Expanded Very Large Array (EVLA)

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Atacama Large Millimeter/submillimeter Array
Expanded Very Large Array
Robert C. Byrd Green Bank Telescope
Very Long Baseline Array

NRAO

The EVLA - Improving the VLA

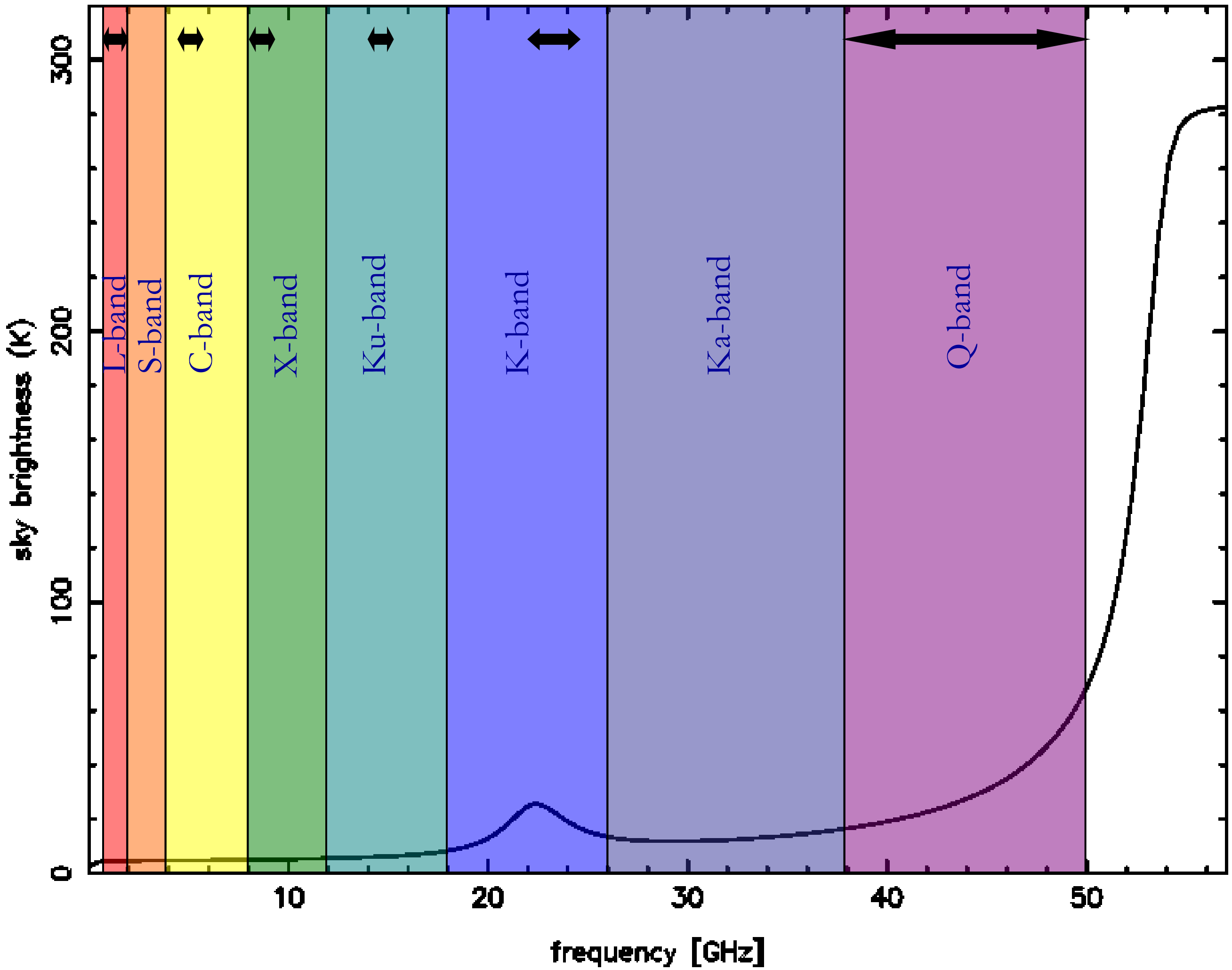
The VLA was the world's most powerful radio wavelength interferometer, but was designed and built in the 1960's/70's, and completed in 1980 - the dark ages relative to "modern" electronics! But the infrastructure (antennas, rails, buildings, etc…) are sound.

The **EVLA** has upgraded (or will):

- Front Ends (feeds + Rx)
- LO
- Data transmission
- Correlator
- Software

Main result is increased sensitivity (a few μJy in 1 hour)

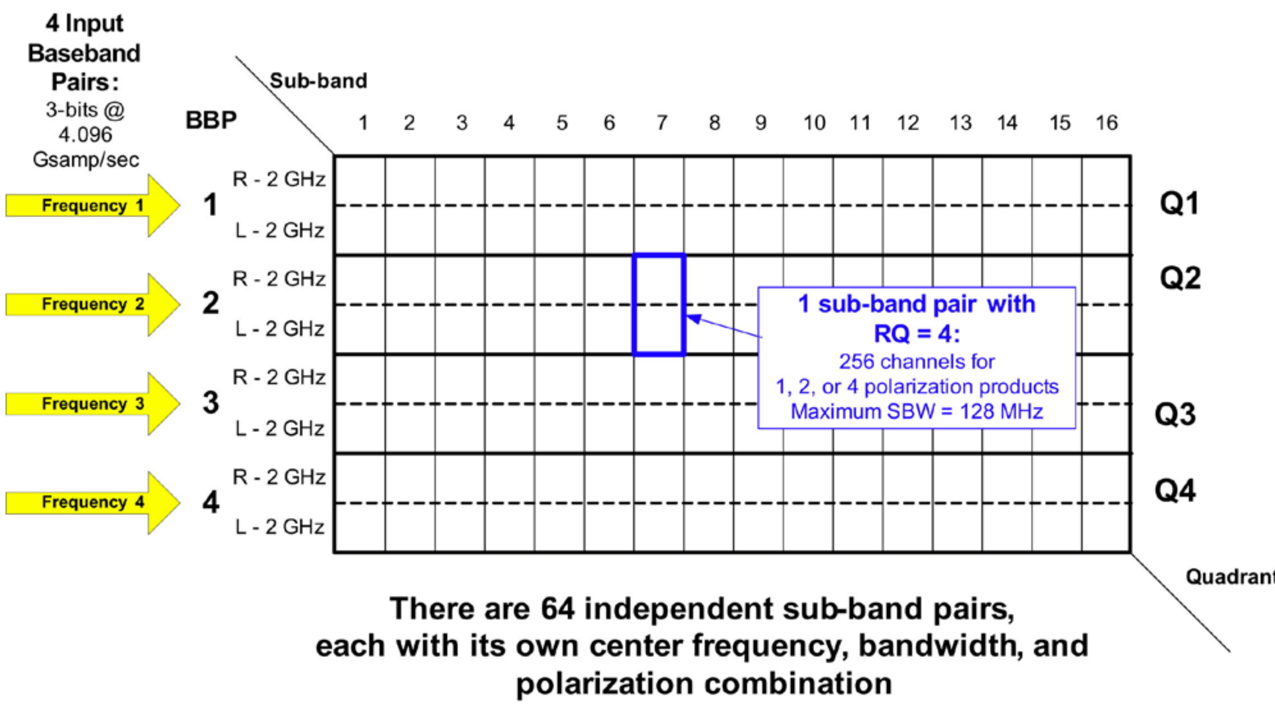
Front Ends



L-band
S-band
C-band
X-band
Ku-band
K-band
Ka-band
Q-band
sky brightness (K)
0
100
200
300
10
20
30
40
50
frequency [GHz]

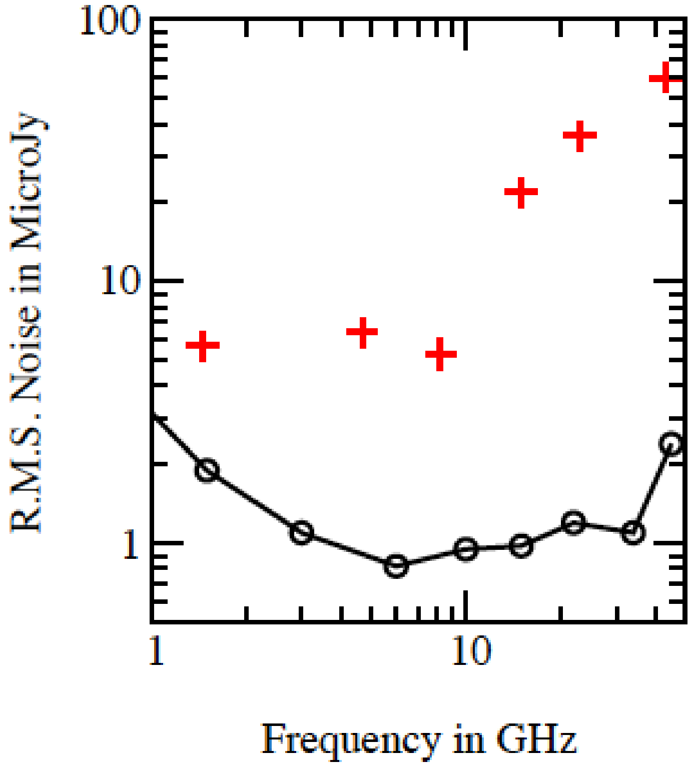
Back End (Correlator - WIDAR)

- Built by DRAO in Canada - 10 POP/s special-purpose computer
- 8 GHz maximum instantaneous bandwidth, full polarization
- 16384 spectral channels minimum, 4.2 million maximum
- 64 almost entirely independently tunable spectral windows

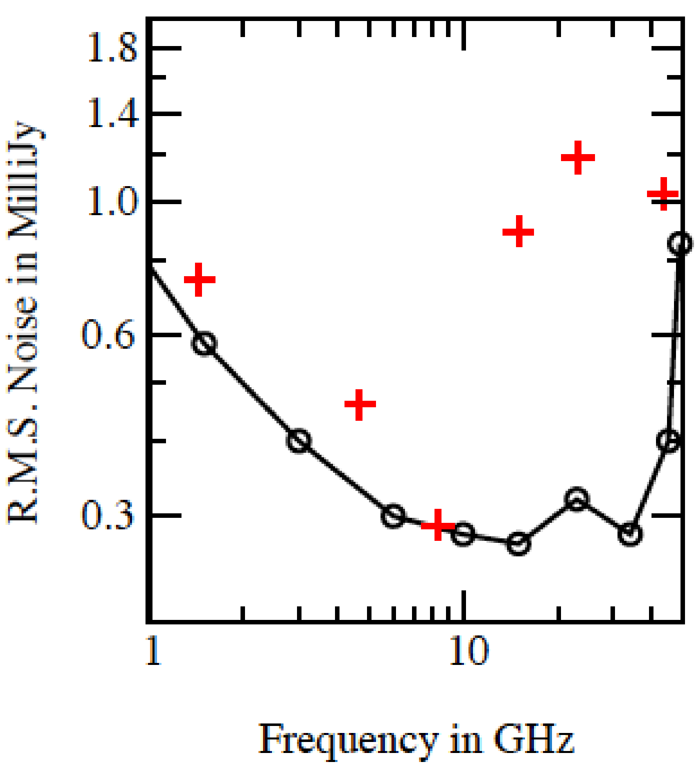


Sensitivity

Continuum Sensitivity



Spectral Line Sensitivity

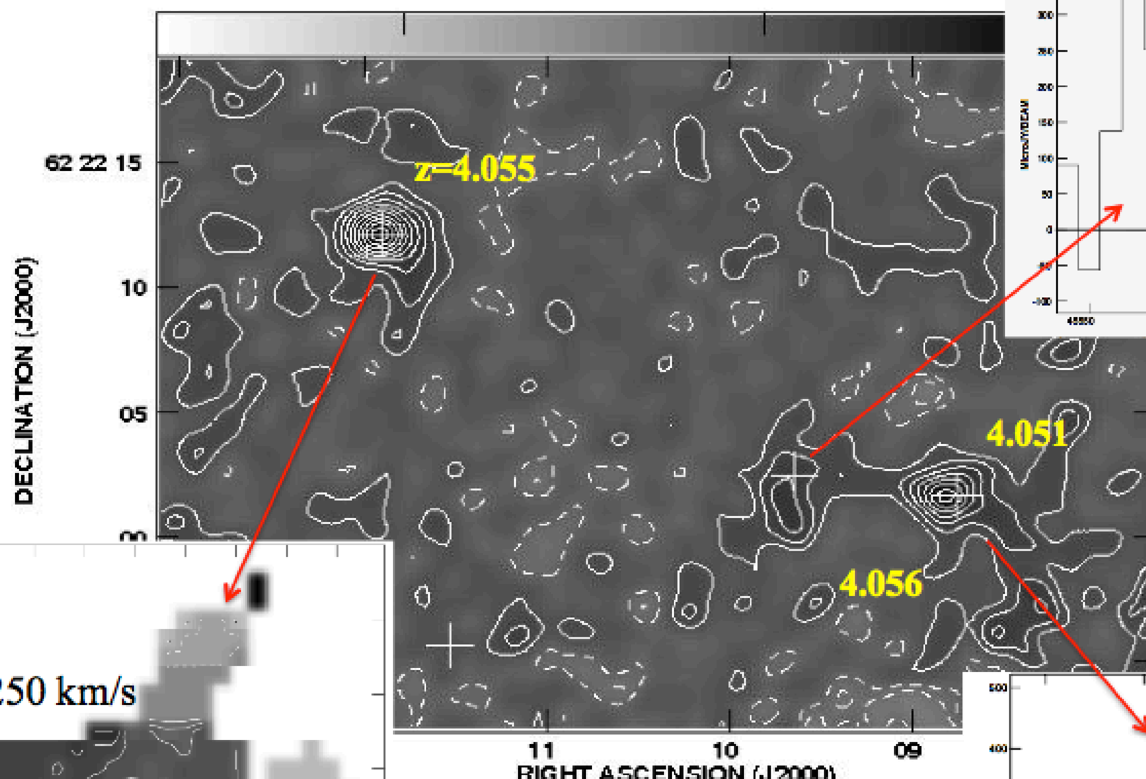


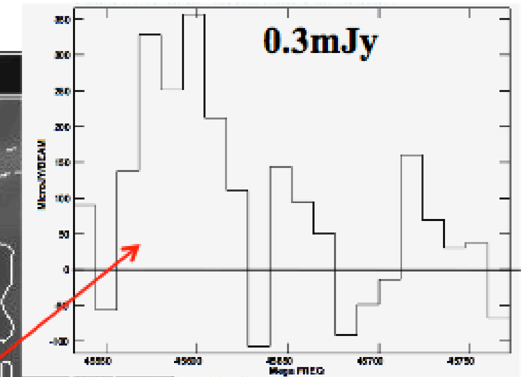
Current Status

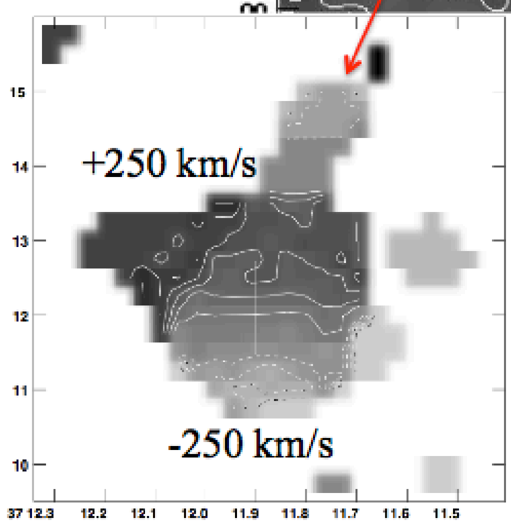
- Fiber optic communications complete
- Central electronics (master LO, timing, etc.) complete
- all antennas structurally modified; antenna electronics refinishing complete
- Receiver delivery close to schedule: K-, Ka-, and Q-bands complete, C-band on most antennas, S-band on ~12 antennas, L-band on ~6, Ku-band on 8, old X-band
- WIDAR being used now for up to 2 GHz bandwidth observing
- First 3-bit samplers (needed for 8 GHz bandwidth) being tested; planned to be used on full array in spring 2012
- Software in place for array control and operations; new user software
- 'Early Science' is being done (since March 2010) with 3 programs: OSRO, RSRO, ECSO

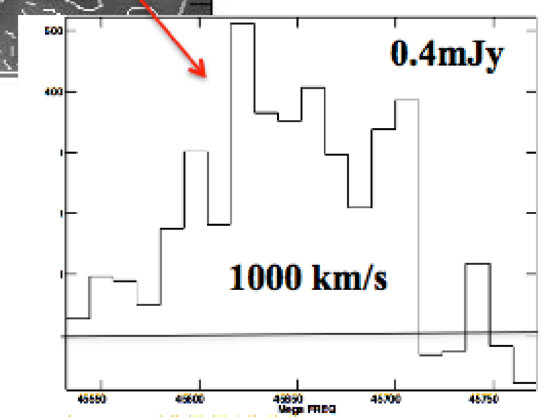
Imaging Molecular Gas in Primeval Galaxies

GN20 molecule-rich proto-cluster at z=4
CO 2-1 in 3 submm galaxies, all in 256 MHz band









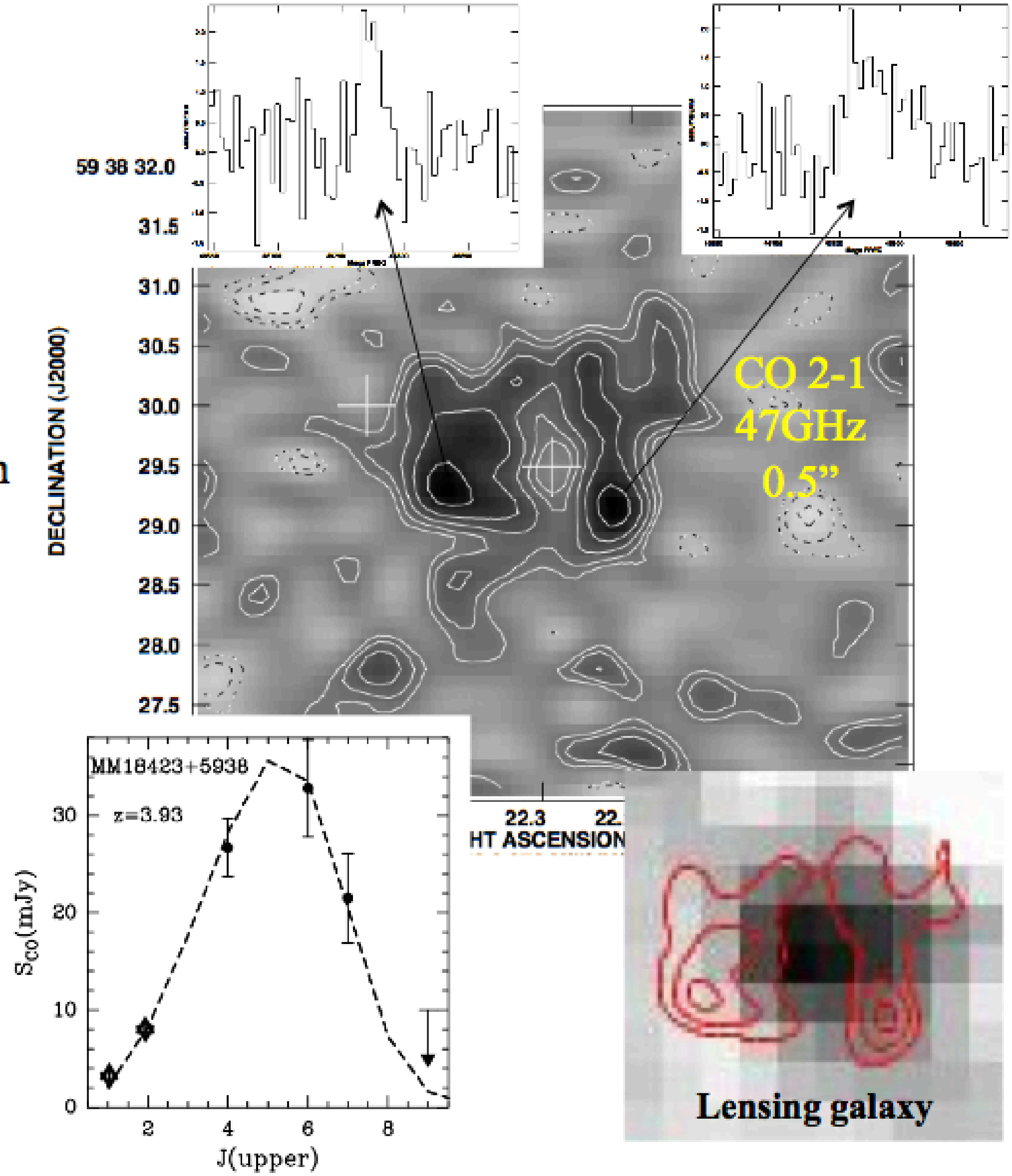
- SFR ~ 10^3 M_o/year
- M_{gas} ~ 10^{11} M_o ~ 1/3 M_{dyn}
- Early, clustered massive galaxy formation

Imaging Molecular Gas in Primeval Galaxies

A molecular Einstein Ring at z=3.9

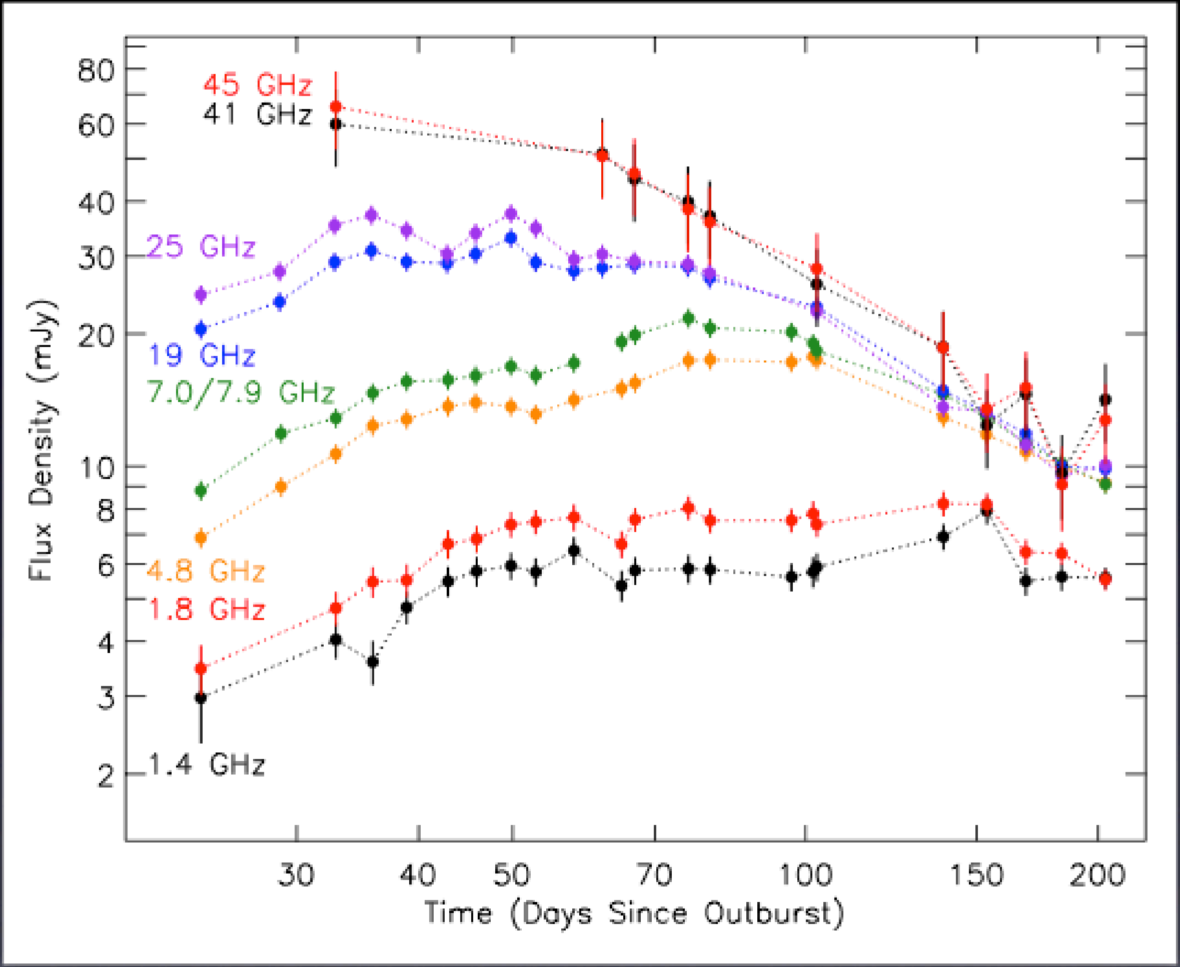
Lestrade, Carilli ea.

- One of most (apparently) luminous SMG known (FIR ~ 5×10^{14}/m L_o)
- Extreme gas mass (~ 10^{12}/m M_o), but CO excitation is lower than most SMG
- EVLA imaging reveals Einstein ring, with m > 10
- Very red lensing galaxy found at center of ring (Karun ea)



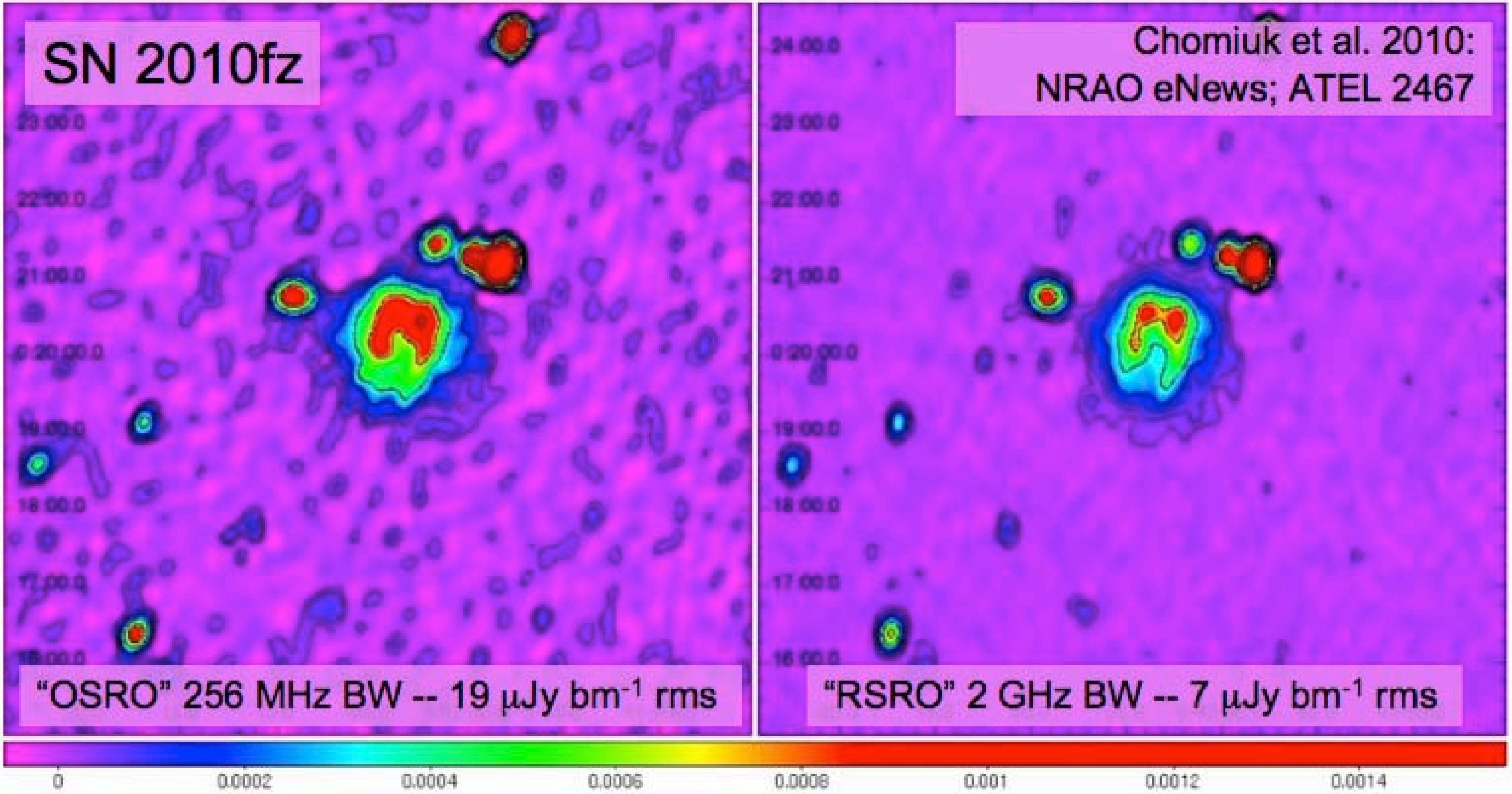
Classical Novae Monitoring

The eNova Project: V407 Cyg modeling



- "Classic" spherical-shell model does not work
- Updated model — layered spherical shells: nova ejecta, shock region, Mira wind
- Thermal bremsstrahlung, emission and absorption
- Physical constraints: X-ray fitting (Swift data), optical lines, distance estimate
- Spectral index: 0.8 at earliest epochs; ~0.1 at latest

Progenitors of Type Ia Supernovae



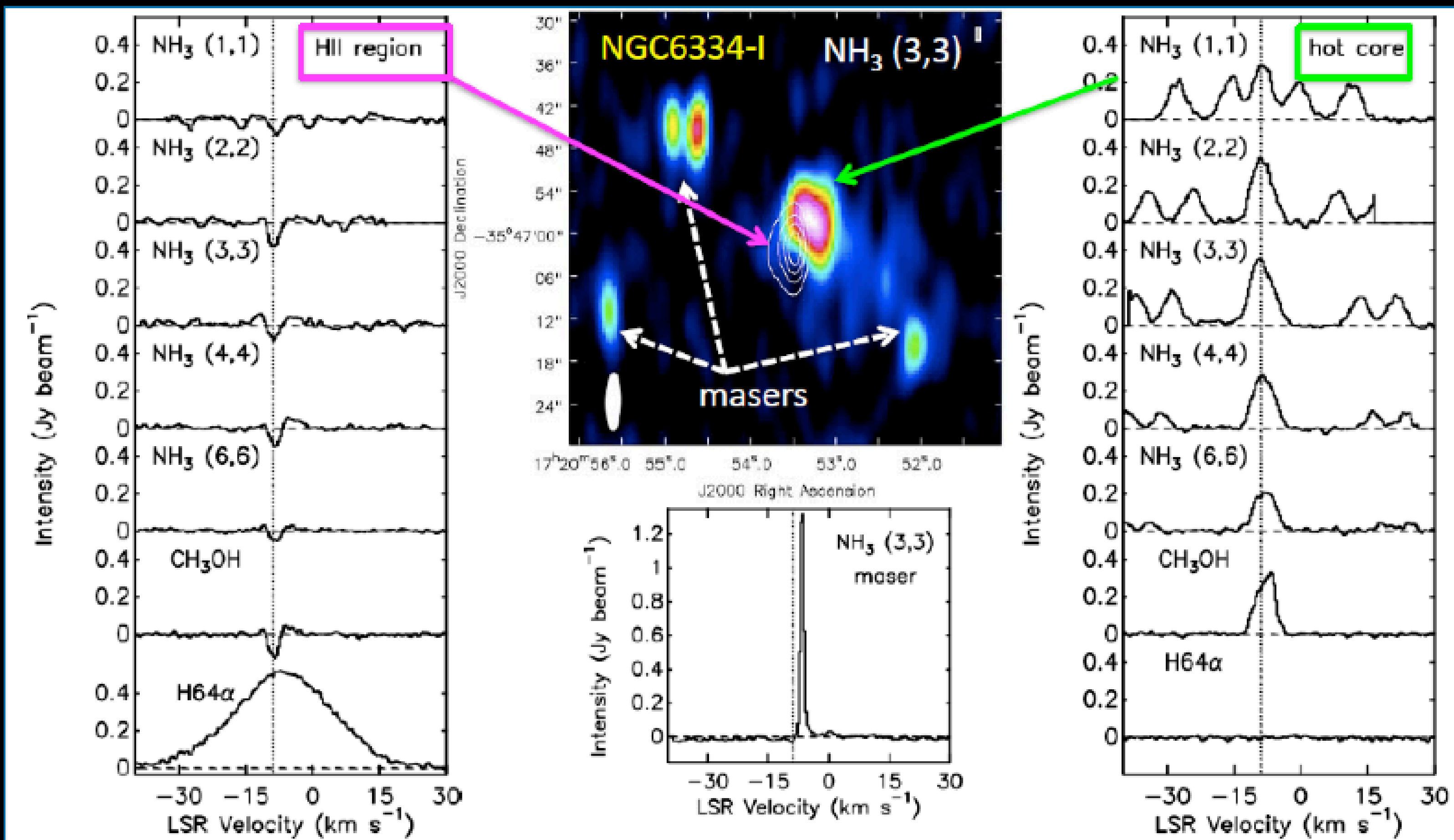
Can routinely reach rms ~ 7 μJy beam^{-1} in a 1 hour observation at 6 GHz.

K-band survey of Massive YSOs

Early Test Result: NGC6334

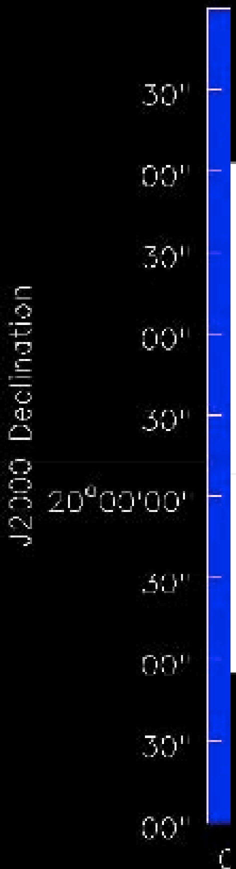
EVLA

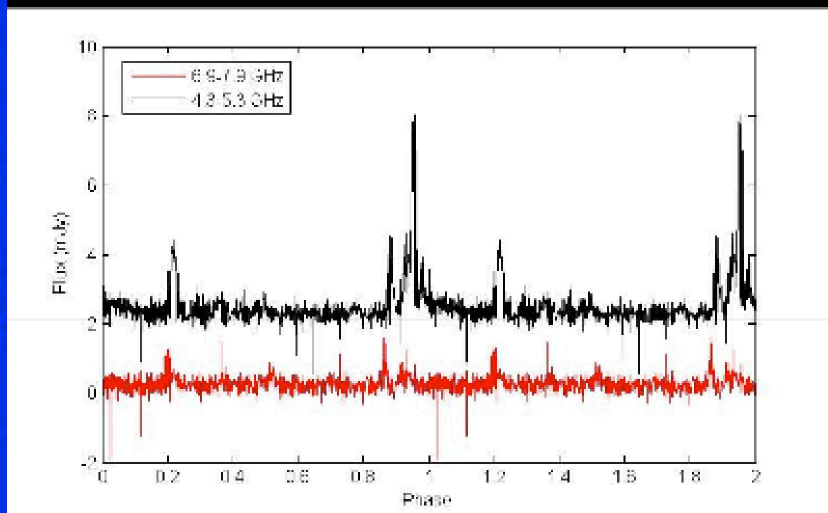
- *Protocluster with 2 hot cores and an ultracompact HII region at D~1.6 kpc*
- *10-minutes on-source*
- *Used 8 narrow (8 MHz) sub-bands*

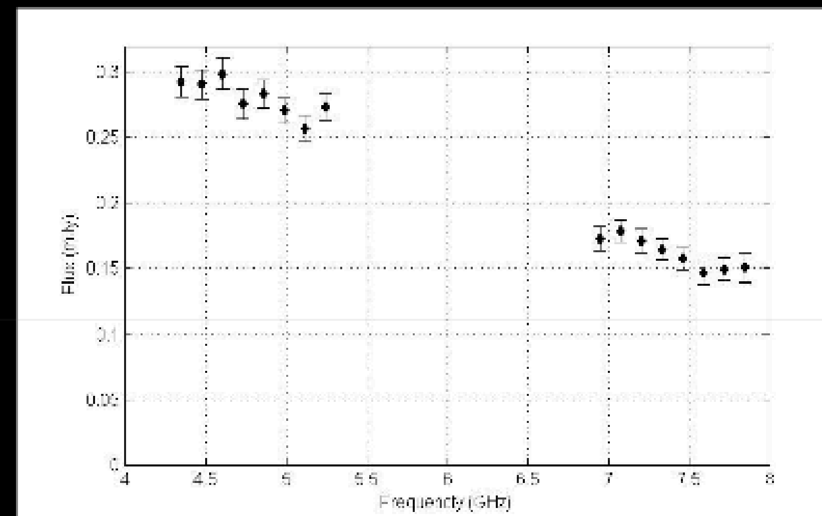


Radio emisson/flares from Brown Dwarfs

EVLA: First results...







- Phase folded light curves.
- Clear difference in time of arrival at higher frequencies.

- First slice of the spectrum
- Spectral Index α~-2 : steep

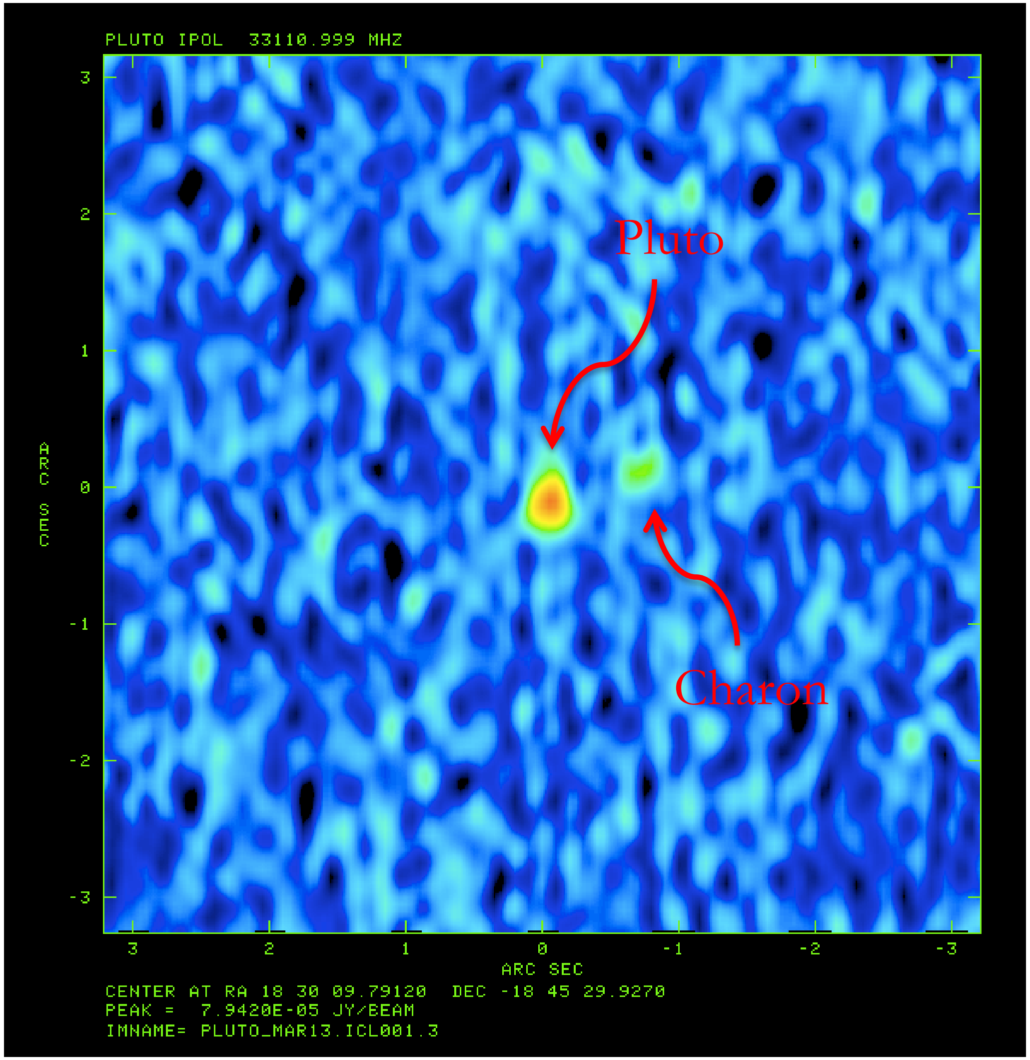
- 5 hours o
- RMS nois

Pluto & Charon with EVLA (1 cm)

Mar 13, 2011; ~2.5 hours on-source

Longest wavelength detection of Pluto & Charon, by almost a factor of 10!

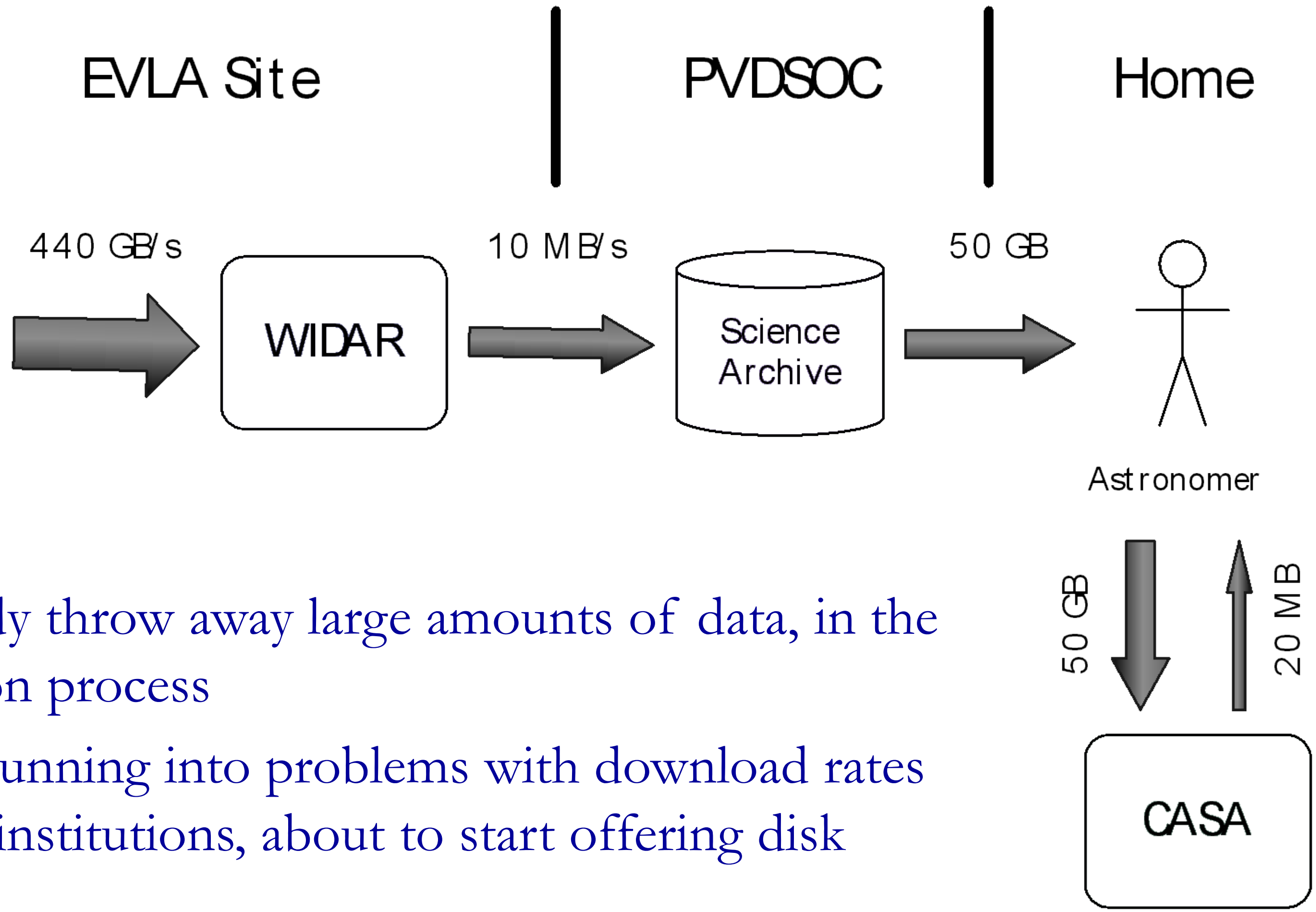
B. Butler, M. Gurwell, A. Moullet



EVLA Software

- The EVLA is a large complex system, and as such has a broad suite of software that supports it, from low-level embedded hardware control (including firmware) to high-level astronomer-focused software.
- Split into 3 broad areas:
  - Monitor & Control – those elements that are required to actually use the telescope to collect data, including antenna control, correlator control, operator interface, etc.
  - Science Support Software – those elements that the astronomer interfaces with (excluding post-processing), including proposal preparation and submission, observation preparation and submission, and archive access.
  - Data Post-processing – how the astronomer turns the raw measured quantity ("visibilities") into the desired product (generally an image cube). For EVLA (as for ALMA), the chosen package is CASA.

Data Flow – Where We Are



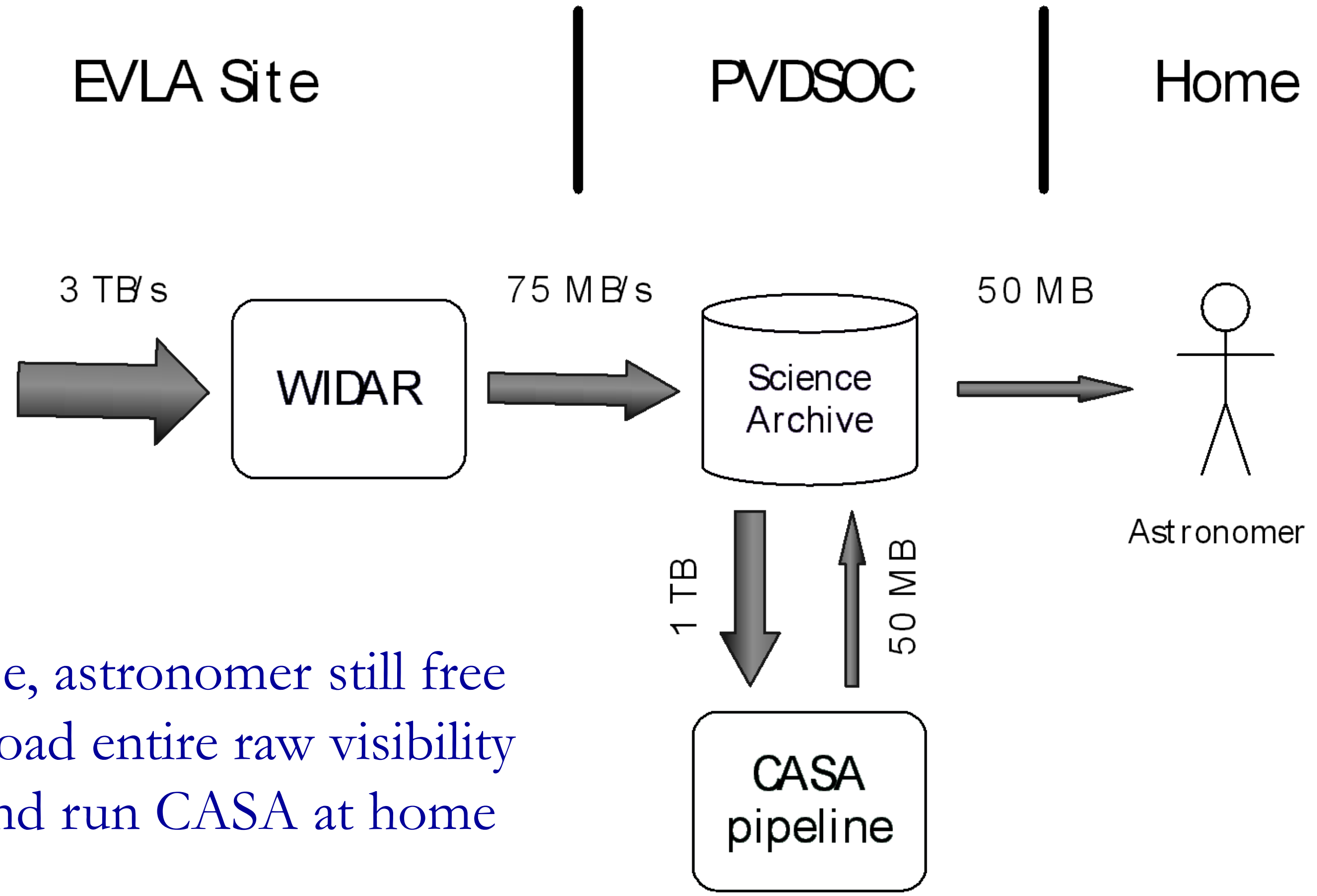
- We already throw away large amounts of data, in the correlation process
- Already running into problems with download rates to home institutions, about to start offering disk shipping

Download Rates

We did a limited experiment, where we timed transfer of a relatively small EVLA dataset (13 GB) to various institutions, with some surprising results.

Institution	Time to download 13 GB (hr)
Caltech	0.3
Uva	0.5
CfA/Harvard	0.65
Macalester College (MN)	1.5
Queen’s U (Canada)	1.5
Berkeley	1.5
MPIA (Germany)	3
Curtin (Australia)	3.75
UNAM (Mexico)	7
NMT (Socorro!)	8
Various (Taiwan)	8-15
NAOJ (Japan)	11
Yunnan (China)	33+

Data Flow – Where We're Going (Soon!)



- Of course, astronomer still free to download entire raw visibility dataset and run CASA at home

Data Volumes

- Entire VLA archive (~30 years) is 9 TB, of which 7 TB is "raw" (uncalibrated visibilities) data, 2 TB is pipeline-produced images
- EVLA archive, after 1 year of early science operations, is 90 TB, all raw data
- Eventual steady state storage in archive is expected to be ~1 PB/yr (counting a duplicate copy in CV)
- All data kept on spinning disks
- Technology behind storage is NGAS (cf ALMA)

Challenges and Future Directions

- Full reduction of all data is an ongoing research exercise (wide-bandwidth wide-field full-polarization imaging of data from a sparsely sampled aperture is hard!).
- Automatic flagging of data is also an ongoing research exercise – this is an extremely difficult problem!
- Pipeline reduction still being developed, at some level limited by the above two points.
- Parallelization of CASA extremely important for the harder reduction problems (cf Jeff Kern's talk).
- Data reduction model (how astronomers access and reduce their data) still being developed – we believe we have a sustainable model, but need to be ready for surprises and adapt to changes in technology (cf Alex's talk about the fear of centralized computing).
- VAO starting to be implemented for EVLA (led by Doug Tody at NRAO) – will be important going forward.