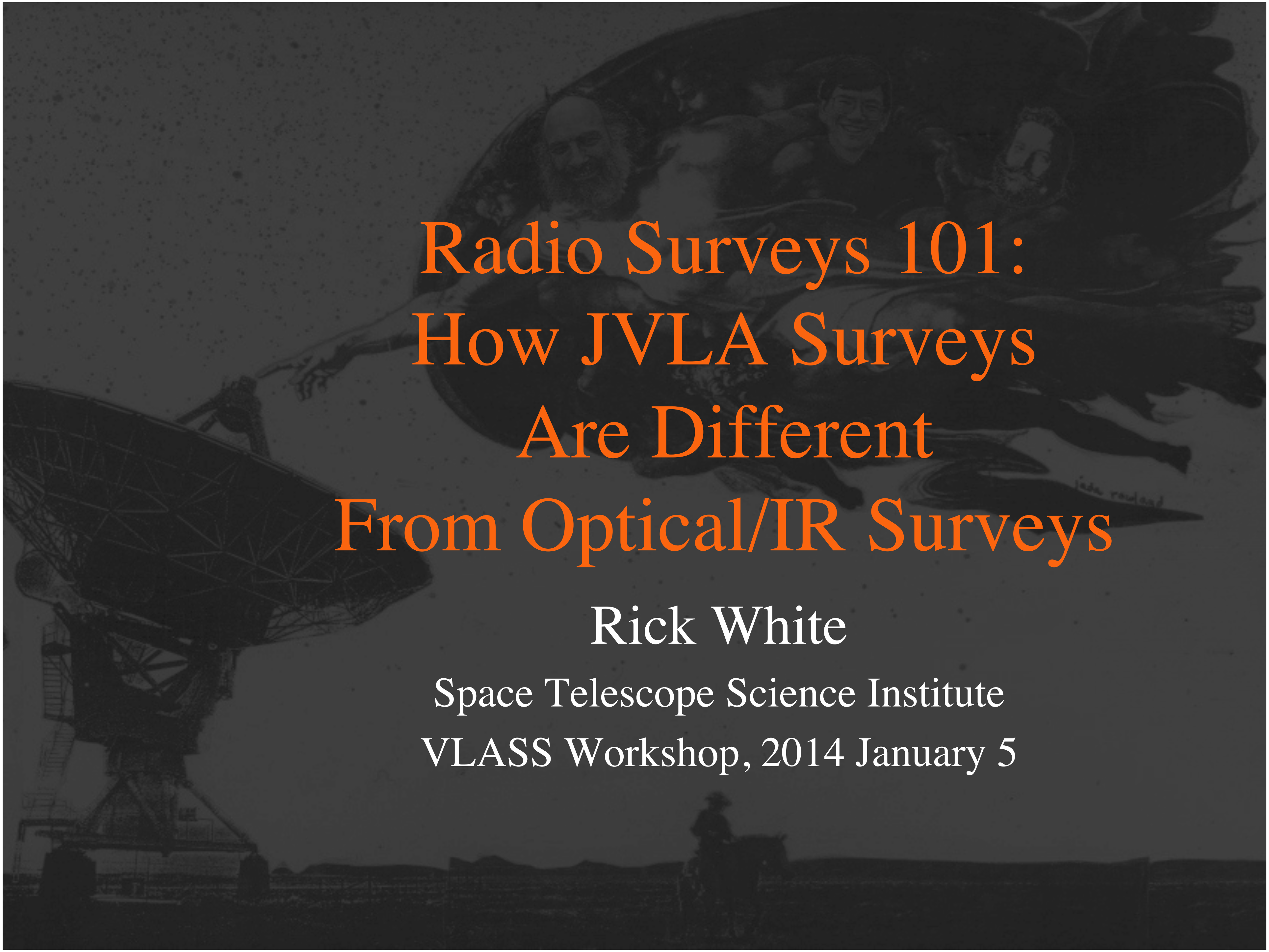

Radio Surveys 101: How JVLA Surveys Are Different From Optical/IR Surveys

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JVLA surveys are weird

- Everything is variable & selectable
  - Field of view, resolution, pixel size, …
- Data collected are not images
  - Interferometric visibility data ≠ pixels
- Data processing is computationally and algorithmically challenging
  - Data rate is only weakly coupled to final map data volume

Designing a survey

- Field of view (primary beam size)
  - Determined entirely by frequency
    - Primary beam size set by antenna diameter
    - FWHM ~ 42 arcmin / frequency in GHz
  - Cover large area with hexagonal grid of pointings
    - Number of pointings increases as frequency squared
    - Spacing is determined by highest frequency in bandpass

- Spatial resolution (PSF = synthesized beam)
  - Determined by frequency plus configuration
    - Configuration determines longest baseline between antennas: A=high res, B, C, D=low res
    - Higher frequency = higher resolution

Field of View & Resolution

		Field of View		Resolution FWHM (arcsec)			
Frequency (GHz)	Band	FWHM (arcmin)	Pointings per sq deg	A	B	C	D
1 – 2	L	28	12	1.7	5.1	15	45
2 – 4	S	14	50	0.9	2.6	7.7	23
4 – 8	C	7	200	0.4	1.3	3.8	12

- Field of view is for band mid-frequency
- Pointings per sq deg is for high-frequency end of band
- Resolution is for band mid-frequency

Field of view oddities

- Field of view changes significantly across bandpass
  - Field area is 4 times smaller at 2 GHz than at 1 GHz in L-band
- Fields are not sharp-edged
  - Circular, roughly Gaussian (really Bessel functions)
    - Sizes quoted are where sensitivity drops to half that at field center
  - Hexagonal pointing centers can be co-added to get nearly uniform sensitivity (~15% variations)
    - cf. FIRST and NVSS survey grids

Resolution oddities

Q: Why not always observe at highest resolution using the A-configuration?

A: Higher resolution is not always better!

- Surface brightness-limited survey: higher resolution makes extended sources harder to detect
  - Half of sources resolved in FIRST survey (5.4” FWHM)
  - Unlike optical/IR survey, cannot smooth images to recover S/N on extended objects
- “Resolved-out” flux: smooth extended emission is not detected in high-resolution configurations
- Computing time increases with inverse PSF area

Interferometry

- Visibility data: samples of Fourier transform of image
  - Each pair of antennas gives a measurement for each frequency channel
- Image construction is a (hard) inverse problem
  - CLEAN algorithm appears simple but is a subtle and complex non-linear process
  - There is not a proven best approach for wide-band, wide-field imaging

Interferometry oddities 1

- Total flux would be measured by zero-spacing baseline
  - But it is not observed by VLA (or other interferometers)
  - Absence of short-spacing information is what causes loss of extended flux at high resolution

Interferometry oddities 2

- Noise is in the visibility (Fourier) domain, not in pixels
  - Noise is global in images
  - Bright sources lead to elevated noise levels (sidelobes) throughout the image
    - Similar to optical diffraction spikes but with widespread peaks that exceed 30% of the central peak
  - Interference is the equivalent of cosmic rays, but impacts entire image rather than a few pixels

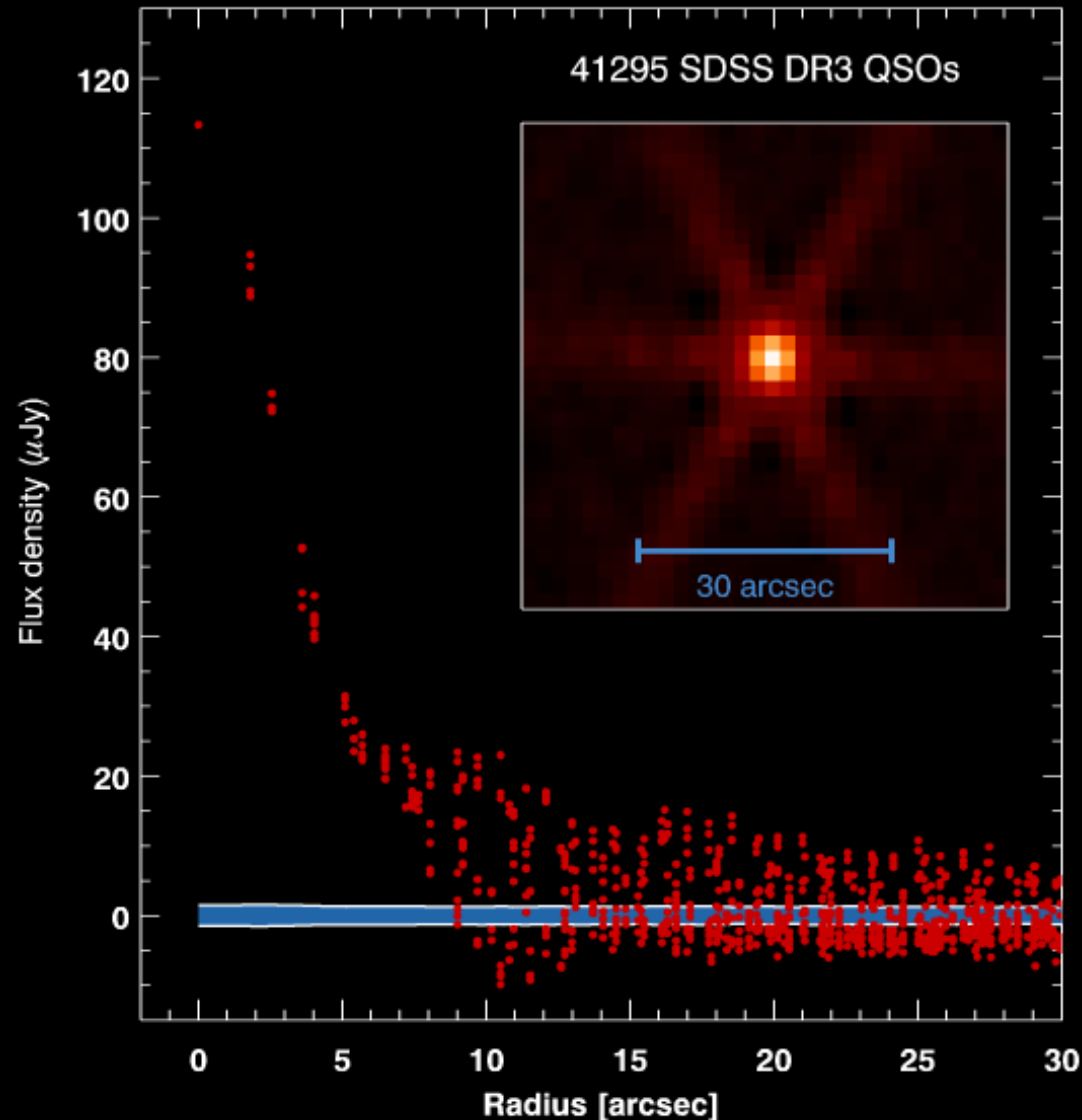
Interferometry oddities 2

- Wide frequency range in JVLA receivers leads to dramatic changes across band
  - Both PSF & field of view areas change by factor of 4 from low to high frequency
  - Want to fit source brightness and spectral index
    - … but apparent spectrum depends strongly on distance from field center
    - … and extended sources are even more complicated due to changing resolution
- Even narrow band CLEAN has weirdness: see “snapshot bias” (White et al. 2007)

Median stacked radio image for 40,000 quasars

One use of untargeted surveys is stacking "blank" fields at known source positions.

We used this to study radio properties of SDSS quasars below the FIRST detection limit.

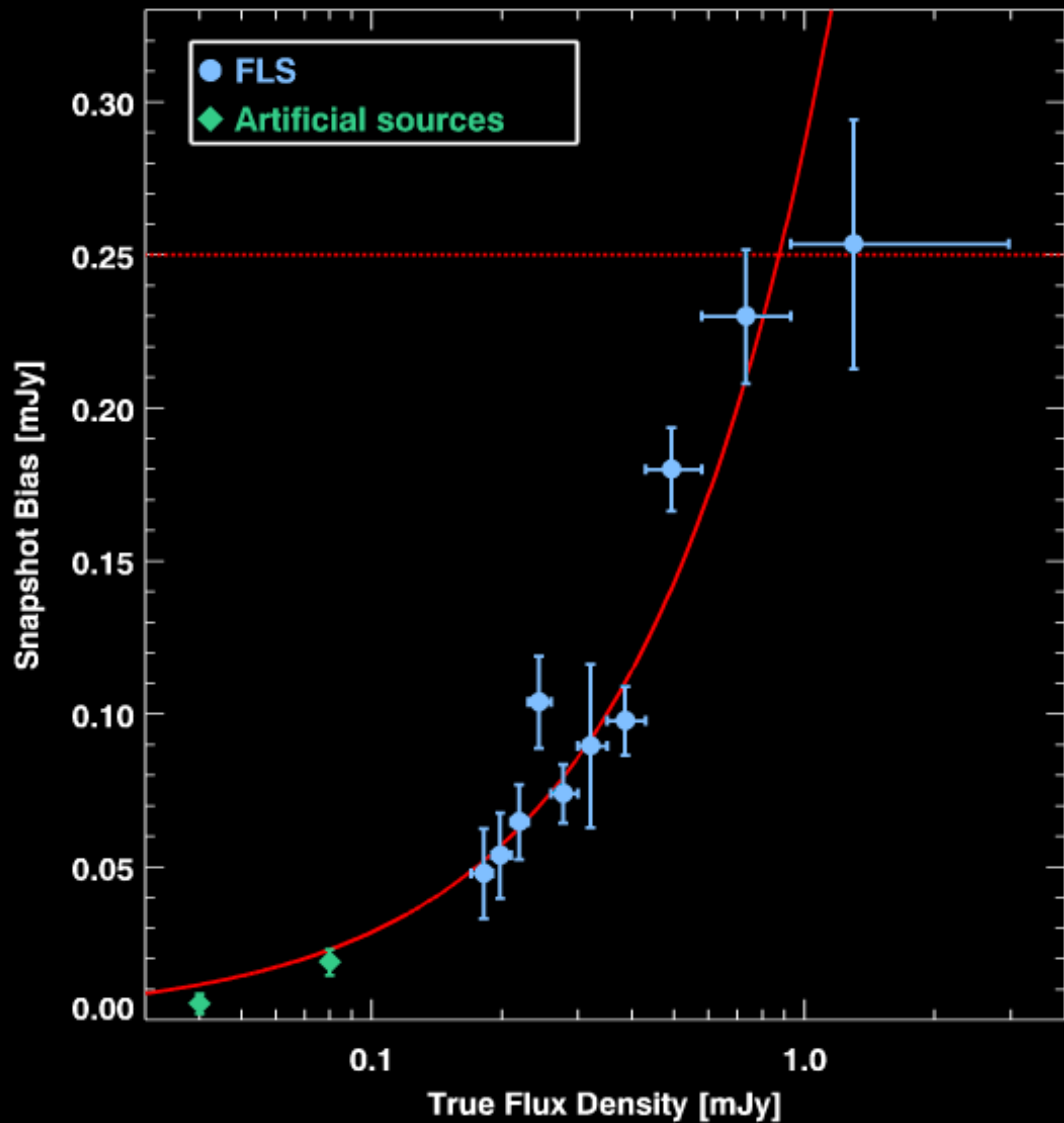


White et al. 2007, ApJ, 654, 99

Snapshot bias in radio images

Unexpected bias:
Objects far below the CLEAN threshold have their fluxes reduced by CLEAN by a constant factor 0.6.

CLEAN steals flux from invisibly faint sources!



White et al. 2007, ApJ, 654, 99

The value of radio surveys

- A radio continuum survey by itself has very limited utility
  - Spectra are almost featureless power laws (no such thing as a radio photometric redshift)
  - Radio sources are optically faint (median magnitude ~ 24)
- If you can't identify a radio source at other wavelengths, you know almost nothing about it
  - Unlike SDSS (e.g.), where the survey provides a great deal of information on the nature of the objects
- High resolution (< few arcsec) is required to unambiguously identify most sources with faint counterparts at other wavelengths

Summary

- JVLA radio surveys are highly configurable
  - Tune frequency and configuration to select resolution, field of view
- Wide-field, wide-band imaging is hard
- High resolution leads to problems (low surface brightness, resolved-out flux) but is necessary for identifications in optical/IR
- Radio surveys without identifications are of very limited value

Questions?

http://third.ucllnl.org/gps/color/