Canberra Deep Space Communication Complex (CDSCC) report

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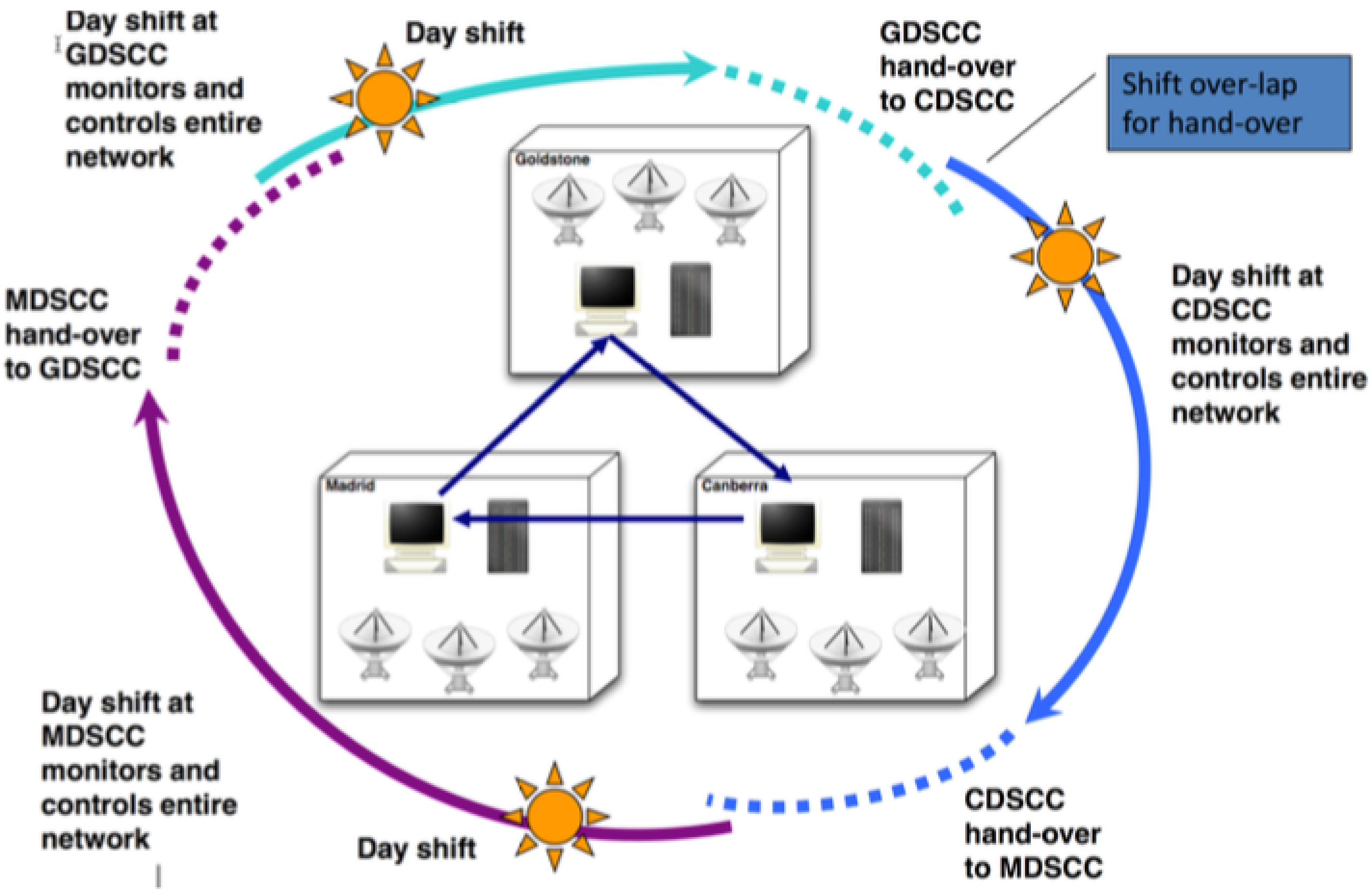
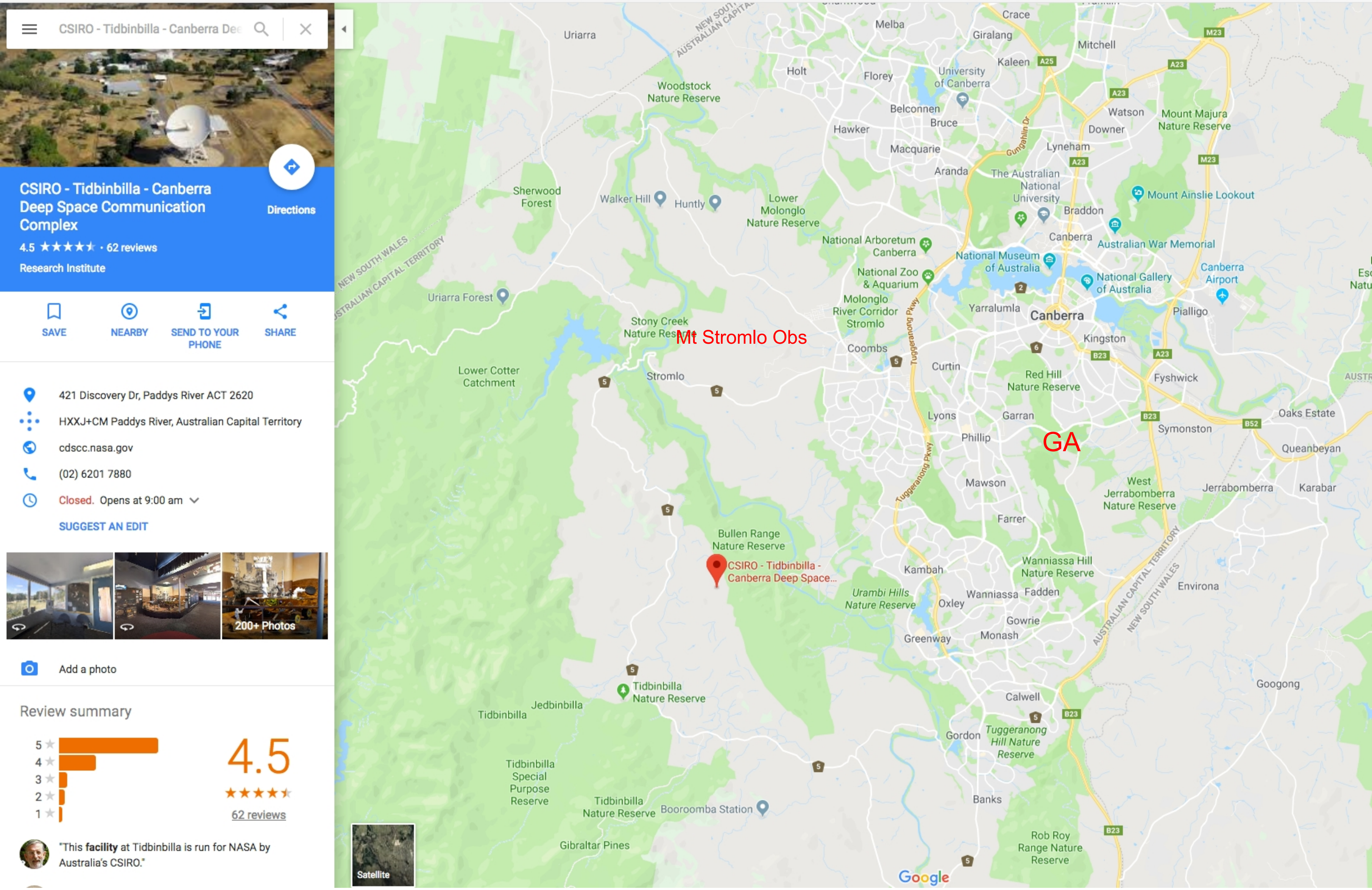
Canberra Deep Space Communication Complex, CSIRO/NASA

3rd General Meeting of AOV Group for Geodesy and Astrometry, November 9-10, 2018, Canberra

NASA's DEEP SPACE NETWORK

Follow-the-Sun Operation the NASA's DSN since November 2017





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CSIRO - Tidbinbilla - Canberra Deep Space Communication Complex
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"This facility at Tidbinbilla is run for NASA by Australia's CSIRO."
Mt Stromlo Obs
GA
CSIRO - Tidbinbilla - Canberra Deep Space...
Canberra
Uriarra
Woodstock Nature Reserve
Holt
Melba
Crace
Giralang
Mitchell
Kaleen
Florey
University of Canberra
Belconnen
Bruce
Hawker
Watson
Downer
Mount Majura Nature Reserve
Macquarie
Lyneham
Aranda
The Australian National University
Braddon
Mount Ainslie Lookout
Sherwood Forest
Walker Hill
Huntly
Lower Molonglo Nature Reserve
National Arboretum Canberra
Australian War Memorial
National Museum of Australia
National Zoo & Aquarium
National Gallery of Australia
Canberra Airport
Molonglo River Corridor Stromlo
Yarralumla
Pialligo
Uriarra Forest
Stony Creek Nature Reserve
Coombs
Kingston
Lower Cotter Catchment
Stromlo
Curtin
Red Hill Nature Reserve
Fyshwick
Lyons
Garran
Oaks Estate
Phillip
Symonston
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Mawson
West Jerrabomberra Nature Reserve
Jerrabomberra
Karabar
Farrer
Bullen Range Nature Reserve
Kambah
Wanniassa Hill Nature Reserve
Environa
Urambi Hills Nature Reserve
Oxley
Wanniassa
Fadden
Gowrie
Greenway
Monash
Tidbinbilla Nature Reserve
Jedbinbilla
Tidbinbilla
Googong
Calwell
Gordon
Tuggeranong Hill Nature Reserve
Tidbinbilla Special Purpose Reserve
Tidbinbilla Nature Reserve
Booroomba Station
Banks
Gibraltar Pines
Rob Roy Range Nature Reserve
NEW SOUTH WALES
AUSTRALIAN CAPITAL TERRITORY
Satellite
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What happened a week ago …

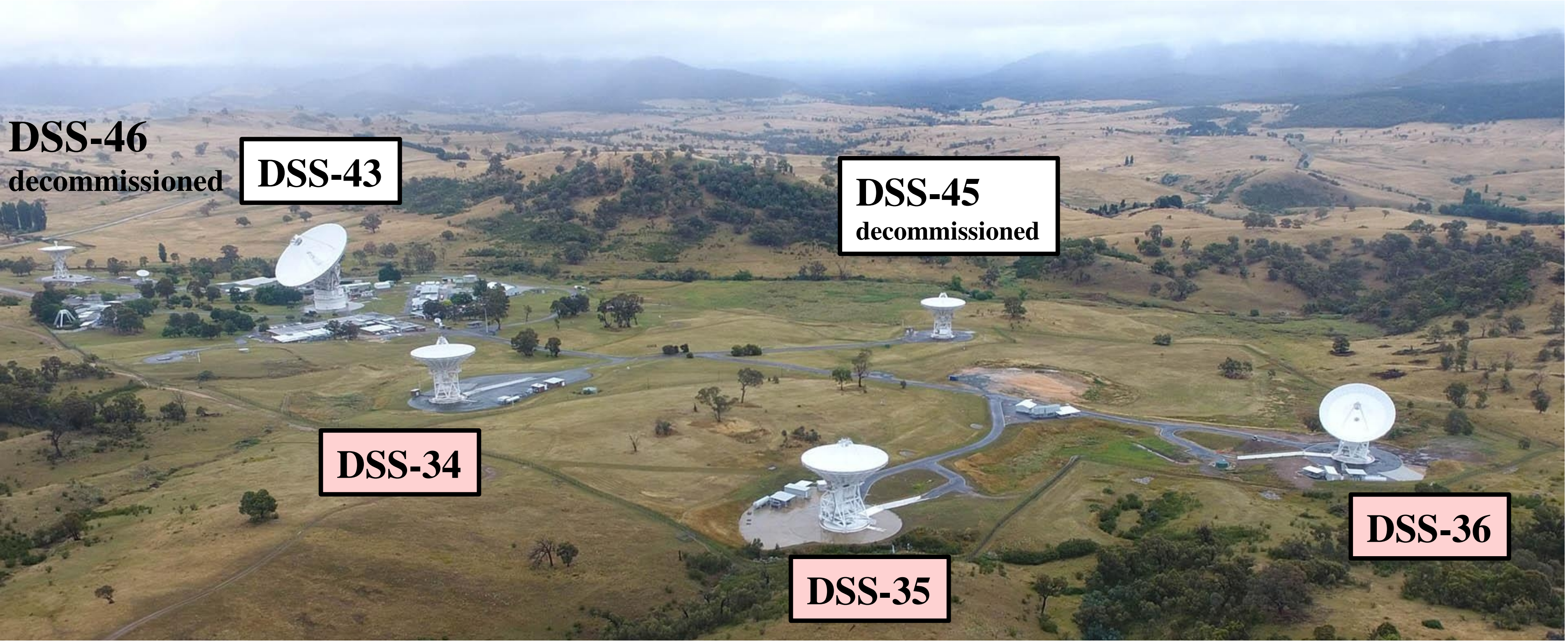
DEEP SPACE NETWORK
Jet Propulsion Laboratory • National Aeronautics and Space Administration

CSIRO

Canberra Deep Space Communication Complex

- Located in Tidbinbilla, near Canberra in Australian Capital Territory.
- One of three JPL Deep Space Network (DSN) stations (together with Madrid and Goldstone) to track NASA spacecrafts for 7 days 24 hours, operated by CSIRO.
- Under the Host Country agreement with NASA, a fraction of the antenna time is available to the Australian astronomical community. Observations are supported by the on-site radio astronomy staff.

NASA Deep Space Network Canberra station Tidbinbilla, Australian Capital Territry



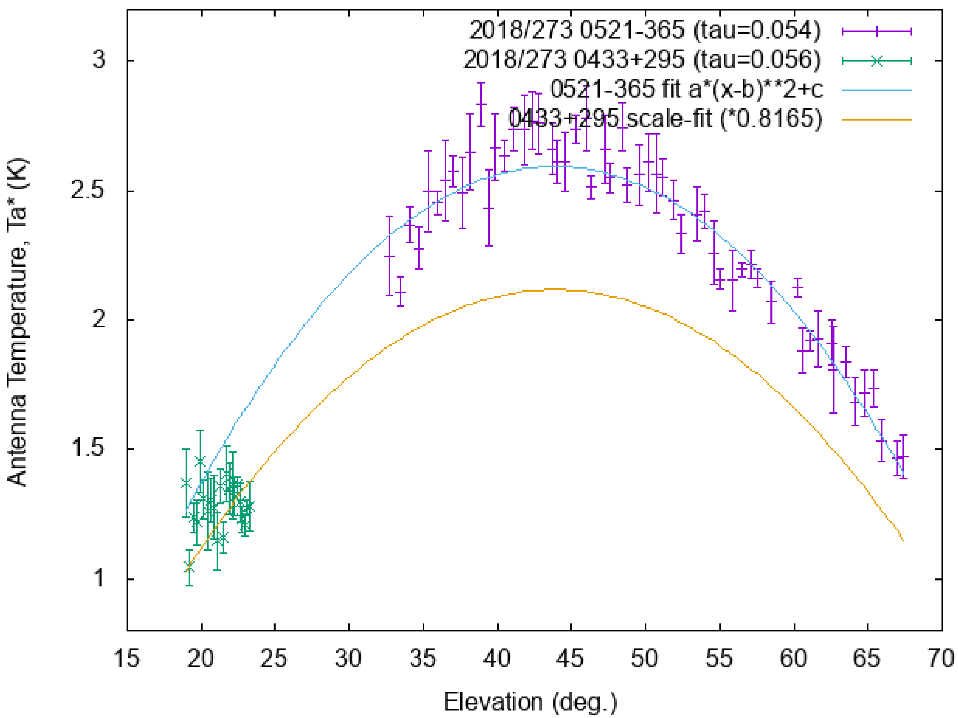
Deep Space Stations (DSS) in Canberra 70m antenna

DSS-43 The largest steerable telescope in the southern hemisphere

L (1.4-1.9 GHz), LCP only
S (2.2-2.3 GHz), dual pol (RCP and LCP)
X (8.3-8.6 GHz), dual pol (RCP and LCP)
K (17-27 GHz), dual pol (linear or circular) x 2 Beams

The most sensitive K-band telescope in the southern hemisphere

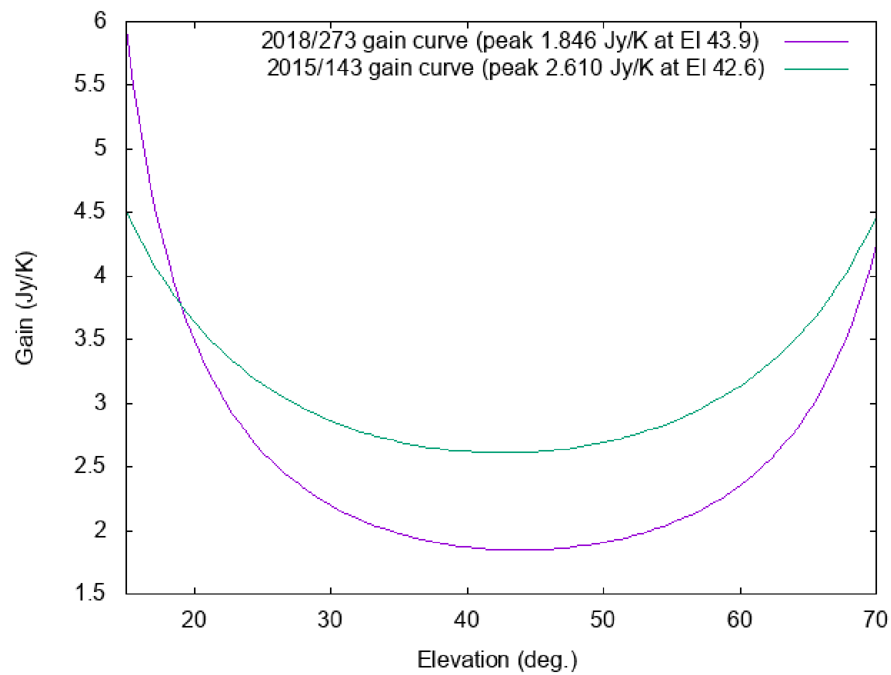
DSS-43 K-band Subreflector Optimization



70m K-band gain has been degraded in the last 10 years

Subreflector optimisation recently recovered gain 40 percent to achieve 1.85 Jy/K at peak (39 % efficiency)

was 1.5 Jy/K (48 % efficiency) in early 2000s
.. needs dish resurfacing?



Deep Space Stations (DSS) in Canberra 34m Beam Wave Guide Antennas

- DSS-34

  S (2.2-2.3 GHz), single pol (RCP or LCP)

  X (8.2-8.6 GHz), single pol (RCP or LCP)

  K (25.5-27 GHz), single Pol (RCP or LCP)

  Ka (31.9-32.2 GHz), dual pol (RCP and LCP)

- DSS-35, started 2014

  X (8.2-8.6 GHz), dual pol (RCP and LCP)

  Ka (31.9-32.2 GHz), dual pol (RCP and LCP)

- DSS-36, started 2016

  S (2.2-2.3 GHz), single pol (RCP or LCP)

  X (8.2-8.6 GHz), dual pol (RCP and LCP)

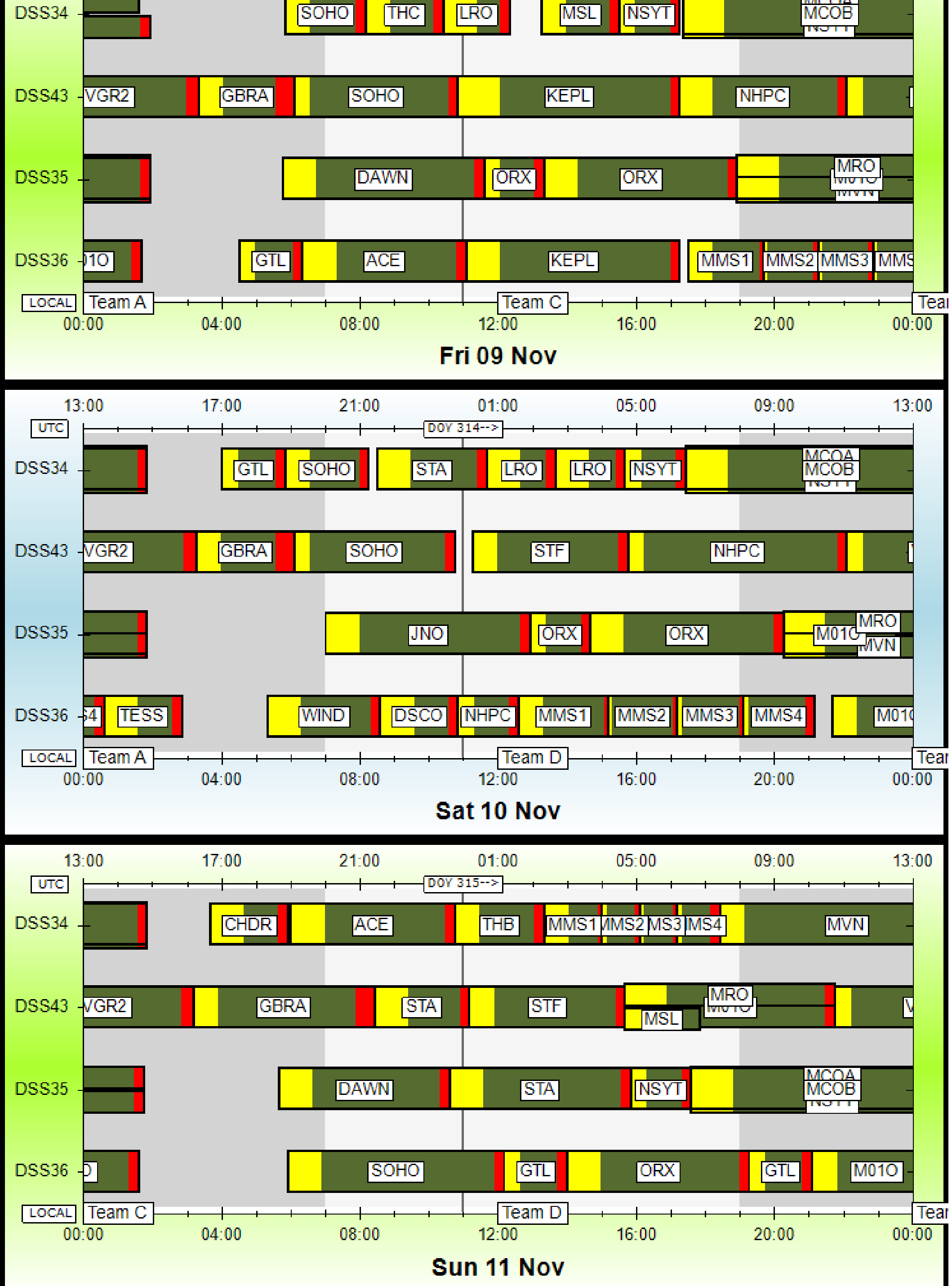
  Ka (31.9-32.2 GHz), dual pol (RCP and LCP)

VLBI Backend in Canberra

- LBA-Data recorder
  LBA-DAS
  16 MHz x 4 IF or 64 MHz x 2 IF
  512Mbps data rate

- DSS VLBI Processor (DVP)
  Mark5C with CASPAR/ROACH board
  Up to 32MHz x 16 IFs
  2048 Mbps data rate
  VDIF format data

- WVSR, Open Loop Receiver (OLR)
  used for Delta-DOR VLBI navigation



Due to spacecraft demands e.g.

- Voyager2 (VGR2) (needs 70m)
- multiple Mars missions

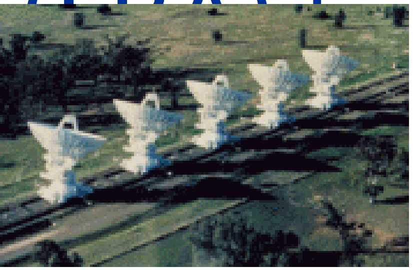
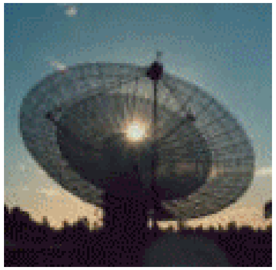
scheduling radioastronomy time is challenge

Ground Based Radio Astronomy (GBRA) are offered only limited LST ranges (for JPL and ATNF/LBA projects)

For global VLBI, JPL schedules

- Reference Frame VLBI
  - 1-2 24h tracks a month
- NASA-ESA Ka RFC experiments
- IVS experiment, only 1-2/yr

The Australian Long Baseline Array (LBA) :

Parkes (64)

ATCA (5x22m)

Mopra (22m)

Hobart (26m)

Ceduna (30m)

Tidbinbilla (70m or 34m), all in Australia,

Hartebeesthoek (26m) , South Africa (Sep2008)

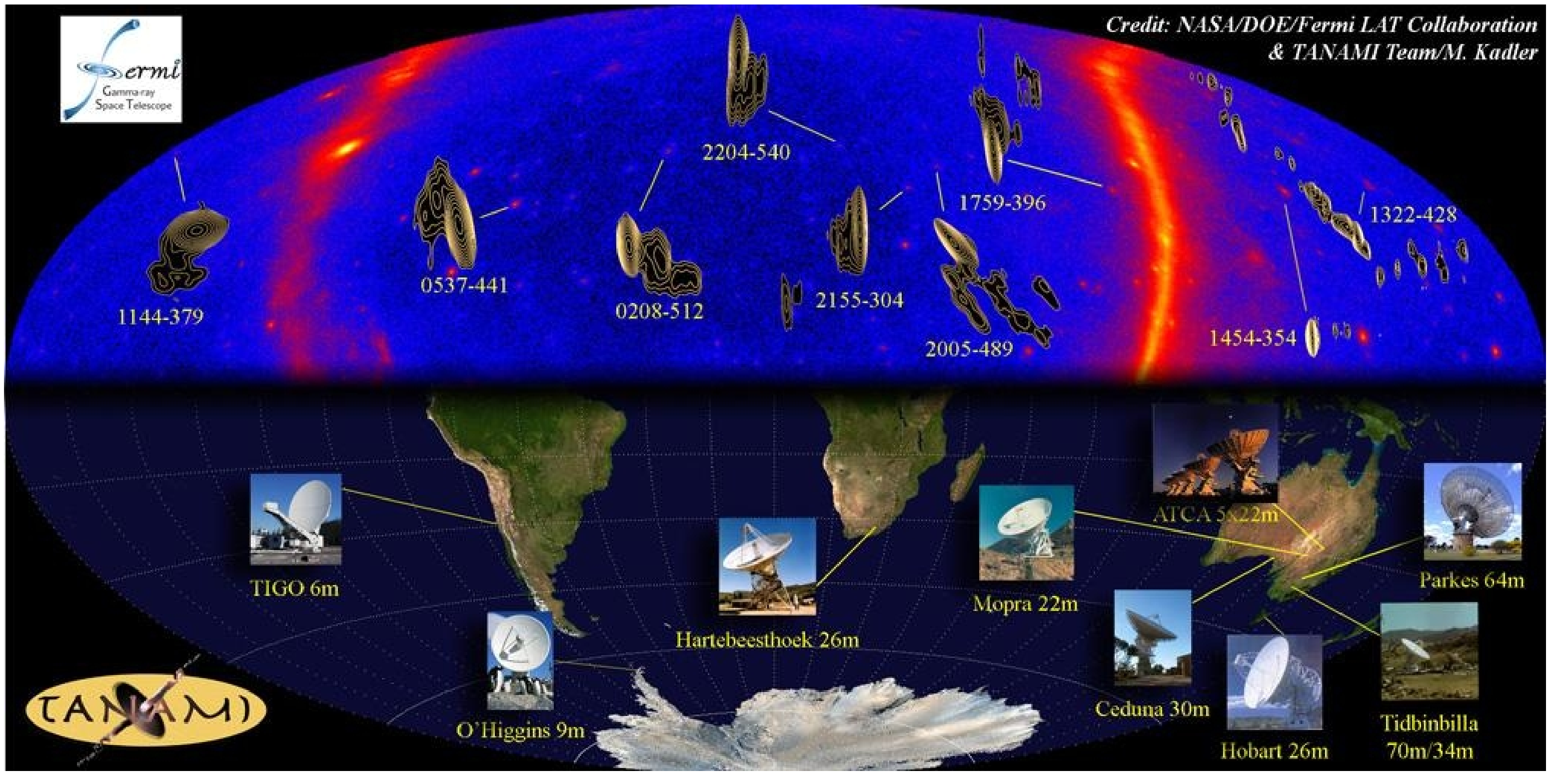
TIGO (6m), Chile

O'Higgins (9m), Antarctica, also NZ, AuScope, ASKAP as new elements

TANAMI-LBA Project to Track FERMI Targets

Tracking Active Galactic Nuclei with Austral Milliarcsecond Interferometry



Australian LBA Monitor at 8/22 GHz (vs. MOJAVE at 15 GHz with VLBA)

Ka-band combined NASA/ESA Deep Space Net

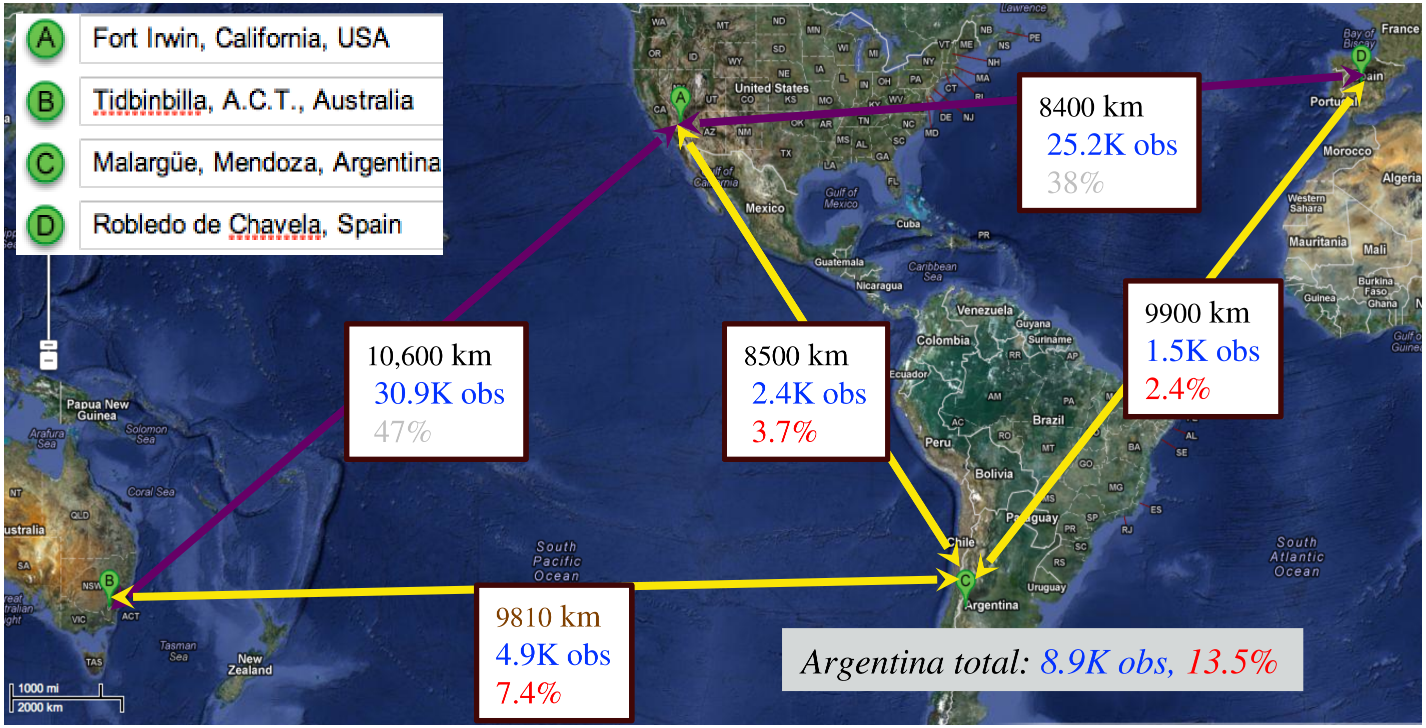
ESA Argentina to NASA-California under-observed by order of magnitude!

Baseline percentages

- Argentina is part of 3/5 baselines or 60% but only 14% of obs
- Aust- Argentina 7.4%
- Spain-Argentina 2.4%
- Calif- Argentina 3.7%

This baseline is under-observed by a factor of ~ 13

More time on ESA's Argentina station would have a huge, immediate impact!!

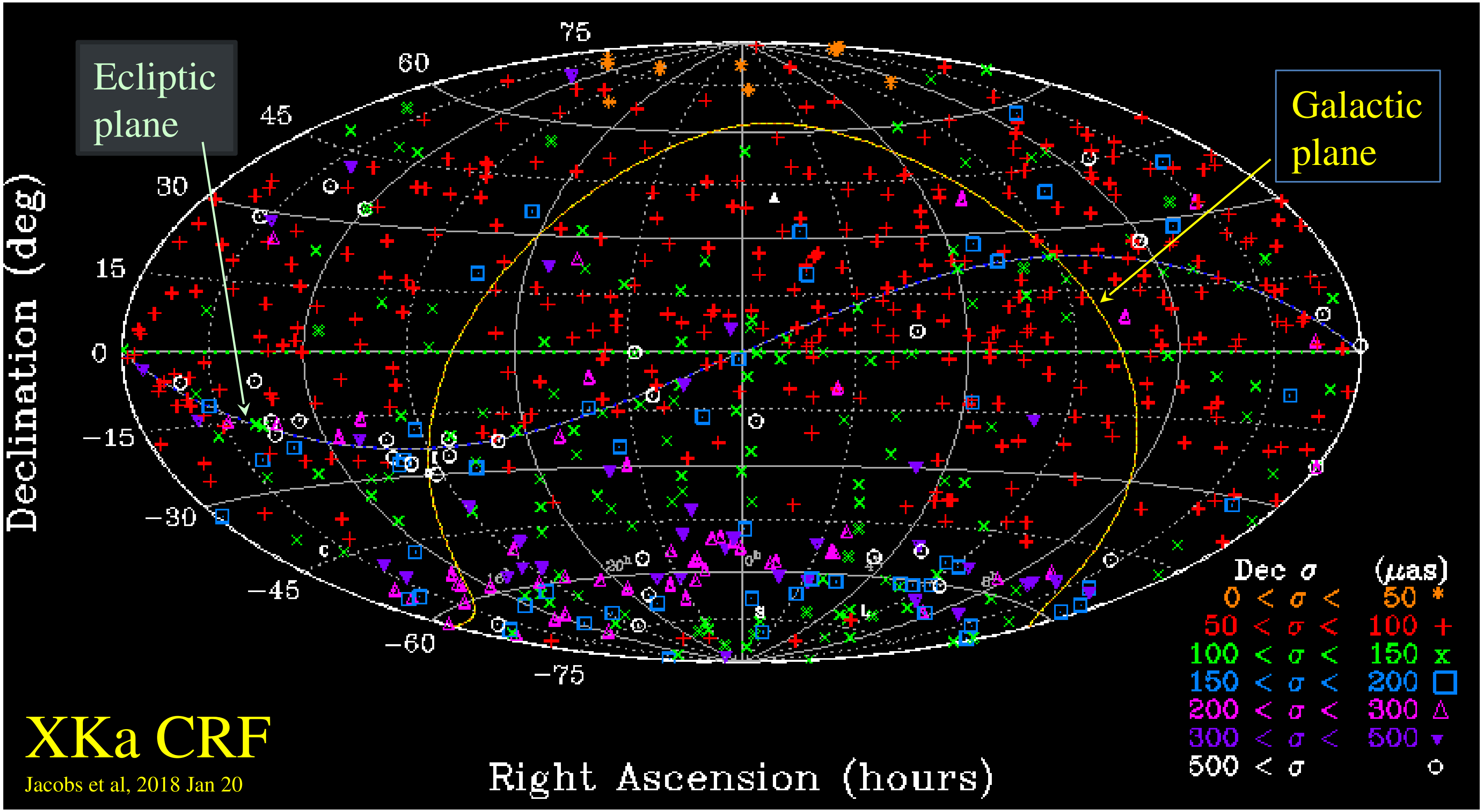


Maps credit: Google maps

ESA's Argentina 35-meter antenna **adds 3 baselines** to DSN's 2 baselines

- Full sky coverage by accessing south polar cap
- near perpendicular mid-latitude baselines: CA to Aust./Argentina

Ka (32 GHz, 9mm) Combined NASA/ESA Network



- Strengths:
  - Uniform spatial density
  - less structure than S/X (3.6cm)
  - precision < 100 μas
  - needed only 68K observations vs. SX's 12 million!

- Weaknesses:
  - Poor near Galactic center due to inter-stellar media scattering
  - South weak due to limited time on ESA's Argentina station
  - Limited Argentina-California data makes vulnerable to δ zonals
  - Limited Argentina-Australia weakens δ from -45 to -60 deg

Optical vs. Radio positions

Positions differences from:

- Astrophysics of emission centroids

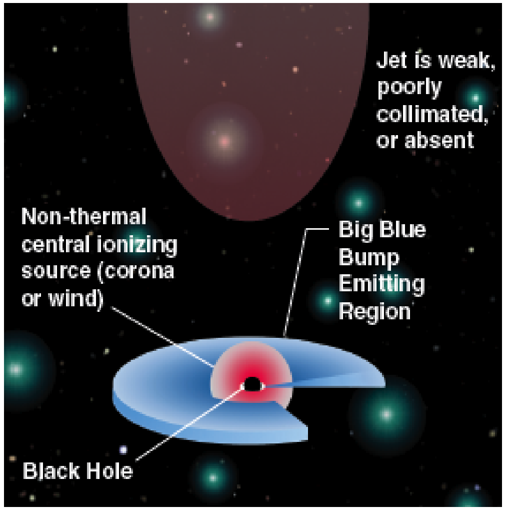
  - radio: synchrotron from jet

  - optical: synchrotron from jet?
    non-thermal ionization from corona?
    big blue bump from accretion disk?

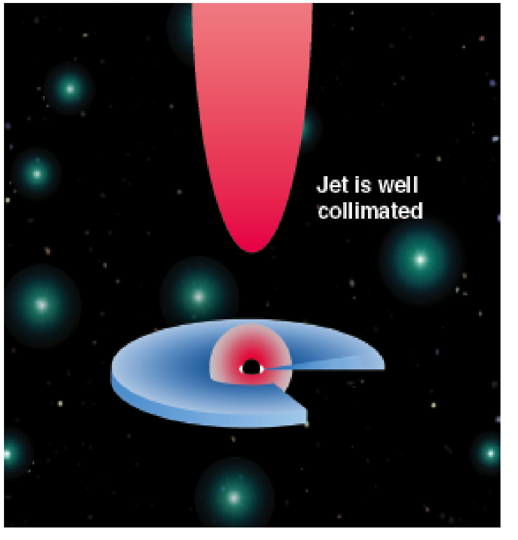
- Instrumental errors both radio & optical

- Analysis errors

Radio-quiet Quasar



Radio-loud Quasar

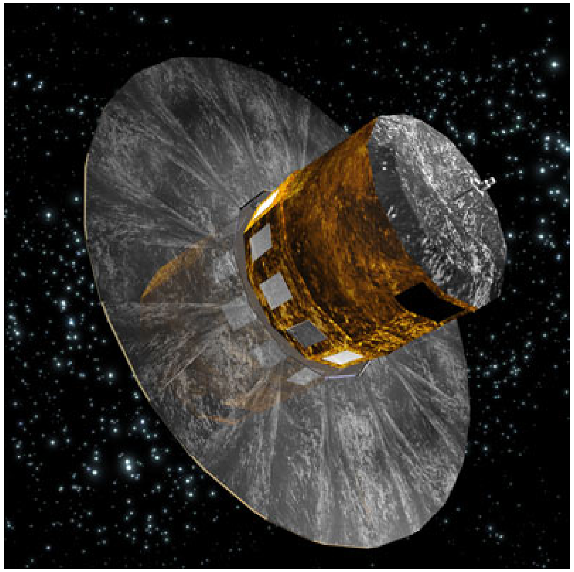


Credit: Wehrle et al, μas Science, Socorro, 2009
http://adsabs.harvard.edu/abs/2009astro2010S.310W

ESA's Gaia optical Astrometry

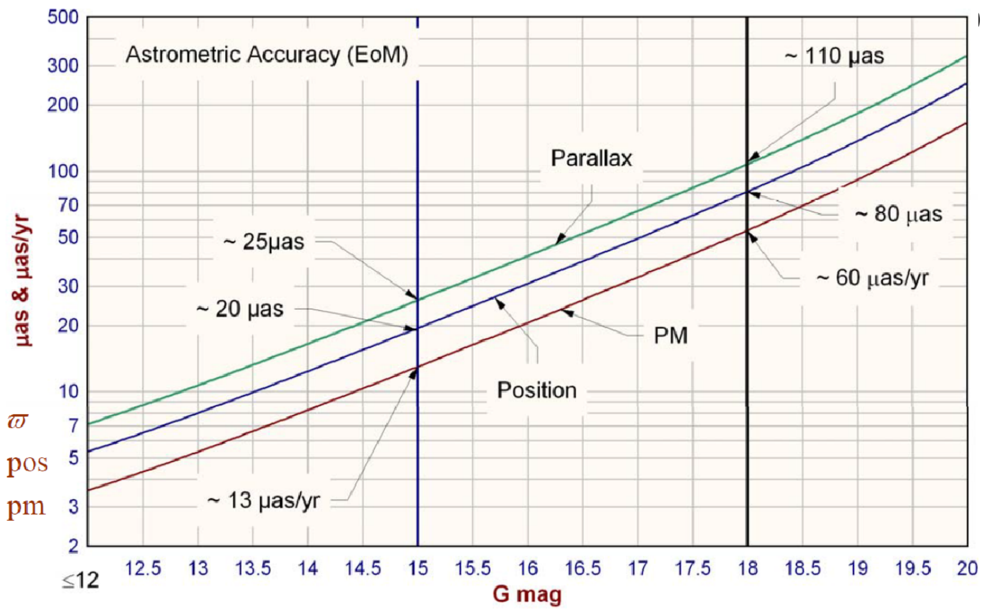
- Method: extremely accurate centroid of 60 mas pixels. Compare to VLBI sub-mas beam.
- **Astrometry & photometric survey to V = 20.7^{mag}**
  - ~10^9 objects: stars, QSOs, solar system, galaxies.
- **Gaia Celestial Reference Frame (GCRF):**
  - Optically bright objects (V< 18mag) give best precision

R1



Credit: F. Mignard (2013)

Anticipated precision of Gaia



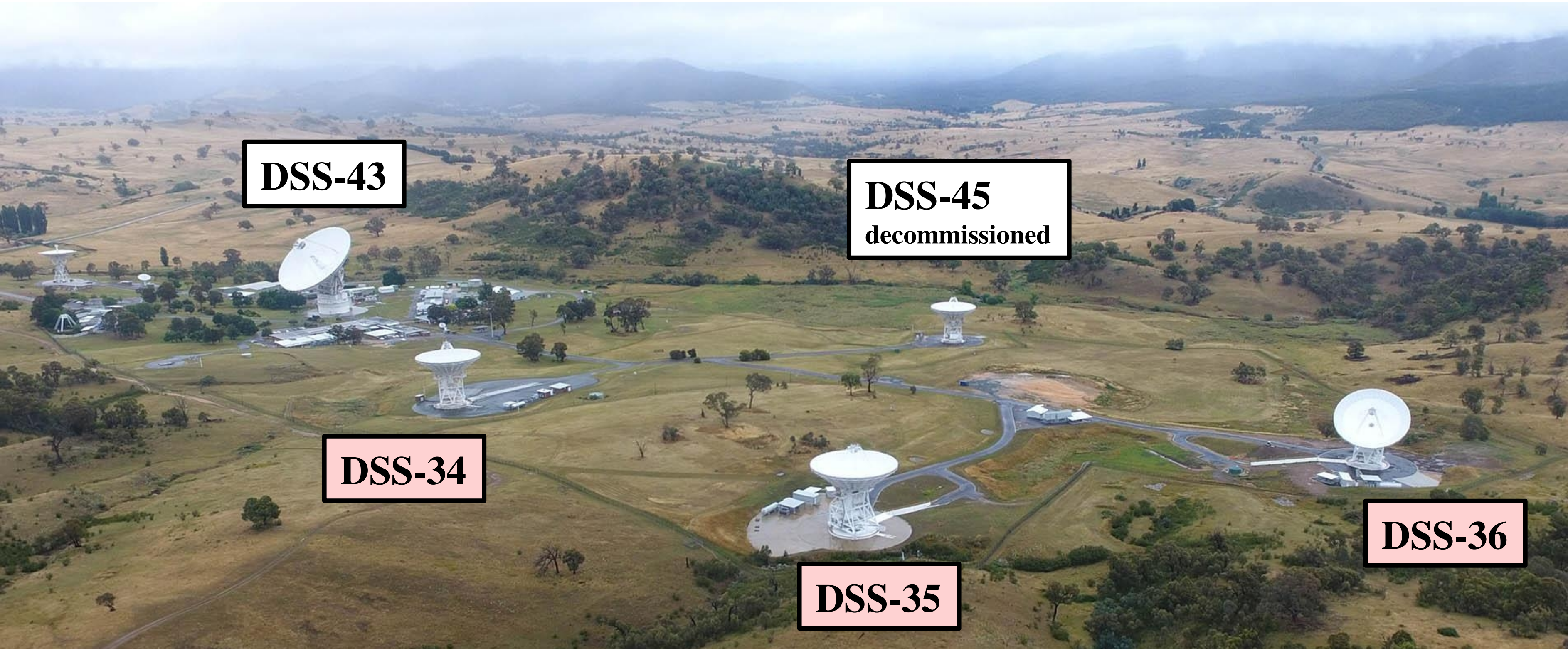
Gaia Data Release-1:

~0.3 mas in positions and parallaxes for 2 million brightest stars

~10 mas for rest of the stars

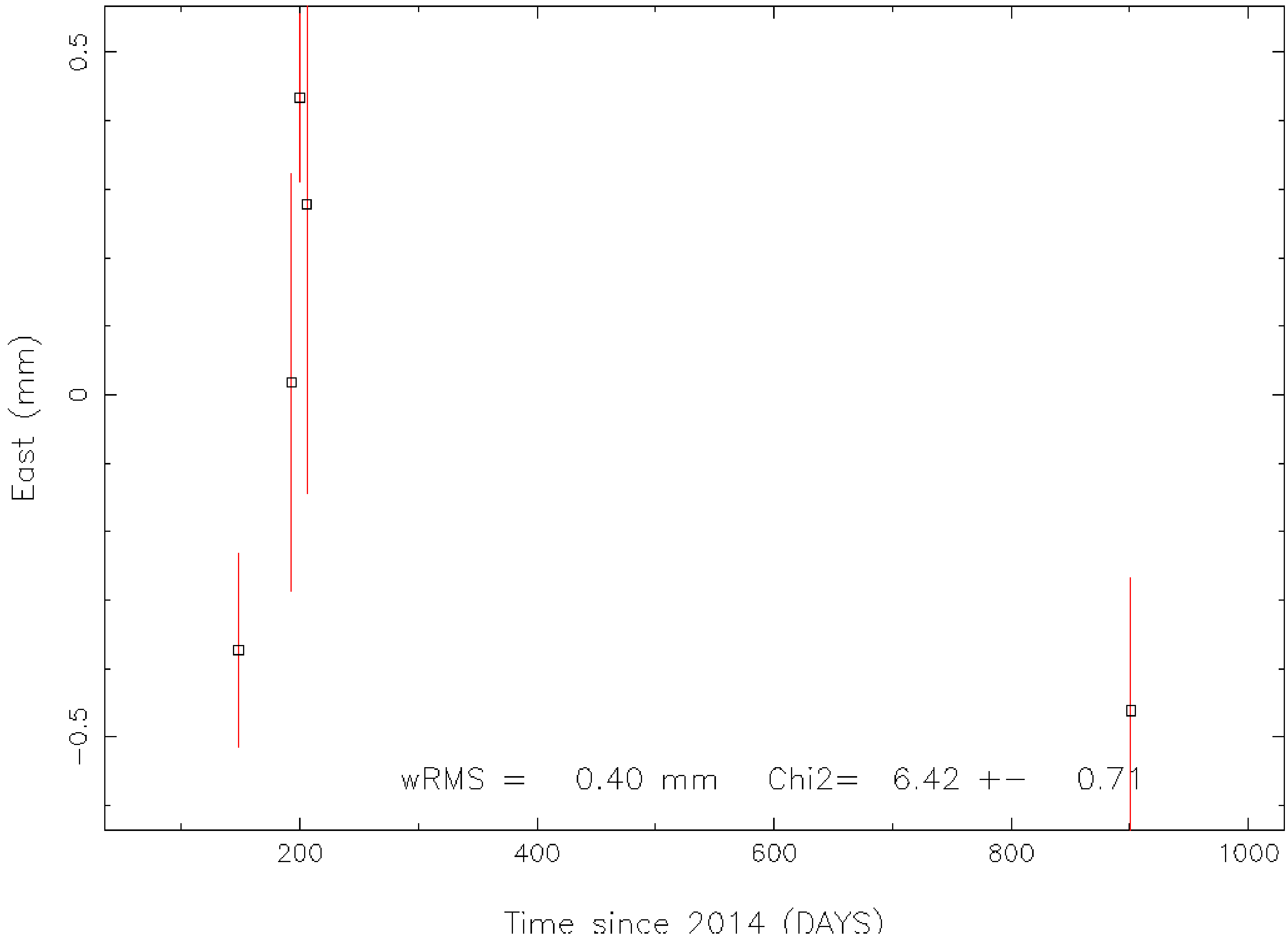
~ 0.5 mas for ICRF2

CDSCC Twin Telescope Test (DSS34-35, DSS34-36)

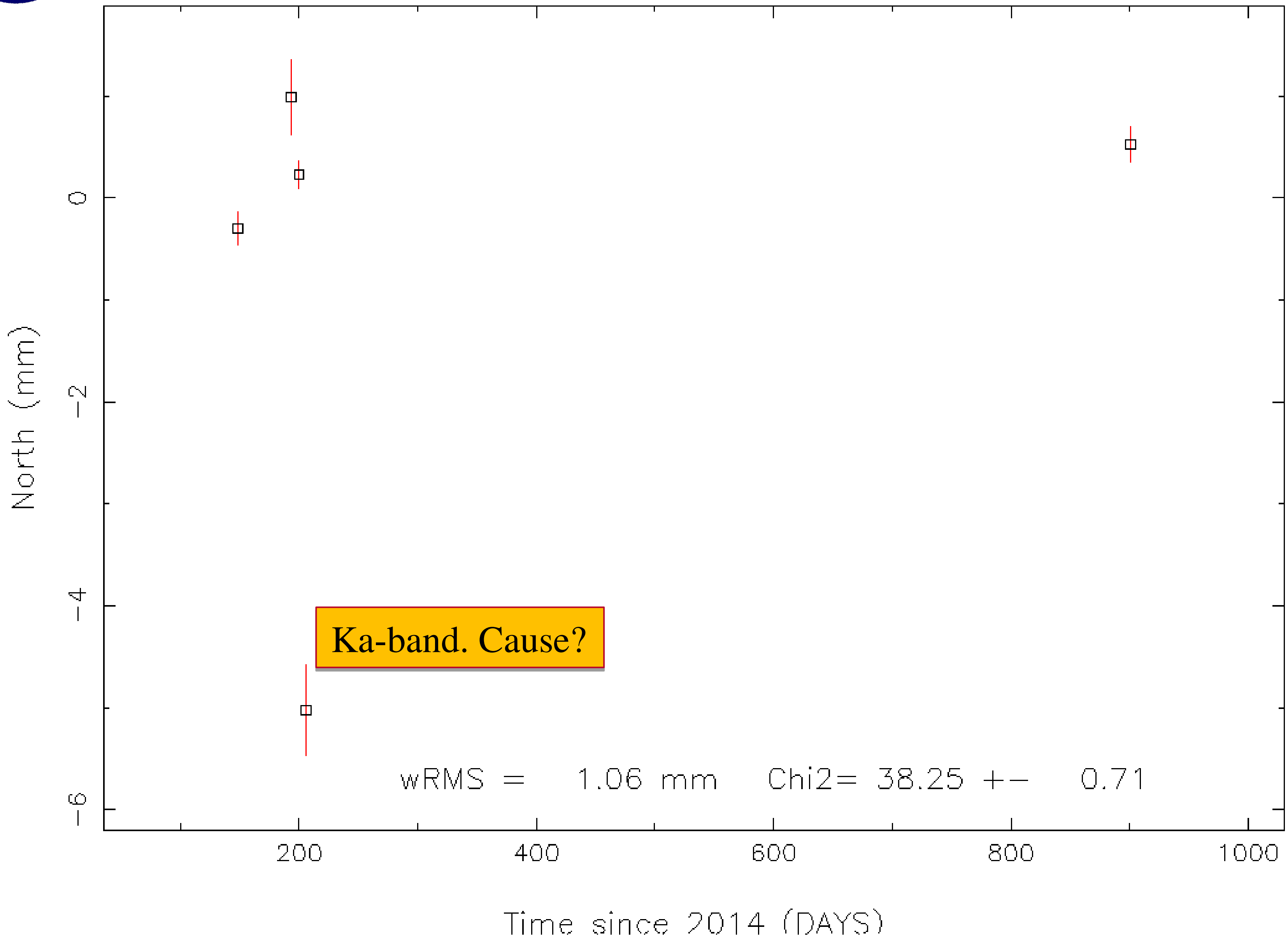


DSS 34, 35, 36 (34m)	**Common:**	**Different**
Beam-waveguides	Mechanical	last few 100m of cabling
“identical” design	Clock	local geophysics
X/Ka-bands	approx. troposphere	local hydrology
	approx. geophysics	out of spec instrumentation?

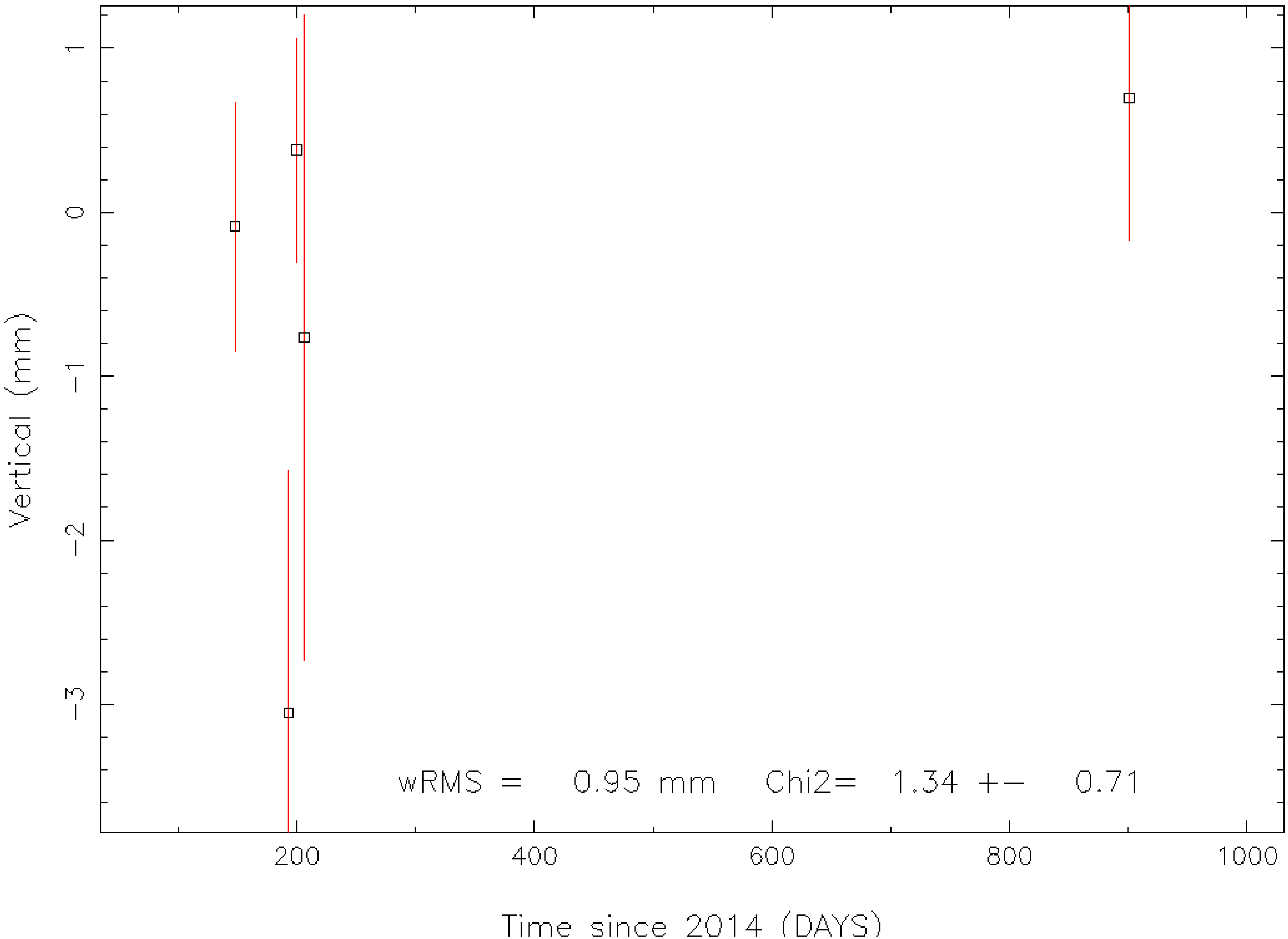
DSS 34 to DSS 35: East Component



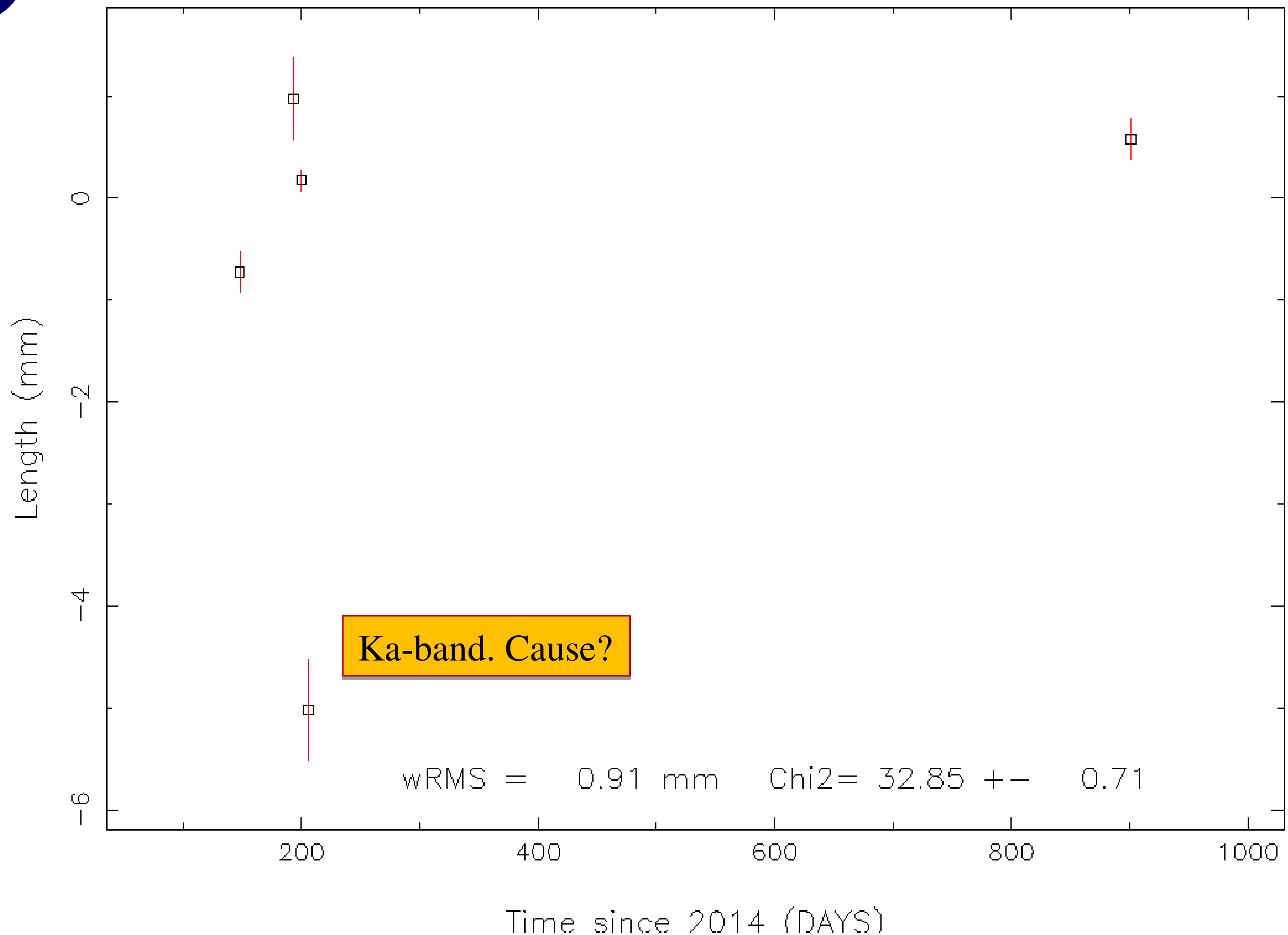
DSS 34 to DSS 35:   North Component



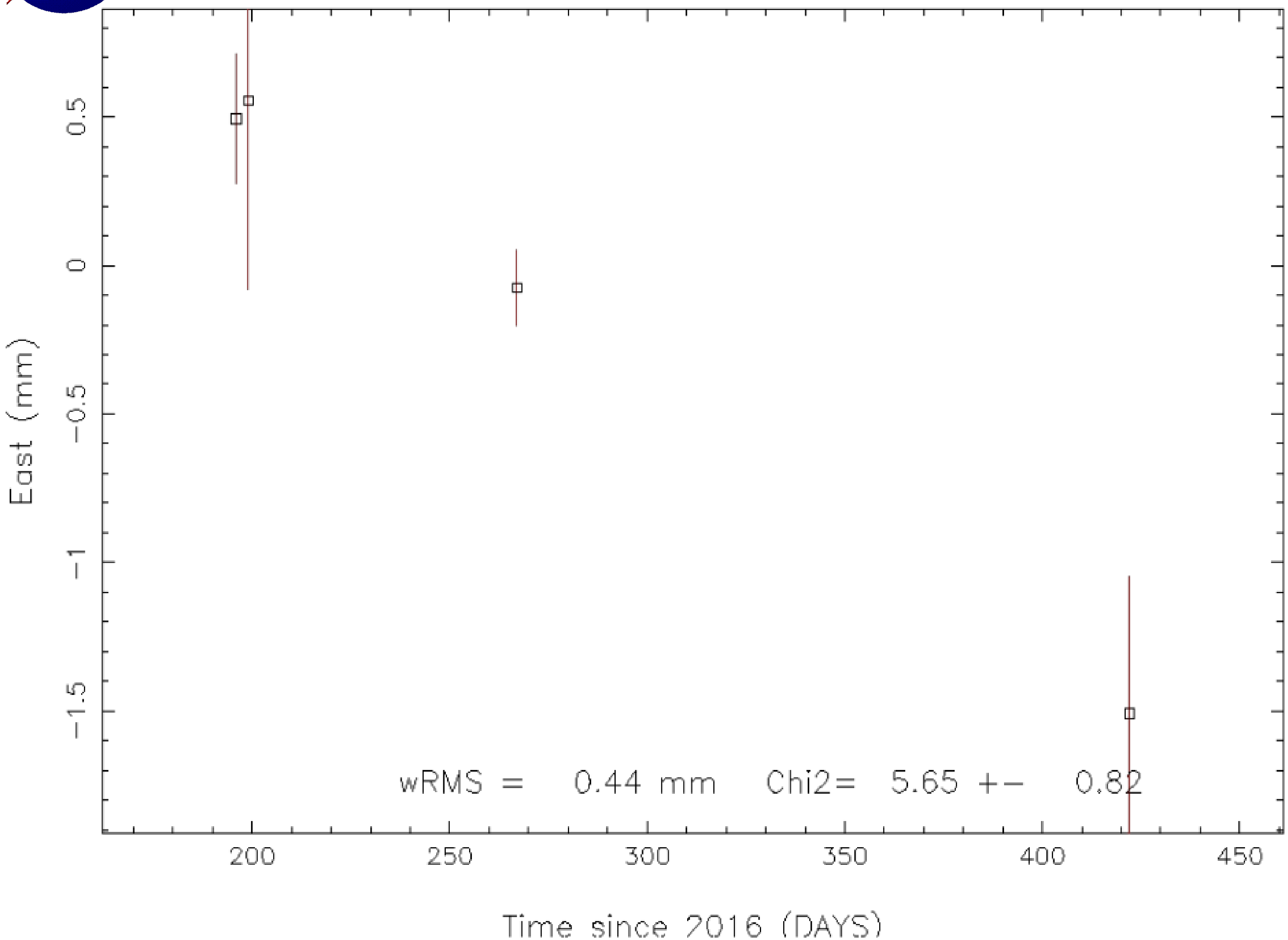
DSS 34 to DSS 35: Vertical Component



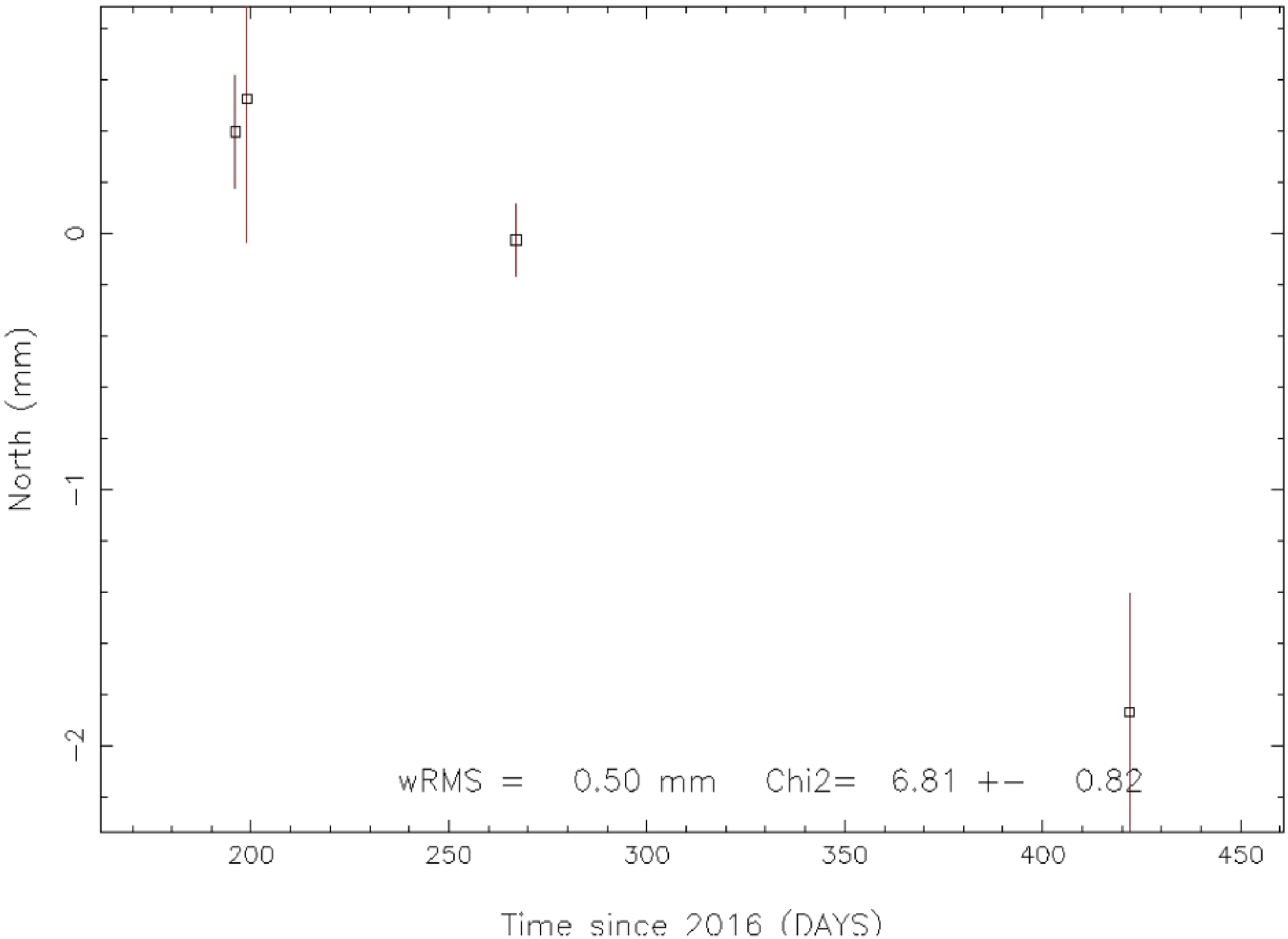
DSS 34 to DSS 35: Length Component



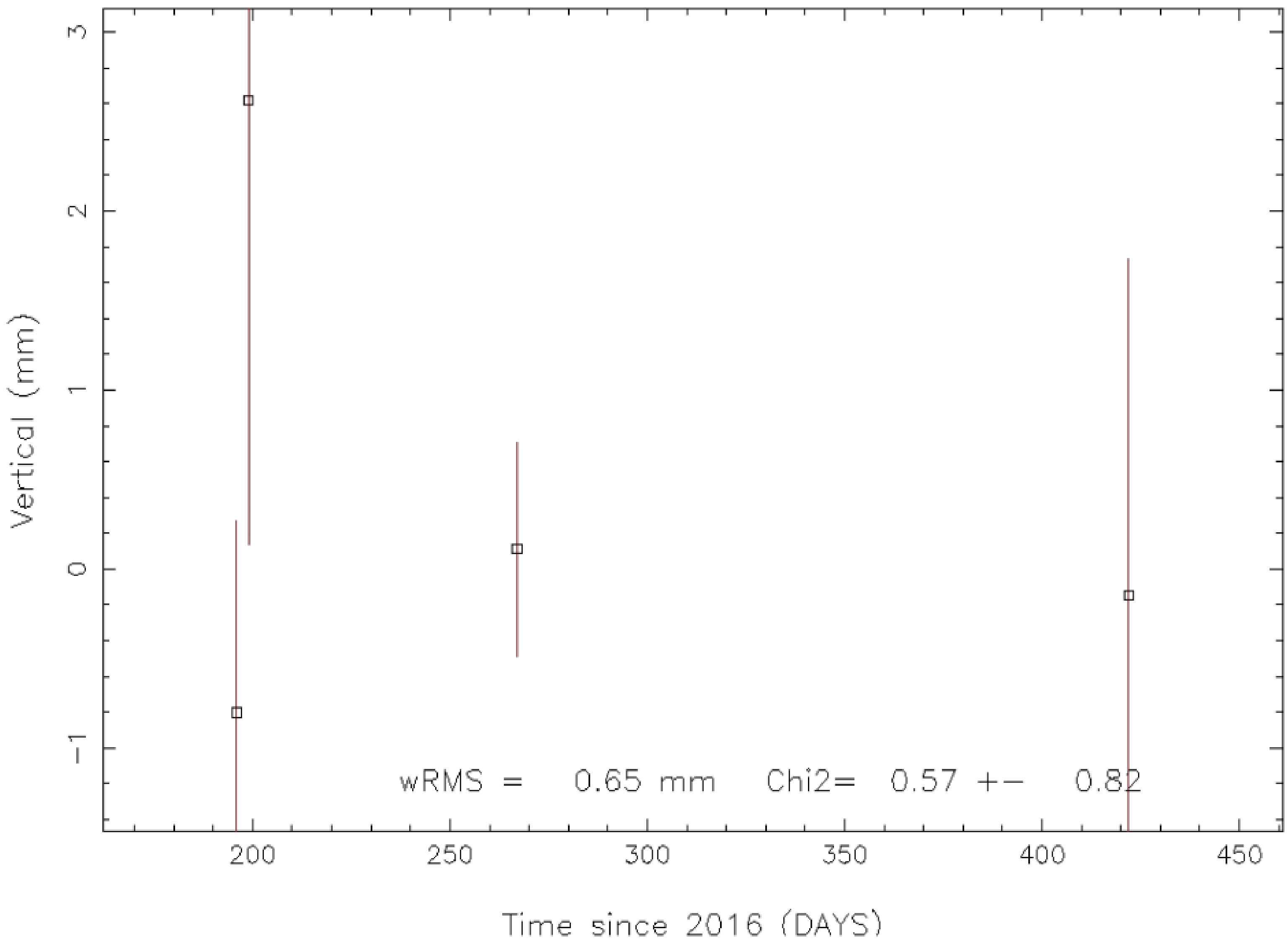
DSS 34 to DSS 36:   East Component



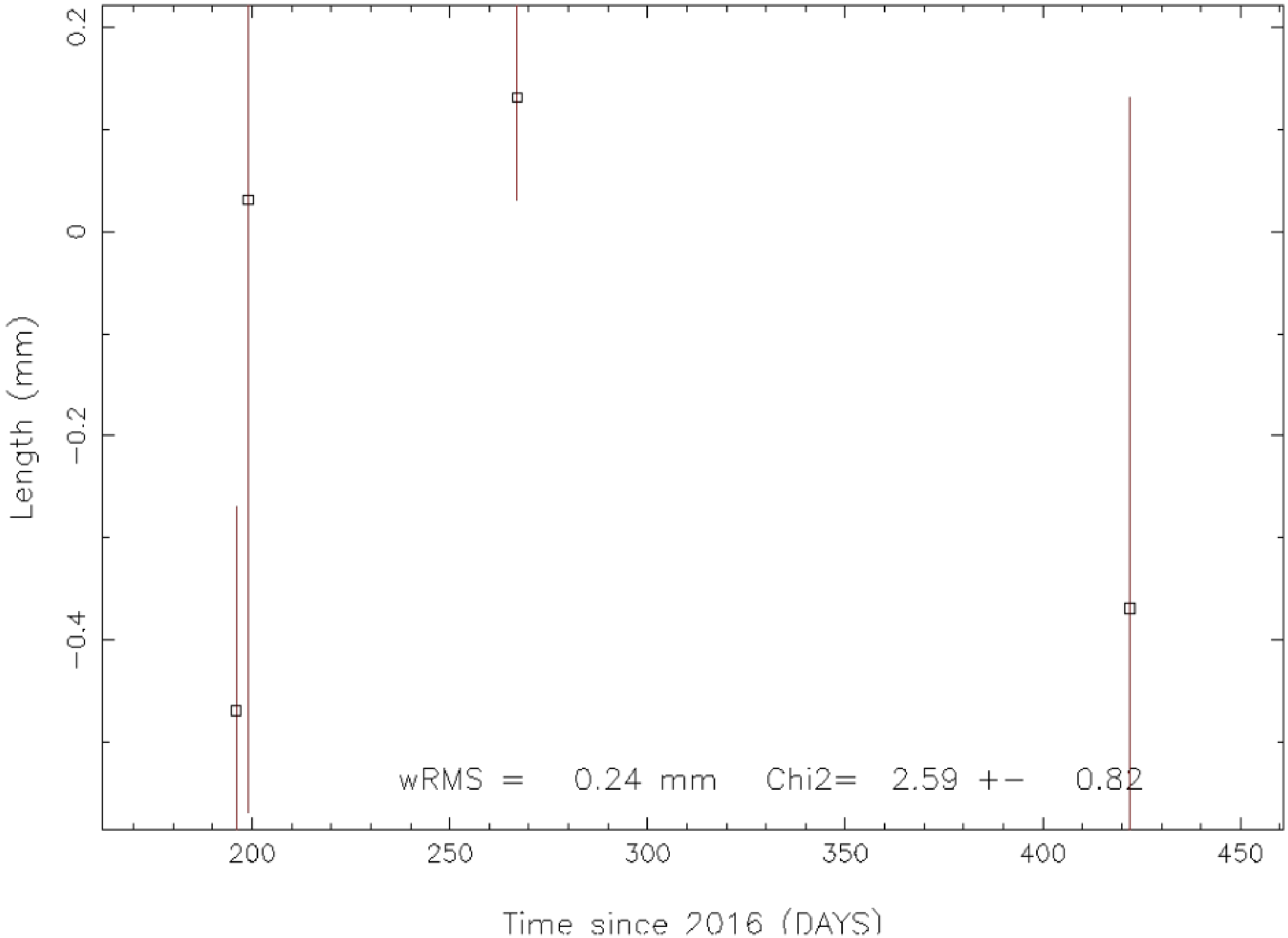
DSS 34 to DSS 36: North Component



DSS 34 to DSS 36: Vertical Component



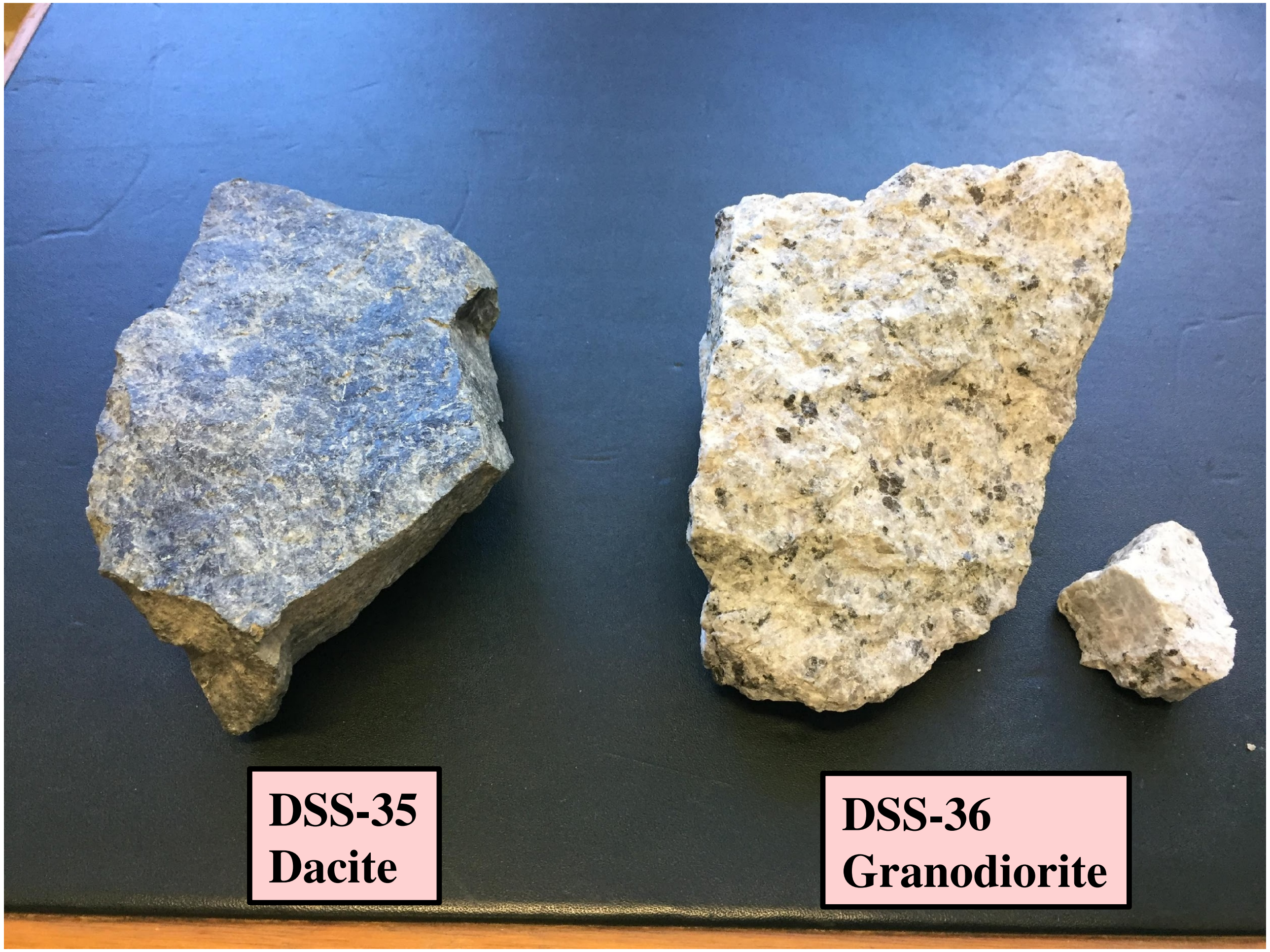
DSS 34 to DSS 36: Length Component



Foundation of DSS-36 under construction

Can the foundation slide horizontally?
Are there local micro-faults? Very local ground water changes?

Rocks under DSS-35 and DSS-36



Soft and fragile rocks (granodiorite) under DSS-36 will affect in longer term?

Lifting up dish on DSS-35 under construction

Can the foundation slide horizontally?
Are there local micro-faults? Very local ground water changes?

Summary of the Twin Telescope Tests

- **Goal:** to isolate telescope to telescope variations by measuring in an environment where most error sources common mode away.

- **Results:**
  A series of short baseline connected element interferometry passes
  8 passes at DSN Canberra (cf. 5 passes DSN Madrid, Jacobs+, 2017)
  1 to 4 mm delay scatter

- Canberra baselines are generally stable at near the +-1 mm level

- DSS34-36 baseline shifts horizontally at the 2 mm/yr level?

- Work is ongoing. Seasonal effects? Outliers? Need bigger sample.

XKa vs SX VLBI reveals zonal differences: Δα cosδ ~ cos2δ

this is quadrupole 2,0 term

Zonal Errors

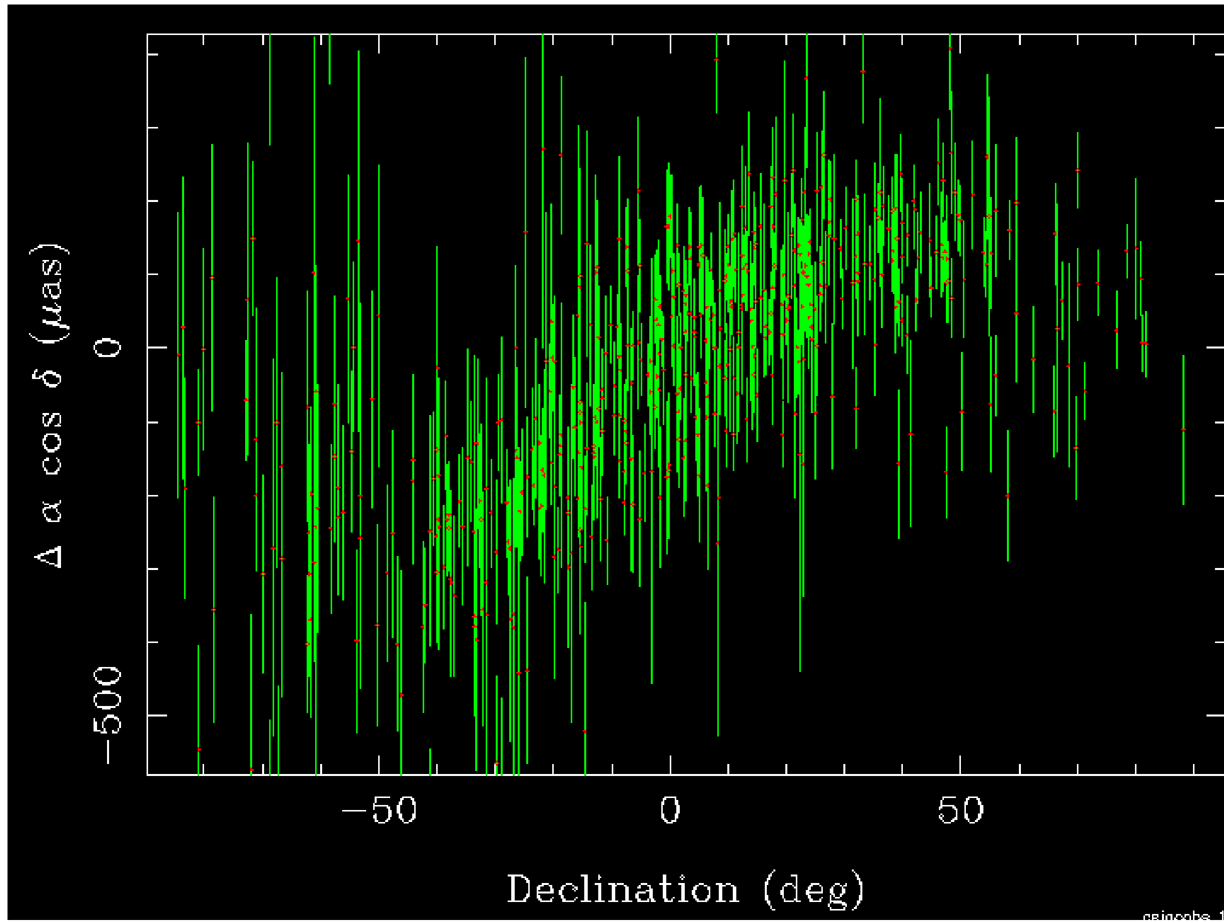
- ΔRA vs. Dec:
  ~300 μas in south, 200 μas in north

- Need 2 baselines to get 2 angles:
  California-Canberra: 31K obs
  California-Argentina: 2K obs

-> Need more California-Argentina data to overcome this 13 to 1 distortion in sampling geometry. ESA's Malargüe is key.

- Usuda, Japan 54-m XKa (2019) would improve North-South sampling geometry and thus control declination zonal differences.

XKa vs. SX: Zonal errors



Credit: SX astrometry, D. Gordon

Thank you for attention.

Overview:

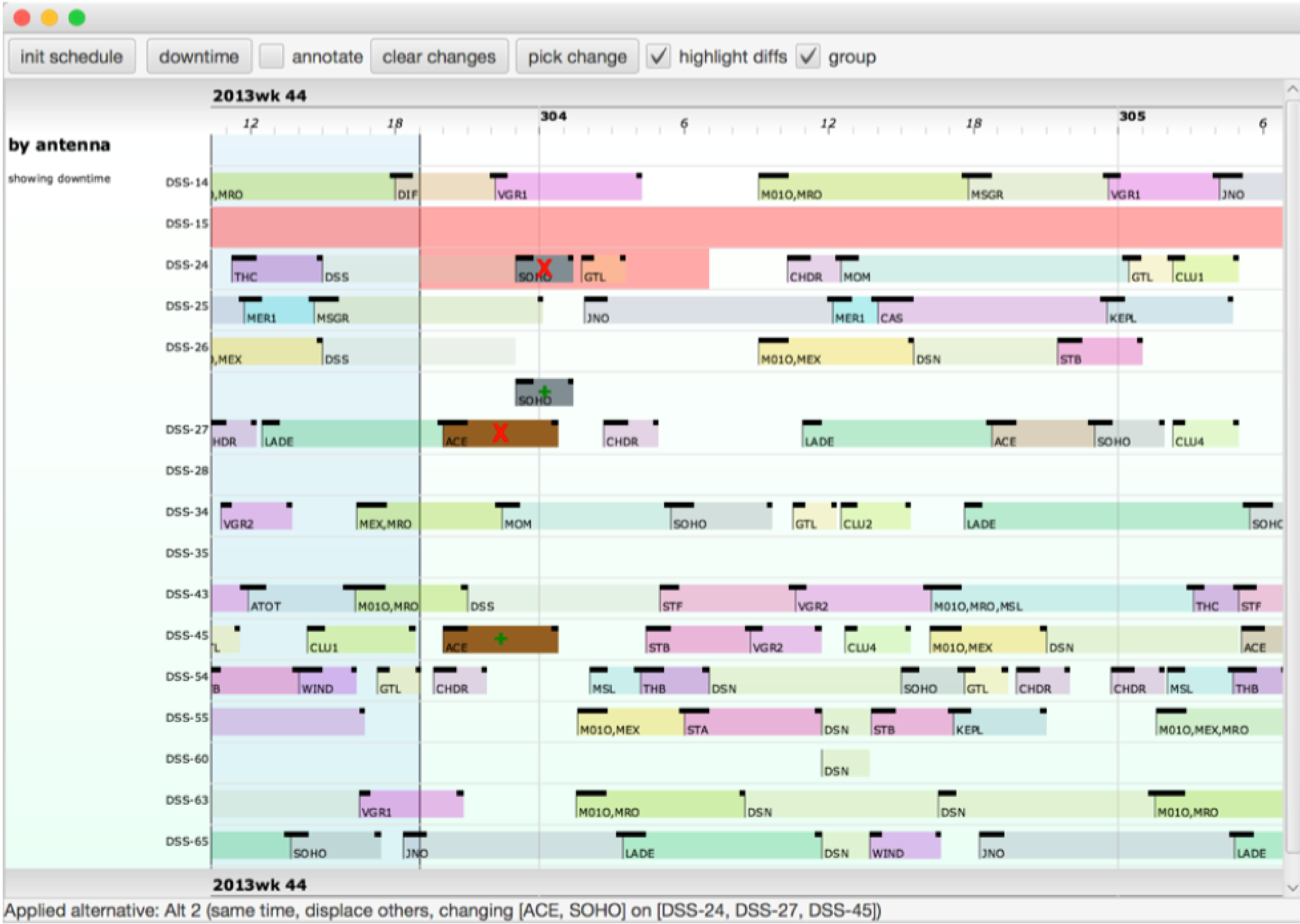
- Introduction to CDSCC, Tidbinbilla, Australia

- The Follow-the-Sun Operation the NASA's DSN

- VLBI Radio Astronomy Projects at CDSCC
  1) DSN Reference Frame Catalogue Projects
  2) LBA

- CDSCC Short Baseline VLBI Testing

- Outlook



init schedule
downtime
annotate
clear changes
pick change
highlight diffs
group
2013wk 44
304
305
by antenna
showing downtime
DSS-14
DSS-15
DSS-24
DSS-25
DSS-26
DSS-27
DSS-28
DSS-34
DSS-35
DSS-43
DSS-45
DSS-54
DSS-55
DSS-60
DSS-63
DSS-65
2013wk 44
Applied alternative: Alt 2 (same time, displace others, changing [ACE, SOHO] on [DSS-24, DSS-27, DSS-45])