Jansky Very Large Array

Current and future capabilities

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

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Location

- 27x25m VLA antennas reconfigurable on baselines 35m to 36km
- located in Southern New Mexico at 2100m altitude
- Construction from 1973-1980, upgrade 2003-2012 to Jansky VLA

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Spatial Resolution

- With reconfiguration of the antennas, the VLA can vary its spatial resolution by a factor of ~50 (depending on *largest* baseline/telescope separation)
- Reconfiguration every 4 months (modifications during commissioning)

Configuration	**A**	**B**	**C**	**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
	Synthesized Beamwidth θ_{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

Largest Angular Scale

- The *shortest* baseline sets the largest angular scale that an interferometer is sensitive to
- Compact configurations images have less spatial resolution but cover larger angular scales and increase surface brightness sensitivity

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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
	Largest Angular Scale θ_{LAS}(arcsec)[1,4]			
74 MHz (4 band)	800	2200	20000	20000
1.5 GHz (L)	36	120	970	970
3.0 GHz (S)[6]	18	58	490	490
6.0 GHz (C)	8.9	29	240	240
8.5 GHz (X)[7]	6.3	20	170	170
15 GHz (Ku)[6]	3.6	12	97	97
22 GHz (K)	2.4	7.9	66	66
33 GHz (Ka)	1.6	5.3	44	44
45 GHz (Q)	1.2	3.9	32	32

Field of view
(depends on diameter of a single antenna)
608'
30'
15'
7.5'
5.3'
3'
2'
1.4'
1'

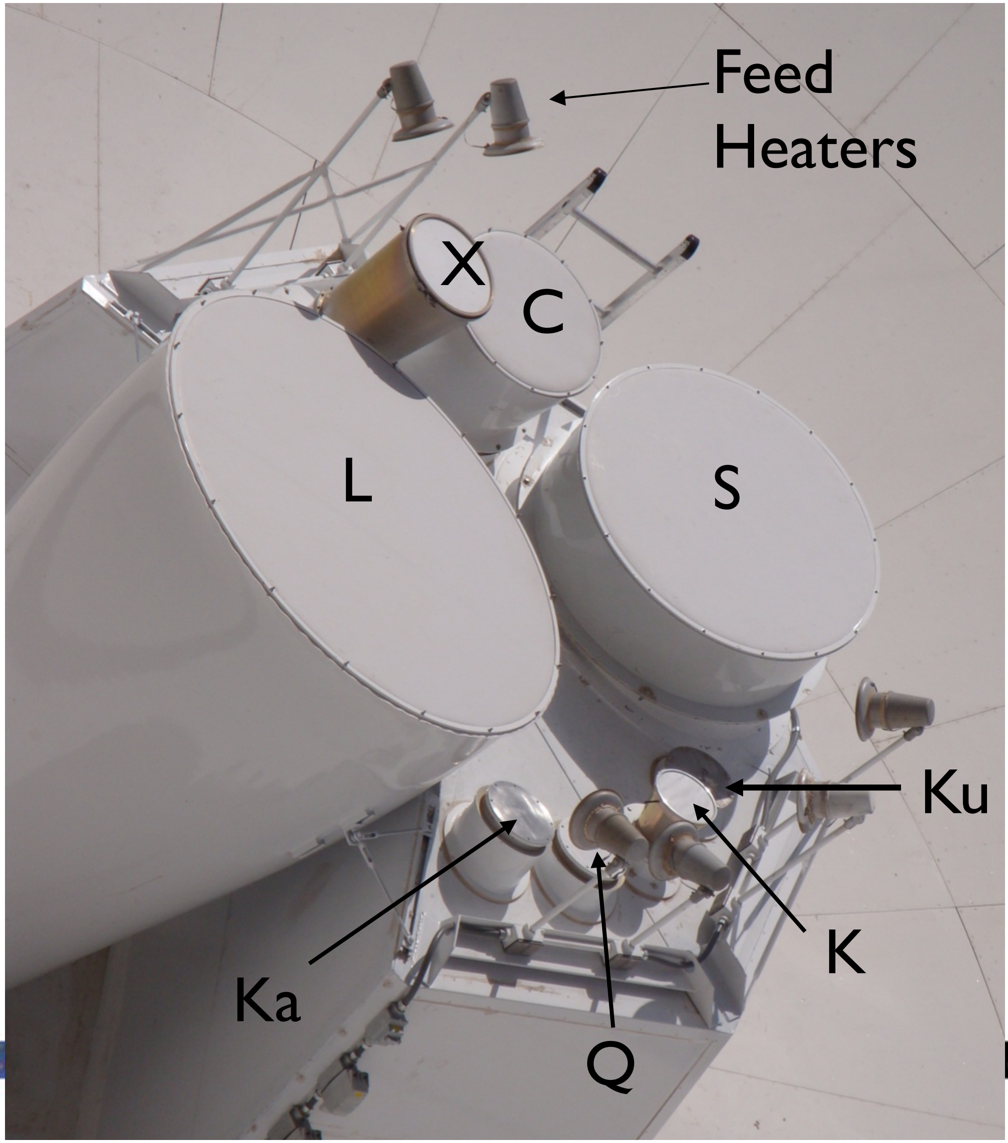
What is the Jansky Very Large Array?

- A major conversion of the Very Large Array (Expanded VLA Project)
- Partners: US, Canada (correlator), Mexico (additional funds)
- First light/fringe in 2010, full operation since early 2013
- 5-10 times better continuum sensitivity
- Accessibility of entire 1-50 GHz frequency range (8 feeds)
- Up to 8 GHz bandwidth per observation and polarization
- High dynamic range imaging
- Spectral channels up to 16000 - 4×10^6 channels in up to 64 independent subbands (equivalent to 64 independent correlators)
- Correlator supports up to 32 antennas
- Dynamical scheduling (based on scientific priority, weather conditions, scheduling efficiency, time critical observations)
- Pipeline-calibrated visibility data (plus reference images)
- New observation preparation software (OPT)
- New data reduction software (CASA)

Full Frequency Coverage with Outstanding Performance

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

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



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Receivers

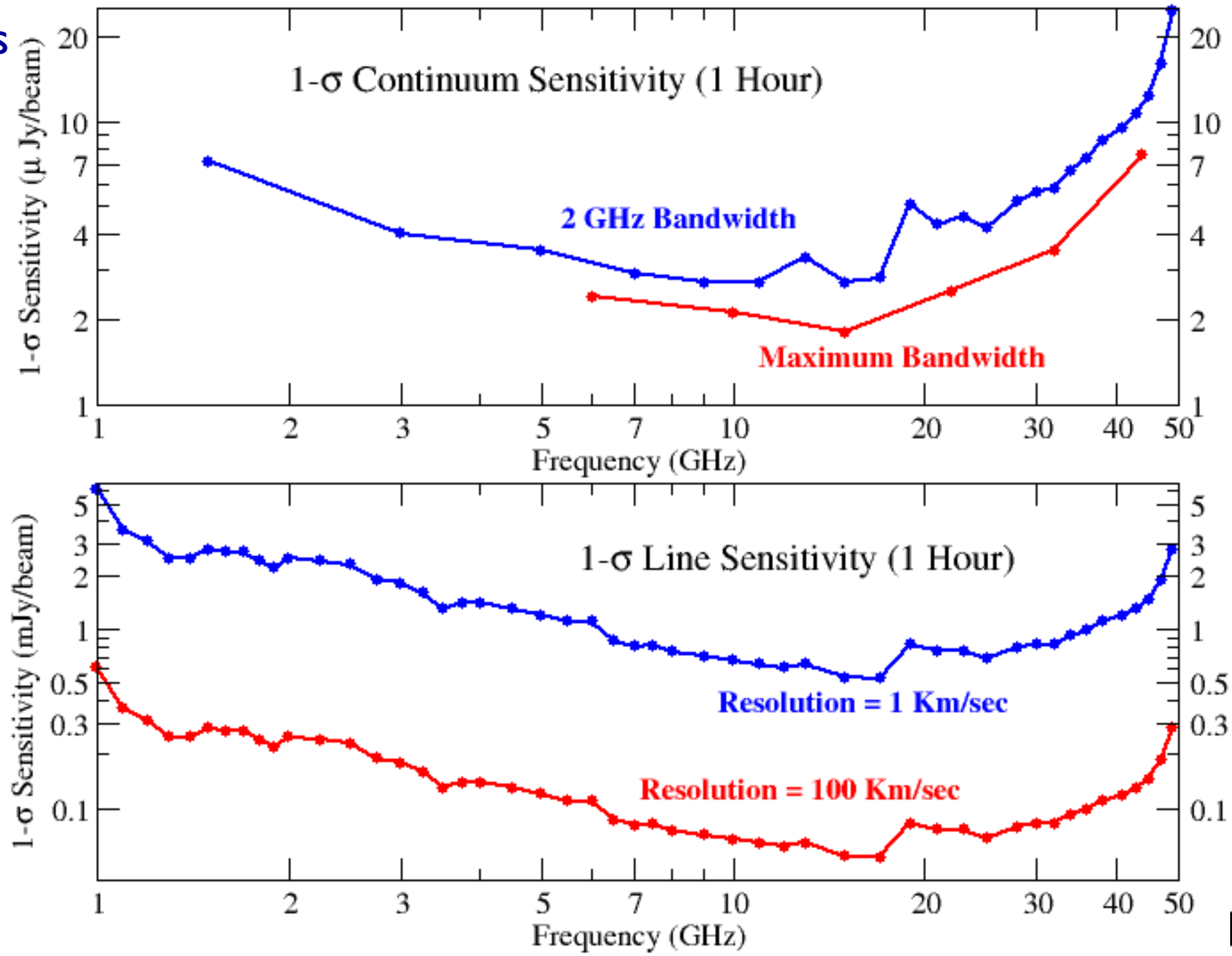
Wideband receivers 1 GHz @ L-band to 10 GHz @ Q-band (correlator can go up to 8 GHz), this implies

- Better sensitivity (cf. VLA max. bandwidth 50 MHz)
- Better image fidelity, higher dynamic range with a goal of 10^6 (filling in gaps in the uv-coverage/multi-frequency synthesis; better RFI isolation)
- Determination of spectral indices in single observations
- Multi-line observations at identical weather conditions for accurate line ratios

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.
2 cm (Ku)	12.0–18.
1.3 cm (K)	18.0–26.
1 cm (Ka)	26.5–40.
0.7 cm (Q)	40.0–50.

VLA Sensitivity (rms in 1 Hour)

- Achieved sensitivities exceed project requirements at all frequencies above 8 GHz.
- Sensitivities below 8 GHz are at, or a little below requirements.
- In most cases, the reasons are understood, and modifications are ongoing.



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Jansky VLA-VLA Capabilities Comparison

The upgraded VLA's performance is vastly better than the VLA's:

Parameter	VLA	EVLA	Factor	Current
Point Source Cont. Sensitivity (1σ,12hr.)	10 μJy	1 μJy	**10**	1 μJy
Maximum BW in each polarization	0.1 GHz	8 GHz	**80**	8 GHz
# of frequency channels at max. BW	16	16,384	**1024**	16,384
Maximum number of freq. channels	512	4,194,304	**8192**	131,072
Coarsest frequency resolution	50 MHz	2 MHz	**25**	2 MHz
Finest frequency resolution	381 Hz	0.12 Hz	**3180**	15.3 Hz
# of full-polarization spectral windows	2	64	**32**	64
(Log) Frequency Coverage (1 – 50 GHz)	22%	100%	**5**	100%

The 'WIDAR' Correlator

- The VLA's new correlator was built to NRAO's requirements by the DRAO correlator group, located at the HIA facility near Penticton, BC, Canada.
- This 'WIDAR' correlator was paid for by the Canadian government, as part of a cooperative agreement between the Canadian NRC and the U.S. NSF.
- Installation of WIDAR began January, 2010. It was turned on for astronomy in early March, 2010.
- This extraordinarily flexible machine is now fully installed at the VLA site, and is working magnificently.
- We are far from deploying all its capabilities – this is a lengthy process, which is months to years away from completion.

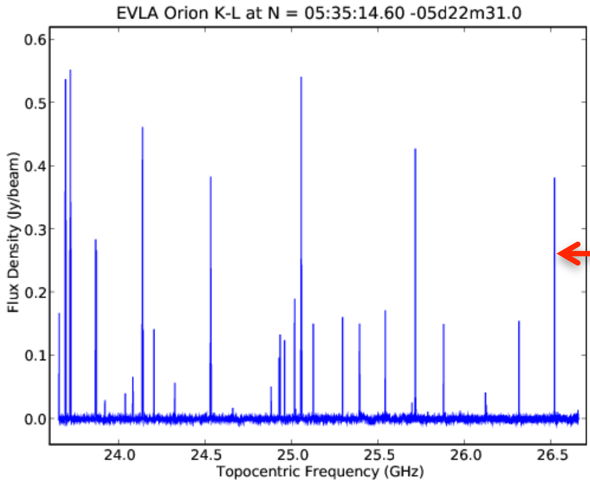
WIDAR Correlator use cases

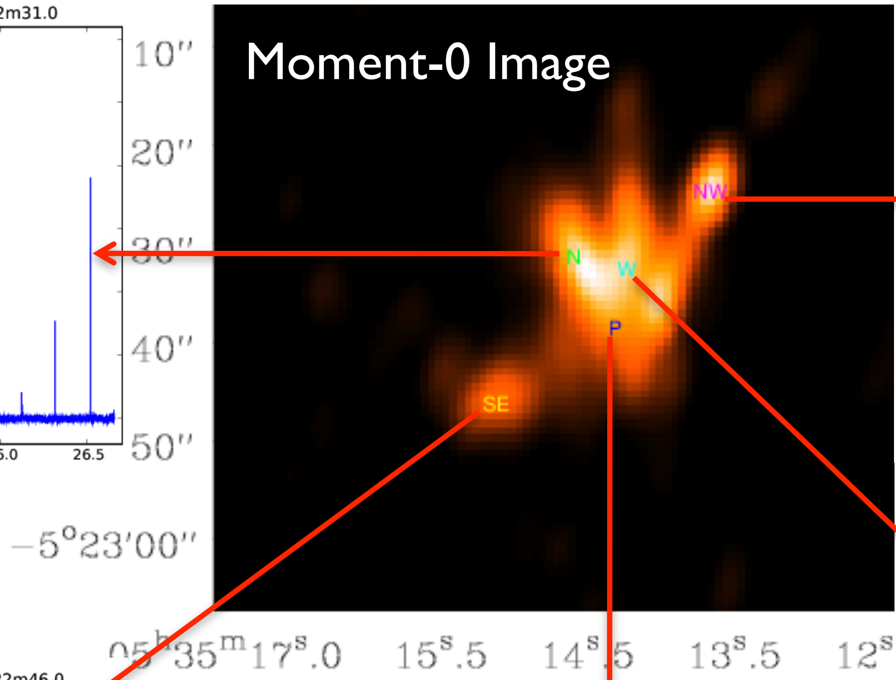
- Ka-band (1cm): 2x1 GHz imaging (captures tens of important molecular lines) with 3 km/s spectral resolution (dual pol), 1sec integration time

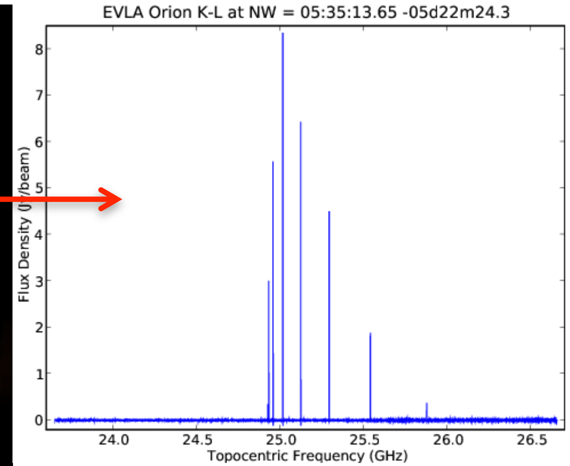
- L-band (21cm): full stokes continuum at 2 MHz resolution (using 8 subbands) plus sub km/s imaging on HI, OH, radio recombination lines (up to 56 additional subbands!), all simultaneously

- S-band (13cm): 31 Radio recombination lines at once with sub-km/s resolution; sensitivity increase by stacking

Multi-Line Imaging: Orion KL

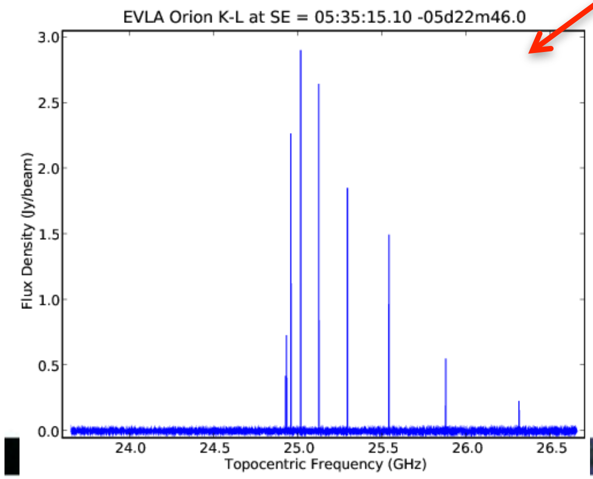


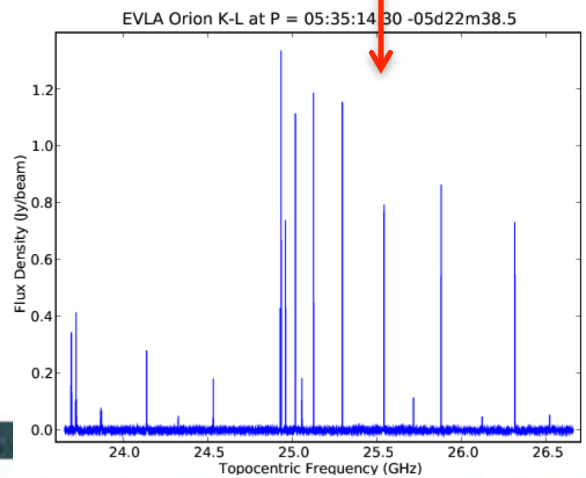


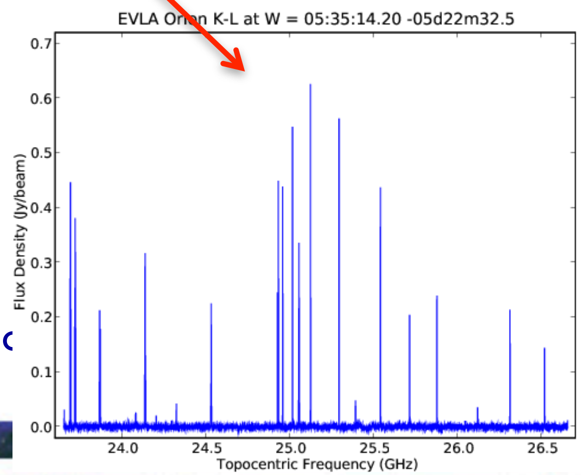


96x96x24012 spectral cube

End to end data processing in CASA

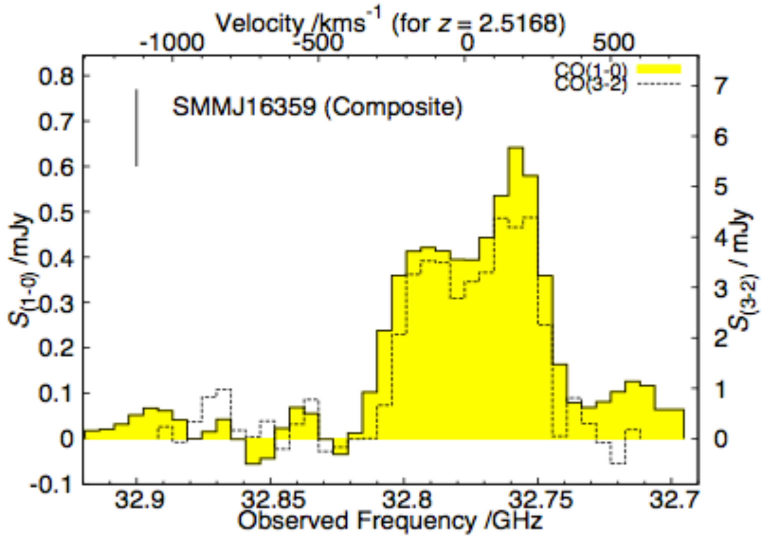


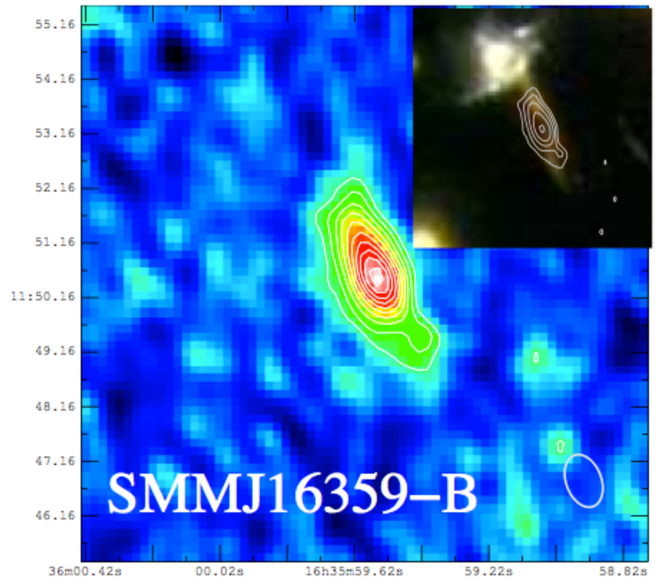




Molecular gas in early main sequence galaxies

- Herschel has identified large samples of gravitationally lensed, very dusty, FIR luminous star forming galaxies, but optical redshifts are difficult to obtain due to obscuration
- Wide bandwidth of VLA has become a powerful tool to obtain redshifts, and molecular gas properties
- VLA has imaged the molecular gas in a set of lower luminosity star forming galaxies at z~2.5
- Large, rotating disks are seen, containing warm molecular gas
- They also detect thermal Free Free emission for the first time in distant galaxies, providing the best measure to date of star formation rates

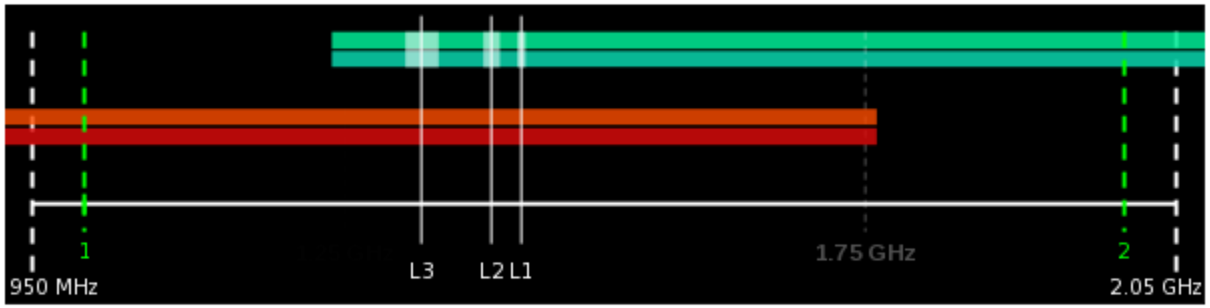




VLA spectra and images of a star forming galaxy at z=2.5 (Thompson et al. 2012)

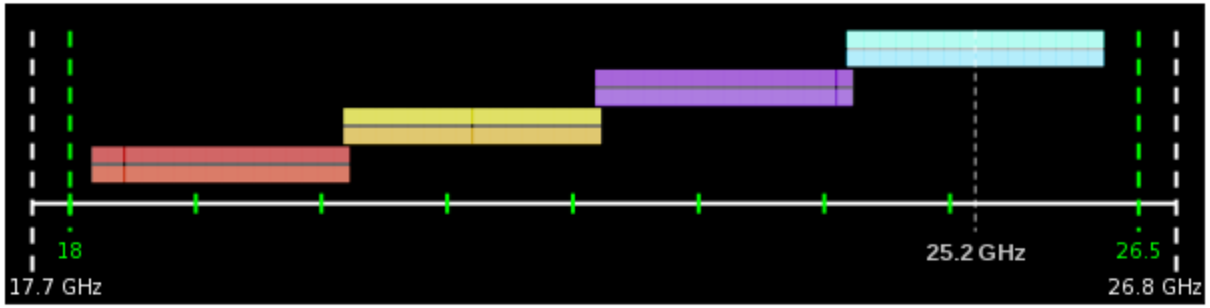
Current General Observing : 8-bit

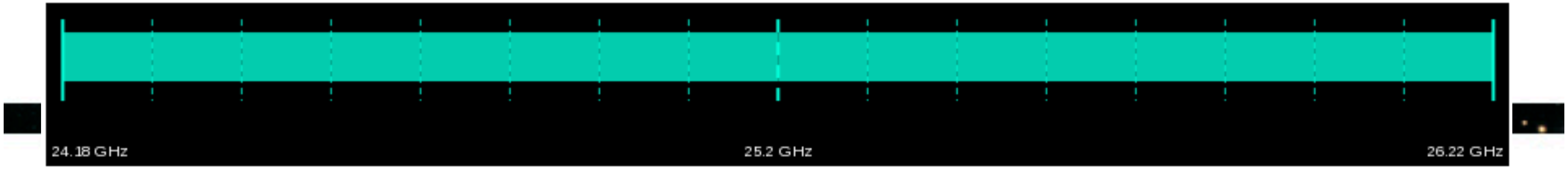
- 8-bit is traditional sampling: offered since WIDAR came online in 2010
- 2 independently tunable basebands of 1 GHz each (cf. old VLA only 0.05GHz each) for a total of 2 GHz
- Each of these basebands can have up to 16 independent and flexibly tunable subbands
- Each subband has 64 (full pol), 128 (dual pol), or 256 (single pol) channels
- Current maximum: 16,384 channels * Npol
- Up to three sub-arrays



Current General Observing : 3-bit

- 3-bit samplers: very new; latest addition to the VLA (2012)
- Part of general observing since January 2013
- 4 independently tunable basebands of 2 GHz each for a total of 8 GHz
- Each of these basebands has 16 subbands
  - 128 MHz each (compare much more flexible 8-bit)
  - Contiguous (compare 8-bit: place subbands where you want)
- Each sub band has 64 (full), 128 (dual) , or 256 (single) channels (like 8-bit)
- K, Ka, and Q-band only; no subarrays





Shared risk observing

- We've covered General Observing. If you want more, two possibilities:
- Shared Risk observing: own risk, but supported by OPT and scheduler
  - Faster correlator dump times (as short as 50ms)
  - 3-bit samplers at C, X, or Ku band
  - Low frequency observing 230 – 470 MHz
- Resident Shared Risk Observing: own risk, visit NRAO in Socorro to help out commissioning, not supported by OPT and scheduler
  - Faster correlator dump times (< 50ms)
  - > 3 subarrays
  - OTF interferometric mosaicking
  - Recirculation in correlator (i.e. get n times more channels by decreasing subband width by factor n)

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Data Reduction

- VLA data reduction is possible in CASA and AIPS
- With higher volumes: CASA only
- Data volumes can be very large and parallelization of the software is currently underway
- CASA contains new wide-band, wide-field imaging algorithms
- On-the-fly Interferometry/Mosaicing
- Development of automatic RFI flagging
- A computing cluster will be available for users in Socorro
- Calibration pipeline is now operational
- Hardware recommendations are provided on our webpage for those who decide to upgrade their own computing equipment

CASA
Common Astronomy Software Applications

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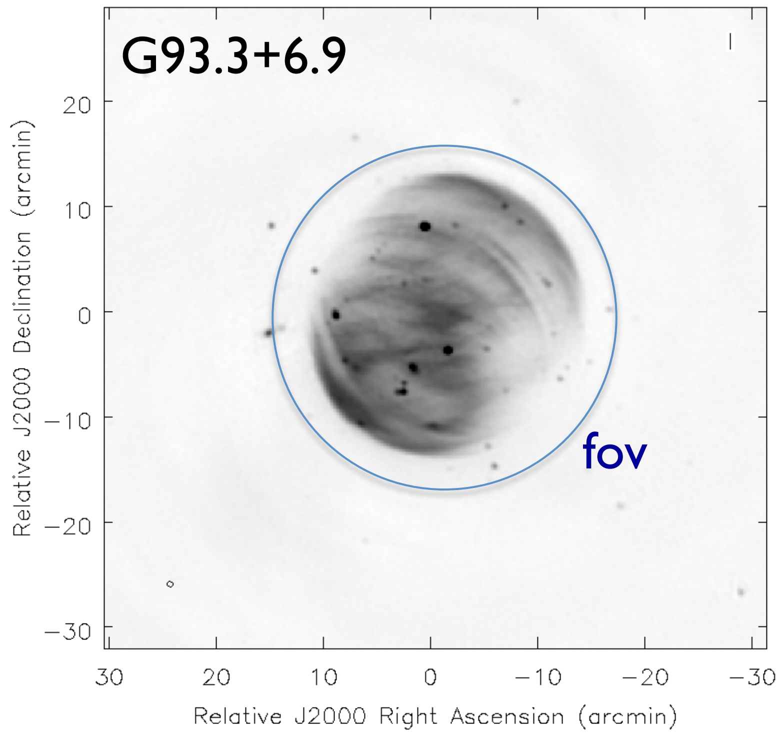
Wideband Imaging

- Wide-band, wide-field imaging
- Multi-scale cleaning
- A-projection for wide-field imaging



Bhatnagar, Green, Rau, Golap, Rupen & Perley

EVLA

Next proposal deadline: 1August 2013

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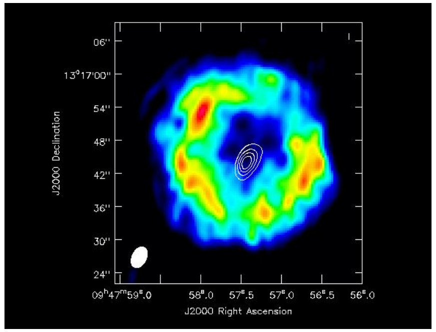

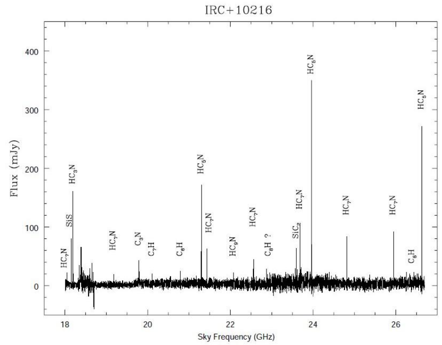

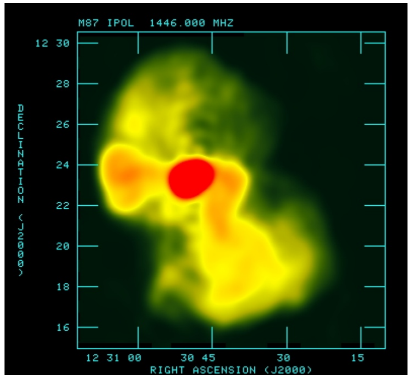

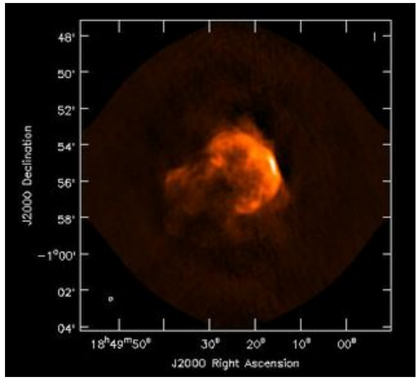

http://science.nrao.edu/evla/earlyscience/demoscience/