

ARECIBO OBSERVATORY  
PUERTO RICO  
SRI • UMET • USRA



# Arecibo Now and in the Future

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Arecibo Observatory

# Layout

- Current status
- Scientific opportunities
- Future plans

# Current Status – Background

- NSF AST Senior Review (2008)
  - Recommended cut in AST funds from 10M to 4M, closure if no new partners found
  - New funds found from NASA for planetary radar (3.5M)
  - Increased contribution from NSF AGS for atmospheric science (from 2M to 4M)

# Current Status – Background

- NSF AST Portfolio Review (2012)
  - Arecibo included in recommended portfolio for both scenarios A (\$269M in FY2017) and B (\$227M in FY2017)
    - Request for FY2017 was \$247M for AST
  - Recommended “AST should reevaluate its participation in Arecibo ... later in the decade in light of the science opportunities and budget forecasts at that time”



# Current Status – EIS

- NSF started Environmental Impact Statement (EIS) process in May 2016
- Draft EIS published in November 2016
- Final EIS expected in May 2017
- Only looks at environmental impacts, no assessment of science opportunities

# Current Status – EIS

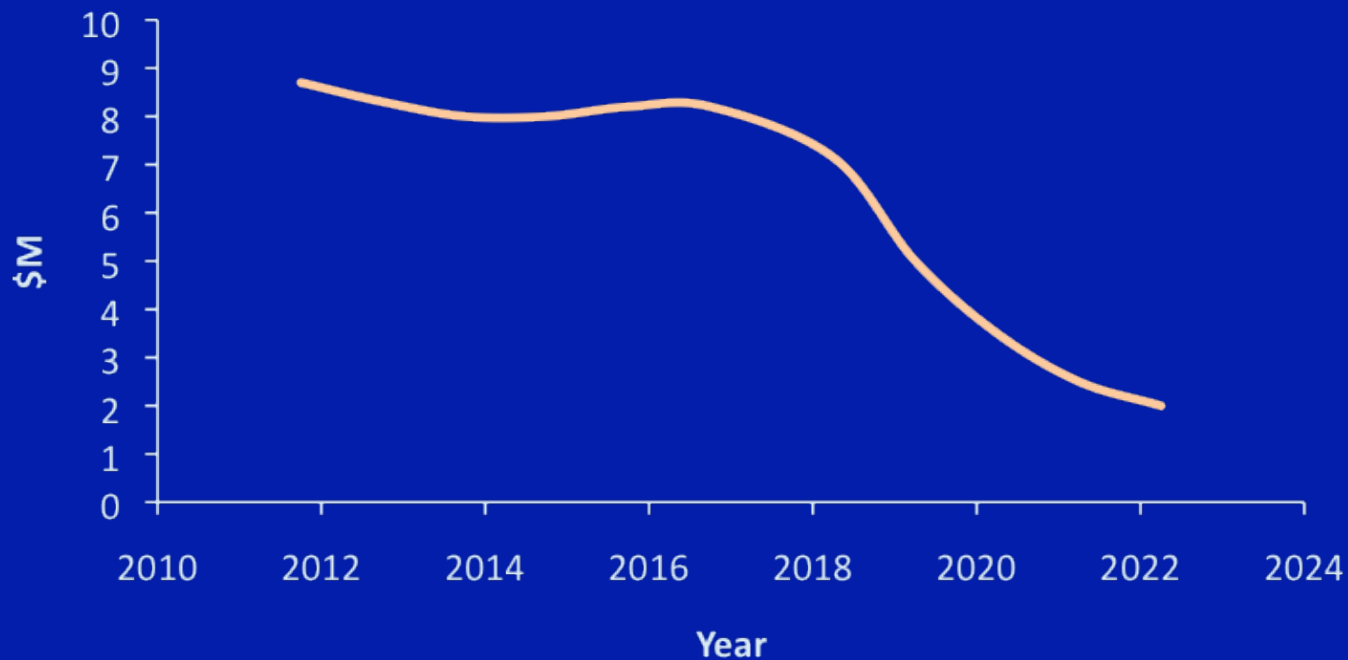
- Six scenarios:
  - Continued NSF investment (no-action)
  - Collaboration for continued science-focused operations (preferred alternative)
  - Collaboration for education-focused ops.
  - Mothballing
  - Partial deconstruction
  - Full deconstruction

# Current Status – CFP

- NSF issued a call for proposals for the management of Arecibo on January 25
- Deadline April 25, extended to May 4
- NSF said at AAS town hall that they would use responses to the call to assess science opportunities
  - This will feed into a “Record of Decision” on the EIS (possibly in August)

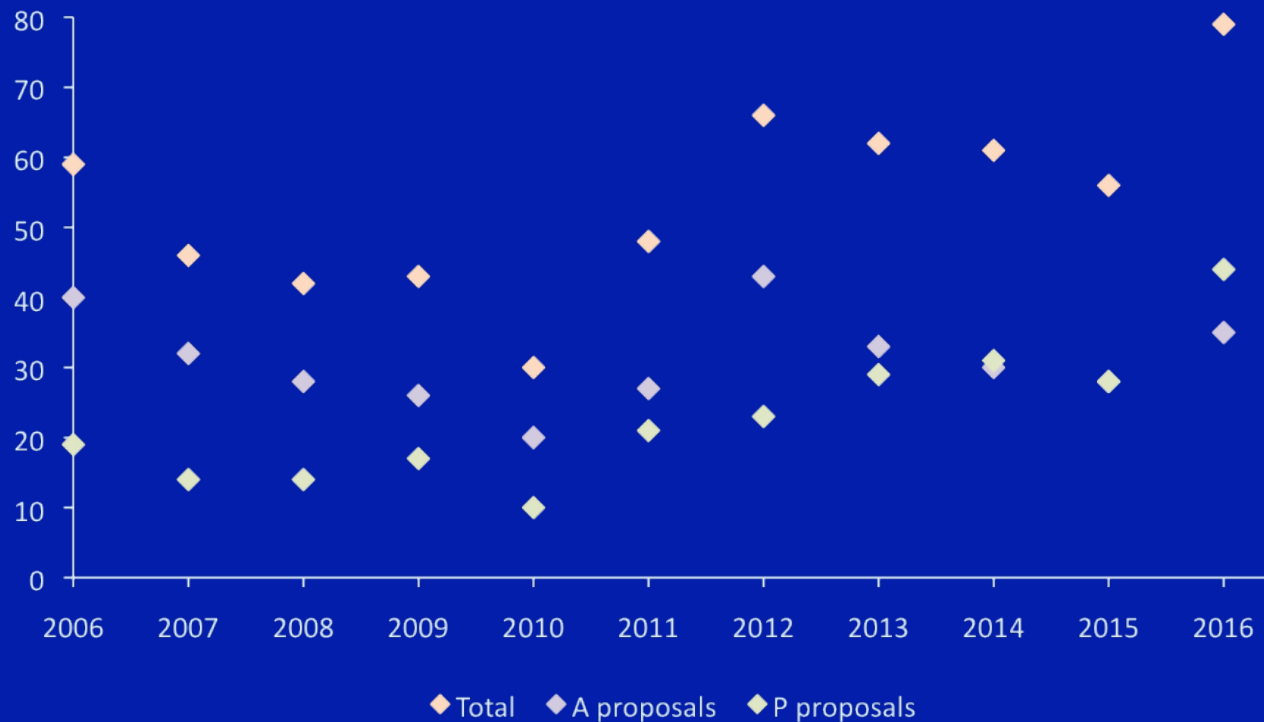
# Current Status – CfP

## Total NSF funding (AST + AGS)



# Current Status – Proposals

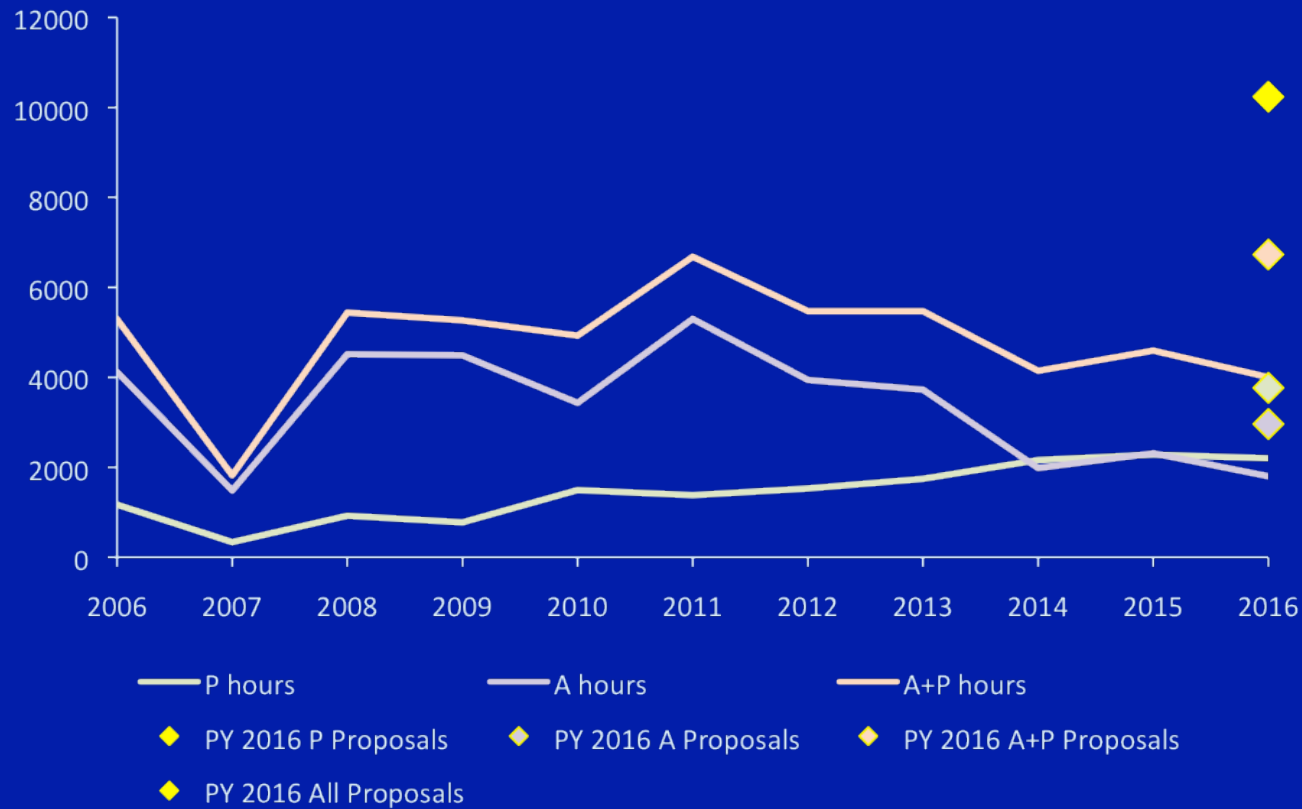
Proposal numbers in astronomy by CY





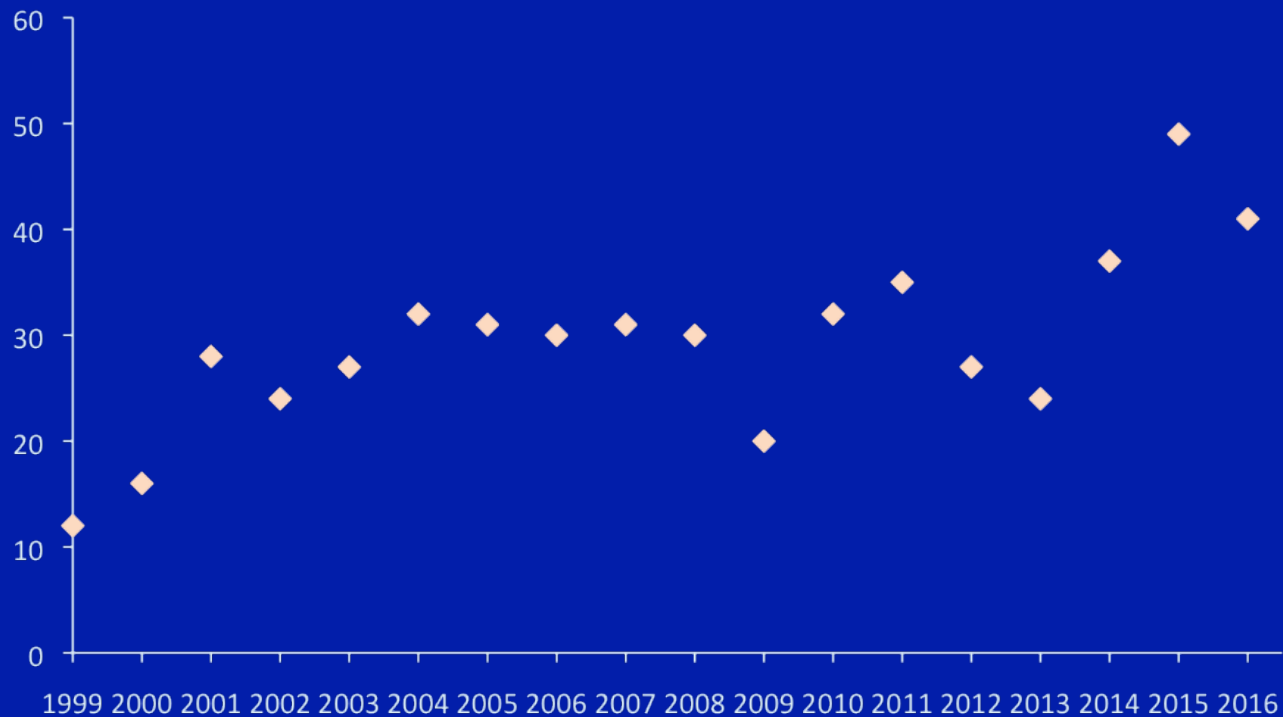
# Current Status – Scheduling

## Scheduled telescope hours by CY



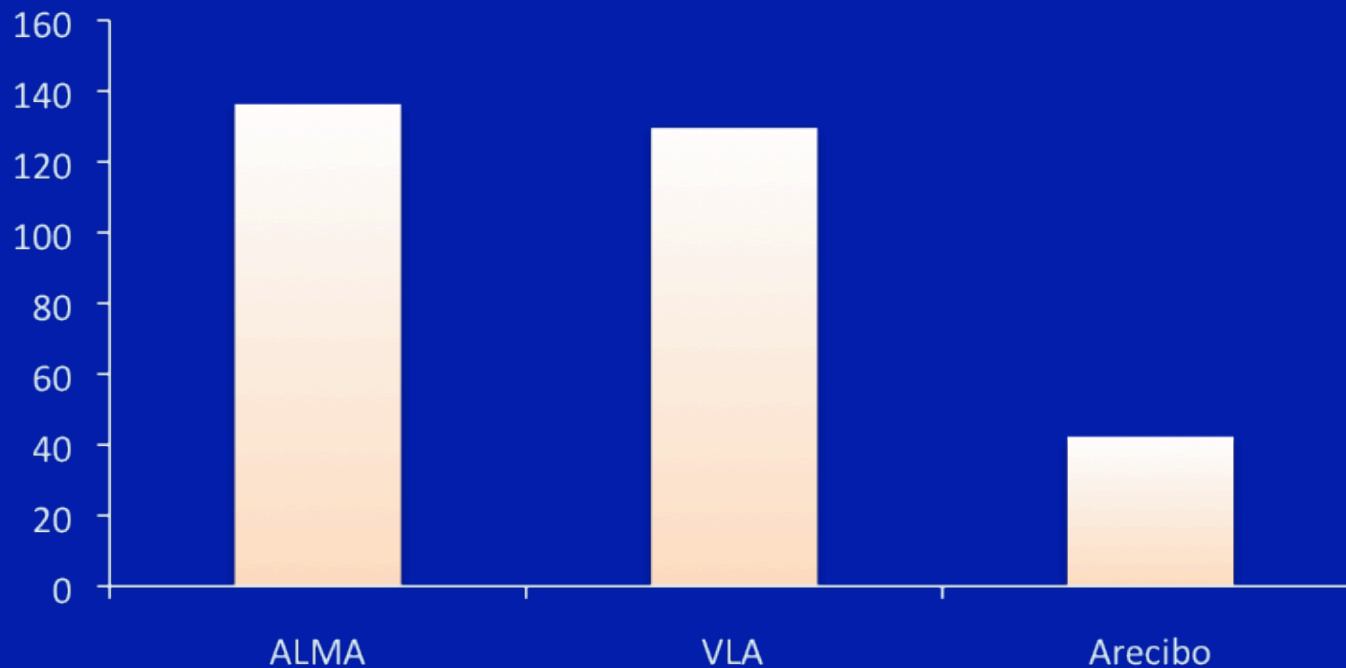
# Current Status – Productivity

Publications in astronomy by PY



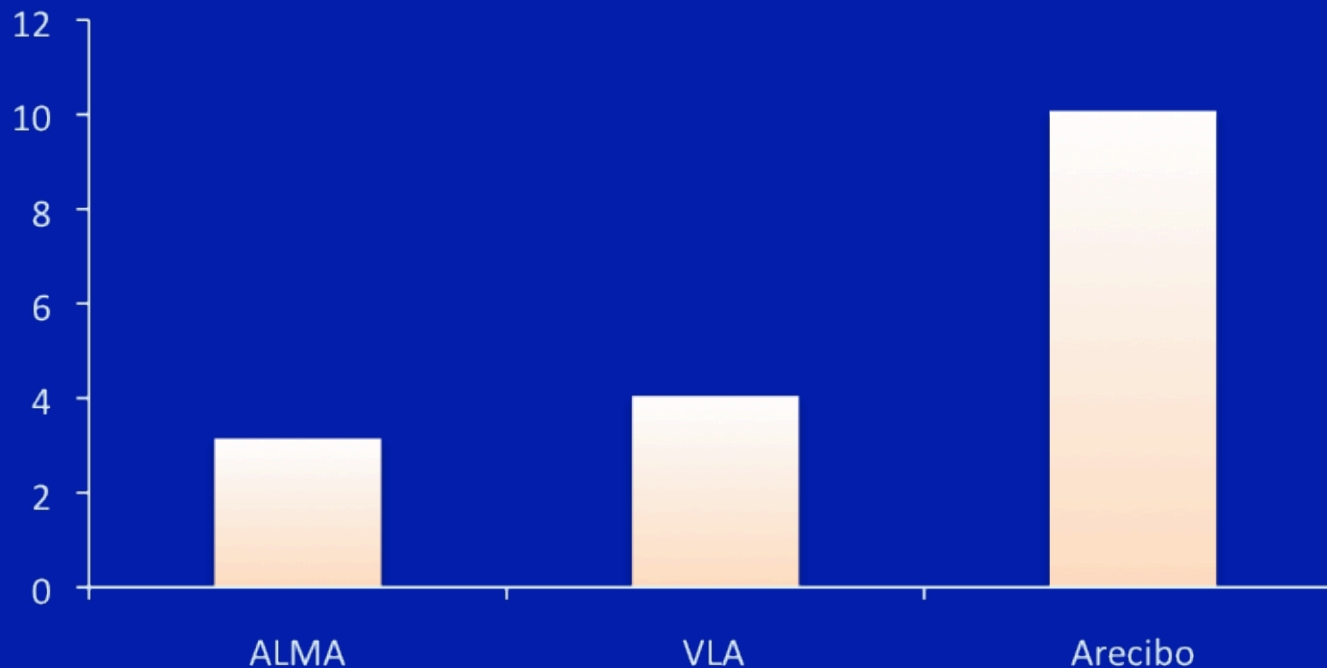
# Current Status – Productivity

Papers per year (2014–16)



# Current Status – Productivity

## Papers per \$M from AST



(Based on NSF-AST budget for Arecibo, NRAO-ALMA and rest of NRAO)

# Current Status – Education

- Around 90,000 visitors to the newly-refurbished Science & Visitor Center
  - A third are Puerto Rican school children
- Arecibo Observatory Space Academy takes 30 high-schoolers per semester
- REU takes 7 undergraduates + 1 teacher each summer, half from PR



# Current Status – Resilience

- Puerto Rico suffered a major black-out on September 21, 2016
- The Observatory's emergency generators kept systems running
- Internet was down for three days making remote observing impossible
- Thanks to operators and post-docs, no observations were lost

# Scientific Opportunities

- Time-domain science
  - Size matters when you can't integrate
- Extended sources
  - Single dishes >> interferometers
- Detection experiments
  - Interferometers too expensive
- VLBI
  - Size matters for baseline sensitivity

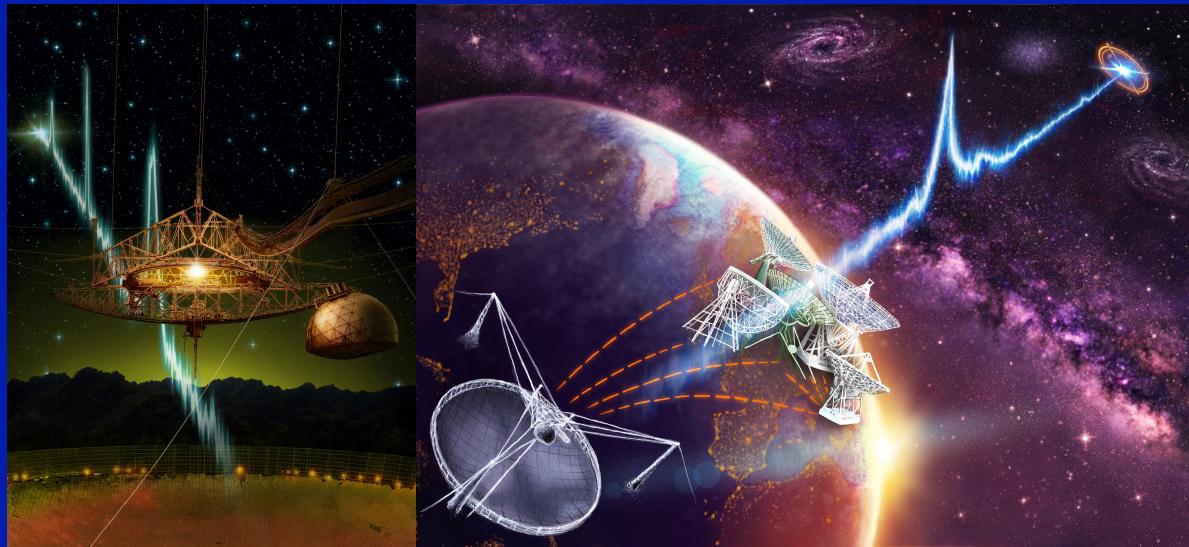
# Time-domain science

- NANOGrav
  - LIGO has now shown gravitational waves exist, and we might be on the verge of detecting them at longer wavelengths
- Testing GR
  - Observations of the (GBT discovered) pulsar in a triple system will allow the best test of the strong equivalence principle

# Time-domain science

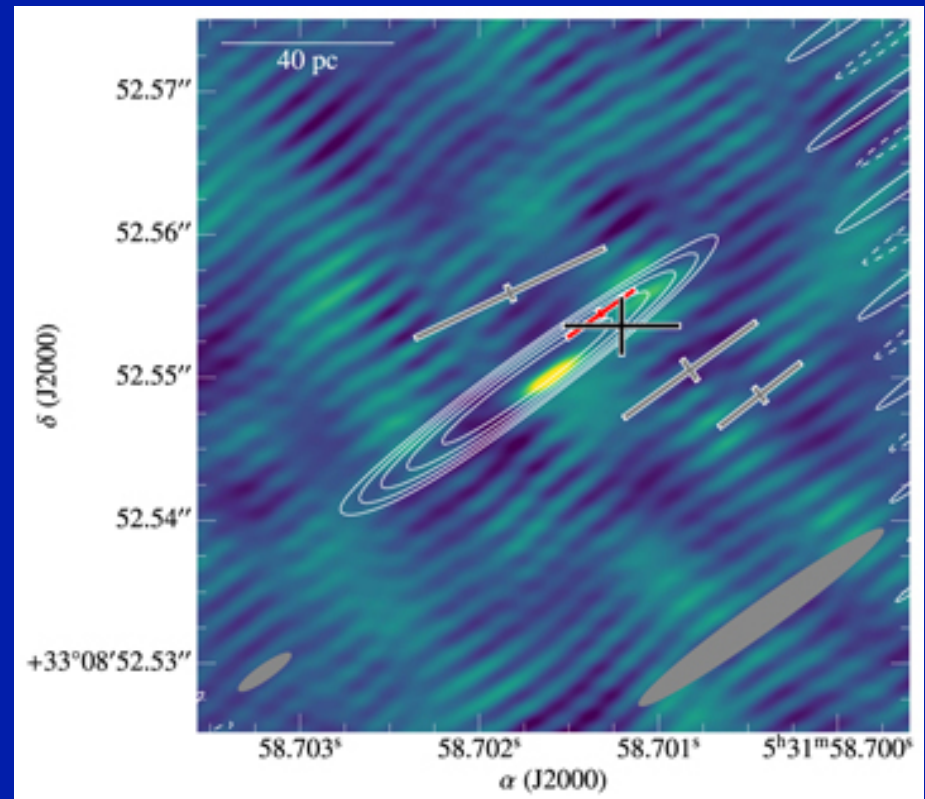
- Fast Radio Bursts
  - Arecibo detected repeating burst and found repetitions; was essential part of VLBI array that provided best localisation

Images credit:  
Danielle Futselaar



# Time-domain science

- Fast Radio Bursts
  - Association of FRBs (crosses) with persistent radio source (contours) (Marcote et al. 2017)

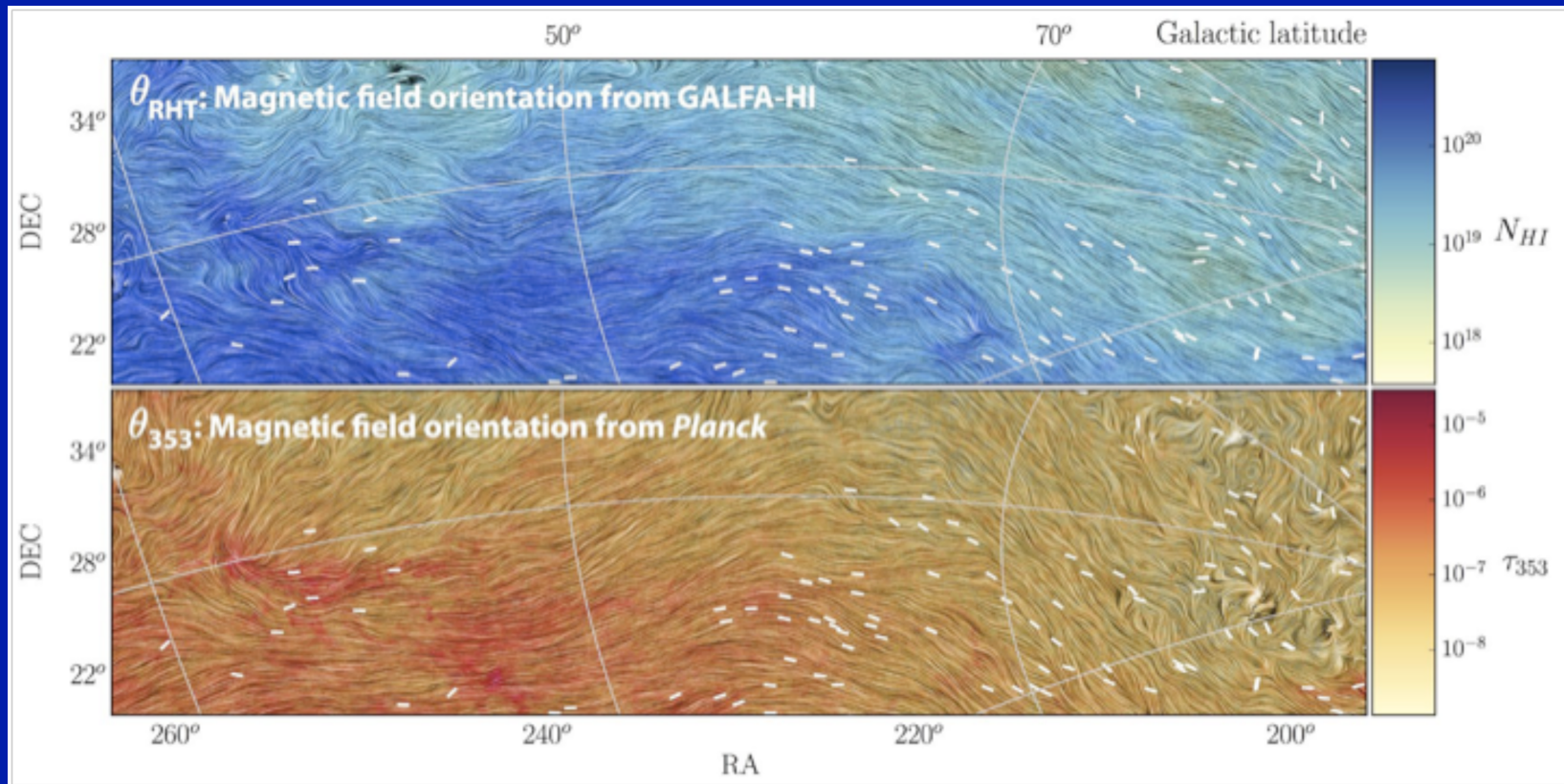




# Extended sources

- GALFA-HI
  - Discovery of filaments in Galactic HI aligned with magnetic field
- ‘Dark gas’
  - Observations of molecular clouds in CH and OH
- GALFACTS
  - Probing Galactic magnetic field

# GALFA-HI



(Clark et al. 2015)

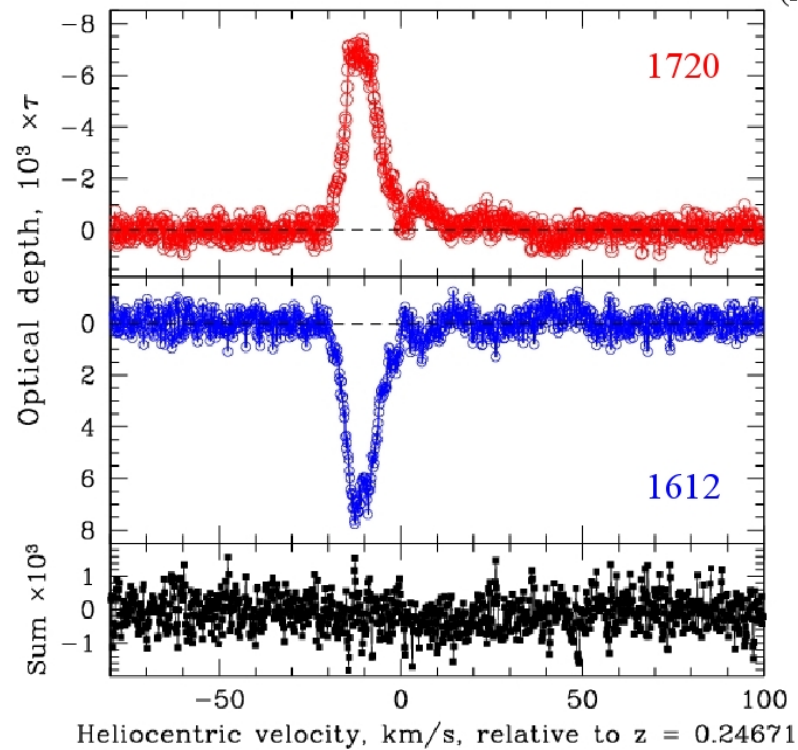
# Detection experiments

- Arecibo cost/hr ~ \$2.1k
- VLA cost/hr ~ \$3.7k
- Time to 1 mJy at 10 km/s res. (for HI):
  - Arecibo: 15 min; VLA: 70 min
- Cost of observation:
  - Arecibo ~ \$500; VLA ~ \$4.3k
- If 1/8 are non-detections, better to check with Arecibo before mapping!

# Extragalactic OH

A 125-HOUR ARECIBO INTEGRATION ON 1413+135

(Kanekar et al. 2017)

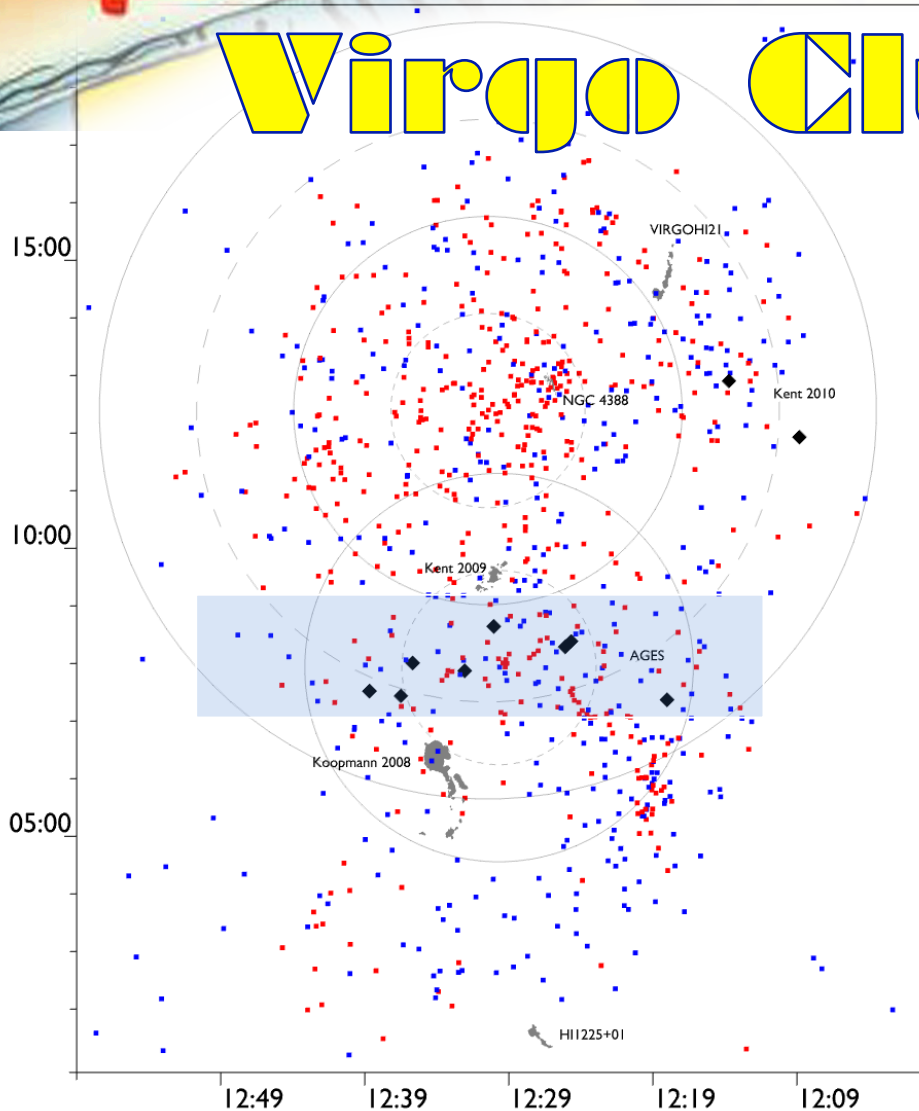


- Conjugate behaviour persists! No evidence of an offset.

$$[\delta\alpha/\alpha] < 1.3 \times 10^{-6} \text{ (} 2\sigma \text{) over 3 Gyr}$$

RETURN TO THE

# Virgo Cluster



Optically dark gas clouds (shown by grey symbols): 15 known – 8 in one area...

The large number of optically-undetected sources found in AGES implies there are many remaining for us to uncover

# VLBI

- Arecibo essential for VLBI determination of the distance to the Pleiades
- Recent work with RadioAstron has shown unexpectedly high brightness temperatures in quasars of  $10^{12}$ – $10^{14}$  K

# Current plans

- PUPPI now available at all frequencies
- “C-wide” 4–8 GHz receiver being installed and commissioned
- Wide-band 4 GHz IF project
- 12-m commissioning
- VLBI upgrades – DDC; Mark 6
- New website being launched

# Future hopes

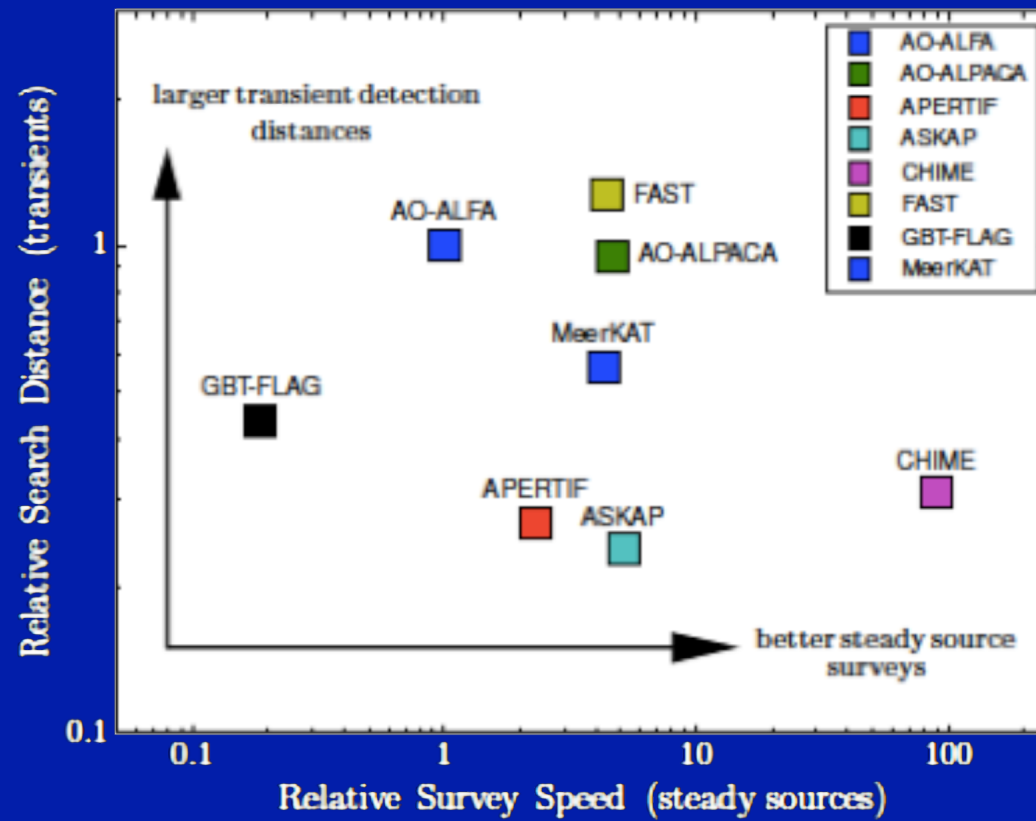
- Wide-band 0.3–3 GHz (PLeaSe)
  - Replace 327, LBW, SBW
  - Particularly useful for pulsars
- Wide-band backend
  - Observations using full bandwidth
- ALPACA as replacement for ALFA
  - Phased array feed for survey work
  - Awaiting funding decision from NSF



# ALPACA

- Similar survey speed to SKA pathfinders
- HI survey for minihalos in the nearby universe – lowest-mass HI dwarfs
- Pulsar survey – expect to detect 270 MSPs in AO sky (60 already known)
- FRB survey – large ‘reach’ makes discoveries likely; near-uniform gain would give better localisation

# ALPACA



# Future operations

- Time available for open-skies observations likely to be reduced as NSF funding falls
- We have NSF permission to sell telescope time
  - Government rate \$2,091.80/hour + tax (includes NSF grantees)
  - Also have commercial rate

# Conclusions

- Arecibo is a highly-productive scientific instrument
- Arecibo has a lot of scientific potential, most obviously in time-domain science
- Arecibo remains a vital part of the radio astronomy ecosystem
- Arecibo with ALPACA will be competitive with SKA pathfinders