



# Implementation and Testing of VLBI Software Correlation at USNO

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# Outline

- VLBI at USNO
- The Washington Correlator (WACO)
- Why a Software Correlator
- The DiFX Software Correlator
- Current setup at USNO
- Preliminary Results
- Future Plans



# VLBI at USNO

- **The Washington Correlator (WACO)**
- **IVS Analysis Center**
  - Responsible for processing IVS-R4 experiments
  - Submit EOP1 series to IVS from 1-hr Intensive experiments
  - Submit EOPS series to IVS from 24-hr experiments
- **IERS Rapid Service/Prediction Center (RS/PC)**
  - VLBI data combined with SLR, GPS, etc. to produce EOP products
- **Provide daily, weekly, and long-term products**
  - Weekly updates (Bulletin A) are issued on Thursdays
  - Determinations of Delta TT (TT-UT1) are updated approximately quarterly, and long-term predictions are updated annually



# The Washington Correlator

- The Washington Correlator (WACO)
  - A Mark IV Correlator
  - designed and constructed by MIT Haystack Observatory
  - operated in cooperation with NASA



# The Washington Correlator

- WACO Work-load
  - Intensives - two stations: 5 per week, 1 baseline, 1-hour
  - Intensives - three stations: every 2 weeks, 3 baselines, 1-hour
  - R4 experiments: one per week, multiple baselines, 24-hour
  - R1 experiments: 1-2 per year, multiple baselines, 24-hour
  - T2 experiments: 1-2 per year, multiple baselines, 24-hour
  - CRF experiments: ~12 per year, 1-6 baselines, 24-hour
  - OTHER: CONT, APSG, R&D, etc



The Washington Correlator (WACO)



# Why a Software Correlator?

## ➤ Backup

- WACO is single point of failure - we only have one

## ➤ Continuity of operations

- Multiple instances at geographically different locations

## ➤ Cost effective

- Can be implemented with commercial off-the-shelf personal computers
- As few or as many CPUs as required for the job



# Why a Software Correlator?

## ➤ Flexible/Scalable

- Software is easily adaptable to changing requirements
- Number of CPUs can be increased/decreased with demand
- Robust to failure of individual CPUs





# The DiFX Software Correlator

- **DiFX is a geocentric FX\* type correlator**
  - Developed at Swinburne University (Australia) by Adam Deller
  - Designed to run in a cluster computing environment
  - Parallel processing fully enabled
  - Supports VLBA, MK5, K5, etc. input formats
  - Geometric model calculation using GSFC CALC software
  - Currently outputs FITS-IDI format

\* In an XF correlator or lag correlator, the correlations are done first followed by a Fourier Transform to obtain the cross-power spectrum. In an FX correlator this order is reversed. WACO is an XF type correlator.



# The DiFX Software Correlator

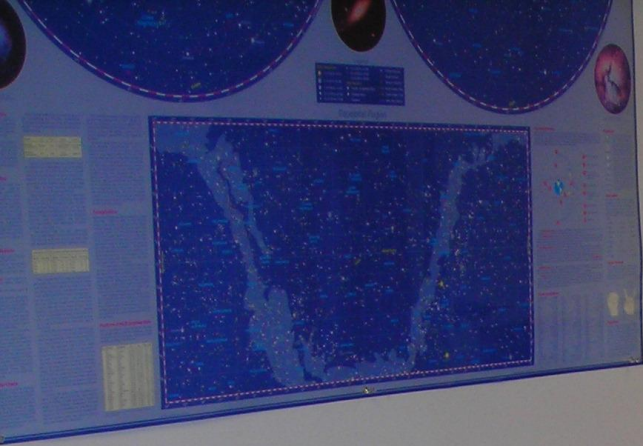
- **Current DiFX limitations for astrometric/geodetic VLBI**
  - Phase-cal extraction not fully implemented
    - Manual phase-cal as temporary work-around
    - Bonn will soon have a solution
  - No output path to HOPS (Haystack Observatory Post-processing System)
    - AIPS data-reduction path as temporary work-around
    - Bonn/USNO currently looking into a solution



# Current Set-up at USNO

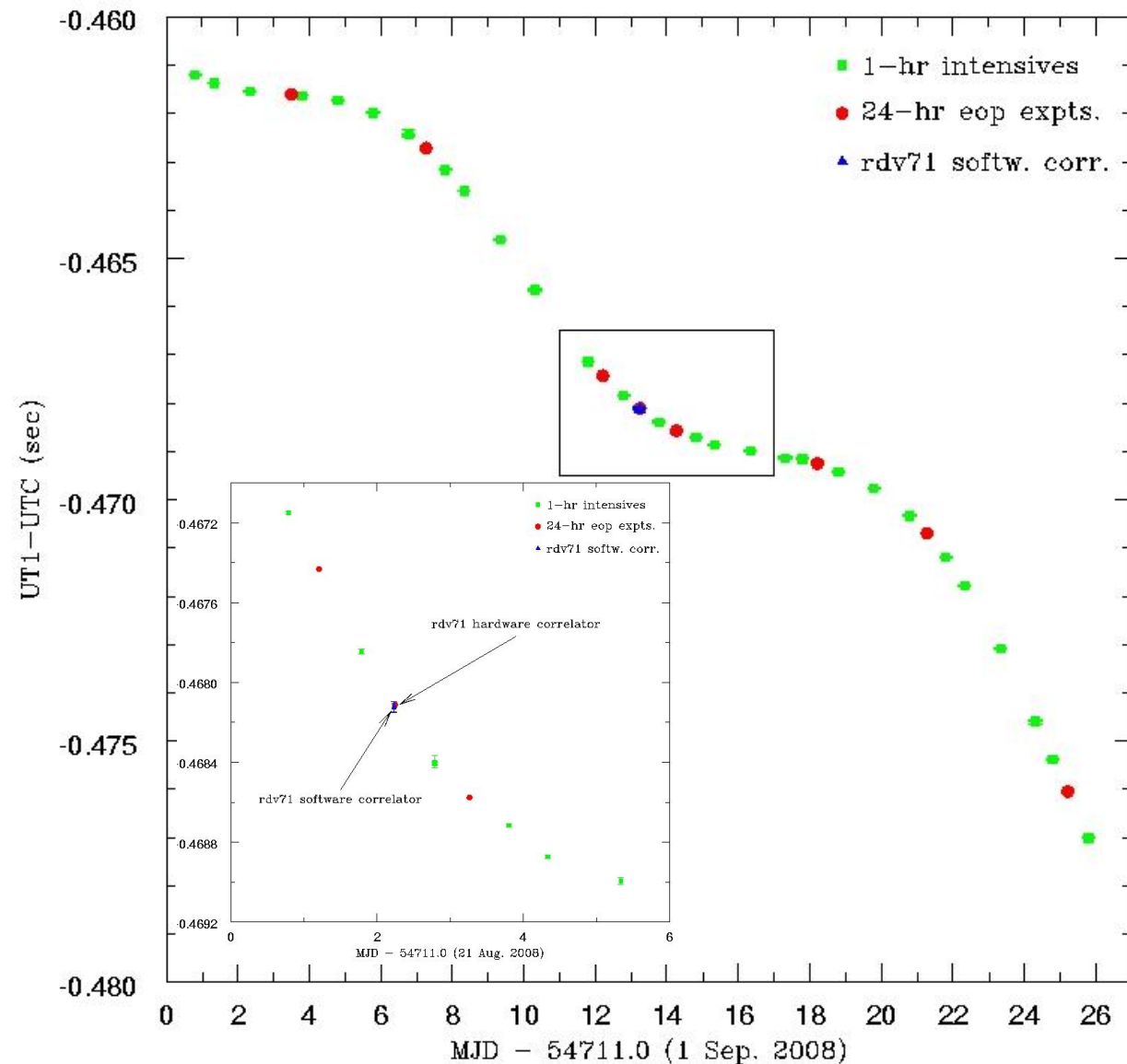
- Currently testing the NRAO\* implementation of the Swinburne University DiFX software correlator
- USNO Prototype Software Correlator (UPSC)
  - Heterogeneous “cluster” of off-the-shelf personal computers
    - 1 dual-quad core Xeon (8 processors)
    - 4 Core 2 duo (8 processors)
  - Linux (32-bit) operating system
  - 2 TB hard drive storage
  - Gigabit Ethernet links

\* National Radio Astronomy Observatory



USNO Prototype  
Software Correlator

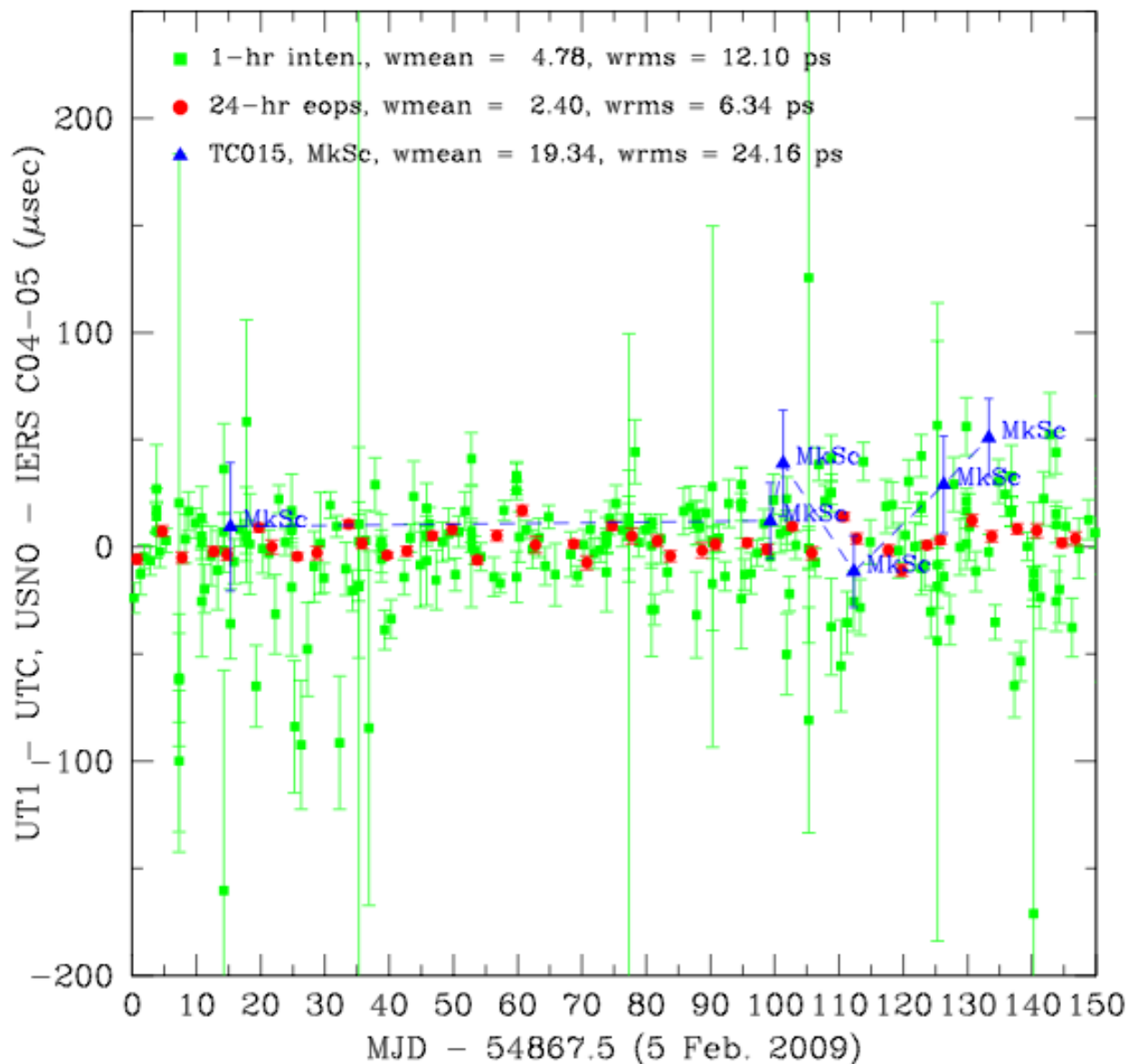
# Preliminary Results



## USNO UT1-UTC series

- Shown over 27 days
- 1-hr intensives (green squares)
- 24-hr experiments (red circles)
- RDV71 data correlated with the UPSC (blue triangle)

# Preliminary Results



## USNO minus IERS C04-05

- Shown over 150 days
- 1-hr intensives (green squares)
- 24-hr experiments (red circles)
- MkSc\* correlated with the UPSC (blue triangle)

\* From a dedicated series of 2-hr “pseudo-intensive” VLBA experiments



# Future Plans

- Preliminary design review - October 2010
- Critical design review - July 2011
  - Design finalized / procure hardware
- Side-by-side operation with WACO - October 2011
  - Daily comparison of results ~1 year
  - Robustness
  - Reliability
  - Additional software development as required
- Software correlator operations - October 2012

