Southern African Large Telescope



Title:RSS stability and flexure modelsAuthor(s):Alexei Kniazev, Anja Schroeder

| Doc. number: | $\mathbf{2202AA1000}$ | |
|--------------|-----------------------|--------------|
| Version: | 1.0 | |
| Date: | October 10, 2013 | |
| Keywords: | RSS, flexure | |
| Approved: | David Buckley (Ast | Ops Manager) |
| | Signature: | Date: |

ABSTRACT

We present in this report a study of different aspects of RSS flexure and repeatability of the RSS spectral setups. We calculated 1D models for RSS flexure and RSS flexure drift depending on two parameters: azimuth angle and rho angle. Our results show that (1) RSS flexure is obviously a function of two parameters: azimuth and rho angle; (2) RSS repeatability after correction for the flexure has a standard deviation of 1.63 pixels (2×2 binning); (3) the RSS flexure drift is obviously a function of two parameters: azimuth and rho angle, but also has a random part with a dispersion of ~0.17 pixels (2×2 binning).

South African Astronomical Observatory, Cape Town 7925, South Africa



Contents

| 1 | Introduction | 3 |
|----------|---|--------------------|
| 2 | Data and Analysis | 3 |
| 3 | Results3.1RSS flexure and RSS stability without flexure3.2RSS flexure drift | 3 7 8 |
| 4 | Summary and recomendations | 8 |

List of Figures

| 1 | The distributions for measured positions depending on azimuth angle (top panel) and rho angle (bottom panel). Result of the second order polynomial fit is also shown for both panels. | 4 |
|---|--|----|
| 2 | Top panel: The histogram of all measured positions for the 5577 night-sky | |
| | line. The mean value 1389.4421 pixel was subtracted from this distribution. | |
| | The standard deviation for this distribution is 2.41 pixels. Bottom panel: | |
| | The same histogram after correction for azimuthal and rho angle. The standard | |
| | deviation for this distribution is 1.63 pixels | 5 |
| 3 | The distributions for measured drift values depending on azimuth angle (top | |
| | panel) and rho angle (bottom panel). The result of the second order polynomial | |
| | fit is also shown for both panels. | 10 |
| 4 | Top panel: The histogram of all measured drifts for the 5577 night-sky line. | |
| | The standard deviation for this distribution is 0.25 pixels. Bottom panel: | |
| | The same histogram after correction for azimuthal and rho angle. The standard | |
| | deviation for this distribution is 0.17 pixels | 11 |
| | The standard deviation for this distribution is 0.25 pixels. Bottom panel: The same histogram after correction for azimuthal and rho angle. The standard | |
| | deviation for this distribution is 0.17 pixels | 11 |



1 Introduction

Understanding the stability and flexure of the Robert Stobie Spectrograph (RSS) is vital for the proposal preparation procedure and for the planning of standard calibrations procedure. Some studies were done previously, see e.g. report from Keith S. on

http://wiki.salt.ac.za/index.php/RSS_wavelength_stability page. With many uniform observations currently available in the SALT database it is possible to measure the stability and flexure and calculate some simple models. In this report we examine a set of spectral data which was obtained with the same setup over a long enough time span and with different azimuthal and rho angles.

2 Data and Analysis

Observational data analysed in this report were taken from commissionning programs with the RSS during 2011–2012. All observations were taken with the same spectral setup: grating GR900 at an articulation angle of 30.25 resulting in a wavelength range of approximately 4200-7200 Å. All data were observed with slit 1.25 arcsec and 2×2 binning. Three exposures were uaually taken.

All data were extracted from the SALT database and the position of the night-sky line 5577.35 Å in the middle of the frame was measured using the IRAF imexam task. No any additional reduction after pipeline was done. All data used are shown in Table 1. The measured position is presented in column (4), and columns (5) and (6) show rho angle and azimuth angle for each frame. Column (7) presents information when frames were observed in sequence.

3 Results

Altogether, 82 frames were measured, which cover all the range of azimuth and rho angles. All studied observations were obtained with the same RSS setup, while the RSS was configured each time before the observation of the block. For that reason all these observations were completely independent and the measured position for the 5577 line has two kind of errors:

- A random error which is the result of the RSS hardware accuracy. We can call it "RSS stability" or "RSS repeatability"
- A systematic error which is the result of RSS flexure depending on some parameters.

We would like to check how accurate the RSS hardware is to the setup instrument. For that we need to exclude flexure first. As a starting point, we suggest that flexure is a function of azimuth and/or rho angle.





Figure 1: The distributions for measured positions depending on azimuth angle (top panel) and rho angle (bottom panel). Result of the second order polynomial fit is also shown for both panels.





Figure 2: **Top panel:** The histogram of all measured positions for the 5577 night-sky line. The mean value 1389.4421 pixel was subtracted from this distribution. The standard deviation for this distribution is 2.41 pixels. **Bottom panel:** The same histogram after correction for azimuthal and rho angle. The standard deviation for this distribution is 1.63 pixels.



| | | Table 1: | Anary | sea obse | ervation | IS | |
|---|----------|--------------------|-------------|----------|----------|----------|----------|
| $ \begin{array}{c cccc} (pixel) & (deg) & (deg) \\ \hline column (deg) & (deg) & (deg) \\ column (deg) & (deg) & (deg) & (deg) \\ column (deg) & (de) &$ | Date | File | Exp. | Position | RHO | AZ | Sequence |
| (1) (2) (3) (4) (5) (6) (7) 20110519 mbxpP20110510002 100. 1385.98 50.91 153.416 3 20110519 mbxpP20110510004 100. 1385.98 50.91 153.416 3 20110519 mbxpP20110510006 100. 1386.08 36.557 160.266 3 20110602 mbxpP20110620015 300. 138.90.67 -76.75 -132.383 2 20110602 mbxpP20110630033 600. 138.81 -8.867 -150.816 1 20110603 mbxpP20110630035 100. 138.82 -4.867 -150.816 2 20110603 mbxpP20110603035 100. 138.827 -62.751 -147.018 2 20110606 mbxpP20110610033 300. 138.827 -62.751 -147.018 2 20110613 mbxpP2011061003 300. 138.827 -62.751 -147.018 2 20110613 mbxpP201101610003 300.1 138.72.0 | | | (sec) | (pixel) | (deg) | (deg) | |
| 20110519 mbxpP201105190003 100. 1385.99 50.91 153.416 2 20110519 mbxpP201105190004 100. 1385.99 50.91 153.416 2 20110519 mbxpP201105190004 100. 1386.08 36.587 160.266 1 20110519 mbxpP20110610006 100. 1386.07 7.6775 -132.383 2 20110602 mbxpP201106020017 300. 1388.05 -8.867 -150.816 2 20110603 mbxpP201106030034 600. 1388.51 -8.867 -150.816 2 20110603 mbxpP201106030034 600. 1388.57 -161.83 -147.018 1 20110603 mbxpP20110600037 300. 1388.72 -67.751 -147.018 1 20110612 mbxpP201106100043 300. 1387.70 5.44 174.046 2 20110612 mbxpP201106120004 300. 1387.47 -99.87 -103.823 4 20110612 mbxpP2011016120004 300. | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| 20110519 mbxpP201105190004 100. 1385.93 50.91 153.416 2 20110519 mbxpP201105190007 100. 1386.08 35.587 160.206 2 20110619 mbxpP201105190007 100. 1386.19 35.587 160.206 2 20110602 mbxpP20110620015 300. 1388.84 76.775 -132.383 1 20110603 mbxpP201106300303 600. 1388.57 -8.667 -150.816 2 20110603 mbxpP201106300303 600. 1388.59 -8.677 -150.816 3 20110603 mbxpP201106300303 600. 1388.59 -16.33 -147.336 5 20110606 mbxpP201106030037 600. 1388.59 -62.751 -147.018 1 20110601 mbxpP201106130003 600. 1388.57 5.44 174.096 2 20110612 mbxpP201106130003 600. 1388.75 5.44 174.096 2 20110613 mbxpP201106130003 600. | 20110519 | mbxpP201105190002 | 100. | 1385.98 | 50.91 | 153.416 | 1 |
| $\begin{array}{c} 20110519 \\ 20110519 \\ mtxpP201105190006 \\ 100. 1386.08 \\ 36.587 \\ 100.206 \\ 100.206 \\ 20110619 \\ mtxpP201106190008 \\ 100. 1386.08 \\ 36.587 \\ 100.206 \\ 20110602 \\ mtxpP20110620015 \\ 300. 1388.08 \\ -76.775 \\ -132.383 \\ 132.383 \\ 132.383 \\ 20110603 \\ mtxpP201106300303 \\ 000. 1388.05 \\ -8.67 \\ -150.816 \\ 122.383 \\ 100003 \\ mtxpP201100300303 \\ 000. 1388.05 \\ -8.67 \\ -150.816 \\ 122.336 \\ 20110603 \\ mtxpP20110030033 \\ 000. 1388.15 \\ -8.67 \\ -150.816 \\ 20110603 \\ mtxpP201106300303 \\ 000. 1388.15 \\ -8.67 \\ -150.816 \\ 20110603 \\ mtxpP201106300303 \\ 000. 1388.15 \\ -8.67 \\ -150.816 \\ 20110603 \\ mtxpP201106300303 \\ 000. 1388.17 \\ -16.33 \\ -147.336 \\ 52.0000003 \\ 000003 \\ 000003 \\ 000003 \\ 000003 \\ 000003 \\ 000003 \\ 000003 \\ 000003 \\ 0000003 \\ 0000003 \\ 00000000$ | 20110519 | mbxpP201105190003 | 100. | 1385.93 | 50.91 | 153.416 | 2 |
| 20110519 mbxp2P21015190007 100. 1386.28 36.587 100.206 2 20110519 mbxp2P21015190007 100. 1386.28 36.587 100.206 2 20110602 mbxpP2201106020015 300. 1388.88 76.775 -132.383 1 20110602 mbxpP2201106020017 300. 1388.86 -8.677 -150.816 1 20110603 mbxpP2201106300305 600. 1388.29 -14.653 -147.974 4 20110603 mbxpP2201106300307 600. 1388.59 -18.381 -146.533 6 20110606 mbxpP2201106030037 600. 1388.59 -62.751 -147.018 2 20110606 mbxpP22011060503 300. 1387.20 5.44 174.096 3 20110613 mbxpP2201106130008 100. 1387.47 -66.751 -147.018 2 20110613 mbxpP201106130008 100. 1388.47 -66.751 -147.0496 3 20110613 mbxpP201106130008 | 20110519 | mbxpP201105190004 | 100. | 1385.96 | 50.91 | 153.416 | 3 |
| 20110519 mbxpP201105190008 100. 1386.19 36.587 100.206 2 20110602 mbxpP201106020015 300. 1388.88 -76.775 -132.383 2 20110602 mbxpP201106020015 300. 1388.05 -76.775 -132.383 2 20110603 mbxpP20110630034 600. 1388.15 -8.867 -160.816 1 20110603 mbxpP20110630037 600. 1388.37 -16.133 -147.366 5 20110603 mbxpP20110630037 600. 1388.77 -16.33 -147.018 1 20110606 mbxpP20110660033 300. 1388.77 -62.751 -147.018 2 20110612 mbxpP20110660033 300. 1387.50 5.44 174.096 2 20110612 mbxpP201106130008 200. 1387.50 5.44 174.096 1 20110613 mbxpP201106130008 120. 1390.09 -99.87 -103.823 4 20110613 mbxpP2011061300086 120. | 20110519 | mbxpP201105190006 | 100. | 1386.08 | 36.587 | 160.206 | 1 |
| $\begin{array}{c} 20110602 \\ 20110602 \\ mbxpP2210106020015 300. 1388.8 - 76.775 \\ 132.383 \\ 12010602 \\ mbxpP2210106020017 300. 1388.05 \\ -76.775 \\ 132.383 \\ 20110603 \\ mbxpP2210106300303 \\ 600. 1388.05 \\ -8.667 \\ -150.816 \\ 122333 \\ 20110603 \\ mbxpP221010630033 \\ 600. 1388.15 \\ -8.667 \\ -150.816 \\ 12330 \\ -16.331 \\ -16.331 \\ -147.333 \\ -16.331 \\ -147.333 \\ -16.331 \\ -147.333 \\ -147.333 \\ -16.331 \\ -147.333 \\ -147.47.147.168 \\ -147.496 \\ -127.147.147.168 \\ -127.147.147.168 \\ -127.148 \\ -1010627 \\ mbxpP221010627002 \\ -101.388.71 \\ -03.798 \\ -03.788 \\ -100.388 \\ -100.388.71 \\ -03.798 \\ -103.423 \\ -20110627 \\ mbxpP221010627002 \\ -101.388.17 \\ -03.798 \\ -103.423 \\ -20110627 \\ mbxpP221010627002 \\ -101.388.17 \\ -03.798 \\ -103.423 \\ -20110627 \\ mbxpP221010627002 \\ -101.388.17 \\ -03.798 \\ -103.423 \\ -20110627 \\ mbxpP221010627002 \\ -101.388.17 \\ -03.798 \\ -103.423 \\ -20110627 \\ mbxpP21010627002 \\ -101.388.10 \\ -29.795 \\ -28.63.3 \\ -20110627 \\ mbxpP21010627002 \\ -101.388.10 \\ -29.795 \\ -28.63.3 \\ -20110627 \\ mbxpP21010627002 \\ -101.388.10 \\ -29.795 \\ -28.63.3 \\ -20110627 \\ mbxpP210106270002 \\ -101.388.10 \\ -29.795 \\ -28.63.3 \\ -20110627 \\ mbxpP210106270$ | 20110519 | mbxpP201105190007 | 100. | 1386.23 | 36.587 | 160.206 | 2 |
| $ \begin{array}{c} 10110002 \\ 0110002 \\ 0110002 \\ 0110002 \\ 0110002 \\ 0110003 \\ 0110000 \\ 01100003 \\ 0110000 \\ 011000$ | 20110519 | mbxpP201105190008 | 100 | 1386 19 | 36 587 | 160 206 | 3 |
| 20110602 mbxpP2101106020017 300. 1389.07 -76.775 -132.383 3 20110603 mbxpP2101106330034 600. 1388.05 -8.867 -150.816 1 20110603 mbxpP2101106330035 105. 1388.13 -8.867 -150.816 2 20110603 mbxpP2101106330037 600. 1388.51 -8.867 -150.816 3 20110603 mbxpP21010630037 600. 1388.57 -16.133 -147.376 4 20110606 mbxpP210106060037 300. 1388.70 -62.751 -147.018 3 20110612 mbxpP2101106120004 300. 1387.20 5.44 174.096 2 20110613 mbxpP2101106120004 300. 1387.53 5.44 174.096 3 20110613 mbxpP2101106130085 100. 1388.74 -66.89 -158.271 2 20110613 mbxpP2101106130085 120. 1390.01 -99.87 -103.423 2 20110613 mbxpP2101106130085 < | 20110602 | mbypP201106020015 | 300 | 1388.88 | -76 775 | -132 383 | 1 |
| 20110602 mbxpP2101106020017 300. 1388.05 -76.775 -132.383 3 20110603 mbxpP2101106030034 600. 1388.15 -8.867 -150.816 2 20110603 mbxpP2101106030034 600. 1388.29 -8.867 -150.816 3 20110603 mbxpP201106030037 600. 1388.37 -16.133 -147.974 4 20110606 mbxpP201106060038 300. 1388.29 -62.751 -147.018 2 20110606 mbxpP201106060038 300. 1387.20 5.44 174.006 3 20110612 mbxpP201106130005 300. 1387.20 5.44 174.006 3 20110613 mbxpP201106130008 120. 1389.74 -66.89 -158.271 2 20110613 mbxpP201106130086 120. 1389.74 -99.87 -103.823 2 20110613 mbxpP201106130086 120. 1389.47 -90.87 -103.823 2 20110613 mbxpP201106130086 1 | 20110602 | mbxpP201106020016 | 300 | 1389.07 | -76 775 | -132.383 | 2 |
| 20110603 mbspP201106030033 600. 1388.05 -8.867 -150.816 1 20110603 mbspP201106030035 105. 1388.21 -8.867 -150.816 3 20110603 mbspP201106030035 105. 1388.37 -16.133 -147.974 4 20110606 mbspP2011060603035 600. 1388.57 -16.133 -147.736 5 20110606 mbspP2011060600383 300. 1388.72 -62.751 -147.018 2 20110606 mbspP201106120005 300. 1387.50 5.44 174.096 2 20110612 mbspP201106130005 600. 1389.47 -40.88 -103.823 2 20110613 mbspP201106130085 120. 1389.03 -99.87 -103.823 2 20110613 mbspP201106130085 120. 1389.47 -40.87 -103.823 2 20110613 mbspP201106130085 120. 1390.03 -99.87 -103.823 2 20110627 mbspP201106270024 | 20110602 | mbypP201106020017 | 300 | 1389.05 | -76 775 | -132 383 | 3 |
| 20110603 mbxpP201106030035 105. 1388.15 -8.867 -150.816 3 20110603 mbxpP201106030035 105. 1388.29 -14.563 -147.366 5 20110603 mbxpP201106030037 600. 1388.59 -18.381 -146.523 6 20110606 mbxpP201106060037 300. 1388.52 -62.751 -147.018 2 20110606 mbxpP201106060033 300. 1387.20 5.44 174.096 1 20110612 mbxpP20110612004 300. 1387.50 5.44 174.096 2 20110613 mbxpP201106130005 100. 1380.38 -46.689 -158.271 2 20110613 mbxpP201106130085 120. 1380.74 -99.87 -103.823 3 20110613 mbxpP201106130085 120. 1380.74 -99.87 -103.823 4 20110627 mbxpP201106270023 500. 1380.71 -103.823 4 20110627 mbxpP201106270024 500. 1390.17 | 20110602 | mbxpP201106030033 | 600 | 1388.05 | -8.867 | -150.816 | 1 |
| 20110003 mbxpP201106030035 105. 1388.21 -8.867 -150.816 3 20110603 mbxpP201106030037 600. 1388.37 -16.133 -147.736 5 20110606 mbxpP2011060603033 600. 1388.57 -16.133 -147.736 5 20110606 mbxpP2011060600383 300. 1388.72 -62.751 -147.018 1 20110616 mbxpP201106120003 300. 1387.50 5.44 174.096 1 20110612 mbxpP201106120005 300. 1387.53 5.44 174.096 2 20110613 mbxpP201106130005 600. 1389.47 -40.689 -158.271 1 20110613 mbxpP201106130085 100. 1389.74 -90.87 -103.823 4 20110613 mbxpP201106130085 100. 1389.47 -100.899 -104.329 5 20110613 mbxpP201106270024 500. 1390.12 -76.126 -137.349 2 20110627 mbxpP201106270024 <td< td=""><td>20110603</td><td>mbypP201106030034</td><td>600</td><td>1388 15</td><td>-8 867</td><td>-150.816</td><td>2</td></td<> | 20110603 | mbypP201106030034 | 600 | 1388 15 | -8 867 | -150.816 | 2 |
| 20110603 mbxpP201106030037 600 1388.59 -14.563 -147.374 4 20110603 mbxpP201106030037 600 1388.59 -18.381 -146.523 6 20110606 mbxpP201106060037 300 1388.52 -62.751 -147.018 2 20110606 mbxpP201106060033 300 1388.52 -62.751 -147.018 2 20110616 mbxpP201106120004 300 1387.50 5.44 174.096 1 20110613 mbxpP201106130005 300 1387.53 5.44 174.096 3 20110613 mbxpP201106130085 100 1389.04 -46.689 -158.271 2 20110613 mbxpP201106130085 120 1389.04 -100.899 -103.823 3 20110613 mbxpP201106130085 120 1389.04 -100.899 -103.823 4 20110627 mbxpP201106370023 500 1390.17 -76.126 -137.349 2 20110627 mbxpP201106270023 500 | 20110603 | mbxpP201106030035 | 105 | 1388 21 | -8.867 | -150.816 | 3 |
| | 20110603 | mbxpP201106030036 | 214 | 1388 29 | -14 563 | -147 974 | 4 |
| 20110003 mbxpP20110603038 600. 1388.59 -118.381 -146.623 6 20110606 mbxpP201106060033 300. 1388.82 -62.751 -147.018 2 20110606 mbxpP201106120004 300. 1388.70 5.44 174.096 1 20110612 mbxpP201106120004 300. 1387.50 5.44 174.096 2 20110613 mbxpP201106130005 300. 1387.53 5.44 174.096 3 20110613 mbxpP201106130005 300. 1389.47 -46.689 -158.271 2 20110613 mbxpP201106130085 120. 1390.03 -99.87 -103.823 3 20110613 mbxpP201106130085 120. 1389.47 +100.899 -104.329 6 20110627 mbxpP20110627002 173. 1389.69 -63.788 +150.756 1 20110627 mbxpP20106270024 500. 1390.12 -76.126 +137.349 2 20110627 mbxpP20107090016 600. <td>20110603</td> <td>mbxpP201106030037</td> <td>600</td> <td>1388.37</td> <td>16 133</td> <td>147 336</td> <td>5</td> | 20110603 | mbxpP201106030037 | 600 | 1388.37 | 16 133 | 147 336 | 5 |
| 20110006 mbxpP201106060038 300. 1388.72 -62.751 -147.018 1 20110606 mbxpP201106060038 300. 1388.97 -62.751 -147.018 3 20110612 mbxpP201106120003 300. 1387.50 5.44 174.096 2 20110612 mbxpP201106120005 300. 1387.50 5.44 174.096 3 20110613 mbxpP201106130005 600. 1389.47 -46.689 -158.271 1 20110613 mbxpP201106130085 300. 1389.47 -103.823 2 1 20110613 mbxpP201106130086 600. 1389.47 -100.899 -103.323 4 20110613 mbxpP201106130086 600. 1389.47 -100.899 -104.329 6 20110627 mbxpP201106270023 500. 1390.17 -76.126 -137.349 2 20110627 mbxpP201106270023 500. 1393.30 -24.747.3 +33.668 2 20110627 mbxpP201107090015 600 | 20110603 | mbxpP201106030037 | 600 | 1388 50 | 18 381 | 146 523 | 6 |
| $ \begin{array}{c} 20110006 \\ mbxpP2011006060038 \\ 201100612 \\ mbxpP2011006120003 \\ 300. \\ 1387.20 \\ $ | 20110606 | mbxpP201106060037 | 300 | 1388 72 | 62 751 | 147.018 | 1 |
| $ \begin{array}{c} 201100006 \\ mbxpP20110061200033 \\ 20110012 \\ mbxpP2011006120004 \\ 300. 1387.20 \\ 5.44 \\ 174.006 \\ 2 \\ 20110012 \\ mbxpP2011006130002 \\ 600. 1389.70 \\ 5.44 \\ 174.006 \\ 2 \\ 20110013 \\ mbxpP2011006130002 \\ 600. 1389.47 \\ -46.689 \\ -158.271 \\ 2 \\ 20110013 \\ mbxpP2011006130085 \\ 300. 1389.76 \\ -90.012 \\ -103.406 \\ 1 \\ 20110013 \\ mbxpP2011006130085 \\ 300. 1389.76 \\ -90.012 \\ -103.406 \\ 1 \\ 20110013 \\ mbxpP2011006130085 \\ 120. 1389.76 \\ -90.97 \\ -103.823 \\ 2 \\ 20110013 \\ mbxpP2011006130087 \\ 120. 1389.74 \\ -99.87 \\ -103.823 \\ 2 \\ 20110013 \\ mbxpP2011006130089 \\ 600. 1389.47 \\ -100.899 \\ -104.329 \\ 5 \\ 20110027 \\ mbxpP201100270001 \\ 600. 1389.47 \\ -100.899 \\ -104.329 \\ 5 \\ 20110027 \\ mbxpP201100270002 \\ 500. 1389.71 \\ -63.798 \\ -150.766 \\ 1 \\ 20110027 \\ mbxpP201100270023 \\ 500. 1389.61 \\ -27.78 \\ -150.788 \\ 150.766 \\ 1 \\ 20110027 \\ mbxpP201100270025 \\ 407. 1390.11 \\ -76.126 \\ -137.349 \\ 1 \\ 20110027 \\ mbxpP201100270024 \\ 300. 1389.80 \\ -27.795 \\ 28.833 \\ 2 \\ 20110709 \\ mbxpP20110720001 \\ 600. 1393.89 \\ -74.773 \\ -135.368 \\ 1 \\ 20110709 \\ mbxpP20110720001 \\ 600. 1393.89 \\ -74.773 \\ -135.368 \\ 1 \\ 20110709 \\ mbxpP20110720001 \\ 600. 1393.49 \\ -74.773 \\ -135.368 \\ 2 \\ 20110709 \\ mbxpP20110720001 \\ 600. 1393.49 \\ -74.773 \\ -135.368 \\ 2 \\ 20110709 \\ mbxpP201107200001 \\ 600. 1391.81 \\ 104.521 \\ 102.98 \\ 1 \\ 20110727 \\ mbxpP201107200001 \\ 300. 1392.81 \\ -25.586 \\ 34.375 \\ 2 \\ 20110731 \\ mbxpP201107200002 \\ 300. 1392.43 \\ -25.586 \\ 34.375 \\ 2 \\ 20110731 \\ mbxpP201107310075 \\ 300. 1392.43 \\ -25.586 \\ 34.375 \\ 2 \\ 20110731 \\ mbxpP201107310075 \\ 300. 1392.43 \\ -25.586 \\ 34.375 \\ 2 \\ 20110731 \\ mbxpP201107310075 \\ 300. 1392.43 \\ -25.586 \\ 34.375 \\ 2 \\ 20110731 \\ mbxpP201107310075 \\ 300. 1392.43 \\ -25.586 \\ 34.375 \\ 2 \\ 20110731 \\ mbxpP201107310075 \\ 300. 1392.43 \\ -25.586 \\ 34.375 \\ 2 \\ 20110731 \\ mbxpP201107310075 \\ 300. 1392.43 \\ -25.586 \\ 34.375 \\ 2 \\ 20110731 \\ mbxpP201107310075 \\ 300. 1392.43 \\ -25.586 \\ 34.375 \\ 2 \\ 20110731 \\ mbxpP201107310075 \\ 300. 1392.43 \\ -25.586 \\ 34.375 \\ 2 \\ 20110731 \\ mbxpP201107310075 \\ 300.$ | 20110606 | mbxpP201106060037 | 300. | 1388.82 | 62 751 | 147.018 | 2 |
| $ \begin{array}{c} 20110612 & \operatorname{mixp} 20110612 0003 & 300. & 1387.20 & 5.44 & 174.066 & 1 \\ 20110612 & \operatorname{mixp} 20110613 00003 & 300. & 1387.50 & 5.44 & 174.066 & 1 \\ 20110613 & \operatorname{mixp} 20110613 0002 & 600. & 1389.38 & -46.689 & -158.271 & 1 \\ 20110613 & \operatorname{mixp} 20110613 0002 & 600. & 1389.38 & -46.689 & -158.271 & 1 \\ 20110613 & \operatorname{mixp} 20110613 0085 & 300. & 1389.69 & -99.012 & -103.402 & 1 \\ 20110613 & \operatorname{mixp} 20110613 0085 & 300. & 1389.69 & -99.017 & -103.823 & 2 \\ 20110613 & \operatorname{mixp} 20110613 0086 & 120. & 1389.04 & -99.87 & -103.823 & 4 \\ 20110613 & \operatorname{mixp} 20110613 0086 & 600. & 1389.47 & -100.899 & -104.329 & 6 \\ 20110627 & \operatorname{mixp} 20110623 0086 & 600. & 1389.47 & -100.899 & -104.329 & 6 \\ 20110627 & \operatorname{mixp} 20110627 0022 & 500. & 1389.69 & -63.788 & -150.756 & 2 \\ 20110627 & \operatorname{mixp} 20110627 0022 & 500. & 1390.17 & -76.126 & -137.349 & 1 \\ 20110627 & \operatorname{mixp} 20110627 0022 & 407. & 1390.11 & -76.126 & -137.349 & 1 \\ 20110627 & \operatorname{mixp} 20110627 0022 & 300. & 1388.61 & -29.742 & 32.864 & 1 \\ 20110627 & \operatorname{mixp} 20110627 0022 & 300. & 1383.61 & -29.742 & 32.864 & 1 \\ 20110709 & \operatorname{mixp} 20110700016 & 600. & 1333.11 & -74.773 & -135.368 & 1 \\ 20110709 & \operatorname{mixp} 20110700016 & 600. & 1333.41 & -74.773 & -135.368 & 1 \\ 20110709 & \operatorname{mixp} 201107200012 & 000. & 1332.21 & 104.221 & 102.98 & 2 \\ 20110772 & \operatorname{mixp} 201107200013 & 000. & 1332.41 & -25.586 & 34.375 & 2 \\ 20110777 & \operatorname{mixp} 201107200003 & 300. & 1322.43 & -25.586 & 34.375 & 2 \\ 20110777 & \operatorname{mixp} 201107200003 & 300. & 1332.43 & -25.586 & 34.375 & 2 \\ 20110777 & \operatorname{mixp} 201107210003 & 300. & 1332.43 & -25.586 & 34.375 & 2 \\ 20110727 & \operatorname{mixp} 201107210003 & 300. & 1332.43 & -25.586 & 34.375 & 2 \\ 20110727 & \operatorname{mixp} 201107210003 & 300. & 1332.43 & -25.586 & 34.375 & 2 \\ 20110731 & \operatorname{mixp} 201107310075 & 300. & 1332.84 & -13.243 & -45.563 & 3 \\ 20110731 & \operatorname{mixp} 201107310075 & 300. & 1332.84 & -25.586 & 34.375 & 2 \\ 20110731 & \operatorname{mixp} 201107310075 & 300. & 1338.84 & 28.623 & 167.774 & 1 \\ 20110731 & \operatorname{mixp} 201108020004 & 300. & 1389.43 & -25.586 & 34.375 & 2 \\ 20110$ | 20110606 | mbxpP201106060038 | 300. | 1388.07 | 62 751 | 147.018 | 23 |
| $ \begin{array}{c} 1 \\ 1 \\ 2 \\ 2 \\ 2 \\ 2 \\ 2 \\ 2 \\ 2 \\ 1 \\ 1$ | 20110612 | mbypP201106120003 | 200 | 1287 20 | 5 44 | 174.006 | 1 |
| $ \begin{array}{c} \begin{tabular}{ c c c c c c c c c c c c c c c c c c c$ | 20110012 | mbypP201106120003 | 200. | 1287.50 | 5.44 | 174.090 | 1 |
| $ \begin{array}{c} 20110012 & 10012 0 10012 0 0 0 0 0 0 0 0 0 0 0 0 0$ | 20110012 | mbxpr 201100120004 | 300. | 1207.50 | 5.44 | 174.090 | 2 |
| | 20110012 | mbxpF201106120005 | 300. | 1307.33 | 0.44 | 174.090 | 3 |
| $\begin{array}{c} \begin{tabular}{l lllllllllllllllllllllllllllllllllll$ | 20110013 | mbxpF201106130002 | 600 | 1200.20 | -40.089 | -100.271 | 1 |
| $\begin{array}{c} 10110013 \\ mbxpP201106130087 \\ 120. 1389.74 \\ .99.87 \\ .103.823 \\ .20110013 \\ mbxpP201106130087 \\ 120. 1389.74 \\ .99.87 \\ .103.823 \\ .4. \\ .20110013 \\ mbxpP201106130089 \\ .100. 1389.47 \\ .100.899 \\ .104.329 \\ .100.890 \\ .101.890 \\ .100.890 \\ .101.890 \\ .100.890 \\ .101.890 \\ .100.890 \\ .101.890 \\ .100.890 \\ .101.890 \\ .100.890 \\ .101.890 \\ .100.890 \\ .101.890 \\ .100.890 \\ .101.890 \\ .100.890 \\ .101.890 \\ .100.890 \\ .101.890 \\ .100.890 \\ .101.890 \\ .100.890 \\ .101.890 \\ .100.890 \\ .101.890 \\ .100.890 \\ .101.890 \\ .100.890 \\ .101.890 \\ .100.800 \\ .100.890 \\ .100.800 \\ .100$ | 20110613 | mbxpr201100130003 | 200 | 1209.38 | -40.089 | -100.271 | 2 1 |
| $\begin{array}{c} 10110013 \\ mbxpP201106130088 \\ 120. \\ 1390.03 \\ -9.87 \\ -103.823 \\ 3\\ 20110013 \\ mbxpP201106130088 \\ 120. \\ 1389.47 \\ -100.899 \\ -104.329 \\ 5\\ 20110027 \\ mbxpP201106270002 \\ 173. \\ 1389.47 \\ -100.899 \\ -104.329 \\ 5\\ 20110027 \\ mbxpP201106270002 \\ 173. \\ 1389.49 \\ -63.798 \\ -150.756 \\ 1\\ 20110027 \\ mbxpP201106270002 \\ 173. \\ 1389.49 \\ -63.798 \\ -150.756 \\ 1\\ 20110027 \\ mbxpP201106270024 \\ 500. \\ 1390.11 \\ -76.126 \\ -137.349 \\ 1\\ 20110027 \\ mbxpP201106270027 \\ 300. \\ 1389.40 \\ -29.742 \\ 32.964 \\ 1\\ 20110027 \\ mbxpP201106270027 \\ 300. \\ 1389.41 \\ -29.742 \\ 32.964 \\ 1\\ 20110709 \\ mbxpP201106270027 \\ 300. \\ 1393.39 \\ -74.773 \\ -135.368 \\ 1\\ 20110709 \\ mbxpP201107200015 \\ 600. \\ 1393.39 \\ -74.773 \\ -135.368 \\ 2\\ 20110709 \\ mbxpP201107200017 \\ 600. \\ 1392.41 \\ -25.866 \\ 34.375 \\ 2\\ 20110727 \\ mbxpP20110720001 \\ 300. \\ 1392.41 \\ -25.866 \\ 34.375 \\ 2\\ 20110727 \\ mbxpP20110720002 \\ 600. \\ 1392.41 \\ -25.866 \\ 34.375 \\ 2\\ 20110727 \\ mbxpP20110720003 \\ 300. \\ 1392.41 \\ -25.866 \\ 34.375 \\ 2\\ 20110731 \\ mbxpP201107310056 \\ 300. \\ 1392.25 \\ -111.829 \\ -86.156 \\ 3\\ 20110731 \\ mbxpP201107310075 \\ 300. \\ 1389.84 \\ 28.623 \\ 167.774 \\ 2\\ 20110731 \\ mbxpP201107310075 \\ 300. \\ 1389.84 \\ 28.623 \\ 167.774 \\ 2\\ 20110731 \\ mbxpP201107310075 \\ 300. \\ 1389.84 \\ 28.623 \\ 167.774 \\ 2\\ 20110731 \\ mbxpP201107310075 \\ 300. \\ 1389.84 \\ 28.623 \\ 167.774 \\ 2\\ 20110731 \\ mbxpP201107310075 \\ 300. \\ 1389.84 \\ 28.623 \\ 167.774 \\ 2\\ 20110731 \\ mbxpP20110830004 \\ 300. \\ 1390.56 \\ 42.433 \\ -48.63 \\ 3\\ 20110801 \\ mbxpP20110800004 \\ 300. \\ 1390.56 \\ 42.433 \\ -48.63 \\ 3\\ 20110802 \\ mbxpP20110800004 \\ 300. \\ 1390.56 \\ 42.433 \\ -48.63 \\ 3\\ 20110802 \\ mbxpP20110800004 \\ 300. \\ 1390.56 \\ 42.433 \\ -48.63 \\ 3\\ 20110802 \\ mbxpP20110800004 \\ 300. \\ 1390.56 \\ 42.433 \\ -48.63 \\ 3\\ 20110802 \\ mbxpP20110800004 \\ 300. \\ 1390.56 \\ 42.433 \\ -48.63 \\ 3\\ 20110802 \\ mbxpP20110800004 \\ 300. \\ 1390.56 \\ 42.433 \\ -48.63 \\ 3\\ 20110802 \\ mbxpP20110800004 \\ 300. \\ 1390.56 \\ 42.433 \\ -48.63 \\ 3\\ 20110802 \\ mbxpP20110800004 \\ 300. \\ 1390.56 \\ 42.433 \\ -48.63 \\ 3\\ 20110802 \\ m$ | 20110613 | mbxpF201106130085 | 300. 190 | 1300.00 | -99.012 | -103.400 | 1 |
| $\begin{array}{c} 1010015 & \text{mbsp}201106130085 & 120. \\ 1390.03 & -99.87 & -103.823 & 4 \\ 20110613 & \text{mbsp}201106130089 & 600. \\ 1389.47 & -100.899 & -104.329 & 6 \\ 20110627 & \text{mbsp}201106270001 & 600. \\ 1389.47 & -100.899 & -104.329 & 6 \\ 20110627 & \text{mbsp}201106270023 & 500. \\ 1390.17 & -76.126 & -137.349 & 1 \\ 20110627 & \text{mbsp}201106270025 & 407. \\ 1390.11 & -76.126 & -137.349 & 1 \\ 20110627 & \text{mbsp}201106270025 & 407. \\ 1390.11 & -76.126 & -137.349 & 2 \\ 20110627 & \text{mbsp}201106270025 & 407. \\ 1390.11 & -76.126 & -137.349 & 3 \\ 20110627 & \text{mbsp}201106270025 & 407. \\ 1390.11 & -76.126 & -137.349 & 3 \\ 20110709 & \text{mbsp}201106270025 & 407. \\ 1393.30 & -29.795 & 28.833 & 2 \\ 20110709 & \text{mbsp}201107090015 & 600. \\ 1393.39 & -74.773 & -135.368 & 1 \\ 20110709 & \text{mbsp}201107090017 & 600. \\ 1393.39 & -74.773 & -135.368 & 2 \\ 20110720 & \text{mbsp}20110720002 & 600. \\ 1392.18 & -10.5286 & 34.375 & 1 \\ 20110727 & \text{mbsp}20110720002 & 600. \\ 1392.43 & -25.586 & 34.375 & 1 \\ 20110727 & \text{mbsp}201107270012 & 300. \\ 1392.43 & -25.586 & 34.375 & 3 \\ 20110721 & \text{mbsp}201107210005 & 300. \\ 1392.43 & -25.586 & 34.375 & 3 \\ 20110731 & \text{mbsp}201107310075 & 300. \\ 1392.44 & -25.586 & 34.375 & 3 \\ 20110731 & \text{mbsp}201107310075 & 300. \\ 1392.48 & -28.623 & 167.774 & 1 \\ 20110731 & \text{mbsp}201107310076 & 300. \\ 1394.84 & 28.623 & 167.774 & 1 \\ 20110731 & \text{mbsp}201107310076 & 300. \\ 1394.84 & 28.623 & 167.774 & 1 \\ 20110731 & \text{mbsp}201107310076 & 300. \\ 1394.84 & 28.623 & 167.774 & 1 \\ 20110801 & \text{mbsp}20110801000 & 600. & 1391.87 & 21.04 & -22.617 & 2 \\ 20110731 & \text{mbsp}20110801000 & 600. & 1391.89 & 22.55 & -29.803 & 3 \\ 20110802 & \text{mbsp}20110800004 & 300. & 1390.56 & 42.433 & -48.563 & 1 \\ 20110801 & \text{mbsp}20110800004 & 300. & 1390.56 & 42.433 & -48.563 & 1 \\ 20110801 & \text{mbsp}20110800004 & 300. & 1390.56 & 42.433 & -48.563 & 1 \\ 20110801 & \text{mbsp}201108050005 & 900. & 1389.157 & 7.24 & -39.912 & 4 \\ 20110802 & \text{mbsp}201108050005 & 300. & 1393.84 & -66.665 & -149.288 & 1 \\ 20110806 & \text{mbsp}201108060087 & 300. & 1393.84 & -66.$ | 20110013 | mbarp 201100130080 | 120. | 1280.09 | -99.01 | 102 002 | 2 |
| $ \begin{array}{c} \begin{tabular}{lllllllllllllllllllllllllllllllllll$ | 20110613 | mbxpr201100130087 | 120. | 1200.02 | -99.87 | -103.823 | 3 4 |
| $ \begin{array}{c} \begin{tabular}{l lllllllllllllllllllllllllllllllllll$ | 20110613 | mbxpP201106130088 | 120. | 1390.03 | -99.87 | -103.823 | 4 |
| $ \begin{array}{c} 20110627 \\ mbxpP201106270001 6000. 1389.71 & -100.899 & -104.329 & 6 \\ 20110627 \\ mbxpP201106270021 173. 1389.69 & -63.798 & -150.756 & 2 \\ 20110627 \\ mbxpP201106270023 500. 1390.12 & -76.126 & -137.349 & 2 \\ 20110627 \\ mbxpP201106270023 500. 1390.12 & -76.126 & -137.349 & 3 \\ 20110627 \\ mbxpP201106270027 & 300. 1389.61 & -29.742 & 32.964 & 1 \\ 20110627 \\ mbxpP201106270027 & 300. 1389.61 & -29.742 & 32.964 & 1 \\ 20110627 \\ mbxpP201107090015 & 600. 1393.30 & -74.773 & -135.368 & 1 \\ 20110709 \\ mbxpP201107090016 & 600. 1393.30 & -74.773 & -135.368 & 1 \\ 20110709 \\ mbxpP201107090016 & 600. 1393.30 & -74.773 & -135.368 & 3 \\ 20110720 \\ mbxpP20110720001 & 600. 1392.12 & 104.521 & 102.98 & 1 \\ 20110727 \\ mbxpP20110720001 & 600. 1392.13 & 104.521 & 102.98 & 1 \\ 20110727 \\ mbxpP20110720003 & 300. 1392.41 & -25.586 & 34.375 & 1 \\ 20110727 \\ mbxpP20110720003 & 300. 1392.43 & -25.586 & 34.375 & 2 \\ 20110731 \\ mbxpP201107310056 & 300. 1392.25 & -111.829 & -86.156 & 1 \\ 20110731 \\ mbxpP201107310057 & 300. 1392.25 & -111.829 & -86.156 & 1 \\ 20110731 \\ mbxpP201107310075 & 300. 1389.84 & 28.623 & 167.774 & 1 \\ 20110731 \\ mbxpP201107310075 & 300. 1389.84 & 28.623 & 167.774 & 3 \\ 20110731 \\ mbxpP201107310075 & 300. 1389.84 & 28.623 & 167.774 & 3 \\ 20110731 \\ mbxpP201107310075 & 300. 1389.84 & 28.623 & 167.774 & 3 \\ 20110731 \\ mbxpP201107310075 & 300. 1389.84 & 28.623 & 167.774 & 3 \\ 20110801 \\ mbxpP2011080004 & 300. 1389.84 & 28.623 & 167.774 & 3 \\ 20110801 \\ mbxpP2011080004 & 300. 1389.84 & 28.623 & 167.774 & 3 \\ 20110801 \\ mbxpP2011080004 & 300. 1389.84 & 28.623 & 167.774 & 3 \\ 20110801 \\ mbxpP2011080004 & 300. 1390.56 & 42.433 & -48.563 & 1 \\ 20110802 \\ mbxpP2011080004 & 300. 1390.56 & 42.433 & -48.563 & 1 \\ 20110802 \\ mbxpP20110800042 & 300. 1390.56 & 42.433 & -48.563 & 3 \\ 20110802 \\ mbxpP20110800042 & 300. 1390.56 & 42.433 & -48.563 & 3 \\ 20110806 \\ mbxpP20110800004 & 300. 1390.56 & -66.052 & -151.239 & 2 \\ 20110806 \\ mbxpP20110800004 & 300. 1393.85 & -60.962 & -151.239 & 1 \\ 20110806 \\ mbxpP201108020004 & 300. 138$ | 20110013 | mbxpr201106130089 | 600. | 1309.47 | -100.899 | -104.329 | Э С |
| | 20110613 | mbxpP201106130090 | 600. | 1389.47 | -100.899 | -104.329 | 6 |
| $ \begin{array}{c} 20110627 \\ mbxpP201106270024 \\ 500. \\ 1390.12 \\ -76.126 \\ -137.349 \\ 120110627 \\ mbxpP201106270024 \\ 500. \\ 1390.12 \\ -76.126 \\ -137.349 \\ 20110627 \\ mbxpP201106270027 \\ 300. \\ 1390.11 \\ -76.126 \\ -137.349 \\ 20110627 \\ mbxpP201106270027 \\ 300. \\ 1389.30 \\ -29.742 \\ 32.964 \\ 12011062 \\ mbxpP201106270027 \\ 300. \\ 1389.30 \\ -29.742 \\ 32.968 \\ 138.33 \\ -29.752 \\ 28.833 \\ 20110709 \\ mbxpP201107090015 \\ 600. \\ 1393.36 \\ -74.773 \\ -135.368 \\ 120110709 \\ mbxpP201107090017 \\ 600. \\ 1393.36 \\ -74.773 \\ -135.368 \\ 120110720 \\ mbxpP20110720001 \\ 600. \\ 1391.81 \\ 104.521 \\ 102.98 \\ 20110727 \\ mbxpP20110720001 \\ 600. \\ 1392.41 \\ -25.586 \\ 34.375 \\ 20110727 \\ mbxpP201107270003 \\ 300. \\ 1392.41 \\ -25.586 \\ 34.375 \\ 20110727 \\ mbxpP201107210003 \\ 300. \\ 1392.41 \\ -25.586 \\ 34.375 \\ 20110731 \\ mbxpP201107310056 \\ 300. \\ 1392.24 \\ -111.829 \\ -86.156 \\ 20110731 \\ mbxpP201107310075 \\ 300. \\ 1392.28 \\ -111.829 \\ -86.156 \\ 20110731 \\ mbxpP201107310075 \\ 300. \\ 1389.84 \\ 28.623 \\ 167.774 \\ 120110731 \\ mbxpP201107310075 \\ 300. \\ 1389.84 \\ 28.623 \\ 167.774 \\ 20110731 \\ mbxpP201107310077 \\ 300. \\ 1389.84 \\ 28.623 \\ 167.774 \\ 20110731 \\ mbxpP201107310077 \\ 300. \\ 1389.84 \\ 28.623 \\ 167.774 \\ 20110801 \\ mbxpP201107310077 \\ 300. \\ 1389.84 \\ 28.623 \\ 167.774 \\ 2011081 \\ mbxpP201107310076 \\ 300. \\ 1389.84 \\ 28.623 \\ 167.774 \\ 20110801 \\ mbxpP201107310076 \\ 300. \\ 1389.84 \\ 28.623 \\ 167.774 \\ 20110801 \\ mbxpP20110830004 \\ 300. \\ 1389.84 \\ 23.847 \\ 169.766 \\ 42.433 \\ -48.563 \\ 20110802 \\ mbxpP20110800008 \\ 300. \\ 1391.81 \\ 22.104 \\ -22.617 \\ 2011080 \\ mbxpP20110800006 \\ 300. \\ 1391.80 \\ -45.340 \\ 38.73 \\ 42.53 \\ 2011080 \\ mbxpP20110800006 \\ 300. \\ 1390.56 \\ 42.433 \\ -48.563 \\ 2011080 \\ mbxpP20110800006 \\ 300. \\ 1393.56 \\ -60.962 \\ -151.239 \\ 2011080 \\ mbxpP20110800006 \\ 300. \\ 1393.56 \\ -60.962 \\ -151.239 \\ 2011080 \\ mbxpP20110800006 \\ 300. \\ 1393.56 \\ -60.962 \\ -151.239 \\ 2011080 \\ mbxP20110800006 \\ 300. \\ 1393.56 \\ -66.962 \\ -151.239 \\ 2011080 \\ mbxP20110800006 \\ 300. \\ 1393.56 \\ -66.962 \\ -151.239 \\ 2011080 \\ mbxP20110800006 \\ 300. \\$ | 20110627 | mbxpP201106270001 | 600. | 1389.71 | -63.798 | -150.756 | 1 |
| $ \begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110627 | mbxpP201106270002 | 173. | 1389.69 | -63.798 | -150.756 | 2 |
| $ \begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110627 | mbxpP201106270023 | 500. | 1390.17 | -76.126 | -137.349 | 1 |
| $ \begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110627 | mbxpP201106270024 | 500. | 1390.12 | -76.126 | -137.349 | 2 |
| $ \begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110627 | mbxpP201106270025 | 407. | 1390.11 | -76.126 | -137.349 | 3 |
| 20110709 mbxpP201107090015 600. 1393.39 -74.773 -135.368 1 20110709 mbxpP201107090016 600. 1393.39 -74.773 -135.368 2 20110709 mbxpP201107200001 600. 1393.56 -74.773 -135.368 3 20110720 mbxpP201107200002 600. 1392.12 104.521 102.98 1 20110727 mbxpP201107270002 300. 1392.41 -25.586 34.375 1 20110731 mbxpP201107310055 300. 1392.20 -111.829 -86.156 2 20110731 mbxpP201107310057 300. 1382.25 -111.829 -86.156 3 20110731 mbxpP201107310075 300. 1389.84 28.623 167.774 2 20110731 mbxpP201107310076 300. 1389.84 28.623 167.774 2 20110731 mbxpP201108010016 600. 1391.87 22.104 -22.617 1 20110801 mbxpP201108000041 30 | 20110627 | mbxpP201106270027 | 300. | 1389.61 | -29.742 | 32.964 | 1 |
| 20110709 mbxpP201107090015 600. 1393.11 -74.773 -135.368 1 20110709 mbxpP201107090016 600. 1393.56 -74.773 -135.368 3 20110720 mbxpP201107200001 600. 1391.81 104.521 102.98 1 20110720 mbxpP201107270002 600. 1392.41 -25.586 34.375 2 20110727 mbxpP201107270003 300. 1392.43 -25.586 34.375 2 20110731 mbxpP201107310055 300. 1392.43 -25.586 34.375 3 20110731 mbxpP201107310056 300. 1392.43 -25.586 34.375 3 20110731 mbxpP201107310076 300. 1389.84 28.623 167.774 1 20110731 mbxpP201107310076 300. 1389.84 28.623 167.774 2 20110731 mbxpP201108010016 600. 1391.81 22.104 -22.617 2 20110801 mbxpP201108000041 300. <td>20110627</td> <td>mbxpP201106270028</td> <td>300.</td> <td>1389.30</td> <td>-29.795</td> <td>28.833</td> <td>2</td> | 20110627 | mbxpP201106270028 | 300. | 1389.30 | -29.795 | 28.833 | 2 |
| 20110709 mbxpP201107090016 600. 1393.39 -74.773 -133.368 2 20110720 mbxpP201107200001 600. 1391.81 104.521 102.98 1 20110720 mbxpP201107200002 600. 1392.81 -25.586 34.375 1 20110727 mbxpP201107270002 300. 1392.61 -25.586 34.375 3 20110731 mbxpP201107310055 300. 1392.43 -25.586 34.375 3 20110731 mbxpP201107310056 300. 1392.25 -111.829 -86.156 2 20110731 mbxpP201107310075 300. 1389.84 28.623 167.774 2 20110731 mbxpP201107310076 300. 1389.84 28.623 167.774 2 20110731 mbxpP2011080100076 600. 1391.81 22.104 -22.617 2 20110801 mbxpP201108010011 50. 1391.81 22.104 -22.617 2 20110801 mbxpP201108020041 300. <td>20110709</td> <td>mbxpP201107090015</td> <td>600.</td> <td>1393.11</td> <td>-74.773</td> <td>-135.368</td> <td>1</td> | 20110709 | mbxpP201107090015 | 600. | 1393.11 | -74.773 | -135.368 | 1 |
| $ \begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110709 | mbxpP201107090016 | 600. | 1393.39 | -74.773 | -135.368 | 2 |
| $ \begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110709 | mbxpP201107090017 | 600. | 1393.56 | -74.773 | -135.368 | 3 |
| $ \begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110720 | mbxpP201107200001 | 600. | 1391.81 | 104.521 | 102.98 | 1 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110720 | mbxpP201107200002 | 600. | 1392.12 | 104.521 | 102.98 | 2 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110727 | mbxpP201107270001 | 300. | 1392.81 | -25.586 | 34.375 | 1 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110727 | mbxpP201107270002 | 300. | 1392.61 | -25.586 | 34.375 | 2 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110727 | mbxpP201107270003 | 300. | 1392.43 | -25.586 | 34.375 | 3 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110731 | mbxpP201107310055 | 300. | 1392.20 | -111.829 | -86.156 | 1 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110731 | mbxpP201107310056 | 300. | 1392.18 | -111.829 | -86.156 | 2 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110731 | mbxpP201107310057 | 300. | 1392.25 | -111.829 | -86.156 | 3 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110731 | mbxpP201107310075 | 300. | 1389.82 | 28.623 | 167.774 | 1 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110731 | mbxpP201107310076 | 300. | 1389.84 | 28.623 | 167.774 | 2 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110731 | mbxpP201107310077 | 300. | 1389.84 | 28.623 | 167.774 | 3 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110731 | mbxpP201107310078 | 300. | 1389.82 | 23.847 | 169.756 | 4 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110801 | mbxpP201108010009 | 600. | 1391.81 | 22.104 | -22.617 | 1 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110801 | mbxpP201108010010 | 600. | 1391.57 | 22.104 | -22.617 | 2 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110801 | mbxpP201108010011 | 550. | 1391.39 | 22.255 | -29.803 | 3 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110802 | mbxpP201108020040 | 300. | 1390.64 | 42.433 | -48.563 | 1 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110802 | mbxpP201108020041 | 300. | 1390.50 | 42.433 | -48.563 | 2 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110802 | mbxpP201108020042 | 300. | 1390.56 | 42.433 | -48.563 | 3 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110825 | mbxpP201108250005 | 900. | 1389.17 | 37.724 | -39.912 | 4 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110825 | mbxpP201108250006 | 900. | 1388.83 | 37.442 | -45.351 | 5 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110803 | mbxpP201108030064 | 300. | 1391.80 | -45.340 | 38.734 | 1 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110803 | mbxpP201108030065 | 227. | 1391.67 | -45.340 | 38.734 | 2 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110806 | mbxpP201108060087 | 300. | 1393.38 | -60.962 | -151.239 | 1 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110806 | mbxpP201108060088 | 300. | 1393.61 | -60.962 | -151.239 | 2 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110806 | mbxpP201108060089 | 300. | 1393.59 | -60.962 | -151.239 | 3 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110806 | mbxpP201108060091 | 300. | 1393.85 | -66.605 | -149.288 | 1 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110806 | mbxpP201108060092 | 300. | 1394.08 | -67.767 | -148.903 | 2 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110829 | mbxpP201108290001 | 600. | 1390.57 | -64.782 | -147.078 | 1 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110829 | mbxpP201108290003 | 600. | 1390.58 | -68.295 | -145.625 | 2 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20110829 | mbxpP201108290004 | 300. | 1390.54 | -70.545 | -144.859 | 3 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20120218 | mbxpP201202180064 | 300. | 1389.17 | 78.412 | 160.723 | 1 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20120218 | mbxpP201202180065 | 300. | 1389.28 | 77.053 | 161.817 | 2 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20120218 | mbxpP201202180066 | 300. | 1389.42 | 75.746 | 162.938 | 3 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20120219 | mbxpP201202190087 | 300. | 1388.23 | -55.032 | -155.229 | 1 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20120219 | mbxpP201202190088 | 60. | 1388.24 | -55.325 | -155.079 | 2 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20120220 | mbxpP201202200003 | 300. | 1388.57 | -42.875 | -164.321 | 1 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20120220 | mbxpP201202200004 | 300. | 1388.75 | -44.361 | -163.678 | 2 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20120221 | mbxpP201202210031 | 300. | 1387.40 | 52.976 | 52.211 | 1 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20120221 | mbxpP201202210032 | 300. | 1387.55 | 50.684 | 53.243 | 2 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 20120412 | mbxpP201204120029 | 300. | 1387.83 | 63.183 | 142.041 | 1 |
| 20120420 mbxpP201204200097 600. 1389.13 -21.975 70.536 1 | 20120412 | mbxpP201204120030 | 300. | 1388.06 | 59.749 | 143.948 | 2 |
| · · · · · · · · · · · · · · · · · · · | 20120420 | mbxpP201204200097 | 600. | 1389.13 | -21.975 | 70.536 | 1 |
| 20120420 mbxpP201204200098 600. 1388.95 -22.536 68.240 2 | 20120420 | mbxpP201204200098 | 600. | 1388.95 | -22.536 | 68.240 | 2 |

Table 1: Analysed observations

SALT 2202AA1000

Page 6 from 9



| | | |
|-------------|-------------|-------------|
| a0 | a1 | a2 |
| 4.6324E-01 | 9.9628E-04 | -5.6693E-05 |
| a3 | a4 | a5 |
| -3.6517E-02 | -3.2858E-04 | -1.4707E-06 |
| a6 | a7 | a8 |
| -1.9955E-05 | 4.3172E-06 | 4.3492E-08 |

| Table ' |). | The | final | coefficients | for | the | flevure | function |
|---------|----|------|-------|--------------|-----|-----|---------|----------|
| Table_4 | 4. | T He | mai | coefficients | 101 | une | nexure | Tunction |

3.1 RSS flexure and RSS stability without flexure

Figure 1 shows the distributions for measured positions depending on azimuth angle (top panel) and rho angle (bottom panel). The mean value was subtracted from these distributions. If some frames were observed in sequence (see Table 1), we show only the measured position for the first frame in these figures. In total, 37 measurements are shown.

There is an obvious dependence of the measured position on both azimuthal and rho angles, which could be fitted with a second order polynomial each:

$$\delta(AZ) = -6.9125 \cdot 10^{-5} \times AZ^2 - 8.1289 \cdot 10^{-3} \times AZ + 0.86012$$
(1)

$$\delta(\text{RHO}) = -7.6123 \cdot 10^{-5} \times \text{RHO}^2 - 2.9840 \cdot 10^{-2} \times \text{RHO} - 0.11321$$
(2)

The top panel of Figure 2 shows the histogram of all measured positions for the 5577 nightsky line. The mean value was also subtracted from this distribution. The distribution has a standard deviation of 2.41 pixels. After correction for azimuth only, the standard deviation is 2.14 pixels, and after correction for rho angle only, the standard deviation is 2.16 pixels.

After that we used a polynomial fit with two independent variables of the form:

$$\begin{split} \delta(\mathrm{AZ},\mathrm{RHO}) &= \mathrm{a0} + \mathrm{a1} * \mathrm{AZ} + \mathrm{a2} * \mathrm{AZ}^2 + \mathrm{a3} * \mathrm{RHO} + \mathrm{a4} * \mathrm{AZ} * \mathrm{RHO} + \mathrm{a5} * \mathrm{AZ}^2 * \mathrm{RHO} \\ &+ \mathrm{a6} * \mathrm{RHO}^2 + \mathrm{a7} * \mathrm{AZ} * \mathrm{RHO}^2 + \mathrm{a8} * \mathrm{AZ}^2 * \mathrm{RHO}^2, \end{split}$$

where final values for the coefficients are shown in Table 2. Using this polynomial fit, after correction for both azimuth and rho angle the final distribution has a standard deviation of 1.63 pixels, and the final histogram is shown in the bottom panel of Figure 2.

Finally, we have to conclude that science spectra, which were taken without a reference spectrum and were corrected for the systematic flexure shown above could still have a random shift of ~ 1.6 pixels or ~ 1.5 Å for GR900 grating. We believe that found fit has to be the same for different gratings since it was found in pixel space.

We have to note here that, from the general point of view, RSS flexure is a 2D function (along columns and rows) and not 1D only (along rows) as we can see in this study. Unfortunately, the shift along columns can not be studied in the same way.



3.2 RSS flexure drift

To study flexure drift, we calculated the difference in the 5577 night-sky line position between the first and the last frames in each sequence and the total exposure time between these frames. The final numbers were normalised to an exposure time of 900s for uniform result. Figure 3 shows the distributions for measured drift values depending on azimuth angle (top panel) and rho angle (bottom panel). In total, 28 measurements are shown.

We make the same analysis as was shown in the previous section and found a second order polynomial fit for each the azimuth and the rwho angle dependence. This fit is also shown in Figure 3:

$$\delta(AZ) = -1.7182 \cdot 10^{-5} \times AZ^2 - 1.2886 \cdot 10^{-4} \times AZ + 0.2395$$
(3)

$$\delta(\text{RHO}) = -2.228 \cdot 10^{-5} \times \text{RHO}^2 - 8.8635 \cdot 10^{-4} \times \text{RHO} + 0.030537$$
(4)

The top panel of Figure 4 shows the histogram of all measured drifts for the 5577 night-sky line, which was normalised to 900s exposure time. This distribution has a standard deviation of 0.25 pixels. After correction for azimuth only, the distribution has a standard deviation of 0.19 pixel. After correction for rho angle only, the distribution has a standard deviation of 0.24 pixel. Correction for both the azimuth and rho angle produces the best result, where the final standard deviation is 0.17 pixels, and the final histogram is shown in the bottom panel of Figure 4. The final coefficients for the best second order polynomial fit with two independent variables are presented in Table 3.

| a0 | al | a2 |
|-------------|-------------|-------------|
| 3.4082E-01 | 3.4054 E-06 | -1.9551E-05 |
| a3 | a4 | a5 |
| -1.8326E-03 | -4.4359E-06 | 7.4197E-08 |
| a6 | a7 | a8 |
| -3.6000E-05 | -2.7353E-08 | 1.3593E-09 |

Table 3: The final coefficients for the flexure drift function

4 Summary and recomendations

We studied different aspects of RSS flexure and the repeatability of RSS spectral setups.

1. We would like to recommend that all PIs during Phase 2 request a reference spectrum immediately **AFTER** or **BEFORE** the spectral observations for **EACH** spectral block. Otherwise, even after correction for the systematic flexure, your data will have random shift with a dispersion of ~ 1.6 pixels (2×2 binning). Please, take into account that since the wavelength calibration function for the RSS is a third order polynomial, this shift will be



NON-LINEAR over the covered spectral region and you will **NOT BE ABLE** to correct for that by just shifting your total spectrum.

2. PIs have to know that RSS flexure drift exist and it is an obvious function of azimuth. The found drift amplitude could be as much as ~ 0.4 pixels (2×2 binning) per 900s of exposure time and has to be **INDEPENDENT** on the used RSS grating even though it was measured only for GR900 in this report. But even after correction for the systematic part, it still has a random part with a dispersion of ~ 0.17 pixels (2×2 binning).

For many science projects, shifts of less than one unbinned pixel are acceptable. However, it could be unacceptable for some projects. In this case, we recommend to correct for this random shift using night sky lines **BEFORE** to sum/average different exposures.





Figure 3: The distributions for measured drift values depending on azimuth angle (top panel) and rho angle (bottom panel). The result of the second order polynomial fit is also shown for both panels.





Figure 4: **Top panel:** The histogram of all measured drifts for the 5577 night-sky line. The standard deviation for this distribution is 0.25 pixels. **Bottom panel:** The same histogram after correction for azimuthal and rho angle. The standard deviation for this distribution is 0.17 pixels.