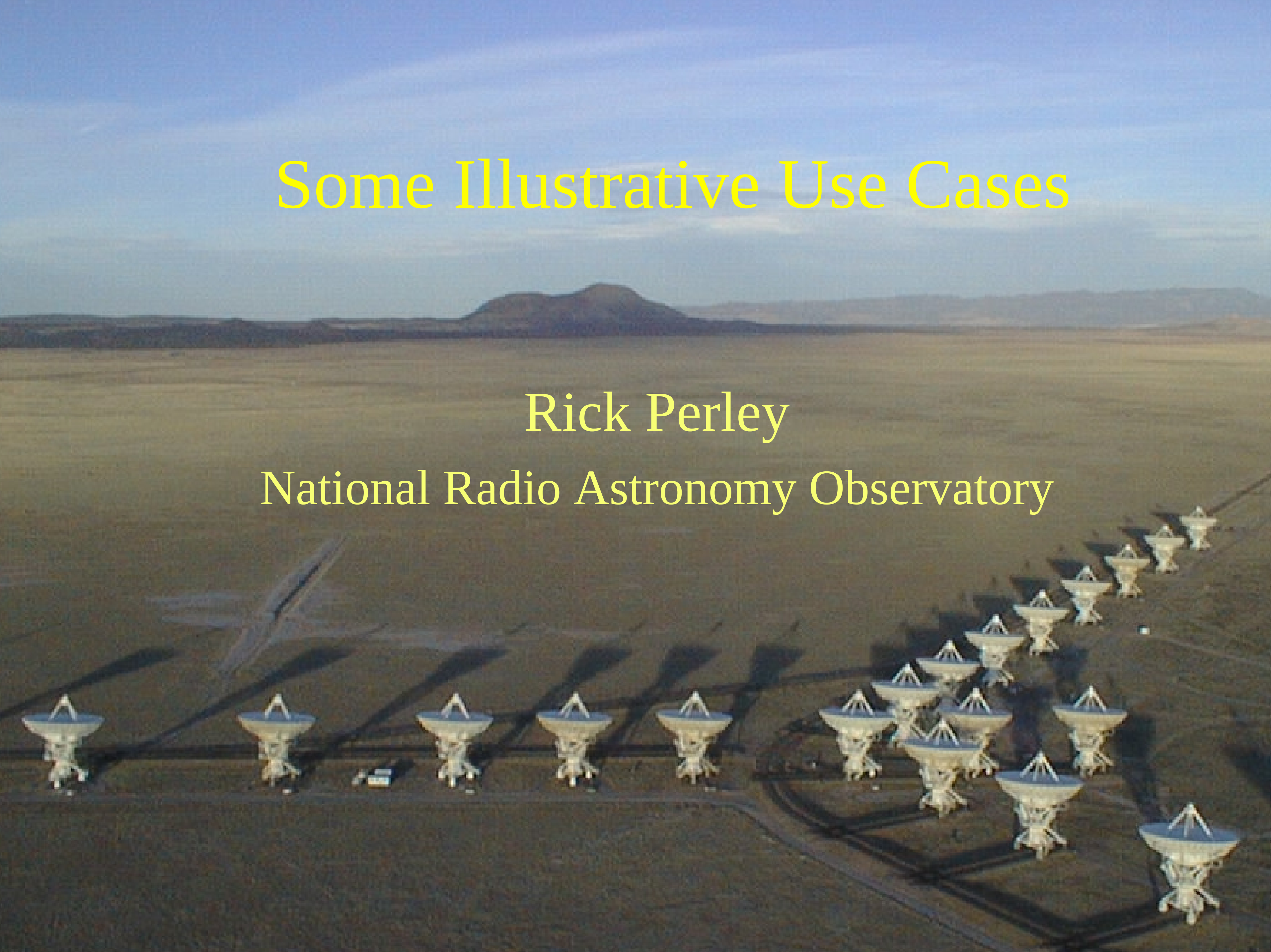

Some Illustrative Use Cases

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WIDAR

- Designed with a wide range of specific modes to permit:
  - ‘standard’ full-band, full polarization spectral imaging
  - Flexible ‘zoom’ modes to concentrate resources in spectral regions of special interest.
  - Very high spectral and spatial fidelity imaging
  - Robust resistance to RFI
  - Pulsar modes, giving 1000 time bins of 0.2 msec width, or less.
  - Phased array modes, and unlimited sub-arraying capabilities.
  - And much more…
- In this talk, I concentrate on the first two modes, to show that much of the science potential of this new facility will be enabled by them alone.

Illustrative Example 1: The simplest correlator mode

- The simplest correlator mode is that which:
  - Processes the entire input bandwidth uniformly (same frequency resolution throughout).
  - Provides all four correlation products (for full polarization information), OR
  - Provides two parallel hand correlations (for total intensity only).
- So – what do you get from this mode alone?

L-Band (1 GHz/polarization)

- In this case, we have two input streams (or one BBPair) of 1 GHz BW each (8 bits depth at 2048 MSamp/sec).
- Each sub-band will be 1024/16 = 64 MHz wide.
- The 1024 channels available per sub-correlator can all be assigned to this single input BBPair.
- With four correlation products, there will be:
  - 1024/4 = 256 channels per spectrum
  - A resolution of 64000/256 = 250 kHz
  - A velocity resolution of 50 km/sec.
- For two correlation products, we get:
  - 512 channels/spectrum
  - 125 kHz channel resolution
  - 25 km/sec velocity resolution.

Other Bands

- S-Band
  - BW = 2 GHz, so we can again use a single BBPair, but with 128 MHz sub-bandwidth.
  - Frequency resolution two times worse than L-band, but velocity resolution the same.
- C, X Bands
  - BW = 4 GHz, so we need two input BBPairs, with 128 MHz sub-bandwidth each.
  - Frequency resolution two times worse than S-band, but velocity resolution the same (at C band).
- K, Ka, Q Bands
  - Here the BW = 8 GHz, so we need all four input BBPairs, with 128 MHz per sub-band.
  - Frequency resolution again degrades by factor of two, but velocity resolution better.

Tabular Results

			Full Polarization		Parallel Hands	
Nchannels	Band	BW (GHz)	Δν (kHz)	Δv (km/sec)	Δν (kHz)	Δv (km/sec)
32768	1 - 2	1	125	25	62.5	25
32768	2 - 4	2	250	25	125	25
32768	4 - 8	4	500	25	250	25
32768	8 - 12	4	500	15	250	15
16384	18 – 26.5	8	2000	27	1000	27
16384	26.5 – 40	8	2000	18	1000	18
16384	40 – 50	8	2000	14	1000	14

Applications

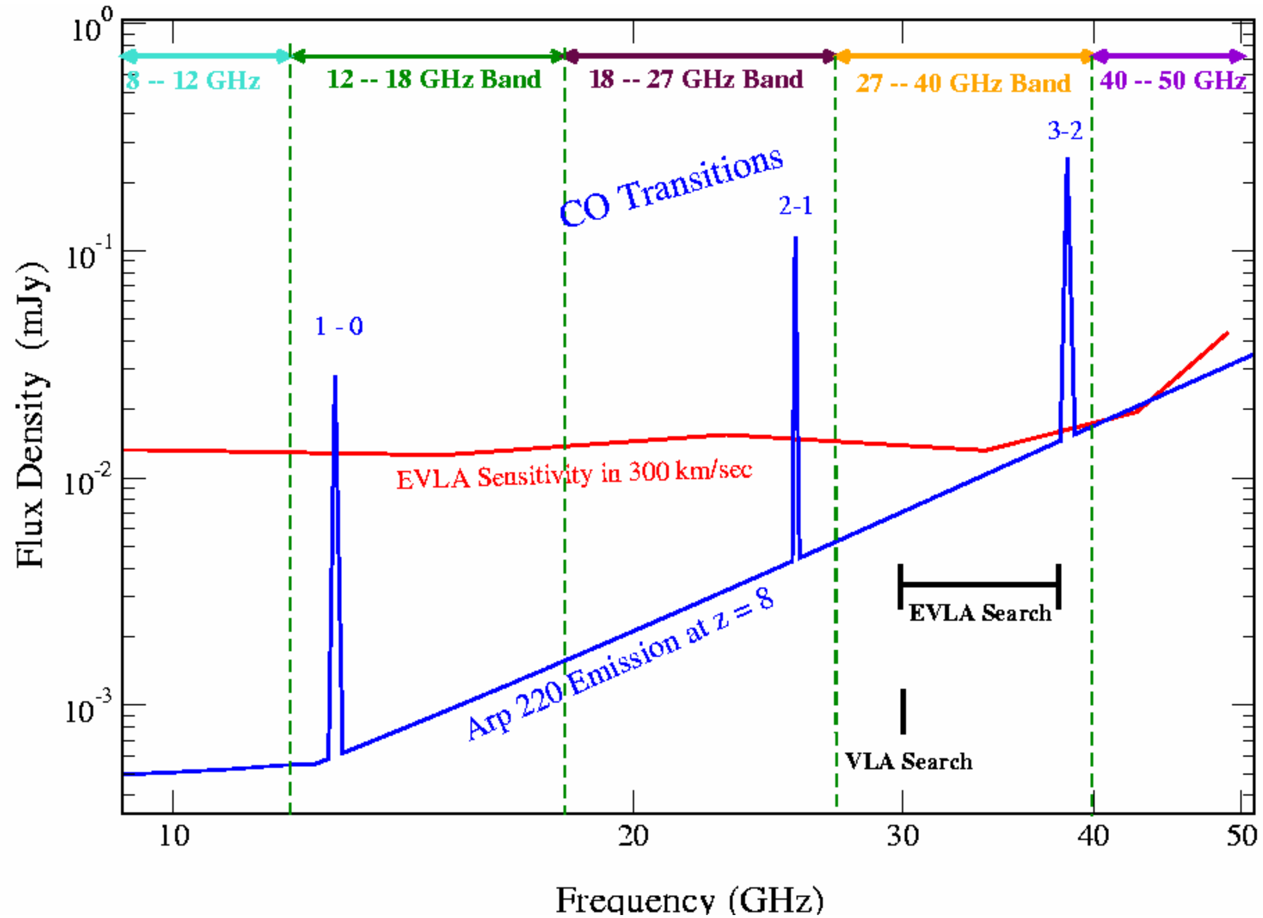
- This very fundamental mode will be sufficient for a wide range of science goals, including:
  - Full-band spectral surveys of galactic or stellar systems
  - Polarization imaging (including RM analysis) of specific objects or full fields.
  - Full-beam imaging for surveys in all Stokes.
  - Deep, targeting observing of individual sources, where background source removal is critical.

Searching Hi-z Galaxies for CO emission

- The plot shows the spectrum of Arp 220, moved to z = 8.

Unless redshift is known accurately in advance, line searches with VLA correlator are hopeless. (VLA search width only ~ 50 MHz).

EVLA search width of 8 GHz, with 16384 channels, makes these surveys almost easy.

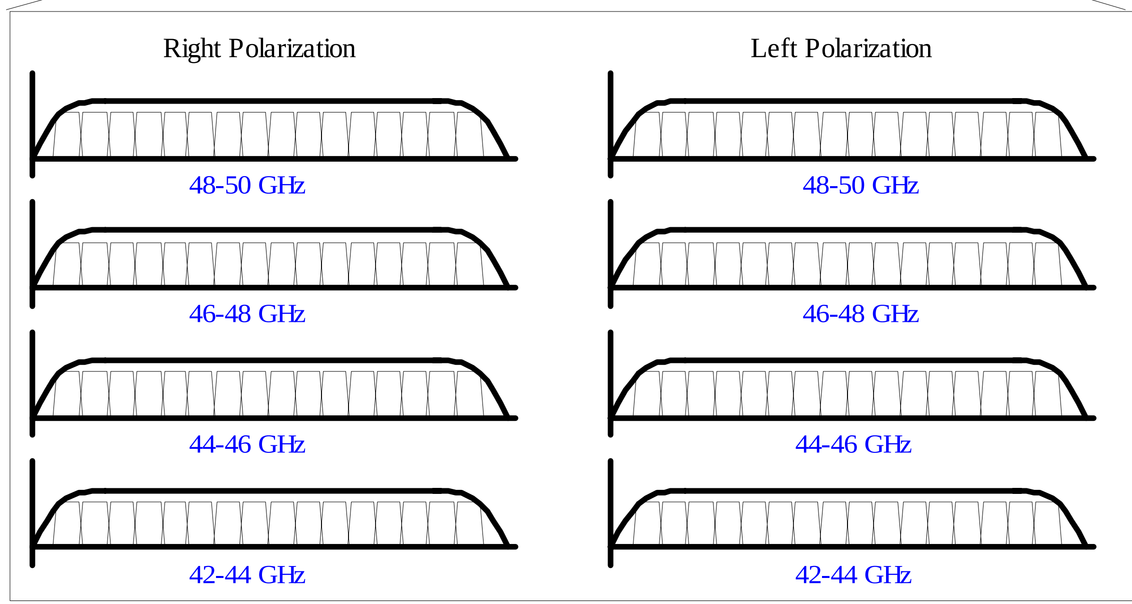


EVLA Setup for CO Z-Search

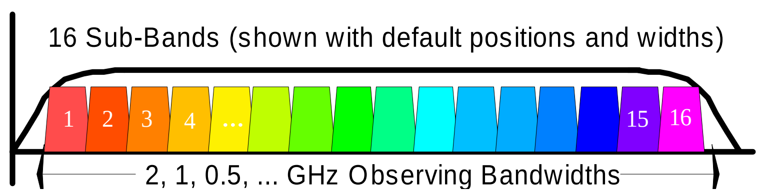
Sky Frequency Bands

1-2	2-4	4-8	8-12	12-18	18-27	27-40	40-50	GHz
L	S	C	X	U	K	Ka	Q	

8 tunable IF Bands



- 40-50 GHz band provides lowest redshift.
- z = 1.4 to 1.9 for J=1-0.
- z = 3.8 to 4.8 for J=2-1.
- $\Delta v \sim 7.0$ km s^{-1} (1 MHz).
- 200 km-s^{-1} galaxy would occupy ~40 channels.
- Interferometry
  - High resolution imaging.
  - Good spectral baselines.



Note: Sub-bands can be seamlessly joined across each observing bandwidth.

Application – Full-Field Imaging

- For this, we wish to image the entire content of the antenna primary beam.
- I distinguish two cases:
  - **Full Imaging:** A distortion-free image is desired for every source, to the antenna's first null. The science is in the full count and structure of the sources.
  - **Background Removal:** A modestly-stretched image of the background objects can be tolerated. The goal is to remove them adequately, to obtain full sensitivity for the target source.
- At L-band, the required channel and time resolutions are:
  - 180 kHz, and ~1 second in A configuration for full imaging
  - 720 kHz and ~4 seconds in A configuration for 'background removal'.
  - (Channel wide and time averaging scale with configuration scale).
- At other bands, the required frequency resolution scales with observing frequency. The required time resolution is independent of frequency.

Full-Field Imaging

- Comparison of the time/spectral resolution requirements with WIDAR wide-band capabilities shows that for all bands:

Data for full-field, full-bandwidth, full-polarization full-fidelity, and full-sensitivity imaging can be provided by WIDAR.

- Caveat: The above is true for low-RFI situations. For high-RFI, a '7-bit' correlator mode can be turned on to provide much higher spectral dynamic range. This mode will require reduction in total bandwidth. The loss fraction is hard to determine at this time.

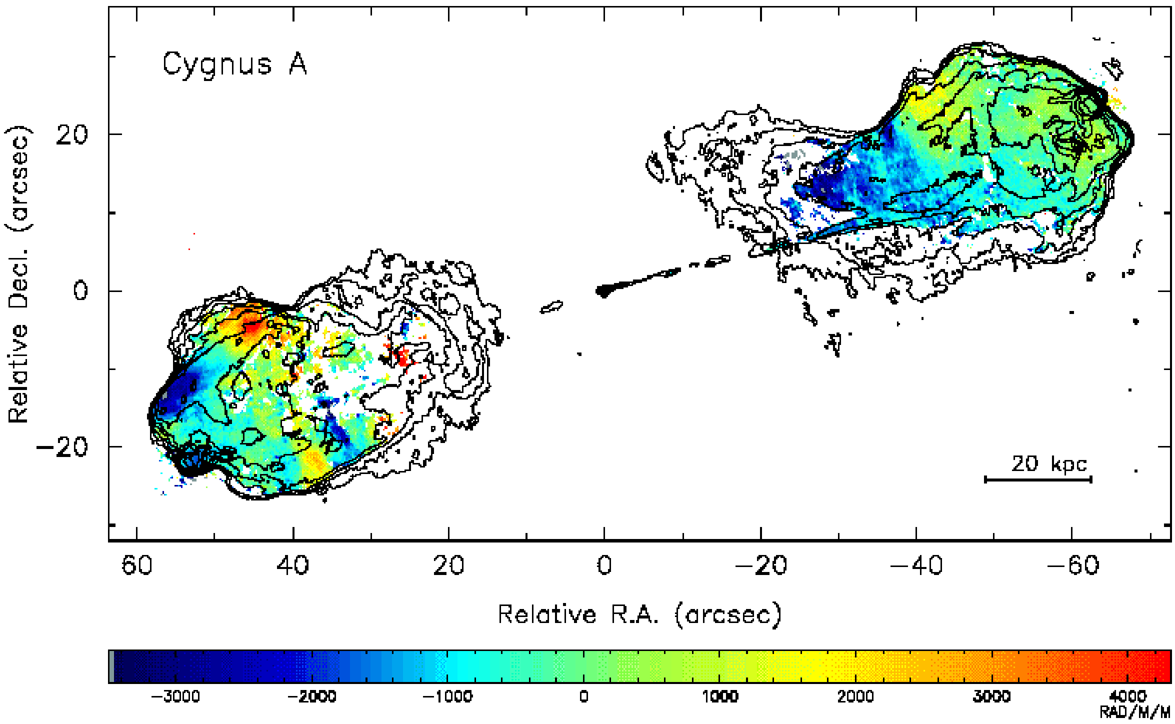
Faraday Rotation Studies

Plane of polarization rotated by Faraday rotation:

$$\chi = \chi_0 + RM\,\lambda^2$$

where RM is the Rotation Measure:

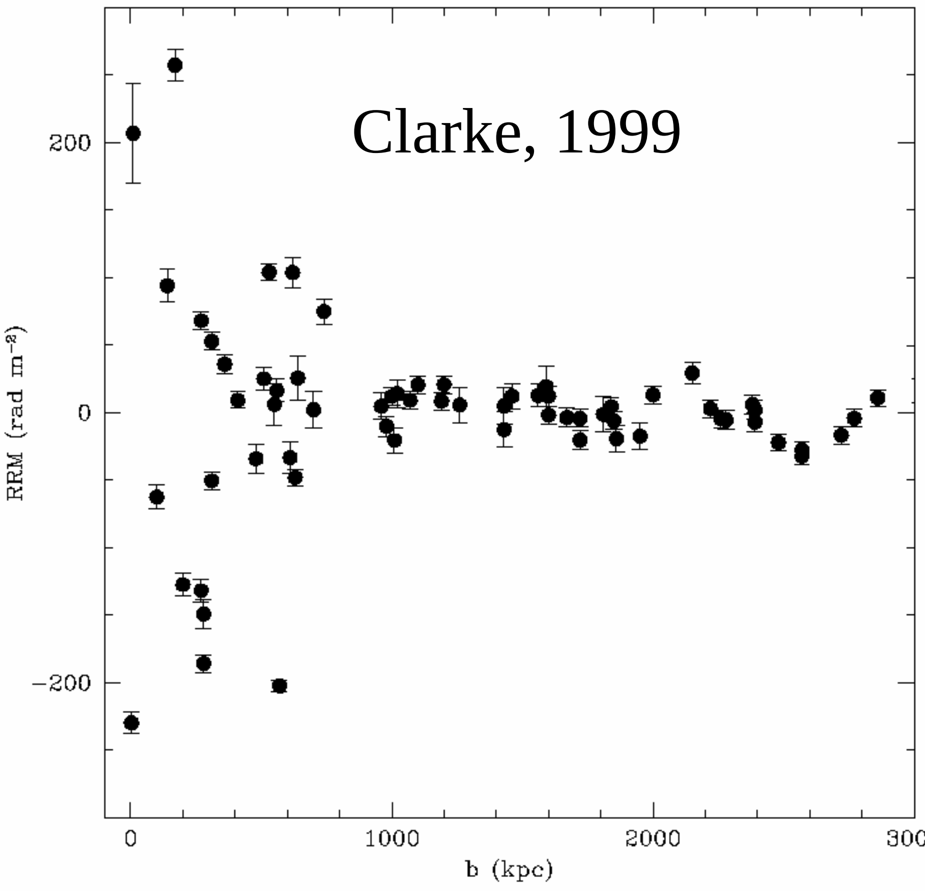
$$RM \propto \int n_e \mathbf{B} \bullet d\mathbf{l}$$



Measuring the slope of the position angle vs. frequency gives RM.
An estimate of **B** can be derived if n_e is known.
Increased sensitivity will allow much deeper studies.

Cluster Magnetic Fields

- Intra-cluster magnetic fields may play an important role in galaxy and cluster evolution.
- Radio observations of Faraday rotation give the only probe of cluster fields.
- VLA sensitivity sufficient only for statistical studies.
- EVLA sensitivity and frequency coverage will allow 20 RRMs, per cluster, for more than 80 clusters.



Illustrative example #2 – A use of WIDAR Zoom Modes

- Zeeman splitting of H recombination lines provide a means of measuring ISM magnetic fields.
- Splitting is weak – 2.8 Hz per μG.
- Must stack multiple lines to improve SNR.
  - Measurement of 100 μG fields possible!
- There are 31 recombination lines in 2 – 4 GHz band.
  - Each is typically 250 kHz wide – they occupy ~0.4% of the total bandwidth.
  - Need 10 kHz resolution (1 km/sec velocity resolution).
- To observe all 31 in a straightforward manner, a 400,000 channel correlator would be needed.
- about 99% of the (continuum) information not needed (and represents wasted effort).
- WIDAR can do better – much better.

Zooming in on RRLs – with Recirculation

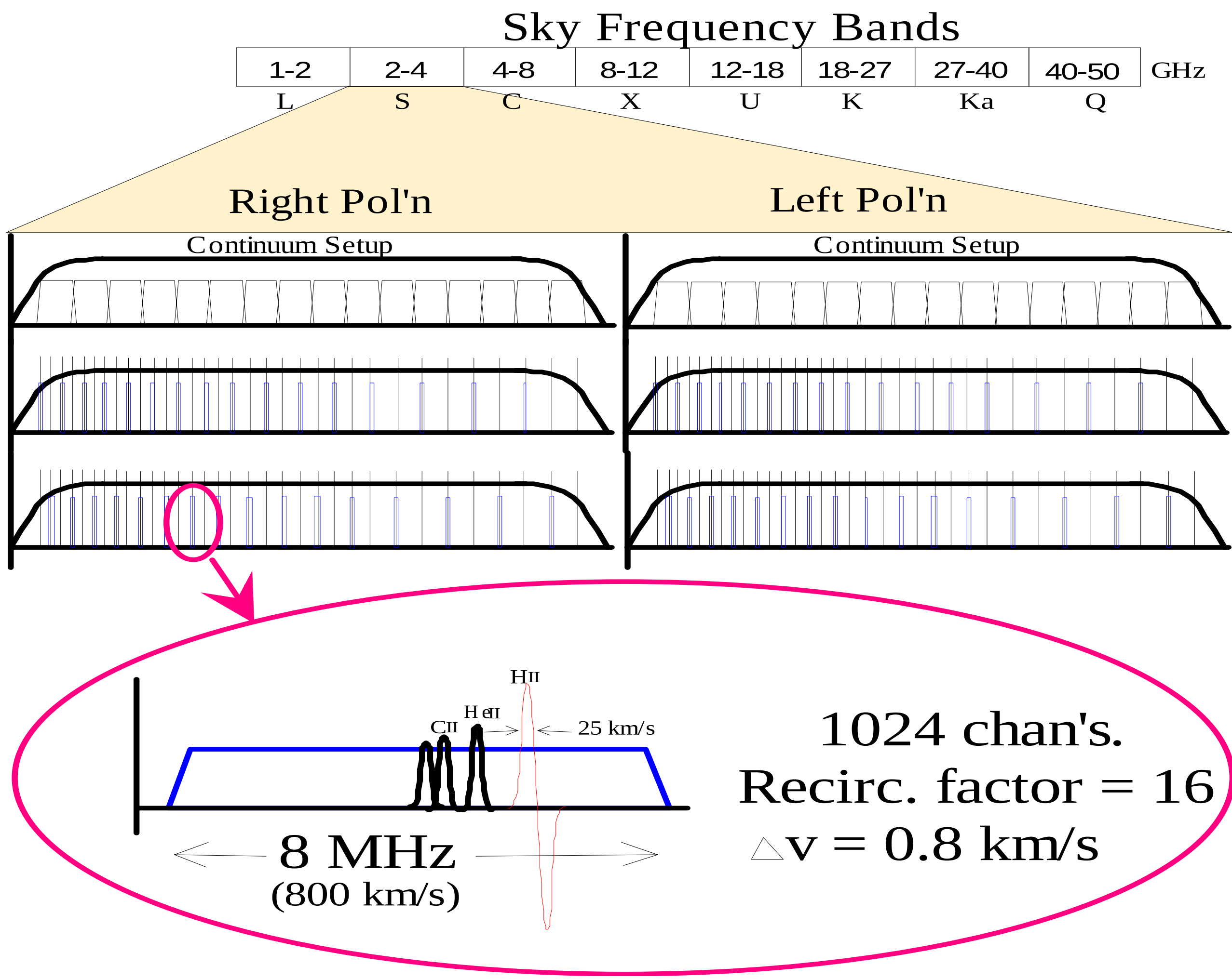
- With recirculation, we can get everything at once!

	Sub-Band Bandwidth (MHz)						
	64	32	16	8	4	2	1
N_{chan}/line	1024	2048	4096	8192	16384	32768	65536
$\Delta\nu$ (full pol)	250	62.5	15.6	3.9	0.98	0.24	0.061
$\Delta\nu$ (2 pol)	125	31.3	7.81	1.95	0.49	0.122	0.031

- The BW is now 8 or 16 MHz, and the resolution more than enough.
- The data rates will be fierce: The dual-polarization mode provides a total of 128,000 channels, or a rate of 200 MB/sec in A configuration with 2 second averaging.
- The four-polarization mode doubles this again.
- But, the CBE (correlator back-end computers) can discard unneeded channels, and smooth the spectra, to considerably reduce data flow.

Correlator Setup for Zeeman Studies at 2 – 4 GHz

- Each line individually targeted.
- H, He, and C lines all within the 16 MHz sub-band width.
- Spectral resolution of 15.6 kHz (1.6 km/sec), or better.
- Each of 62 spectra gets 4096 channels.
- Alternatively, could use 8 MHz sub-band, with 8192 channels, giving 0.2 km/sec resolution!



Other Modes …

- WIDAR has many other basic modes, each with science applications. Some are:
  - Pulsar modes:
  - Phased array modes – for pulsars or VLBI
  - ‘Radar’ modes, for bistatic planetary radars.
  - RFI-excision ‘modes’.