Time Domain, Cosmology, **Fundamental Physics**

Participants

- External Chair: Geoff Bower (ASIAA) * slides compliments of
- Internal Chair: Paul Demorest (NRAO)
- Jim Braatz
- Avery Broderick
- Sarah Burke-Spolaor
- Bryan Butler
- Tzu-Ching Chang
- Laura Chomiuk
- Jim Cordes
- Jeremy Darling
- Jean Eilek
- Dale Frail

- Gregg Hallinan
- Nissim Kanekar
- Michael Kramer
- Dan Marrone
- Walter Max-Moerbeck
- Brian Metzger
- Miguel Morales
- Steve Myers
- Rachel Osten
- Frazer Owen
- Michael Rupen
- Andrew Siemion
- Ashley Zauderer

Important

- Wide frequency coverage
- Large field of view/fast survey speed
- Balance:
 - High resolution (localization)
 - Faithful imaging (diffuse plasma structures)
- A case for long baselines?

Headliners

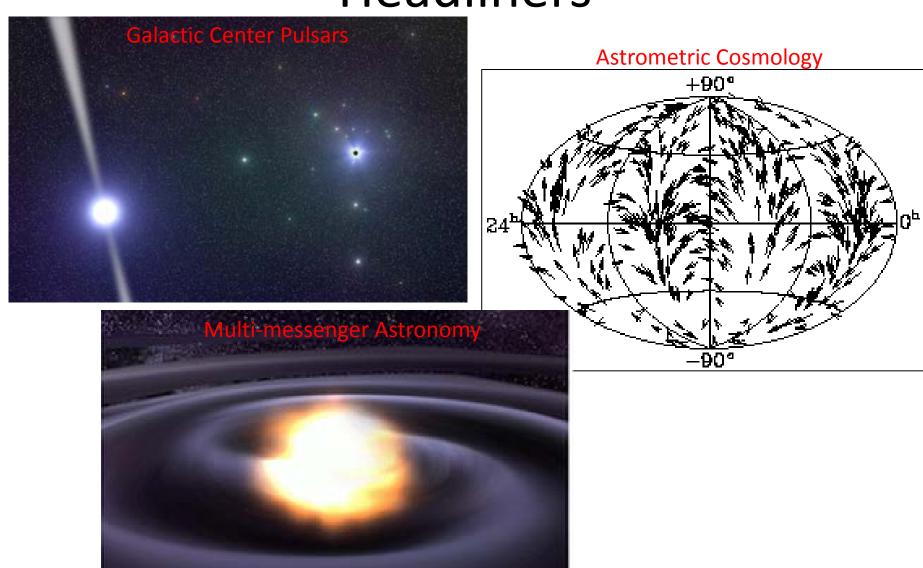
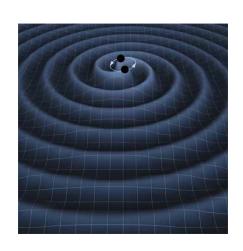
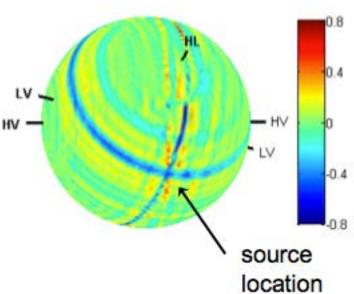


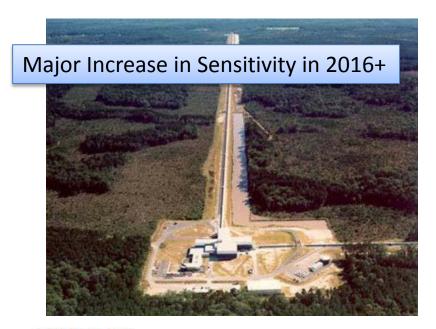
Image credits: R. Eatough/MPIfR; NASA;

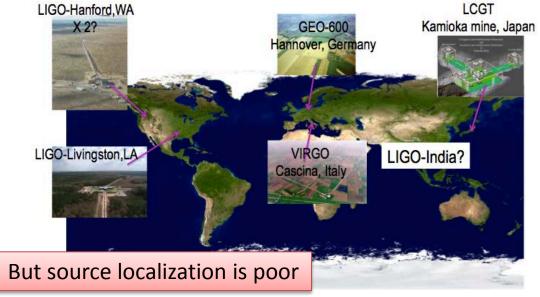
Time Domain

Advanced LIGO and GW Detection

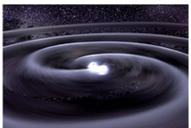


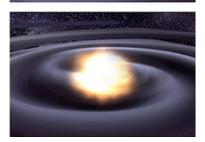


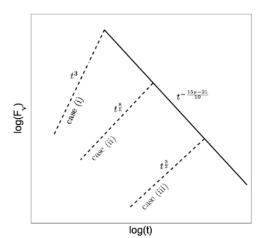


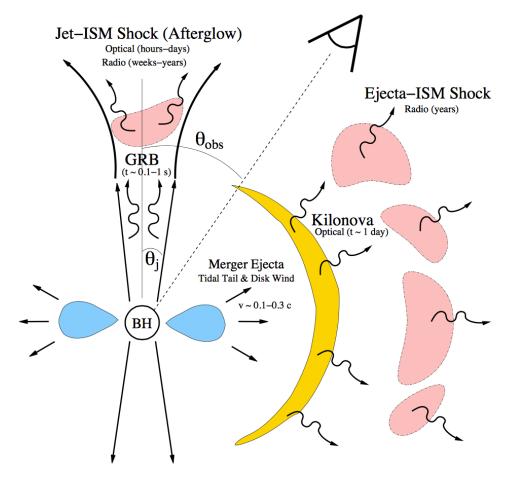


Radio Counterparts of LIGO Gravitational Wave Sources



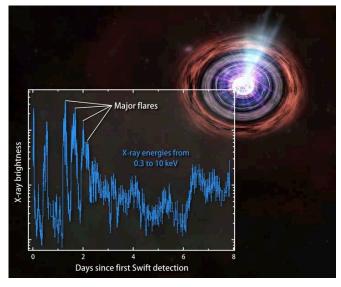


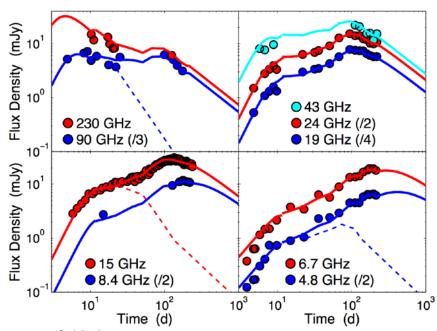


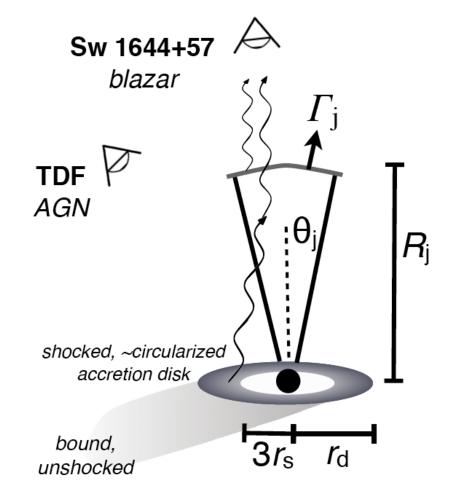


Metzger & Berger 2012

Jetted Stellar Tidal Disruption Events





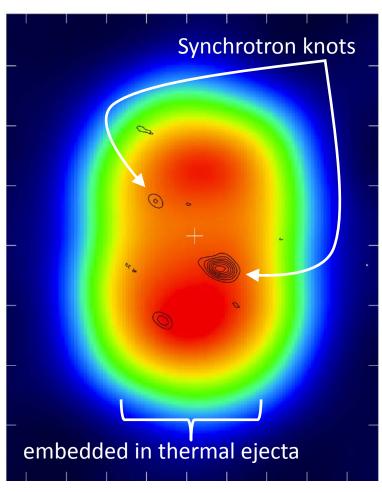


Bloom et al. 2011

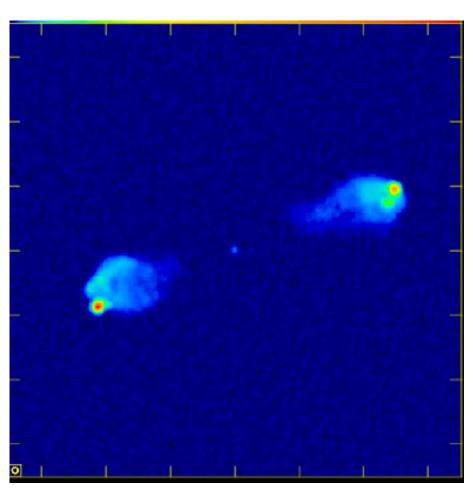
Synchrotron Radio Emission from Shocked ISM Around Black Hole (Giannios & Metzger 2011)

Berger et al. 2012

Under the Hood of Nature's Particle Accelerators



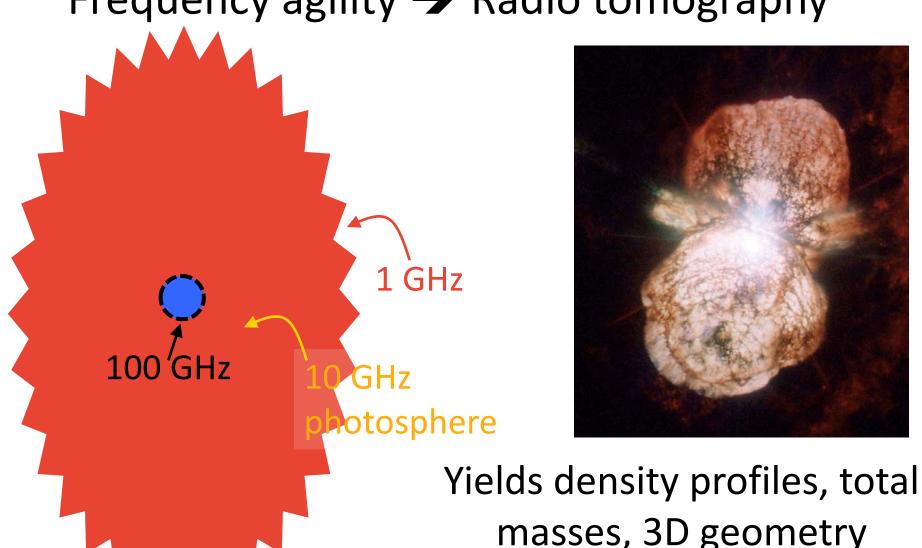
Gamma-Ray Novae (Chomiuk et al. 2014, Nature)



Simulated image of X-ray binary GRS 1915+105

Peeling the Onion:

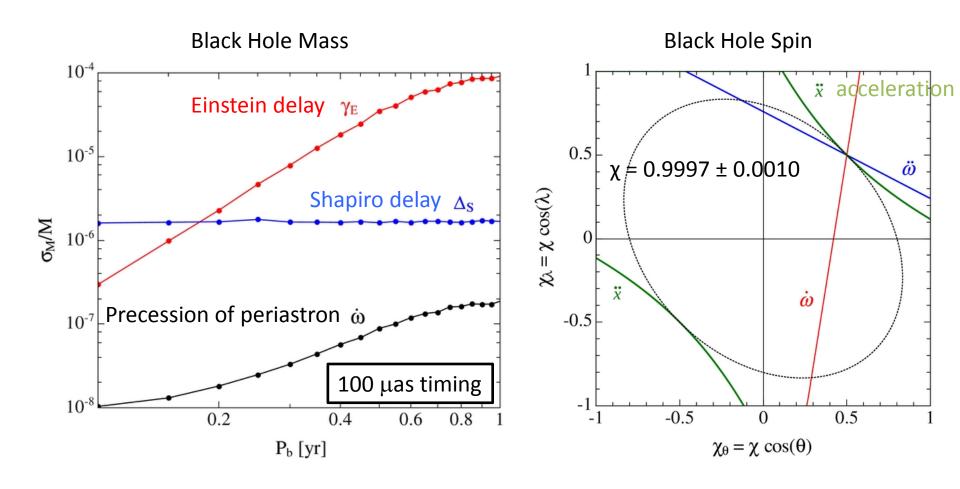
Frequency agility -> Radio tomography



masses, 3D geometry

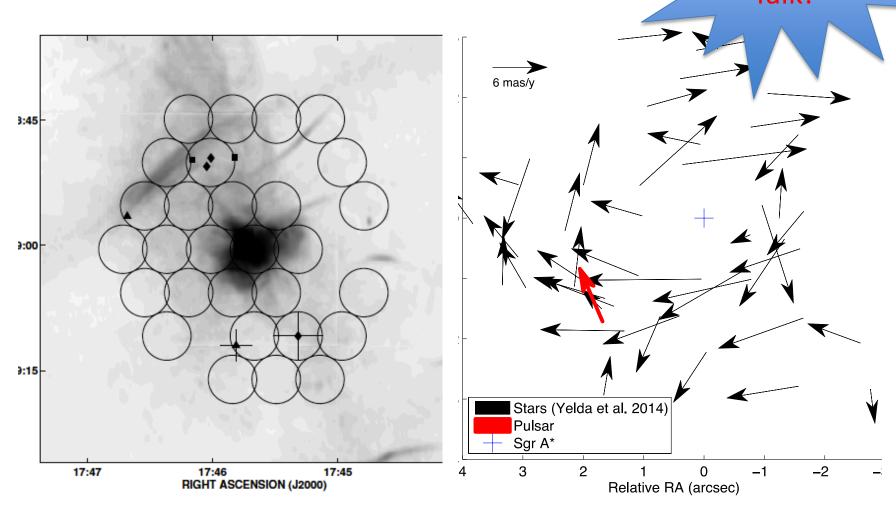
Fundamental Physics

Using Pulsars to Measure Spacetime Around Sgr A*



GC Radio Pulsars

Kramer Talk!



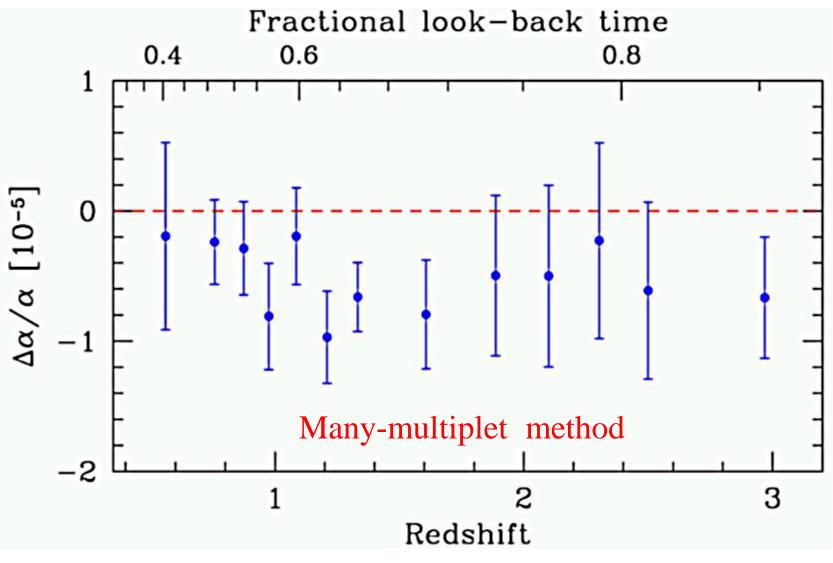
Deneva et al 2009

Bower et al 2014

Fundamental Constant Evolution

- 22 free parameters in Standard Model of particle physics and General Relativity
- Fine structure constant, $\alpha = e^2/\hbar c$; protonelectron mass ratio, $\mu = m_p/m_e$. Changes in μ likely larger than those in α .
- Astronomical spectroscopy in different atomic/molecular lines from high-z absorbers allows us to probe cosmological evolution in μ , α .

"EVIDENCE" FOR A CHANGING α ?



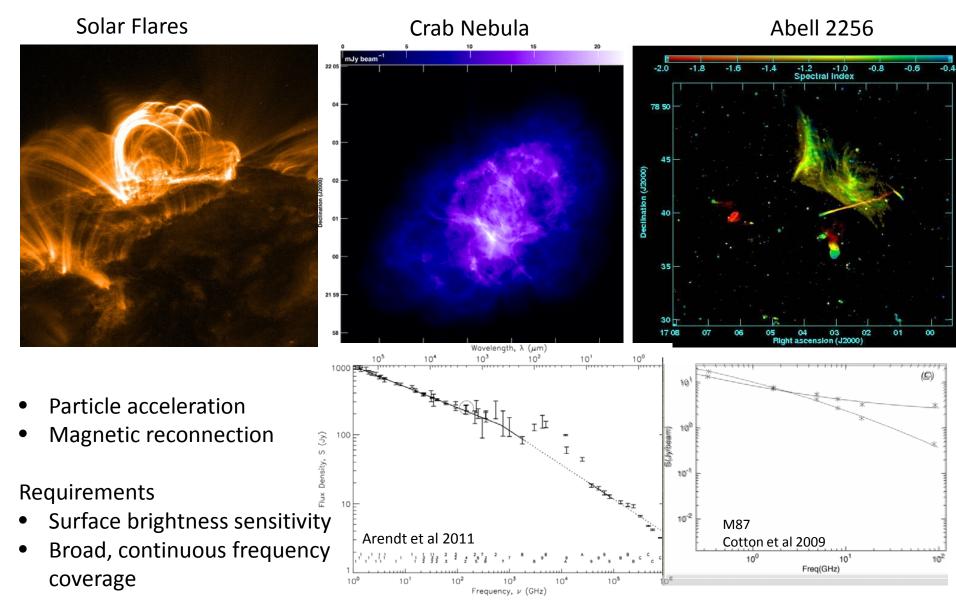
 $[\Delta \alpha/\alpha] = (-5.4 \pm 1.1) \times 10^{-6}$ (0 < z < 1.8)

(Murphy et al. 2004, Lect. Notes Phys.)

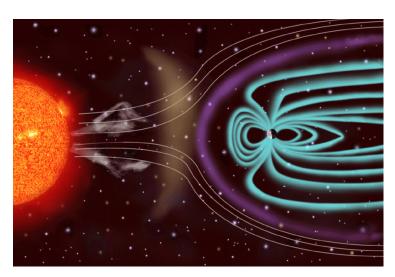
Fundamental Constants Radio Wave Results

- Best constraints on changes in μ !
 - $[\Delta \mu/\mu] < few \times 10^{-7}$ (NH₃, CH₃OH: Effelsberg, GBT, VLA)
- - $-10 \times VLA$: $[\Delta \mu/\mu] \sim \text{few} \times 10^{-10} \text{ from } z \sim 2$.

Plasma Physics



Revealing the Plasma Physics of Star-Planet Interactions



Earth-Sun interaction is complex, composed of radiation, particles and magnetic field interactions



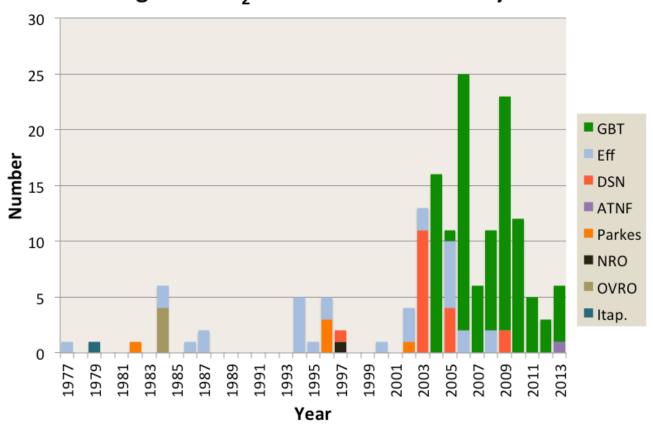
artist's conception of evaporating exoplanet atmosphere

- Cool stellar mass loss characterized by an ionized stellar wind → favors higher radio frequencies for detection
- Star-exoplanet interactions: evaporation of atmosphere from close-in planetary companion
- Particle flux interaction with exoplanet magnetic field can affect planetary dynamo
- NGVLA can provide the most sensitive direct detection of the stellar wind

Cosmology

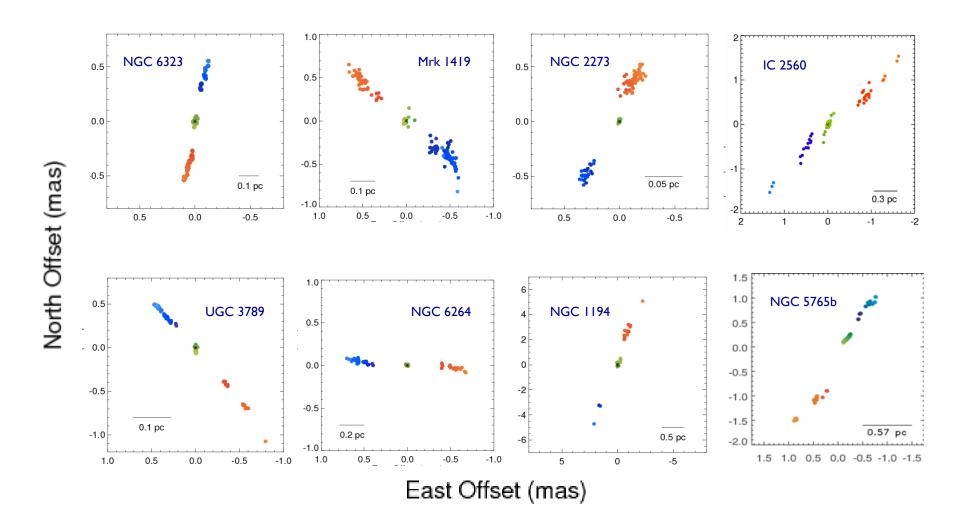
Progress with Megamaser Surveys

Extragalactic H₂O Maser Discoveries by Year

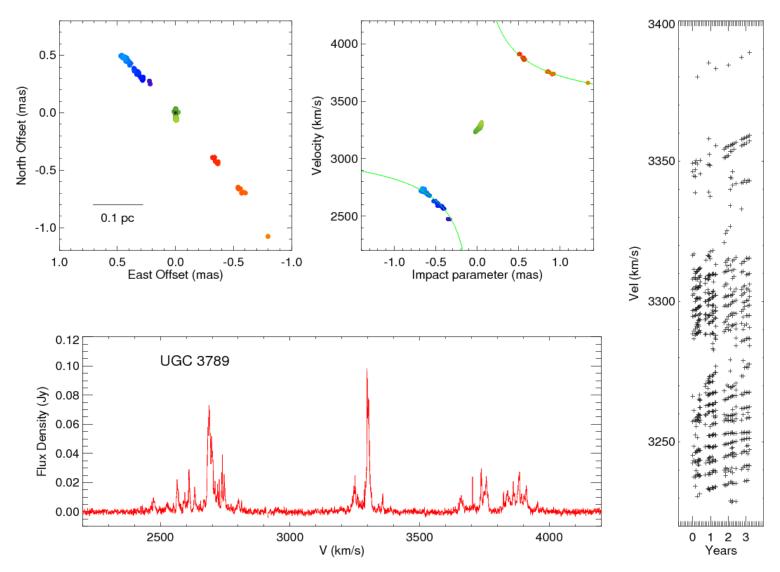


- 162 galaxies detected out of > 3000 observed
- ~ 37 have evidence of being in a disk and are suitable for M_{BH} measurement
- ~ 10 suitable for distance measurement
- Primary sample for surveys: Type 2 AGNs at z < 0.05

A Sample of VLBI Maps of H₂O Megamaser Disks



The H₂O Megamaser in UGC 3789



Summary of Results for Megamaser Science

- MCP measurement of H₀ is one-step, geometric measurement that provides a critical complement to measures using standard candles.
- Megamasers determine $H_0 = 70.4 \pm 3.6 \text{ km s}^{-1} \text{ Mpc}^{-1}$. The measurement can be improved by measuring additional galaxies, and increasing sensitivity.
- Megamasers have determined gold standard masses of SMBH in ~20 galaxies. These measurements demonstrate departures from M-σ relation at the lowmass end and provide a more realistic view of galaxy/BH evolution than a universal M-σ relation.
- Megamasers provide the only means of direct imaging gas in AGN on sub-pc scales. Thin megamaser disks present a puzzle for AGN unification models

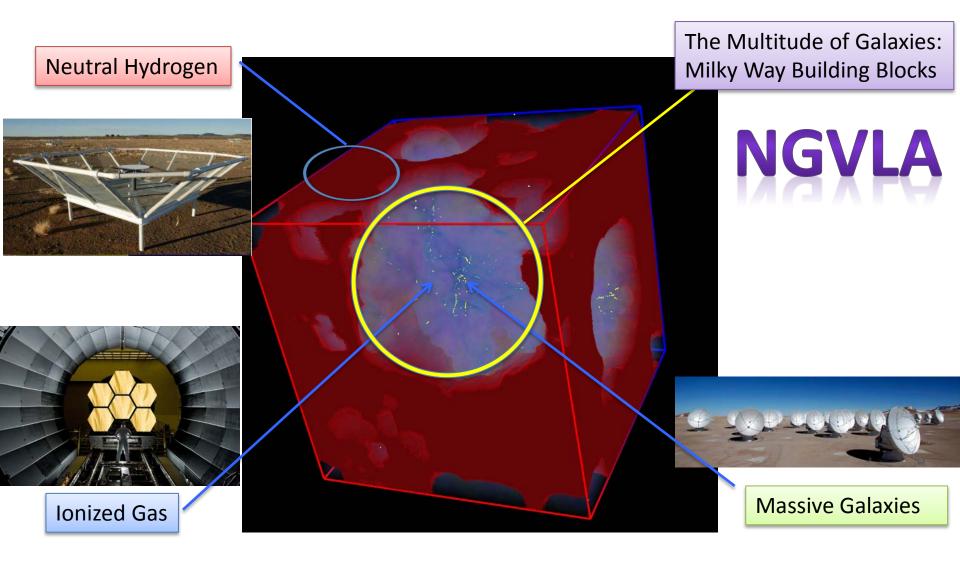


Requirements for a Next Gen Radio Telescope for Megamaser Science and Astrometry

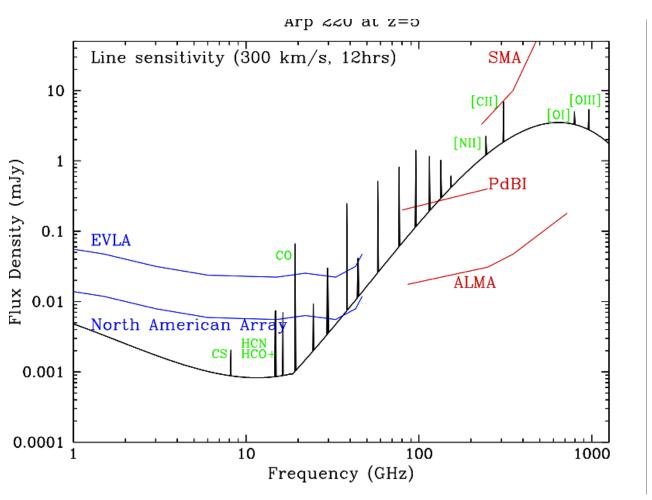
- With the NG instrument, we would aim to measure H_0 to ~1% to constrain models of dark energy and fundamental physics, and we aim to measure BH masses in >> 100 galaxies.
- Sensitivity and resolution are key. To optimize science, a new telescope should have at least ~20% of its collecting area in long baselines (~ 5000 km).
- UV coverage requirements are modest. The long baselines could be achieved with ~ 5 100-m class apertures.
- Frequency coverage for the long baselines must include up to 22 GHz to get the H₂O line. Higher frequencies may prove useful for imaging other maser lines (e.g. SiO at 46 GHz) but are currently lower priority.
- The recording and correlator requirements for spectral line work are in line with current capabilities. It should permit imaging ~ 1 GHz contiguously with spectral resolution of at least ~ 25 kHz.



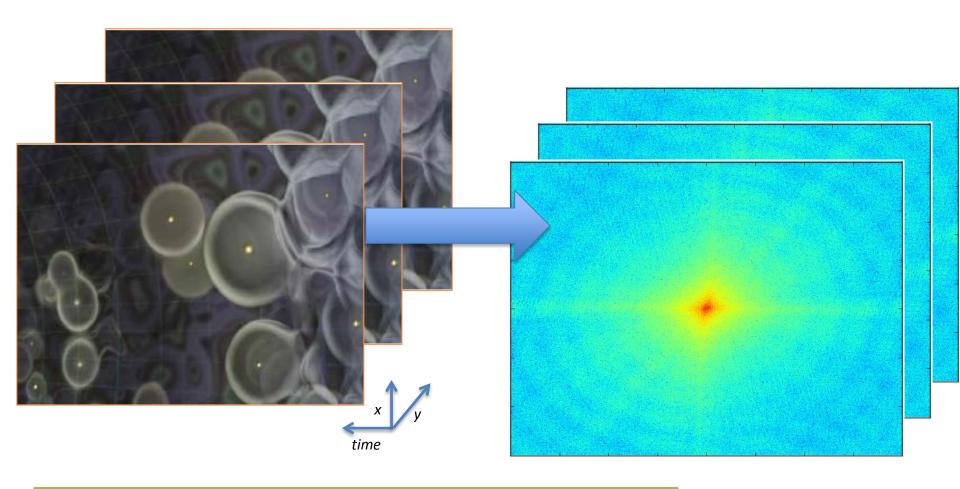
Intensity Mapping the Cosmic Web



Even NG VLA Is Limited in the Galaxy Population it Can See

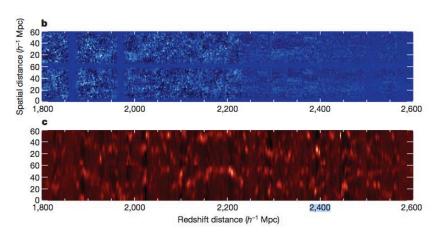


3D Power Spectrum → Intensity Mapping

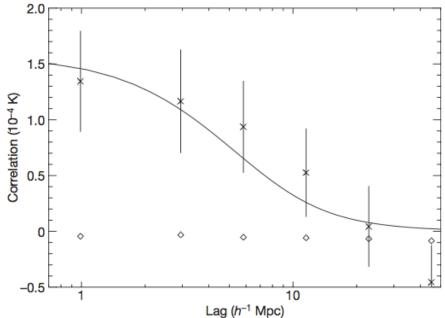


Same approach as taken for microwave background and HI EoR

HI Intensity Mapping

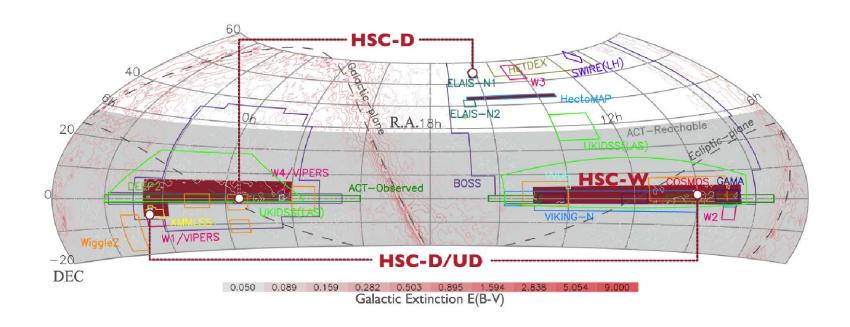


- GBT HI @ 600 MHz
- DEEP2 Galaxies @ Z~1



- Statistical detection of angular correlation between HI noise and galaxies
- Chang et al. 2010
- Masui et al 2012

The Era of Wide Area OIR Surveys



Technical Requirements of Intensity Mapping

- Wide field of view
- Dense (u,v) coverage
- Broad frequency coverage
- Coarse frequency resolution





Technical Requirements

Technical Requirement	Science Case
Long Baselines	Megamasers, astrometry, resolved galactic transients
Compact Configuration	Plasma physics, intensity mapping, GC pulsars, megamasers, fundamental constants
Wide Field of View/Survey Speed	Intensity mapping, EM GW sources
High Frequencies (> 50 GHz)	Fundamental constants, intensity mapping, plasma physics
High Time Resolution (imaging, beamforming)	GC Pulsars
Real time processing	Transients

More information

- Wiki
 - https://safe.nrao.edu/wiki/bin/view/NGVLA/Time CosmologyPhysicsSWG
- Whitepaper
 - arXiv:1510.06432



Next Generation Very Large Array Memo No. 9
Science Working Group 4
Time Domain, Fundamental Physics, and
Cosmology

To Consider

- Compact Configurations and Field of View
 - What fraction of the collecting area should be packed into a dense configuration?
- Long Baselines
 - Astrometric science requires an integrated long baseline array
- Synoptic Surveys
 - Do the science cases favor a model of individual targets or large area surveys?
- Experiment or Facility?