURSTS

Bright, single flashes of light

EXTRAGALACTIC

Billions of light years distant

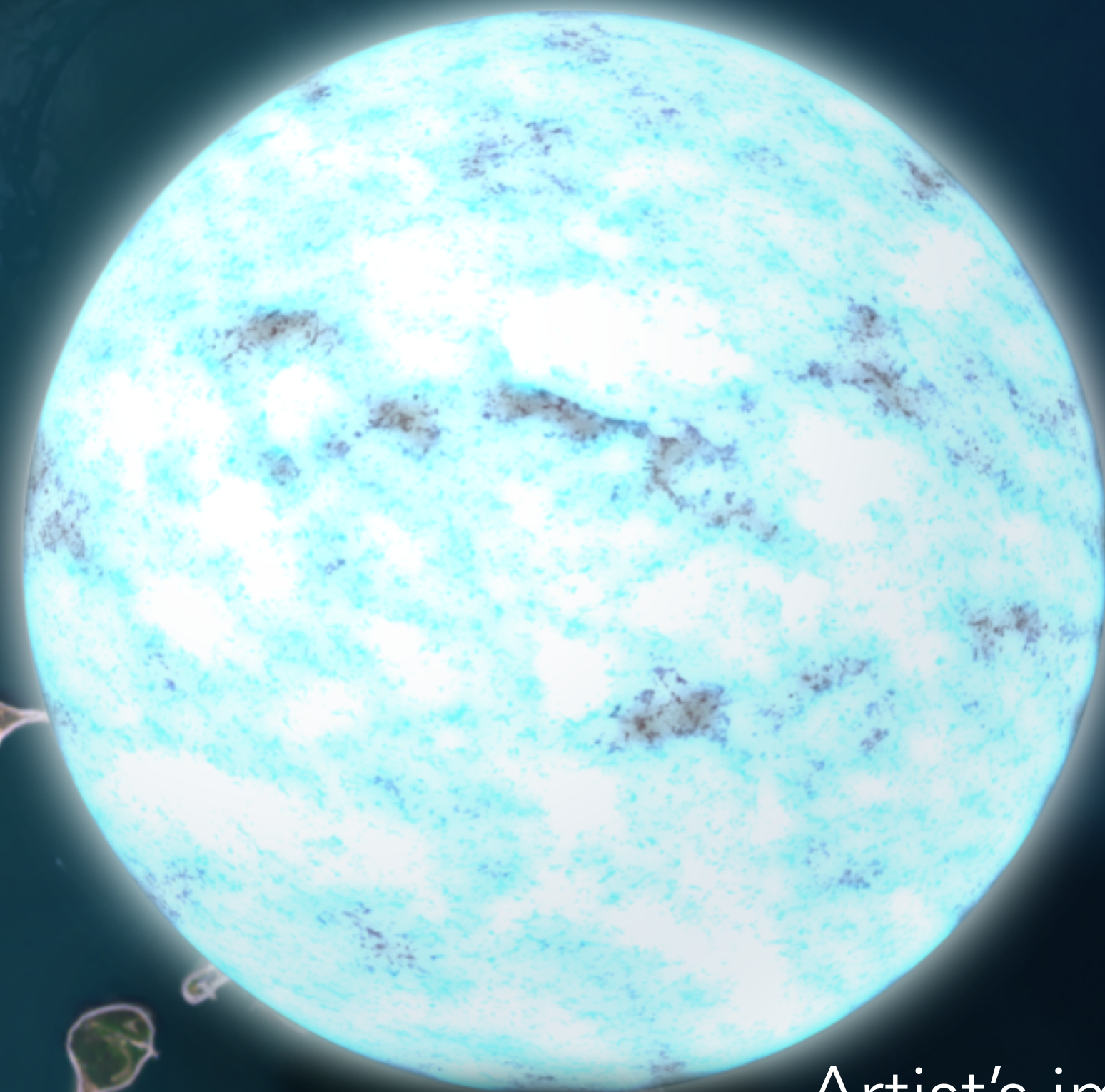
LUMINOUS

~1 Jansky flux ~ bright radio galaxy

POORLY
LOCALIZED

Usually degree scale localization,
host galaxies unidentified

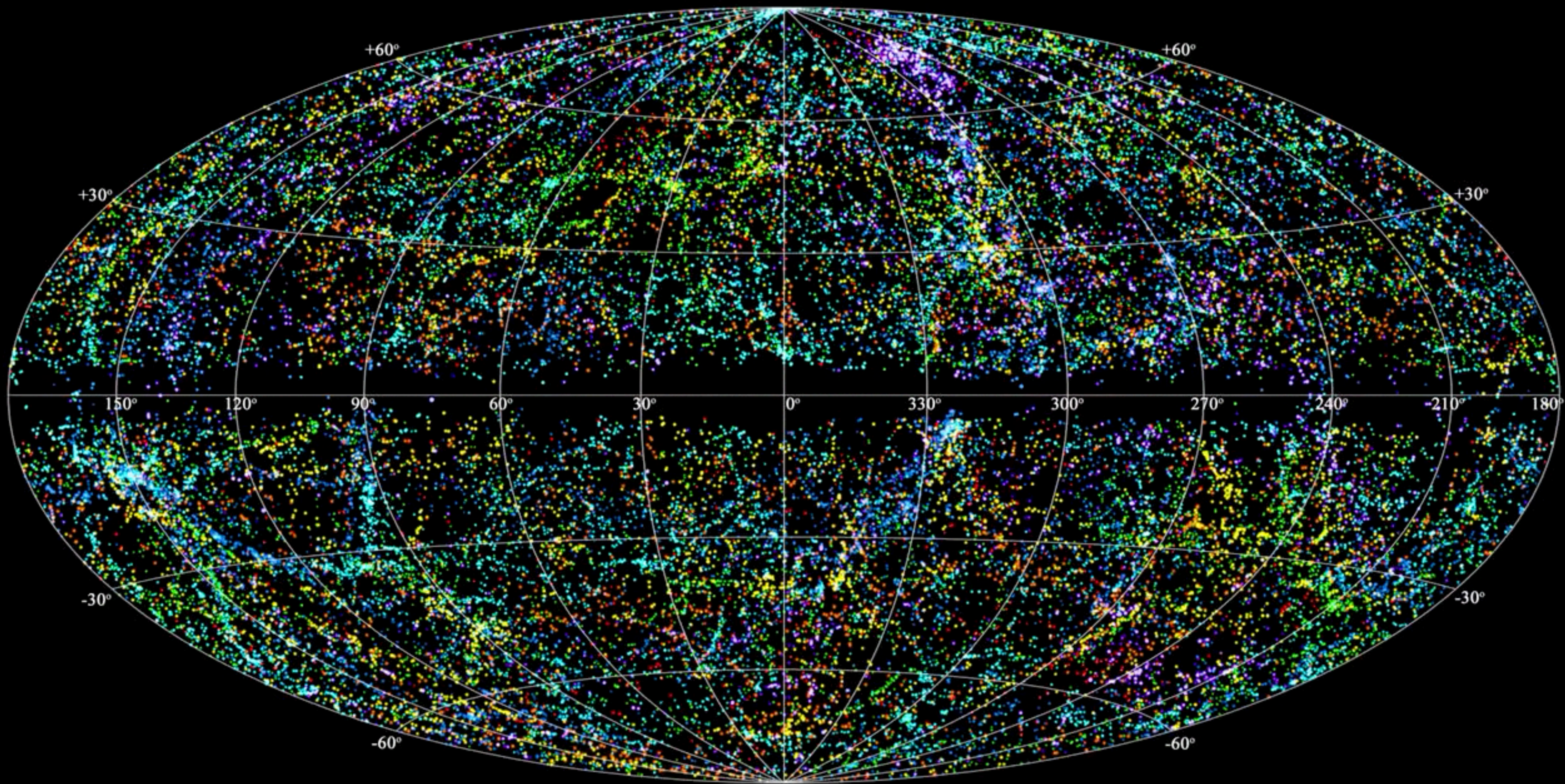
RELATED TO NEUTRON STARS?



Artist's impression of a
neutron star to scale vs
Boston

~50 observed from 2007-2017 but ~thousands/sky/day





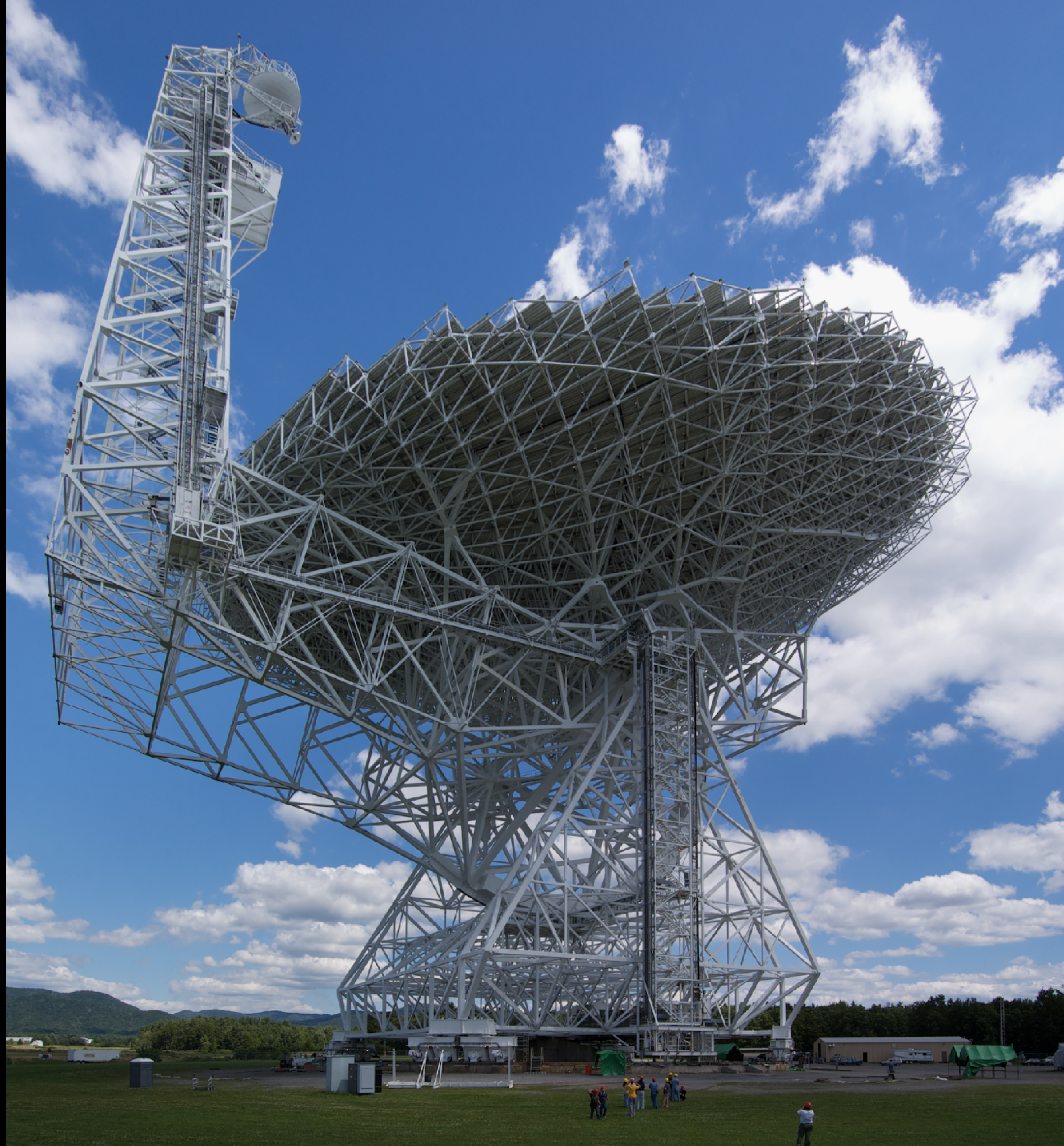
TO UNDERSTAND THESE THINGS

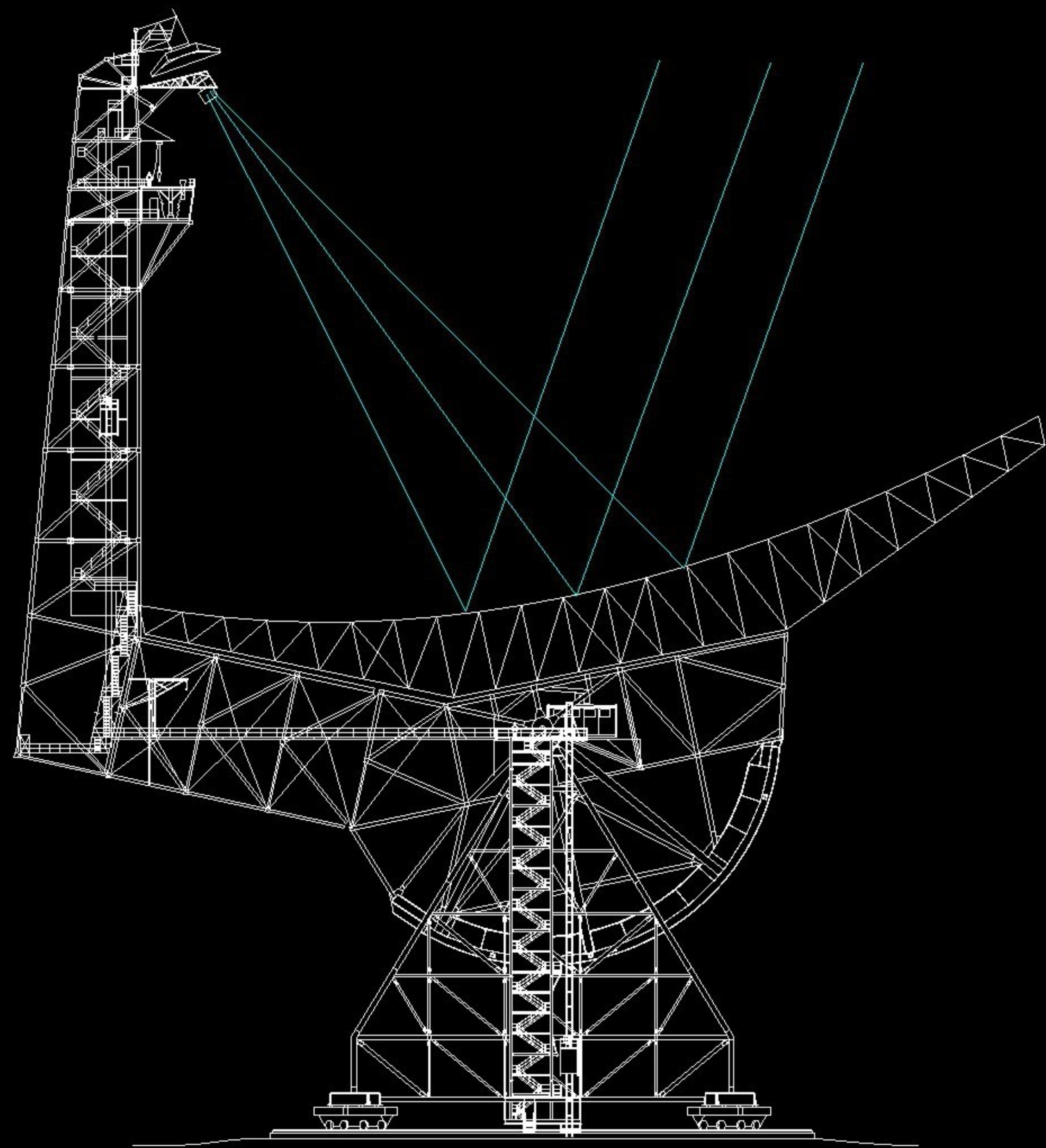
We need a larger sample

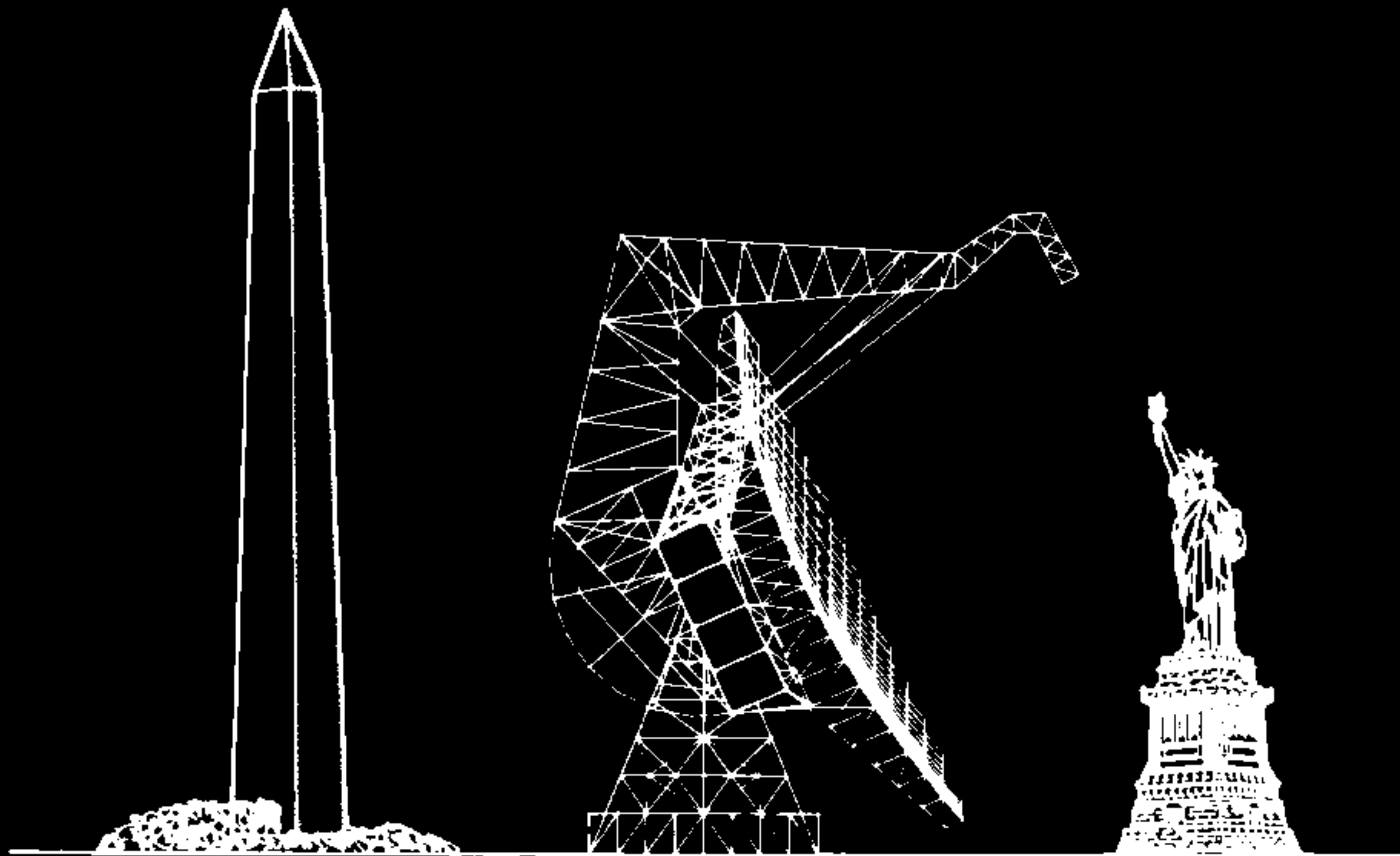
TO GET A BIGGER SAMPLE WE NEED

A new kind of radio telescope

WHAT LIMITS THESE?







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NEW TECHNOLOGY

WHAT HAS CHANGED?



KIYOSHI MASUI

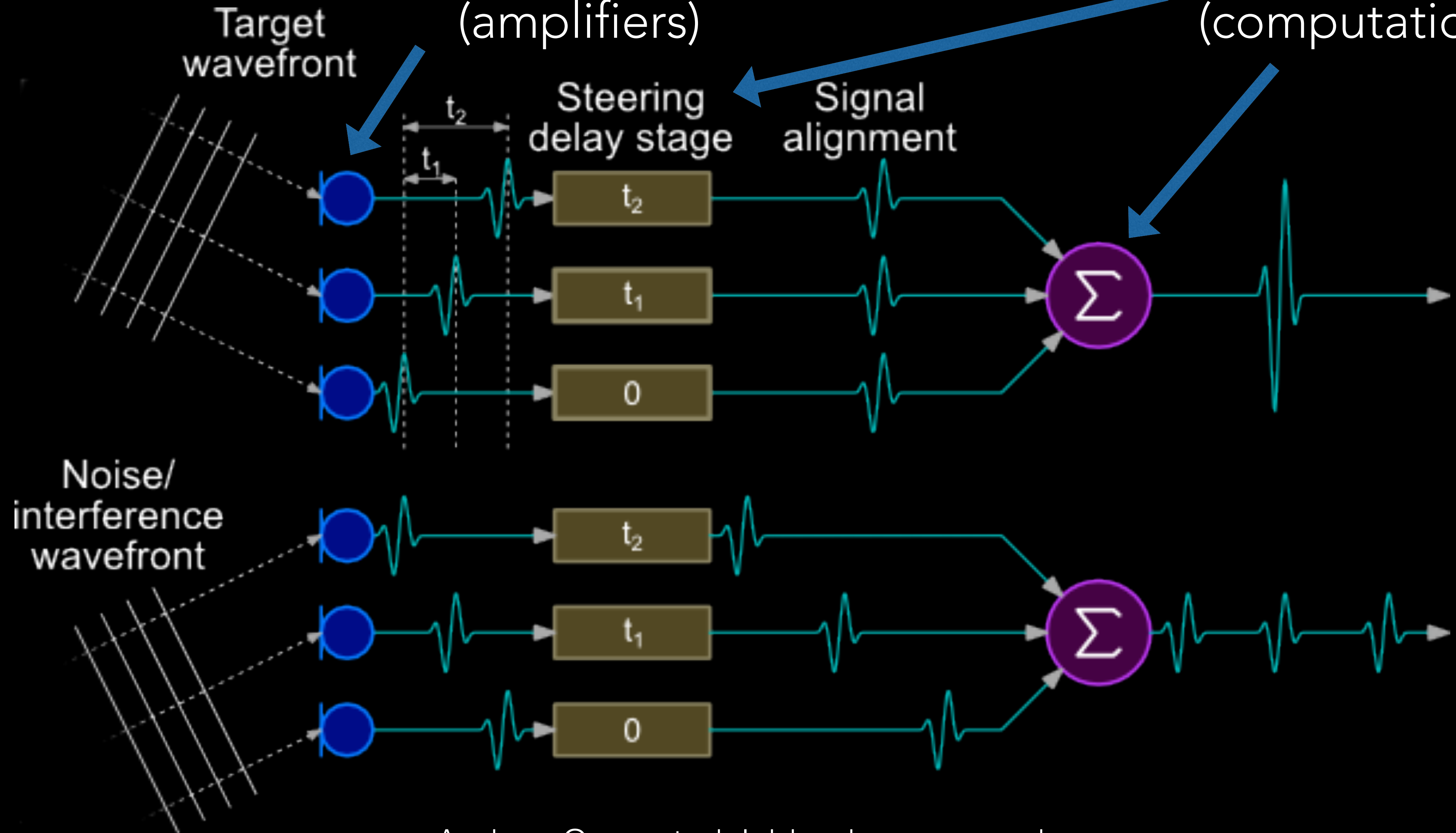


Artist's Impression of SKA Low



Cell Phones
(amplifiers)

Graphics Cards
(computation)



CANADIAN HYDROGEN INTENSITY MAPPING EXPERIMENT

CHIME



CANADIAN HYDROGEN INTENSITY MAPPING EXPERIMENT

CHIME

- Digitally driven telescope operating from 400 to 800 MHz
- Large field of view (~ 200 sq. deg.)
- High sensitivity (80m x 80m aperture)





UNIVERSITY OF
TORONTO



McGill

Canada
MRC-CMRC



chime



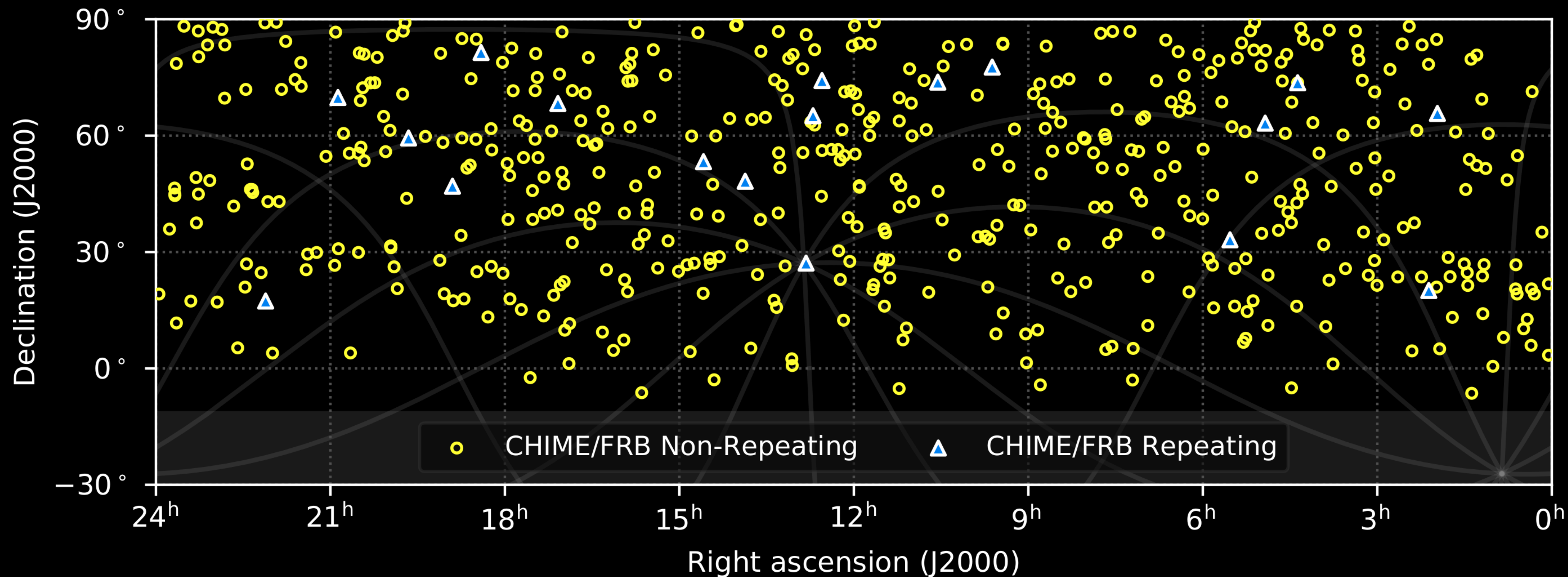
Yale



Massachusetts
Institute of
Technology



CHIME DETECTS ~ 1000 FRBS/YEAR



CHIME/FRB Collaboration 2021: "Catalog 1" (year 1)

PROGRESS ON PROGENITORS

Detection at low frequencies

CHIME/FRB Collaboration 2019, *Nature*, arXiv:1901.04524

Subpopulation of sources that emit repeat bursts

CHIME/FRB Collaboration 2019, *Nature*, arXiv:1901.04525

CHIME/FRB Collaboration 2019, *ApJL*, arXiv:1908.03507

A repeater that is active on a 16-day period

CHIME/FRB Collaboration 2020, *Nature*, arXiv:2001.10275

An FRB with 100 ms quasi-periodicity

CHIME/FRB Collaboration 2022, *Nature*, arXiv:2107.08463

A repeater near a star-forming region of a nearby galaxy

Marcote et al. 2020, *Nature*, arXiv:2001.02222

A repeater in a globular cluster in M81

Kirsten et al. 2022, *Nature*, arXiv:2105.11445

A fast radio burst emitted from a Galactic magnetar

CHIME/FRB Collaboration 2020, *Nature*, arXiv:2005.10324

nature

THE INTERNATIONAL WEEKLY JOURNAL OF SCIENCE

SPACE AND CHIME

First observations by Canadian telescope capture a slew of fast radio bursts **PAGES 230 & 235**



ARCHAEOLOGY

HOW THE MAYA LIVED

Meet the bioarchaeologist reshaping views of the past

PAGE 168

RESEARCH INTEGRITY

QUALITY CONTROL

Time to set up a US research policy board

PAGE 173

DRUG DISCOVERY

VIRTUAL DRUG SCREENING

A rapid route to viable candidate compounds

PAGES 193 & 224

NATURE.COM

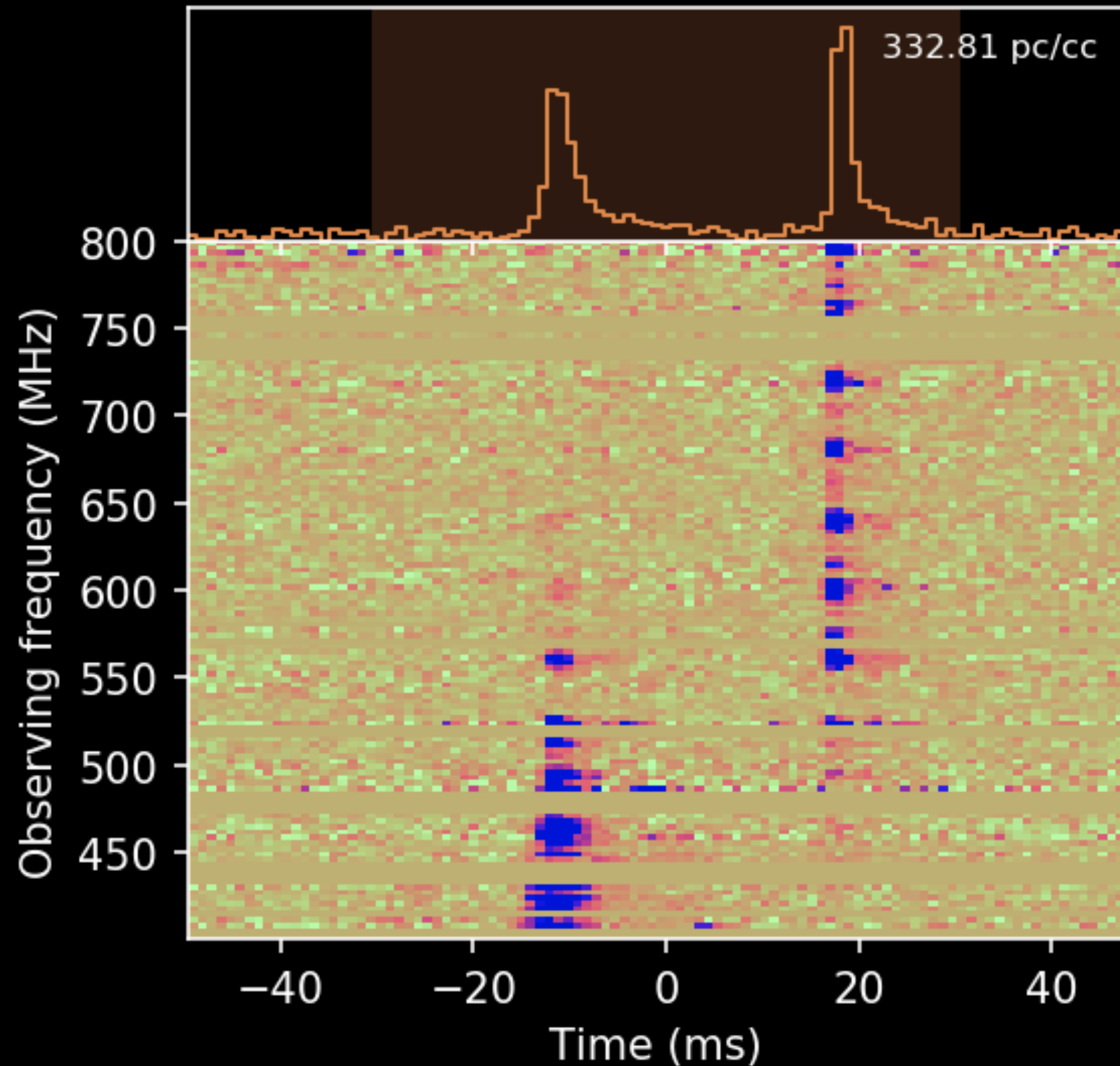
14 February 2019 £10

Vol. 566, No. 7743

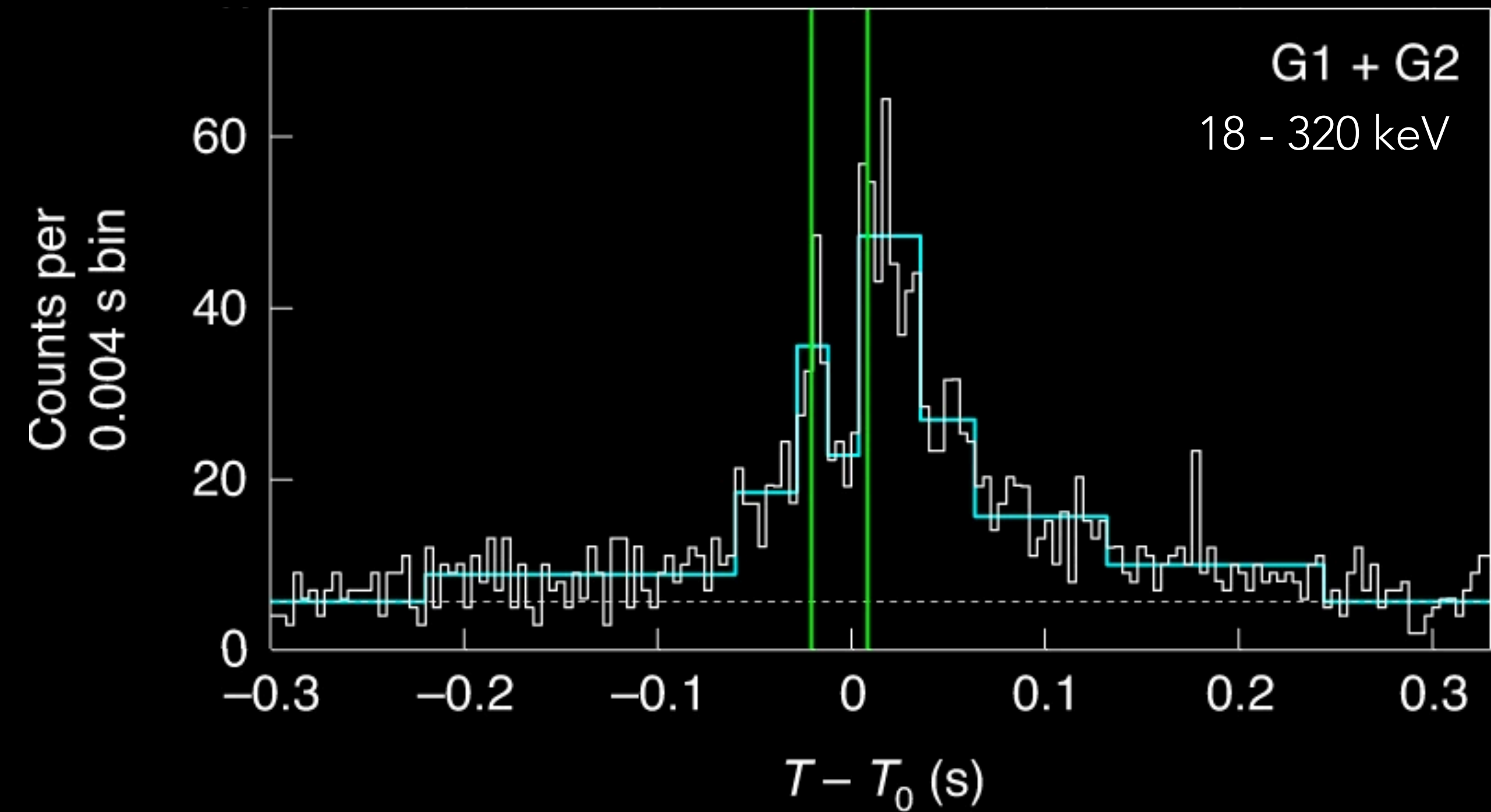


FRB FROM A GALACTIC SOURCE

CHIME/FRB



Simultaneous X-rays (Konus-Wind)



PUNCHLINE AFTER 6 YEARS OF CHIME/FRB

- At least some FRBs come from magnetars
- But phenomenology far more diverse than expected, maybe hinting at multiple populations

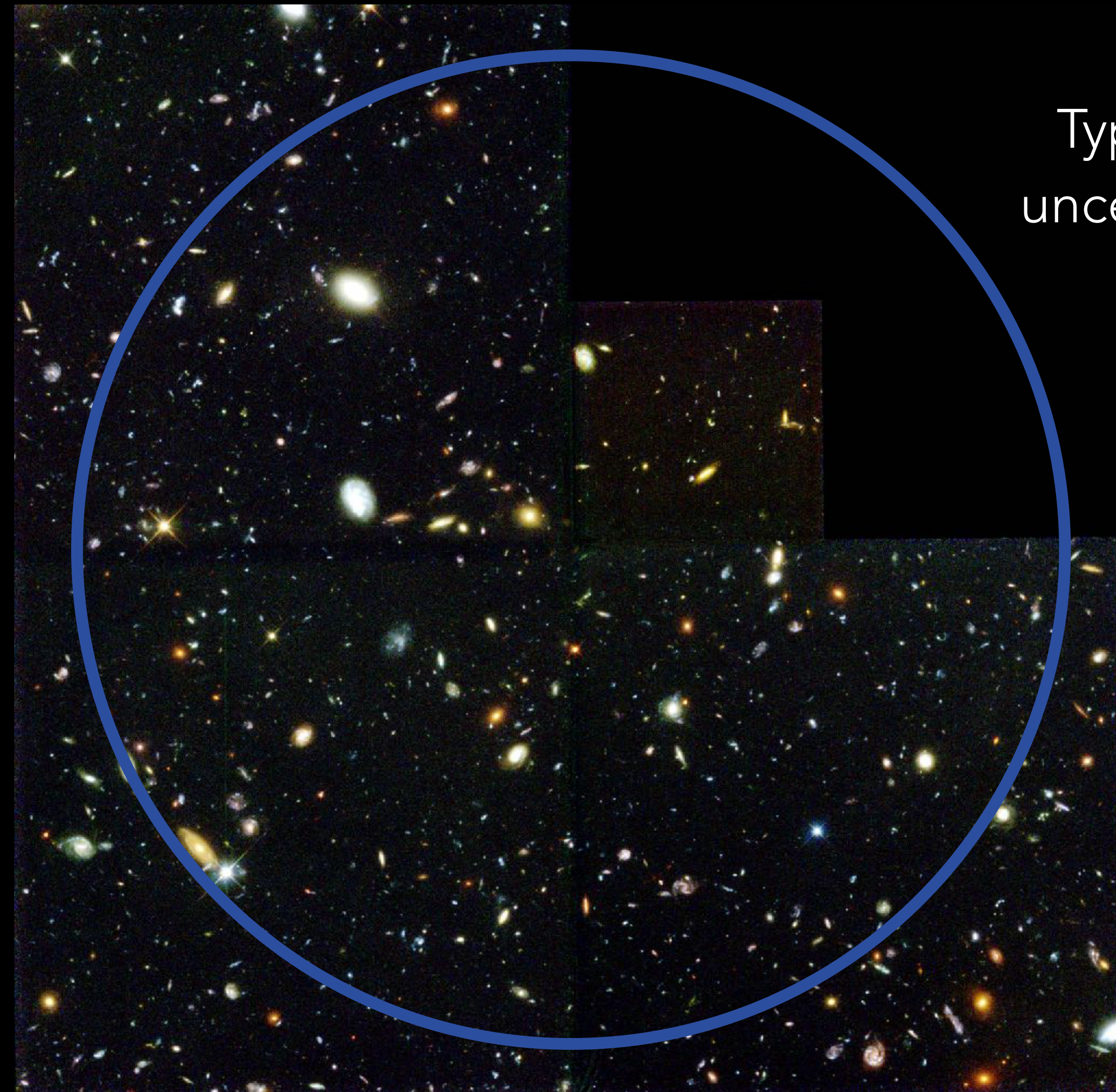


Artist's impression of a
magnetar

THAT'S A GOOD START

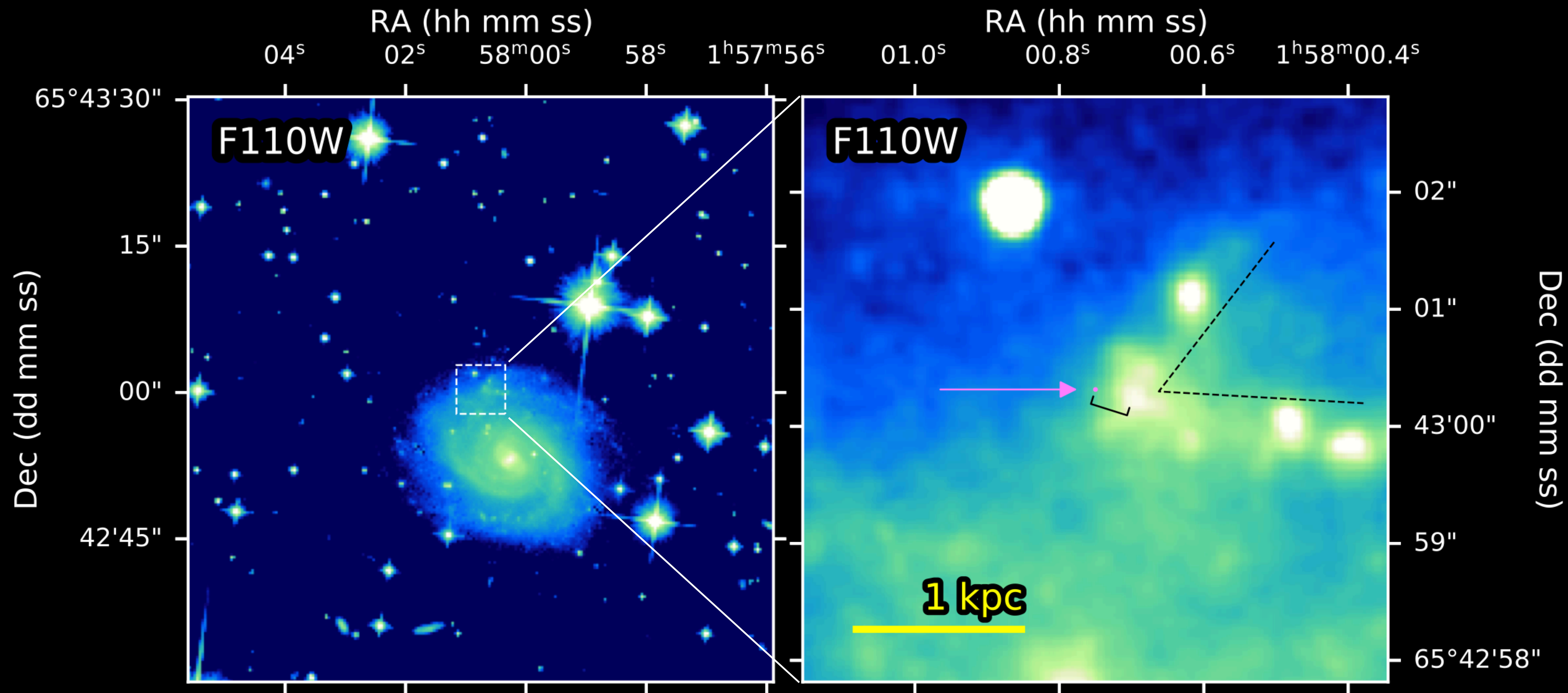
Where to we go from here?

CHIME'S WEAKNESS: RESOLUTION

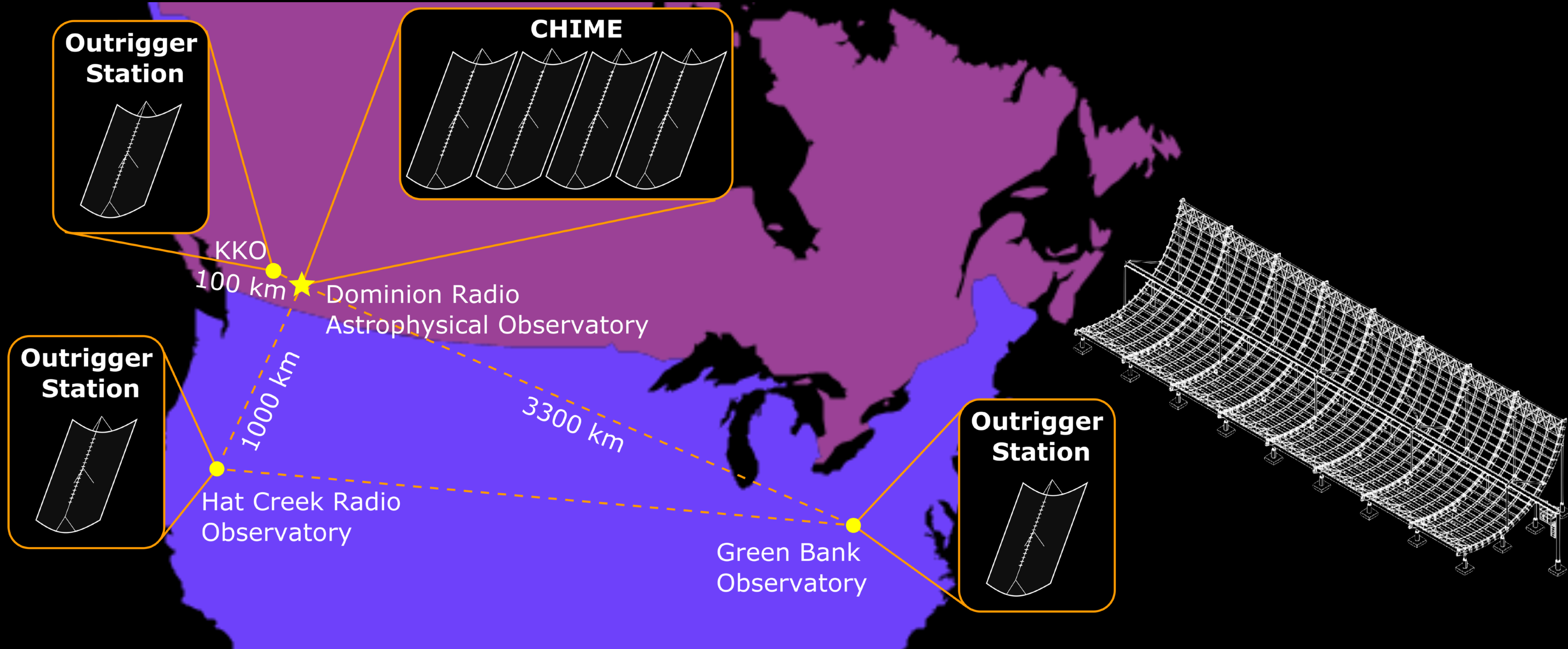


Typical localization
uncertainty ~ 1 arcmin

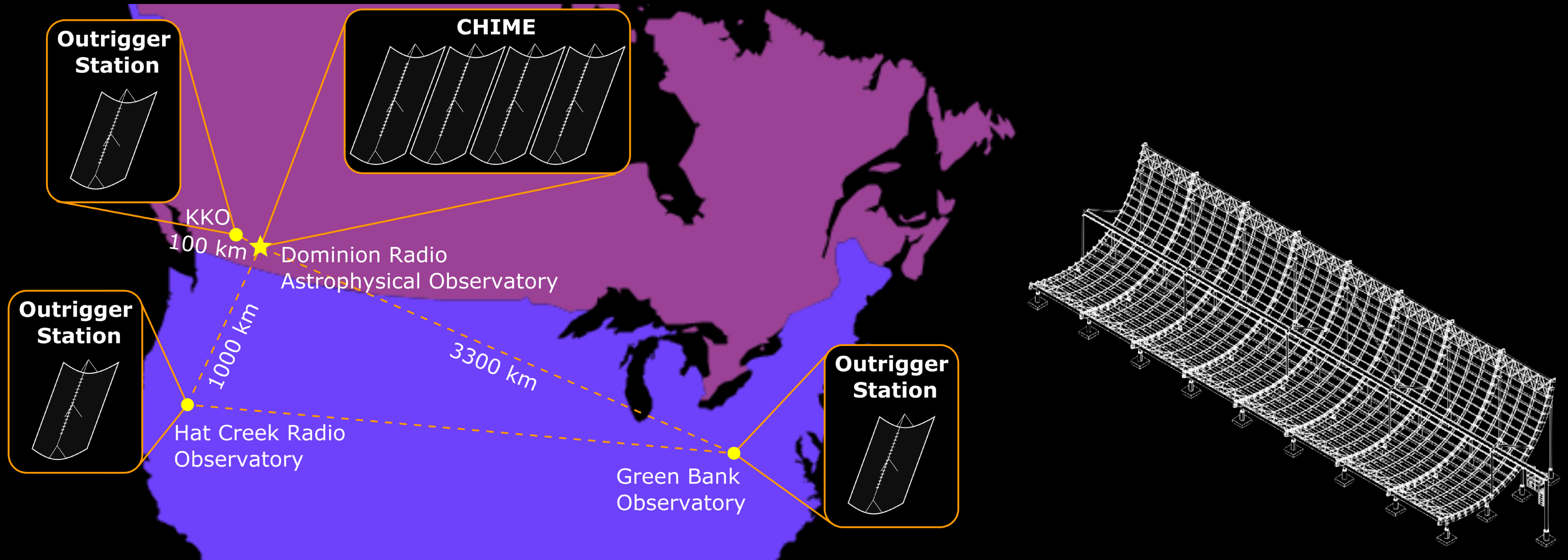
WHAT WE WOULD LIKE



CHIME/FRB VLBI OUTRIGGERS



CHIME/FRB VLBI OUTRIGGERS



- Each outrigger about 1/8 CHIME collecting area
- “Rolled” reflectors but otherwise nearly identical optical, analog, and digital systems

GOAL:

Localize Every CHIME-Detected FRB (few thousand) to < 50 mas

HAPPENING NOW IN BC

k'ni?atn k'l_stk'masqt Outrigger (KKO)
Name was a generous gift from the
Upper Similkameen Indian Band.
Listening device for outer space



Photo: NRC

HAPPENING NOW IN GREEN BANK

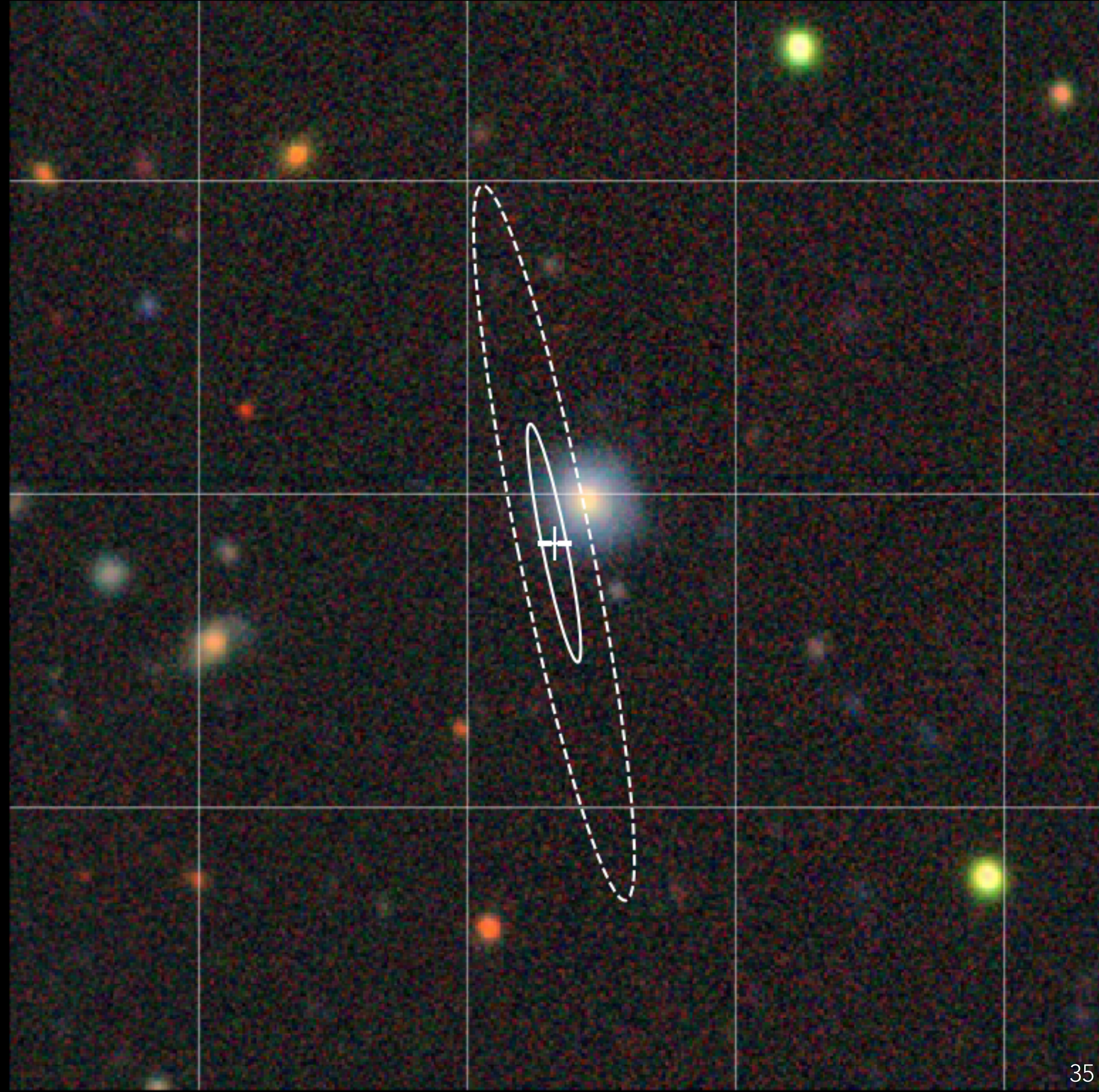


HAPPENING NOW IN HAT CREEK



KKO LOCALIZATION

- FRB localized using the first (shortest) Outrigger baseline
- Host galaxy clearly identified
- Addition of GBO, HCO baselines will greatly improve precision



FINAL THOUGHT

FRBs as Cosmological Probes

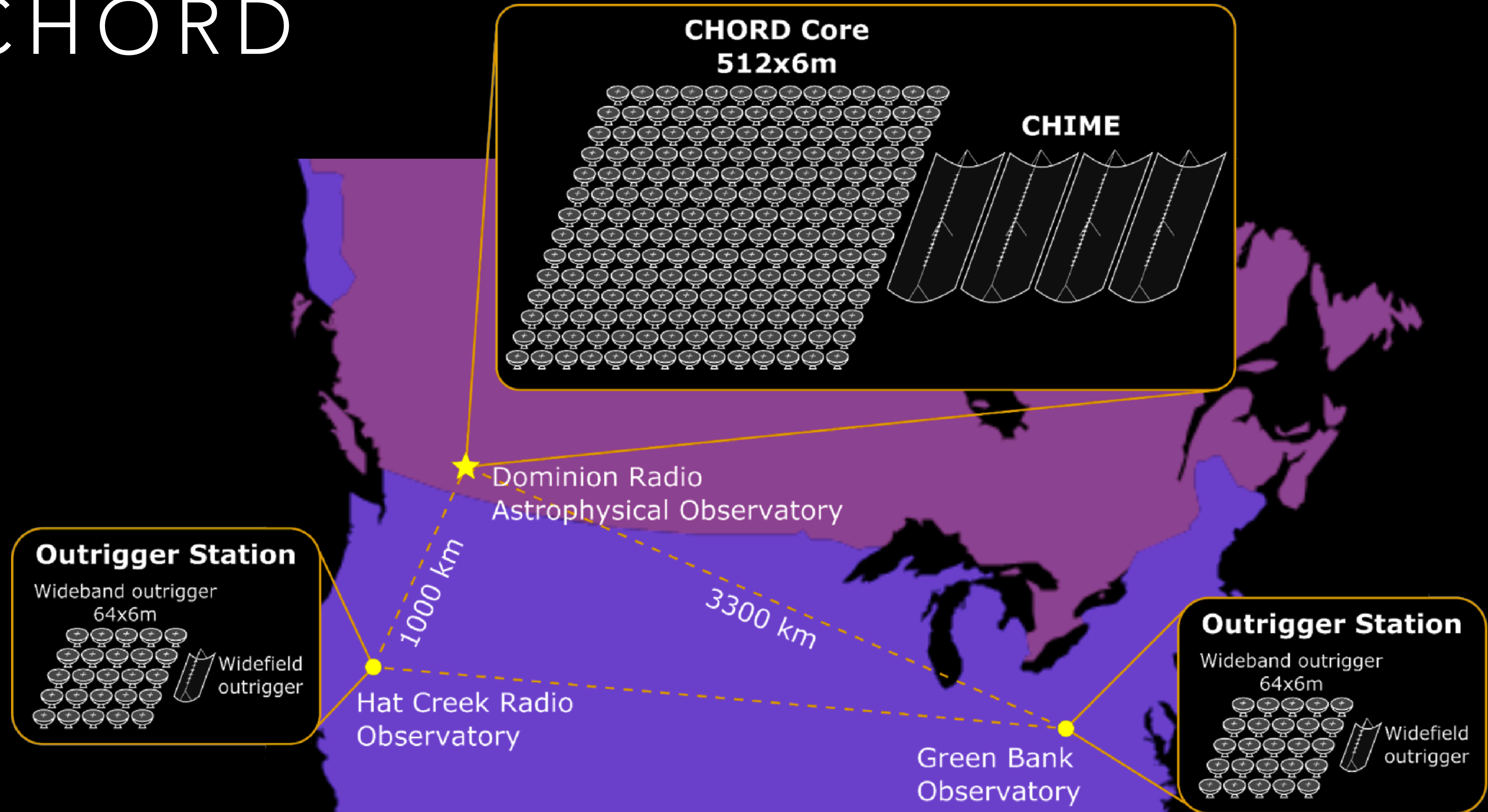
FRBS PROBE LINE-OF-SIGHT GAS

Dispersion and other propagation effects
impart distinct signatures on FRB morphology

We can leverage this to understand the
distribution of otherwise-invisible intergalactic gas

CANADIAN HYDROGEN OBSERVATORY AND RADIO-TRANSIENT DETECTOR

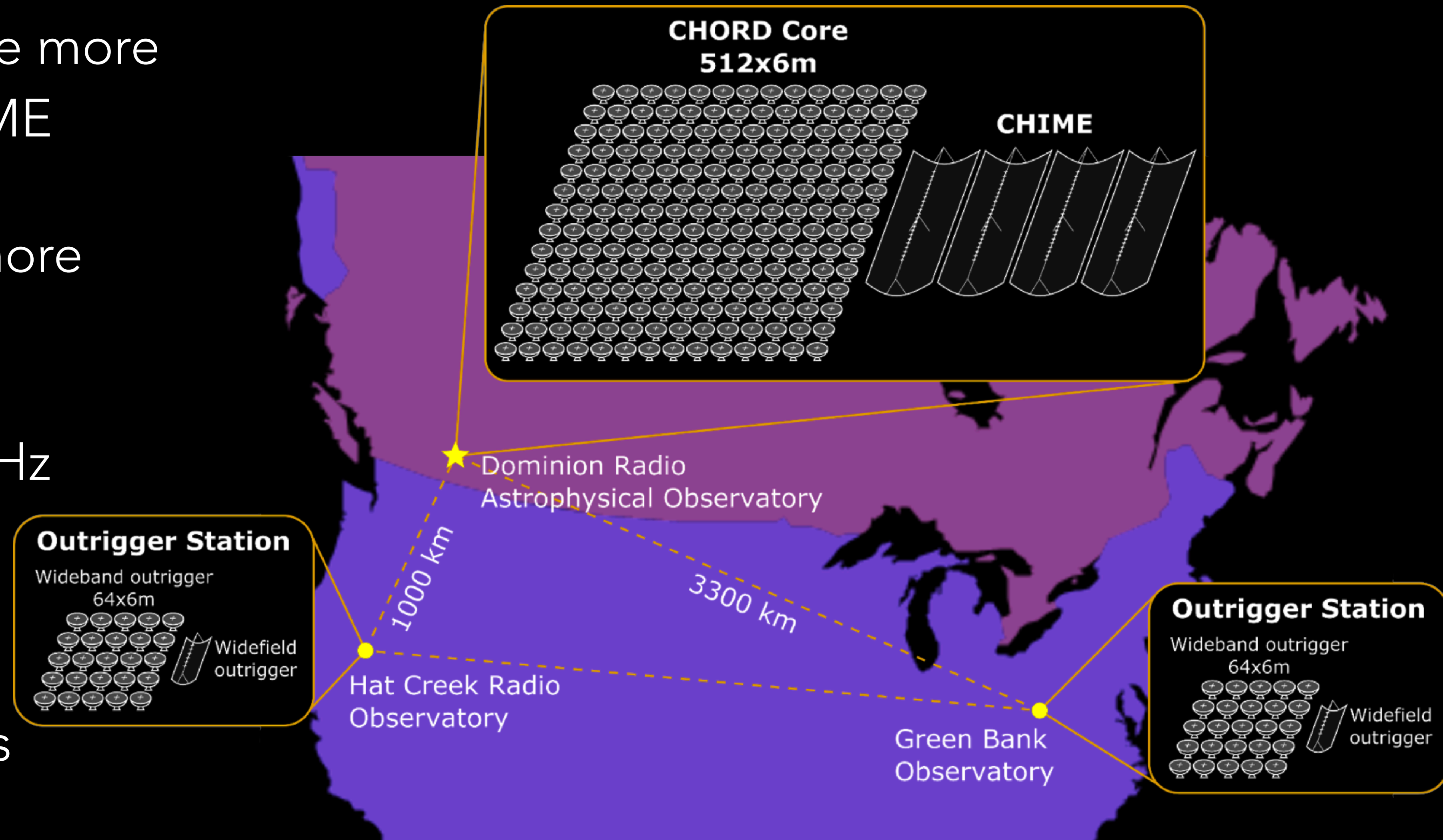
CHORD



CANADIAN HYDROGEN OBSERVATORY AND RADIO-TRANSIENT DETECTOR

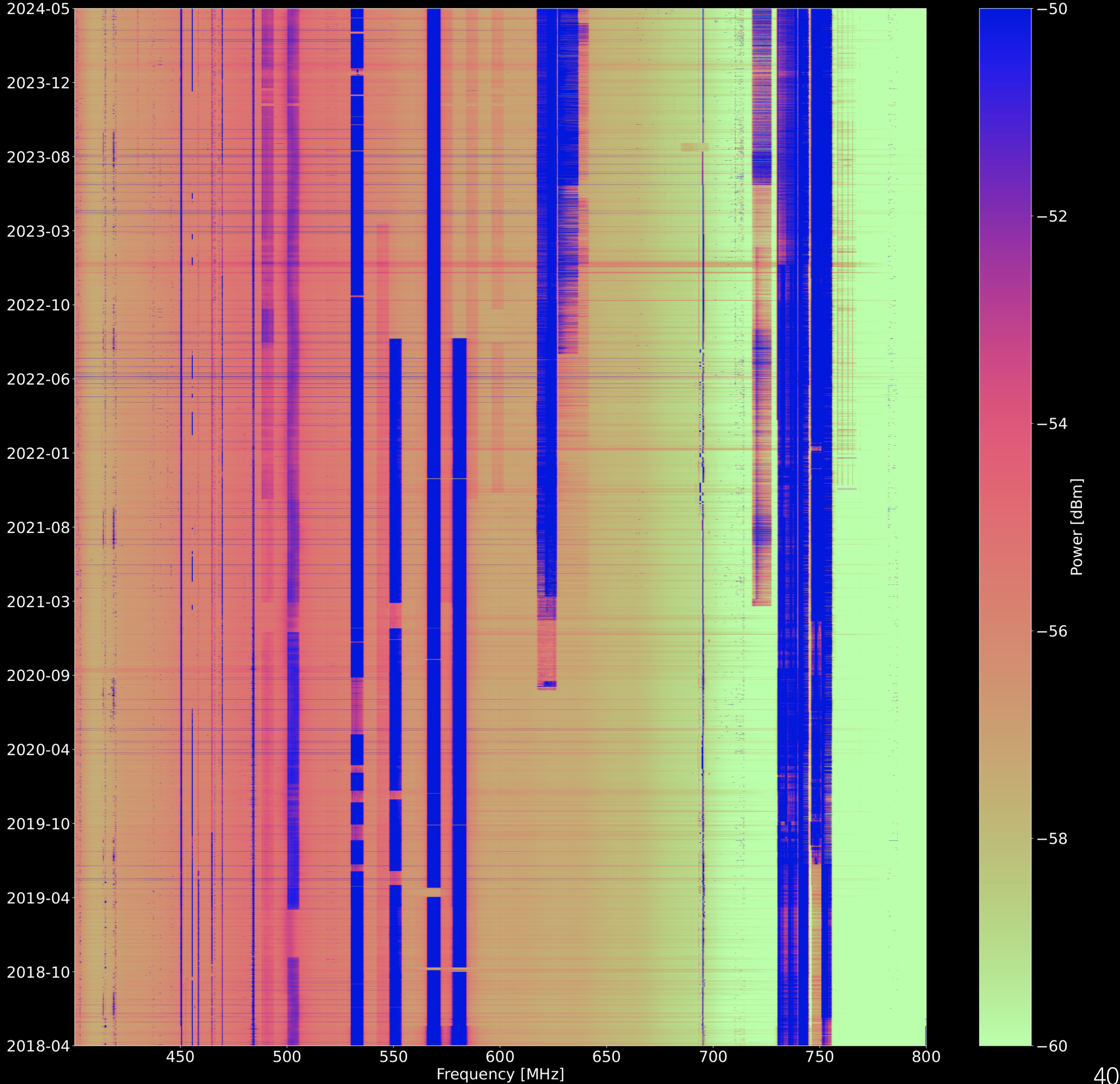
CHORD

- Order of magnitude more sensitive than CHIME
- Larger sample of more distant FRBs
- Wide 300 - 1500 MHz band
- Precisely measure propagation effects



BUT ONLY IF THE
SPECTRUM CAN
BE RESPONSIBLY
MANAGED.

Plot: Seth Siegel, McGill



CONCLUSIONS

- Fast radio bursts are a mysterious high-energy phenomena
- CHIME is discovering thousands, showed some come from magnetars, but evidence for multiple populations
- CHIME VLBI Outriggers here soon, providing rich spatial information that will dramatically improve our understanding
- FRB data from CHIME and future instruments like CHORD will be a unique probe of the large-scale distribution of intergalactic gas

