DSA-2000

First UVEX Community Workshop

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Caltech SCHMIDT FUTURES NANOGrav Physics Frontiers Center NSF

A world-leading radio survey telescope and multi-messenger discovery engine

- 2000 x 5m dishes
- Hot Creek Valley Nevada
- Frequency: 0.7 - 2 GHz band
- Spatial resolution: 3.3 arcseconds
- **Highly optimized for surveys**

- First light: 2026
- Key surveys: 2027 – 2032

- Design: $6.5m (Schmidt Futures)
- Construction costs: $144m

Unparalleled Survey Speed

31,000 deg^2 to 500 nJy

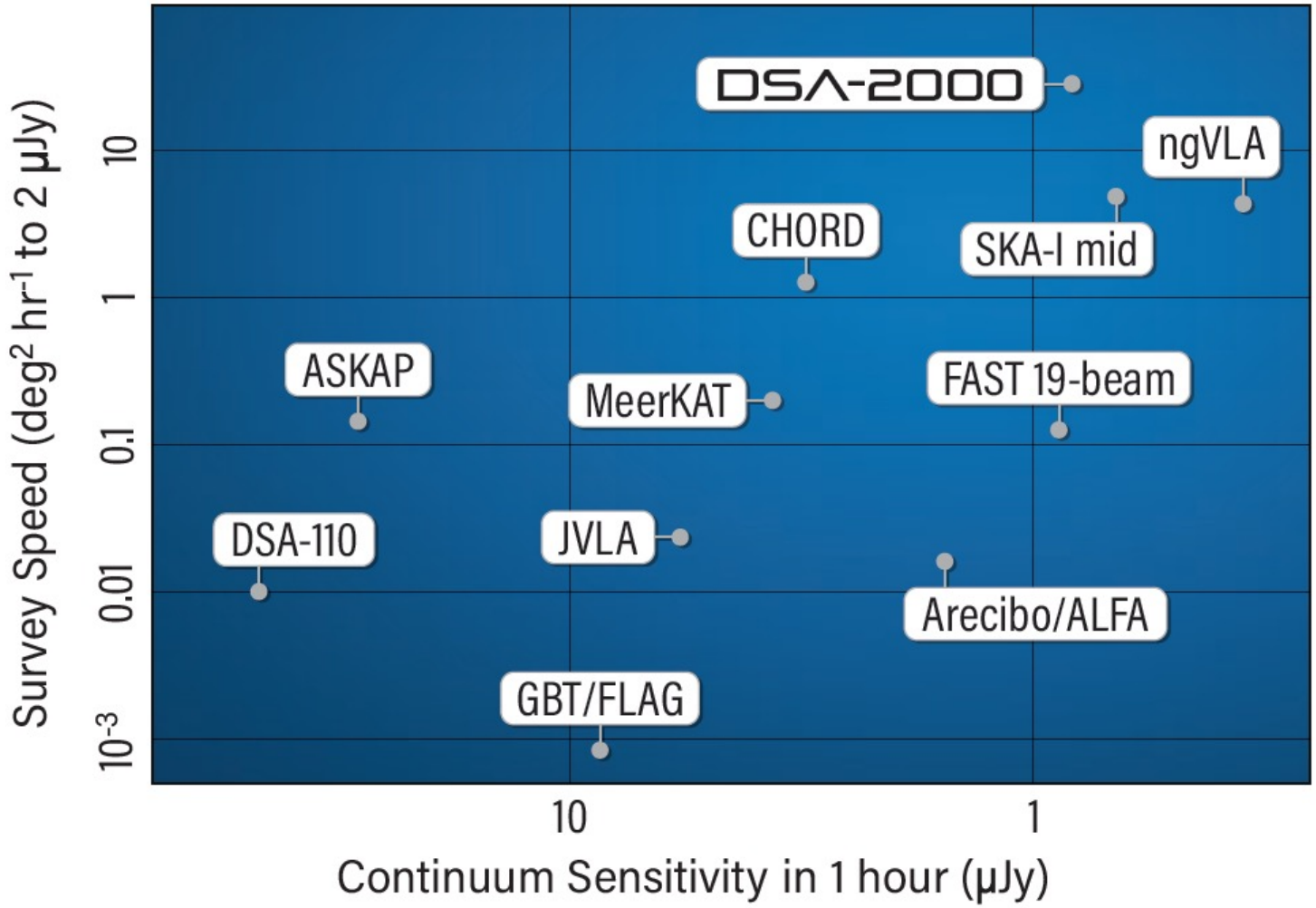
>1 billion radio sources (Stokes IQUV)

~10 million galaxies in HI

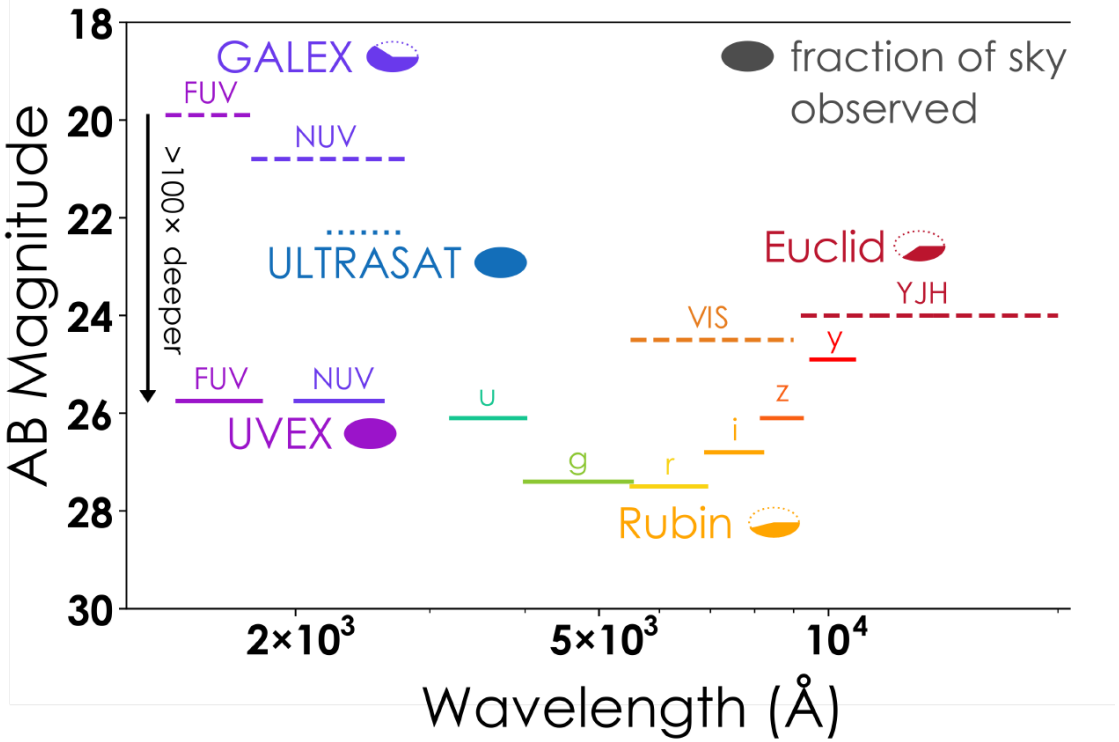
~10^5 FRBs and pulsars

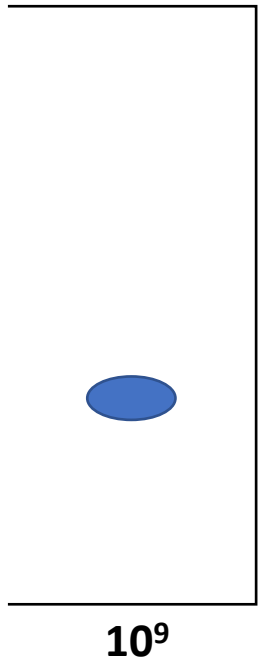
Enabled by two key technologies:

- A “radio camera” digital back-end
- A cryo-free antenna/receiver



Legacy of Deep Synoptic Surveys





500 nJy
(AB: 24.7)

UVEX

Field of view: 3.1 deg
Resolution: 3.3”
Integration time: 15 minutes
16 epochs

DSA-2000

Continuous and Commensal

Every 15 minutes (14k images):

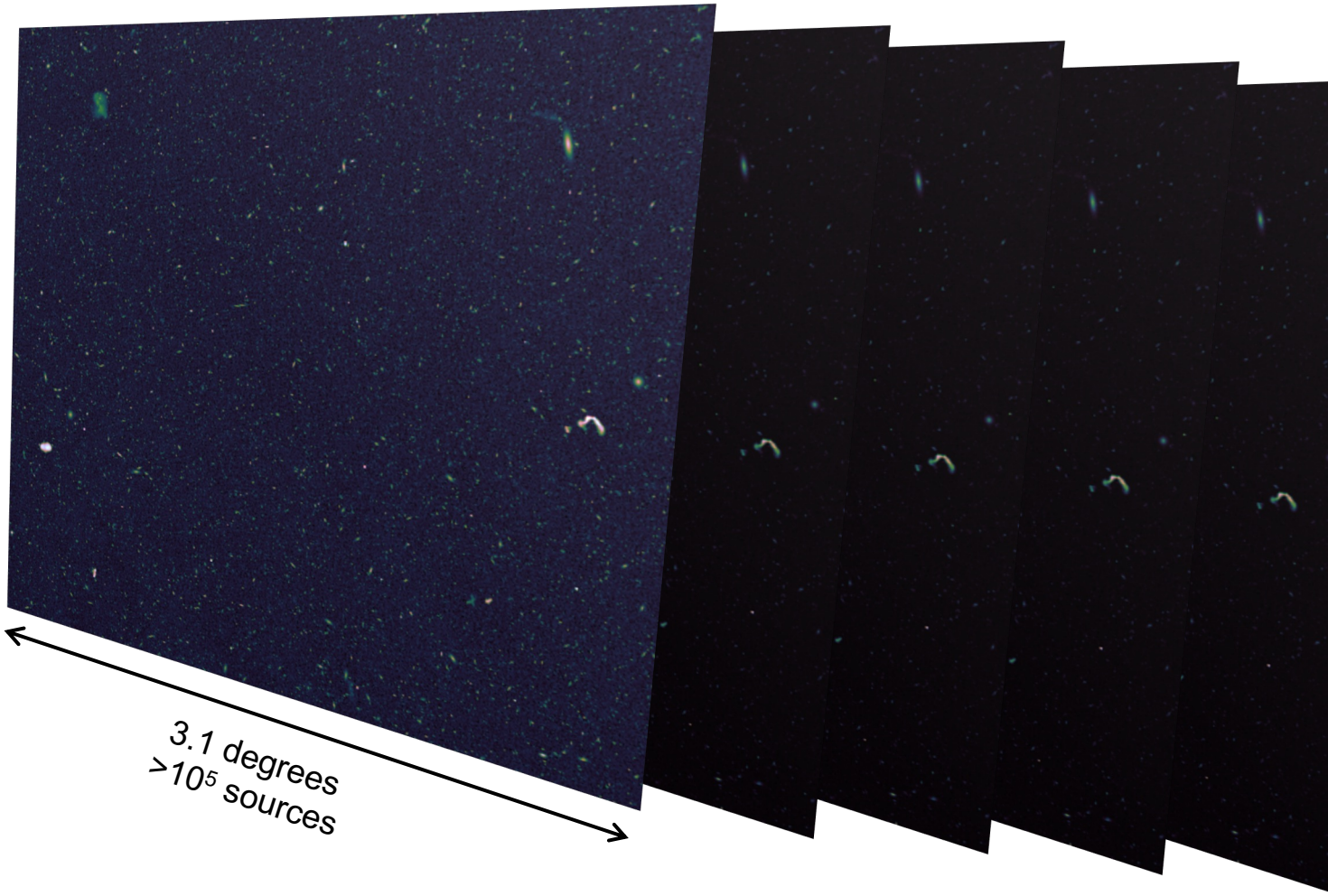
Continuum
2 μJy rms per epoch (10 spectral windows)

Spectral Line

Galactic HI	*0.25 km/s ($R\sim10^6$)*
Local universe HI (<100 Mpc)	*1.75 km/s ($R\sim10^5$)*
High-redshift HI (z<1)	*28 – 56 km/s ($R\sim10^4$)*

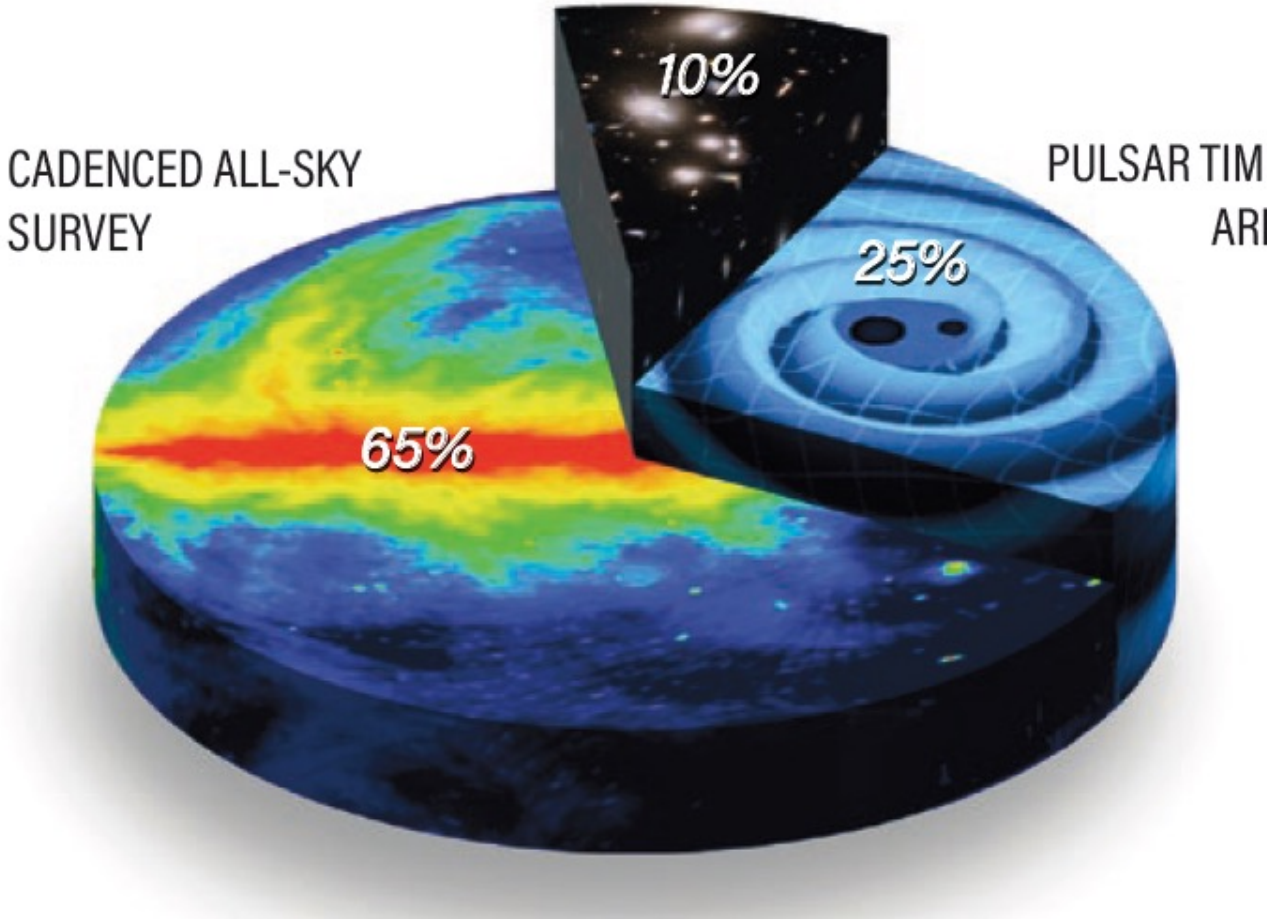
Polarization
Stokes IQUV images (605 x 2.05 MHz)

Fast Time Domain
FRB search
pulsar search



5-Year Surveys

Assumes 65% usable bandwidth and 80% usable time



GW (Triggered)

Deep: 30 deg^2 to 50 nJy

30,000 deg^2 to 500 nJy

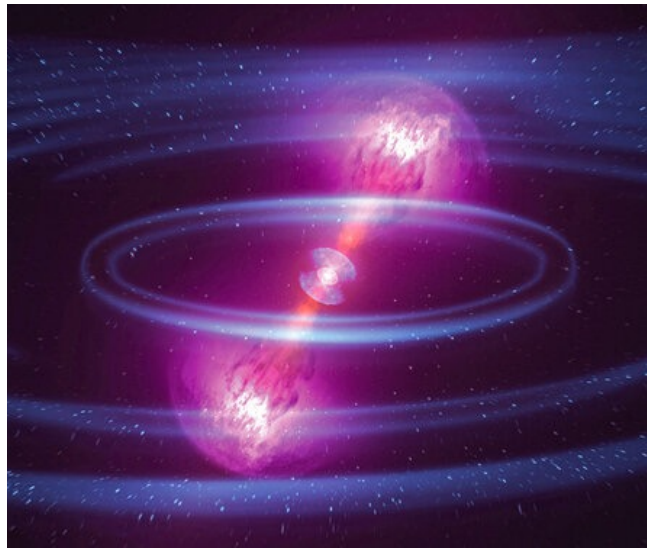
16 epochs

~2,000 deg^2 to 200 nJy

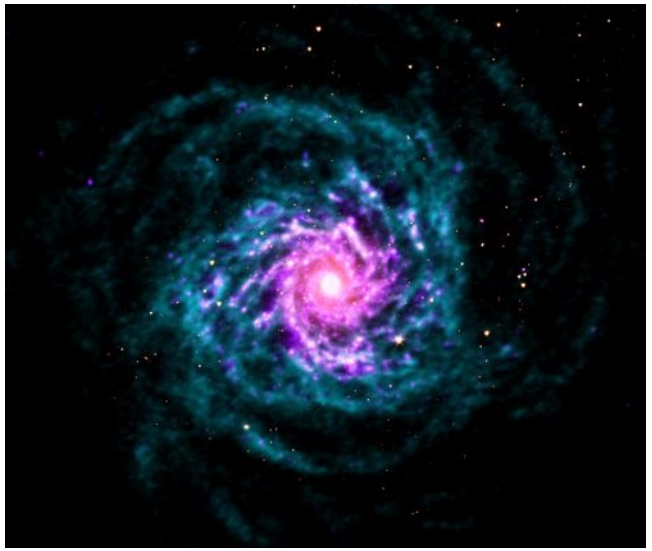
~weekly cadence

DSA-2000 Key Science

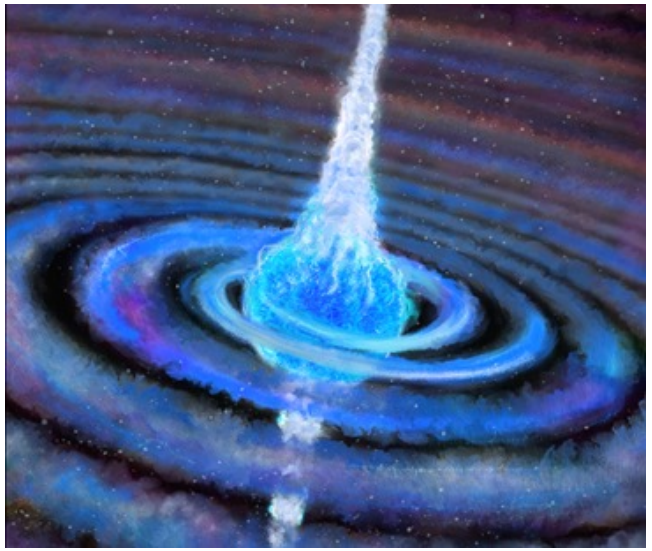
Multi-Messenger Astronomy



Our Cosmic History



The Dynamic Radio Sky



New Messengers and New Physics

Cosmic Ecosystems

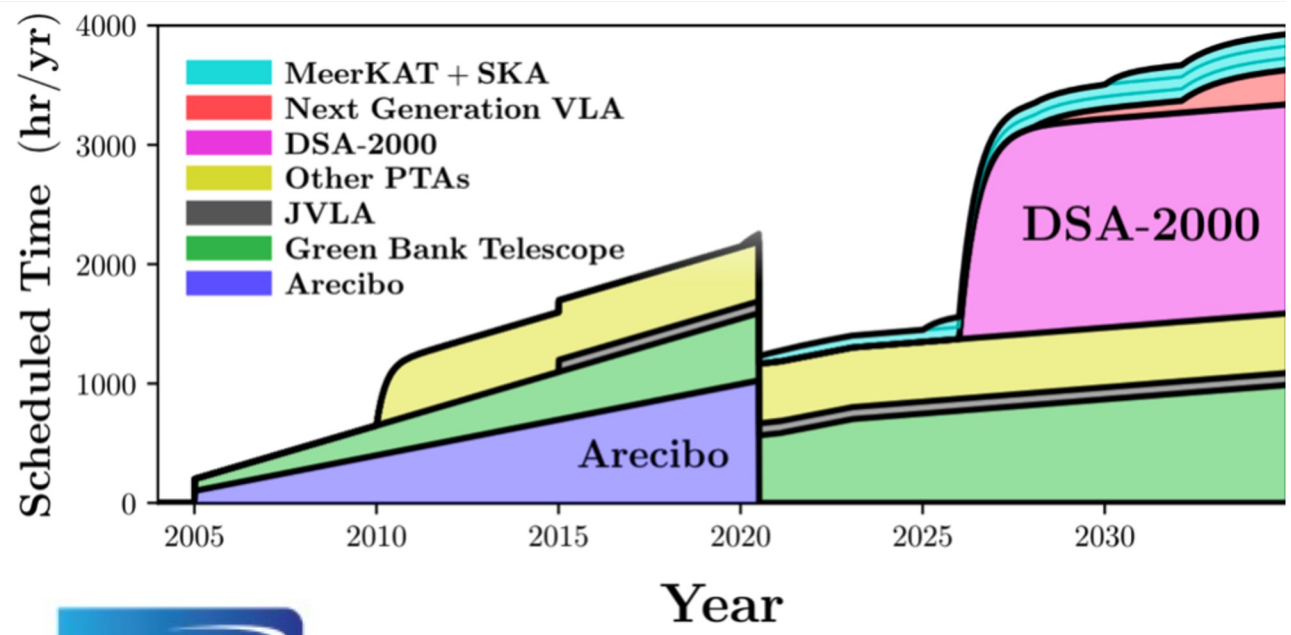
New Messengers and New Physics

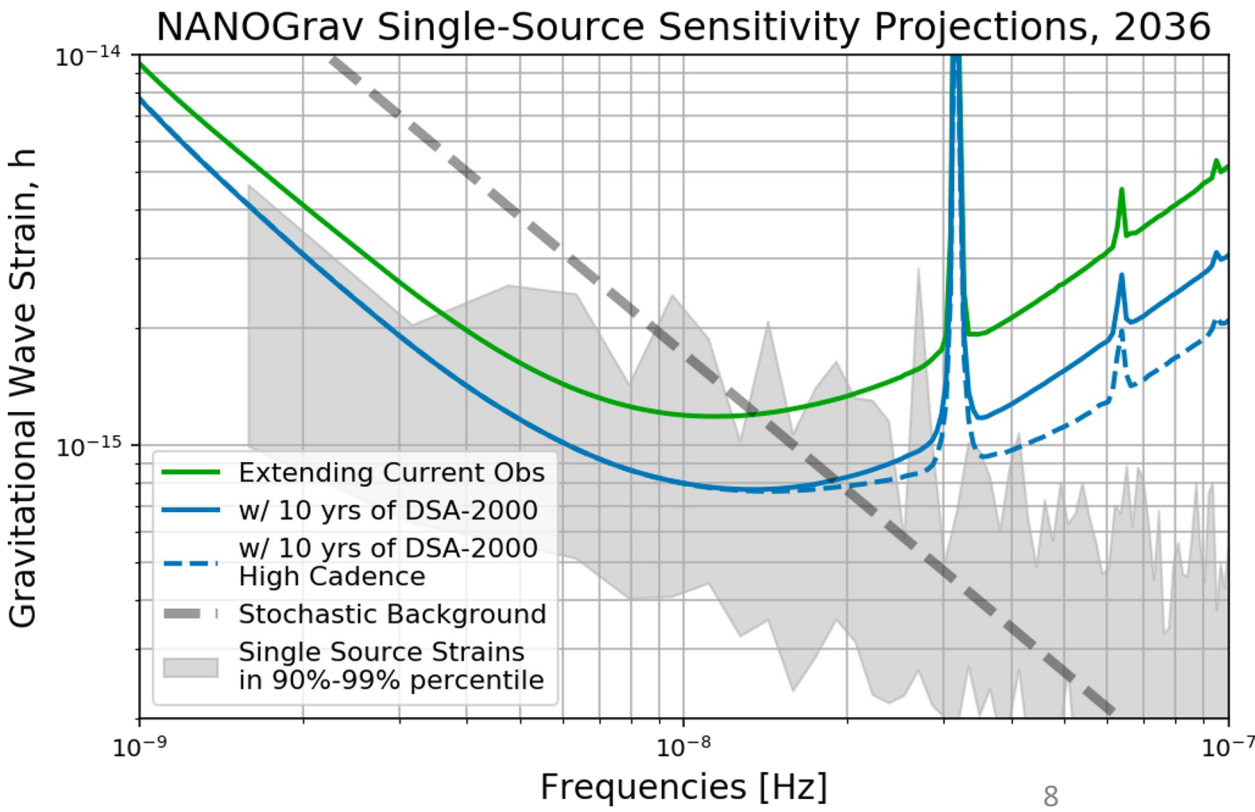
Worlds and Suns in Context

Pulsar Timing: NANOGrav

Characterize the nanohertz gravitational wave (GW) universe through high-precision radio timing of millisecond pulsars

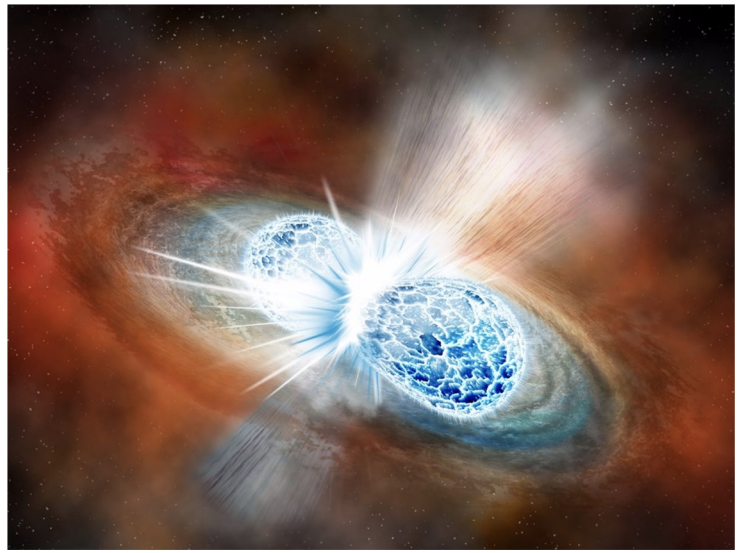
- Supermassive black hole binaries [stochastic background, continuous wave signals, bursts with memory
- Last parsec problem, merger rates, SMBHB populations
- Exotic sources and gravity beyond GR





LIGO-Virgo-KAGRA Compact Binary Coalescences

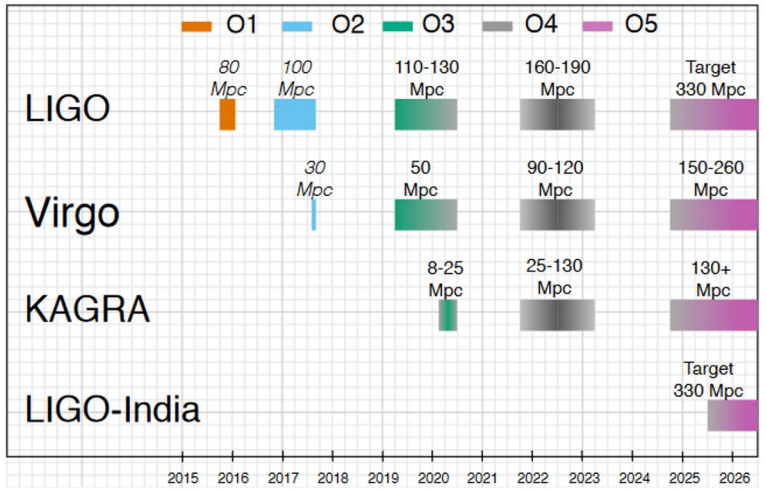
2017



GW170817

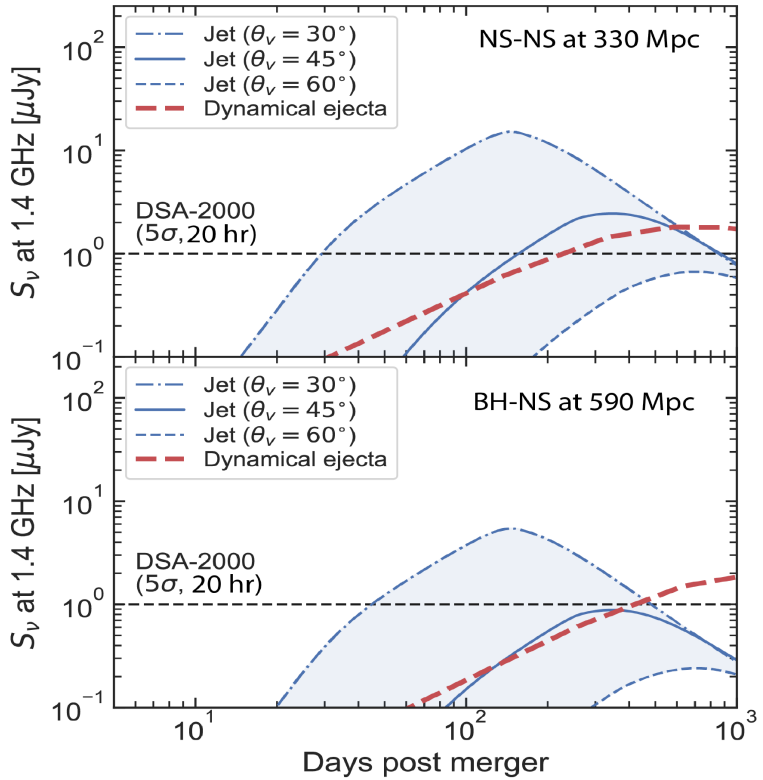
Radio afterglow played a key role in confirming a classical off-axis sGRB

No confirmed EM counterparts in O3 (Kasliwal et al. 2020)



Median EM afterglow is 10x fainter
Median localization area is 100x smaller

2027



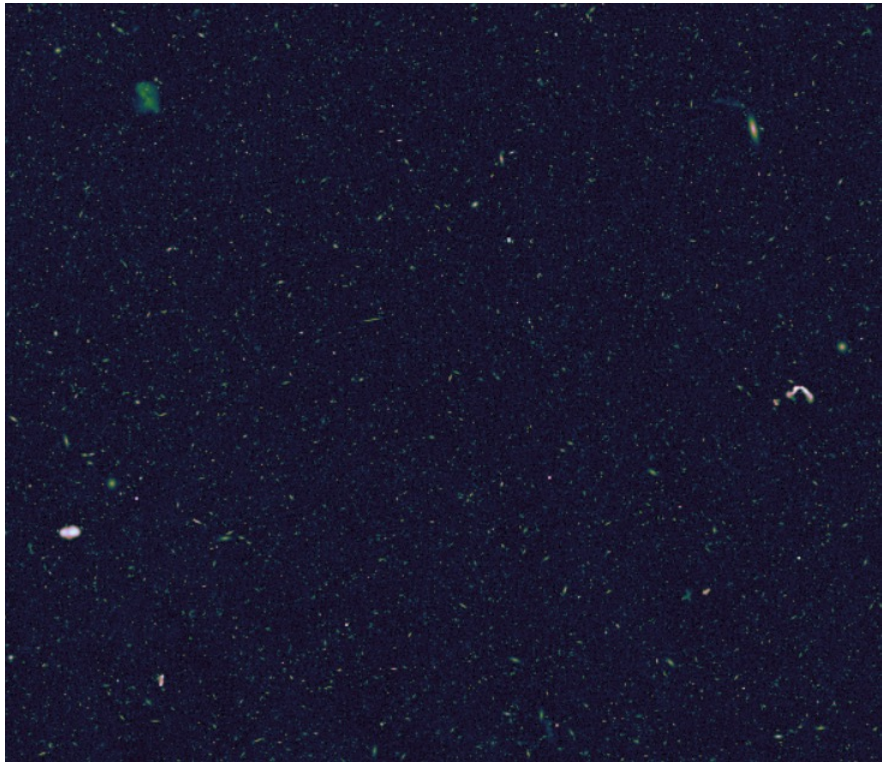
DSA-2000 can map median localization in 2x pointings

Synergies: characterizing structured outflows

DSA-2000 can detect median events to the full range of a 5-detector array

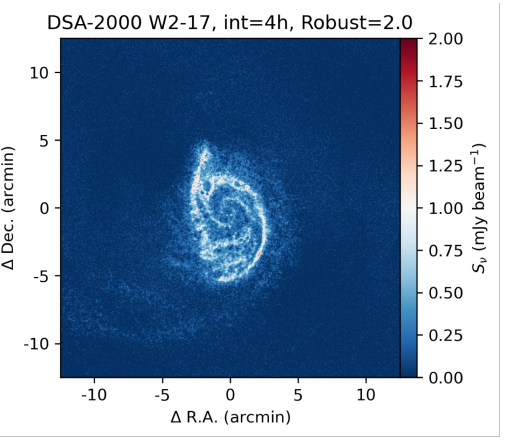
Our Cosmic History

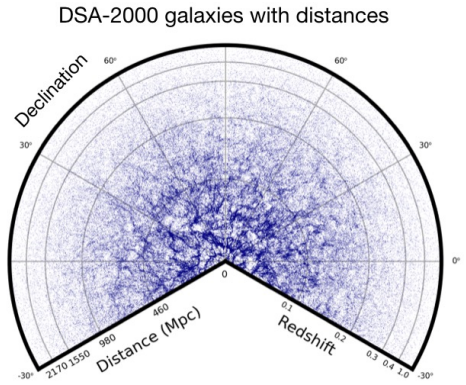
(Credit: Yuping Huang, Tyrone McNichols, Fabian Walter, Marcel Neelemans)



1 billion radio sources (full polarization)

- Trace star formation back to the epoch of reionization
- Trace the effects of AGN on their host galaxies and the formation mechanisms of SMBHs
- Trace large-scale structure in continuum, polarization, HI





- **10 million galaxies in HI**
- Few 100k galaxies (<100 Mpc): gas contents, kinematics, spatial distribution
- 10 million galaxies (z~1): First robust measurement of the galaxy HI mass function beyond the local Universe.

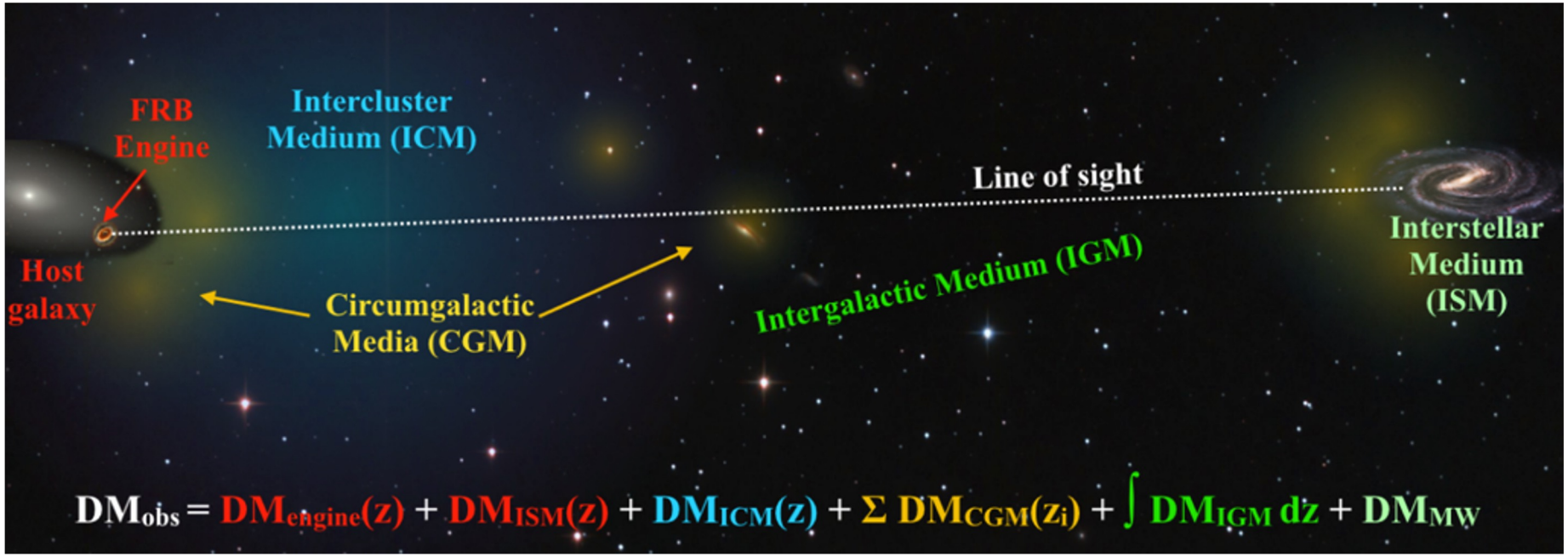
Synergies: tracing star formation and cool gas history of the Universe

Fast Radio Bursts

- FRBs are a window into an unknown process associated with compact objects
  - **What are the progenitor(s) of FRBs**
- FRBs trace the contents and physical conditions in gas along their sightlines
  - **What is the distribution of matter of matter around and in between galaxies**

- DSA-2000 will localize ~10^4 FRBs in a 5-year survey (many 10^4 pulsars)

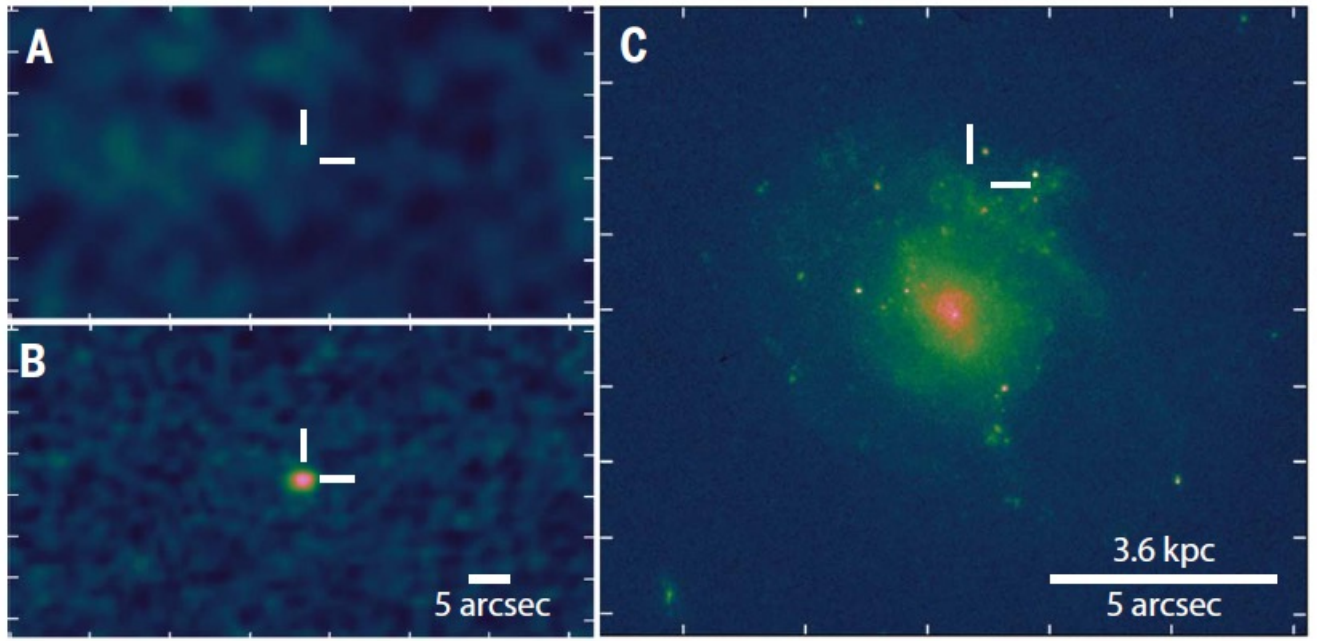
Ravi+19

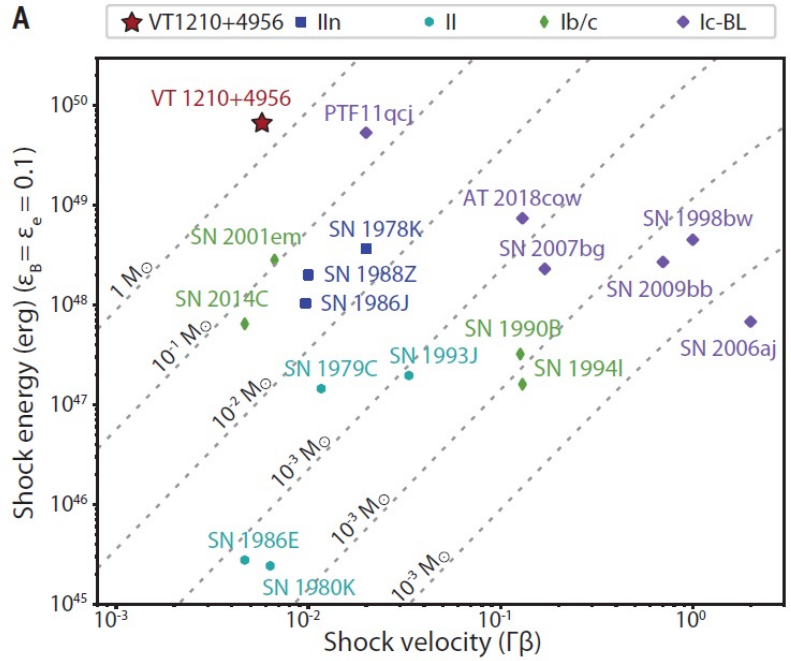


Slow Transients and Variables

- ***The Radio Transient Sky is finally revelaing itself. Examples from VLA Sky Survey (VLASS):***

- *A merger-driven core collapse supernova (Dong et al. 2021)*
- *An extragalactic pulsar wind nebula (Dong & Hallinan 2023)*
- *A candidate orphan GRB (Law et al. 2019; Mooley et al. 2021)*
- *A growing sample of radio-discovered TDEs (Anderson et al, 2019, Ravi et al. 2021; Somalwar et al. 2021)*
- *Quasars transitioning from radio-quiet to radio-loud on decade timescales (Nyland et al. 2020)*
- *Luminous afterglows to historical supernovae (Stroh et al. 2021)*





(Dong. GH et al. 2021)

Synergies: tracing mass loss centuries pre-supernovae

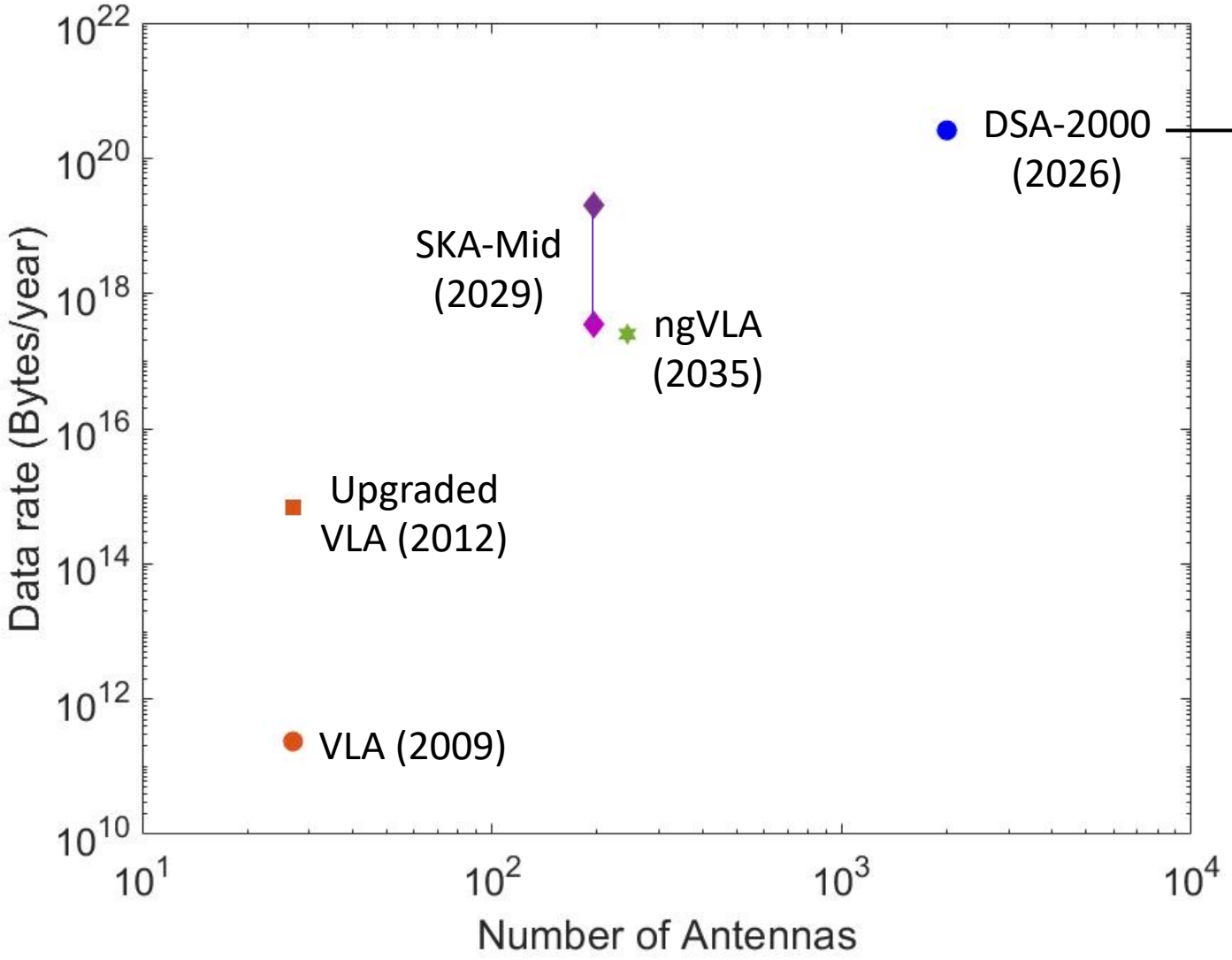
Key Technology 1

A low-cost uncooled antenna/receiver

DSA-110

NSF MSIP: DSA-110 will localize 100 FRBs/yr to <3 arcseconds

Radio Camera Motivation

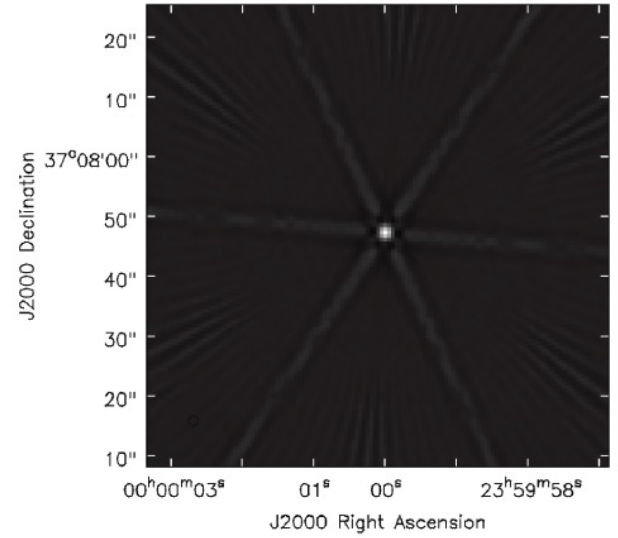


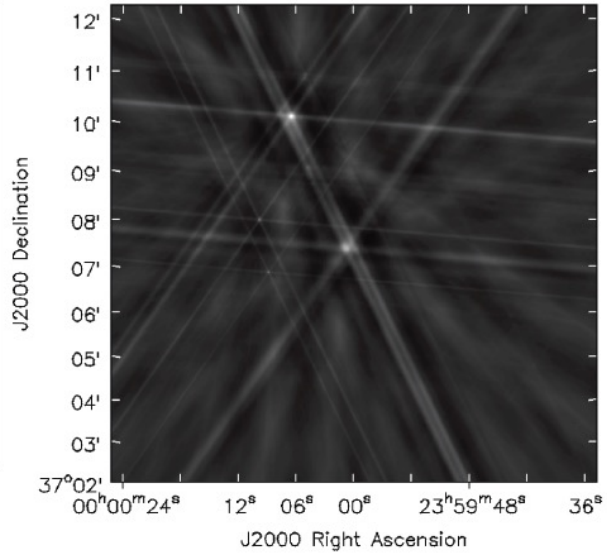
0.7 Zettabytes/yr of voltage data

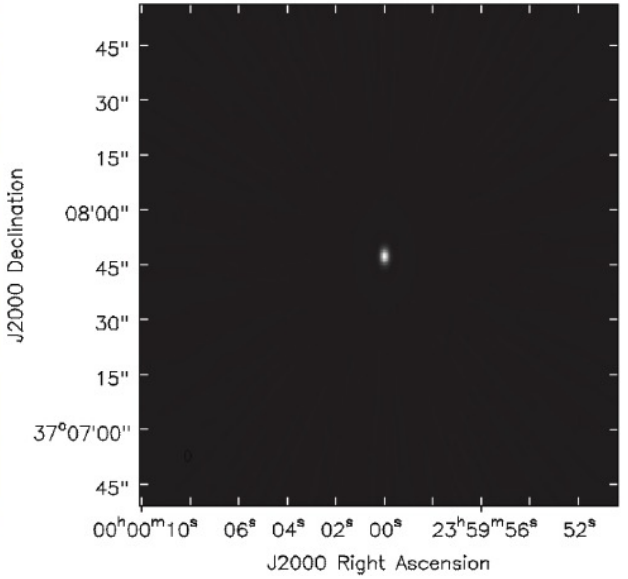
20 Exabytes/year of visibility data

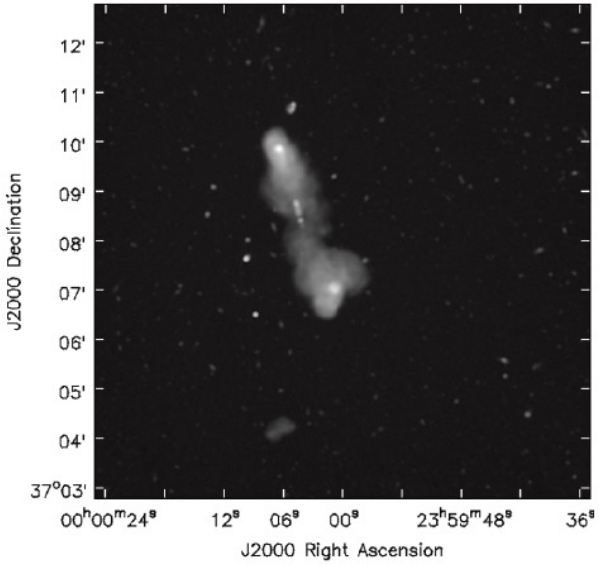
$100 million per year in storage costs

Key Technology 2: A Radio Camera







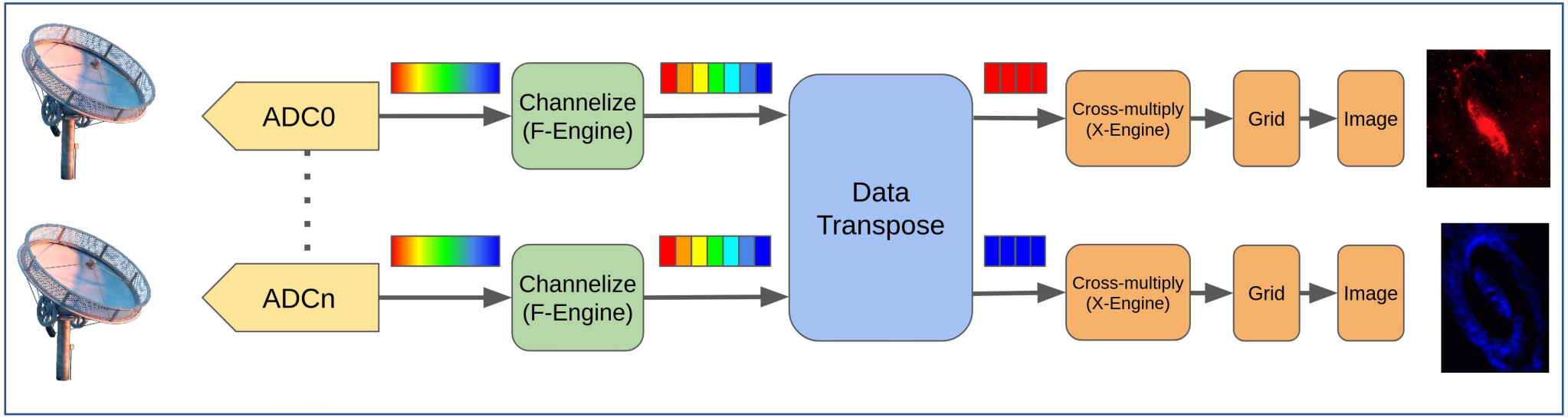


- No need for visibility-based deconvolution

- Enables a deterministic stream processing pipeline that creates images

The First Radio Camera

Real-time



50 Petabytes of image data over 5 years

500 TB Public Archive

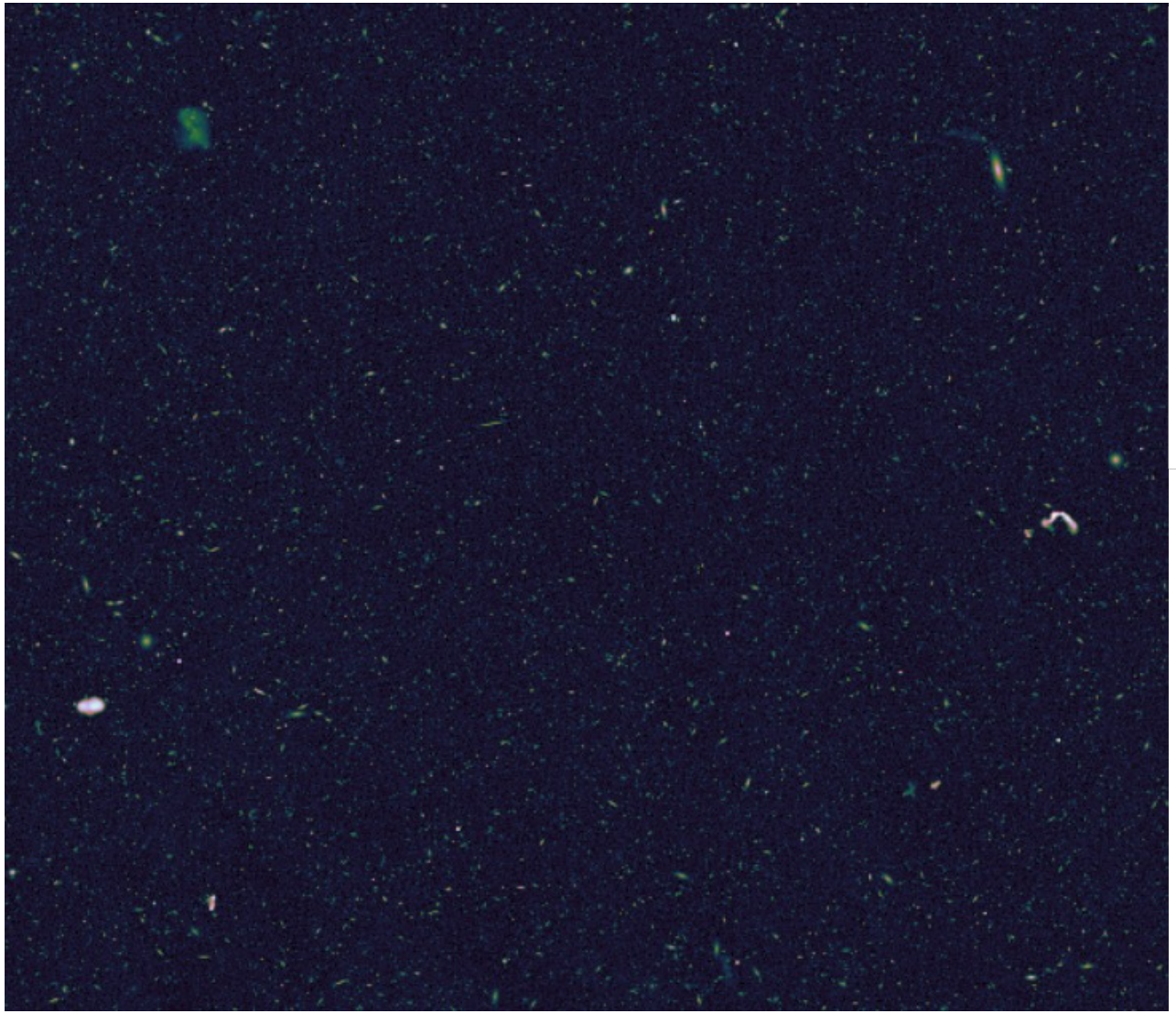
2000 x ADCs, FPGAs

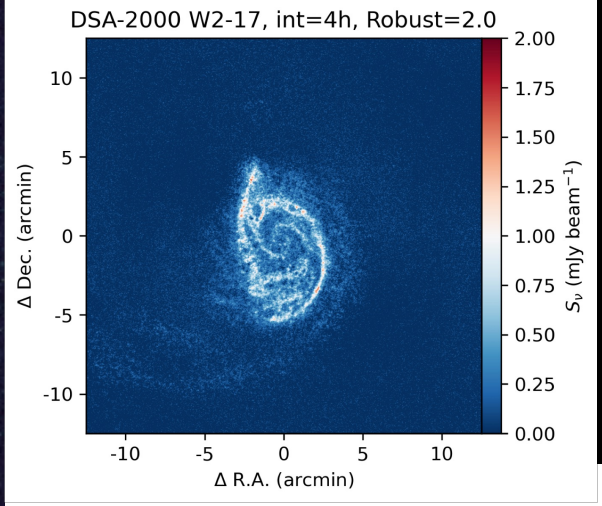
55x 100 GbE switches, cables

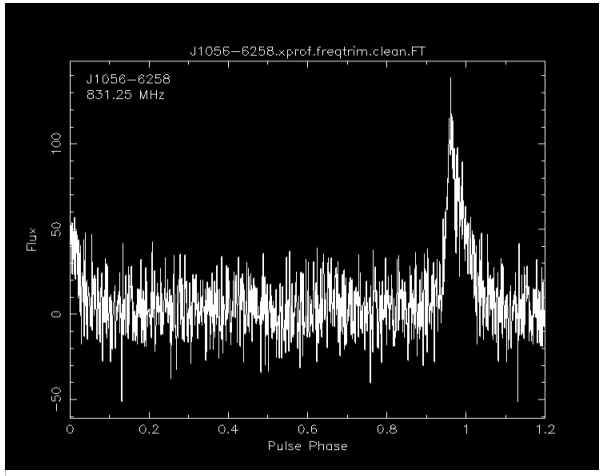
5160 NVIDIA GPUs (860 servers)

Huge processing power with excellent power efficiency

Data Archive: IPAC







- Continuum: Photometry, lightcurves, spectral fits

- HI: Galaxy spectral data cubes

- Polarization cubes

- Pulsar timing: folded profile with 2048 phase bins, 1 second resolution

- FRBs: dedispersed time-frequency data

DSA-2000 is targeting rapid and complete data releases for all data products