How Compact are Faint Radio Sources ?

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1 Introduction

- Astronomers and geodetic community are both interested in radio sources
- Astronomers plan to study yet fainter radio sources with new instruments
  Square Kilometer Array (SKA)
- Geodesists have interest in increasing the number of useable sources
  Densification of the ICRF by 2010 ? (Charlot, IVS 2004 GM)
  Must go to fainter sources....!
- Astronomers are interested in source angular structures
  Geodesists would like structure-less point sources
- How many structure-less point sources are there ?

2 Nature of this investigation

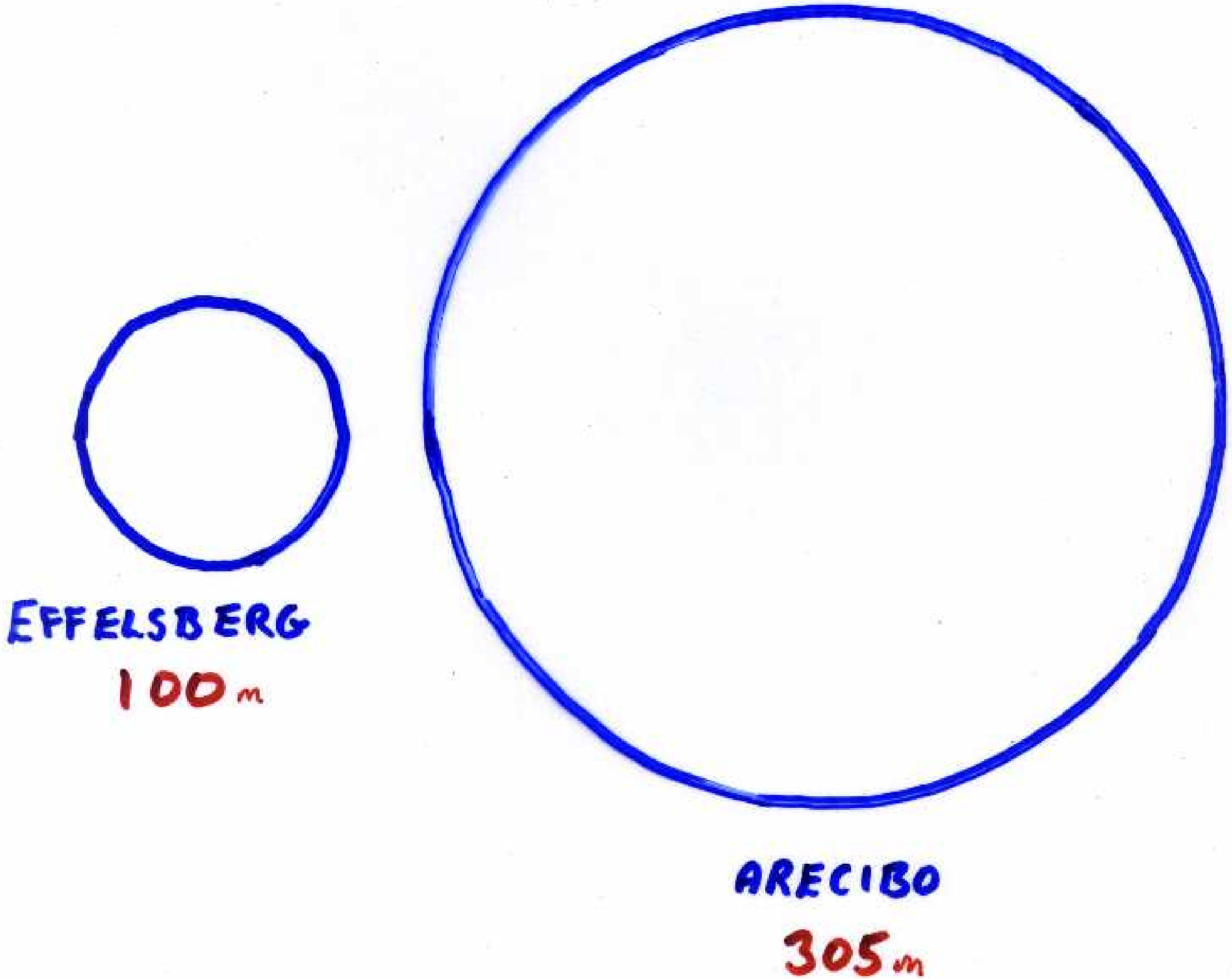
- **What fraction of faint radio sources have compact structure on VLBI (few mas) scales ?**
- **How does this relate to object type ?**
- **Want large number of sources for robust statistics**
- **Use unbiased selection, not based on *a priori* knowledge of spectral or structural classification**
- **High-resolution VLBI detection is sufficient - don't wish to image the sources**
  Preston et al. 1984, DSN observations to find ICRF sources
- **Not a survey of blank sky:**
  Target a large number of known weak radio sources

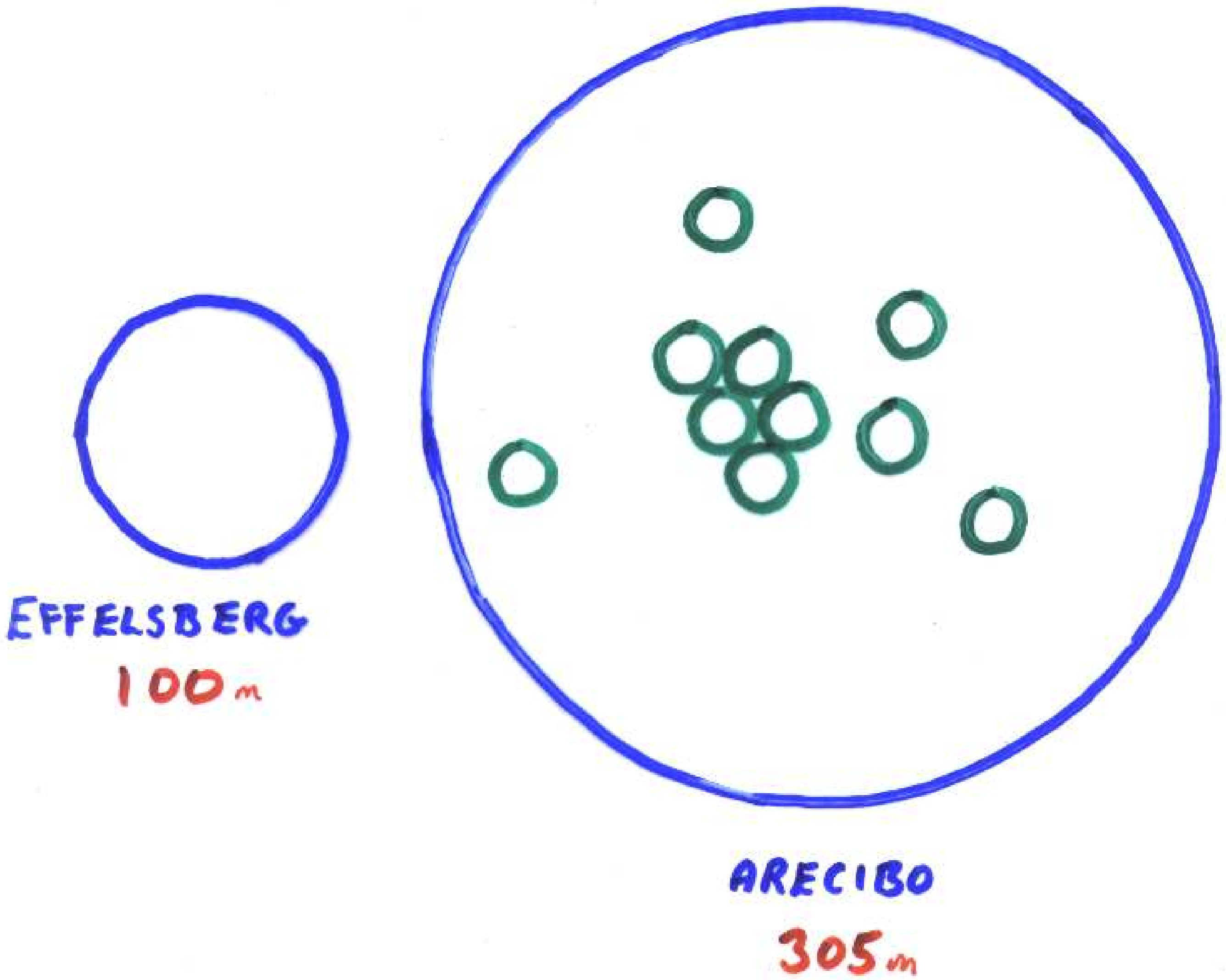
3 The NRAO FIRST Survey

- **Becker et al, 1995, Ap.J. 450, 559**
- **Survey with the VLA in B–configuration**
- $\lambda = 21$ **cm** **beamwidth = 5.4"** $1\sigma = 0.15$ **mJy**
- **First installment: 138,665 sources > 1 mJy**
- **Covers large areas of the sky**
- **How can one get structural information for a representative sub-sample of these sources ?**

4 Very Sensitive (single) Long Baseline

- **ARECIBO (305 m) to EFFELSBERG (100 m)**
- λ **= 21 cm** **(same as FIRST Survey)**
- **42 times more sensitive than a single VLBA to VLBA baseline**
- **6.2 times more sensitive than the full (phase-referenced) VLBA**
- **Using 512 Mbps is 12.5 times more sensitive than the VLBA at 128 Mpbs**
- **Sensitivity (1**σ**) in 1 minute =** $\sim$ **100** μ**Jy (**$\equiv$ **VLBA in 2.5 h)**


EFFELSBERG
100 m
ARECIBO
305 m


EFFELSBERG
100m
ARECIBO
305m

5 Observing strategy

- Target ∼ 1000 FIRST Survey sources
- 1 minute per source   1 mJy source detected at 10σ if unresolved
- 30 s drive time   ∼ 1000 sources in 24 h
- AR-EB fixed hour-angle   resolution ∼ 6 mas in P.A. = 20^o
- Unbiased selection of FIRST sources in Declination range 28^o–29^o
  Nearest source to Arecibo hour-angle = –30 m
  Minimize Arecibo drive time; Effelsberg elevation 34^o
- 11699 FIRST sources in this declination strip in RA range 0718–1727
  ∼ 87 sources per square degree
- No selection by flux-density, spectral index or angular extension

6 Observations

- **512 Mbps: 64 MHz RHC + 64 MHz LHC (2-bit sampling)**
  1366 MHz – 1430 MHz
  Arecibo thin tape; Effeleberg MK5A disk-packs
- **4 observations (6–7 h runs)   OCT 2003   MAR 2004   JUN 2004 (x 2)**
- **11 selected FIRST sources replaced by VLBA calibrator sources in this declination strip**
- **992 target FIRST sources + 11 calibration sources**
- **Correlation at Bonn MK4 correlator**
- **Additional ∼ 400 FIRST sources within Arecibo beam (FWHM = 210”)**
  Extracted using second correlation field centre

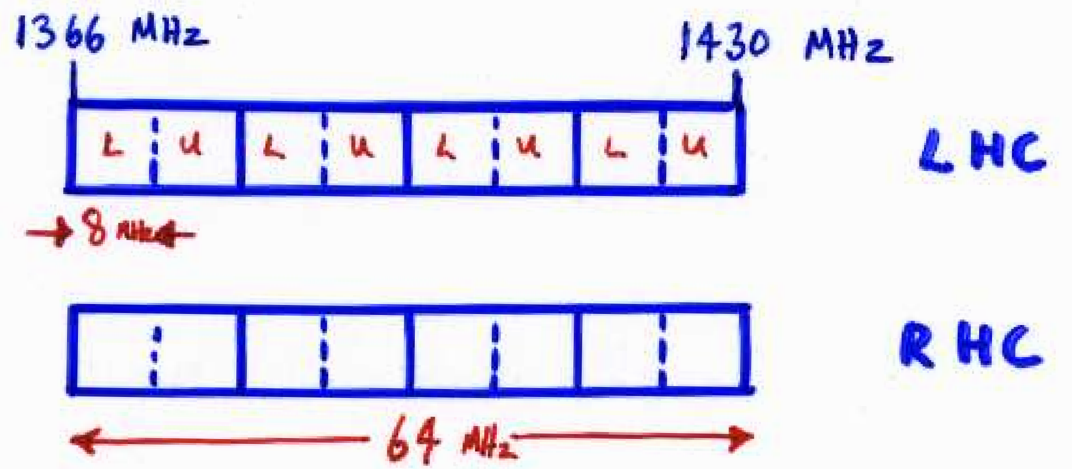


Figure 1: **Configuration of recording bands**

7 Preliminary Results

- **Analysis of only 1 epoch 22 March 2004**
- **Data uncalibrated**
- **Separate RHC and LHC fringe-fit runs (lose 1.4 in detection sensitivity)**
- **Total source targets: 252 (+11 calibrators)**
- **Total detected ($> 8\sigma$) in either polarization: 71 (28 %)**
- **Total detected ($> 8\sigma$) in both polarizations: 63 ($\equiv 11\sigma$)**
- **Likely further detections ($> 8\sigma$) for polarization-added data: $\sim$14**
- **Fraction of FIRST sources showing compact structure: $\sim$33 %**
- **Total additional sources within target fields: 86**
- **Total detected in both polarizations: 11 (13%)**
  Lower detection rate due to beam attenuation away from field centre

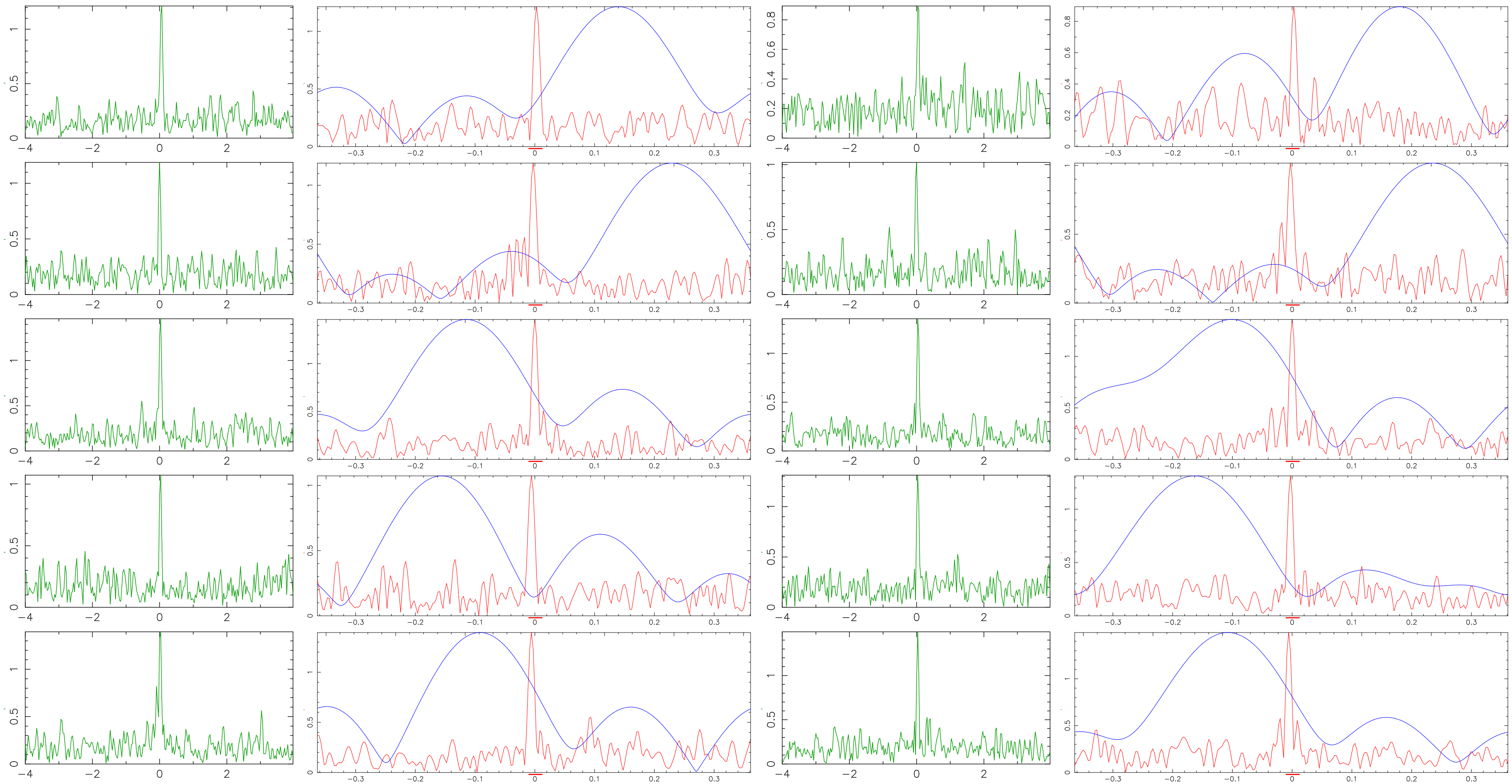


Figure 2: **Single-band delay (GREEN) and fringe-rate (RED) functions for the 5 detected sources with the lowest listed flux densities in the FIRST catalogue (1.03, 1.11, 1.21, 1.27 and 1.28 mJy). (Left) RHC Polarization; (Right) LHC Polarizat ion**

- **Detection need not imply it is a "COMPACT SOURCE".**
- **Rather, that the source contains COMPACT COMPONENT(S) visible at this particular baseline orientation.**
- **Dependence of detection rate on FIRST catalogue flux-density**
- **Divide target sources into 4 flux-density bins with equal source numbers Quartiles: 1.41 2.24 4.86 mJy**

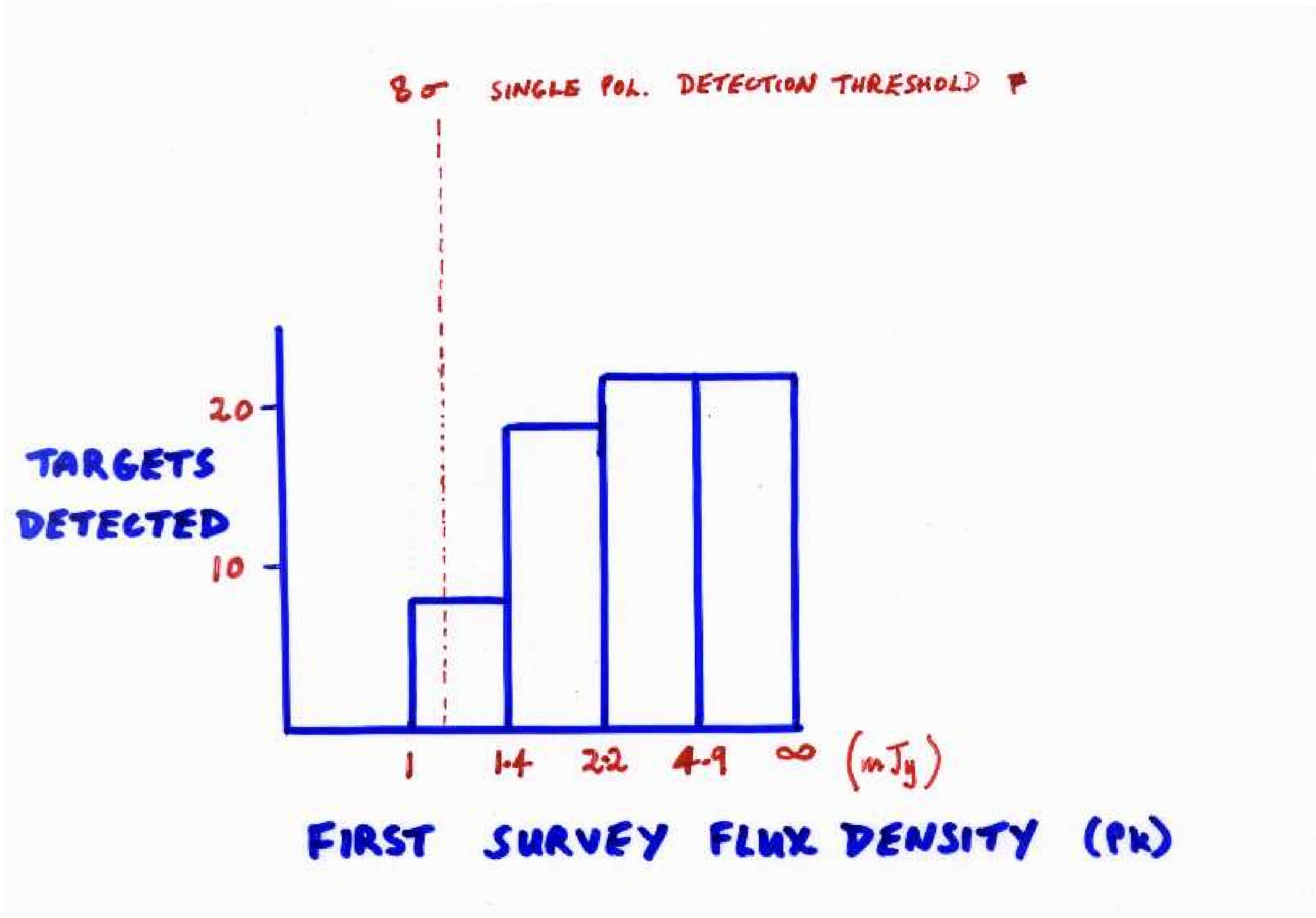


Figure 3: **Histogram of detected sources (8-sigma)**

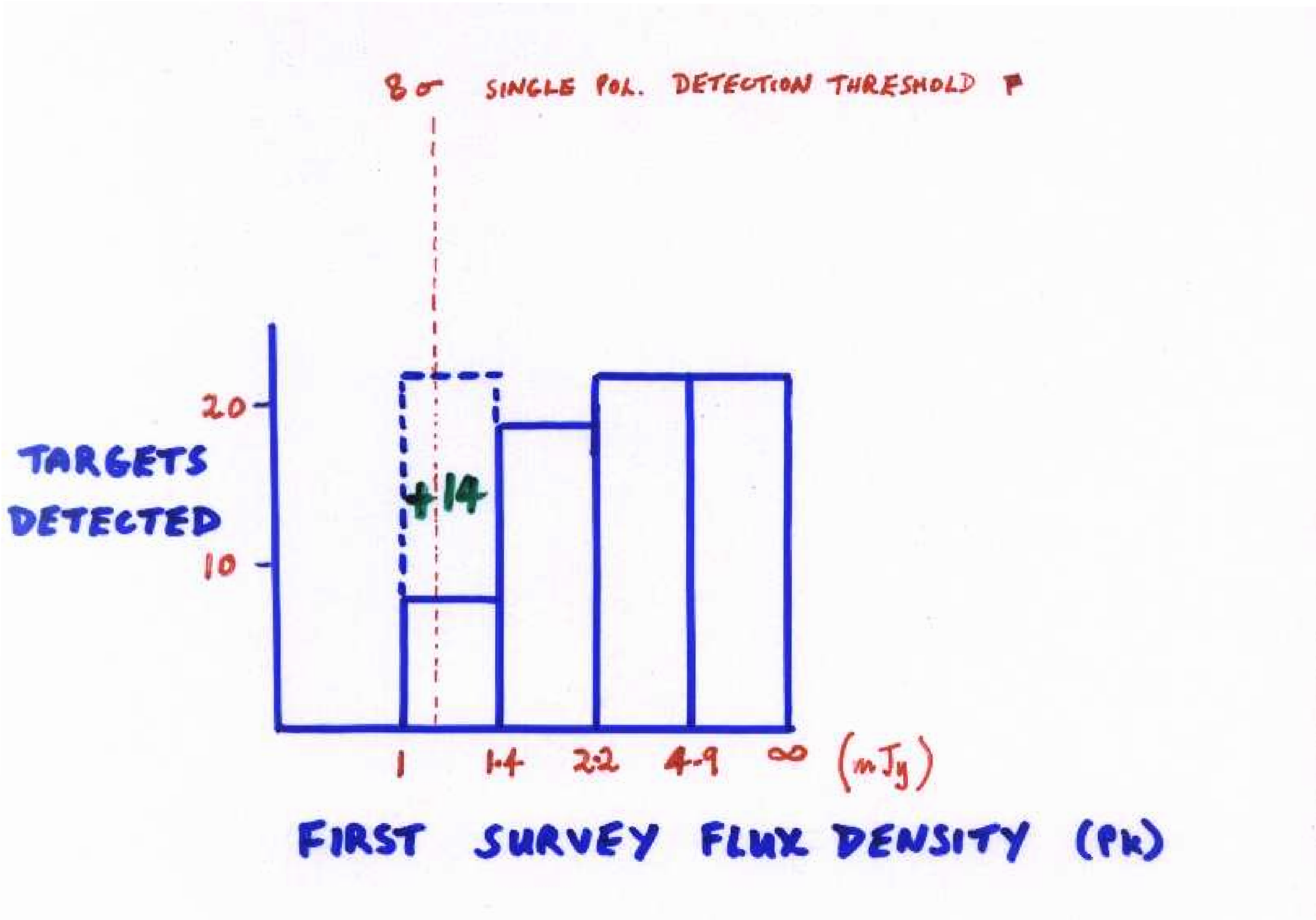


Figure 4: **Histogram of detected sources (8-sigma), estimated for polarization-added data**

8 Work in Progress

- **Analyse the remaining 75 % of data**
- **Amplitude calibration** **examine visibility vs. S_{FISRT}**
- **Refine fringe-search windows**
  reduce windows to lower detection threshold below 8σ
- **Add RHC and LHC data to lower detection threshold**
- **Examine position differences from FIRST catalogue using delay/rate resolution**
  FIRST positions have accuracies of 1" or better

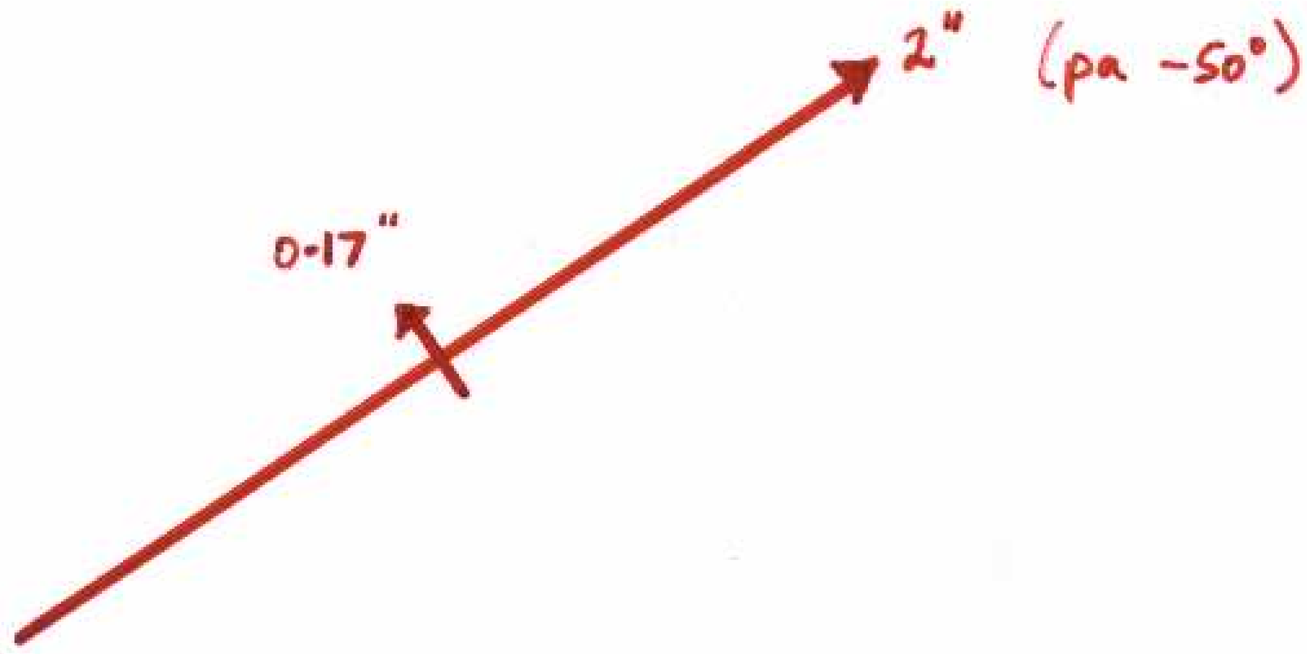


Figure 5: **Fringe-rate (0.17") and Delay (2") resolutions**

- **Investigate variability of FIRST sources** ($\gamma > 1$?)
- **Search of primary beam for further, weaker sources**
  Ar–Eb is 40 % more sensitive than the FIRST observations so one can look for new sources and investigate the completeness of the FIRST survey
- **Follow-up observations of detected sources to determine structure, spectrum and optical identification**