Multi-wavelength Reference Frame Activities at USNO

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Current USNO Multi-Wavelength Celestial Reference Frame Work

- Optical and Optical-Radio

- Infrared

- Radio

Optical-Radio Offsets

- Zacharias
  - "DARN" work
  - URAT-VLBI
  - SDSS-VLBI

- Makarov
  - PanSTARRS-VLBI
  - Intercatalog comparisons
  - New observations with VLBI

URAT deployed at Naval Observatory, Flagstaff Station


PS-1 Telescope, Maui

Gaia tie sources: Initial Comparison

- Initial comparison of Gaia radio-optical link source list
- Compared radio position (OCARS) with URAT1 and PS-1 positions
  - URAT1: 107 sources overlap
  - PS1: 162 sources overlap
- PS-1-radio ~ 60 mas ➔ likely PS-1 measurement errors
- URAT-radio ~ 40 mas ➔ likely URAT-1 measurement errors
- Additional work required


107 sources, median offset: 44 mas
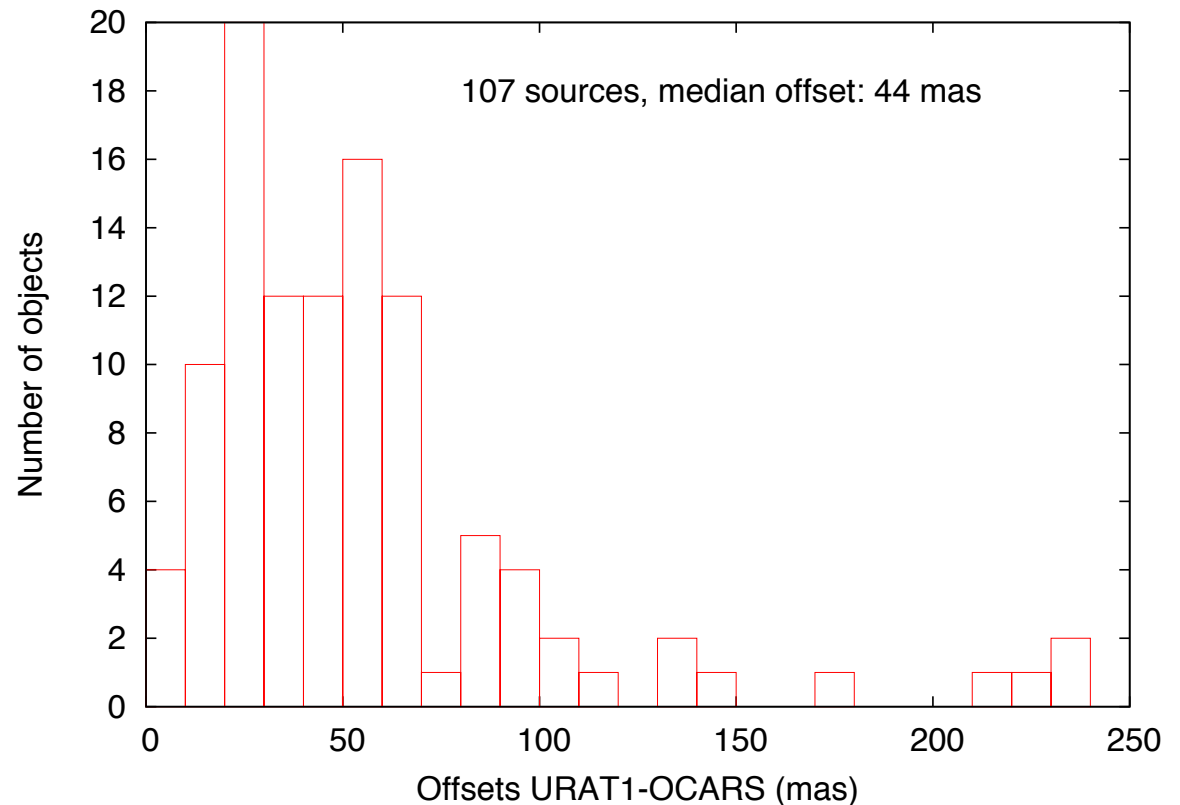
Gaia tie sources: Initial Comparison (2)
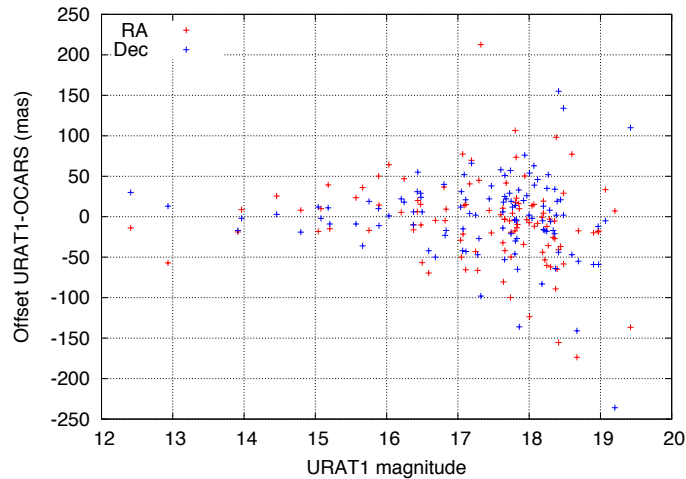

Offset vs. URAT magnitude

Normalized errors

- At faint end, errors dominated by low SNR
- Errors at bright end ~ consistent with URAT1 measurement errors
- Normalized distributions wider than expected
- Preliminary assessment: most bright QSOs errors likely constrained at 10—20 mas level
  - "Fat" offset distributions indicate additional problems present
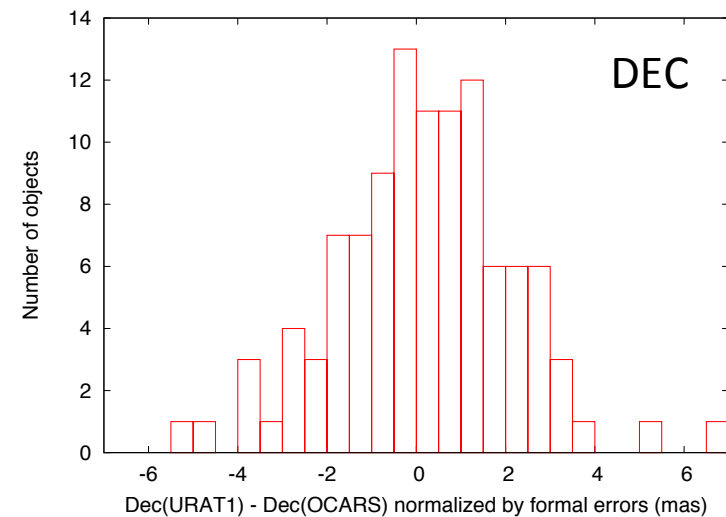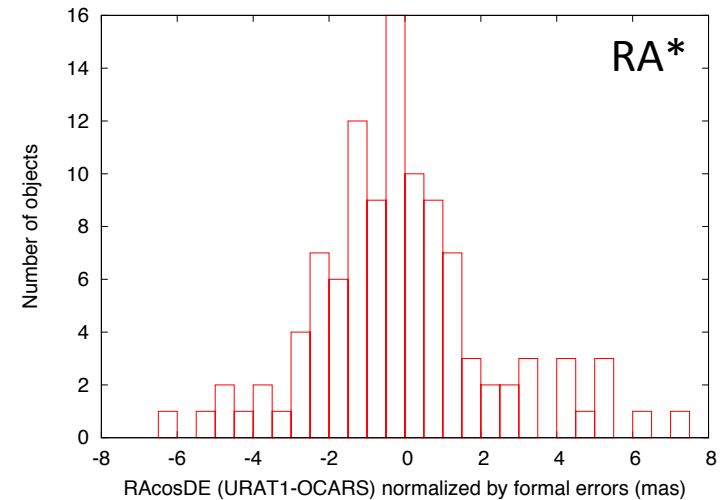
IR: WISE AGN Color-Color Selection

Wright et al. (2010)
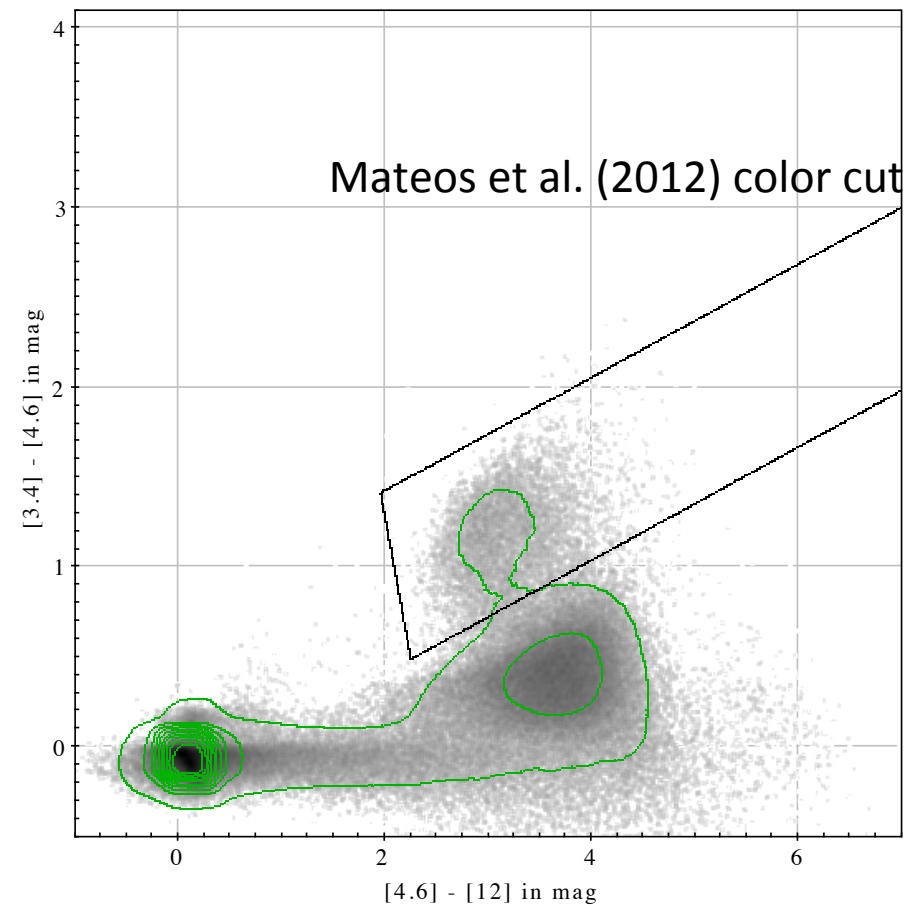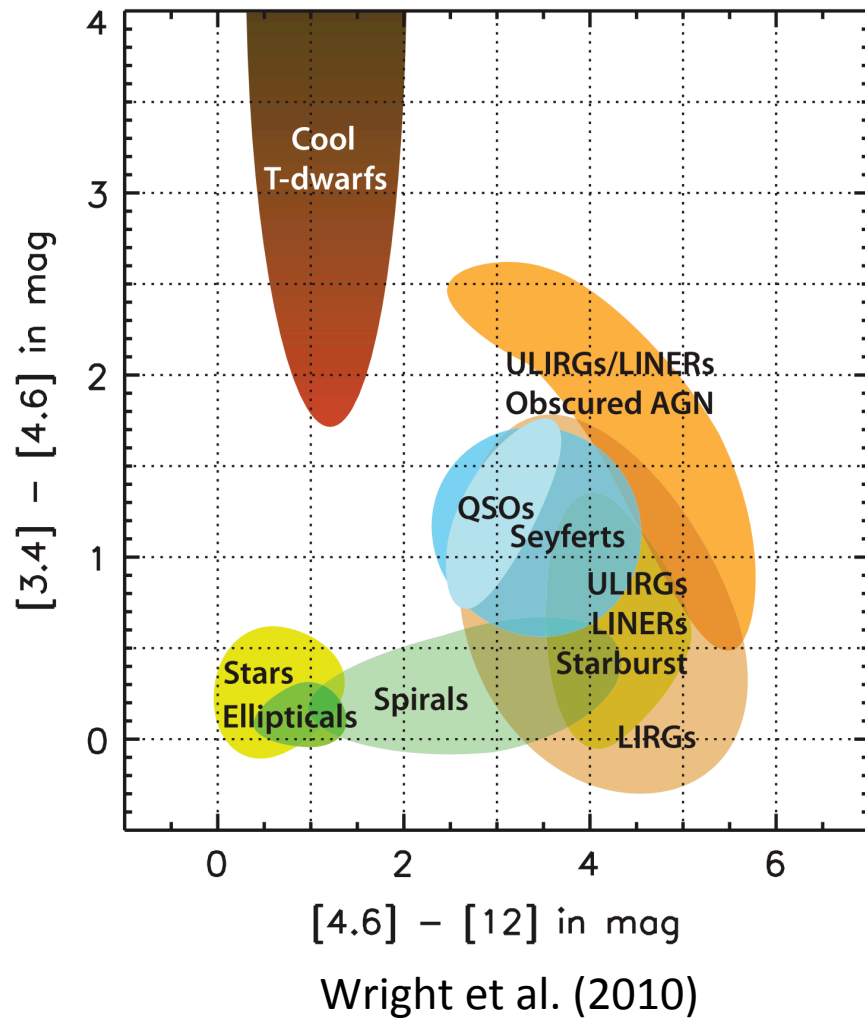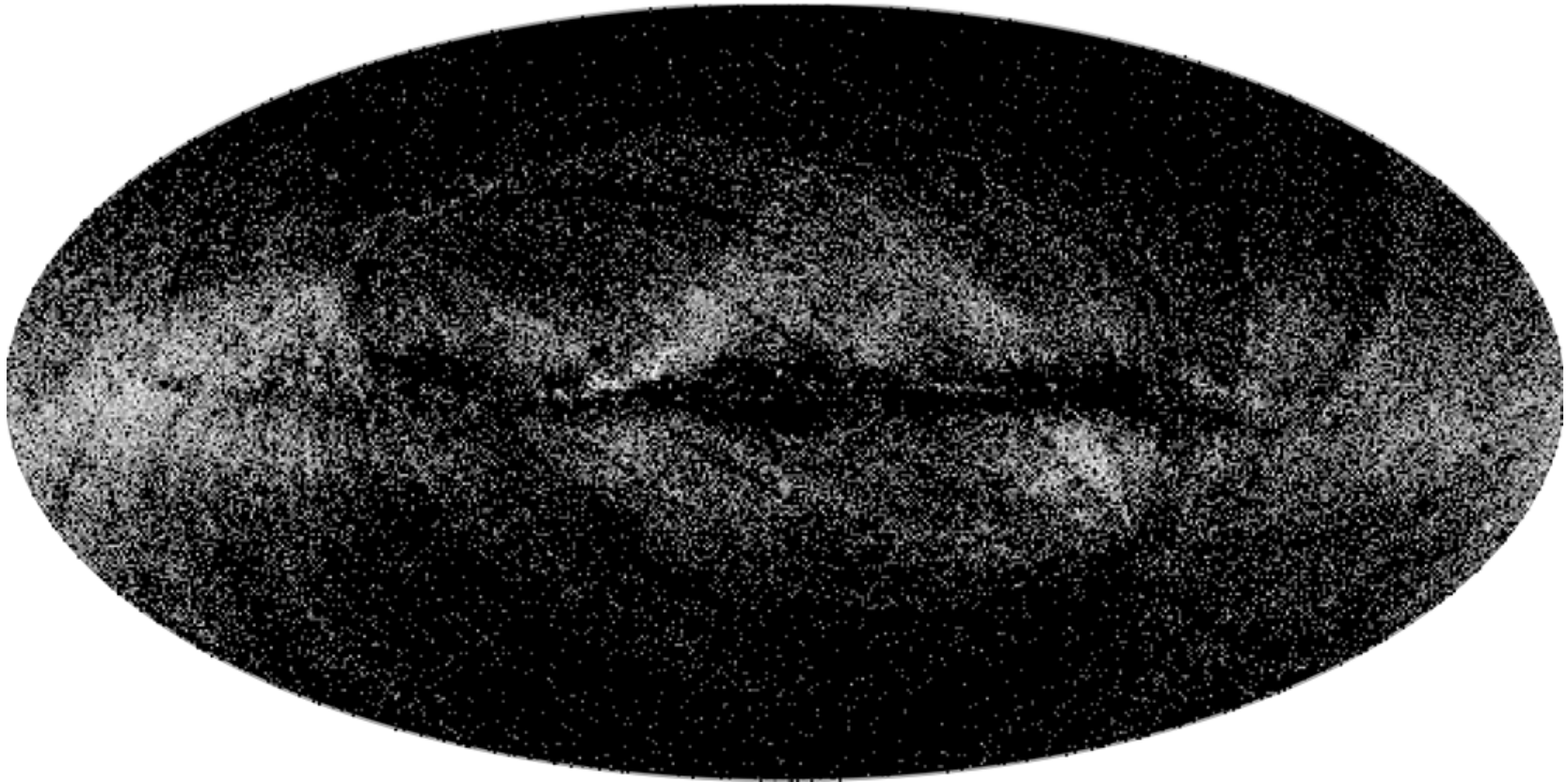
Secrest et al. 2015 (submitted)
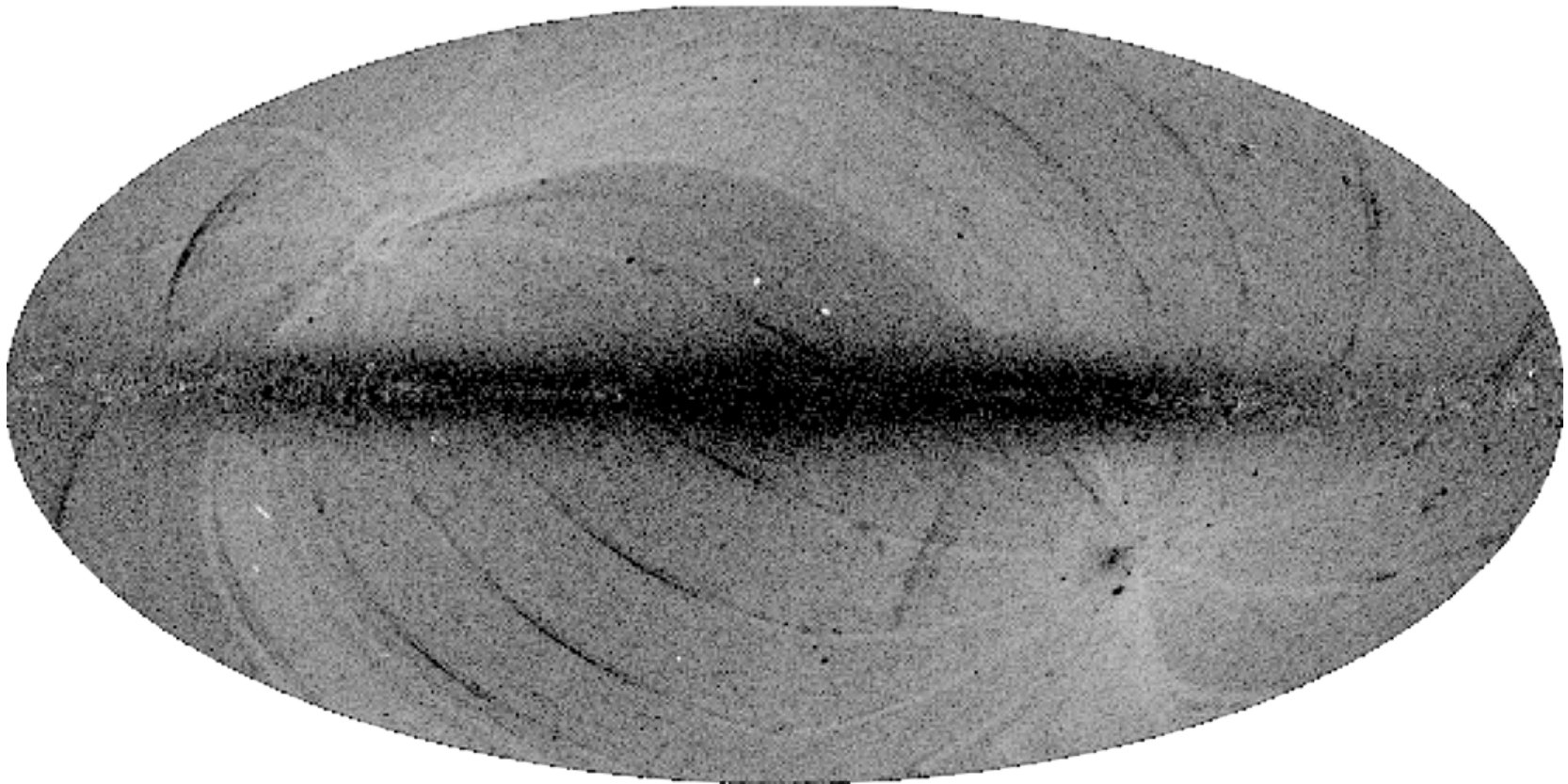
WISE Stars

WISE stars

Mid-IR selected stars cluster along Galactic plane

Secrest et al. 2015 (submitted)

Selected Sources

MIRAGNs

1,354,775 objects, spanning full sky

Secrest et al. 2015 (submitted)

IR AGN Analysis

- Secrest et al. 2015 (submitted): AGN detection in WISE data
- 1.4 million sources identified as AGN using this technique
  - > 30 per sqr deg over sky (mean)
  - > 1 million "new" detections
- Errors
  - Completeness: 80—90% vs. visible
    - Comparison to other, known AGN
    - "Missed detections" (incompleteness) due to limiting magnitude in visible
  - False positives: ≤ 1.4% total population
    - Calculated using 225k PPMXL sources (known stars); P_{FD}= 4.4 10^{-5}

- Next step: Identify optical and radio counterparts and assess source phenomenology
  - e.g., search URAT observational database to analyze photometric variability

- *WISE W1 color (3.4 um) (red)*
- *g (green)*

Secrest et al. 2015 (submitted)
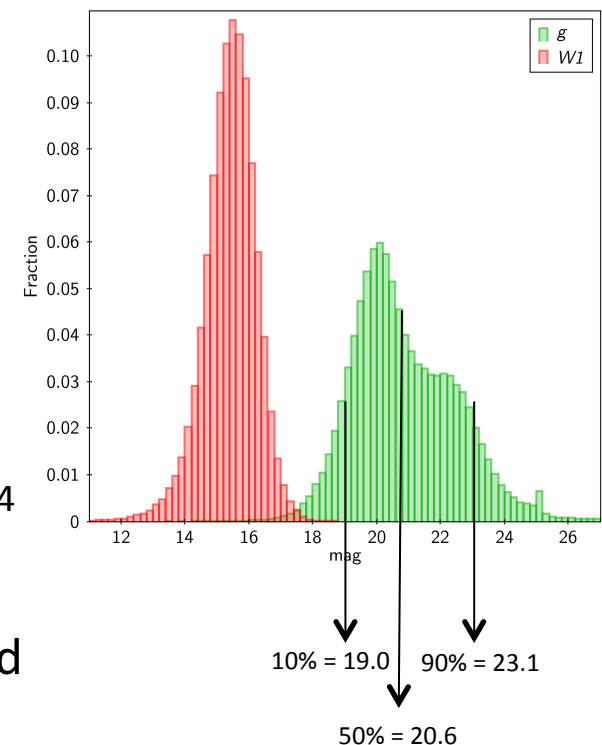
Radio Reference Frame Work

- Evaluating significantly increasing VLBA use to support celestial reference frame work
  - Includes positional measurements and imaging
  - Unlikely to include upgrades to X/Ka bands, but still under discussion
  - Should be available to support ICRF3 and beyond research
- Source structure/radio imaging analysis
- Observations of stars as link objects
  - VLBI/VLBA/VLA
  - ALMA

The Very Long Baseline Array (VLBA)

Brewster, Wash.

Pie Town and Los Alamos, N.M.

Hancock, N.H.

North Liberty, Iowa

Owens Valley, Calif.

Kitt Peak, Ariz.

Fort Davis, Texas

Mauna Kea, Hawaii

St. Croix, V.I.

1,000 km
1,000 miles

Summary

- Active, multi-wavelength work on reference frames ongoing at USNO
  - VLBI, VLBA (radio), WISE, TBD (IR), URAT1, PanSTARRS-1 (Visible), others...
- The goal of this work is to
  - better quantify/understand multi-wavelength offsets and understand impact to reference frame
  - Support development of ICRF3 and beyond
  - Support alignment/incorporation of Gaia reference frame with fundamental reference frame
  - Support the extension of the reference frame into new wavelengths/magnitudes as appropriate