WALLABY Source Finding Tests
Data Sets and Algorithms

Tobias Westmeier
CSIRO Astronomy and Space Science
Arniston, 5 May 2010

www.csiro.au

CSIRO

WALLABY

- The Wide-field ASKAP L-band Legacy All-sky Blind Survey.
  - PIs: Bärbel Koribalski & Lister Staveley-Smith
- Main aim:
  - Catalogue of extragalactic H I sources out to $z \approx 0.26$.
- Source finding requirements:
  - 3-dimensional source finding in (α,δ,ν) space.
  - Objects spatially compact, but well resolved in velocity / frequency.
  - 500,000 expected galaxies, hence fully automatic source finding and cataloguing required.

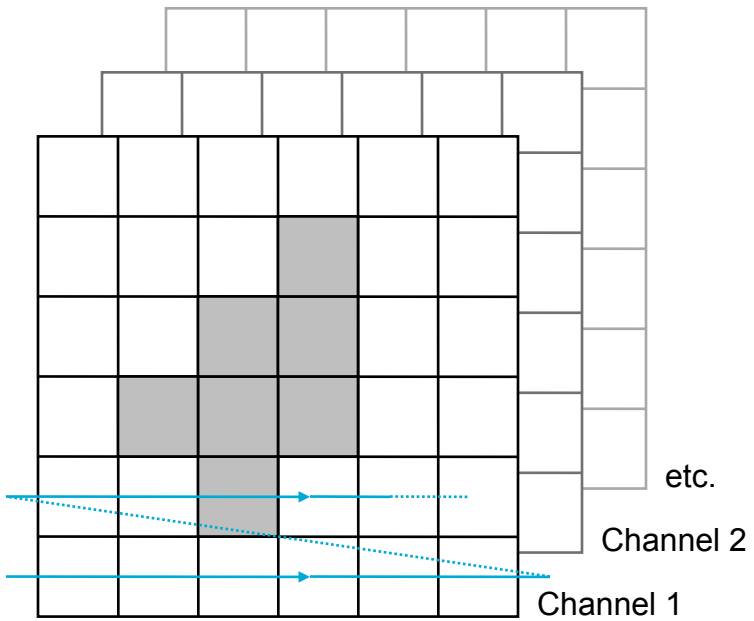
- TWG 4 – "Source Finding and Cataloguing":
  - *D. Barnes, G. Józsa, N. Gupta, T. Henning, T. Jarrett, H. Jones, R. Jurek, V. Kilborn, B. Koribalski, Á. López-Sánchez, T. Murphy, T. Oosterloo, A. Popping, P. Serra, T. Westmeier, M. Whiting, B. Winkel*

Source Finding Algorithms

Duchamp

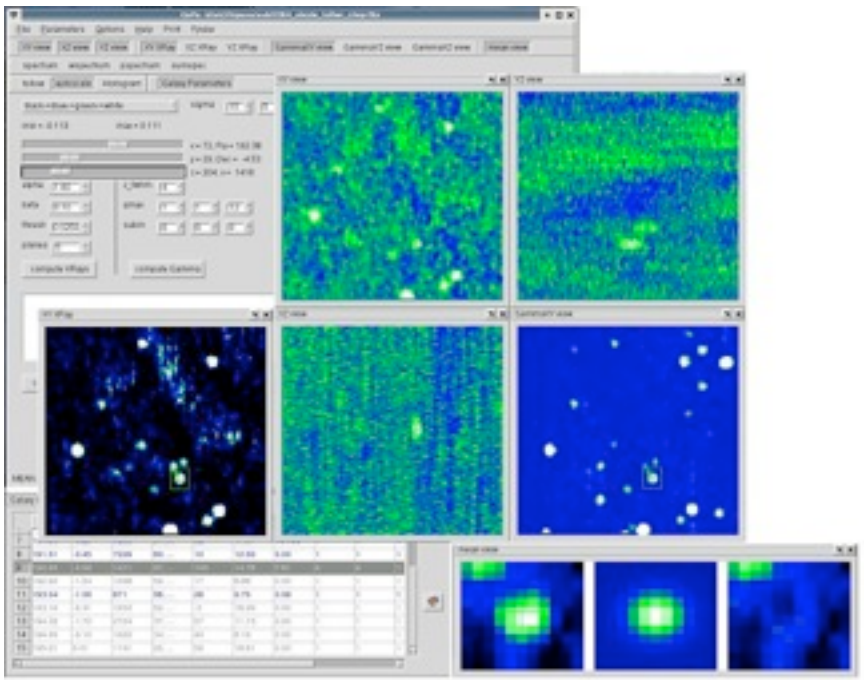
- Duchamp developed my Matthew Whiting at ATNF.
- Duchamp scans data cube for pixels above a given threshold.
- Detections will be joined into objects under various conditions.
- Several methods of filtering can be applied.
- Duchamp makes no assumptions about source morphology.

Marcel Duchamp (1887–1968)



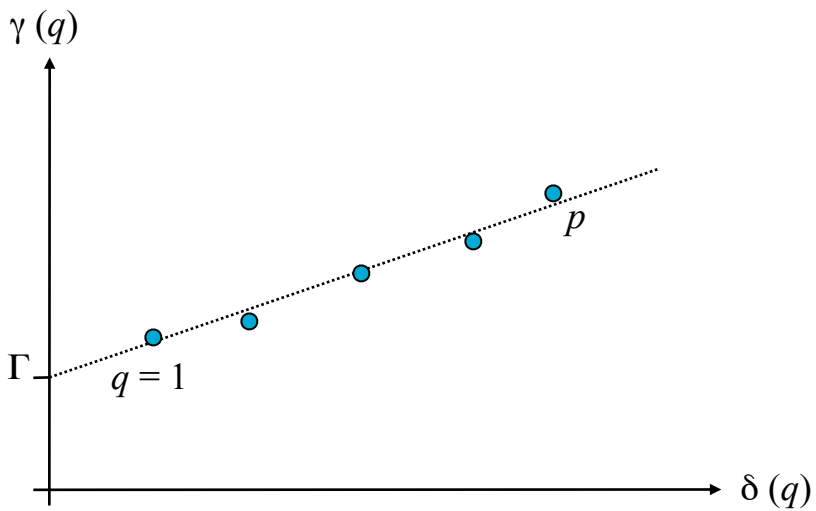
Gamma Test

- Source finder based on Gamma Test developed by Benjamin Winkel in Bonn.
- Used for the Effelsberg all-sky H I Survey.



Gamma Test

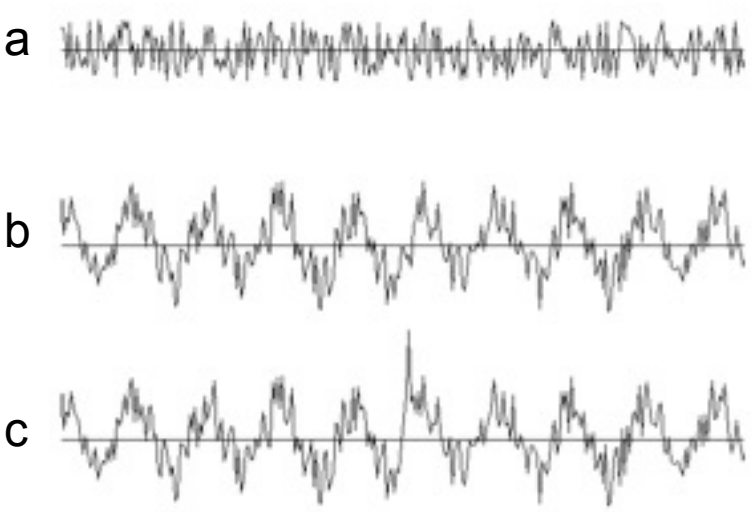
- Assume spectrum with noise + underlying smooth function $f(x)$:
  - $y = f(x) + n$
- Define the following two functions:
  - $\gamma(q) = (1/2M) \sum |y_{N(i,q)} - y_i|^2$
  - $\delta(q) = (1/M) \sum |x_{N(i,q)} - x_i|^2$
- Linear relation between $\gamma(q)$ and $\delta(q)$:
  - $\gamma(q) = A \times \delta(q) + \Gamma$
- Offset Γ equal to variance of spectral baseline noise:
  - $\sigma^2 = \Gamma$
- Gamma Test allows determination of noise!



(For details see Evans & Jones 2002; Boyce 2003)

Gamma Test

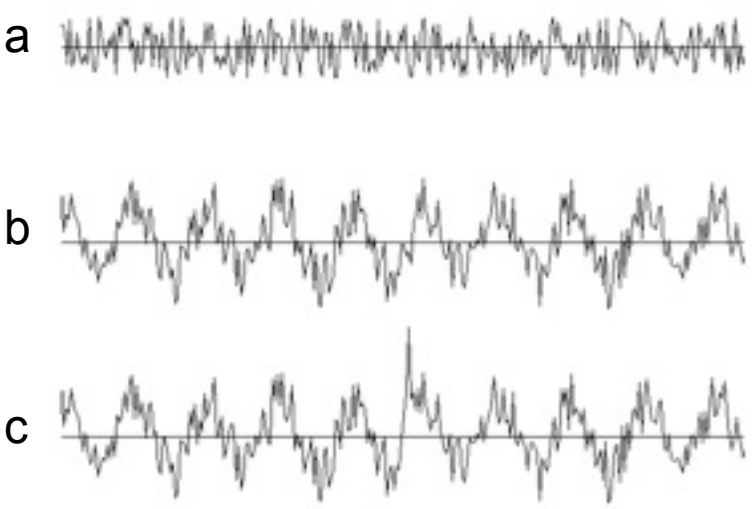
- Gamma Test on artificial noise spectrum with rms of 15 mJy.
- Case a: Gaussian noise
  - $\Gamma^{1/2}$ = 15.3 mJy (✓)



Peter J. Boyce (2003), Master Thesis

Gamma Test

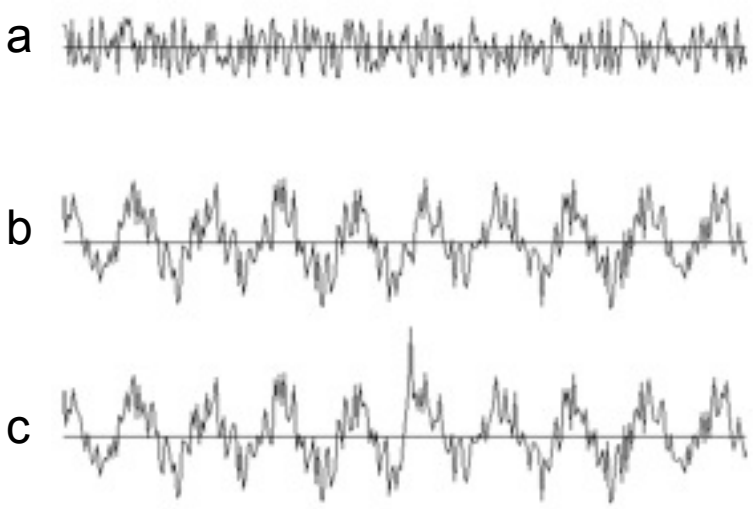
- Gamma Test on artificial noise spectrum with rms of 15 mJy.
- Case a: Gaussian noise
  - $\Gamma^{1/2}$ = 15.3 mJy (✓)
- Case b: Gaussian noise + baseline ripple
  - $\Gamma^{1/2}$ = 15.7 mJy (✓)



Peter J. Boyce (2003), Master Thesis

Gamma Test

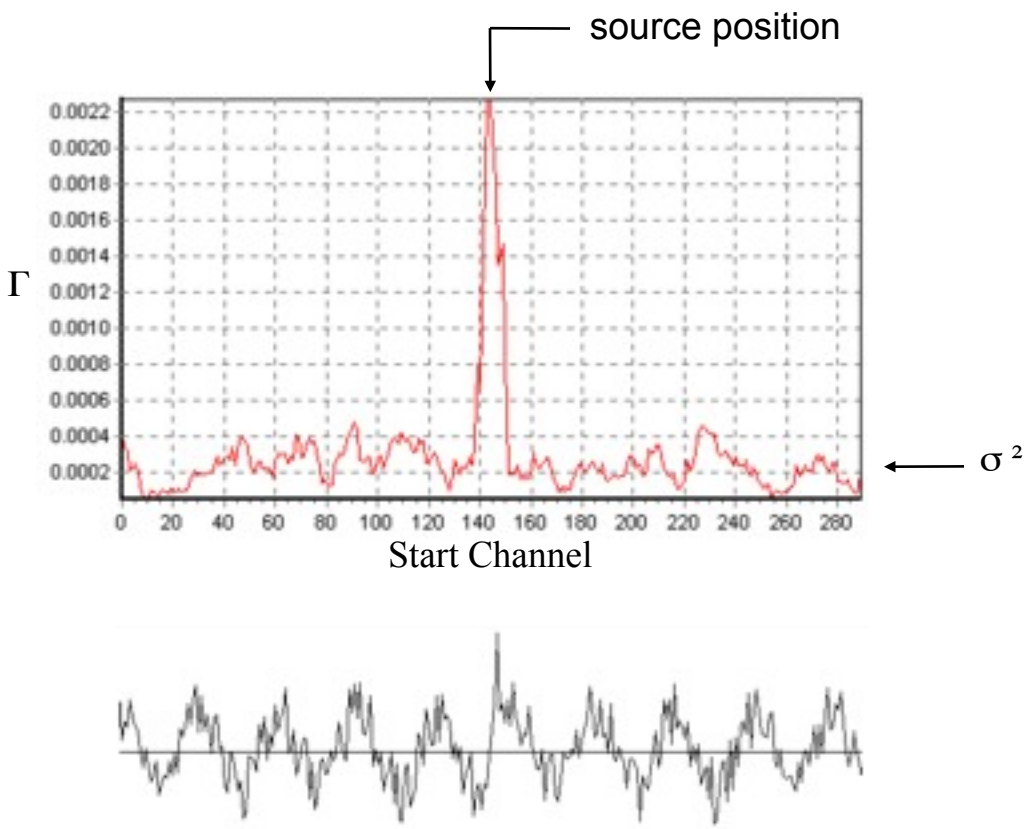
- Gamma Test on artificial noise spectrum with rms of 15 mJy.
- Case a: Gaussian noise
  - $\Gamma^{1/2}$ = 15.3 mJy (✓)
- Case b: Gaussian noise + baseline ripple
  - $\Gamma^{1/2}$ = 15.7 mJy (✓)
- Case c: Gaussian noise + baseline ripple + narrow emission line
  - $\Gamma^{1/2}$ = 17.6 mJy (x)
- What went wrong?
- Reason: underlying function $f(x)$ not smooth, but narrow emission line.



Peter J. Boyce (2003), Master Thesis

Gamma Test

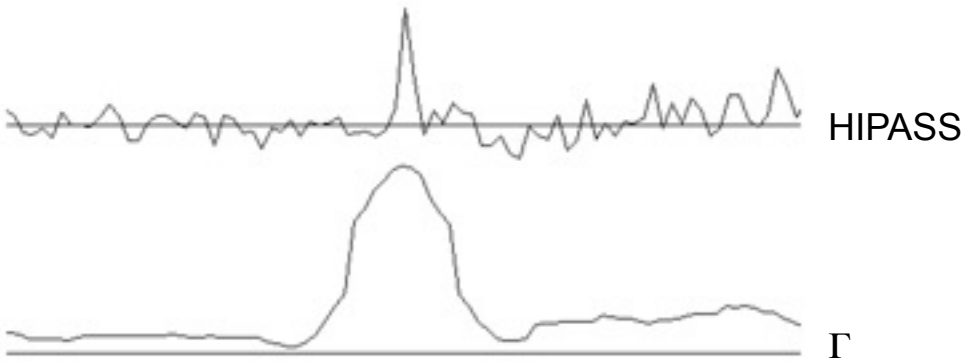
- Let's try a "moving-window" Gamma Test:



Peter J. Boyce (2003), Master Thesis

Gamma Test

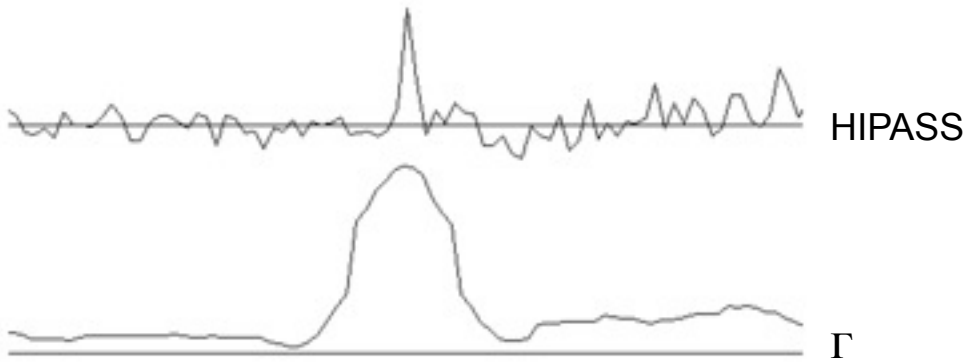
- Gamma Test will detect compact sources and certain types of radio frequency interference.
- Example: UGC 05701 from HIPASS



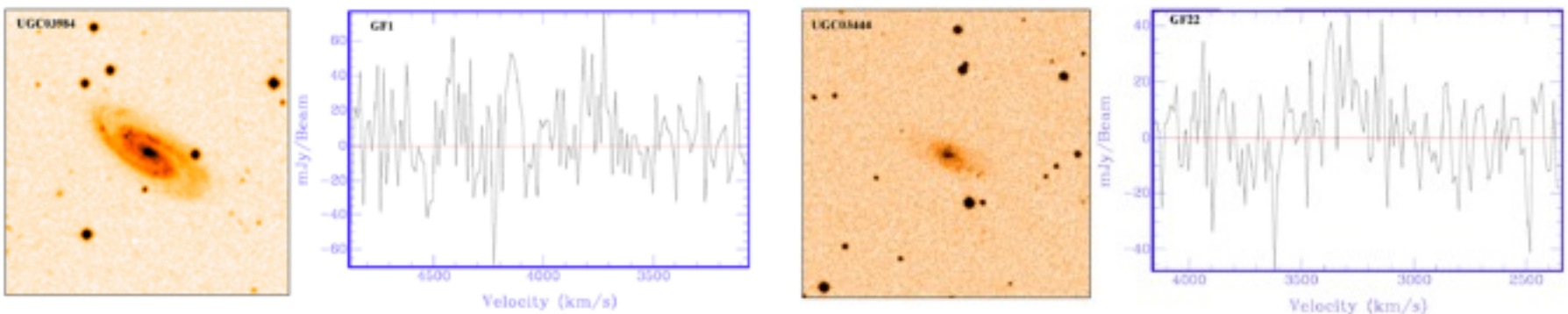
Peter J. Boyce (2003), Master Thesis

Gamma Test

- Gamma Test will detect compact sources and certain types of radio frequency interference.
- Example: UGC 05701 from HIPASS

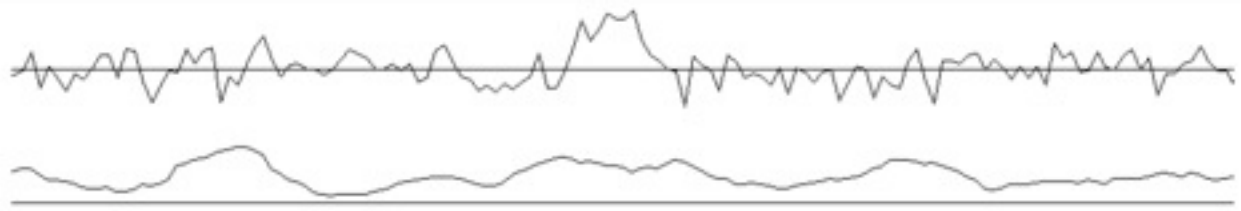


Peter J. Boyce (2003), Master Thesis



Gamma Test

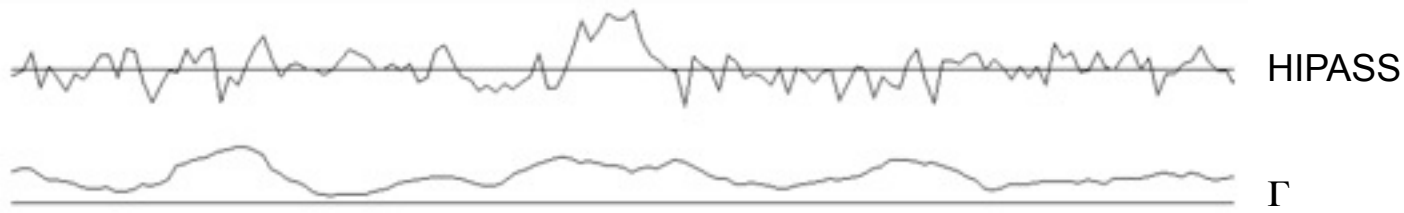
- What about broad spectral lines?



Peter J. Boyce (2003), Master Thesis

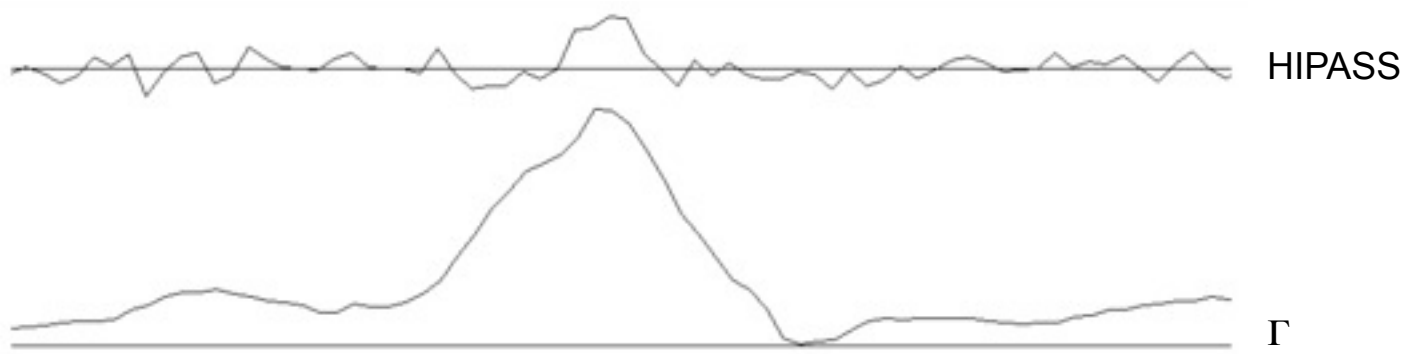
Gamma Test

- What about broad spectral lines?



Peter J. Boyce (2003), Master Thesis

- Solution: Hanning smoothing

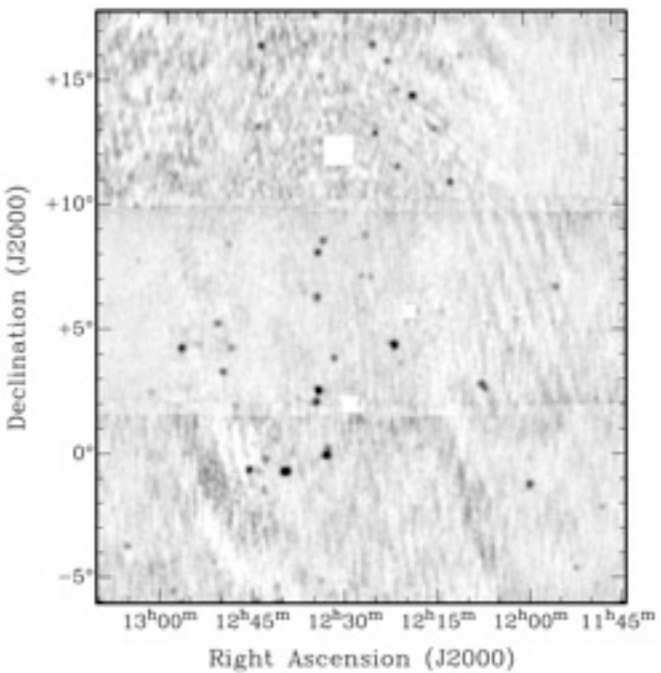


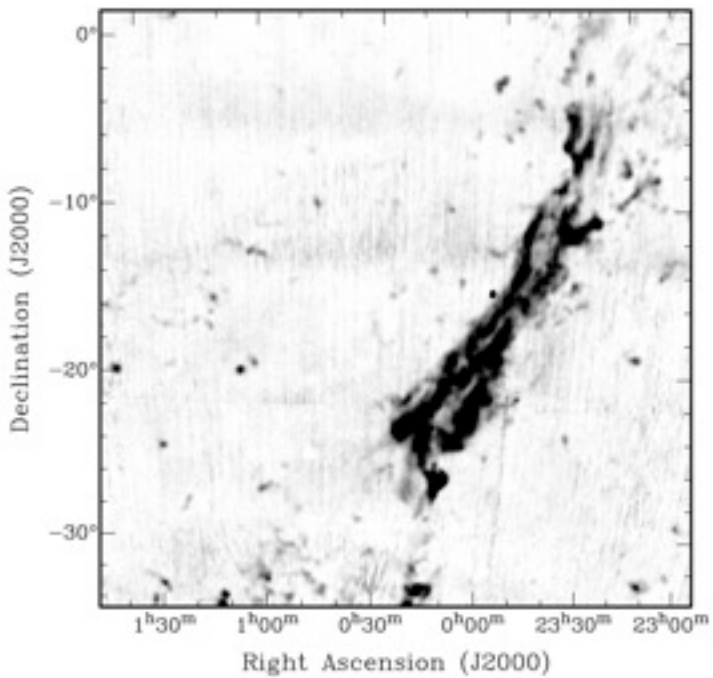
Peter J. Boyce (2003), Master Thesis

Data Sets for Source Finding Tests

Data Sets: HIPASS

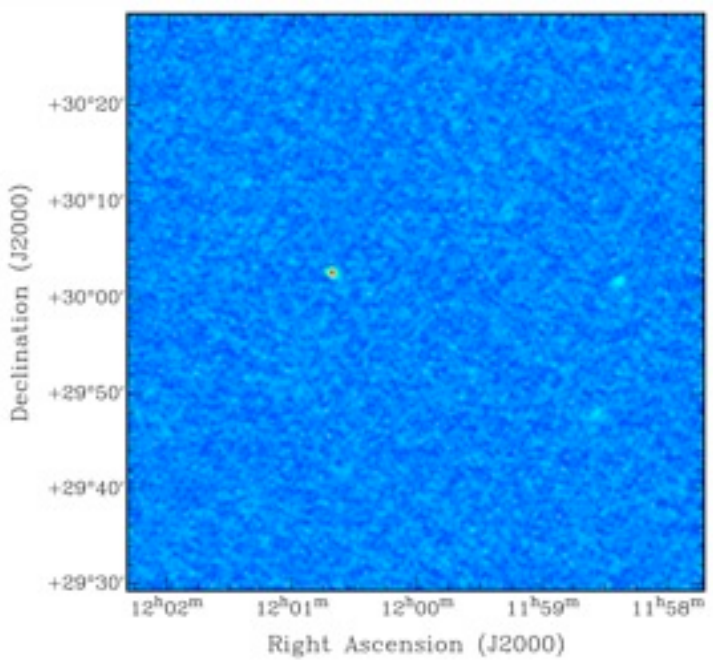
- HIPASS
  - Virgo Cluster
  - Magellanic Stream
- Advantage: real sources (galaxies, high-velocity clouds, etc.).
- Problem: serious artefacts in HIPASS challanging for SFs.





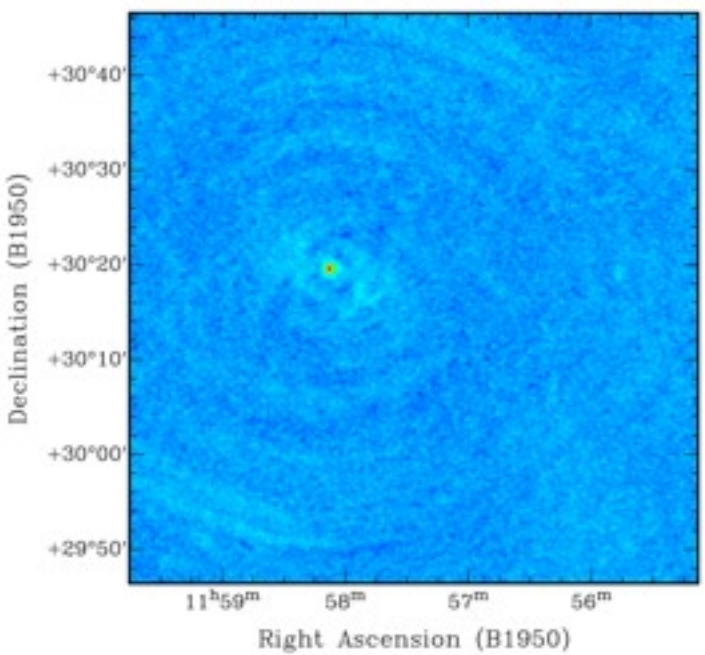
Data Sets: WSRT Model Cube

- Model cube created by Paolo Serra at ASTRON.
- 100 WHISP galaxies (van der Hulst et al. 2001), artificially redshifted and copied into WSRT noise cube.
- Parameters:
  - Field of view: 1 deg²
  - Redshift range: 0.02…0.04
  - Spectral channels: 1464
  - Channel width: 18.3 kHz
  - Velocity resolution: 4 km s^{-1}
  - Beam width: 30 arcsec
  - Pixel size: 10 arcsec
  - rms noise: 1.6 mJy
- Advantages: real galaxies and real interferometer noise with telescope errors and RFI.



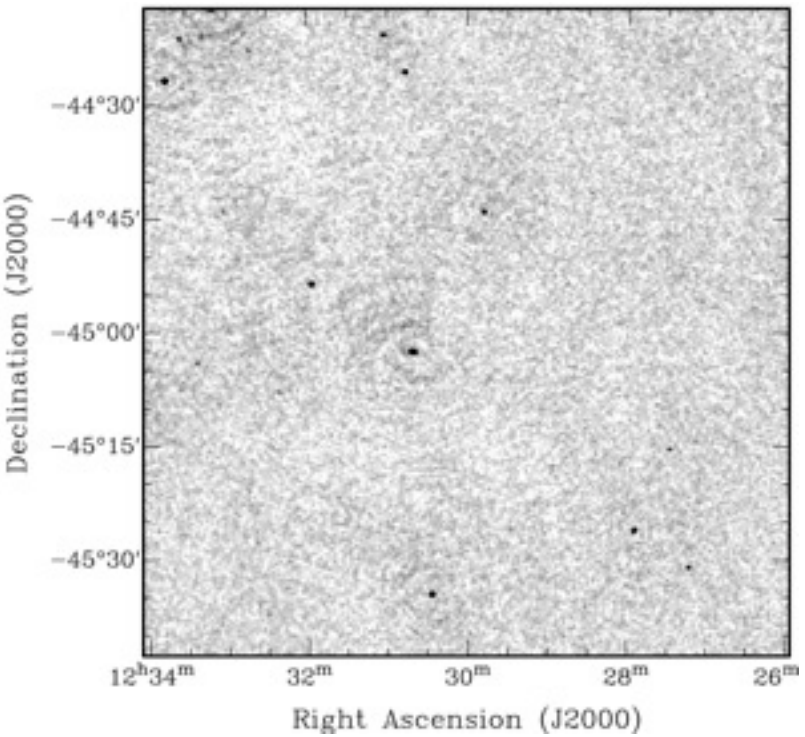
Data Sets: ASKAP Model Cube

- Same 100 WHISP galaxies as in WSRT model cube.
- ASKAP noise and beam model generated with Miriad (uvgen).
- Parameters:
  - ASKAP core configuration of 30 antennas
  - 8 h integration time (hour angles of ± 4 h) in 1-minute intervals
  - 1° × 1° field of view with 10-arc-sec pixels
  - Uniform noise across the field, scaled to about 1.6 mJy
- Even more realistic: real galaxies, ASKAP noise and sidelobes, but no telescope errors and RFI.

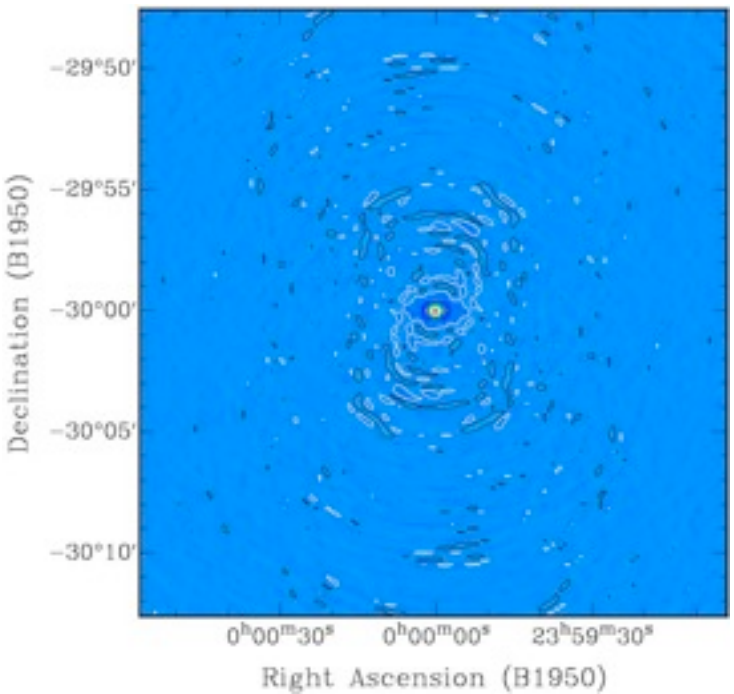


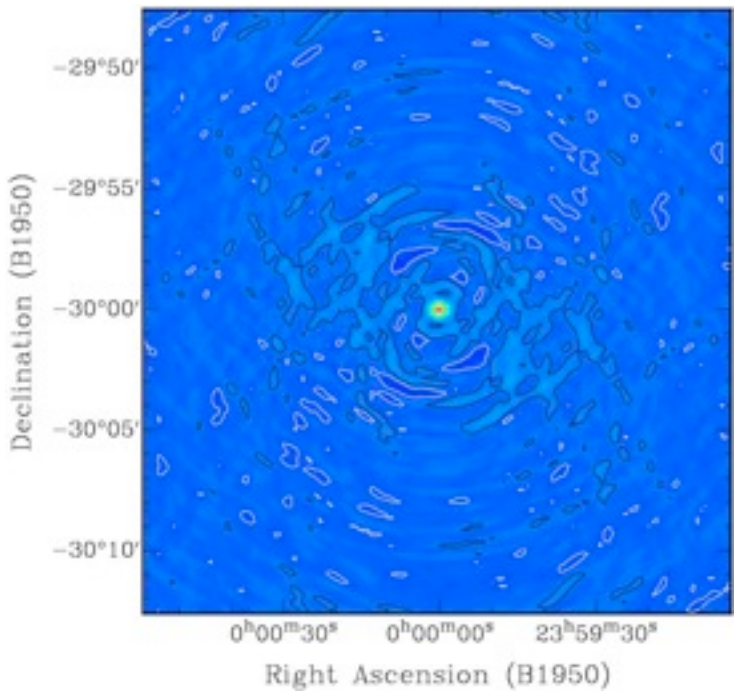
Data Sets: ASKAP Simulations

- Provided by the ASKAP Computing Team.
- Based on SKADS models.
- Latest release includes cube with reduced noise for source finder testing.



ASKAP Beam and Sidelobes at δ = −30°





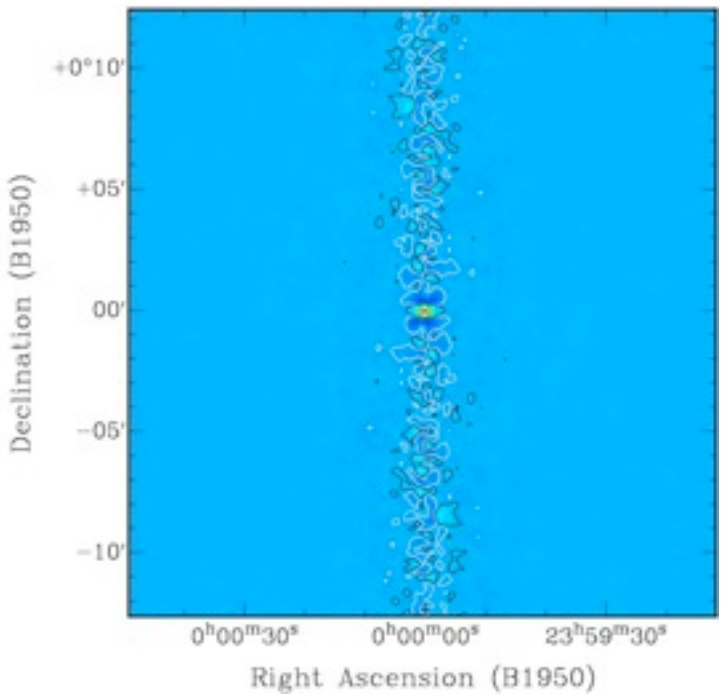
Uniform weighting

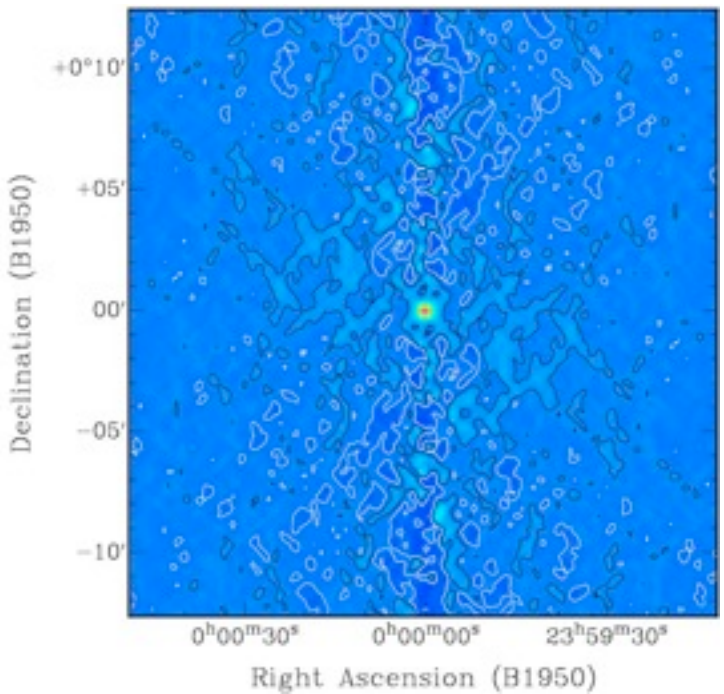
FWHM: 18.9 arcsec
Sidelobes: −5.5%…+3.1%

Natural weighting

FWHM: 27.5 arcsec
Sidelobes: −2.4%…+4.9%

ASKAP Beam and Sidelobes at δ = 0°





Uniform weighting

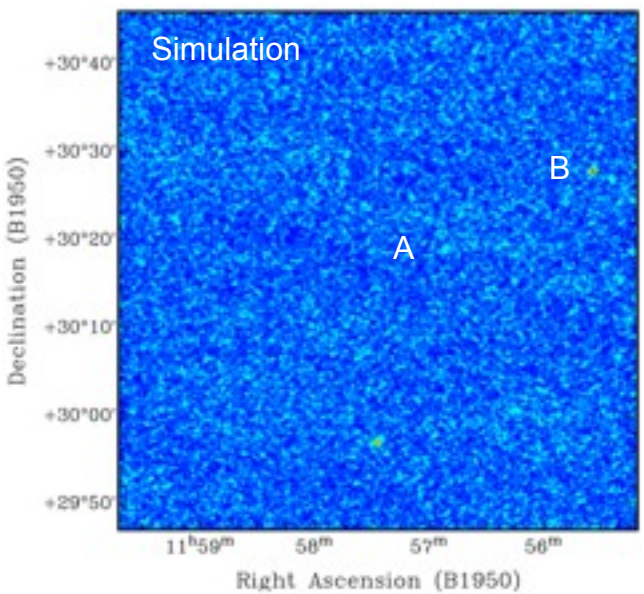
FWHM: 21.5 arcsec
Sidelobes: −9.8%…+15.4%

Natural weighting

FWHM: 30.0 arcsec
Sidelobes: −4.2%…+19.8%

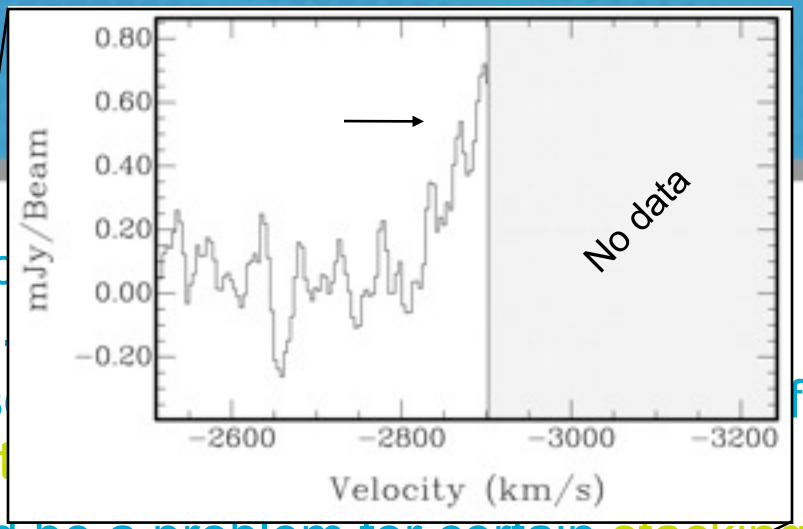
Deconvolution and Stacking

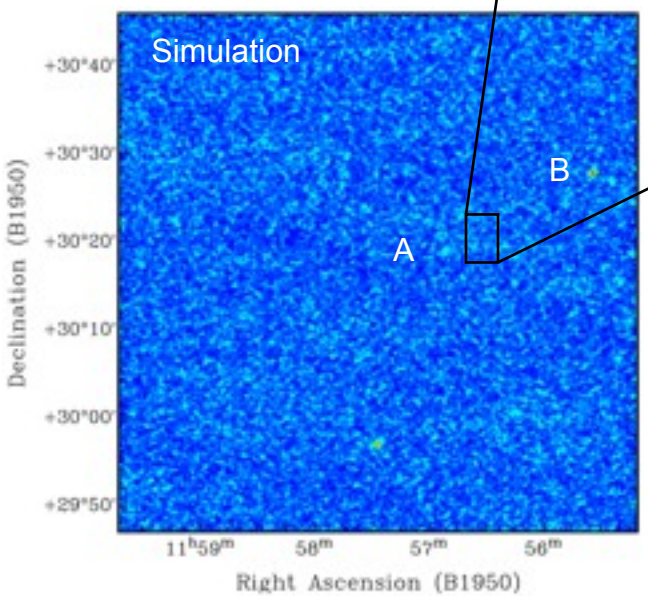
- Sources of 100 mJy will cause noticeable sidelobes in WALLABY data cubes (1.6 mJy rms).
- There will be dozens of sources with S > 100 mJy in each field of 30 deg², so deconvolution generally required.
- Low sidelobe levels could be a problem for certain stacking experiments which will pick up sidelobes as well.



Deconvolution and

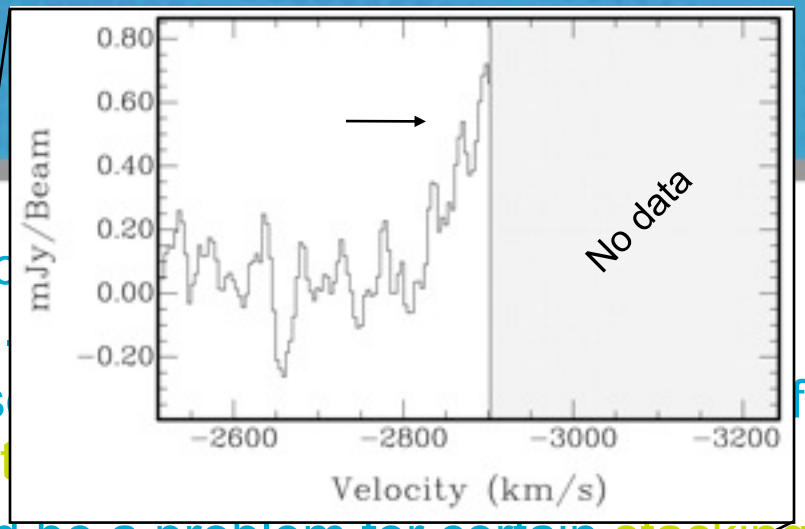
- Sources of 100 mJy will c
  WALLABY data cubes (1.
- There will be dozens of s field
  of 30 deg², so deconvolut
- Low sidelobe levels could be a problem for certain stacking
  experiments which will pick up sidelobes as well.

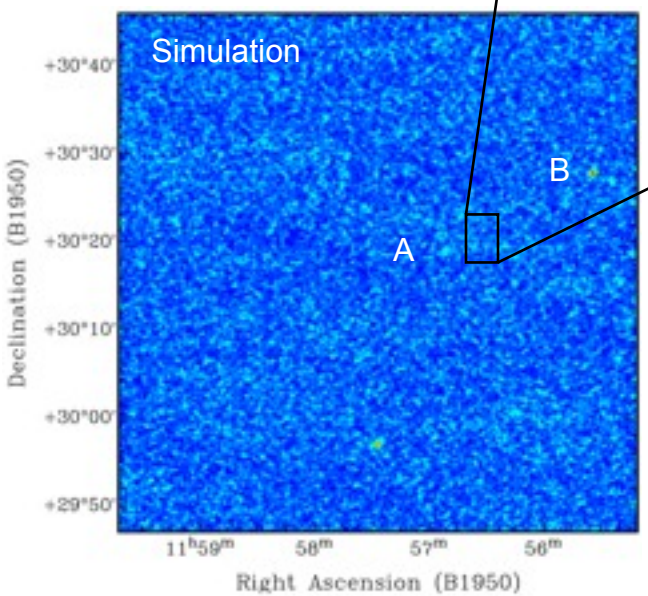


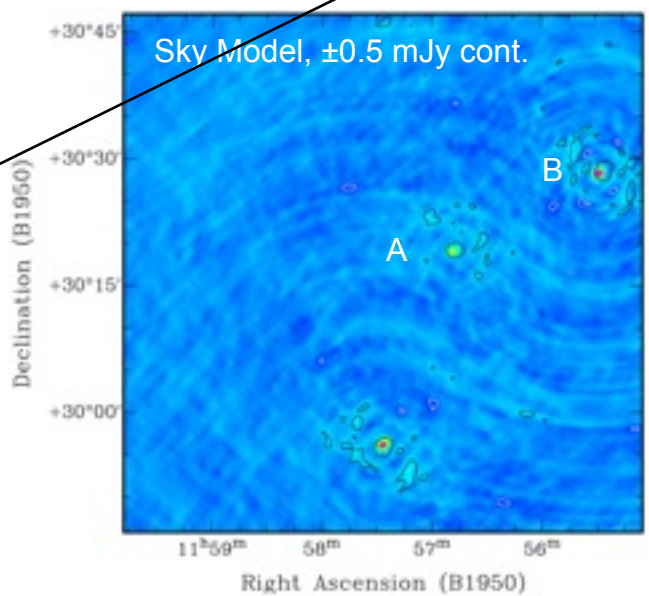


Deconvolution and

- Sources of 100 mJy will c
  WALLABY data cubes (1.
- There will be dozens of s field
  of 30 deg², so deconvolut
- Low sidelobe levels could be a problem for certain stacking
  experiments which will pick up sidelobes as well.



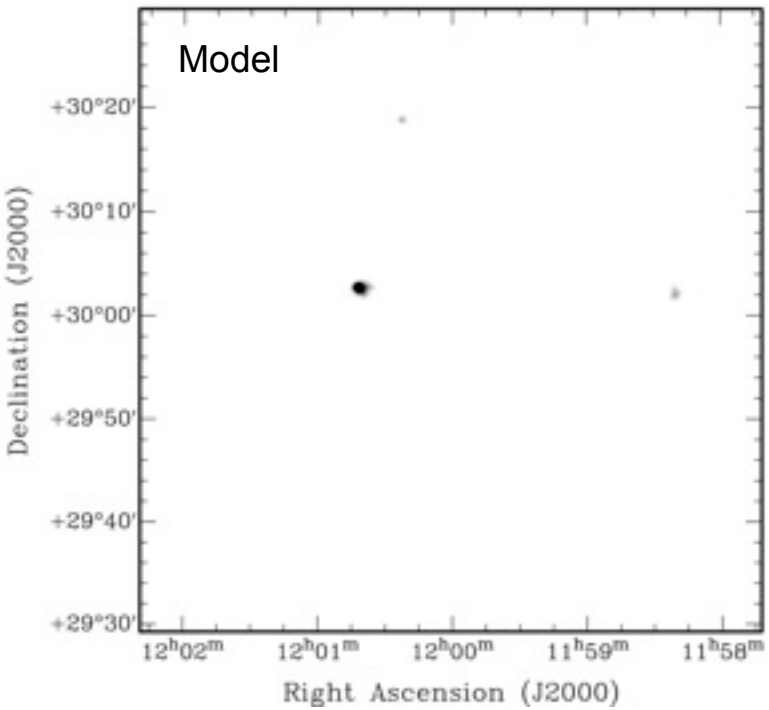


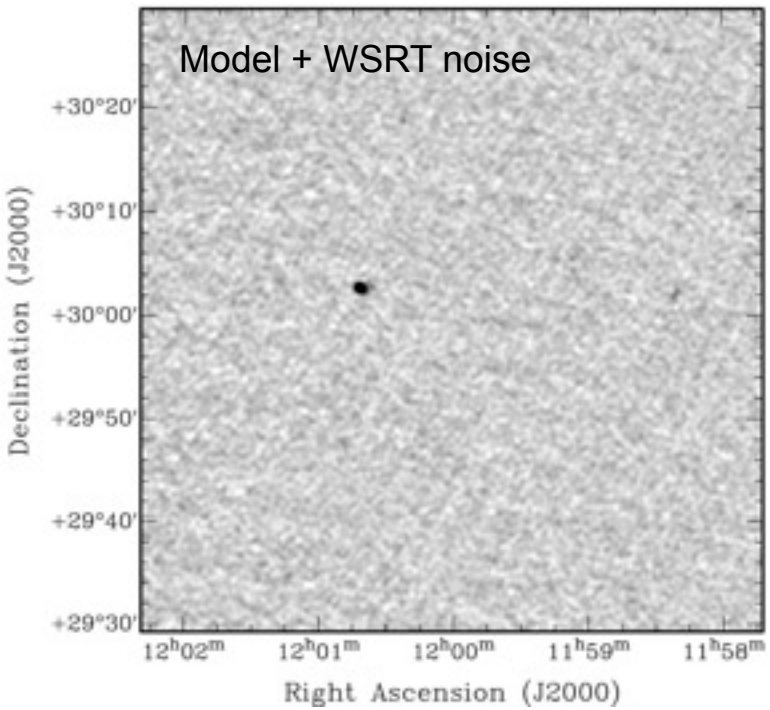


First Results

Duchamp vs. WSRT Model Cube

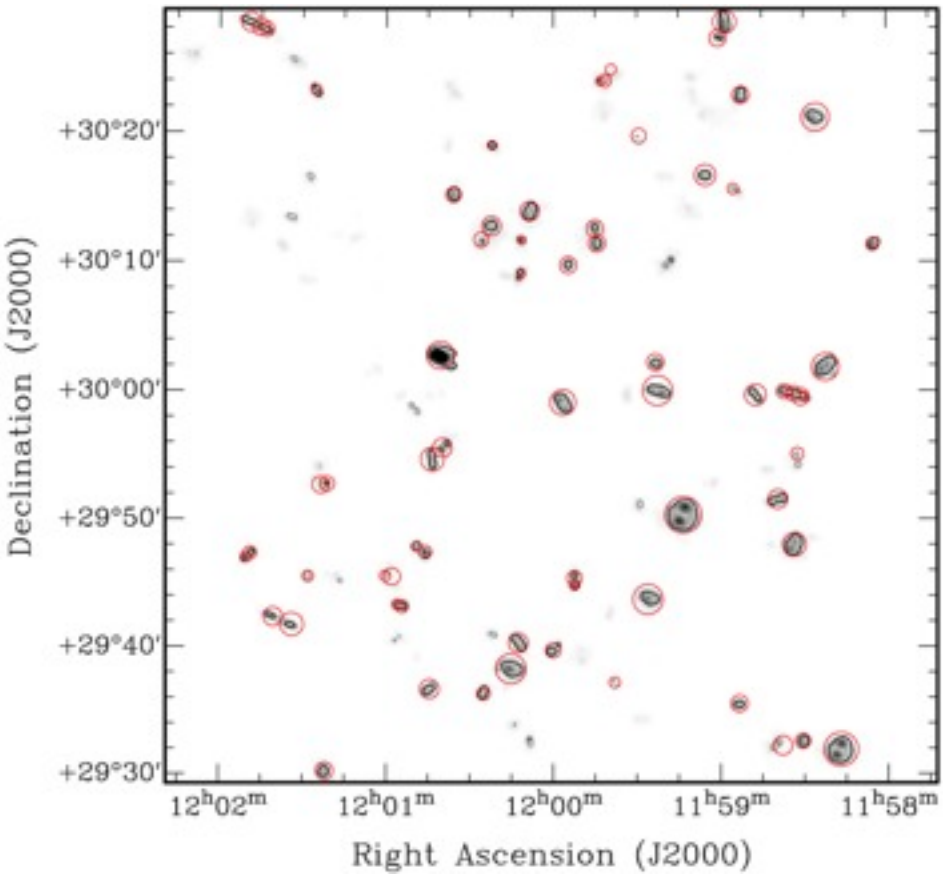
- Running Duchamp on WSRT-based model cube.
- Model contains about 100 artificially redshifted WHISP galaxies.





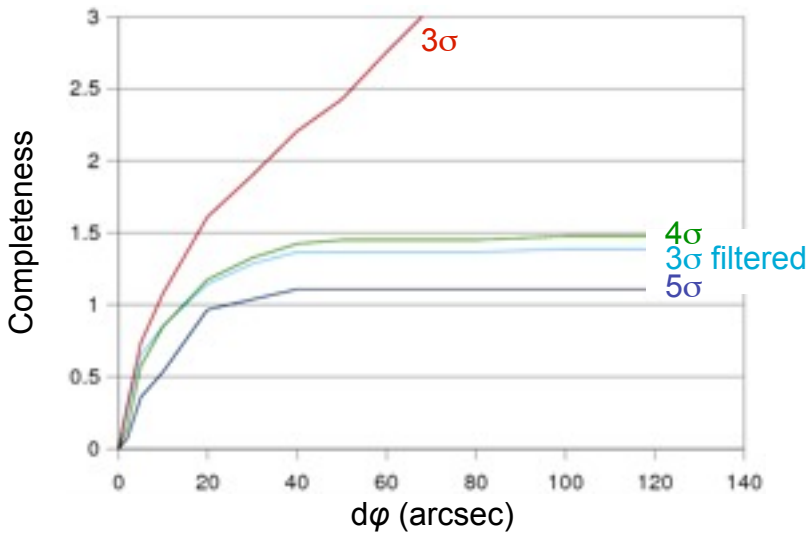
Duchamp vs. WSRT Model Cube

- 4σ and 5σ cutoff levels fast and efficient.
- 3σ cutoff detected thousands of noise peaks.
  - 4061 detections!
- Extensive filtering of 3σ results.
  - Removal of false detections.
  - But: enormous time penalty (many hours on standard PC).
- Yet, 3σ results very promising.



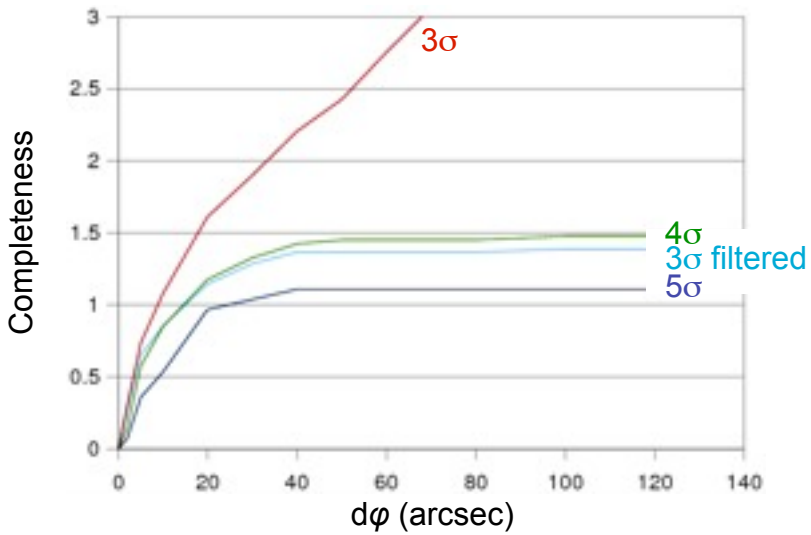
Duchamp vs. WSRT Model Cube

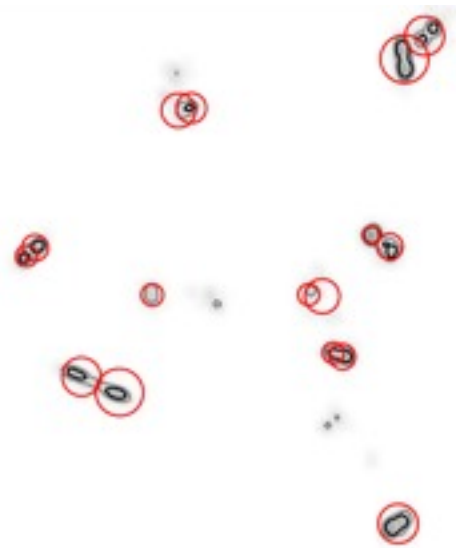
- Completeness:
  - 3σ: 4061 / 49 sources
  - 4σ: 59 / 40 sources
  - 5σ: 31 / 28 sources
  - 3σ (filt.): 68 / 49 sources



Duchamp vs. WSRT Model Cube

- Completeness:
  - 3σ: 4061 / 49 sources
  - 4σ: 59 / 40 sources
  - 5σ: 31 / 28 sources
  - 3σ (filt.): 68 / 49 sources
- Why more than 100% completeness?
  - Double-peak profiles of faint edge-on galaxies detected as two (or more) separate sources.
- For the same reason, completeness below 100% for smaller search radii (< 40 arcsec).





Summary

- WALLABY
  - 500,000 galaxies out to $z \approx 0.2$ in H I with ASKAP
- Source finding algorithms
  - Duchamp
    - Detection of objects above flux threshold
    - Standard ASKAP source finder
  - Gamma Test algorithm
    - Based on statistical method of determining noise level
    - Standard source finder for Effelsberg all-sky H I survey
- Data sets
  - HIPASS (lots of artefacts)
  - WSRT and ASKAP model cubes
  - ASKAP simulations
- First results
  - Sidelobe levels 3 – 5%, deconvolution required, stacking issues
  - Duchamp works, but slow at 3σ, problems with edge-on galaxies

CSIRO Astronomy and Space Science
Tobias Westmeier
Bolton Postdoctoral Fellow, ASKAP Project Scientist

Phone: +61 2 9372 4622
Email: tobias.westmeier@csiro.au
Web: http://www.atnf.csiro.au/

www.csiro.au

Thank you

Contact Us
Phone: 1300 363 400 or +61 3 9545 2176
Email: enquiries@csiro.au Web: www.csiro.au

CSIRO