



EVLA Capabilities at K, Ka and Q Bands

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EVLA Project Overview

- The Expanded Very Large Array is a major upgrade of the Very Large Array.
- The fundamental goal is to improve all the observational capabilities of the VLA -- except spatial resolution -- by at least an order of magnitude
- Counting all sources, a \$90M project.
- The Project began in 2001, and will be completed in 2012.

Key EVLA Project Goals

- Full frequency coverage from 1 to 50 GHz.
 - Provided by 8 frequency bands with cryogenic receivers.
- 8 GHz/polarization instantaneous bandwidth
 - Provides two independent simultaneously available dual-polarization IF pairs, each of up to 4 GHz bandwidth/polarization.
- New correlator with 8 GHz/polarization capability
 - Designed, funded, and constructed by our Canadian partners, HIA/DRAO
 - Essentially comprises 64 separate full-polarization ‘sub-correlators’, each of maximum 128 MHz BW with 256 channels.
 - Unprecedented flexibility in allocating resources.
- $<1 \mu\text{Jy}$ point-source continuum sensitivity ($1-\sigma$, 12-Hr), ($2 \mu\text{Jy}$ at L and Q bands)
- Noise-limited, full-field imaging in all Stokes parameters for most observational fields.

Overall EVLA Performance Goals

The EVLA's performance will be vastly better than the VLA's:

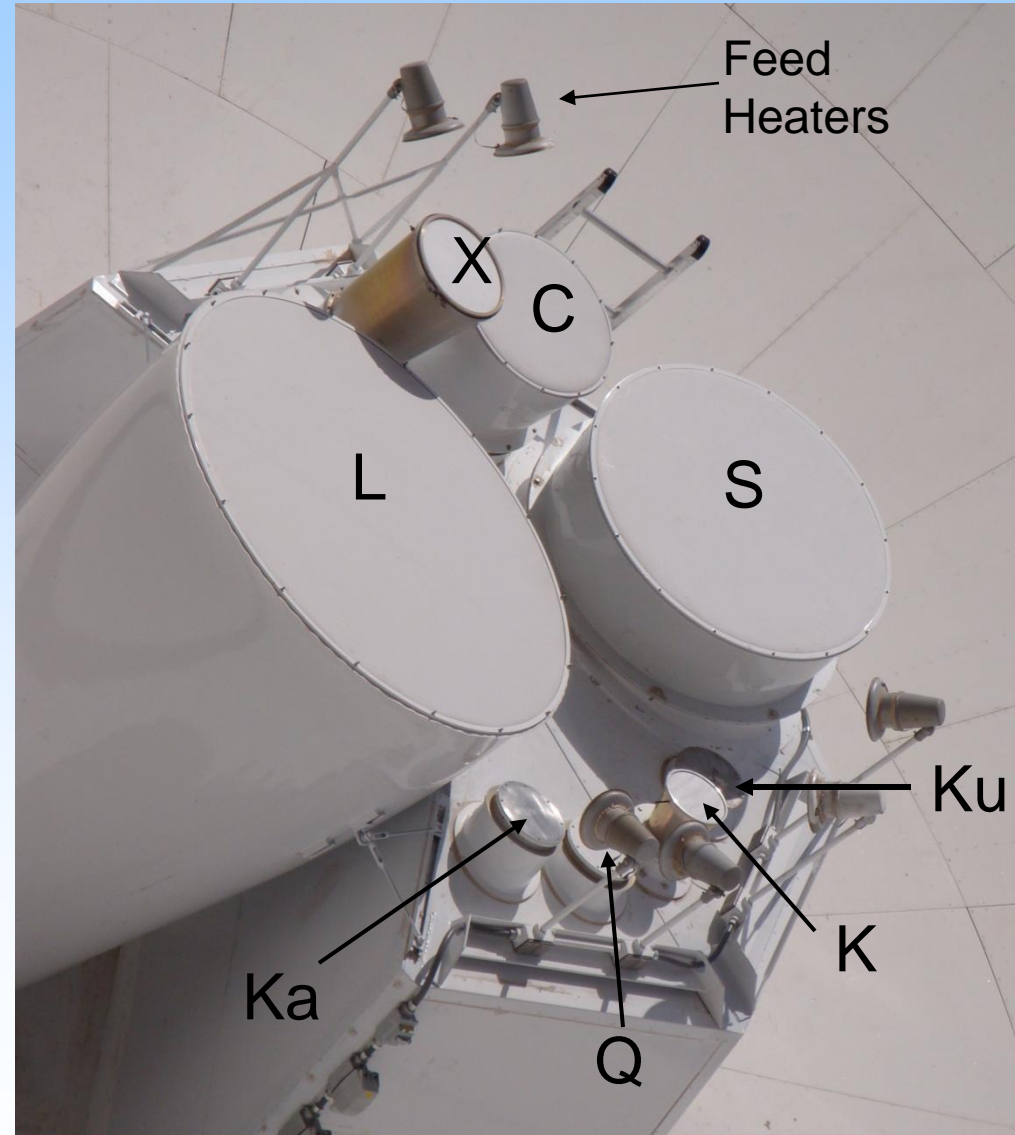
Parameter	VLA	EVLA	Factor
Point Source Sensitivity (1- σ , 12 hr.)	10 μ Jy	1 μ Jy	10
Maximum BW in each polarization	0.1 GHz	8 GHz	80
# of frequency channels at max. BW	16	16,384	1024
Maximum number of freq. channels	512	4,194,304	8192
Coarsest frequency resolution	50 MHz	2 MHz	25
Finest frequency resolution	381 Hz	0.12 Hz	3180
# of full-polarization sub-correlators	2	64	32
(Log) Frequency Coverage (1 – 50 GHz)	22%	100%	5

Full Frequency Coverage with Outstanding Performance

- There are eight cassegrain feeds, tightly packed around the feed ring.

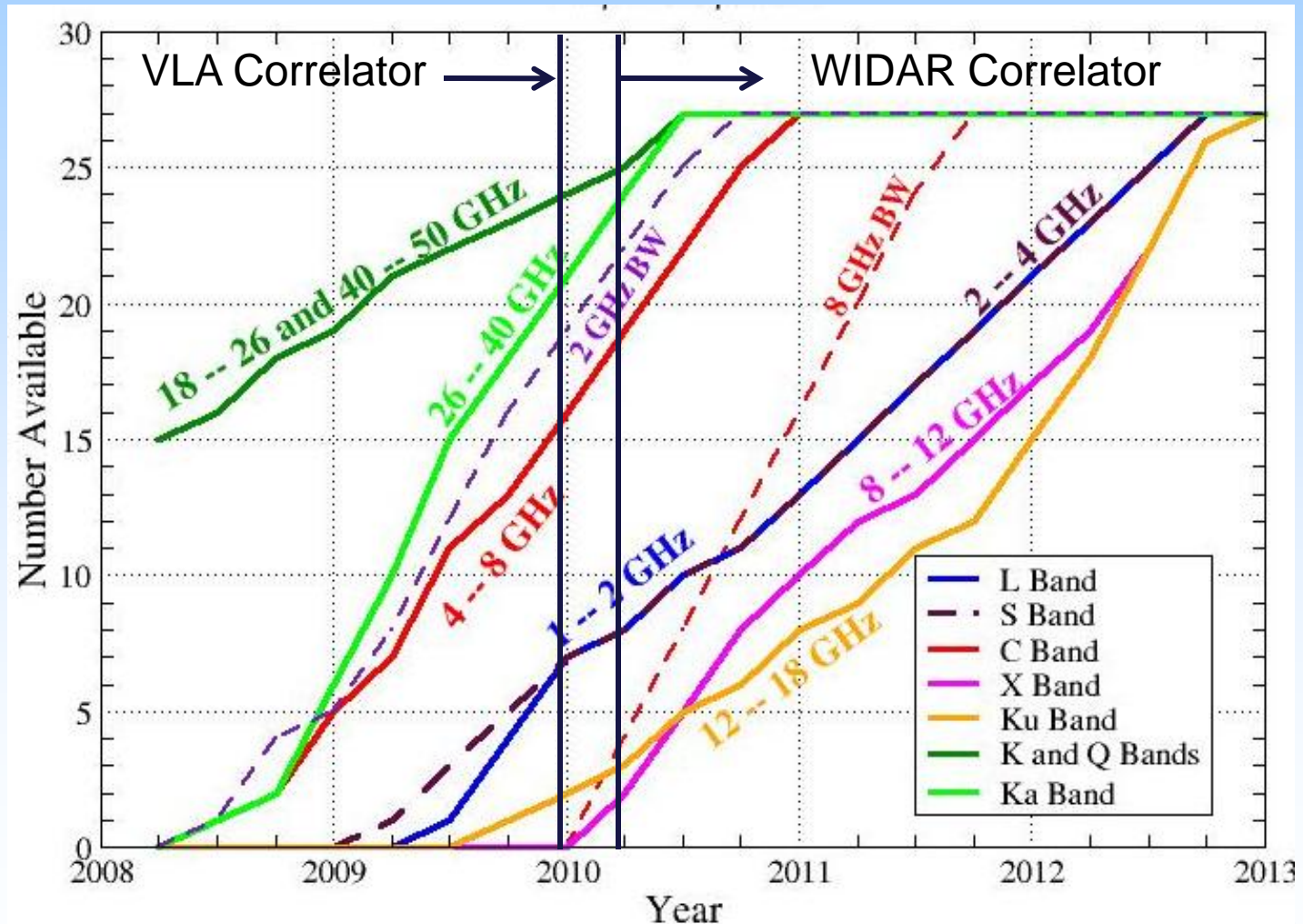
Band (GHz)		T_{sys}/ϵ (best weather)
1-2	L	60 -- 100
2-4	S	55 -- 70
4-8	C	45 -- 60
8-12	X	45*
12-18	Ku	50*
18-26.5	K	70 -- 80
26.5-40	Ka	90 -- 130
40-50	Q	160 - 360

* : Anticipated value



Full-Band Receiver Availability Timescale

- Note that during transition, L, C, X, K and Q band receivers are on all antennas.

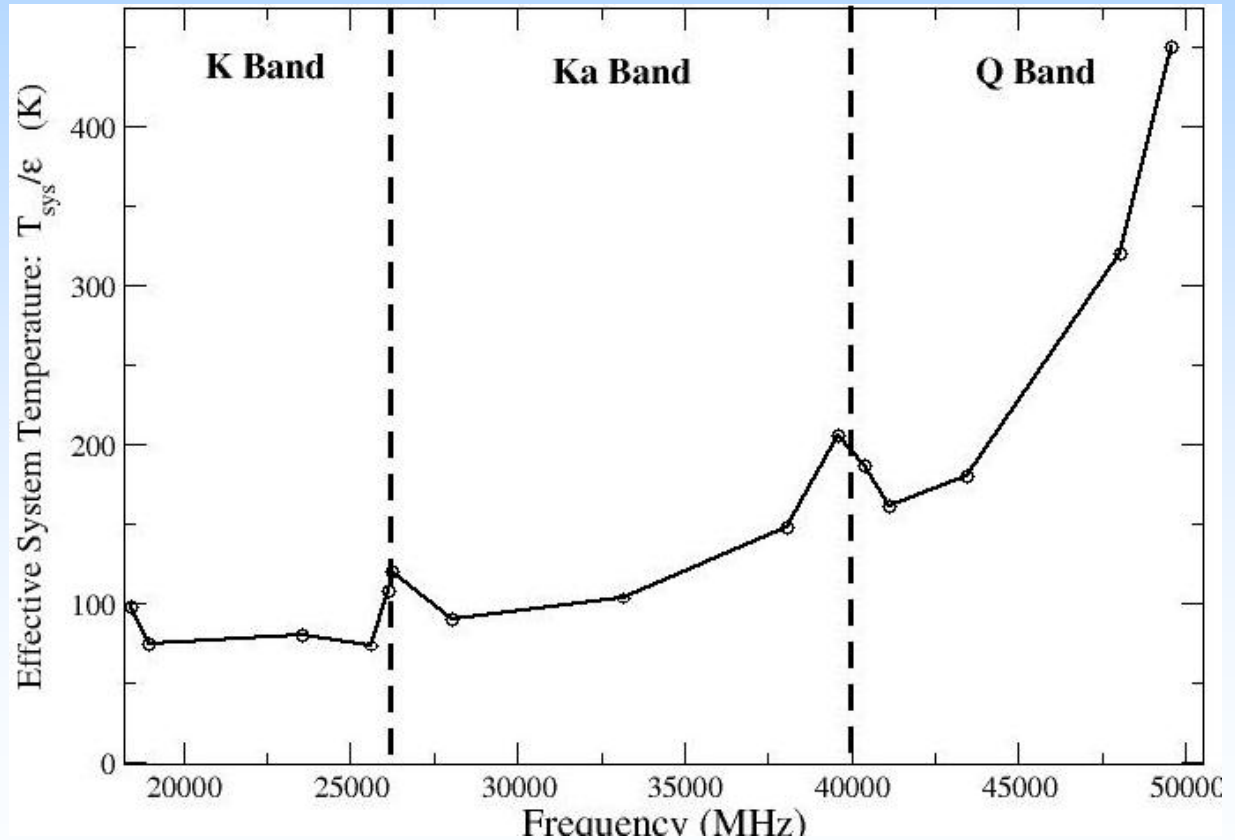


EVLA High Frequency Sensitivity

- The three high frequency bands provide excellent sensitivity from 18 through 50 GHz.
- Shown is the Effective System Temperature: T_{sys}/ϵ

Notes:

- Clear, dry weather
- Zenith
- Adjusted for atmospheric emission and opacity



EVLA & ALMA Point-Source Sensitivities

1- σ in 1 hour

- The EVLA continuum sensitivity will be much higher than the VLA's, particularly at high frequencies, where much better receivers and much more bandwidth are available.
- Anticipated best sensitivity, for line and continuum:

Freq. GHz	Continuum Sensitivity μ Jy		Line Sensitivity In 1 km/sec mJy	
	EVLA	ALMA	EVLA	ALMA
18	2.0	...	0.7	...
22	2.0	...	0.6	...
26	2.0	...	0.6	...
28	2.5	...	0.7	...
33	3.0	3.8	0.8	1.0
38	4.0	3.8	1.0	1.0
40	4.5	3.9	1.1	0.9
44	5.4	4.0	1.2	0.9
48	9.2	...	2.0	...
49	13	...	2.9	...

The 'WIDAR' Correlator

- The key element of the EVLA is its Canadian funded 'WIDAR' correlator.
- Designed and built by the correlator group at HIA/DRAO in Penticton BC, to meet or exceed NRAO requirements.
- WIDAR is a 'full-service' correlator, designed to meet the diverse needs of our user community.
- Major capabilities:
 - 8 GHz/polarization maximum instantaneous bandwidth
 - Full polarization
 - Minimum # channels – 16384, up to 4.2 million maximum.
 - Spectral resolution from 2 MHz to 0.19 Hz.
 - Spectral dynamic range up to 58 dB
 - Extensive special modes
 - 64 independently tunable sub-band pairs, each pair effectively forms an independent 'sub-correlator'.

WIDAR Flexibility

- Each of the 64 sub-band pairs:
 - Is independently tunable to any frequency*
 - Has a sub-band width of any of 128, 64, 32, ..., .03125 MHz
 - Has recirculation available* (doubles the number of spectral channels for each halving of the sub-band width)
 - Can utilize the computational resources of any number of other sub-band pairs (trading bandwidth for channels).
- Number of channels is from 16384 to 4194304
- Frequency resolution is from 2 MHz to 0.19 Hz.
- Numerous special modes and capabilities:
 - Pulsar binning and gating
 - Phased array
 - Burst mode
 - Multiple subarrays
 - 4 or 7-bit internal mode
 - 1,2,3,4 or 8 bit input
 - Online RFI excision
 - Fully VLBI ready

* There are some limitations

Initial EVLA Capabilities for Science -- 2010

- VLA correlator will be decommissioned on Jan 11, 2010.
- The array will return to service, using WIDAR, around March 1.
- Basic initial observational mode:
 - All converted EVLA antennas (26 by March)
 - Two independently tunable sub-band pairs with 64 channels for each of four cross-correlations (total 512 channels)
- OR
- One tunable sub-band pair, with 256 channels for each of two cross-correlations (512 total channels).
 - Sub-band width adjustable to one of $128/2^n$ MHz ($n = 0, \dots, 12$).
- Growth in observational capabilities will be set by growth of software capabilities – all correlator hardware in place by March 2010.

OSRO and RSRO

- OSRO = ‘Open Shared Risk Observing’.
 - Is in fact ‘business as usual’.
 - Observers will access EVLA in same manner as current for VLA.
 - For continuity with existing VLA observing, the **initial** WIDAR capabilities have been based on existing VLA capabilities.
 - But in fact, observers will get much, much more.
- RSRO = ‘Resident Shared Risk Observing’
 - For those willing to spend significant time in Socorro, and have skills & interest in assisting in implementing advanced correlator modes or calibration methodologies.
 - Participants will have available much more extensive capabilities.
 - Participants with the right skills should have the opportunity to greatly accelerate the development/availability of special observing modes.

Initial 'OSRO' Capabilities

- By March 2010, we plan to provide the following for non-resident observers.
 - Table 1: Full Polarization Continuum and Spectropolarimetry Applications.

Sub-BW (MHz)	Sub-BW (MHz)	# Chan/product	Chan Width (kHz)	Velocity Width (km/sec)	Velocity Coverage (km/sec)
128	4	64	2000	$600/v_G$	$38400/v_G$
64	4	64	1000	$300/v_G$	$19200/v_G$
32	4	64	500	$150/v_G$	$9600/v_G$
...	4	64
0.0625	4	64	0.98	$0.29/v_G$	$18.75/v_G$
0.03125	4	64	0.488	$0.15/v_G$	$9.375/v_G$

There will be two independently tunable sub-bands, each with the capabilities noted in the table.

Initial OSRO Capabilities (cont.)

Table 2: Spectral Line Applications

Sub-BW (MHz)	Sub-BW (MHz)	# Chan/product	Chan Width (kHz)	Velocity Width (km/sec)	Velocity Coverage (km/sec)
128	2	256	500	$150/v_G$	$38400/v_G$
64	2	256	250	$75/v_G$	$19200/v_G$
32	2	256	124	$37.5/v_G$	$9600/v_G$
...	2	256
0.0625	2	256	0.244	$.073/v_G$	$18.75/v_G$
0.03125	2	256	0.122	$0.037/v_G$	$9.375/v_G$

For both modes:

- minimum integration time is 1 second.
- Doppler tracking will be available.
- Data can be reduced via AIPS (but CASA is encouraged!)

WIDAR Growth

- The expansion in observational capabilities will be rapid, but measured.
- All initial observations will be with the ‘fundamental homogeneous correlator setup’
 - All sub-band pairs with the same width and channelization, arranged to maximize total bandwidth coverage.
- Resident observers (RSRO program) should have access to (for all available EVLA antennas):
 - 2 GHz/polarization BW (all antennas) by mid-2010
 - 8 GHz/polarization BW (all antennas) by end of 2011.
 - Recirculation by late 2010
 - Independent sub-band tuning by early 2011
 - Flexible resource allocation by mid 2011.
- Schedule for availability of special modes dependent on availability of resources.

RSRO Details

- Program will run from March 2010 to end of 2011.
- Application through regular proposal deadlines
 - Special rules apply – see website
- Intent is to attract skilled individuals to assist with commissioning process.
- Minimum residency ~ 1 month. Time available proportional to time spent in Socorro.
- Up to 25% of all observing time to be made available.
- NRAO should be able to provide housing in Guest House
- Applicants with their own support will definitely have advantage. NRAO support level unknown ...
- Full details on: www.aoc.nrao.edu/evla/astro/rsro.shtml

Final WIDAR Capabilities

- The ultimate WIDAR correlator's capabilities are too vast to describe in one or two slides.
- To give a flavor, I describe two correlator setups.
- First: the 'homogeneous setup':
 - All subbands arranged to cover the entire BW of a particular band
 - All subbands have the same width and number of channels.

Summary of Wide-band Coverage:

- For dual (RR,LL) polarization, with no recirculation

	Freq.	IF BW	SBW	# SBP	Δv	Δv	Nch per	Nch
	GHz	GHz	MHz		kHz	km/s	spctrm	total
K	18—26.5	8.192	128	64	1000	13	128	16384
A	26.5—40	8.192	128	64	1000	9	128	16384
Q	40--50	8.192	128	64	1000	6.5	128	16384

- For full polarization, resolutions are 2 x poorer.
 - The data rate is 6.2 MByte/sec for 10-second integration
 - The resulting data volume is 22 GB in 1 hour

~1 km/sec resolution coverage

- Obtaining ~few km/sec velocity resolution will result in the frequency coverage listed below:

	Freq.	SBW	Freq Cov.	Δv	Δv	Nch per	Nch	Rate (10 s avg)	
	GHz	MHz	MHz	kHz	km/s	spctrm	total	MB/sec	GB/Hr
K	18-26	64	4.096	250	3.1	256	32767	12	45
A	26-40	64	4.096	250	2.1	256	32767	12	45
Q	40-50	64	4.096	250	1.7	256	32768	12	45

- This velocity resolution covers 4 GHz total, per polarization.
- Another factor of four improvement in velocity resolution can be obtained with halving the frequency coverage to 2 GHz/poln.

Some Science Applications

- Even this most basic setup enables a huge range of new science capabilities. Some examples:
 - $\sim 1 \mu\text{Jy}/\text{beam}$ sensitivity full-polarization continuum observations over the full primary beam.
 - Wide-band high-redshift surveys of molecules in absorption and emission.
 - Wide-band molecular surveys of dense molecular clouds.
 - Deep polarimetric imaging and RM analysis of bright sources, the galaxy, and clusters.

A Second Setup – Flexible Tuning with Adjustable Sub-band Widths.

- Individual tuning of each of the 64 sub-band pairs is scheduled for RSRO availability in T1 2011.
 - Each of the 64 sub-band pairs would be digitally tunable to any given frequency within the input bandwidth.
 - The sub-band width and spectral resolution of each will also be variable.
 - Recirculation and correlator resource reallocation will also be enabled, allowing enormous flexibility in ‘tuning’ the correlator to fit the science requirements of any given experiment.
- This will enable greatly improved capabilities in studying spectral emission of atomic and molecular emission from specific regions, where:
 - Full bandwidth coverage is not needed, and/or
 - Adjustable spectral resolution is advantageous.

Molecular Line Emission Studies of Massive Star-Forming Regions

- Claire Chandler has proposed two K-band experiments:
 1. Studies of a Massive Star-Forming Region
 - 32 molecular transitions, to be observed at 0.2 km/sec, and
 - 8 RRLs, to be observed with 1 km/sec, and
 - some reasonable amount of continuum.
 2. Studies of a Cold Dark Cloud.
 - 54 molecular transitions (mostly heavy molecules) requiring 0.01 km/sec resolution, plus
 - Some reasonable amount of continuum

* I wouldn't give these examples if it couldn't ...

Massive star-forming region – Goals and Requirements

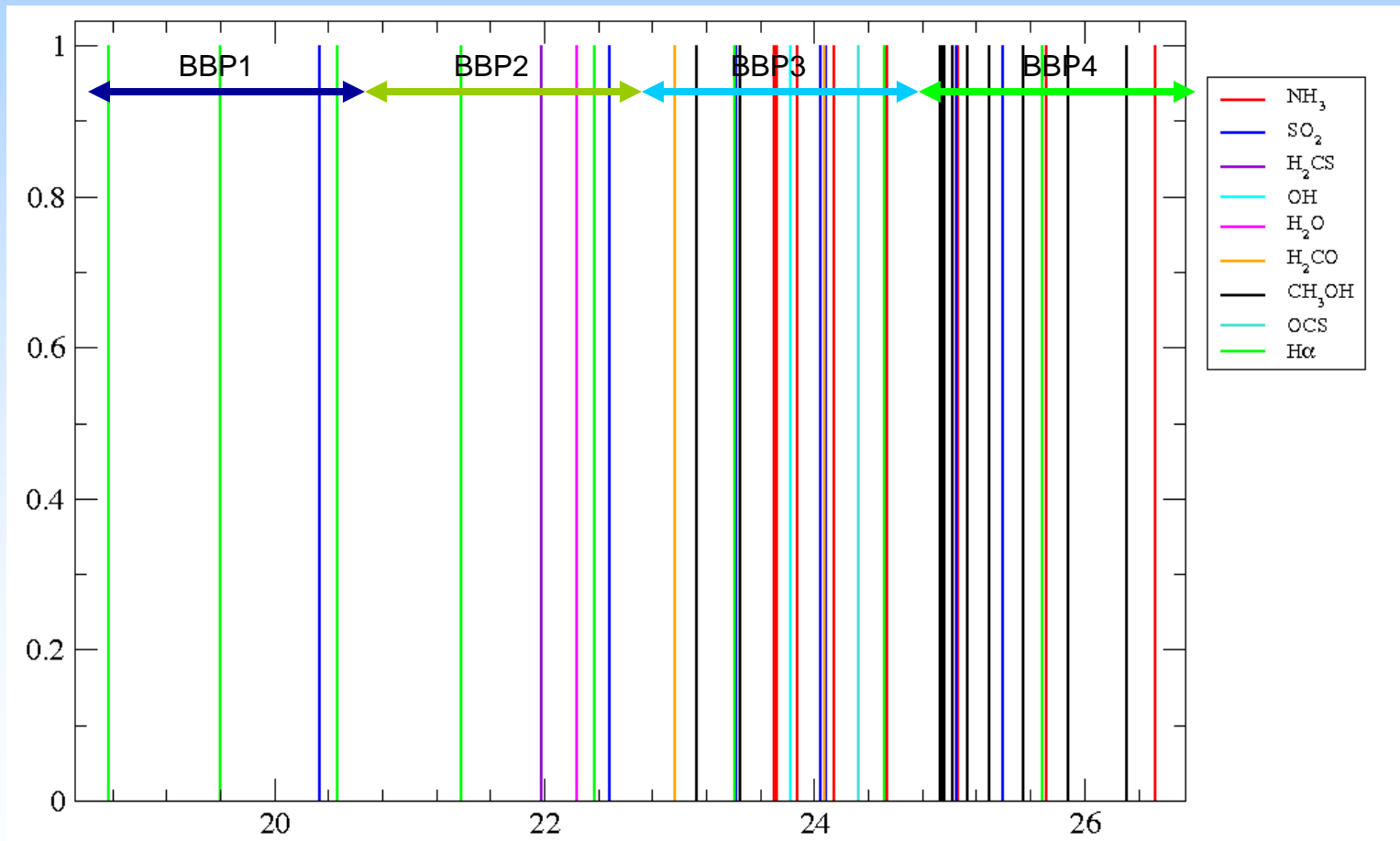
- observe high-density tracers NH_3 , all available transitions from (1,1) to (8,8), and CH_3OH ;
 - gives density and temperature structure of hot cores (very young, massive, protostars)
- observe shock tracers, interaction of protostars with surrounding cloud: transitions of SO_2 , H_2O , OCS , H_2CS , H_2CO , OH
- observe radio recombination lines and continuum emission from a nearby HII region
- spectral resolution required for molecular lines: 0.2 km/s
- spectral resolution required for RRLs: 1 km/s
- need as much line-free continuum as possible for the free-free emission

Massive SFR – Correlator Setup

- Tune the four available baseband frequency pairs to:
 1. 18.6 – 20.6 GHz which covers 3 RRL + 1 Mol (12 SBP free)
 2. 20.6 – 22.6 GHz which covers 2 RRL + 3 Mol (11 SBP free)
 3. 22.6 – 24.6 GHz which covers 2 RRL + 14 Mol (all SBP used)
 4. 24.6 – 26.6 GHz which covers 1 RRL + 14 Mol. (1 SBP free)
- Set the 32 SBPs covering the molecules to a BW = 16 MHz, providing 1024 channels in both RR and LL.
- Set the 8 SBPs covering the RRLs to BW = 32 MHz, providing 512 channels in both RR and LL.
- This leaves 24 SBPs to cover the continuum (at 128 MHz BW each), or for other transitions.
- A total of 79872 channels ... a high data rate of 30 MB/sec with 10 sec averaging.
 - Could reduce this rate to more manageable size by averaging.

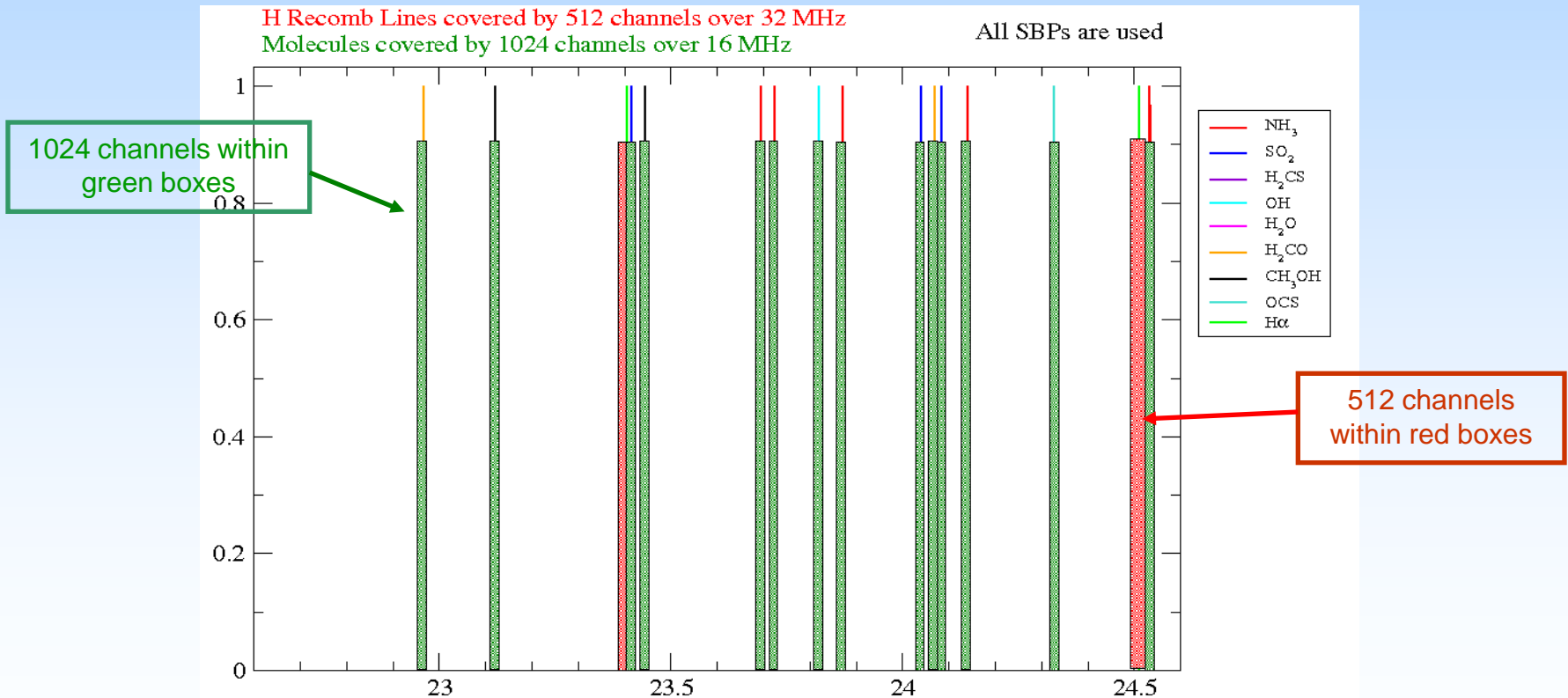
The Entire Spectrum

- Showing the distribution of the SFR lines, color coded by species.
- The spans for the four BBPs are as shown.



Within BBP #3:

- Showing a 'close-up' of the coverage within one of the BBPs.
- The green rectangles show the SBP frequency coverage for the molecules.
- The red rectangles shows the (wider) SBP coverage for the RRLs.



EVLA/ALMA/GBT Synergies

- All three instruments offer comparable sensitivities combined with fabulous imaging/spectral capabilities.
- EVLA/GBT in the north, ALMA in the south.
- EVLA matched with VLBA for northern sources.
- EVLA and GBT have more complete frequency coverage
 - But must ALMA be constrained to 31 – 45 GHz?
- EVLA has higher resolution than ALMA (factor 2.5)
- ALMA will have better imaging characteristics for extended emission.
 - More antennas, smaller antennas.
 - Much better pointing characteristics.

Summary

- EVLA will provide a fabulous capability for 30 -- 50 GHz science, with sensitivity, resolution and imaging capabilities comparable to ALMA (provided it is outfitted with Band 1 receivers ...)
- The EVLA and ALMA are – again – complementary
- All EVLA high frequency receivers will be available by mid-2010.
- Initial WIDAR capabilities begin March 2010.
- 2 GHz/Polarization available by mid 2010.
- 8 GHz/Polarization available late in 2011.
- Specific observing capabilities and timescales are now being defined
- You can influence these by joining the RSRO program!