Working Group Report:

Time Domain

Fundamental Physics

Cosmology

Participants

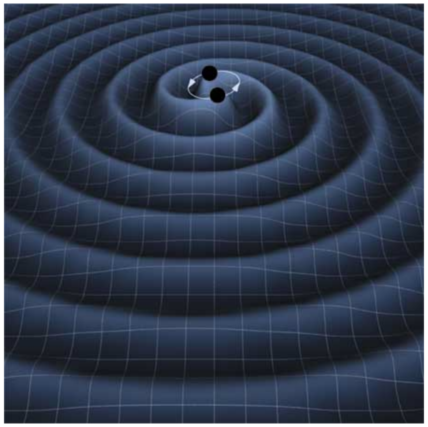
- External Chair: Geoff Bower (ASIAA)
- Internal Chair: Paul Demorest (NRAO)
- Jim Braatz
- Avery Broderick
- Sarah Burke-Spolaor
- Bryan Butler
- Tzu-Ching Chang
- Laura Chomiuk
- Jim Cordes
- Jeremy Darling
- Jean Eilek
- Dale Frail
- Gregg Hallinan
- Nissim Kanekar
- Dan Marrone
- Walter Max-Moerbeck
- Brian Metzger
- Miguel Morales
- Steve Myers
- Rachel Osten
- Frazer Owen
- Michael Rupen
- Andrew Siemion
- Ashley Zauderer

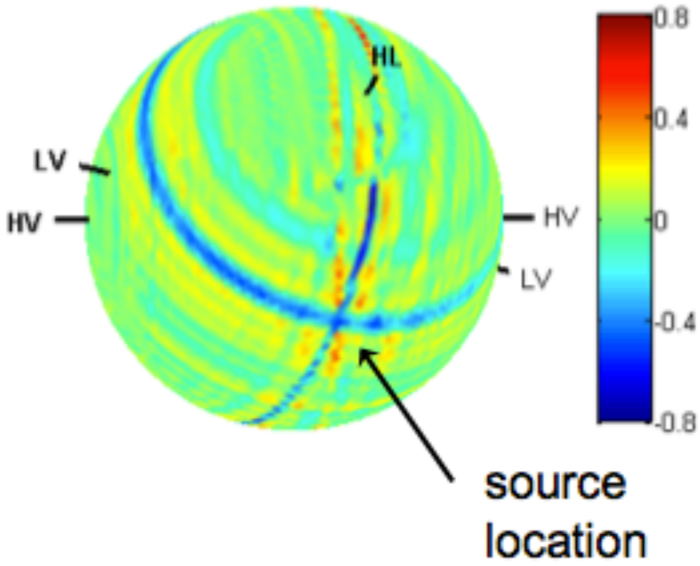
Activities

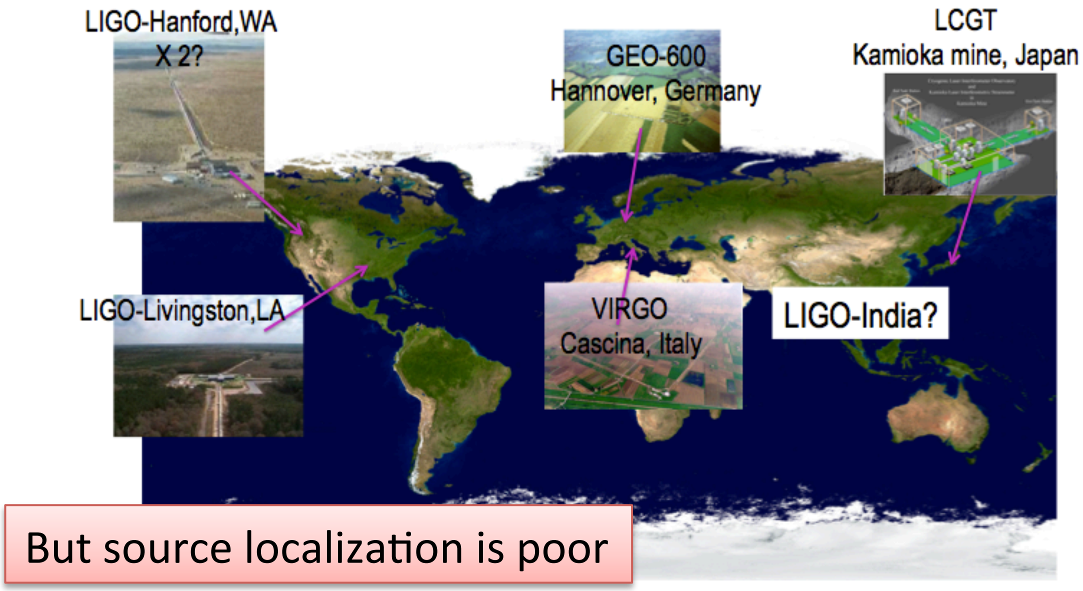
- Four telecons: October through November
- Wiki
  - https://safe.nrao.edu/wiki/bin/view/NGVLA/TimeCosmologyPhysicsSWG

Time Domain

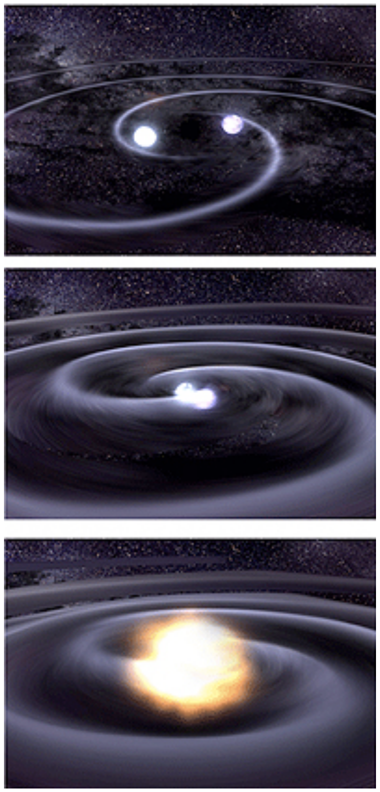
Advanced LIGO and GW Detection

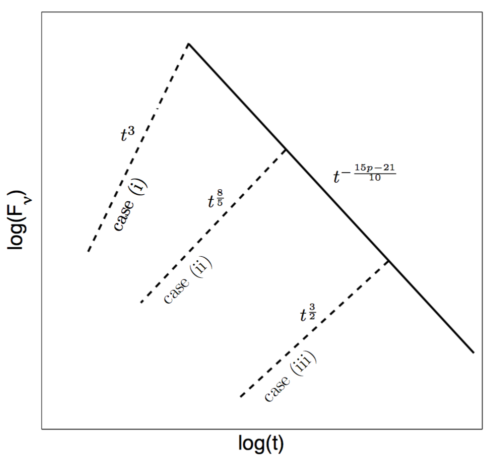




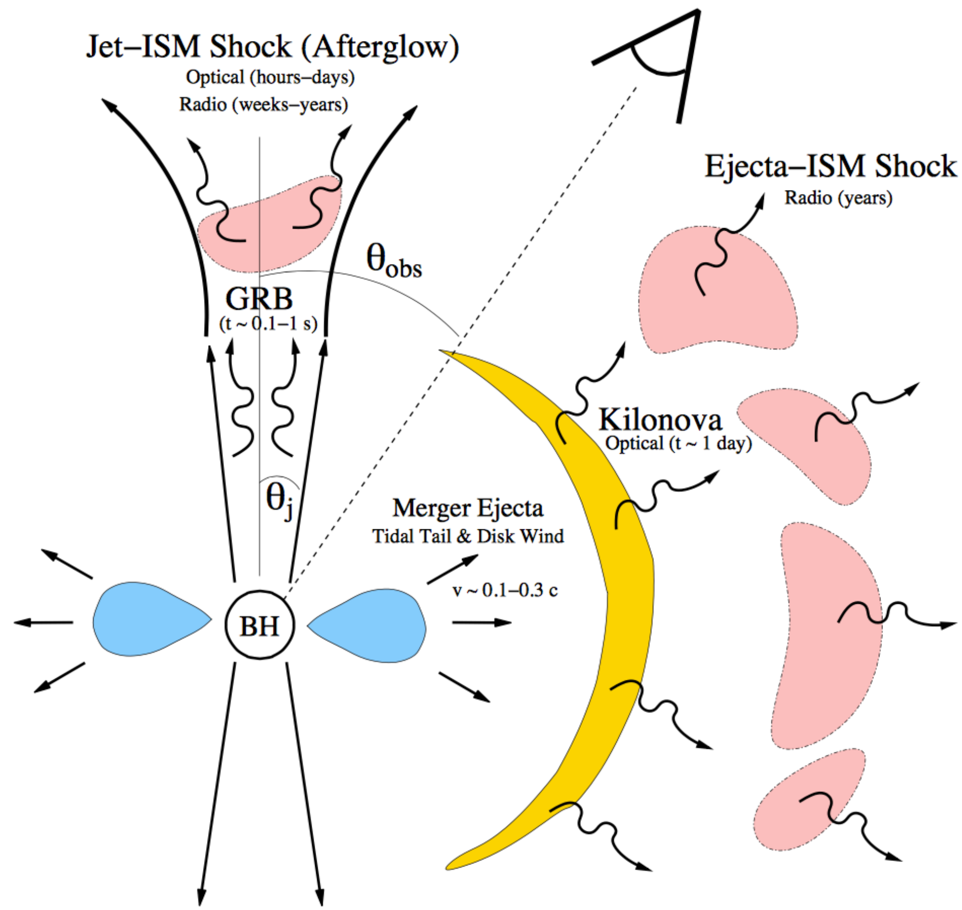


Radio Counterparts of LIGO Gravitational Wave Sources



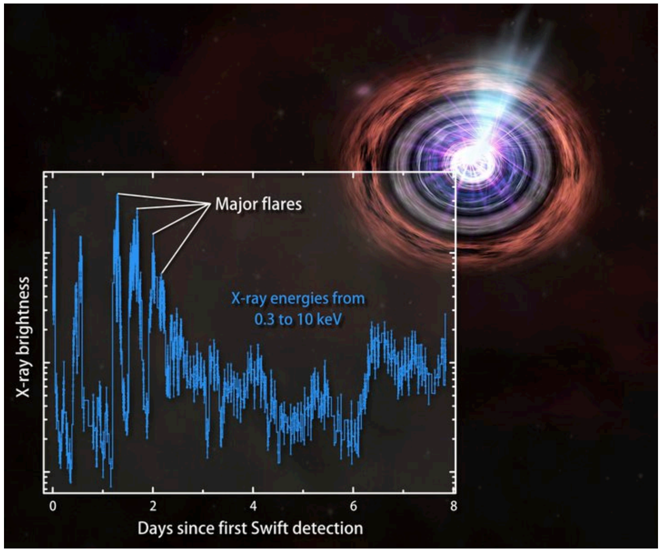


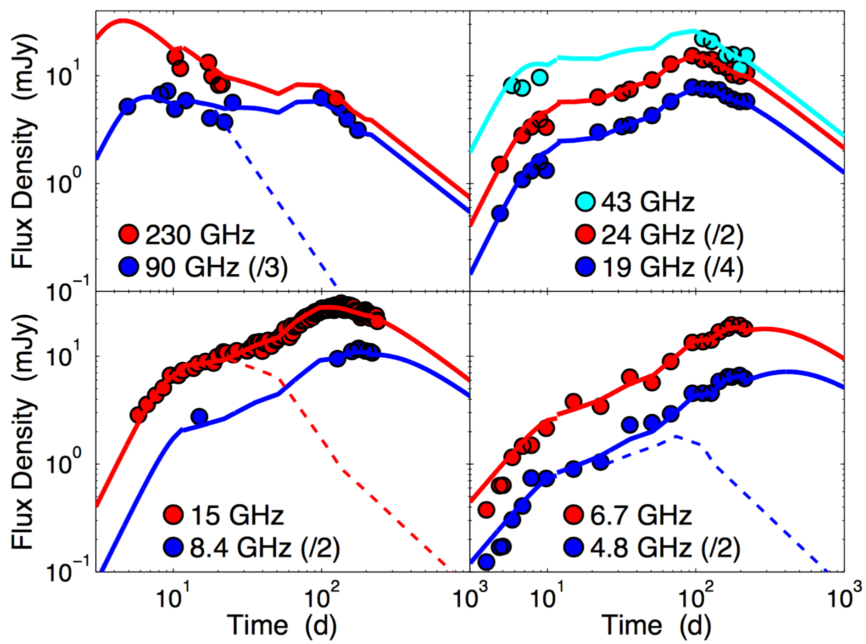
Nakar & Piran (2011)



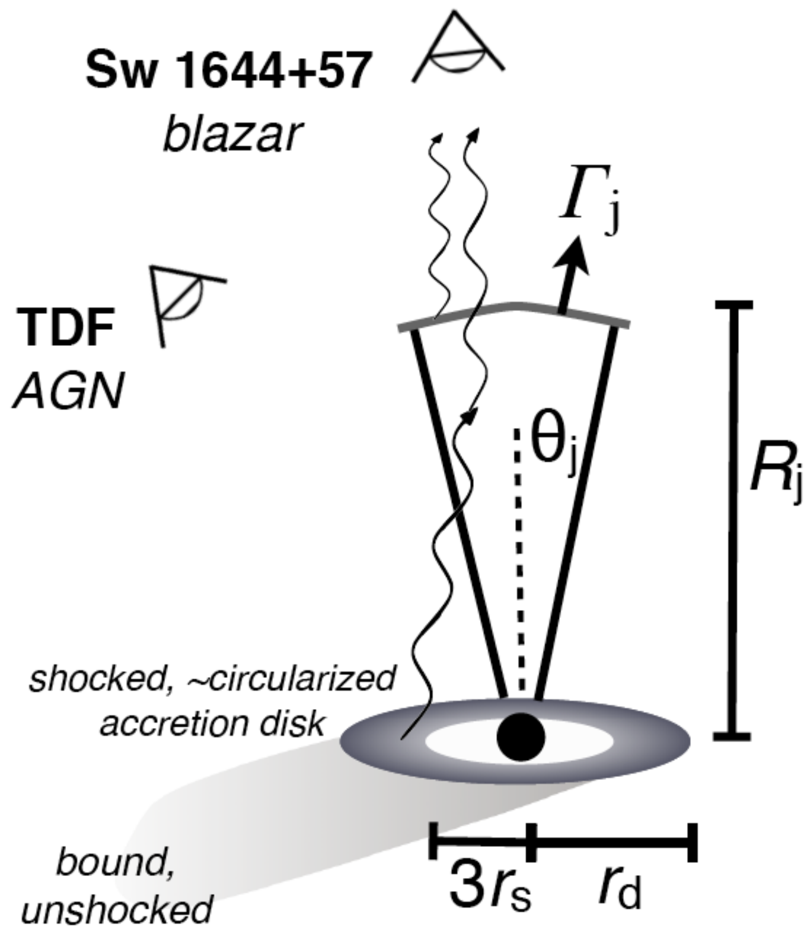
Metzger & Berger 2012

Jetted Stellar Tidal Disruption Events





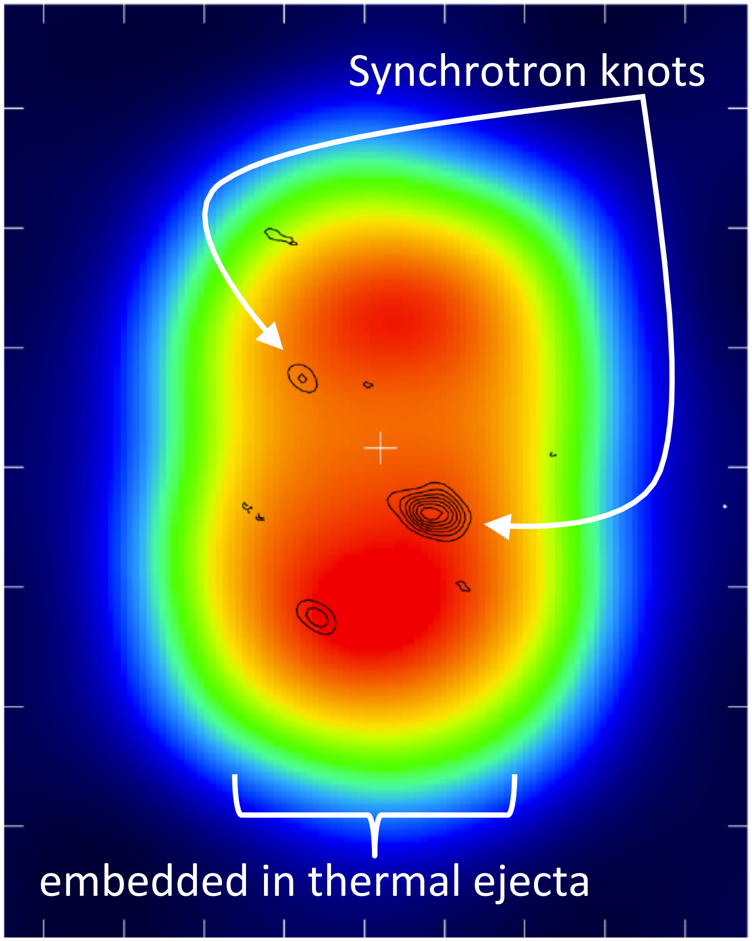
Berger et al. 2012



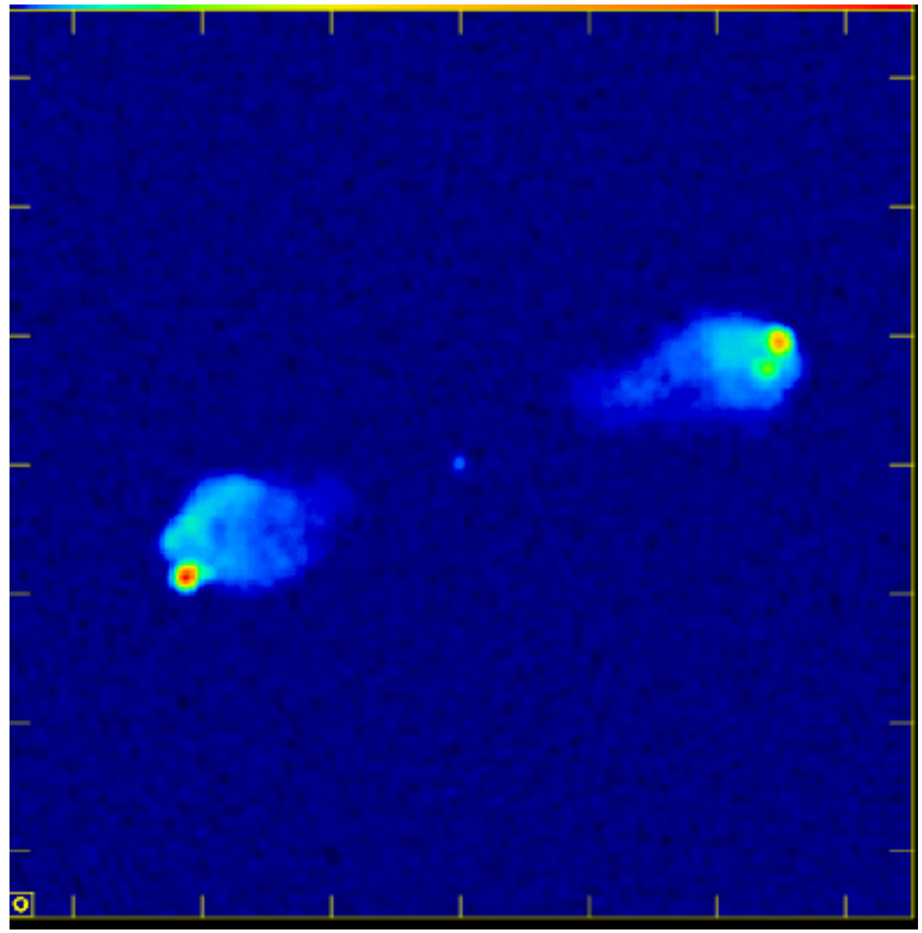
Bloom et al. 2011

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

Under the Hood of Nature's Particle Accelerators



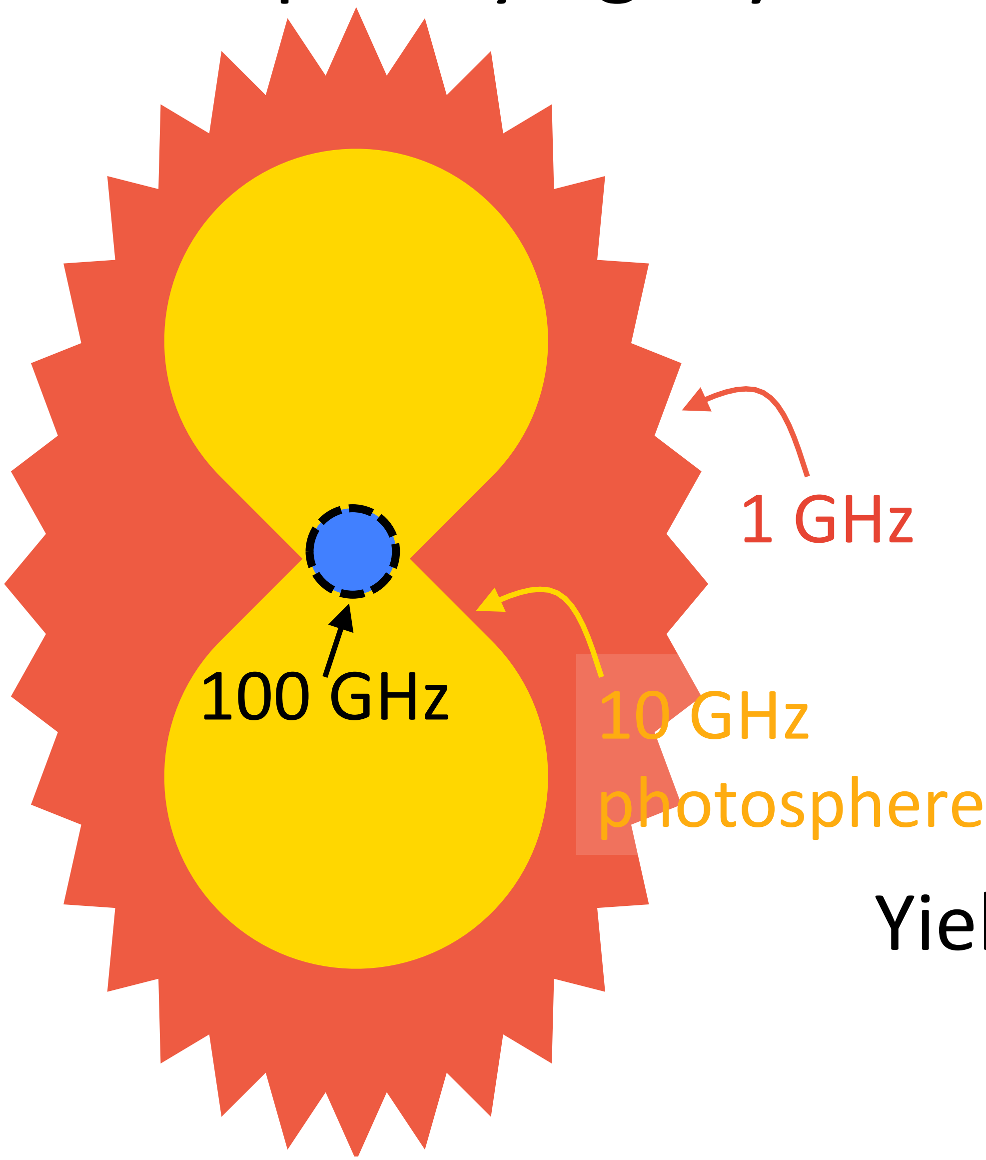
Gamma-Ray Novae
(Chomiuk et al. 2014, Nature)



Simulated image of X-ray binary GRS 1915+105

Peeling the Onion:

Frequency agility → Radio tomography

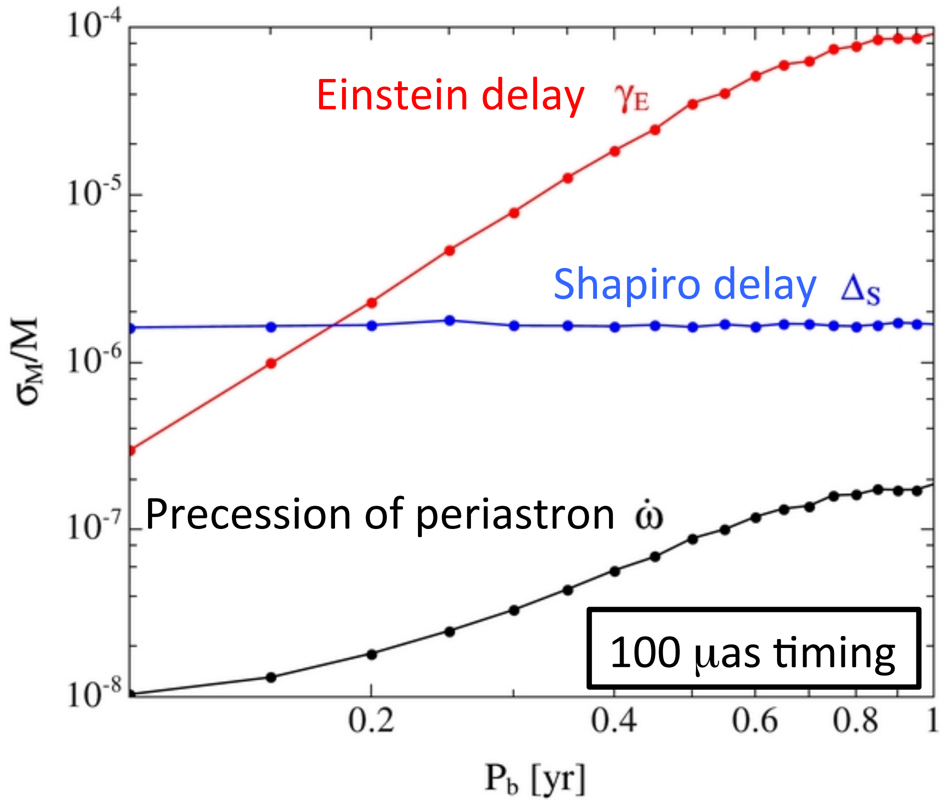


Yields density profiles, total masses, 3D geometry

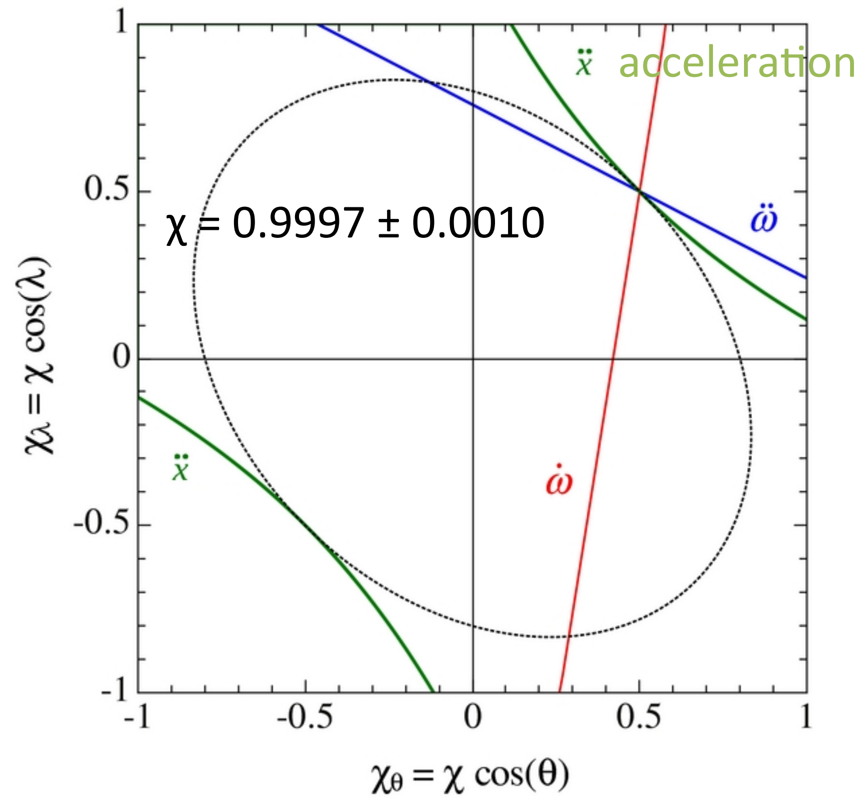
Fundamental Physics

Using Pulsars to Measure Spacetime Around Sgr A*

Black Hole Mass



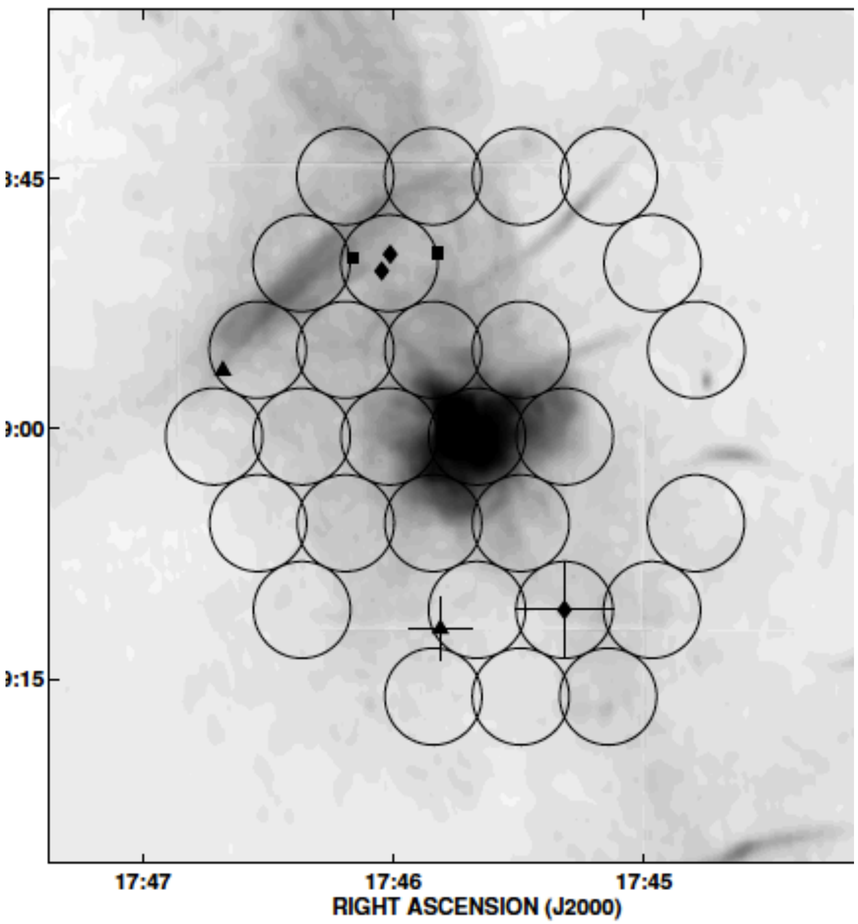
Black Hole Spin



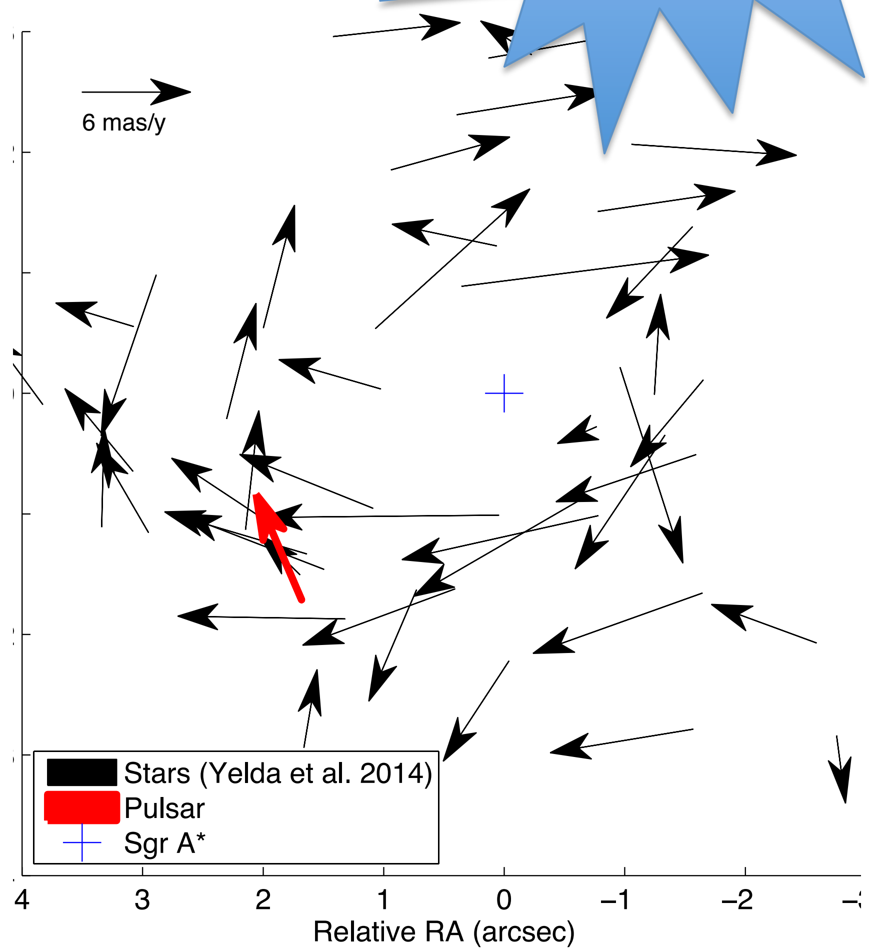
Liu et al 2012

GC Radio Pulsars

Kramer Talk!



Deneva et al 2009

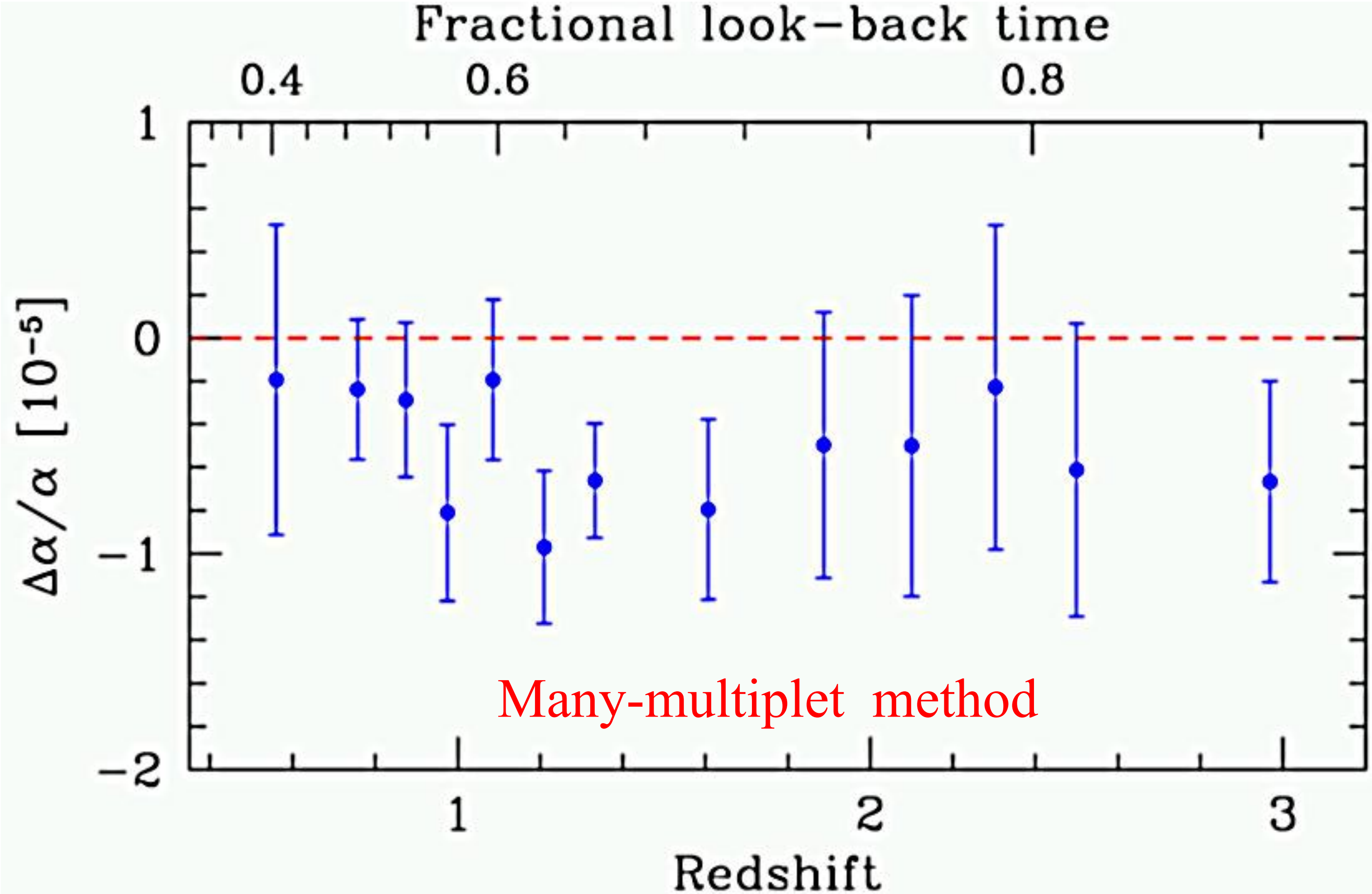


Bower et al 2014

Fundamental Constant Evolution

- 22 free parameters in the Standard Model of particle physics and General Relativity
- Fine structure constant, $\alpha = e^2/\hbar c$; proton-electron 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 ?



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

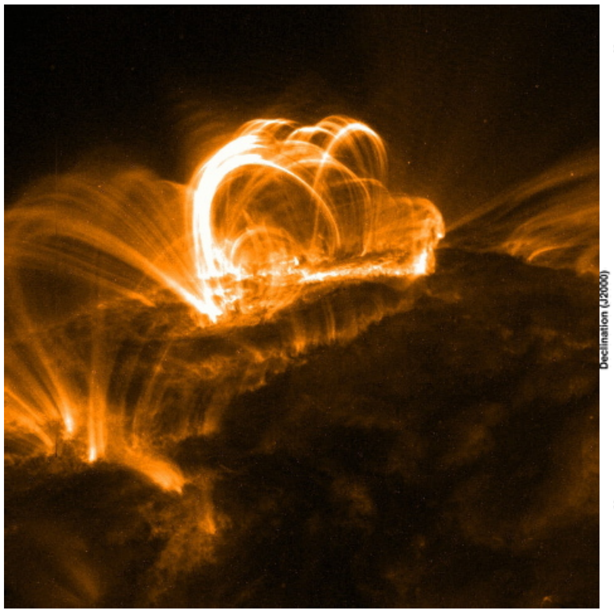
(Murphy et al. 2004, Lect. Notes Phys.)

Fundamental Constants Radio Wave Results

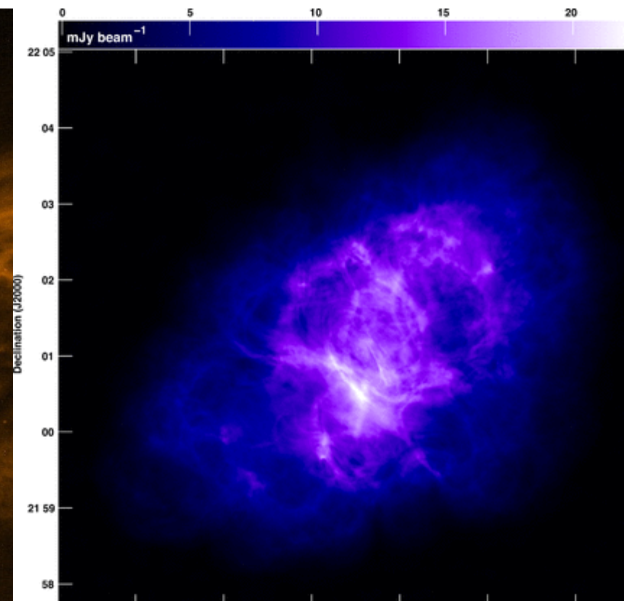
- Many molecular transitions sensitive to changes in α, μ. Few systematics if all lines from single molecule.
- Best constraints on changes in μ !
  - [$\Delta\mu/\mu$] < *few* × 10^{-7} (NH_3, CH_3OH: Effelsberg, GBT, VLA)
- Sensitivity to changes in α, μ increases non-linearly with telescope sensitivity, due to multiple absorbers and multiple techniques.
  - 10 × VLA: [$\Delta\mu/\mu$] ~ few × 10^{-10} from $z \sim 2$.

Plasma Physics

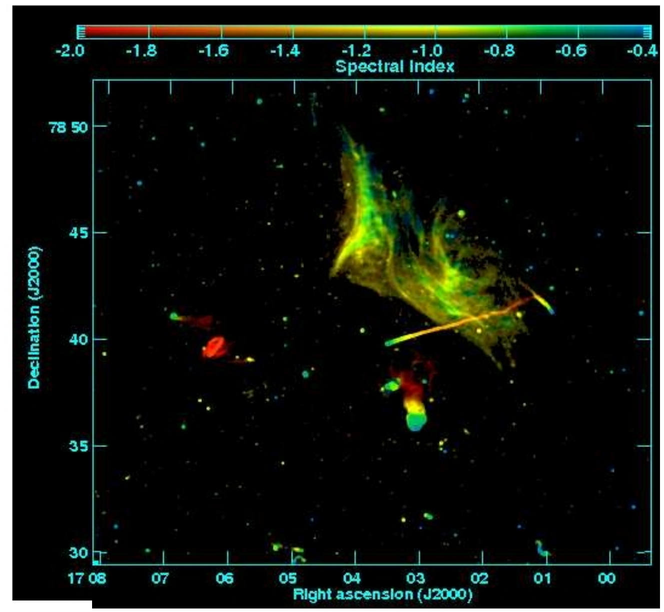
Solar Flares

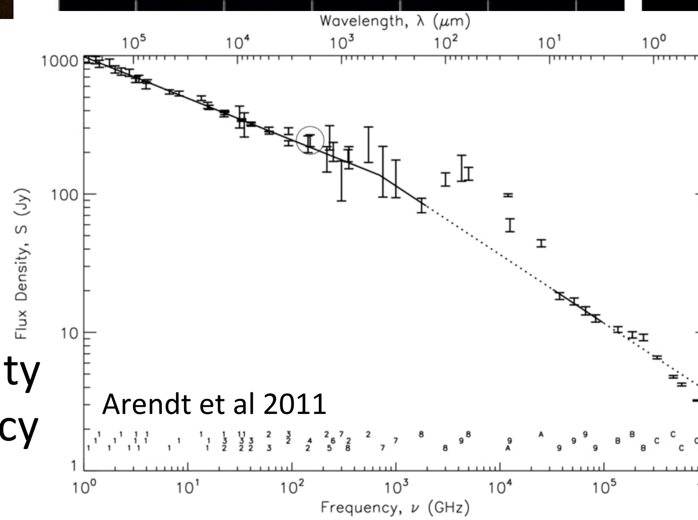


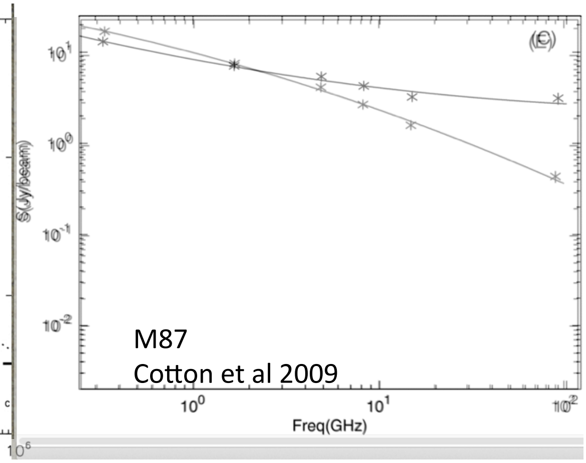
Crab Nebula



Abell 2256





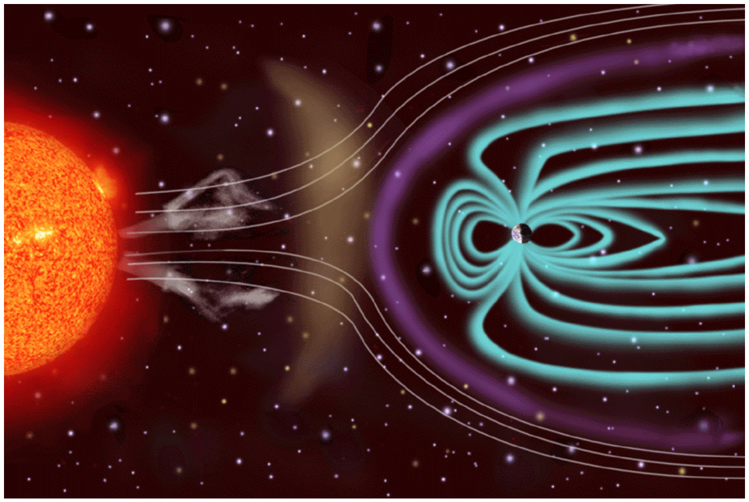


- Particle acceleration
- Magnetic reconnection

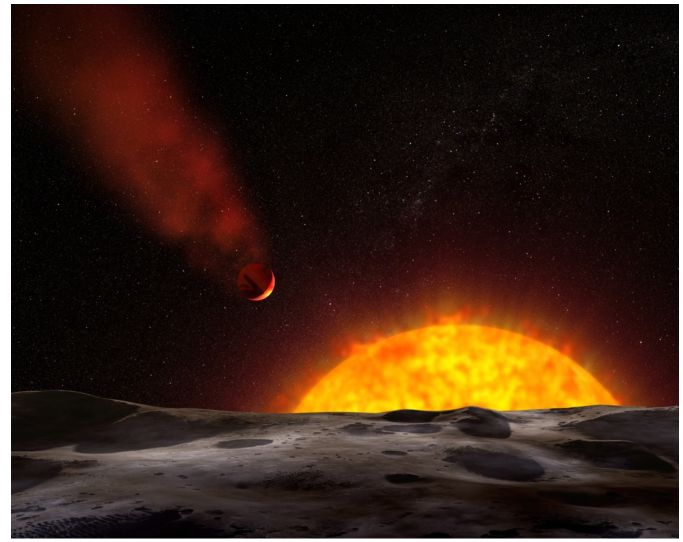
Requirements

- Surface brightness sensitivity
- Broad, continuous frequency coverage

Revealing the Plasma Physics of Star-Planet Interactions



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

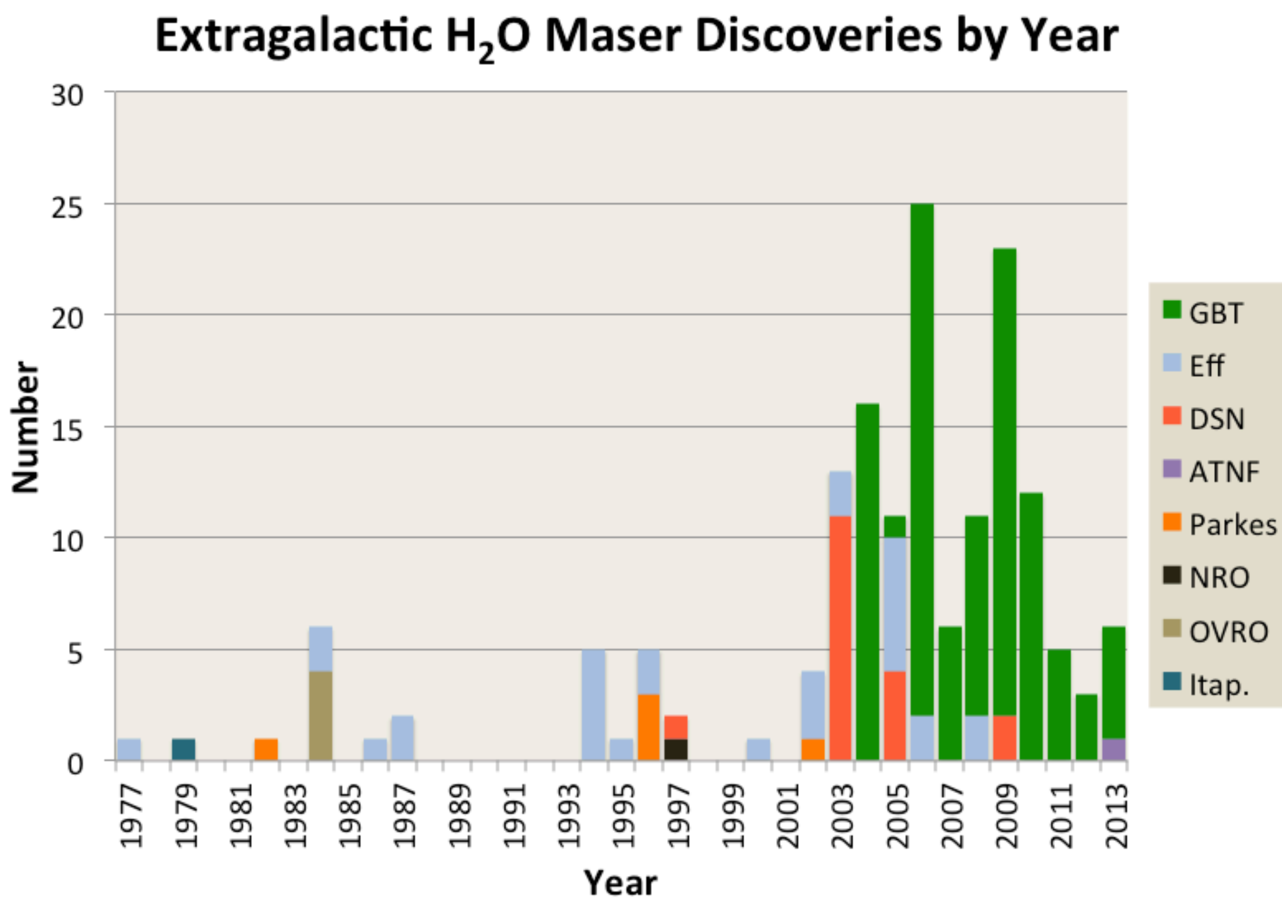


artist's conception of evaporating exoplanet atmosphere

- 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

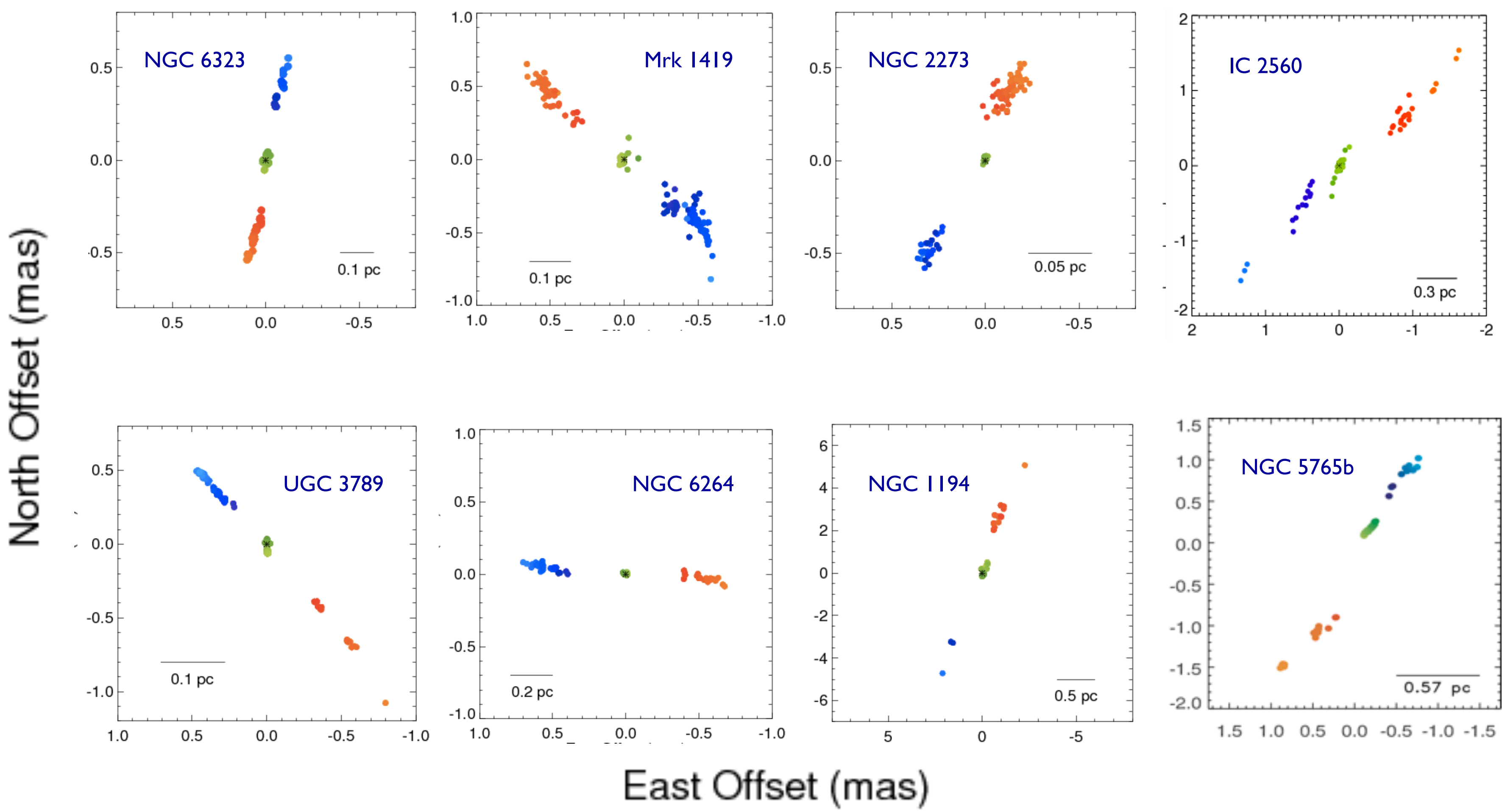
Cosmology

Progress with Megamaser Surveys

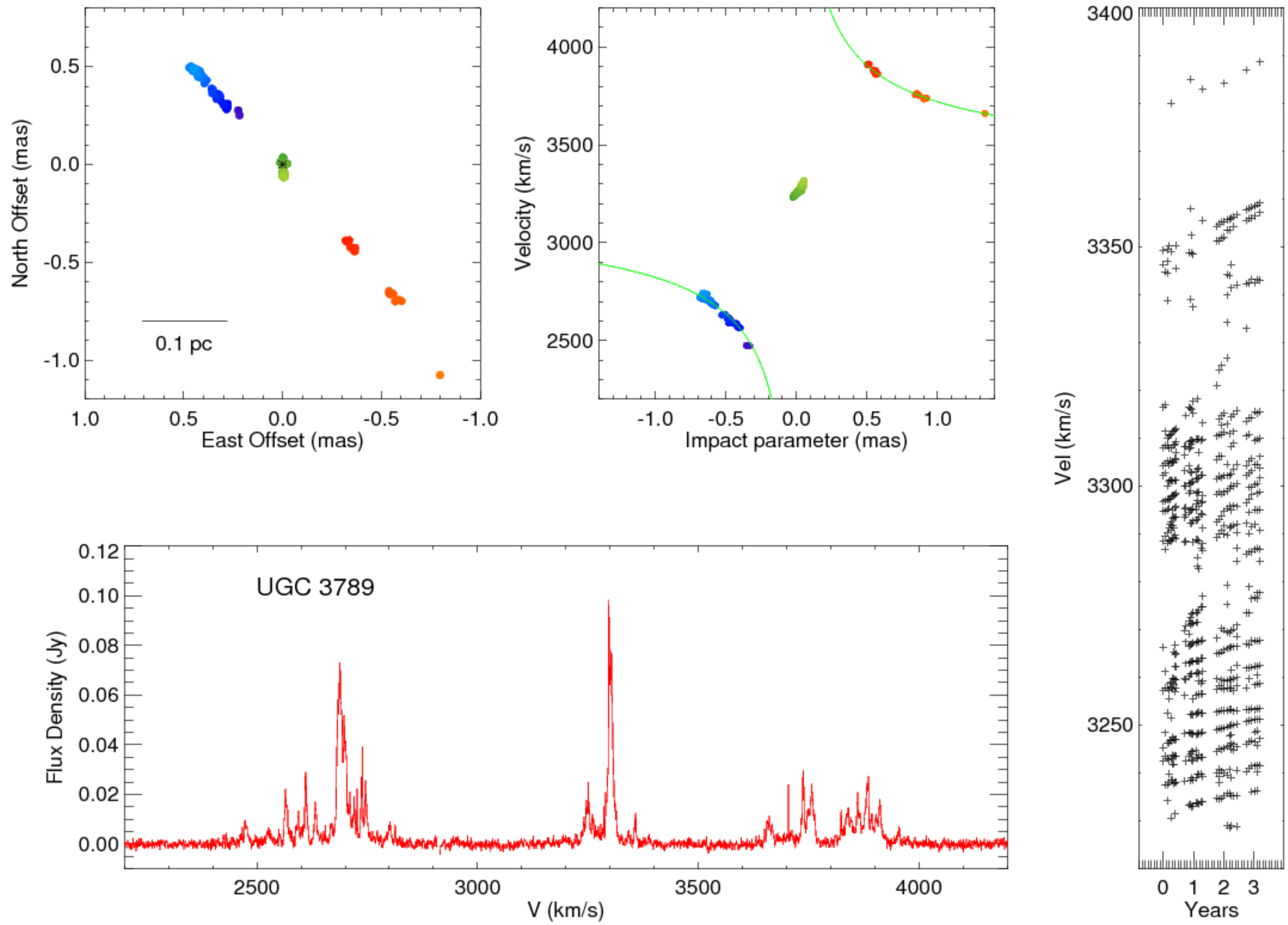


- 162 galaxies detected out of > 3000 observed
- ~ 37 have evidence of being in a disk and are suitable for M_{BH} measurement
- ~ 10 suitable for distance measurement
- Primary sample for surveys: Type 2 AGNs at $z < 0.05$

A Sample of VLBI Maps of H_2O Megamaser Disks



The H_2O Megamaser in UGC 3789



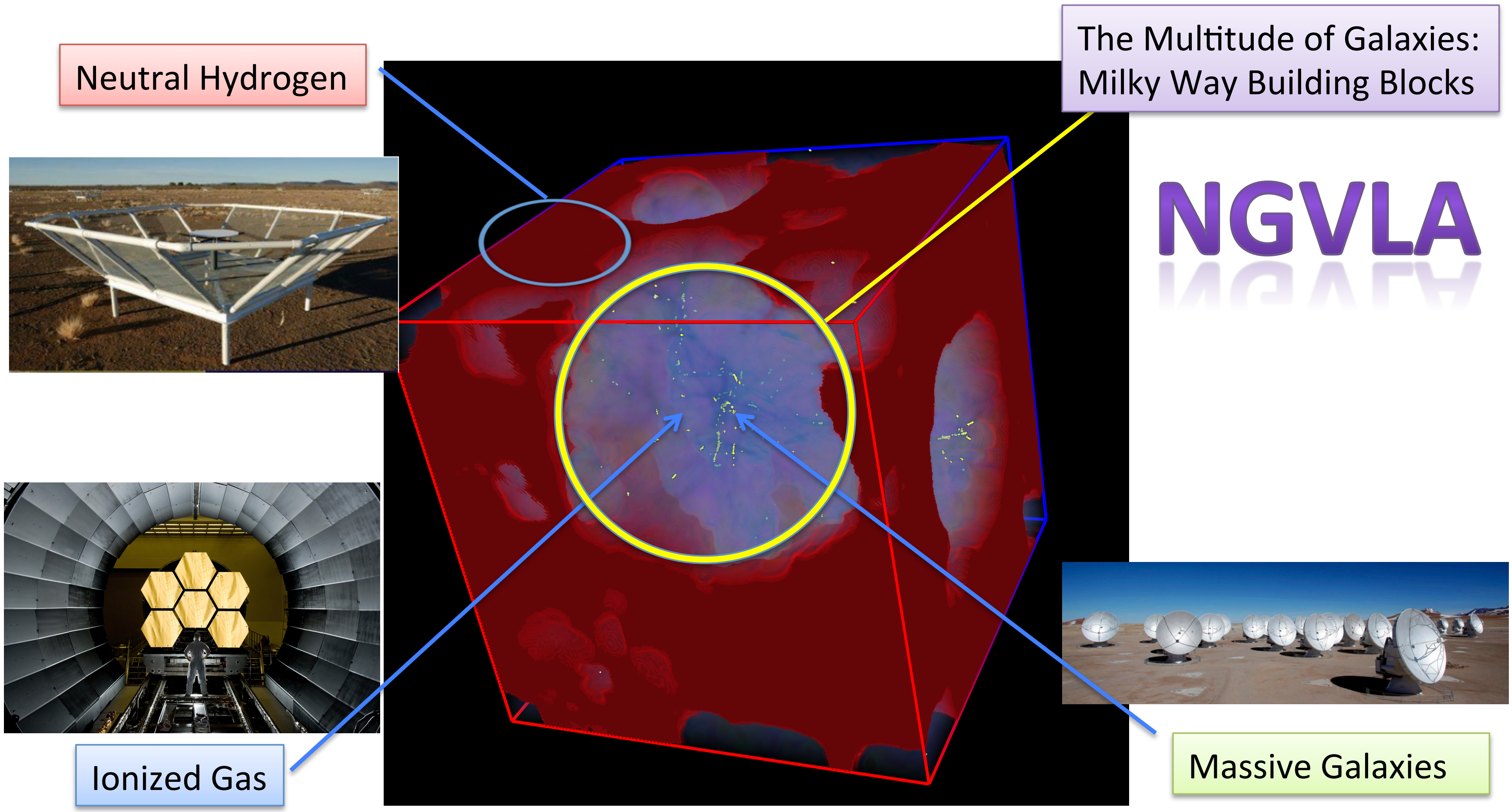
Summary of Results for Megamaser Science

- MCP measurement of H_0 is one-step, geometric measurement that provides a critical complement to measures using standard candles.
- Megamasers determine $H_0 = 70.4 \pm 3.6$ km s^{-1} 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 low-mass 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

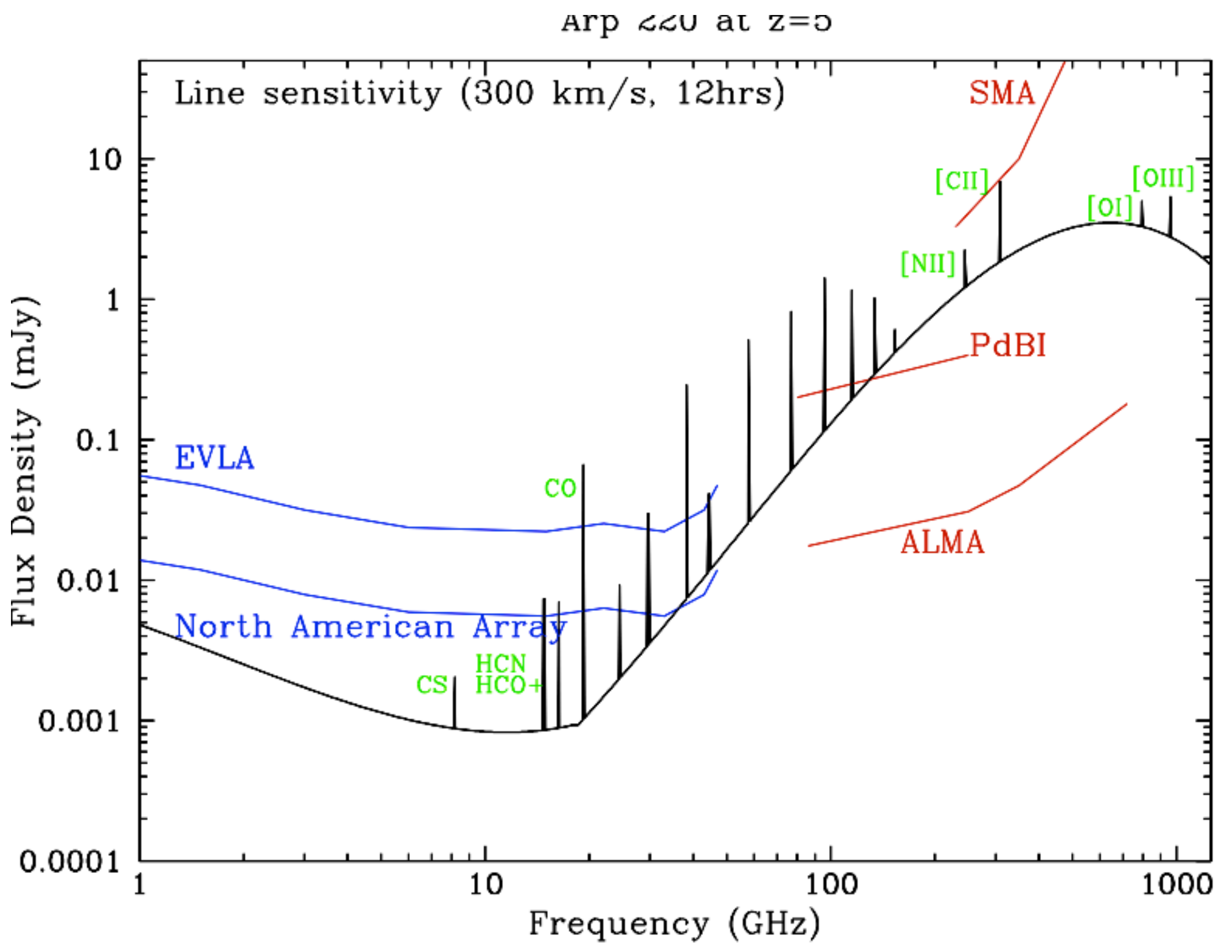
Requirements for a Next Gen Radio Telescope for Megamaser Science and Astrometry

- 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 H_2O 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.

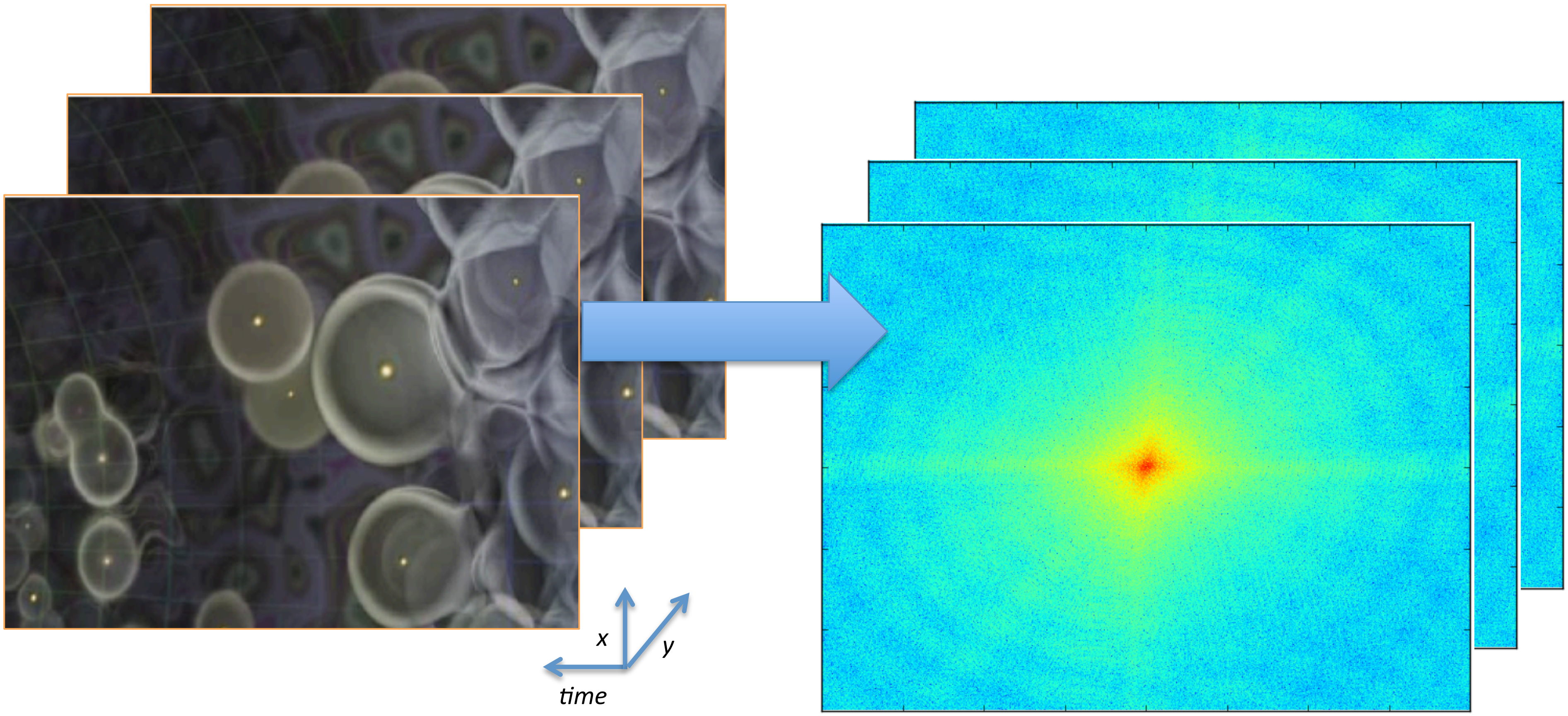
Intensity Mapping the Cosmic Web



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

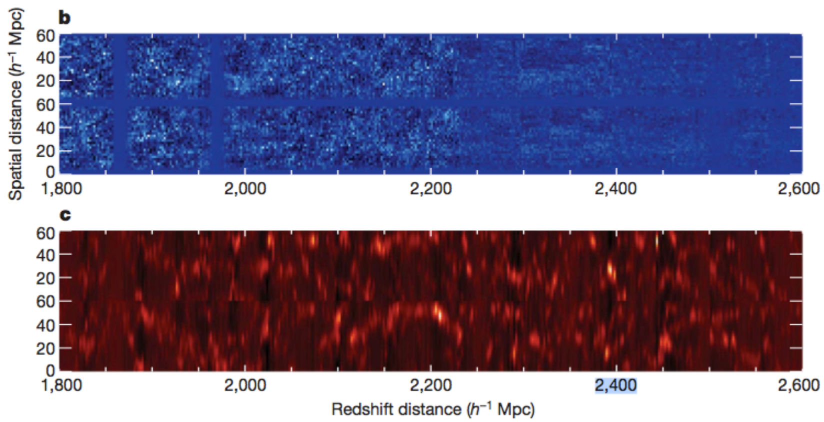


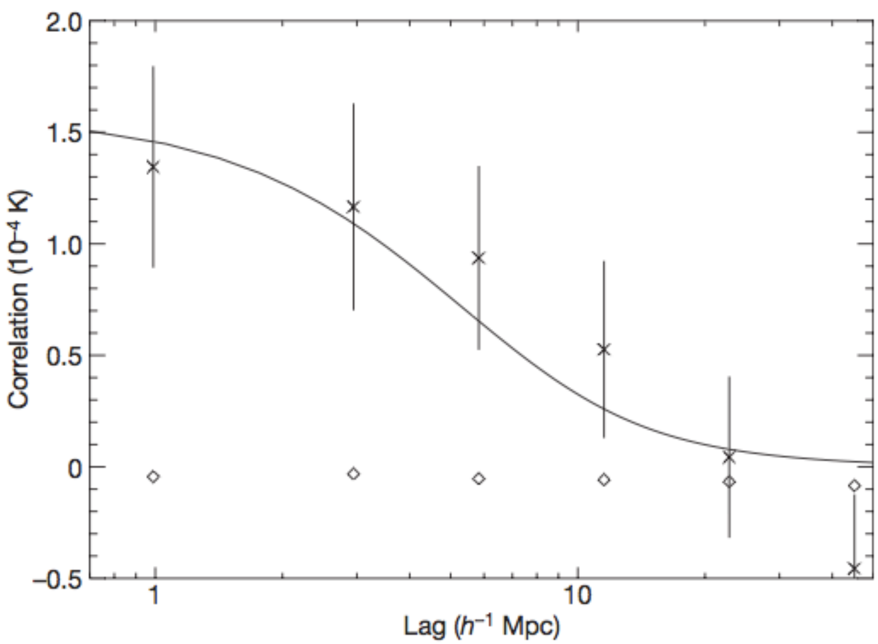
3D Power Spectrum → Intensity Mapping



Same approach as taken for microwave background and HI EoR

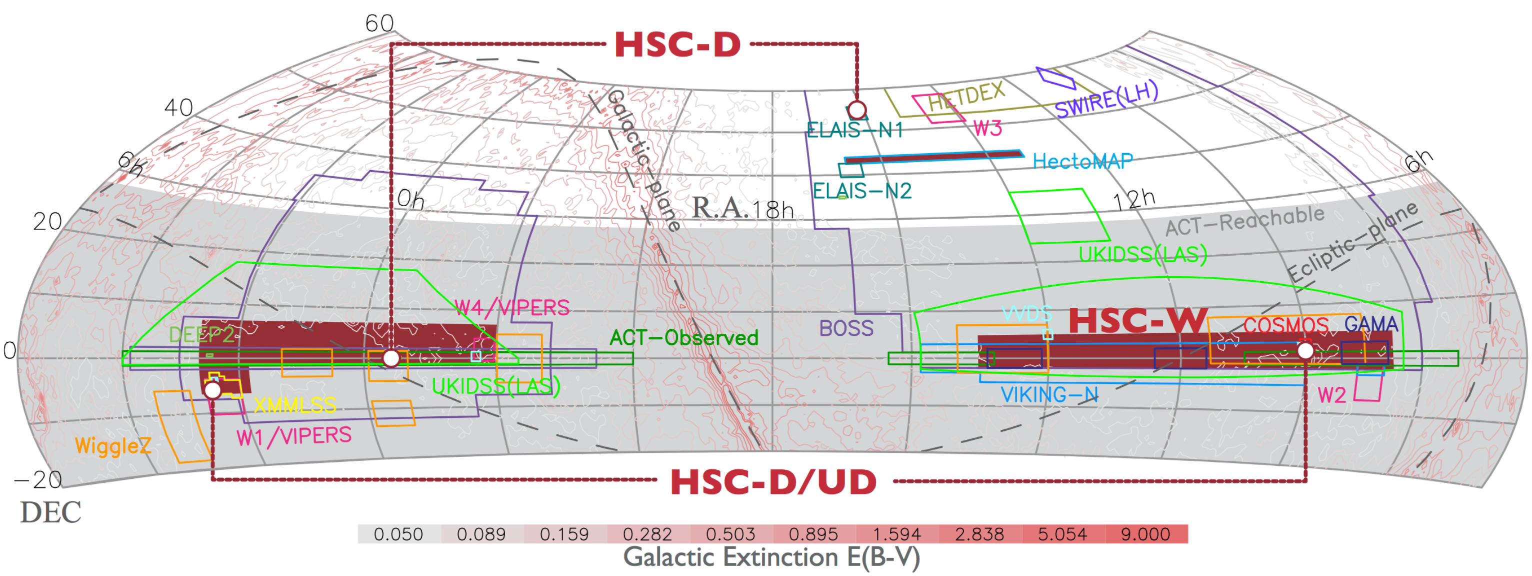
HI Intensity Mapping





- 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

Discussion Topics

- 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 → *Darling talk*
- Synoptic Surveys
  - Do the science cases favor a model of individual targets or large area surveys?
- Experiment or Facility?