Deep Impact Observations with MIRO

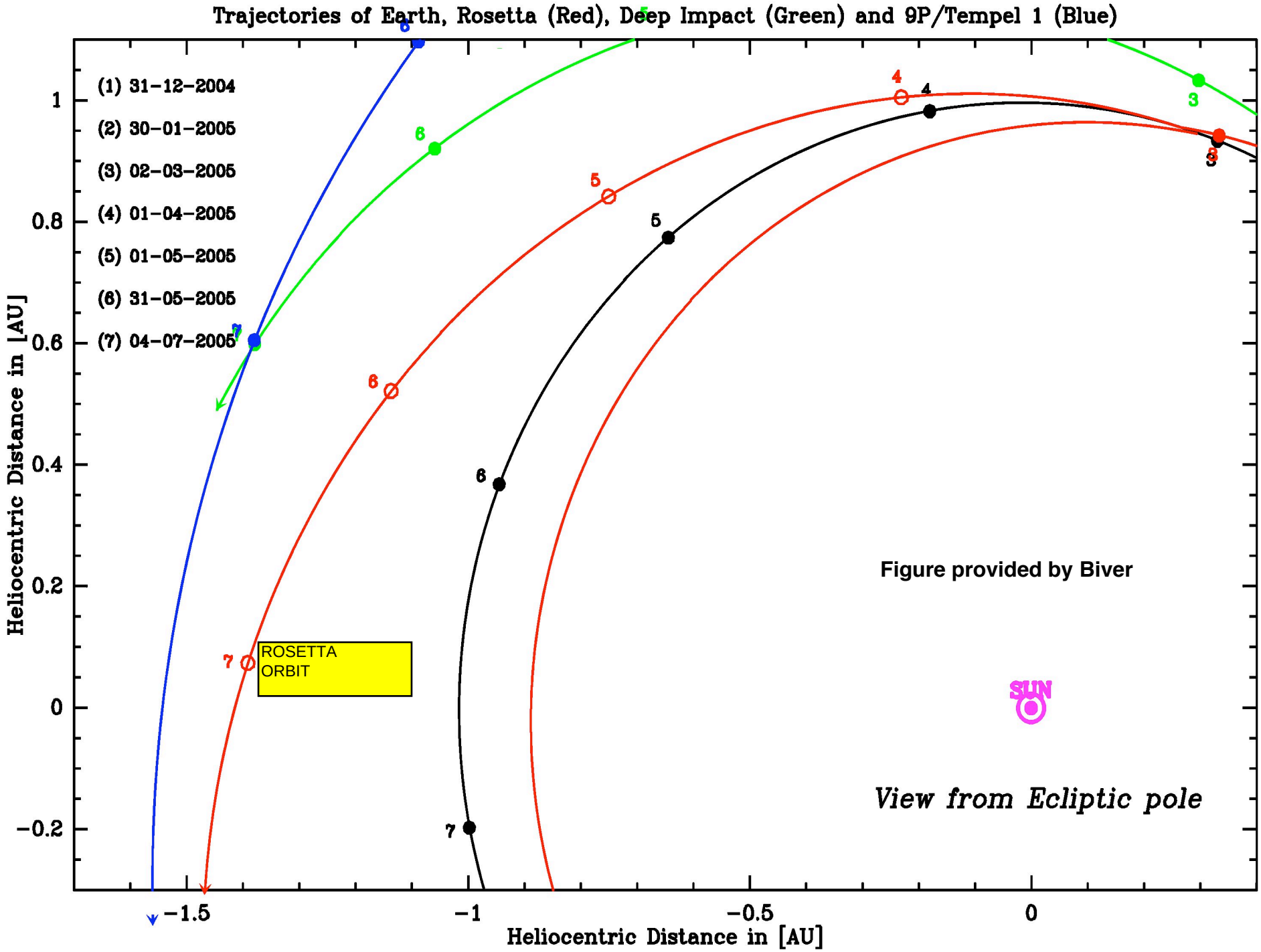
19th SWTM for the
International ROSETTA Mission
ESOC
Darmstadt, Germany
September 2, 2005

Samuel Gulkis

Submillimeter Observations of Tempel 1 with the MIRO Spectrometer on ROSETTA during the encounter of DEEP IMPACT

Samuel Gulkis[1], Mark Allen[1], Charles Backus[1], Gerard Beaudin[2], Dominique Bockelee-Morvan[2], Nicolas Biver[2], Jacques Crovisier[2], Didier Despois[3], Pierre Encrenaz[2], Therese Encrenaz[2], Margaret Frerking[1], Mark Hofstadter[1], Paul Hartogh[4], Wing Ip[5], Mike Janssen[1], Lucas Kamp[1], Emmanuel Lellouch[2], Ingrid Mann[6], Duane Muhleman[7], Heike Rauer[8], Peter Schloerb[9], and Thomas Spilker[1]

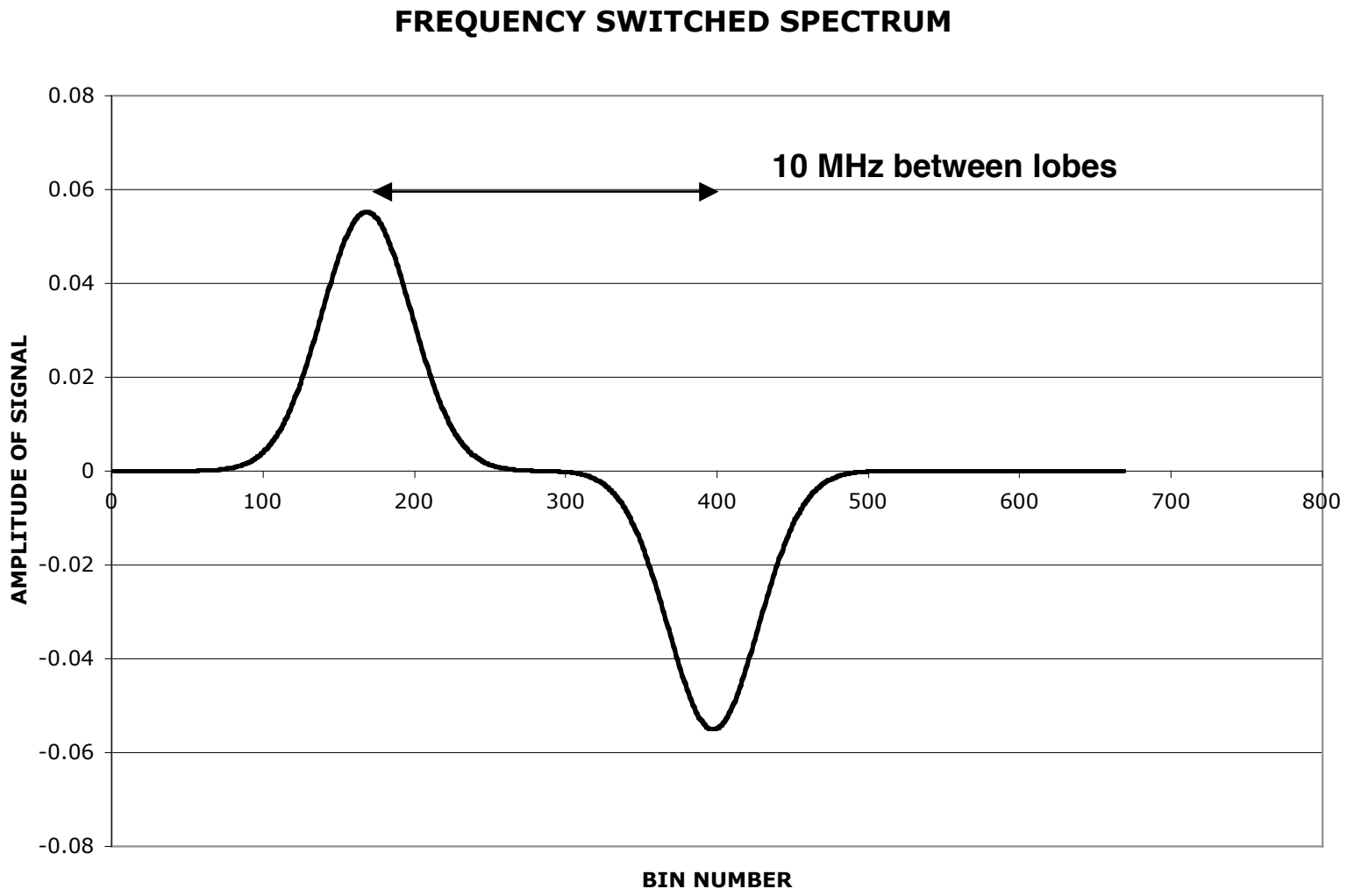
1. Jet Propulsion Laboratory, Cal. Inst. of Tech. , 2. Obs. de Paris, 3. Obs. de Bordeaux, 4. Max Planck Inst. Solar System Research, 5. National Central University, Taiwan, 6. University Wilhelm, Germany, 7. Cal. Inst. Of Tech. , 8. DLR, Germnay, 9. Univ. of Mass.


Trajectories of Earth, Rosetta (Red), Deep Impact (Green) and 9P/Tempel 1 (Blue)
(1) 31-12-2004
(2) 30-01-2005
(3) 02-03-2005
(4) 01-04-2005
(5) 01-05-2005
(6) 31-05-2005
(7) 04-07-2005
ROSETTA ORBIT
Figure provided by Biver
SUN
View from Ecliptic pole
Heliocentric Distance in [AU]
Heliocentric Distance in [AU]
1
0.8
0.6
0.4
0.2
0
−0.2
−1.5
−1
−0.5
0

Instrument Description

- 30 cm aperture telescope (7.6 arc min at 560 GHz)
- 2 uncooled, heterodyne mixers (190 GHz and 560 GHz) with phase lock loop and Ultra Stable Oscillator on 560 GHz receiver
- 2 Continuum channels
- Submillimeter (560 GHz) mixer feeds 4096 channel, high resolution (44 kHz /23 m/s) chirp transform spectrometer (CTS)
  - Fixed tuned to transitions of
    - H_2O^{16} (556.936 GHz)
    - H_2O^{17} (552.021 GHz)
    - H_2O^{18} (547.676)
    - CH_3OH (3 TRANSITIONS) (553.146, 568.566, 579.151 GHz)
    - NH_3 (572. 498 GHz)
    - CO (576.268 GHz)
- Thermal line width of 560 GHz water line at 10 K is 300 kHz
- LO is frequency switched ± 5 MHz every 5 seconds and alternate spectra are subtracted to produce frequency switched spectrum
- Subject of this presentation is MIRO observations of the ground state rotational transition of water at 556.936 GHz

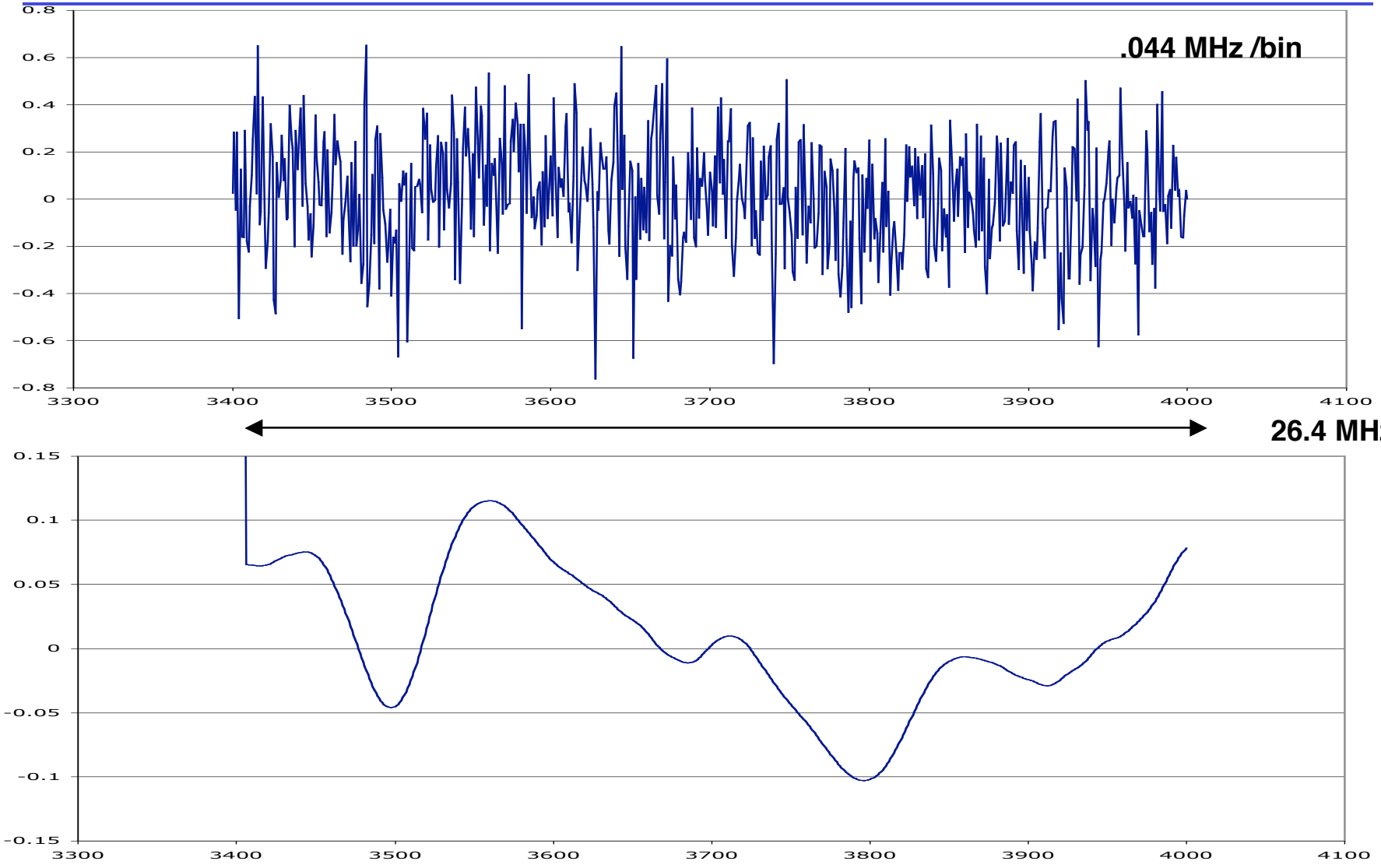
Ideal Frequency Switched Spectrum



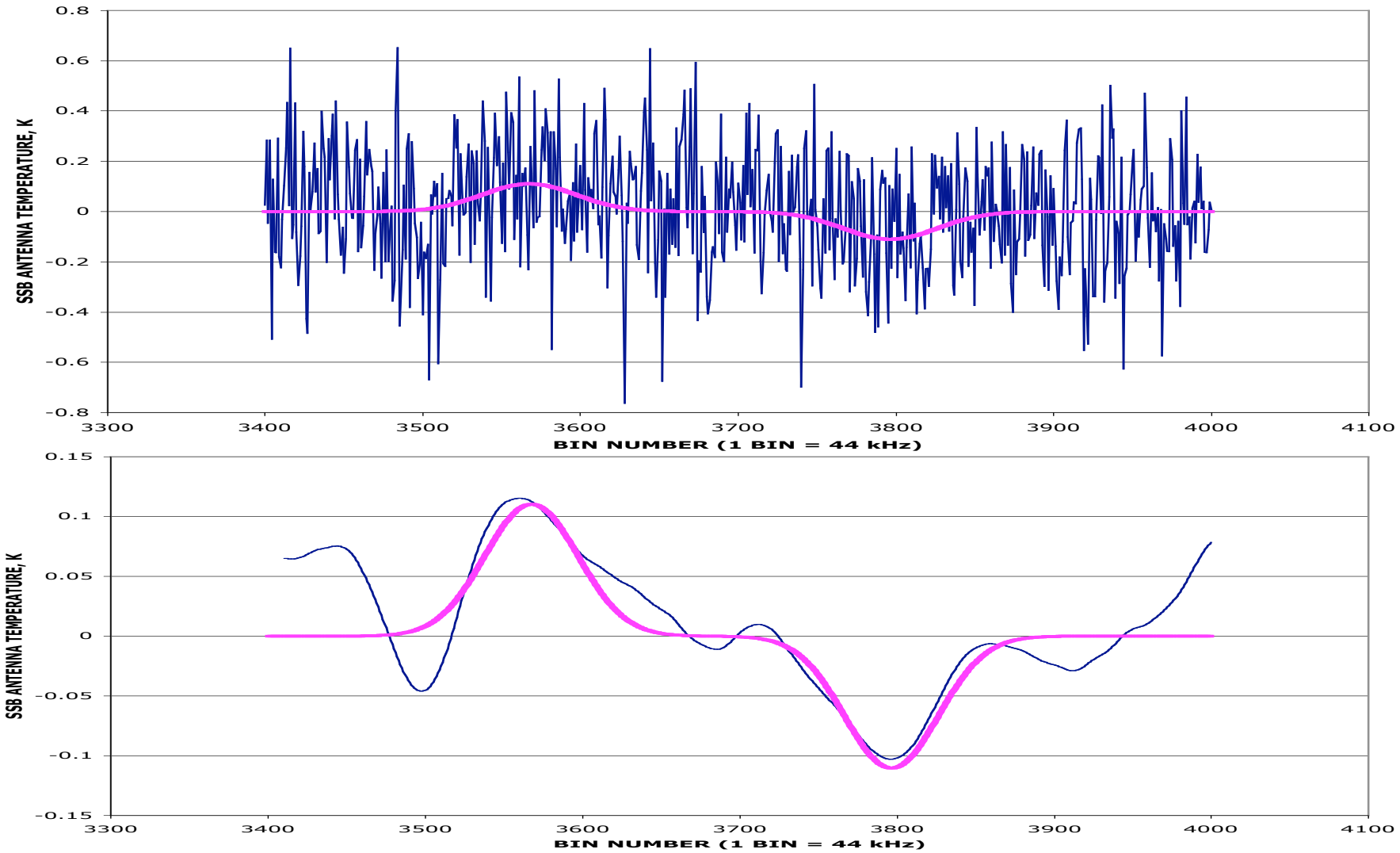
Tempel 1 Observations with MIRO

- Pre-Impact Observations June 29, 2005 (02 hr) to July 4, 2005 (05hr45m) [20051800200 to 20051850545]
- Post-Impact Observations July 4, 2005(06hr) to July 8, 2005 (09hr58m) [20051850600 to 20051890958]
- Observations divided into on source (Tempel 1) and off source positions.
- There is an automatic calibration every 30 minutes- movable mirror directs beam to warm calibration target, cold calibration target, and then to sky
- Spectrum is recorded every 30 seconds following the sequence of local oscillator (LO) settings [-5 MHz, +5MHz, -5MHz, +5MHz, -5MHz, + 5MHz] - each LO position is held for 5 seconds. Recorded spectrum is difference between two local oscillator settings

UNBINNED AND SMOOTHED SPECTRA POST IMPACT (4Jul-0600/8Jul-0958)2005



UNBINNED AND SMOOTHED DATA WITH SUPERIMPOSED MODEL - POST IMPACT



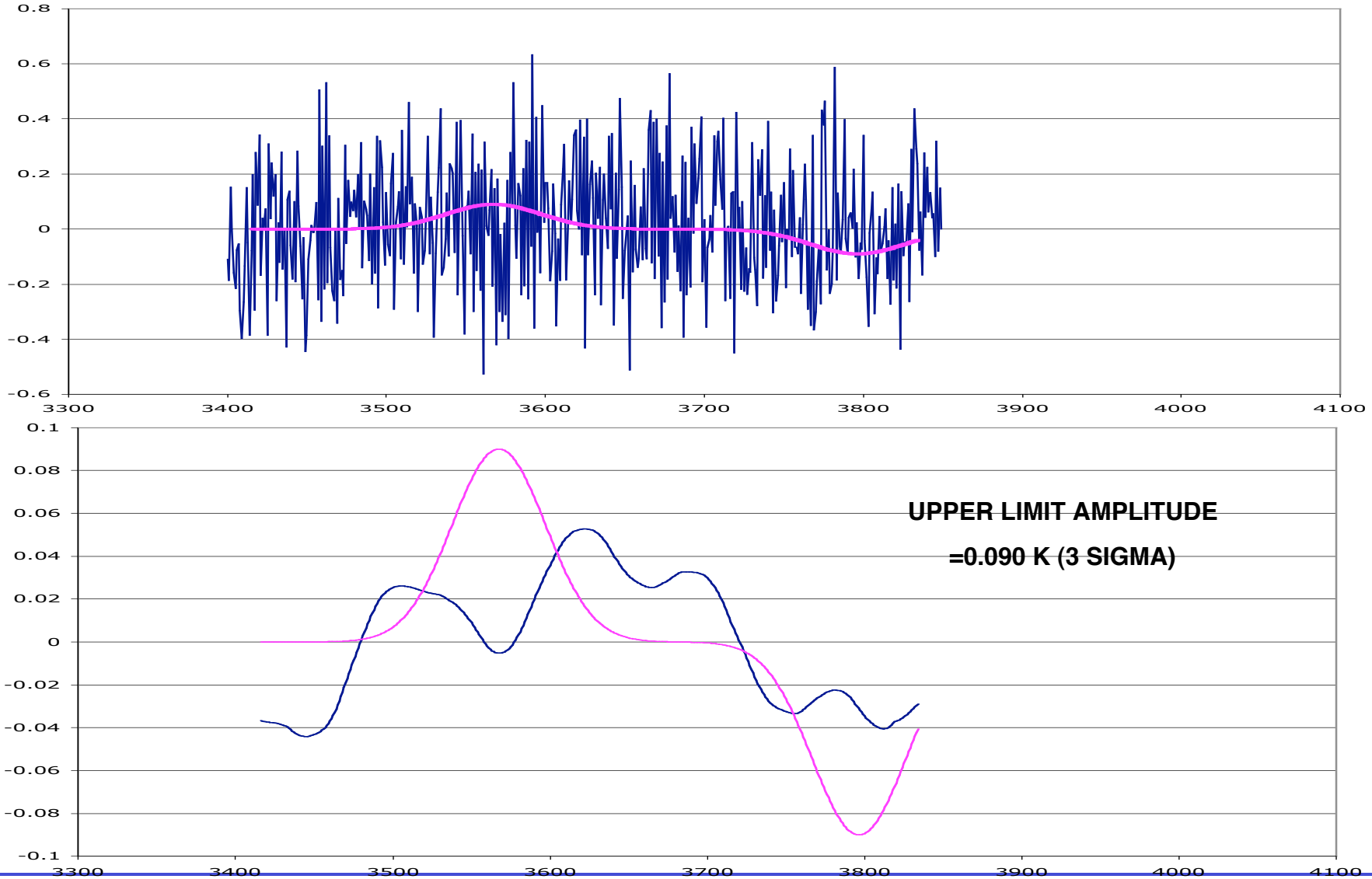
LEAST SQUARE FIT LINE PARAMETERS

DATA	LINE AMPLITUDE	LINE WIDTH	UNSWITCHED LINE POSITION
UNBINNED (IDL)	0.095 ± 0.021 K	85.2 ± 24 BINS 3.75 MHz ± 1.0 MHz 2 Km/s± 0.54 km/s	Bin 3689.5 ± 16 Red shift 53.0 ± 16 bins = 2.33 MHz ± 0.7 MHz =1.25 km/s ± 0.4 km/s
SMOOTHED (EXCEL SOLVER)	0.11 ± 0.028 K	70 Bins 3.1 MHz 1.65 Km/s Deconvolved (2.50 MHz/1.34 km/s)	Bin 3682 Redshift 45.4 bins = 2.0 MHz =1.07 km/s

PRE-IMPACT OBSERVATIONS

- DATA FROM 29JUNE02HR TO 4JUL05HR45MIN 2005 [20051800200 TO 20051850545]
- 32 BIN DATA HAS RMS OF .030 K
- NO SIGNAL WAS DETECTED
- ASSUMING A 3 SIGMA UPPER LIMIT, WE ESTIMATE AN UPPER LIMIT SIGNAL AMPLITUDE OF .090 K
- ANALYSIS IS STILL UNDERWAY

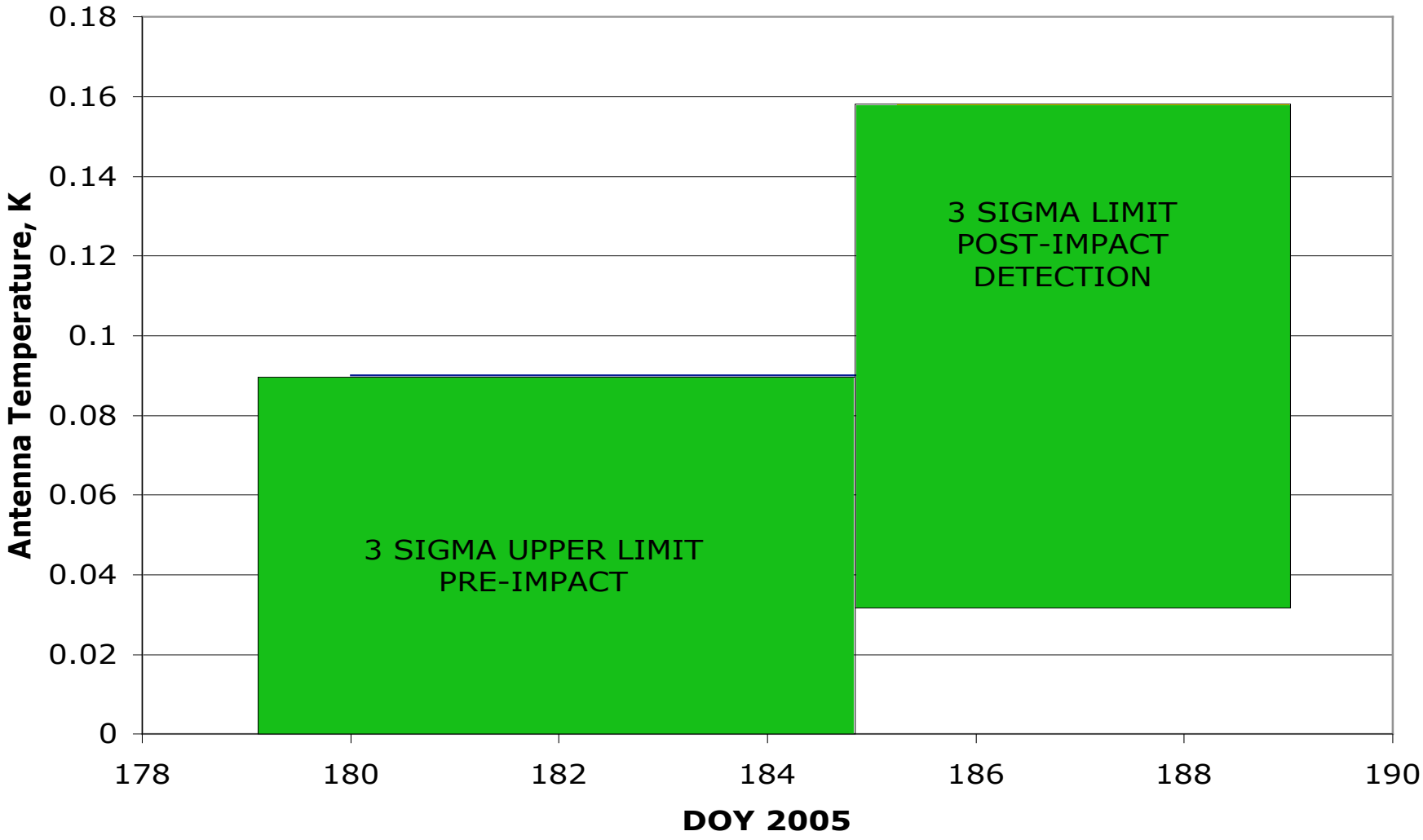
UNBINNED & SMOOTHED PRE-IMPACT DATA WITH SUPERIMPOSED 3 SIGMA UPPER LIMIT MODEL



PRODUCTION RATES

- NO DETAILED ANALYSIS HAVE BEEN PERFORMED AT THIS TIME
- PRIOR TO THESE OBSERVATIONS, BIVER ESTIMATED (MIRO TEAM MEETING, UNPUBLISHED) THAT WATER PRODUCTION RATE OF 1E(28) MOLECULES/SEC WOULD LEAD TO A PEAK ANTENNA TEMPERATURE OF 0.125 K.
- SCALING FROM BIVER'S ESTIMATE, UNBINNED LEAST SQUARE FIT OF POST-IMPACT DATAT YIELDS PRODUCTION RATE OF 7.6E(27) ± 1.6E(27) MOLEC /S
- PRE-IMPACT 3 SIGMA UPPER LIMIT YIELDS MAXIMUM PRODUCTION RATE CONSISTENT WITH POST IMPACT DETECTION PRODUCTION RATE
- BOCKELEE-MORVAN ESTIMATES QH2O - 6.3E(27) to 9.7E(27)(preferred value)

PRE- AND POST-IMPACT ANTENNA TEMPERATURE LIMITS



Conclusions

- The ground state rotational transition of water at 556.936 GHz was detected by the MIRO instrument in the post-impact phase of the observations. (0.204 K km/s) The estimated production rate of water is 7.6E(27) ± 1.6E(27) MOLEC /S. THIS IS A PROVISIONAL NUMBER.
- The detection of water required long integration times. The signal to noise was too low to detect variability in the water production rate in the post-impact phase
- No water was detected in the pre-impact phase. Assuming a 3 sigma upper limit, we cannot conclude if the water production rate changed(increased or decreased) after the DI impact
- The MIRO results suggest a red shift gas velocity of 1.25 km/s after removing the comet - S/C doppler velocity