EVLA Status and First Ligh
Science Opportunities

EVLA: A Major New Facility and SKA Demonstrator (2003-2012)

Ten Times the Astronomical Capability of the VLA.

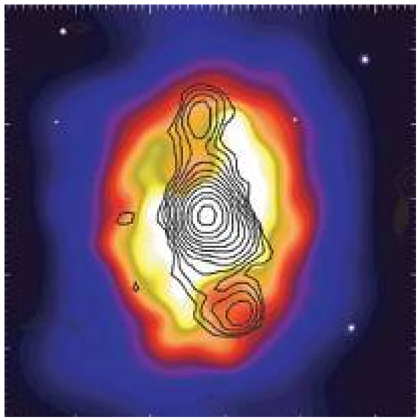
- Sensitivity, Frequency Access, Image Fidelity, Spectral Capabilities, Spectral Fidelity, Spatial Resolution, User Access

ALMAs centimetre "twin"

First light science is now!

Design Driven By Four Science Themes

Magnetic Universe



Measure the strength and topology of the cosmic magnetic field.

Obscured Universe

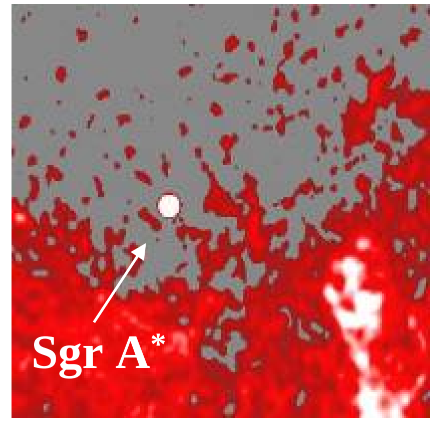
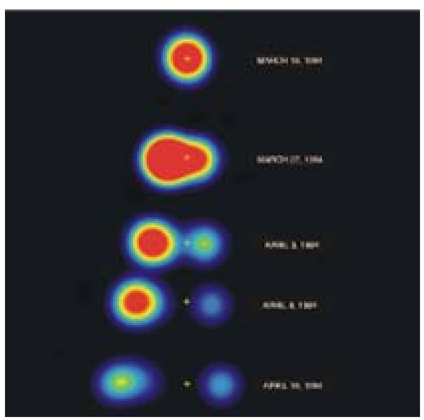


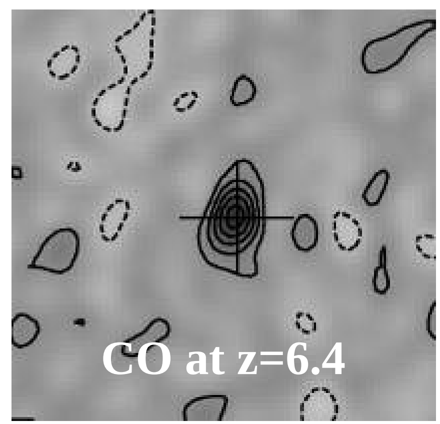
Image young stars and massive black holes in dust enshrouded environments.

Transient Universe



Follow the rapid evolution of energetic phenomena.

Evolving Universe



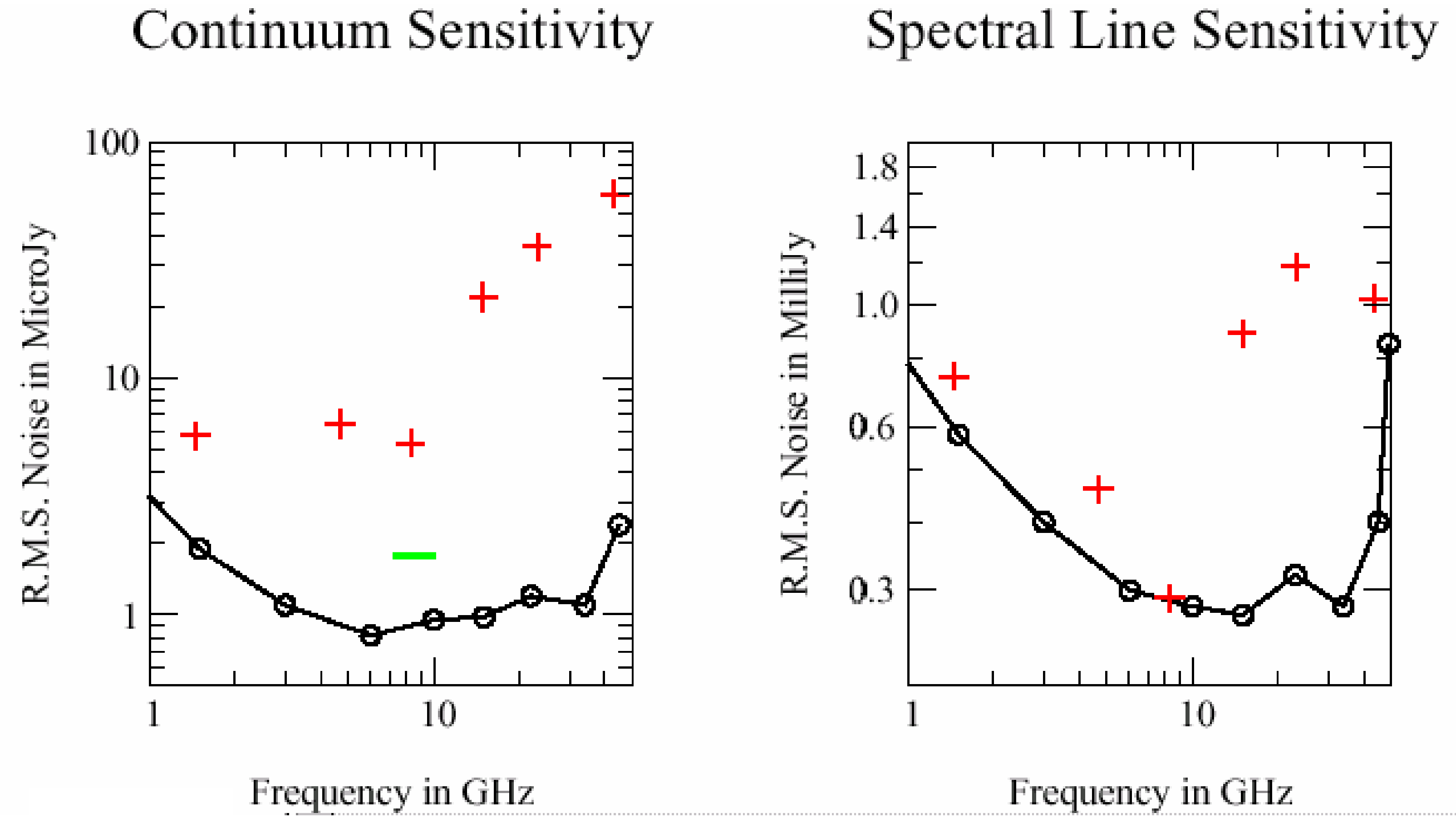
Study the formation and evolution of stars, galaxies and AGN.

EVLA Performance Goals

Parameter	VLA	EVLA	Factor
Point Source Sensitivity (1-σ, 12 hours)	10 μJy	1 μJy	10
Maximum BW in each polarization	0.1 GHz	8 GHz	80
# of frequency channels at max. bandwidth	16	16,384	1024
Maximum number of frequency channels	512	4,194,304	8192
Coarsest frequency resolution	50 MHz	2 MHz	25
Finest frequency resolution	381 Hz	0.12 Hz	3180
(Log) Frequency Coverage (1 – 50 GHz)	22%	100%	5

The cost to the NSF for this >10-fold improvement is $57M – about 1/3 the cost of the original VLA.

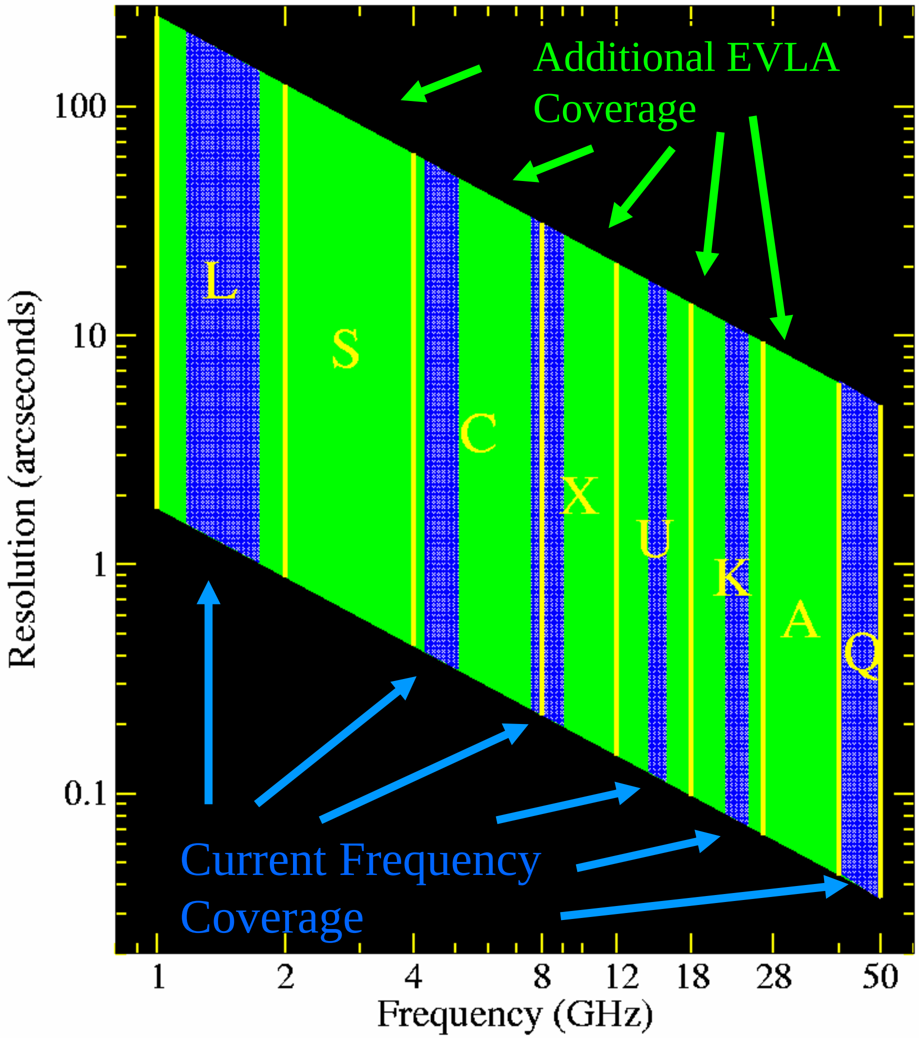
Sensitivity Improvement



(1 σ , 12 hours: VLA Y2000 152 hrs VLA Black: EVLA Goals)

Frequency - Resolution Coverage

- A key EVLA requirement is continuous frequency coverage from 1 to 50 GHz.
- This will be met with 8 frequency bands:
  - Two existing (K, Q)
  - Four replaced (L, C, X, U)
  - Two new (S, A)
- Existing meter-wavelength bands (P, 4) retained with no changes.
- Blue areas show existing coverage.
- Green areas show new coverage.
- The two IF pairs can be tuned *anywhere* in the selected band.



A North American Partnership

NRAO

Associated Universities, Inc.

NSF

NRC · CNRC
Herzberg Institute of Astrophysics

National Research Council Canada

Conseil national de recherches Canada

CONACYT

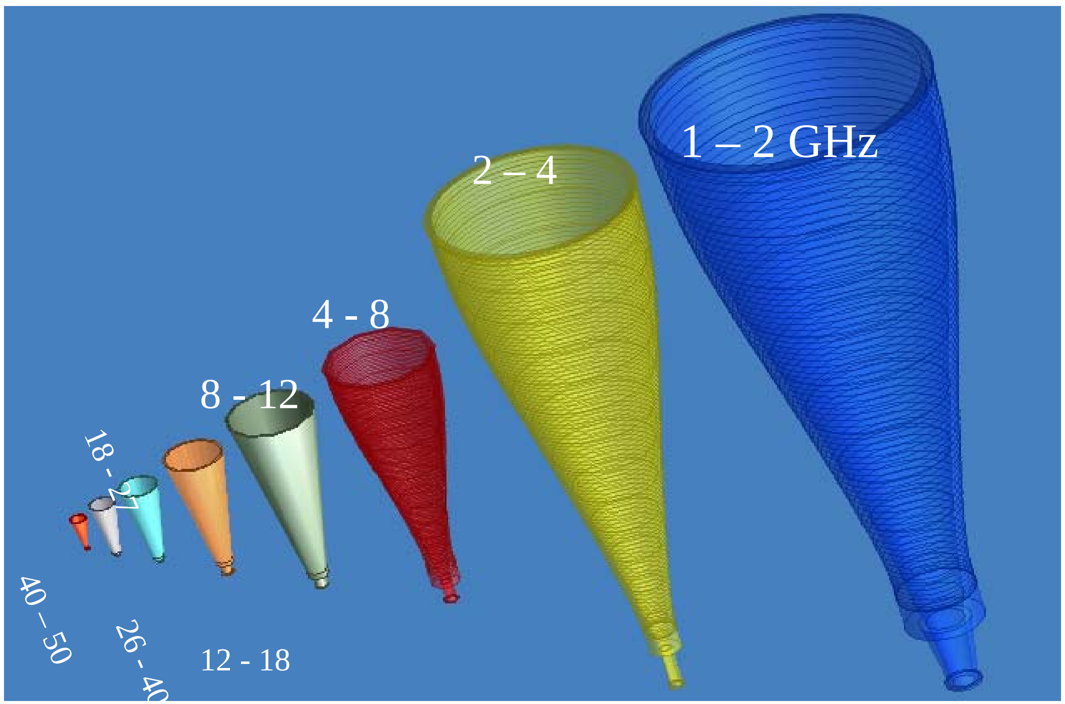
The EVLA Project on the Web
http://www.aoc.nrao.edu/evla/

EVLA Status: April 2008

- Antennas
  - More than half of all 27 antennas have a EVLA retrofit
  - New antennas outfitted at rate of one per 2 months
  - Complete in 2010
- Receivers
  - Mechanical design for L, C and C, Ku are mature
  - Final development work on orthomode transducers (OMT) is still ongoing. Interim C and L bands are on now.
  - Testing of prototype Ka (26.5-40 GHz) and S (2-4 GHz) receivers underway (new bands)
- Correlator
  - 4-station prototype arrives June 2008
  - 10-station “science capable” correlator arrives Fall 2008

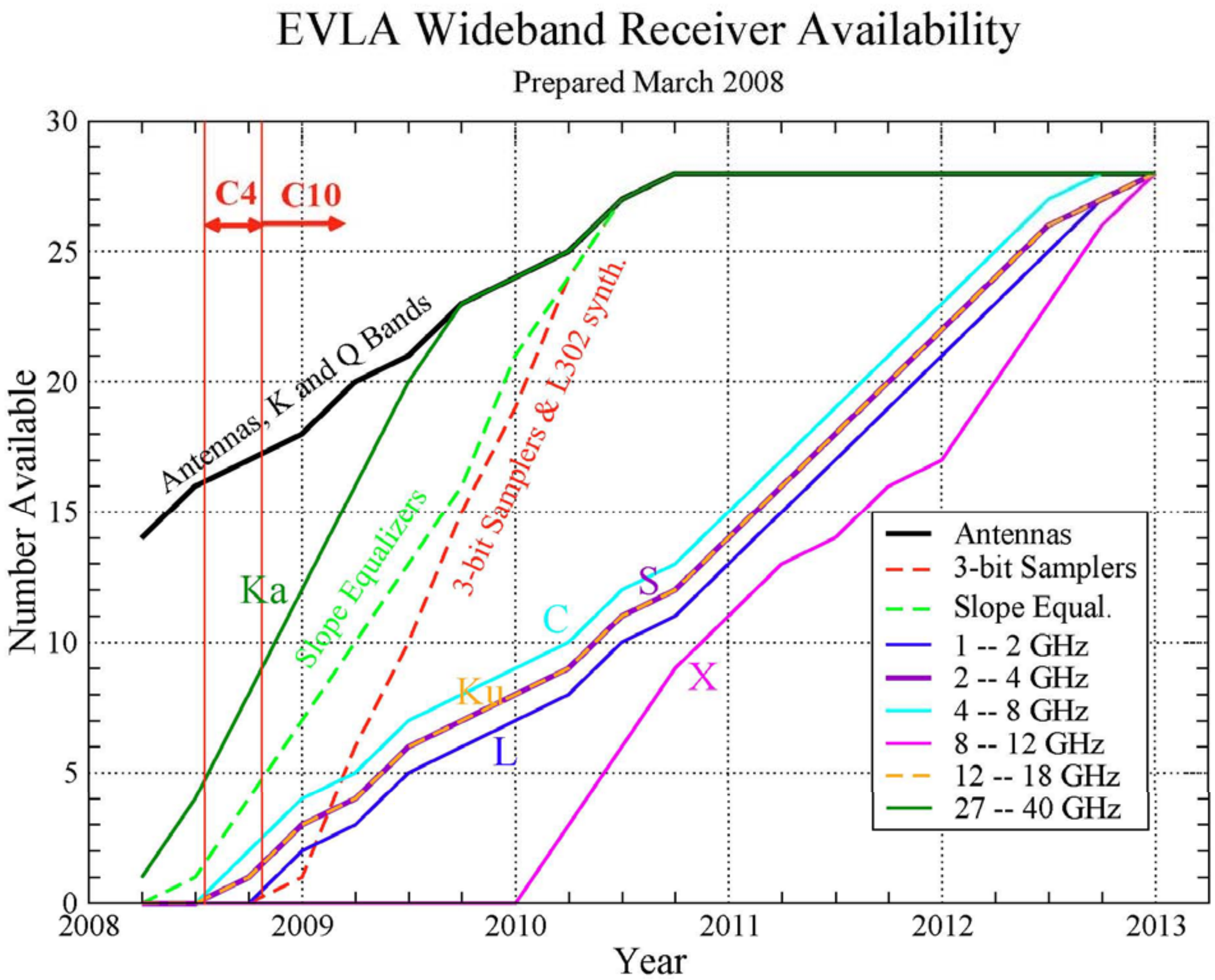
EVLA Feed System

All eight Cassegrain feeds are compact or linear taper corrugated horns with ring loaded mode converters



New Capabilities Timescale

- Full band tuning available now
- Old correlator's limitations remain:
  - 50 MHz BW
  - 16 to 512 channels
- The old correlator will likely be available until the WIDAR correlator achieves full 27-antenna capability – mid 2009.



Proposed Capabilities Timeline

2008		2009				2010				2011		2012
Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	...	Q1

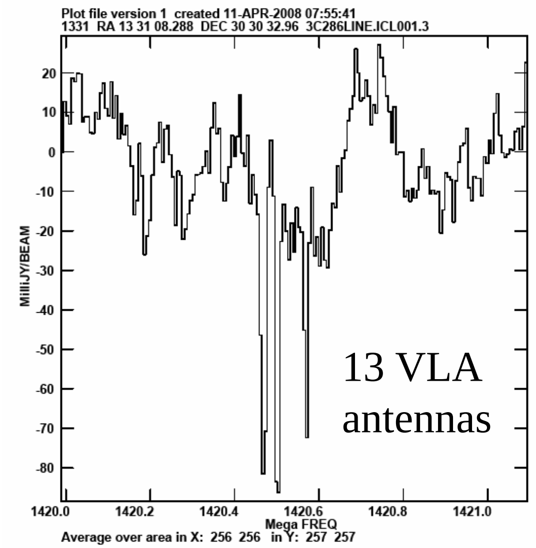
- On-the-sky tests
- Call for Ka band proposals
- Call for RSR observing proposals
- Basic science modes commissioned using 10-station/8-bit WIDAR VLA correlator with $20 \le N_{ant} \le 27$
- Resident Shared-Risk (RSR) observing begins, Turn off VLA correlator?
- Call for L, S, Ku band proposals
- Special science modes commissioned 2´64 MHz BW with 8-bit WIDAR, 27 antennas, for "regular" observers 8 GHz BW with ≥ 10 antennas for RSR observers
- Open Shared Risk (OSR) observing begins, ~27 antennas, 8 GHz BW
- Full science operations begin

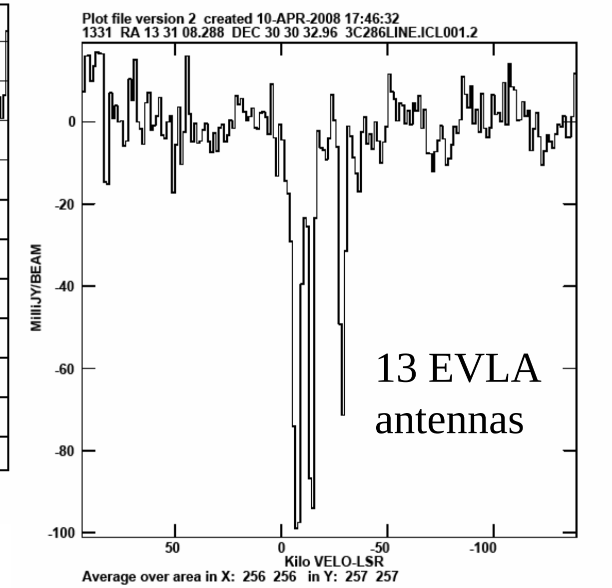
Science Capabilities Timeline

Science	Timescale	High Freq. (>18 GHz)	Low Freq. (<18 GHz)	Correlator Capabilities
Full VLA Operations	Now	27 receivers *(K & Q)*	27 receivers *(interim C & L)*	27 ants, 2x50 MHz *(newly tunable)*
Resident Shared Risk (RSR)	Q4 2009	23 receivers	~10 receivers	10 ants, 8 GHz BW 27 ants, 2x64 MHz
Open Shared Risk (OSR)	Q1 2011	27 receivers	~15 receivers	27 ants, 8 GHz BW
Full EVLA Operations	Q1 2012	27 receivers	~24 receivers	27 ants, 8 GHz BW

Science Capabilities Now!

- Increased spectral fidelity from modern EVLA electronics
- Detection of faint lines in absorption and emission
- *e.g.* small, cold neutral hydrogen clouds in ISM
  - VLA: time-variable bandpass. $\sigma_{\tau} = 2x10^{-3}$
  - EVLA: $\sigma_{\tau} = 3x10^{-4}$
- Spectral fidelity expected to be >100,000: 1





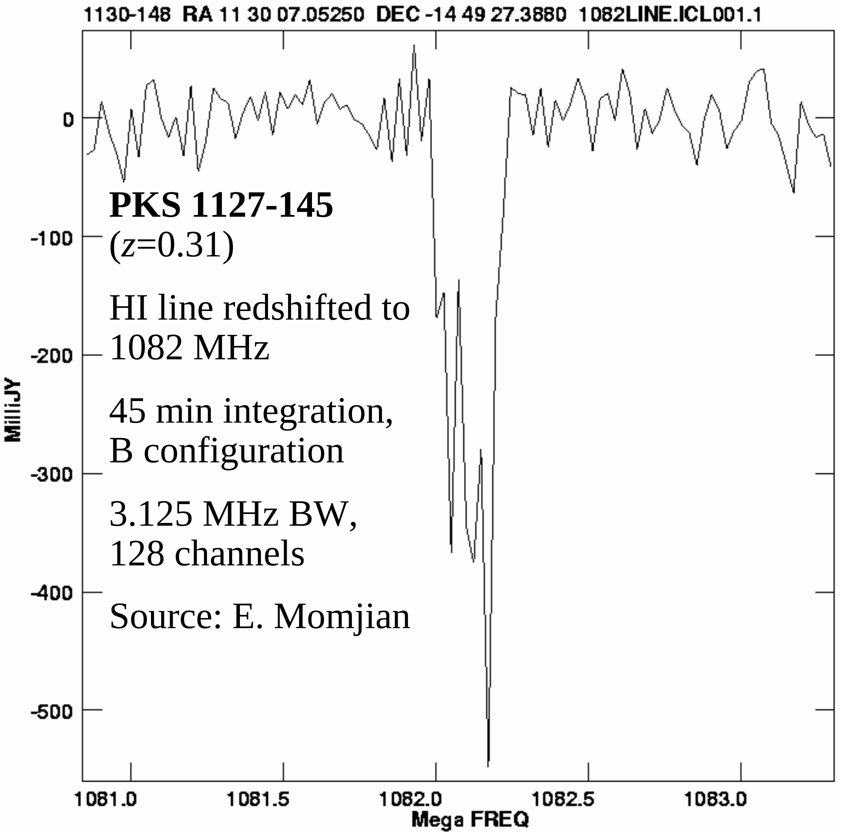
Details: 3C 286 (S=15 Jy)

1.56 MHz, 256 channels, 11 hrs

(Source: M. Goss)

Redshifted Atomic (HI) and Molecular (OH) Gas in Absorption

- Access to new frequencies
- VLA optics limit routine observations to ν >1225 MHz
  - some narrow windows possible in 1100-1225 MHz area
- EVLA works to 1000 MHz <u>now</u> and eventually down to 940 MHz
- Surprise! RFI is benign
- Blind H/OH survey
  - trace gas evolution ahead of SKA
  - Complements DLA surveys
  - Full redshift range in one wide field

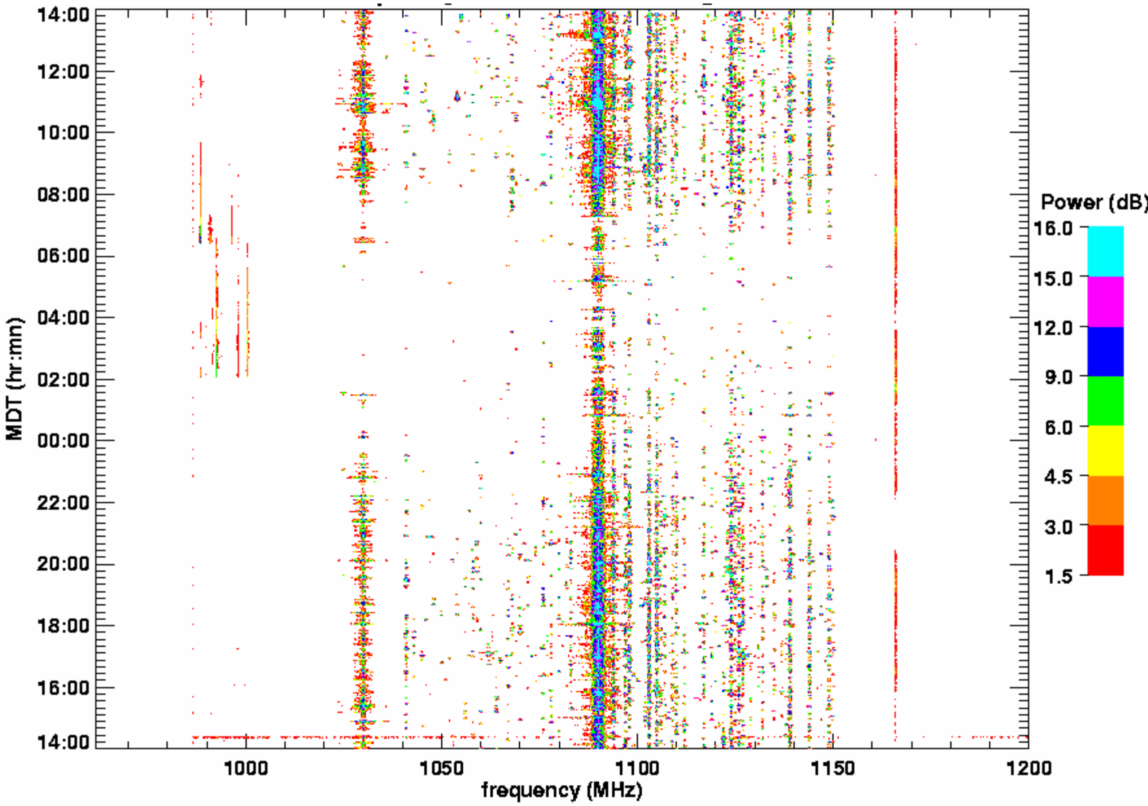


HI: 0< *z* <0.5
OH: 0< *z* <0.8

(Compare: Arecibo ALFALFA Survey to z<0.06)

RFI (960 to 1200 MHz)

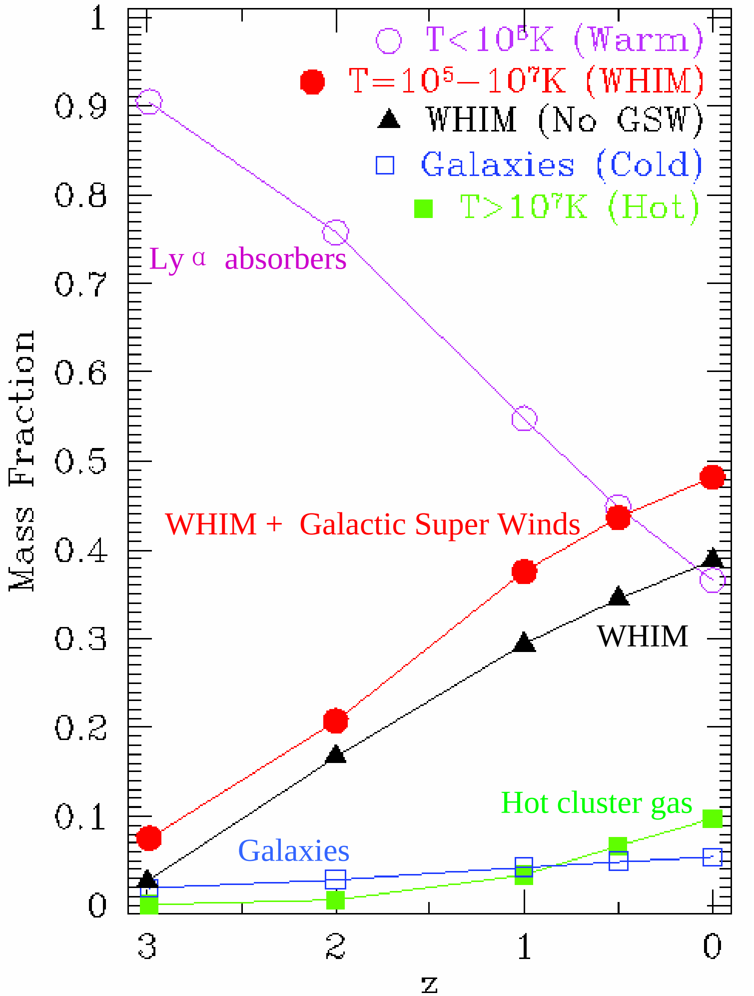
- RFI below 1150 MHz is primarily due to radar transponders used in aeronautical navigation.
  - 1090 MHz (air to ground)
  - 1030 MHz (ground to air)
- Short pulses are not seen on long baselines
  - 3.5 microsecond long (1.1 km) separated by 12 microsecond.
  - Easy to clean on short (B-array) baselines



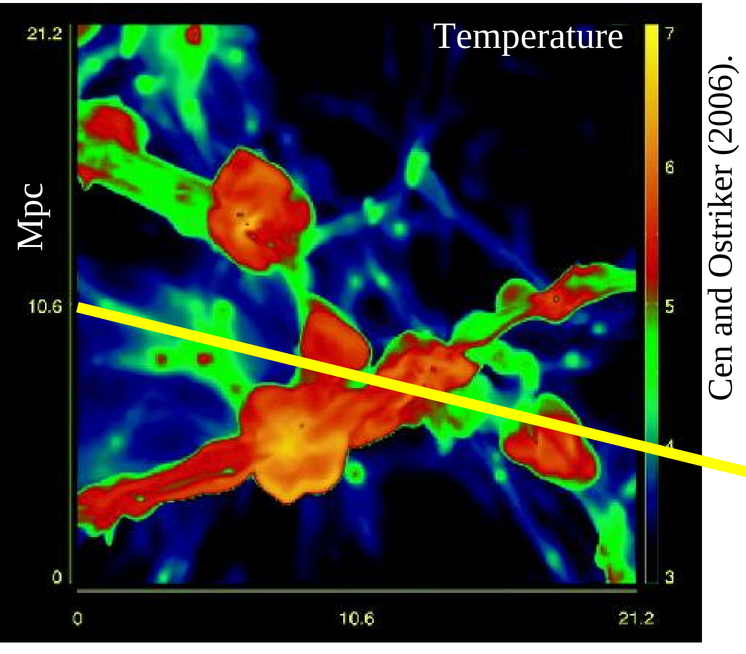
The “Missing” Baryon Problem

- Ω_b well-determined by CMB
- Shortfall in census of local (z~0) baryons. Half missing
- Λ CDM structure formation models predict majority of baryons are in Mpc scale filaments joining clusters
  - “cosmic web”
  - $10^5 < T < 10^7$ K
  - Warm Hot Ionized Medium (WHIM)

Adapted from Cen & Ostriker (2006)



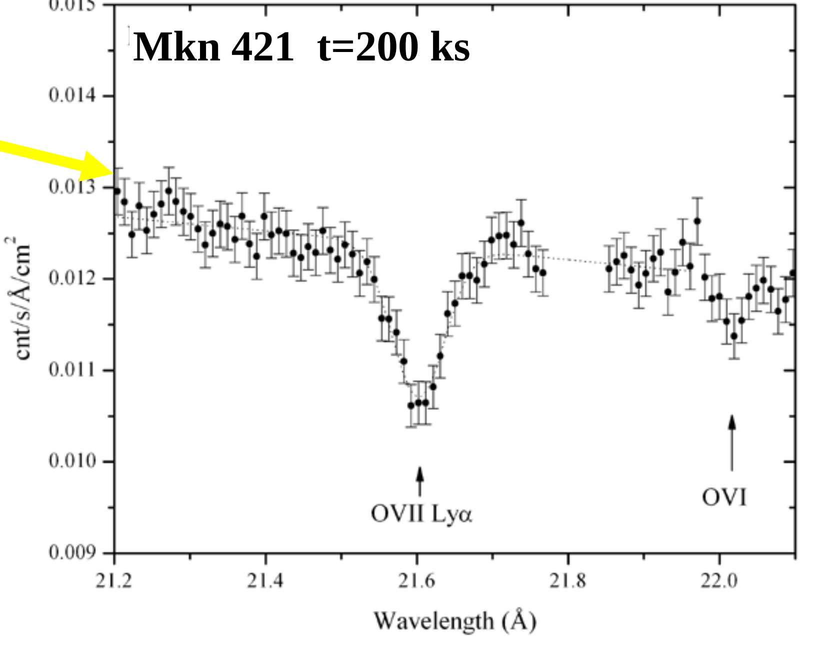
Current Diagnostics of the WHIM



Ultraviolet (OVI)

- FUSE and HST/COS (on SM4)
- $T<10^{5.5}$ K
- <7% of baryons

Adapted from Nicastro et al (2005)



X-rays (OVII)

- *Chandra* and XMM
- $T \sim 10^6$ K
- controversial

A Hot New Diagnostic

- Hydrogenic-like ion NVII *(Sunyaev & Churazov 1984)*
- Hyperfine spin-flip transition at ν_o=53.1 GHz
- Detect cosmic web at T=10^6 K in absorption against QSOs
- Ideal early EVLA science *(Frail. Bregman, & Irwin)*
  - New high frequency receivers
  - Full 8 GHz BW, velocity resolution and BP stability
- In 12 hrs EVLA-10 is comparable 1 Msec Chandra/XMM obs

Band	Frequency (GHz)	Δz	WHIM	σ_{line} (km/s)
Q (0.7 mm)	40-50	0.06-0.33	55%	0.4
Ka (1 cm)	26.5-40	0.33-1.00	40%	0.3
K (1.3cm)	18-26.5	1.00-1.95	30%	0.3

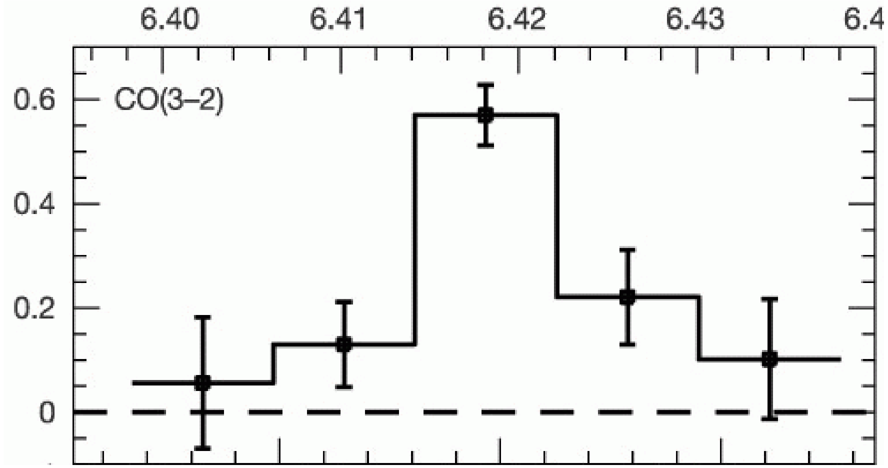
Small print: Δt=12 hrs, ΔV=10 km/s, 10 antennas, $V_{thermal}$=34 km/s, Xiso~10^{-4}, σ =3.8x10^{-19} cm^2, [N/H]=10^{-4}, 15 Jy cont.

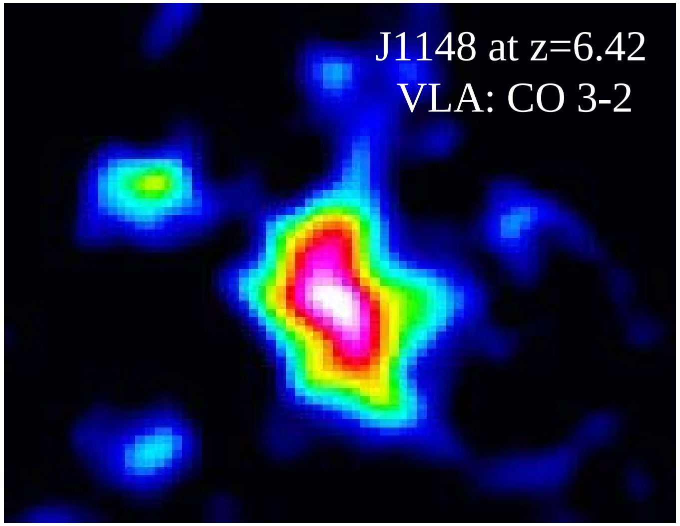
7.5 σ detection of τ =2.4x10^{-4}

Cosmological Galaxy Evolution

- Major science driver for all future large telescopes
- EVLA will study dust obscured SF through synch continuum and lower order CO transitions
- Complementary capabilities
  - Normal galaxies. z~1
  - Starburst galaxies z~2-4
  - ULIGRs & QSO z~6

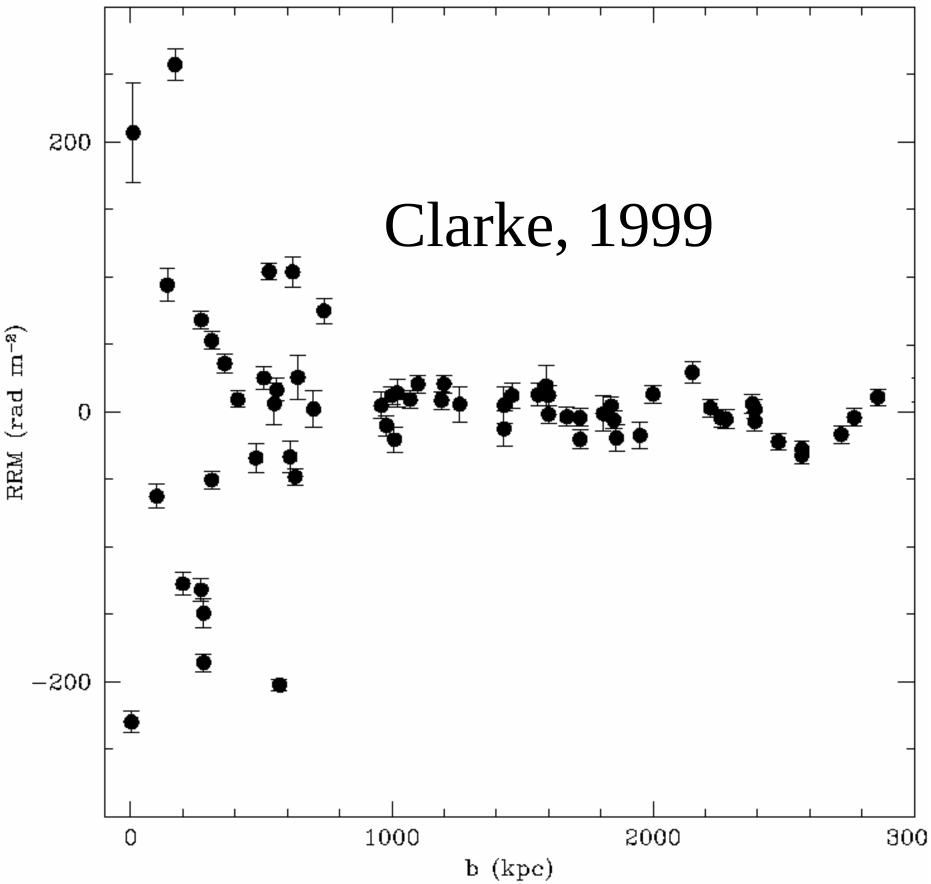
- Imaging molecular building blocks (θ)
- Blind searches of ULIRG (BW)
- Targeted search of high z clusters (FoV)



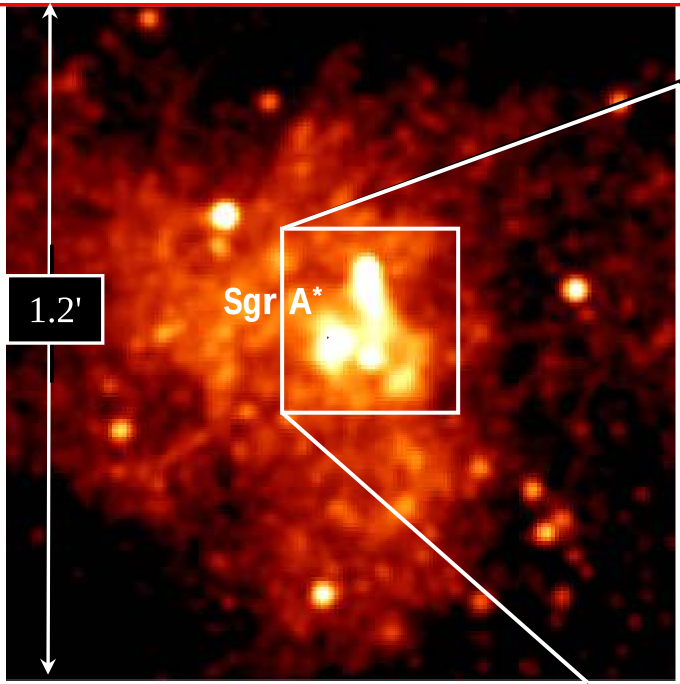


Cluster and Galaxy Magnetic Fields

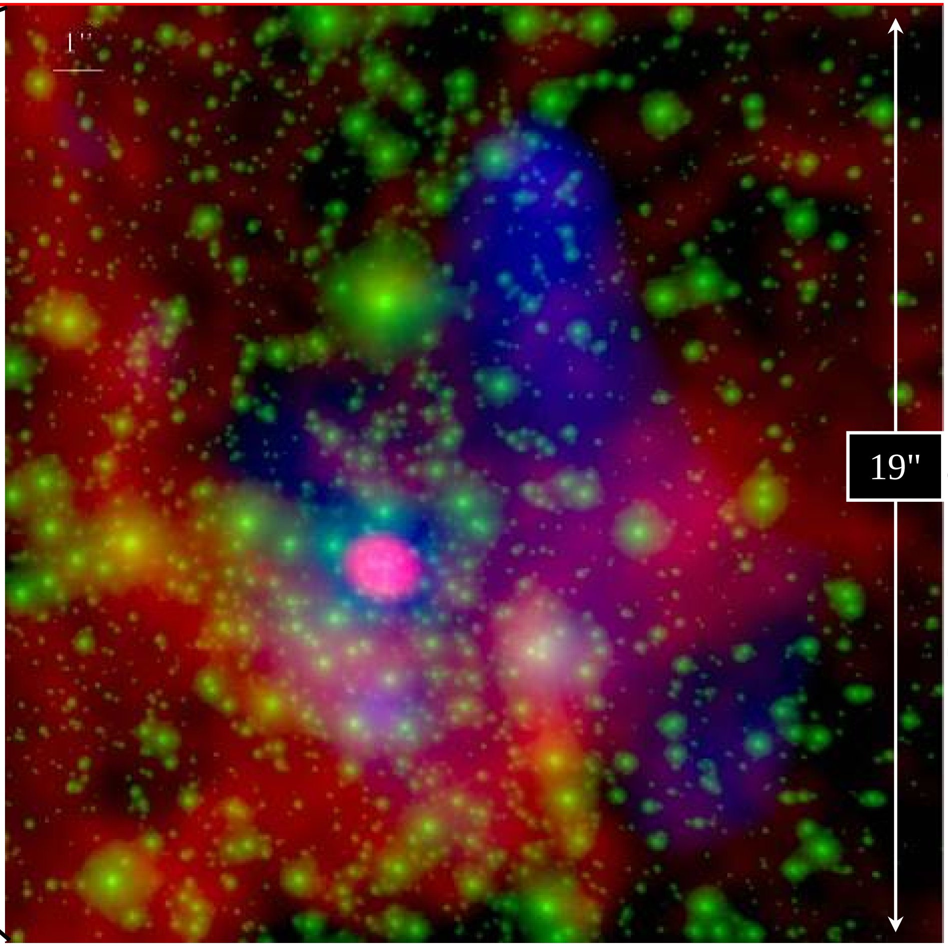
- Intra-cluster magnetic fields may play an important role in galaxy and cluster evolution.
- Radio observations of Faraday rotation give only probe of cluster fields.
- VLA sensitivity sufficient only for statistical studies.
- EVLA sensitivity will allow 20 RRMs, per cluster, for more than 80 clusters.
- OSR science: Detection of ionized edge of nearby galaxies. (100-200 srcs)



Strong Gravity and Black Hole Accretion



(Credit: NASA/CXC/MIT/F.K. Baganoff et al.)



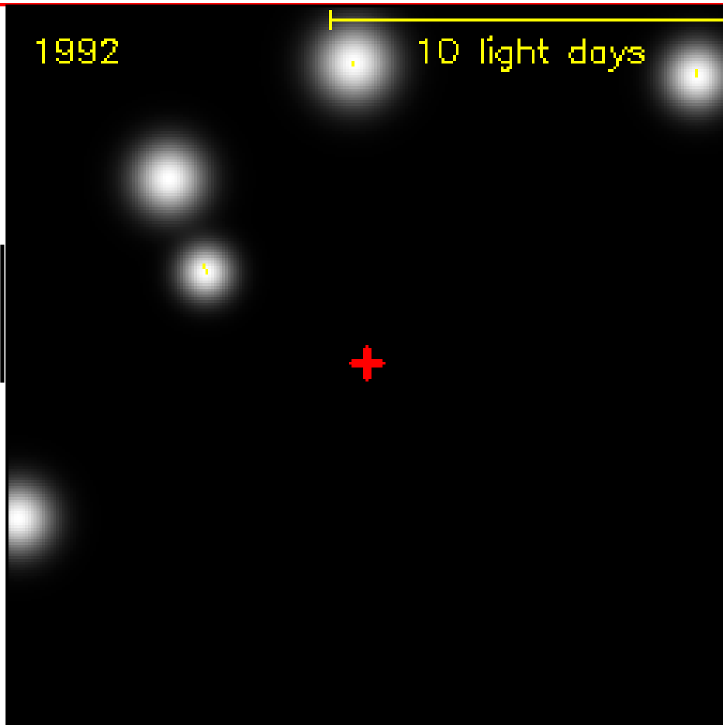
(Credit: Wang et al. astro-ph/0512643)

(Red=radio; blue=X-ray; Green=NIR)

Galactic center is rich in massive stars and hence NS and BH remnants

- 10^2-10^3 PSRs with P_{orbit}<100 yr
- Current GC PSR searches are insensitive due to turbulent ionized gas

Strong Gravity and Black Hole Accretion



Credits: MPE, Genzel et al.

$\text{At 22 GHz}: \quad \text{rms (50 ksec)} = 1\ \mu\text{Jy}$

$\vartheta_{\text{scat}} = 2\ \text{mas};\ \ t_{\text{scat}} = 1.3\ \text{msec}$

$\text{VLA beam} = 100\ \text{mas};\quad \text{FOV} = \pm 60''$

$\text{Detect 2-15 PSRs within 4000 AU of SgrA}^*$

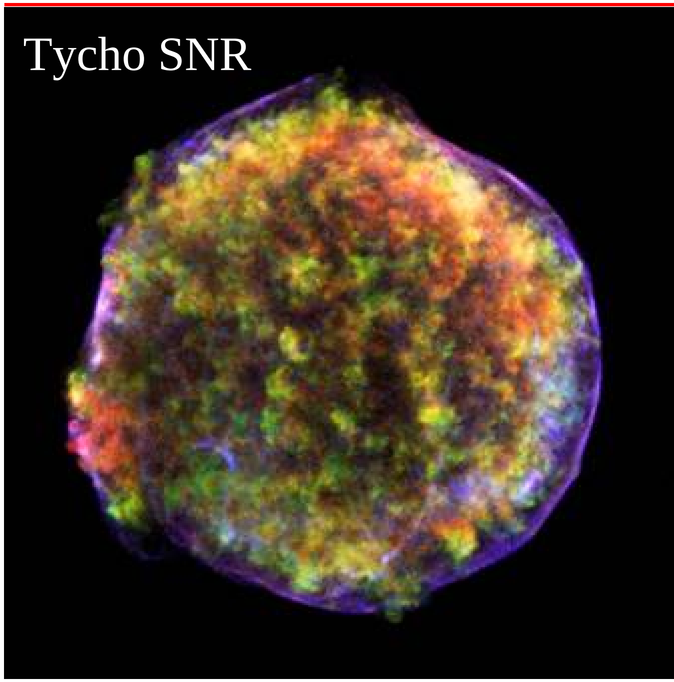
EVLA capabilities

- 10-fold increase in sensitivity (rms=1 uJy)
- 10^6 : 1 image fidelity (PSR : SgrA*)
- 10’s mas position astrometry
- Millisecond pulsar timing

Results from long-term timing and astrometry

- Measure mass and <u>spin</u> of SMBH
  - Keplerian orbits (M_{BH})
  - Relativistic spin-orbital coupling $(\vec{\Omega})$
  - Complements Con X Fe-line florescence
- Tests of GR in ultra-strong regime
  - And alternate theories of gravity
- Probes of the magneto-ionic accretion environment around a black hole

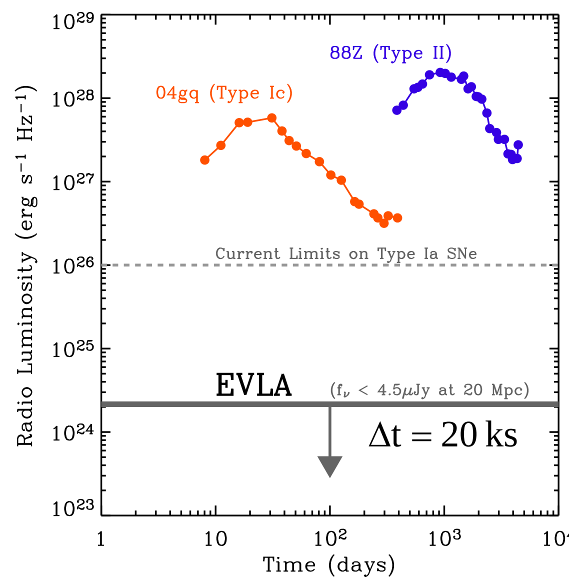
The Progenitors of Type Ia Supernova



Credit: NASA/CXC/Rutgers/J.Warren et al.

EVLA capabilities

- order of magnitude (20X) increase in instantaneous sensitivity
- continuous frequency coverage
- real-time dynamic scheduling

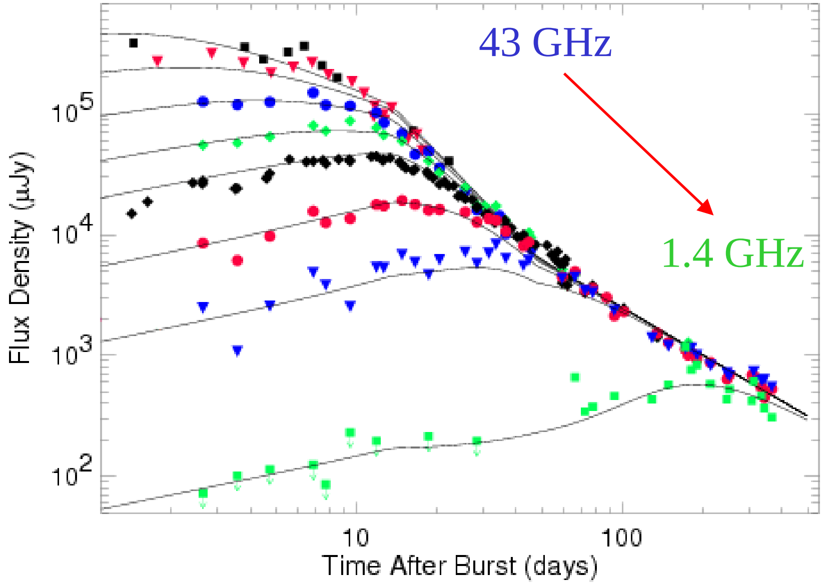


Deep ignorance about SN Ia progenitor and explosion mechanism

- high spatial and spectral X-ray observations combined w/ theory
- ✓ detect progenitor circumstellar medium

100-fold increase in SN Ia event rate

Gamma-Ray Bursts: Black Hole Birth



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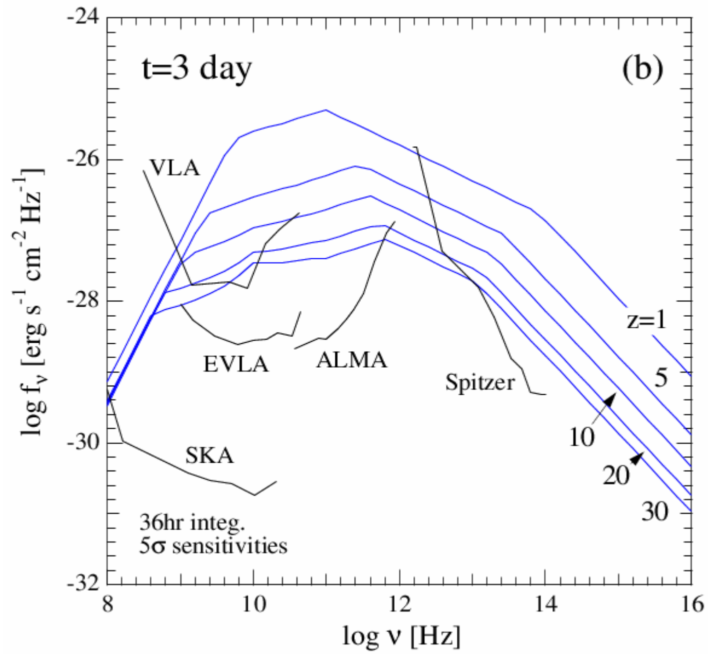


Inoe, Omukai, & Ciardi 2004

Radio observations of GRB afterglows are key but are currently severely sensitivity limited

- Constrains the total energy released by central engine independent of θ_{jet}, θ_{view}, or Γ

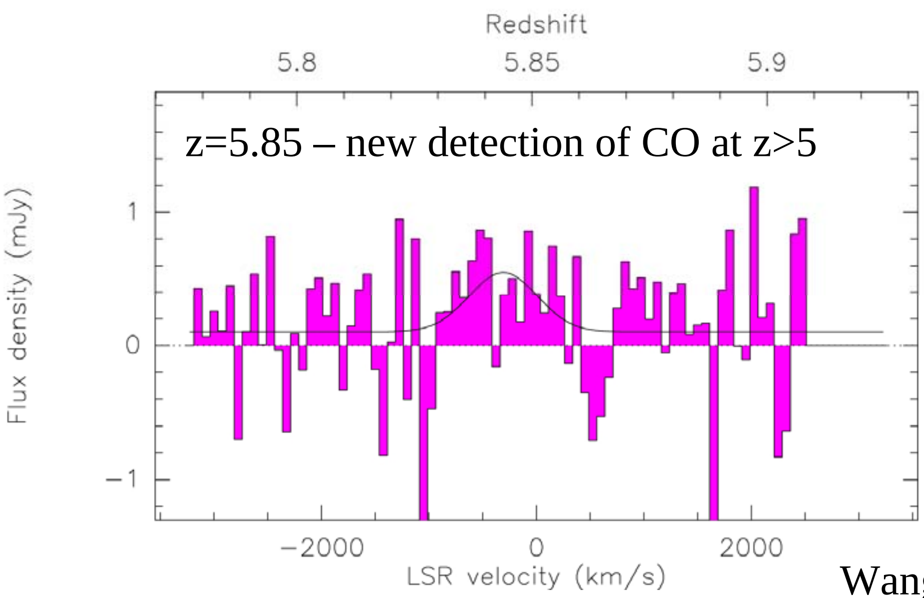
Probes density structure of circumburst medium

- Breaks optical/X-ray degeneracy

We Welcome Chinese Collaborators

Ran Wang, Peking U.

- Beijing to NRAO, Socorro
- C. Carilli cosmology group
- 9 peer-reviewed papers
- Observing and proposals at IRAM 30-m, IRAM PdBI, SMA, CSO, VLA, HST, Spitzer



Wang et al. *in prep.*


Fin …in 2012