Observation Overview

Welcome to the Grand Finale Orbits!
- Just 8 RSS observations remaining (not including EOM occultation)
- Extremely busy, but very exciting, two months ahead

- S99 Rev 273 RSS observations
  - Include
    - Gravity observation (24hrs in duration)
    - Periapse ring occultation
    - Distant ingress and egress ring occultations
  - 2-way/3-way mode
  - Periods of Telemetry OFF, Ranging OFF, 2-way/3-way mode (during occultations)
  - Playbacks planned during gravity observation when TLM is not off
  - Eight tracks scheduled
    - Seven DSN, one ESA
  - Observation is preceded by a downlink track over Canberra

Science Highlights

Gravity Observation - From Luciano less

Rev 273 is the first of six orbits devoted to the determination of Saturn's gravity field and the mass of the B ring. The spacecraft will collect gravity and magnetic field data from a distance as close as 3000 km from the cloud level. Those data are crucial to build interior models of the planet and to determine the depth of zonal winds.

The Cassini radio science investigation will measure Saturn gravity field and the ring mass by means of range rate measurements enabled by the onboard X band (7.2-8.4 GHz) radio system, and the antennas of NASA's Deep Space Network and ESA's tracking network. The gravity determination is obtained by fitting the radial velocity of the spacecraft with accuracies of about 0.05 mm/s (at a time scale of 60 s) with a model of the spacecraft dynamics. Due to the large Doppler rate, the measurements are aided by predictions obtained from a model of the orbital dynamics.

Cassini orbital geometry is crucial for the gravity experiment. The highly eccentric 6-day orbit has a pericenter close to Saturn's clouds, within the inner edge of the rings. With Cassini passing between the rings and the planet, Cassini will be able to disentangle the strong acceleration due to Saturn's oblateness from that due to tiny pull of the rings. In addition, going close to Saturn Cassini will be affected by tiny density inhomogeneities inside the planet, thus providing clues on their structure.

Cassini gravity passes will be able to provide the density distribution inside Saturn. In particular, it will tell us how massive the core is (we are expecting something like 20 Earth masses of heavy elements in the central part of the planet). The gravity field of Saturn as measured by Cassini depends on how mass is distributed inside the planet. We may imagine that layers of different densities give different contributions to the total gravity. However, it is only the fast rotation of the planet that makes the shape oblate and generates sufficient latitudinal gravity variations to allow inferring the density profile at depth. We know the planet's bulk density from it's mass and radius. (Radius gives us the volume.) The gravity field yields the density as a function of radius in the H/He envelope of the planet. So, in a sense, since we know the density of the whole planet, and the density of the H/He envelope, we can infer that we are, or are not, "missing" mass in the deep interior of the planet, based on how dense the H/He mixture would be extended to very deep interior conditions. If we are missing mass, one can calculate out how much that is, and that is the core mass.

Science Highlights Cont'd

Gravity Observation Cont'd - From Luciano less

The tiny pull of the hemispherically asymmetric gravity field we'll also allow Cassini to tell us how deep the winds are inside Saturn. We know that the winds at the cloud level are up to 300 km/h strong, but we do not know if the flow goes down to just 100, or 1000, or even 10000 km. This is another important science goal of the Grand Finale.

The mass of the rings (concentrated mostly in the B ring) remains uncertain. Its value, generally expressed in terms of Mimas masses, bears crucial information on how and when the rings formed, and their relation with Saturn and its moons. Models predict that a large ring mass implies that the rings are old, dating back to the formation of the Saturnian system 4.5 billion years ago. A small mass implies that the rings are much younger, possibly formed by the impact with a comet.

By the end of July Cassini will tell us a lot about the interior structure and the formation of the Saturnian system. We are anxious to analyse the data, and proud to be part of this endeavor which sees the effort of so many people in the Project and the DSN.

Science Highlights Cont'd

Ring Occultations - From Essam Marouf

The Rev 273 RSS periapse, ingress, and egress ring occultations are the first group in a unique Grand Finale (Proximal Orbits) campaign of Cassini radio occultations of Saturn's ring system. The campaign takes advantage of occultation track geometry that systematically sweeps across the ring system. Collectively, the occultation tracks capture a spread in: 1) Earth relative longitude , and 2) inertial ring longitudes. The first allows characterization of the virtual azimuthal ring asymmetry due to gravitational wakes known to permeate Rings A and B. The second allows characterization of true azimuthal ring asymmetry driven by ring dynamics, including sharp edges and resonant interaction with the satellites and with Saturn's interior structure. Also unique about the campaign is that the rings are close to their maximum opening angle (B~26-27°) as seen from the Earth, possible only near the 2017 epoch of the Proximal Orbits. The large *B*-angle allows maximum penetration of the radio signals of optically thick features, especially Ring B, the many density and bending waves everywhere, confined optically thick ringlets including the Ring C plateaus. Radio occultations enjoy the advantage of measurements using three coherent observation wavelengths (0.94, 3.6, and 13 cm; Ka-, X-, and S-band), allowing not only profiling of ring structure but also constraining the structures physical properties.

The Grand Finale campaign includes ring occultations on the 6 RSS gravity orbits (Revs 273, 274, 275, 278, 280 and 284) and two on Rings segments (Revs 276 and 282). The 6 on the gravity orbits include never before attempted close occultations observing the rings from a distance < ~1 RS near orbit periapse. Dubbed "periapse ring occultations," they start almost immediately after Cassini dives through the ring plane and are short in duration (< 26 m) but cover the complete main ring system. High spatial resolution scattered and direct signals measurements are expected because of the small HGA footprint and the small Fresnel scale, respectively. The collective ring coverage of the RSS Grand Finale occultations is unprecedented in the Cassini Mission.

DSN and ESA Antennas

- DSN Coverage

		Pre	BOT	EOT	Post				
17	128	0940	1110	2315	2330	DSS-35 CAS	TP RSS GRAV L3	7165 N750	1A1
17	128	1010	1110	1930	1945	DSS-43 CAS	TKG PASS	7165 N003	1A1
17	128	2125	2255	0645	0700	DSS-55 CAS	TP RSS GRAV L3	7165 N750	1A1
17	129	0000	0045	1130	1145	DSS-84 CAS	RSS ESA	7165 0142	1A1
17	129	0440	0610	1440	1455	DSS-25 CAS	RSS GRAV L3	7165 N748	1A1
17	129	0510	0610	1440	1455	DSS-14 CAS	RSS GRAV L3	7165 1647	1A1
17	129	0845	1015	2200	2215	DSS-35 CAS	RSS GRAV L3	7166 N750	1A1
17	129	0910	1010	2200	2215	DSS-43 CAS	RSS GRAV L3	7166 1647	1A1

- DSS-35, DSS-55, DSS-84, DSS-14 and DSS-43 will be providing the uplink

Receivers scheduled

- 2 closed-loop receivers per antenna
- DSN Open-loop receivers (RSRs, WVSRs, VSRs, PRSRs)
- PRSR at Malargue
- Open-loop data are prime for occultations. Closed-loop data are prime for gravity
  - Gravity will also use open-loop data
- Only RCP will be recorded
  - 2-way/3-way and 1-way modes

S99 Rev 273 Open-Loop Receiver Assignment

DSS Prdx Mode	Operator (S) Scripted By	Ops Machine	Open-loop Receiver	Channels	Subchannels	Bandwidths KHz
DOY 128						
35 1-/2-way	Elias/Danny/ Clement (S)Elias	rsops1	RSR1	RSR1A -> XRCP RSR1B -> KRCP	1, 2, 3, 4 1, 2, 3, 4	1, 16, 50, 100 1, 16, 50, 100
35 1-/2-way	Danny (S)Danny	rsops4	WVSR1	WVSR1A -> XRCP WVSR1B -> KRCP	1, 2, 3, 4 1, 2, 3, 4	1, 16, 50, 100 1, 16, 50, 100
35 1-/2-way	Danny (S)Danny	rsops4	WVSR2 Precision Mode	WVSR2A -> XRCP WVSR2B -> KRCP	1, 2, 3, 4 1, 2, 3, 4	1, 16, 50, 100 1, 16, 50, 100
43 1-/3-way	Elias/ Danny (S)Elias	rsops1	RSR2	RSR2A -> XRCP	1, 2, 3, 4	1, 16, 50, 100
55 1-/2-/3-way	Clement (S)Clement	rsops1	RSR2 RSR1	RSR2A -> XRCP RSR1B -> KRCP	1, 2, 3, 4 1, 2, 3, 4	1, 16, 50, 100 1, 16, 50, 100
55 1-/2-/3-way	Danny/Aseel (S)Danny	rsops4	WVSR1	WVSR1A -> XRCP WVSR1B -> KRCP	1, 2, 3, 4 1, 2, 3, 4	1, 16, 50, 100 1, 16, 50, 100
55 1-/2-/3-way	Danny/Aseel (S)Danny	rsops4	WVSR2 Precision Mode	WVSR2A -> XRCP WVSR2B -> KRCP	1, 2, 3, 4 1, 2, 3, 4	1, 16, 50, 100 1, 16, 50, 100
DOY 129						
84 2-/3-way	Aseel	rsops6/ psdg5	PRSR 168.96.250.72	PRSR -> XRCP	1, 2, 3, 4	1, 16, 50, 16
14 2-/3-way	Elias/Clement (S)Elias	rsops2	RSR3	RSR3A -> XRCP RSR3B -> SRCP	1, 2, 3, 4 1, 2, 3, 4	1, 16, 50, 16 1, 16, 50, 100
14 1-way	Jay/Danny (S)Jay	rsops5	WVSR2	WVSR2A -> XRCP WVSR2B -> SRCP	1, 2, 3 4, 5, 6, 7 8, 9 1, 2, 3 4, 5, 6, 7	1, 16, 50 1, 16, 50, 100 (with offset) **1, 16** (with offset) 1, 16, 50 1, 16, 50, 100 (with offset)

S99 Rev 273 Open-Loop Receiver Assignment

DSS Prdx Mode	Operator	Ops Machine	Open-loop Receiver	Channels	Subchannels	Bandwidths KHz
25 2-/3-way	Elias/Danny (S)Elias	rsops2	RSR1	RSR1A -> XRCP RSR1B -> KRCP	1, 2, 3, 4 1, 2, 3, 4	1, 16, 50, **16** 1, 16, 50, **16**
25 2-/3-way	Elias (S)Elias	rsops2	RSR2 Precision Mode	RSR2A -> XRCP RSR2B -> KRCP	1, 2, 3, 4 1, 2, 3, 4	1, 16, 50, **16** 1, 16, 50, **16**
25 1-way	Jay/Danny (S)Danny	rsops3	VSR1	VSR1A -> KRCP	1, 2, 3, 4	1, 16, 50, 100 (with offset)
43 2-/3-way	Elias/Clement (S)Clement	rspos1	RSR1	RSR1A -> XRCP RSR1B -> SRCP	1, 2, 3, 4 1, 2, 3, 4	1, 16, 50, **16** 1, 16, 50, **16**
43 1-way	Jay/Danny (S)Jay	rsops4	WVSR1	WVSR1A -> XRCP 1, 2, 3 4, 5, 6, 7 WVSR1B -> SRCP 1, 2, 3 4, 5, 6, 7	1, 16, 50 1, 16, 50, 100 (with offset) 1, 16, 50 1, 16, 50, 100 (with offset)
35 2-/3-way	Elias/Danny (S)Clement	rsops1	RSR2	RSR2A -> XRCP RSR2B -> KRCP	1, 2, 3, 4 1, 2, 3, 4	1, 16, 50, **16** 1, 16, 50, **16**
35 1-way	Jay/Danny (S)Jay	rsops4	WVSR2	WVSR2A -> XRCP 1, 2, 3 4, 5, 6, 7 WVSR2B -> KRCP 1, 2, 3 4, 5, 6, 7	1, 16, 50 1, 16, 50, 100 (with offset) 1, 16, 50 1, 16, 50, 100 (with offset)

WVSR1A at Goldstone unavailable (being used by VLBI)
PRSR1 at Madrid is backup
VSR1 at Canberra is backup
No precision mode recordings at DSS-35 on DOY 129

Don't record
Same fgain throughout (use TLM off fgain)
Re-set fgain when TLM is off at 06:41:55 and don't change

DSN Open-Loop Receiver Status

Email from Danny on 4/12

Goldstone

RSR1 – Green (X-band power jumps observed on RSR1A)
RSR2 – Green with date rate != num_samples warnings
RSR3 – Green
VSR1A – "Orange" - DP Internal Error Error may occur; try restarting; reliability in question
VSR1B – "Red" - DP Internal Error Error may occur; try restarting; reliability in question
WVSR1 – Green w/ with fgain bug
WVSR2 – Green w/ with fgain bug
No PRSR

Canberra

RSR1 – Green
RSR2 – Green
VSR1 – Green
PRSR1 –Red
WVSR1 – Green w/ with fgain bug
WVSR2 – Green w/ with fgain bug

Madrid

RSR1A – Red but can be used by overriding dig vfy test
RSR1B - Green
RSR2A – Green
RSR2B – Digitizer test fails due to unknown cause. Can be used by overriding dig vfy test
VSR1 – Red
PRSR1 – Green
WVSR1 – Green w/ with fgain bug
WVSR2 - Green w/ with fgain bug

Real-Time Support

RSSG will be in Ops Room at 2:30 am on Monday, May 8 (128/0930)
- Last post-cal ends at 3:15 pm on Tuesday, May 9 (129/2215)
- 37 hours!!!

Observation is preceded by a downlink track over Canberra
- DSN level 3 support begins at 128/09:40:00 (Mon, May 8, 2:40 am)
  - DSS-35 Pre-cal
- Official start of gravity observation is not until 128/19:33:31 (Mon, May 8, 12:33 pm)
- Level 3 starts earlier because DSS-35 will be providing uplink for gravity
  - If no downlink period, gravity uplink start time would be 16:59:47 (Mon, May 8, 9:59 am)
- Monitor beginning of DSS-35 track and if all is nominal, return before gravity start of uplink time?

NOA support?

ACE support?

Predicts

- Last NAV OD delivery was on April 23 (prior to OTM-470 and right after T126)
- Next scheduled delivery in May 9 (could be delivered on May 8), but too late to use
- NAV is willing to make another delivery today for predicts generation
  - Includes two tracks after T126 and after periapse
  - They were planning on making an unofficial delivery, but will make it official by delivering to SPS
  - Will have review meeting at 1:30 and deliver soon after
- RSS will not be modifying the uplink predicts
- Lu: Can you please ask SPS to provide uplink predicts tomorrow (Wed)
- Elias and Danny will generate and verify the open-loop downlink predicts
- RSS usually uses three sets of downlink predicts in the open-loop receivers for occultations:
  - #1: Coherent (2-way/3-way)
  - #2: 1-way coherent:1-way predicts offset in real-time to coherent downlink frequency
  - #3: 1-way (no offset): For 1-way baseline and when the DST loses lock (for example, dense ring regions)
- If an additional receiver is available, will record in high precession mode for gravity

ORTs

ORT on DOY 113 (April 23) over DSS-25, X- and Ka-band Completed

17 113 0545 0715 1545 1600 DSS-25 CAS RSS OCCORT MC 7149 N748 1A1

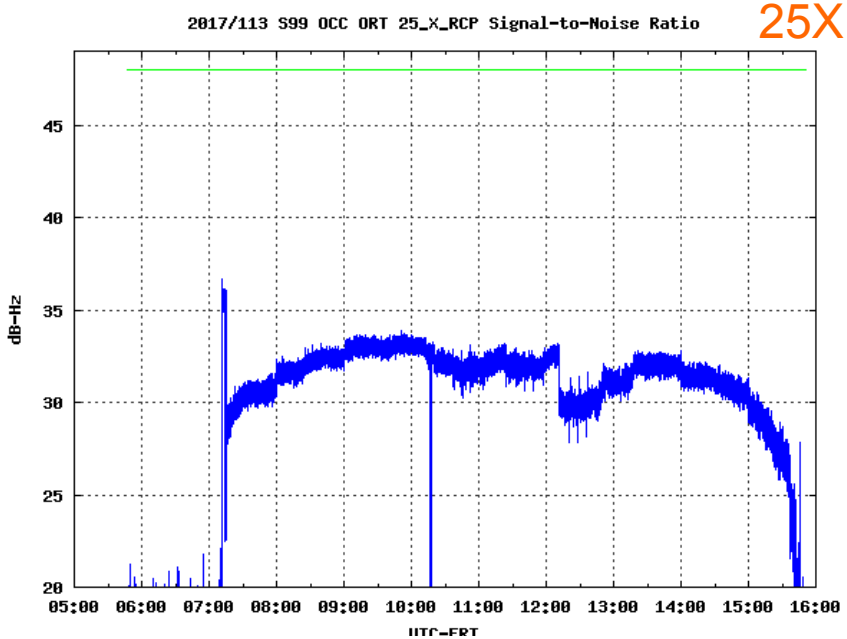
17 113 0615 0715 1545 1600 DSS-14 CAS TKG PASS 7149 N003 1A1

- Shadow DSS-14 (prime TP)
- DSS-25 return from downtime
  - Ka-band HEMT was replaced
  - On-point phase cals needed to update the Tau value
- Monopulse on-point phase calibrations performed
- Pointing data acquired and sent to David for assessment
- ESA Malargue (DSS-84) test track was added

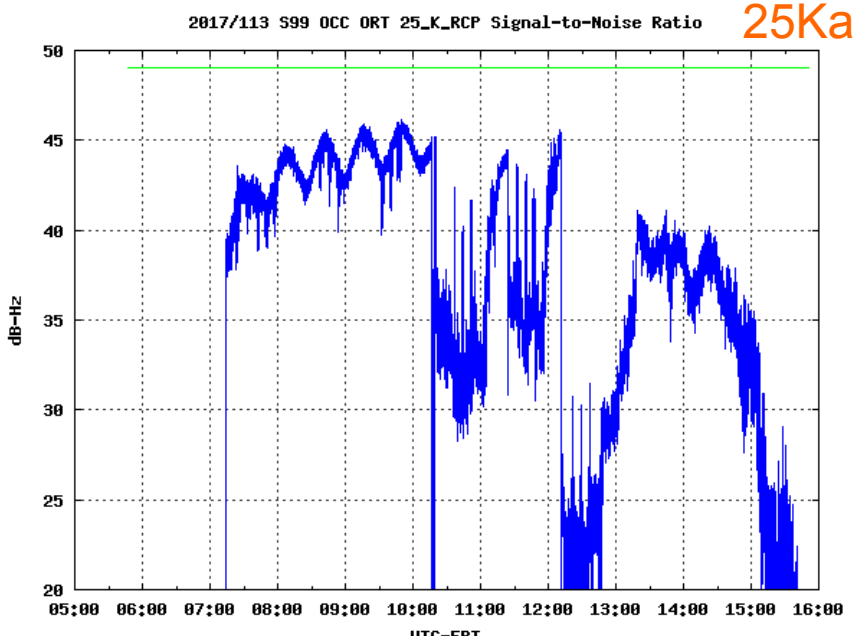
  BOT 1040, EOT 1325
- First ESA PRSR recording of rolling downlink
  - Stable Ka-band signal
  - No Monopulse!

DOY 113 ORT Cont'd

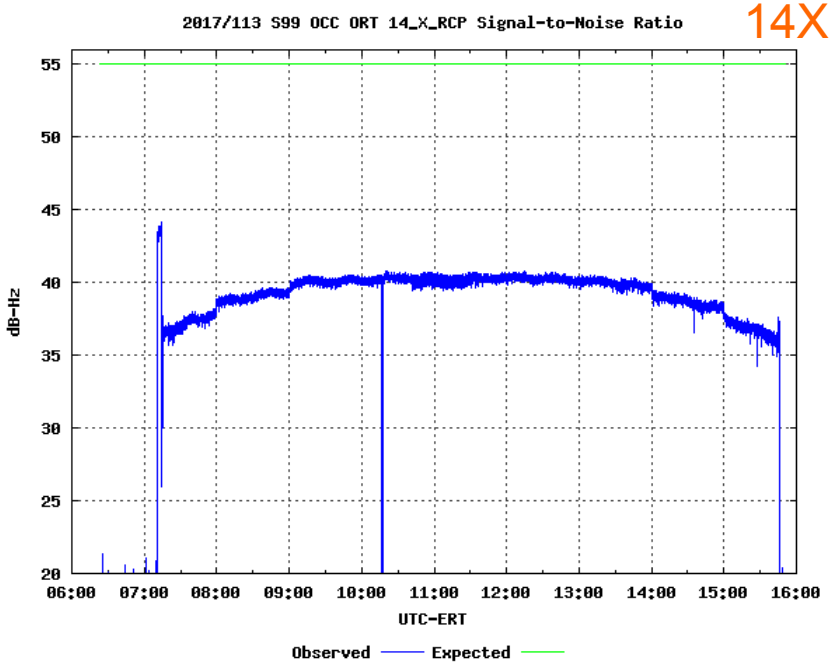
25X



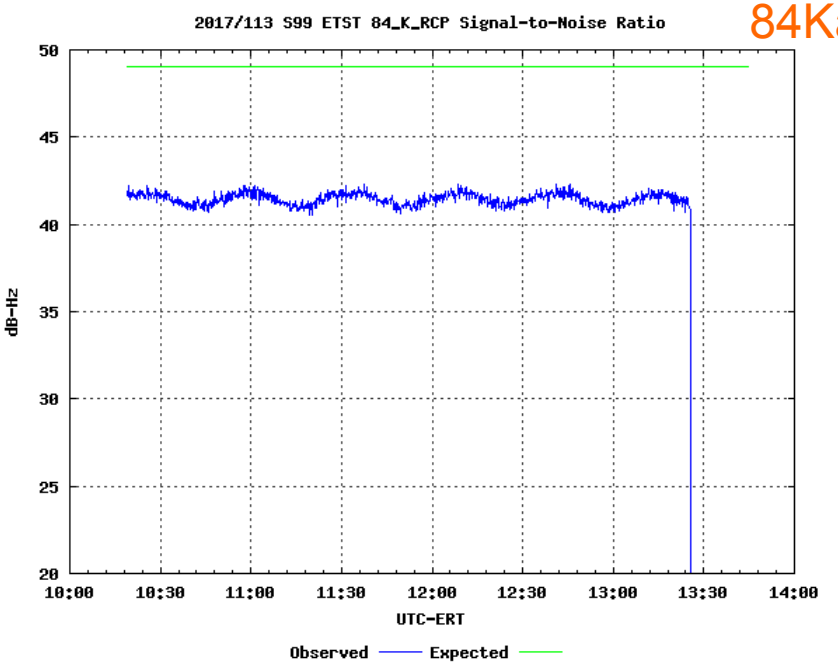
25Ka



14X



84Ka



ORTs cont'd

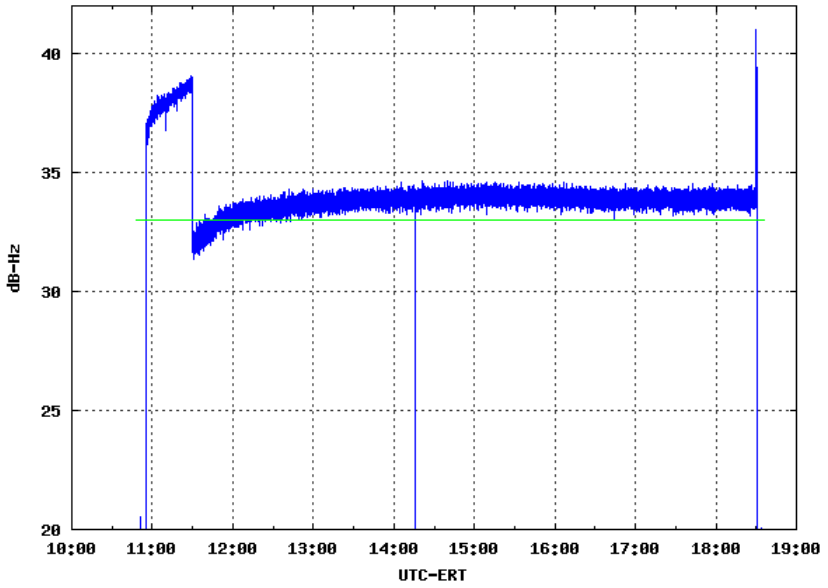
ORT on DOY 120 (April 30) over DSS-35 and DSS-25, X- and Ka-band Completed

17 120 1000 1130 1520 1535 DSS-25 CAS RSS OCCORT MC 7156 N748 1A1
17 120 1000 1130 1830 1845 DSS-35 CAS TP RSS OCCORT MC 7157 N750 1

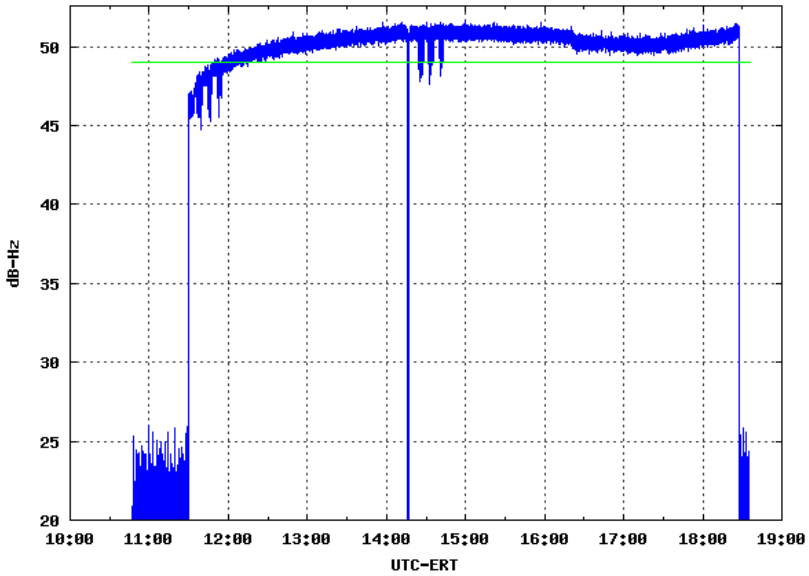
- DSS-35 also prime TP
- Verified Monopulse
- Stations conducted on-point phase calibrations
- Acquire pointing data and sent to David for assessment

DOY 120 ORT Cont'd

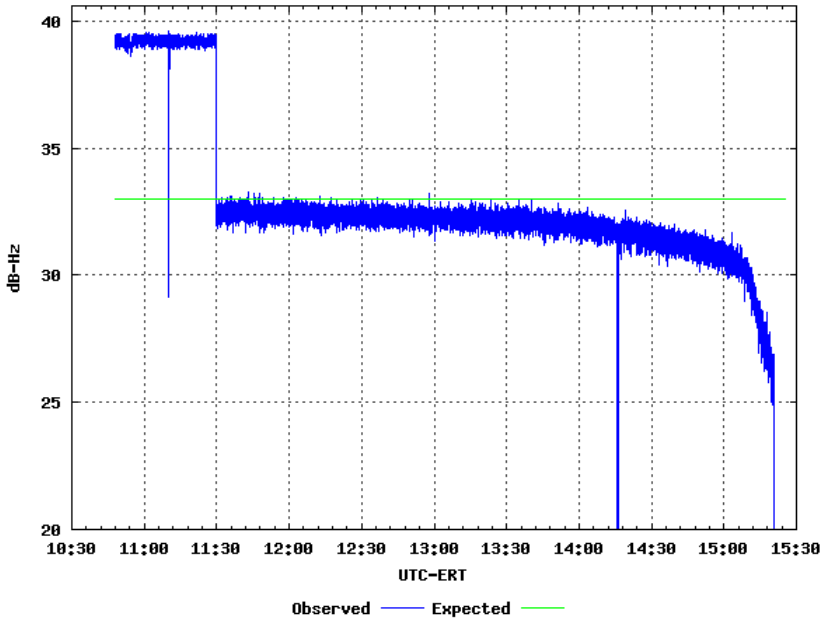
35X



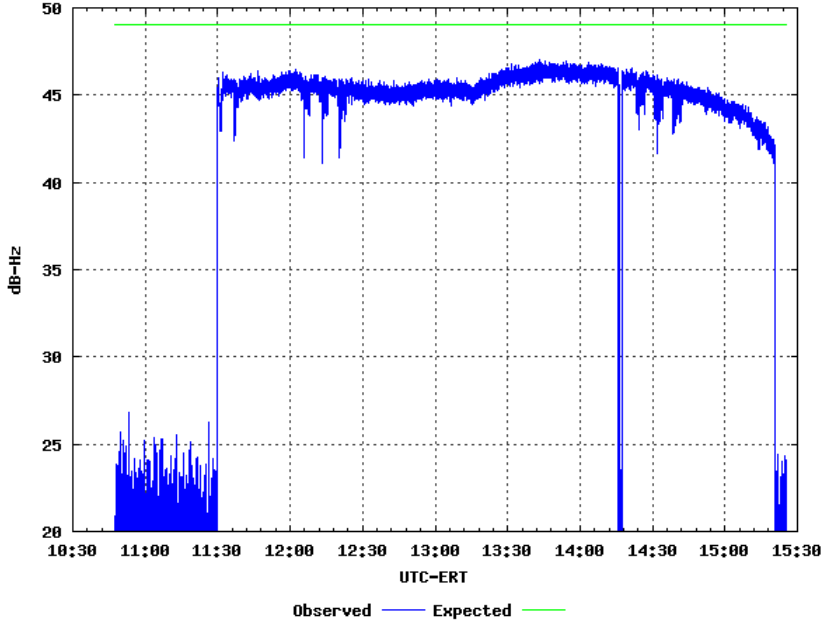
35Ka



25X



25Ka



ORTs cont'd

Upcoming

DSN Monopulse cal on DOY 124 (May 4) over DSS-34 and DSS-25, X- and Ka-band

17 124 1105 1235 1500 1515 DSS-25 CAS RSS MONCAL 7160 N748 1A1
17 124 1105 1235 2135 2150 DSS-34 CAS TP RSS MONCAL 7161 N750 1A1

- DSS-34 is prime TP (not part of Rev 273 support)
- Verify Monopulse and acquire pointing data

ORT on DOY 125 (May 5) over DSS-35 and DSS-25, X- and Ka-band

17 125 1100 1230 2130 2145 DSS-35 CAS TP RSS OCCORT MC 7162 N750 1A1
17 125 1200 1300 1500 1515 DSS-25 CAS RSS OCCORT MC DL 7161 N71L 1A1

- DSS-35 is prime TP
- Verify Monopulse and acquire pointing data

ORT on DOY 127 (May 7) over DSS-55, X- and Ka-band

17 127 0105 0235 0540 0555 DSS-55 CAS TP RSS OCCORT MC 7163 N750 1A1

- DSS-35 is prime TP
- Day before Rev 273 observations
- Last DSS-55 ORT was on DOY 061 (March 2)
- DSS-55 occultation support on DOY 096 (April 4), Rev 268
- Verify Monopulse and acquire pointing data

Misc

Uplink Strategy

- DSS-35, 18 kW, ramped, sweep
- DSS-55, 18 kW, ramped, no sweep
  - Uplink transfer between Canberra and Madrid not possible
    - ~30min gap in uplink due to transmitter elevation limits
      DSS-35 transmitter off limit: 128/22:54:11 ERT
      DSS-55 transmitter on limit: 128/23:23:41 ERT
    - Timeline has DSS-35 stopping the uplink at 128/225400, and DSS-55 starting at 128/232500
- DSS-84, 18 kW, ramped, no sweep
  - Uplink transfer from DSS-55
- DSS-14, 18 kW, ramped, no sweep
  - Uplink transfer from DSS-84
- DSS-43, 18 kW, ramped, no sweep

BLF

- Check with Telecom if an update is needed before we start predicts generation

DKF

- Does not have the correct uplink or AOS/LOS times. Use times in RSS timeline
- DKF has playback times

Misc Cont'd

DSS-84 will be prime (2-way) during closest approach period

Monopulse
- Per timeline
  - Stations to enable and disable Monopulse only when requested by RSS
- Rising stations - Wait for ~10 degrees elevation to enable Monopulse

4th Order Blind Pointing Models
- Plan for updating DSS-25, DSS-35, and DSS-55 models?
- Pointing data sent to David
- Additional data will be sent this week

Timeline
- There will be a v2
- Comments are welcome – Plan to keep same format/colors for remainder of observations

Doppler Dynamics
- NOA-s will check accelerations during periapse period
- Need to increase carrier loop bandwidth around periapse?

Misc Cont'd

Two rolling periods planned during the observation

- Don't expect and impact to X- or Ka-band
- S-band power variations were observed during Rev 236 data processing, but may not be visible in real-time

NOPEs

- Equipment Status?

RSSG

Ops room displays

- Started by first shift, updated as needed by later shifts

Danny

- Please check open-loop receivers status, availability and disk space