

Planning JVLA Observations

Capabilities & practicalities



Michael P. Rupen Project Scientist for the WIDAR Correlator



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





What is the JVLA?

A very quick introduction



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The JVLA

- •VLA came on-line in the 1980s
- •Huge upgrade (x10 in major parameters) over the past decade
- •Super-powerful
- •Super-flexible
- •Available now







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EVLA

28x25m antennas, 8 feeds, 0.035-36.4 km

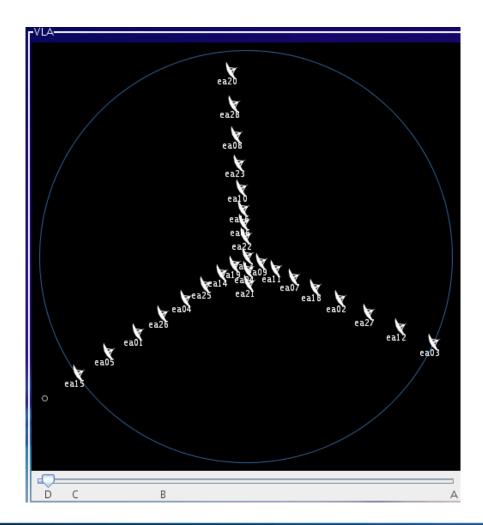






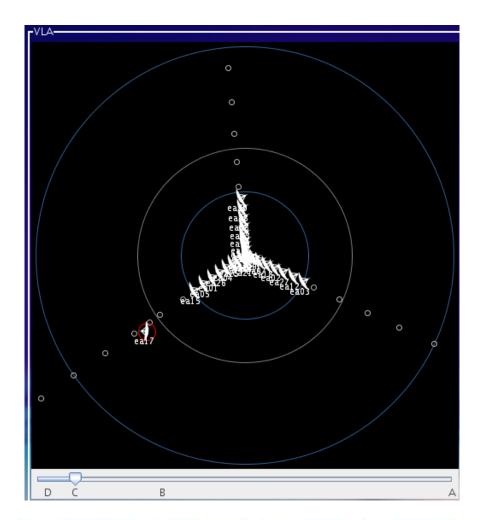


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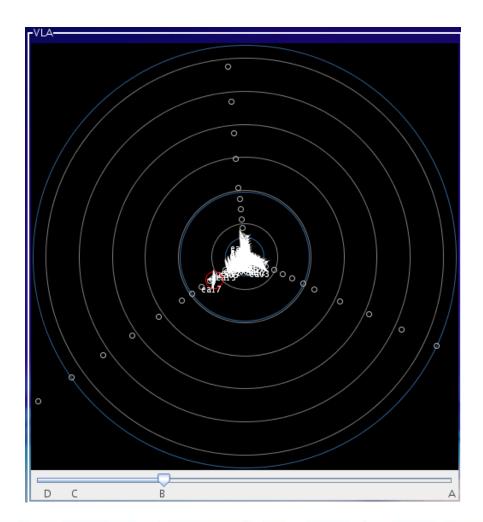
Reconfigured every 4 months Spatial dynamic range in l cfg: ~20-100 Currently $D \rightarrow C \rightarrow B \rightarrow A$ (x3.3 in baseline length) "Hybrids" for southern sources Short baselines retained in C cfg





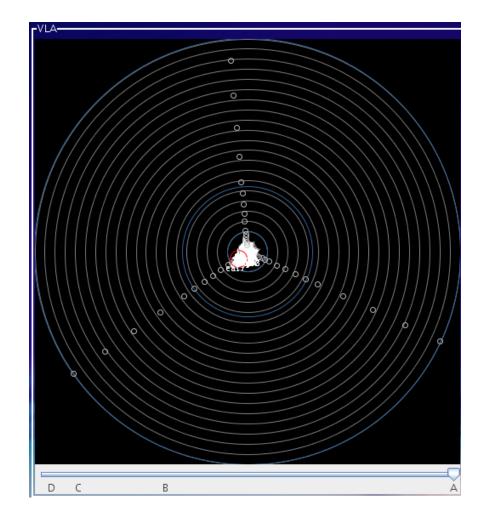
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I-50 GHz in 8 bands



Can switch bands in ~20 sec

Band	Range
	(GHz)
20 cm (L)	1.0-2.0
13 cm (S)	2.0-4.0
6 cm (C)	4.0-8.0
3 cm (X)	8.0-12.0
2 cm (Ku)	12.0-18.0
1.3 cm (K)	18.0-26.5
1 cm (Ka)	26.5–40.0
0.7 cm (Q)	40.0–50.0

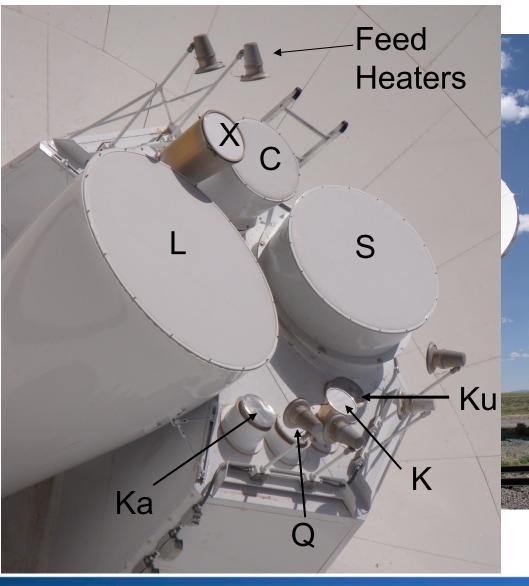




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0.7 cm (Q)	40.0–50.0



EVLA

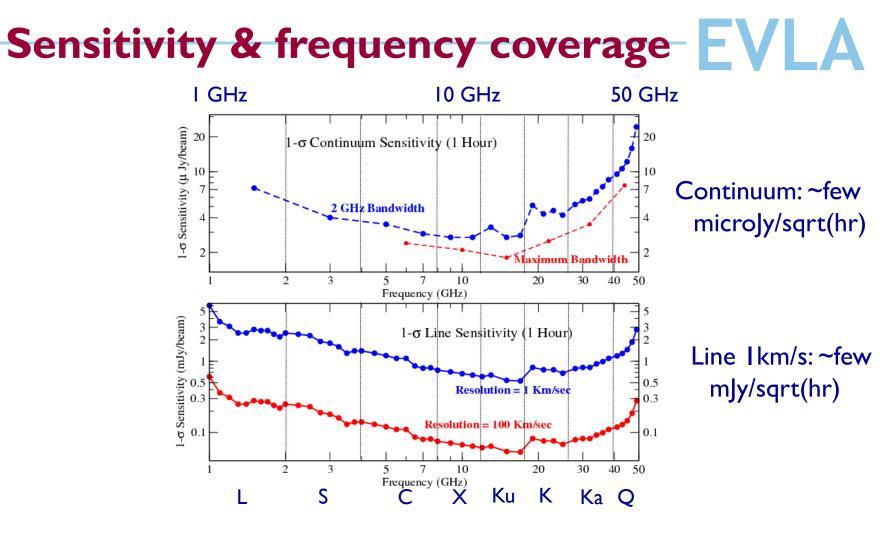


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Basic scientific capabilities



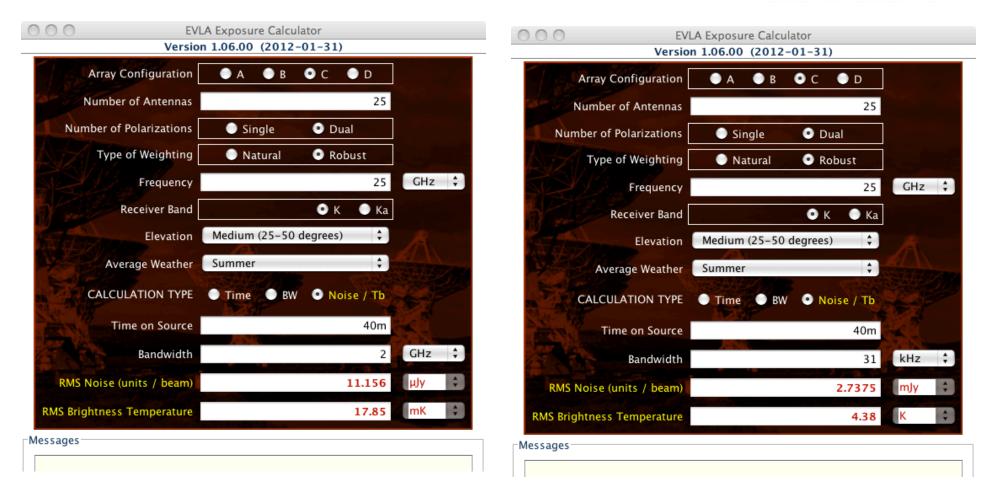


8-bit: 2 x I GHz basebands within a given band3-bit: 4 x 2 GHz basebands within a given band (only offered for wideband)

NRAC



Sensitivity & frequency coverage EVLA





Sensitivity & frequency coverage EVLA

Band	Range
	(GHz)
20 cm (L)	1.0-2.0
13 cm (S)	2.0-4.0
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2 cm (Ku)	12.0–18.0
1.3 cm (K)	18.0–26.5
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0.7 cm (Q)	40.0–50.0

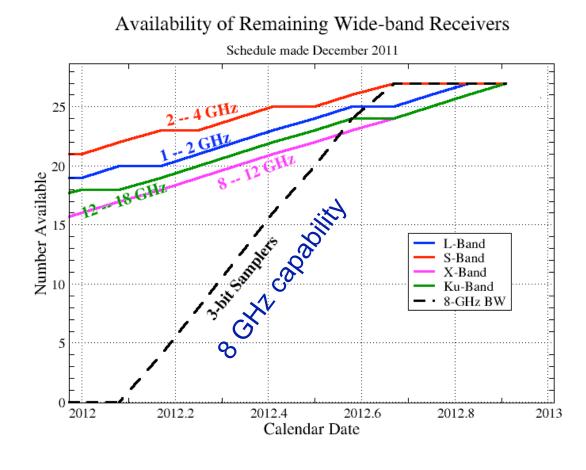
- Up to 2:1 bandwidth ratios
- Worst spectral resolution: 2 MHz/ channel (full pol'n products)
- Bandwidth synthesis for better uvcoverage
- →Instantaneous spectral indices



Receiver Availability

Most receivers are installed

21 antennas have wideband (3-bit) samplers (8 GHz/pol'n)



Complete: C: 4-8 GHz K: 18-26.5 GHz Ka: 26.5–40GHz Q: 40-50GHz

EVLA



Angular resolution



Configuration	Α	В	С	D
B _{max} (km ¹)	36.4	11.1	3.4	1.03
B _{min} (km ¹)	0.68	0.21	0.035 ⁵	0.035
	Synthesiz	ed Beamv	vidth 0 _{HPBW} (arcsec) ^{1,2,3}
74 MHz (4 band)	24	80	260	850
1.5 GHz (L)	1.3	4.3	14	46
3.0 GHz (S) ⁶	0.65	2.1	7.0	23
6.0 GHz (C)	0.33	1.0	3.5	12
8.5 GHz (X) ⁷	0.23	0.73	2.5	8.1
15 GHz (Ku) ⁶	0.13	0.42	1.4	4.6
22 GHz (K)	0.089	0.28	0.95	3.1
33 GHz (Ka)	0.059	0.19	0.63	2.1
45 GHz (Q)	0.043	0.14	0.47	1.5

4 configurations: A \rightarrow big; D \rightarrow small

~4 months in each configuration, cycling D C B A

(plus hybrids for southern sources)

Largest angular scale & field-of-view



		-	-		Field of view
Configuration	Α	В	С	D	(depends on
B _{max} (km ¹)	36.4	11.1	3.4	1.03	diameter of a
B _{min} (km ¹)	0.68	0.21	0.035 ⁵	0.035	single
	Synthesiz	ed Beamv	width 0 _{HPBW} (arcsec) ^{1,2,3}	antenna)
74 MHz (4 band)	24	80	260	850	608'
1.5 GHz (L)	1.3	4.3	14	46	30'
3.0 GHz (S) ⁶	0.65	2.1	7.0	23	15'
6.0 GHz (C)	0.33	1.0	3.5	12	7.5'
8.5 GHz (X) ⁷	0.23	0.73	2.5	8.1	5.3'
15 GHz (Ku) ⁶	0.13	0.42	1.4	4.6	3'
22 GHz (K)	0.089	0.28	0.95	3.1	2'
33 GHz (Ka)	0.059	0.19	0.63	2.1	1.4'
45 GHz (Q)	0.043	0.14	0.47	1.5	1'
					

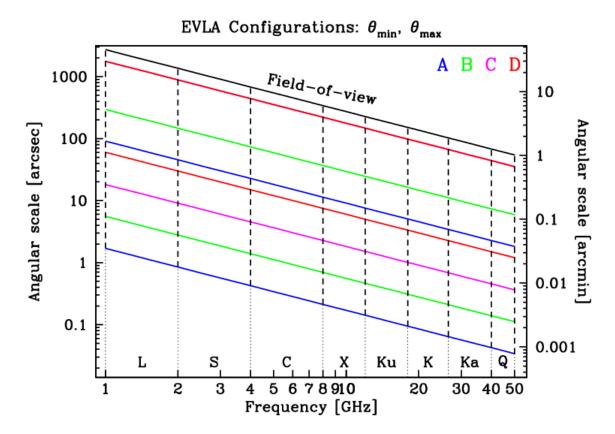
Smaller configurations give better surface brightness sensitivity and don't filter out larger structures



Imaging beyond primary beam requires mosaicking

Angular resolution, largest angular scale, & field-of-view







WIDAR Correlator

- WIDAR: Wideband Interferometric Digital Architecture
- I0¹⁶ calculations/s (I0 P-ops)
- Fiber bandwidth: 3 Tbits/s
- I6 GHz per antenna = 2600 TV channels
- 175 kW
- I28 Gbits/s output ~ 3 DVD
- 128 baseline boards
- 128 station boards



*



EVLA



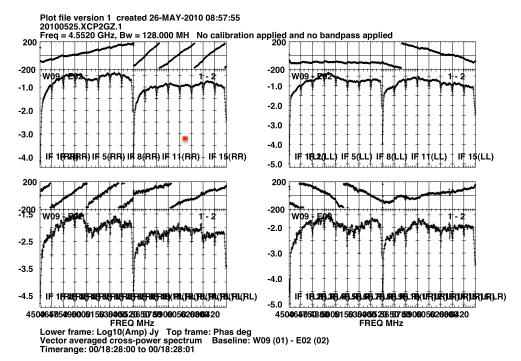


	VLA	WIDAR-now	WIDAR-2013	
Quantization	3-level	16/256-level	16/256-level	
# antennas	27	28	(32)	
Max. bandwidth	0.2 GHz	16 GHz	16 GHz	
# subband pairs	1 - 2	1-64	1-64	
# channels (total)	2-512	256 – 32,768	256 – (4,194,304)	
Max./min. δν	50 MHz / 381 Hz	2 MHz / 122 Hz	2 MHz / (0.12 Hz)	
dt _{min}	1.7 sec	0.01 sec	0.01 sec	
Max. data rate	3.3 x 10 ³ vis/sec	~10 x 10 ⁶ vis/sec	(1600-16000 x 10 ⁶ vis/ sec)	
Extras Phasing VLBI Subarrays		Phasing Subarrays	Phasing VLBI Subarrays (Pulsar phase bins)	
Corrélateur VIDAR Correlator		Auto-correlation	(Burst mode) Auto-correlation	
NRAO	*	Synthesis Imaging Workshop, Socorro, NM May 31, 2012 22		



One baseline, one dump

- 2 x I GHz baseband pairs
- = 16 x 128 MHz subband pairs
- 64 ch/pp/sb → 4096 x 2 MHz channels
- One baseline, one dump!







Flexibility: truly independent subbands

64 independent Spectral Windows

Ability to make simultaneous continuum & multiple line measurements

- Example: L band, all at once:
 - continuum
 - galactic + extragalactic HI imaging & absorption
 - **OH** lines
 - >10 radio recombination lines





EVLA

Flexibility: truly independent subbands

64 independent Spectral Windows

- Tuning
- Bandwidth (31.25 kHz 128 MHz)
- Number of polarization products (single, dual, full)
- Number of channels
- Trade subbands for channels (hardware stacking)
- Trade time resolution for channels (recirculation)
- Dump rates







Dynamic scheduling

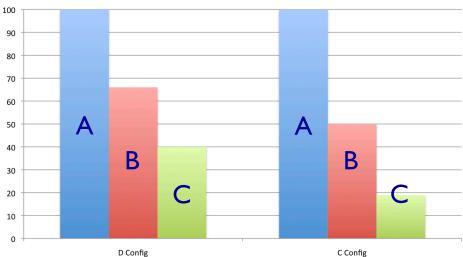
- Everything is dynamically scheduled
- Can't tell exactly when your schedule will run, or what will have been observed just before that
 - Initial slew is uncertain
- Scheduling is based on:
 - TAC priority (A B C, science, etc.) i.e., competition
 - Current weather (rms phase, wind by-band defaults, which you can override) – note we do not yet look at the ionosphere, weather predictions, solar activity, opacity, RFI
 - Efficiency



EVLA

Scheduling considerations

Percentage of observing completed vs. observing priority



- Priority A: observe during requested observing conditions, long SBs are fine
- Priority B: number of projects approved designed to fit into available hours per configuration, but shorter SBs help with scheduling around priority A projects
- Priority C: filler, short SBs (0.5 to 1.0 hr) will improve chances of observation





Dynamic scheduling

- Getting on the telescope:
 - Get your observing schedules in early
 - Short blocks are easier...but require more overhead
 - Can request `filler' time (short bad weather blocks) note we are accepting much more Priority C than in the past
 - Daytime is harder (competes with commissioning, maintenance)
 - The weather changes during the year





Computing challenges

- The EVLA produces a LOT of data: ~50 MB/s now, ~75 MB/s for this proposal cycle
 - I hour= 180 GB @ 50 MB/s
 - Simply transferring the data is painful \rightarrow internet or disks
- Complete frequency coverage and wide bandwidths
 - Radio frequency interference (RFI) everywhere
 - Instruments vary (e.g., field-of-view goes as wavelength)
 - Sources vary (e.g., freq² → factor 4 different in flux over
 2:1 bandwidth ratio)
 - Extremely sensitive \rightarrow sidelobes and dynamic range issues



LOTS more science: lines, spectral shapes, polarization, mosaics, on-the-fly mapping



Proposing for the EVLA

A preview of the July 7, 2012 call for proposals



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Initial capabilities for full operations, 2013A

- The move to D configuration in Jan 2013 will mark the start of full operations for the JVLA; at that time we will offer:
- 8-bit sampler system with:
 - Independent and flexible sub-bands, up to 32 total sub-bands, max. 16,384
 spectral channels distributed over 2 GHz bandwidth per polarization
- 3-bit sampler system with:
 - Low spectral resolution with full 8 GHz bandwidth per polarization for "continuum" observations and high frequency extragalactic line work
- Multiple sub-arrays:
 - Up to 3 independent sub-arrays, any band, using low spectral resolution ("continuum" mode) with 2 GHz bandwidth/polarization
- Phased array for VLBI:
 - Up to I28 MHz BW for 2 sub-bands to match VLBA 2 Gbps system
- Data dump times >=50 ms, data rates <=20 MB/s standard



EVLA

Wideband with low res'n: 8 GHz/pol'n

- Full pol'n products:
 2 MHz/channel
- Dual pol'n products:
 I MHz/channel
- Single pol'n product:
 0.5 MHz/channel

JVLA Co	orrelator C	onfiguration for PST	
<u>R</u> esource TEST Ver	sion 1.13-	SNAPSHOT (2012-05-30)	<u>H</u> elp
 Wideband Spectral Line Subarrays 	iver Band	K (18-26.5 GHz)	
Total Bandwi Baseband Cent		8 19, 21, 23, 25	
Polarization Dum	n Products p Time (s)	Full (2.0 MHz / ch)	
	Data Rate	15.8MB/s, 56.9GB/h	



Flexible subbands over 2 x I GHz basebands LA

- Two independently-tunable I GHz basebands
- Up to 16 subbands in each baseband
 - -Each independently tunable, but can't cross I 28 MHz boundaries
 - -128, 64, 32, ..., 0.03125 MHz bandwidths
 - -Can choose different bandwidths, polarization products, and channelization for each subband

-All must share the same dump time

• Total of 16384 channels spread flexibly over subbands and polarization products: "Baseline Board stacking"

Flexible subbands over 2 x I GHz basebands LA

JVLA Correlator Configuration for PST					
<u>R</u> esource TEST Version 1.13-SNAPSHOT (2012-05-30)					
	Receiver Band K	18-26.5 GHz)			
	Baseband Centers (GHz) 25	, 26			
	Dump Time (s) 3.	,			
Baseband 1		Baseband 2			
Frequency Range 24.488GHz - 25.512GHz		Frequency Range 25.488GHz - 26.512GHz			
DataRate 6.9MB/s, 24.7GB/h		DataRate 8.8MB/s, 31.6GB/h			
Subbands		Subbands			
SB BW Prod BIBPs # Chan Ch Width (f)	Ch Width (v) MB/s	SB BW Prod BIBPs # Cha	an Ch Width (f) Ch Width (v) MB/s		
1 128.0MHz Full 1 64 2MHz	23.1km/s 0.25	1 128.0MHz Full 1	64 2MHz 24.0km/s 0.25		
2 128.0MHz Full 1 64 2MHz	23.1km/s 0.25	2 128.0MHz Full 1	64 2MHz 24.0km/s 0.25		
3 128.0MHz Full 1 64 2MHz	23.1km/s 0.25	3 128.0MHz Full 1	64 2MHz 24.0km/s 0.25		
4 128.0MHz Full 1 64 2MHz	23.1km/s 0.25	4 128.0MHz Full 1	64 2MHz 24.0km/s 0.25		
5 128.0MHz Full 1 64 2MHz	23.1km/s 0.25	5 128.0MHz Full 1	64 2MHz 24.0km/s 0.25		
6 128.0MHz Full 1 64 2MHz	23.1km/s 0.25	6 128.0MHz Full 1	64 2MHz 24.0km/s 0.25		
Z 128.0MHz Full 1 64 2MHz	23.1km/s 0.25	7 128.0MHz Full 1	64 2MHz 24.0km/s 0.25		
8 128.0MHz Full 1 64 2MHz	23.1km/s 0.25	8 128.0MHz Full 1	64 2MHz 24.0km/s 0.25		
9 16.0MHz Dual 4 512 31.3kHz	360.3m/s 0.98	9 16.0MHz Dual 4	512 31.3kHz 374.7m/s 0.98		
10 16.0MHz Dual 4 512 31.3kHz	360.3m/s 0.98	10 16.0MHz Dual 4	512 31.3kHz 374.7m/s 0.98		
11 16.0MHz Dual 4 512 31.3kHz	360.3m/s 0.98		396 4.5kHz 53.5m/s 1.71		
12 16.0MHz Dual 4 512 31.3kHz			768 1.3kHz 15.6m/s 0.73		
16.0MHz Dual 4 512 31.3kHz	360.3m/s 0.98	31.25kHz RR 10 2,5	60 12.2Hz 0.1m/s 2.42		
14					
15					
16		16			
	Total Data Rate 15.6MB/	56.3GB/b			

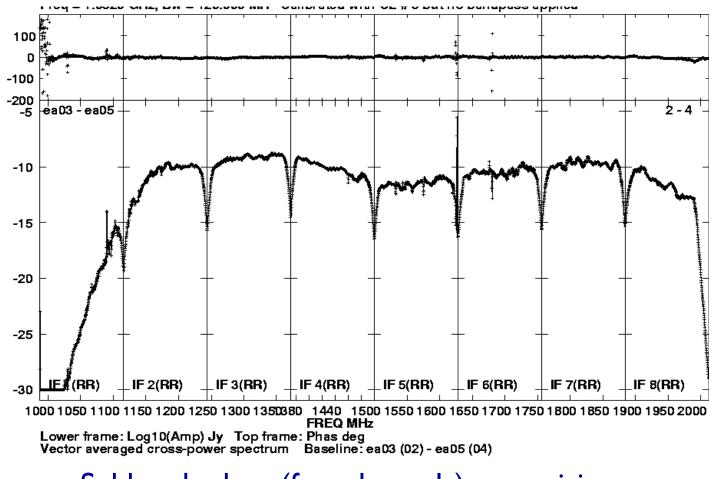
Save



Edge effects

NRAC





- Subband edges (few channels) are noisier
- Can lose 10s of channels for narrowest subbands

Up to 3 "continuum" subarrays



- 2 x I GHz bandwidth —Independently tunable
- Spectral resolution:
 - -2 MHz with full pol'n products
 - -I MHz with dual pol'n products
 - -0.5 MHz with single pol'n product

JVLA Correlator Configuration for PST							
	<u>R</u> esource		TEST Version 1.13-	Version 1.13-SNAPSHOT (2012-05-30)			
Subarray 1			Subarray 2		Subarray 3		
Number of Antennas 10 💂			Number of Anten	nas 9 🖨	Number of Antennas 8 🔷		
Basebands 2 x 1GHz 4 x 2GHz Receiver Band S (2-4 GHz)		1GHz O 4 x 2GHz	Basebands 💿 2 x 1GHz 🔾 4 x 2GHz		Basebands 💿 2 x 1GHz 🔾 4 x 2GHz		
		Receiver Band	C (4-8 GHz)	Receiver Band	X (8-12 GHz)		
	Total Bandwidth (GHz)	2	Total Bandwidth (GHz)	2	Total Bandwidth (GHz)	2	
	Baseband Centers (GHz)	2.5, 3.5	Baseband Centers (GHz)	5.5, 6.5	Baseband Centers (GHz)	9.5, 10.5	
	Polarization Products	Full (2.0 MHz / ch)	Polarization Products	Full (2.0 MHz / ch)	Polarization Products	Full (2.0 MHz / ch)	
	Dump Time (s)	0.2	Dump Time (s)	0.2	Dump Time (s)	0.2	
	Data Rate	8.0MB/s, 28.8GB/h	Data Rate	6.5MB/s, 23.4GB/h	Data Rate	5.1MB/s, 18.3GB/h	

Total Data Rate 19.6MB/s, 70.5GB/h

Save



EVLA

Dump times and data rates

• Standard allows: >= 50msec, <= 20 MB/s

-20 MB/s = 70 GB/hr

- Special justification needed for dump times faster than the defaults (Isec A & B-high, 3sec B-low/C, 5sec D)
- Data rate limit is set by disk space (!), which translates directly to \$\$\$



Phased VLA for VLBI



- Two independently-tunable subband pairs
 - -Cannot change bandwidth during the observation think hard about phasing!
- •2 bit sampling \rightarrow max 2 Gbps



Shared Risk observing, semester 2013AA

- In order to push boundaries of standard capabilities we will continue to offer a Shared Risk observing program
 - Correlator set-ups that are not well tested but can be scheduled through dynamic scheduler
 - Programs will receive test time to verify feasibility
 - Residence not required (unless the tests fail)
 - Examples:
 - Sub-arrays with 3-bit samplers
 - Fast dump modes up to 60 MB/s (8-bit)
 - 3-bit with sub-band BWs narrower than 128 MHz



RSRO program, semester 2013A EVLA

- RSRO program will continue for technically challenging capabilities driven by the community
 - Residency requirements will be relaxed over current (no 3month minimum)
 - Examples:
 - On-the-fly (OTF) mosaics
 - Phased array for non-VLBI
 - General recirculation set-ups (more channels)
 - Real-time transient detection
 - Pulsar observing modes





Proposals



August I, 2012 deadline



- Any configuration
- D config currently scheduled Jan 25- Apr 27, 2013
- Regular, Rapid response, Large proposals (>200 hrs)
 - Key science
 - Proprietary period normally 12months since last observations
- **Observing time includes overheads** (flux, phase, bandpass calibration; slew time; dummy scans)
- Joint proposals with Chandra, Fermi, Spitzer
- Future calls: Feb I, Aug I
- DDT (ToO/Exploratory/EPO) proposals anytime (<=6 mos. proprietary period)



Proposal Submission Tool (PST) EVLA

• <u>http://my.nrao.edu</u>, click on Proposals

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Telescope:	VLA/12A-479	84	AC1109	The E-Nova Project: Probing Nova Sgr 2012	Complex Mass Ejection in	Laura Chomiuk	05/21/2012	SUBMITTE
Trimester / Semester:	VLA/12A-459	R F A	AC1106	EVLA Nova Project: Confirmin Ejection in Recurrent Nova T		Laura Chomiuk	03/18/2012	SUBMITTE
Year:	VLA/12B-350	ð 4 A	AS1180	The EVLA Nova Project: Imag Classical Novae	jing the Fireball Stage of	Jennifer Sokoloski	02/01/2012	SUBMITTE
ALL 🗾	VLA/12B-344	ð 4 A	AR809	Characterizing Hard X-rays S Swift Galactic Plane Survey	ources Discovered in the	Mark Reynolds	02/01/2012	SUBMITTE
	VLBA/12B-330	ð 4 A	BH187	DETERMINING THE NATURE (EMISSION FROM ACTIVE M D		Gregg Hallinan	02/01/2012	SUBMITTE
	VLBA/11B-254	ð 4 A	BB318	Measuring the Expansion Velo SN 2011dh	ocity and Deceleration of	Michael Bietenholz	02/01/2012	SUBMITTE
	VLA/12B-287	r	AR807	The EVLA Nova Project: Radi Classical Novae	o Light Curves of Young	Michael Rupen	02/01/2012	SUBMITTE
	VLA/12B-270	R F B	AN149	The EVLA Nova Project: Conf T Pyx's 2011 Outburst	irming a Massive Ejection in	Thomas Nelson	02/01/2012	SUBMITTE
	VLA/12B-235	R F B	AK791	EVLA Survey of cataclysmic v	variable outbursts	Elmar Koerding	02/01/2012	SUBMITTE
	VLA/12B-226	B F d	AK790	The EVLA Nova Project: Moni Nova V1723 Aql	toring the Unusual Classical	Miriam Krauss	02/01/2012	SUBMITTED
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NRAO

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VLA/12A-280		
VLA/12A-234	Title	
···· Authors	A deep 6cm radio continuum survey of LITTLE THINGS	
Science Justification		
Sources	Туре	
Resources	Regular	
Sessions Student Support	Scientific Category	
Print Preview	Normal Galaxies, Groups, and Clusters	
VLBA/12A-228		
VLA/12A-226	Abstract	
VLA/12A-191	We ask for 40 hours to obtain deep EVLA full polarisation radio continuum observations at 6 cm in C-array of the entire LITTLE THINGS	
VLA/2011-06-004	ancillary GALEX FUV, optical (including Halpha), Spitzer NIR and MIR imaging, and VLA HI data (all at matched resolution). We will on separate thermal bremsstrahlung (based on Halpha) from non-thermal continuum and, based on equipartition arguments, determine	
VLA/11A-280	explore to what extent the above components correlate with galaxy mass (or luminosity), spatially resolved star formation (SF) activity	
DVLA/11A-277	overall kinematics (shear). This project goes well beyond anything that has been done before and has ``Legacy" value.	
VLBA/11A-139		
VLBA/11A-138 VLBA/11A-135	Joint	
VLA/11A-263	Not a Joint Proposal	
VLA/11A-261	Observing Type(s)	
VLBA/11A-133	Continuum, Polarimetry, Single Pointing(s)	
VLA/11A-254		
VLA/11B-170	Dissertation Research Plan	
VLA/11B-157	Dissertation Research Plan(s) not required	
VLA/11B-135	Observer Present for Observations	
VLA/11B-129		
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VLBA/12A-324	Order	Name	Em	ail	Affiliation	Disserta	ation Plan	
VLA/12A-305 VLA/12A-288	up / down	Elias Brinks	E.Brinks@herts.ac	uk	Hertfordshire, University of	N/A		
VLA/12A-280	up / down	Volker Heesen	v.heesen@herts.a	c.uk	Hertfordshire, University of	N/A		
VLA/12A-234 General	up / down	Deidre Hunter	dah@lowell.edu		Lowell Observatory	N/A		
Authors Science Justification	up / down	Michael Rupen	mrupen@nrao.edu	L	National Radio Astronomy Observatory	N/A		
Sources Resources	up / down	Urvashi Rao Venkata	rurvashi@nrao.ed	U	National Radio Astronomy Observatory	N/A		
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Proposal Submission Tool (PST) EVLA

Preview, verify, & submit!

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Status: ALL	VLA/12A-482			JVLA Monitoring of the Type Evidence of Nova Shells	Ia SN2012cg: Searching fo	r Alicia Soderberg	05/31/2012	SUBMITTED
Telescope:	VLA/12A-479			The E-Nova Project: Probing Nova Sgr 2012	Complex Mass Ejection in	Laura Chomiuk	05/21/2012	SUBMITTED
Trimester / Semester:	VLA/12A-459	2 F =		EVLA Nova Project: Confirm Ejection in Recurrent Nova 1		Laura Chomiuk	03/18/2012	SUBMITTED
Year:	VLA/12B-350	24		The EVLA Nova Project: Ima Classical Novae	ging the Fireball Stage of	Jennifer Sokoloski	02/01/2012	SUBMITTED
ALL _	VLA/12B-344	r -		Characterizing Hard X-rays Swift Galactic Plane Survey	Sources Discovered in the	Mark Reynolds	02/01/2012	SUBMITTED
	VLBA/12B-330	r -		DETERMINING THE NATURE EMISSION FROM ACTIVE M		Gregg Hallinan	02/01/2012	SUBMITTED
	VLBA/11B-254			Measuring the Expansion Ve SN 2011dh	locity and Deceleration of	Michael Bietenholz	02/01/2012	SUBMITTE
	VLA/12B-287			The EVLA Nova Project: Rad Classical Novae	io Light Curves of Young	Michael Rupen	02/01/2012	SUBMITTE
	VLA/12B-270	r		The EVLA Nova Project: Con T Pyx's 2011 Outburst	firming a Massive Ejection	in Thomas Nelson	02/01/2012	SUBMITTE
	VLA/12B-235		AK791	EVLA Survey of cataclysmic	variable outbursts	Elmar Koerding	02/01/2012	SUBMITTE
	VLA/12B-226			The EVLA Nova Project: Mor Nova V1723 Aql	nitoring the Unusual Classic	al Miriam Krauss	02/01/2012	SUBMITTED
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Things to think about

- **Overhead:** >50% at high frequencies in big configurations
 - -Moving the antennas, calibration, ...
 - -Huge overhead for short Scheduling Blocks
- Available time: more time is available at night, and some parts of the sky are highly over-subscribed (e.g., Galactic Center)
- Weather: high-frequency daytime observations in the summer will be painful. Low-frequency during solar max won't be fun either.
- **Sensitivity:** see JVLA Exposure Calculator
- **Spatial scales:** resolution, largest angular scales, field-of-view
- Uv-coverage: 10sec may get you the sensitivity, but you can't image a complex source
- RFI





What NRAO can do for you



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Documentation on the Web

Go to <u>www.nrao.edu</u>, click on astronomer, then EVLA:

- **Observational Status Summary**: basic introductory guide with (almost) everything in this talk, and more!
- EVLA Exposure Calculator: how long does it take to get to ImicroJy/ beam?
- **FAQs**: how much overhead do I need?
- **eNews:** late-breaking news for our observing community
- **Data archive**: all VLA, VLBA, EVLA data are accessible through the NRAO archive
- Plus information on proposal submission, observing scripts, memo series, RFI plots and lists, data reduction...



EVLA

Support

- Travel support
- Observing/data reduction visits
- Preprint and page charges
- Large proposal/key science support
- Students (undergraduate and graduate)
 - Summer students
 - Student observing support (also class observations in some cases)
 - Co-op program (undergraduates)
 - Graduate student internships
 - Graduate fellowships
- Postdoctoral fellowships (Jansky and others)
- Short- or long-term visits



PhD astronomers or radio engineers, preferably junior

EVLA

NRAO staff

- Helpdesk: pundits on demand!
- E-mail, telephone
- Wide variety of radio expertise
 - Data analysts
 - Software engineers
 - Hardware gurus
 - Scientific staff
- Friendly, helpful (well, at least we try our best...)
 - We really do like working in a national observatory
 - You can't possibly have crazier ideas than we do

