The accuracy of the RGS Wavelength Scale XMM-SOC-CAL-TN-0098 issue 1.1

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1 Introduction

The improvement of the wavelength scale of the RGS instruments has been one of the prime objectives of the XMM-Newton calibration since the beginning the mission.

The accuracy of the wavelength scale of a given RGS spectrum depends on one side on the knowledge of all the parameters involved in the geometry of the system (given in the calibration files) and on the other, on the precision of the coordinates of the considered source, that are needed by SAS to process the data.

Previous studies of RGS spectra of emission line sources have shown that there is a systematic shift of the line positions with respect to laboratory wavelengths, and that the wavelength scales of both RGS are displaced by a few mÅ. These works have also established that wavelengths measured in RGS spectra are accurate to $\approx$ 7 mÅ in first order and to $\approx$ 5 mÅ in second order (Lorente et al. 2003).

Along the last years, several studies have been carried out to clarify the origin of these systematic effects and to identify possible ways to minimise them.

Coia and Pollock (2007, hereafter CP07) measured global fits of 66 observations of the four wavelength calibrators (AB Dor, Capella, Procyon and HR 1099). Special care was put in using accurate coordinates, taking into account the proper motion of the stars. They found a systematic shift of 5 mÅ between first order RGS1 and RGS2 spectra. The shift in second order was smaller, only 2 mÅ. A further study by the same authors (Coia and Pollock, 2008) showed that this systematic shift can be suppressed by changing the incidence angle α_0 by 1.2 and 3.4 arcsec for RGS1 and RGS2, respectively.

González-Riestra (2008, hereafter GR08) tried to find a correlation between the wavelength shift and other parameter (time, position angle...). This work used a sub-sample of CP07 data (38 observations), and confirmed the shifts previously found, as well as the tight correlation between the shifts of both instruments. The main result of this work was the correlation found between the wavelength shift and the the spacecraft "Solar Angle"[1] (the angular distance between the Sun and the pointing direction, see clarification below).

The application of this correction, in addition to make the average shifts close to zero and to align both instruments, decreases the scatter of the line shifts by $\approx$ 20%.

This study left some points open. The present report has the following goals:

- To investigate the effect of correcting the observed wavelengths for the velocity of the Earth with respect to the Solar System barycentre,
- To determine if that correction improves the correlation between line shifts and Solar Angle.
- To study the possible dependence of line shifts on wavelength.

To address these points it is necessary to know not only the global shift of each spectrum, but the positions of the individual lines. Therefore the dataset of CP07 is not suitable for this purpose, and a different approach is needed. Also, recent data have been added to the sample.

[1]The relation between wavelength shift and Solar Angle has been confirmed independently by Kaastra et al. (2011) in their analysis of RGS spectra of Mkn 509.

2 Methodology

The new sample is composed of 119 exposures (59 for RGS1, 60 for RGS2) of the four wavelength calibrators (AB Dor, Capella, HR 1099 and Procyon) observed between rev. 54 (March 2000) and 2027 (Jan 2011). The list of spectra used in this work is given in Table 6.

The observations used in the analysis were selected with the following criteria:

- Prime instrument: RGS1
- Maximum offset of the target from the on-axis position: 60 arcsec
- Minimum number of counts in the spectrum: 3000 in first order

All the data where processed with SAS using coordinates corrected for proper motion.

The following lines were considered, with the laboratory wavelengths taken from the CHIANTI database:

```
Mg XII    8.419 Å              In first order only:
Ne X     12.132 Å              O VII    21.602 Å
Fe XVII  15.015 Å              O VII    22.101 Å
Fe XVII  16.777 Å              N VII    24.779 Å
O VIII   18.967 Å              C VI     33.734 Å
```

Lines were measured on the fluxed spectra computed with a wavelength bin of 10 mÅ. No specific shape of LSF was used. The line profile was assumed to be composed of a gaussian plus a lorentzian. The only constrains imposed on the fit were that both components should have the same central wavelength, and that the widths are within some reasonable limits. The relative intensity of both components was left free. Fits were made using the IDL Library MPFIT, taking into account the errors in the data points as derived by the SAS task `rgsfluxer`. Only measurements with an error of less than 5 mÅ in the line position were used in the analysis.

Note that the values in the CP07 dataset did not include the errors in the measurements, and they were - arbitrarily - assumed in GR08 to be proportional to the number of counts in the spectrum. The errors computed here are more realistic and reliable.

Two corrections were applied to the line positions:

- The velocity of the Earth with respect to the barycentre of the Solar System, projected in the direction of the target. These correction is listed in Table 6. Due to its ecliptic coordinates, this correction is negligible for AB Dor, while for the three other stars it can go up to $\pm$ 29 km s^{-1}, that represents $\approx$ 3 mÅ in the C VI line.
- The radial velocity of the object[2]:
  - Capella: 29 km s^{-1} (Ishibashi et al. 2006)
  - AB Dor: 30 km s^{-1} (Nordstroem et al. 2004)
  - HR 1099: -15 km s^{-1} (Nordstroem et al. 2004)
  - Procyon: -4 km s^{-1} (Nordstroem et al. 2004)

No corrections have been made:

- For the velocity of the spacecraft in its orbit (not more than 3 km s^{-1}).
- For the velocities of the emitting star in the binary systems Capella and HR 1099 and for the possible rotational modulation in AB Dor:
  - Ishibashi et al. (2006) in their analysis of Chandra/HETGS data, show that in the case of Capella the lines seem to come from the primary star, and then they follow its radial velocity, that has an amplitude of approximately 40 km s^{-1}, and a period of 104 days. Nevertheless, these authors point out that there could also exist a variable contribution from the secondary star in the higher temperature lines that may cause a shift in the line centroid.

[2]In the first version of this report, slightly different radial velocities were used, within $\pm$2 km s^{-1} of the values listed here, except for HR 1099, where the value previously used was -23 km s^{-1}. This difference in the radial velocities does not change substantially the results.

Table 1: Comparison of average shifts with previous results

	Line shift (mÅ)				RGS 1-RGS 2 (mÅ)		Order 1-Order 2 (mÅ)	
	RGS1 o1	RGS2 o1	RGS1 o2	RGS2 o2	Order 1	Order 2	RGS1	RGS2
GR08	6±8	11±9	2±6	5±7	-5±2	-2±3	2±6	5±7
GR12	5±7	10±7	4±4	5±4	-4±2	-1±1	2±4	5±4
GR12v	3±6	8±7	3±4	4±4	-5±2	-1±1	2±4	4±4

GR08: Data from CP07.
GR12: This work without velocity corrections.
GR12v:This work, with object and barycentre velocity correction.
errors are standard deviations.

- The Lyman α Ne X line in HR 1099 appears to come from the subdwarf star (Ayres et al. 2001). The orbital period of the system is 2.84 days. The average exposure time of the HR 1099 spectra in the sample is 0.4 days, 13% of the orbital period, and then the position of the lines can change substantially during an observation.
- In AB Dor, rotationally modulated shifts of the order of 30 km s^{-1} have been observed in the O VIII line (Hussain et al. 2005). The rotation period of the star is 0.5 day, of the order of the average exposure time of these data (0.43 days).

These velocities could cause a shift in the line positions of at most $\approx \pm 3$ mÅ at 20 Å.

For comparison with previous works, an *average shift* was computed for each spectrum as the weighted average of the individual line shifts, weighted by their errors.

3 Results

3.1 Average Shifts

The average shifts per spectrum, with and without correction for star and barycentre velocities, are shown in Tables 7, 8, 9 and 10 and Fig. 6, 7, 8 and 9, together with the data of CP07, for comparison.

Table 1 shows the average shifts per instrument and spectral order computed in this work compared to those given in GR08. Discrepancies can be explained by the different data samples used.

- We have first compared GR08 results with the values derived here without applying any velocity correction. The new average shifts agree with those derived in GR08 within 2 mÅ. It must be noted that the rms of the newly derived values is 2 mÅ smaller, though the sample is larger (60 vs. 38 observations).
- The application of the velocity corrections decreases systematically the average shifts by 2 mÅ, independently of the instrument and the order.
- The shift between both orders and both instruments does not change (see Fig. 1).

3.2 Correlation of line shifts with Solar Angle

In GR08, line shifts were correlated with the angular distance between the target and the Sun. In what follows we shall refer to this parameter as "Solar Angle" (SA[3]).

Results of the fit of average shifts with Solar Angle are shown in Table 2 and Fig. 2. The data errors used in the fit are the errors of the mean of the line shifts in each spectrum.

The application of the SA correction removes naturally the systematic shift between instruments and orders.

[3]This angle is equivalent to the Fine Sun Sensor Pitch Angle + 90 degrees. In GR08 this angle was called "Solar Aspect Angle" (SAA), though, rigorously, the SAA and the SA only coincide for a Roll angle of 0 (as it happens in most of the cases).

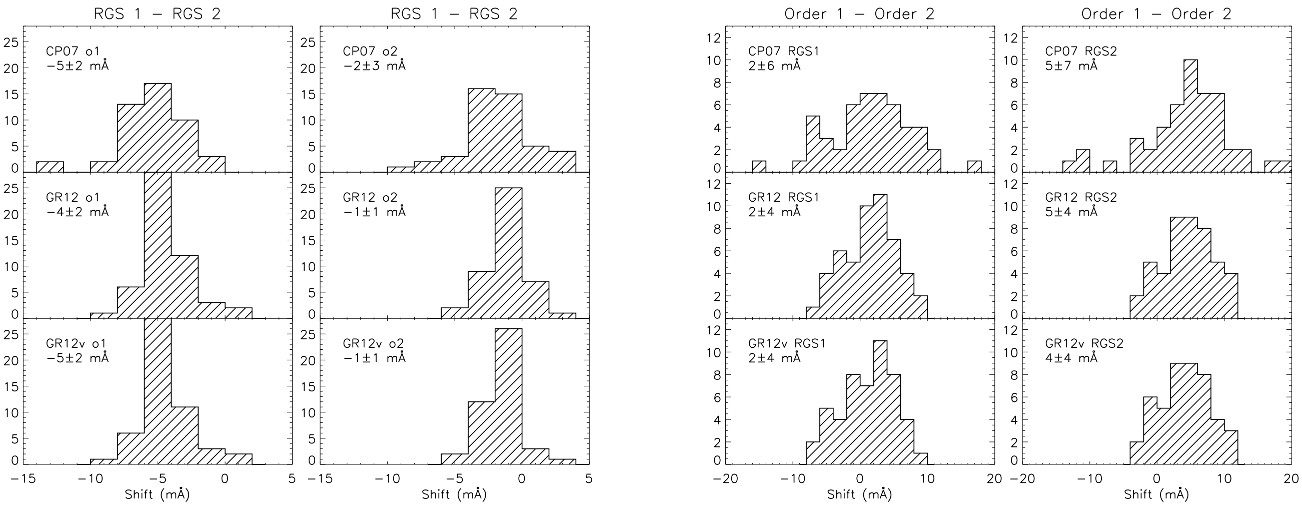

Figure 1: Shifts between both instruments and both orders for different datasets (see text for details). Left: Shift between RGS1 and RGS2. Right: Shift between first and second order. Numbers given in the plots are the median and the standard deviation of the distributions.

Table 2: Fits to Solar Angle

	GR08			GR12			GR12v		
	a	b	Res	a	b	Res	a	b	Res
RGS1 o1	2.3±0.3	-0.62±0.03	-1±6	3.7±0.2	-0.54±0.02	0±5	1.9±0.2	-0.57±0.02	1±5
RGS2 o1	7.3±0.3	-0.66±0.03	-2±7	8.3±0.2	-0.56±0.02	0±5	6.8±0.2	-0.57±0.02	1±5
RGS1 o2	2.3±0.8	-0.32±0.06	0±6	3.7±0.2	-0.31±0.03	-1±3	1.4±0.1	-0.30±0.02	1±3
RGS2 o2	3.4±0.8	-0.36±0.06	0±6	4.2±0.1	-0.33±0.01	0±3	2.8±0.1	-0.32±0.02	1±3

line shift (mÅ) = a + b x (SA - 90)
Res: residuals of the fit in mÅ, errors are standard deviations.
GR08: Data from CP07.
GR12: This work without velocity corrections.
GR12v:This work, with star+barycentre velocity correction .

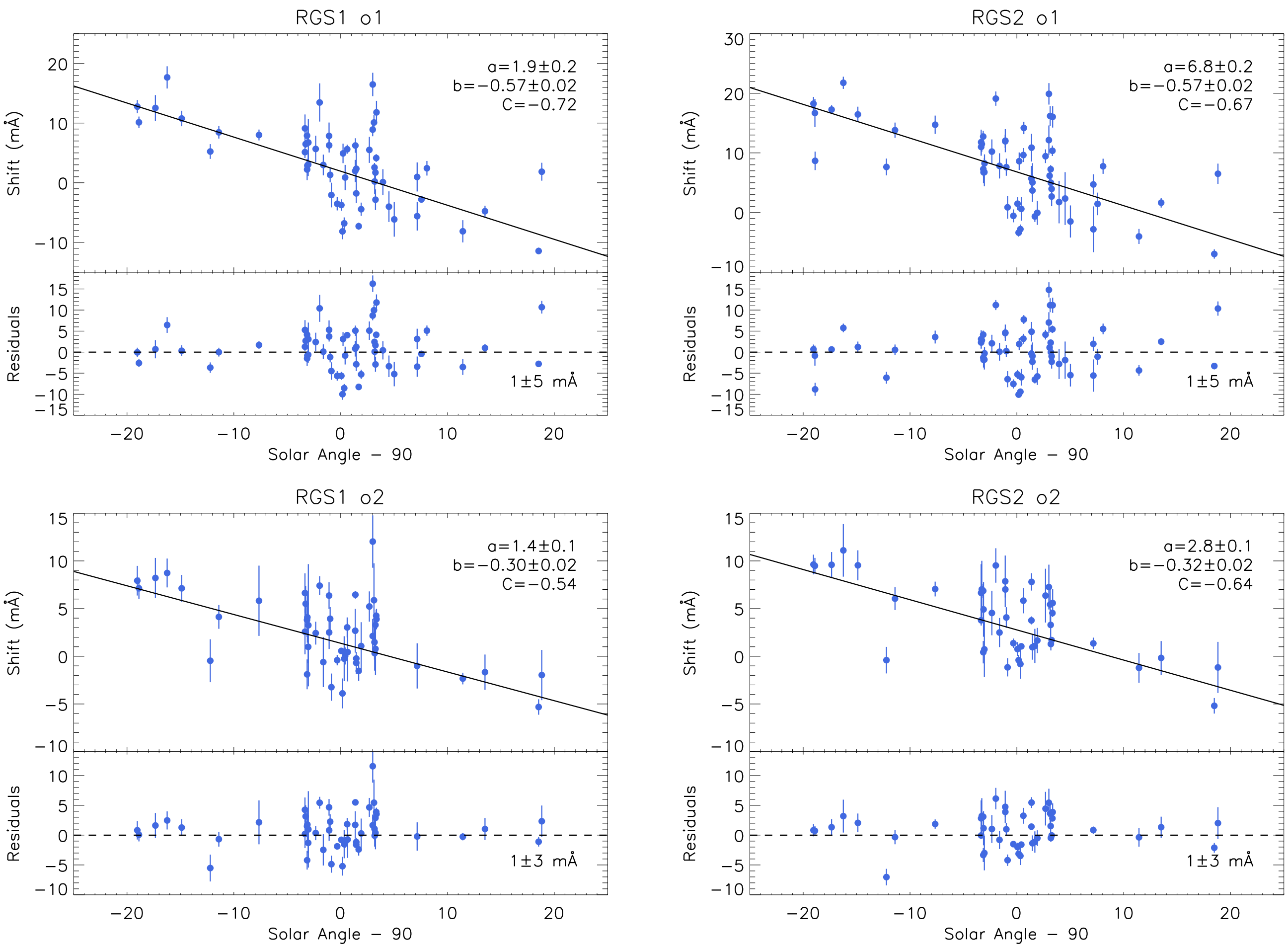

Figure 2: Linear fits of the average line shifts to the Solar Angle (top: first order, bottom: second order). The parameters of the linear fit, as well as the correlation coefficient (C) are shown in the plots.

The slope of the fits, that in GR08 were rather different for RGS1 and RGS2 in first order (-0.62 vs. -0.66 for first order, -0.32 vs. -0.36 for second order) agree better when the new measurements are used. The rms of the residuals of the fit decreases by ≈ 2 mÅ with respect to GR08.

A summary of the results is presented in Table 3. After correction for star and barycentric velocities, and application the Solar Angle correction, the rms of the average shifts is substantially reduced with respect to the values obtained in GR08, from 8 to 5 mÅ in first order, and from 6 to 3 mÅ in second order (see Fig. 4).

The Sun Angle correction has been applied to the individual lines, and re-computed the line shifts. Histograms of the line shifts are shown in Fig. 5, where the original shifts are shown in black, and the new ones (corrected for stellar and barycentric velocities and after application of the Sun Angle correction) in red.

3.3 Correlation of line shifts with wavelength

We have performed a study similar to what has been described in the previous section, but on an individual line basis. We report here only the results obtained after correcting the line positions for star and barycentre velocities.

There seems to exist a trend of the shift being systematically smaller at longer wavelengths (see Table 4 and Fig. 3), but it is not statistically significant. More evident is the trend of the slope of the linear relation with SA being steeper at longer wavelengths. The slope for the C VI line is significantly more negative than for the other lines (Table 5). This effect needs to be further investigated.

Table 3: Summary

	GR08	GR08s	GR12	GR12v	GR12vs
RGS1 o1	6±8	-1±6	5±7	3±6	1±5
RGS2 o1	11±9	-2±7	10±7	8±7	1±5
RGS1 o2	2±6	0±6	4±4	3±4	1±3
RGS2 o2	5±7	0±6	5±4	4±4	1±3

Line shifts in mÅ, errors are standard deviations.
GR08: Data from CP07
GR08s: Data from CP07, with Solar Angle correction.
GR12: This work without velocity corrections.
GR12v: This work with system and barycentre velocity correction.
GR12vs:This work with star+barycentre velocity and Solar Angle correction.

Table 4: Shifts of individual lines

	Line shift (mÅ)				RGS1-RGS2 (mÅ)		Order 1-Order 2 (mÅ)	
Line	RGS1 o1	RGS2 o1	RGS1 o2	RGS2 o2	Order 1	Order 2	RGS1	RGS2
8.419	3±8	8±8	-1±6	-3±6	-5±6	-1±5	6±6	6±8
12.134	4±2	9±7	3±4	4±4	...	-1±2	0±10	6±10
15.015	3±7	10±7	1±5	4±4	-7±3	-2±4	2±10	0±10
16.777	3±7	5±7	1±5	1±5	-1±4	-2±4	6±8	2±10
18.969	4±7	8±6	1±4	...	-4±3	...	5±11	...
21.602	1±7	...	...	...	...	...	...	...
22.101	-1±7	...	...	...	...	...	...	...
24.781	...	8±8	...	...	...	...	...	...
33.736	0±9	4±10	...	...	-6±6	...	...	...
Avg	3±6	8±7	3±4	4±4	-5±2	-1±1	2±4	4±4

Avg: from Table 1, shown for comparison.
errors are standard deviations.

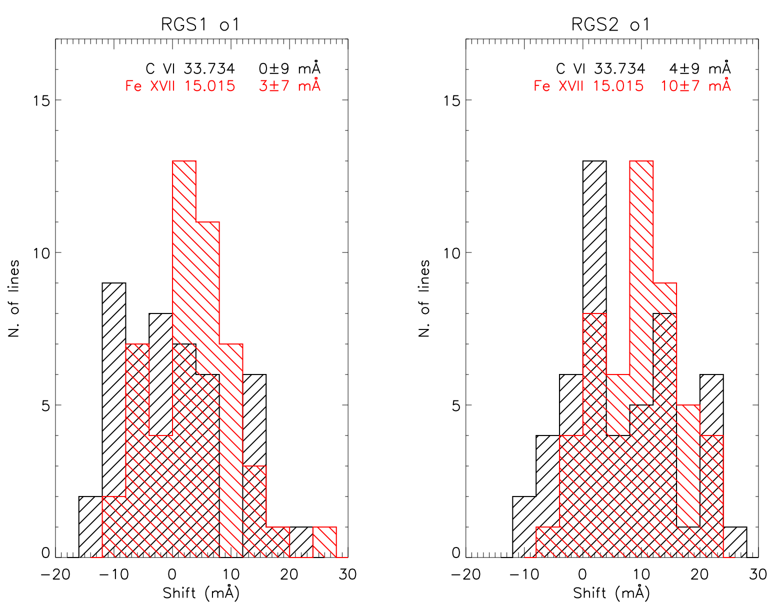

Figure 3: Comparison of the shifts of two lines at different wavelengths: C VI 33.73 Å (black) Fe XVII 15.01 Å (red).Numbers given in the plots are the median and the standard deviation of the distributions.

Table 5: Fit of shifts of individual lines with Solar Angle

	RGS1 o1			RGS2 o1		
	a	b	Res (mÅ)	a	b	Res (mÅ)
8.419	-0.7±0.7	-0.51±0.05	-1±5	6.5±0.8	-0.41±0.06	-2±6
12.134	...	...	...	7.0±0.2	-0.54±0.02	1±6
15.015	4.0±0.2	-0.37±0.01	-1±6	9.6±0.2	-0.48±0.01	-1±6
16.777	4.1±0.2	-0.53±0.01	0±6	6.7±0.3	-0.47±0.02	-2±6
18.969	3.6±0.1	-0.56±0.01	0±5	7.4±0.1	-0.56±0.01	1±6
21.602	2.2±0.2	-0.56±0.02	0±6	...	...	...
22.101	-0.7±0.3	-0.56±0.02	0±5	...	...	...
24.781	...	...	...	7.6±0.3	-0.59±0.03	0±6
33.736	-0.7±0.4	-0.63±0.04	1±8	6.1±0.3	-0.74±0.03	-2±8
Avg	1.9±0.2	-0.57±0.02	1±5	6.8±0.2	-0.57±0.02	1±5

	RGS1 o2			RGS2 o2		
	a	b	Res (mÅ)	a	b	Res (mÅ)
8.419	-4.2±0.8	-0.32±0.06	1±4	-1.0±0.9	-0.12±0.07	-1±6
12.134	2.7±0.2	-0.29±0.02	0±3	3.3±0.2	-0.34±0.02	0±3
15.015	1.8±0.2	-0.30±0.01	0±4	4.2±0.2	-0.33±0.01	0±3
16.777	-1.8±0.6	-0.28±0.05	1±5	0.9±0.3	-0.33±0.02	0±3
18.969	1.3±0.2	-0.29±0.02	1±4	...	...	...
Avg	1.4±0.1	-0.30±0.02	1±3	2.8±0.1	-0.32±0.02	1±3

line shift (mÅ) = a + b x (SA - 90)
Avg: from Table 1, shown for comparison.
Res: residuals of the fit in mÅ, errors are standard deviations.

4 Conclusions

We have shown that the accuracy of the RGS wavelength scale, derived using a dataset of observations with precise coordinates and corrected for Earth and stellar velocities, is 6 and 4 mÅ, for first and second order spectra, respectively (from measurement of individual lines; the accuracy derived from average shifts is 5 and 3 mÅ). Both spectrographs show a systematic offset with respect to laboratory wavelengths, that is larger for RGS2.

It must be noted that these values have been obtained from a well controlled dataset, to which several corrections were applied. Wavelengths measured on spectra to which no (or different) corrections are applied would be less accurate.

Using this improved dataset, we have derived new values of the parameters of the "Solar Angle" correction (i.e. the dependence of the line shift with the angular distance between the target and the Sun). The error in the slope of the linear fit decreases with respect to previous values, for first order data from 0.03 to 0.02, and from 0.06 to 0.02 in second order. The application of this correction allows to align both instruments and both spectral orders, and decreases the scatter in the average shifts to 5 and 3 mÅ for first and second order spectra, respectively.

We have also studied a possible dependence of the line shifts on wavelength (i.e. different lines having different shifts), but we have not found a clear correlation. There are some indications of the shift of the C VI line being systematically smaller than for e.g. Fe XVII. The slope of the relation with SA is definitely steeper for the C VI line. More work needs to be made in this respect. Until this study is done, the application of the SA relation derived from the average spectrum shifts would represent already a significant improvement in the RGS wavelength scale.

The conclusions of this report are as follows:

- The accuracy of the RGS wavelength scale can be improved through the application of several corrections.
- Some of them cannot be generally applied to all observations, in particular in the context of Pipeline processing. This is the case of a proper assessment of the object coordinates (e.g. effects

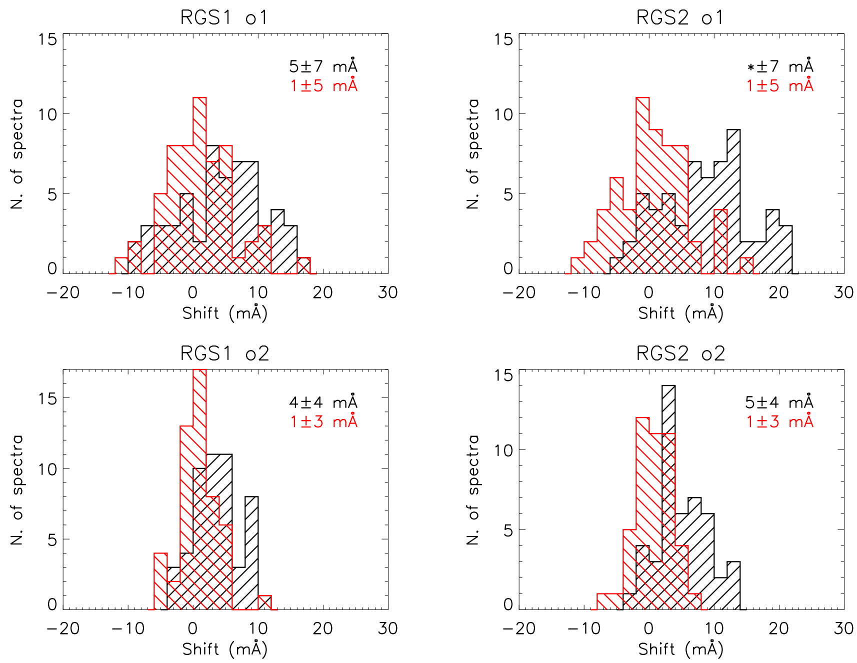

Figure 4: Comparison of the *average spectrum shifts* before (black) and after (red) applying velocity and Solar Angle corrections. Numbers given in the plots are the median and the standard deviation of the distributions.

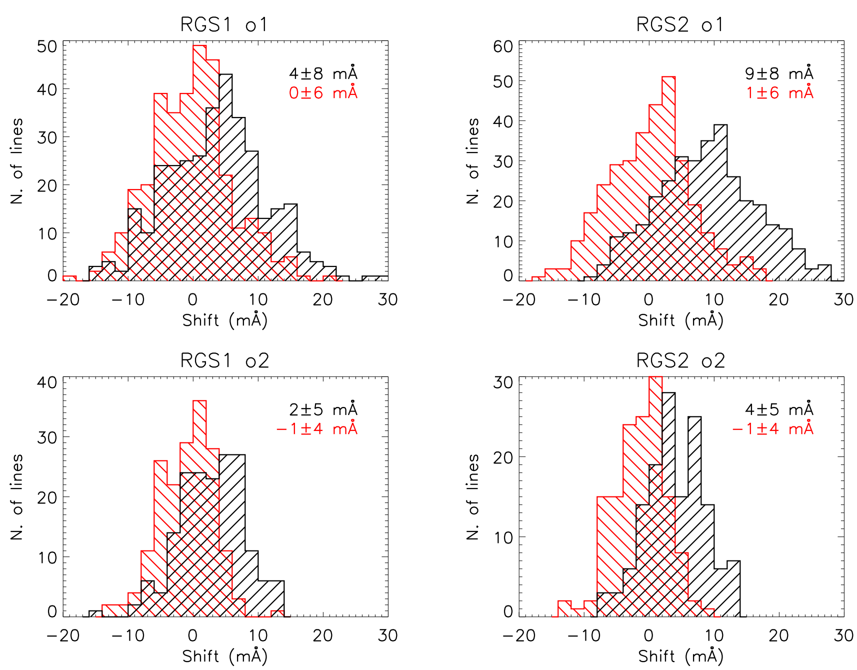

Figure 5: Comparison of the *individual line shifts* before (black) and after (red) applying velocity and the average Solar Angle corrections. Numbers given in the plots are the median and the standard deviation of the distributions.

of proper motion, the case of extended objects), that can nevertheless be applied by the user re-processing the data with SAS. In case accurate wavelengths are needed, a correction for the radial velocity of the studied object must be applied as well, but this should be left to the user during the analysis of the data.

- On the other hand, some important corrections can be easily implemented within SAS:
  - The wavelength scale should be referred to the barycenter of the Solar System. Therefore, a *barycentric* correction has to be applied to the observed wavelengths. This correction is the velocity of the Earth with respect to the barycentre of the Solar System projected in the direction of the target, that depends only on the date of the observation and the coordinates of the object. It can amount up to $\approx \pm 2$ mÅ at 20 Å.
  - The correction for dependence of the wavelength scale with Solar Angle (up to ± 18 mÅ, depending on instrument and spectral order).

5 References

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Kaastra, J. et al. 2001, A&A, 534 Lorente, R. et al. 2003, XMM-SOC-CAL-TN-0041
Nordstroem, B. et al. 2004, A&A, 418, 989

6 Appendix: Tables and Figures

Table 6: List of Observations

Obsid	Expid	Target	Date	Rev	Texp (sec)	Beta	V_{bary}	Offset
1219201	R1S007	Capella	2000-03-25	54	52900	78	-27	22
1219201	R2S002	Capella	2000-03-25	54	51800	78	-27	22
1237202	R1S001	AB Dor	2000-05-01	72	49000	87	1	9
1237202	R1S008	AB Dor	2000-05-01	72	11800	87	1	9
1237202	R2S002	AB Dor	2000-05-01	72	47500	87	1	9
1237202	R2S009	AB Dor	2000-05-01	72	11500	87	1	9
1261302	R1S001	AB Dor	2000-06-07	91	57800	88	2	9
1261302	R2S002	AB Dor	2000-06-07	91	56000	88	2	9
1239401	R1S004	Procyon	2000-10-23	160	45100	94	29	1
1239401	R2S005	Procyon	2000-10-23	160	44200	94	29	1
1239402	R1S004	Procyon	2000-10-23	160	43700	94	29	1
1239402	R1S006	Procyon	2000-10-24	160	16300	95	29	1
1239402	R2S005	Procyon	2000-10-23	160	42500	94	29	1
1239402	R2S007	Procyon	2000-10-24	160	16000	95	29	1
1237203	R1S001	AB Dor	2000-10-27	162	57600	93	-1	9
1237203	R2S002	AB Dor	2000-10-27	162	56000	93	-1	9
1331201	R1S001	AB Dor	2000-12-11	185	57000	91	-2	9
1331201	R2S002	AB Dor	2000-12-11	185	55200	91	-2	9
1331207	R1S001	AB Dor	2000-12-11	185	8800	91	-2	9
1331207	R2S002	AB Dor	2000-12-11	185	8400	91	-2	9
1345203	R1S001	AB Dor	2001-01-20	205	51100	89	-2	9
1345203	R2S002	AB Dor	2001-01-20	205	49600	89	-2	9
1345403	R1S001	HR 1099	2001-02-07	214	3600	93	-29	9
1345403	R2S002	HR 1099	2001-02-07	214	3500	93	-29	9
1345401	R1S001	HR 1099	2001-02-22	221	42500	79	-29	9
1345401	R2S002	HR 1099	2001-02-22	221	41300	79	-29	9
1347201	R1S007	Capella	2001-03-15	232	30100	87	-28	22
1347201	R2S008	Capella	2001-03-15	232	29200	87	-28	22
1345207	R1S001	AB Dor	2001-05-22	266	48500	88	1	9
1345207	R2S002	AB Dor	2001-05-22	266	47200	88	1	9
1345404	R1S001	HR 1099	2001-08-18	310	25700	93	28	9
1345404	R2S002	HR 1099	2001-08-18	310	25000	93	28	9
1345405	R1S001	HR 1099	2001-08-18	310	10500	93	28	9
1345405	R2S002	HR 1099	2001-08-18	310	10200	93	28	9
1345213	R1S001	AB Dor	2001-10-13	338	38700	93	0	9
1345213	R2S002	AB Dor	2001-10-13	338	37600	93	0	9
1345214	R1S001	AB Dor	2001-12-26	375	5000	91	-2	9
1345214	R2S002	AB Dor	2001-12-26	375	4600	91	-2	9
1345215	R1S001	AB Dor	2002-04-12	429	51900	87	0	9
1345215	R2S002	AB Dor	2002-04-12	429	50400	87	0	9
1345216	R1S001	AB Dor	2002-06-18	462	43200	89	2	0
1345216	R2S002	AB Dor	2002-06-18	462	42000	89	2	0
1345406	R1S001	HR 1099	2002-08-22	495	35000	97	28	0
1345406	R2S002	HR 1099	2002-08-22	495	34000	97	28	0
1347204	R1S007	Capella	2002-10-05	517	32200	109	26	1
1347204	R2S008	Capella	2002-10-05	517	31300	109	26	1
1345218	R1S001	AB Dor	2002-11-05	532	19500	93	-1	0
1345218	R2S002	AB Dor	2002-11-05	532	18800	93	-1	0
1345217	R1S001	AB Dor	2002-11-15	537	19800	93	-1	0
1345217	R2S002	AB Dor	2002-11-15	537	19800	93	-1	0
1345220	R1S001	AB Dor	2002-12-03	546	19800	92	-1	0
1345220	R2S002	AB Dor	2002-12-03	546	19800	92	-1	0

Table 6 – continued from previous page

Obsid	Expid	Target	Date	Rev	Texp (sec)	Beta	V_{bary}	Offset
1345221	R1S001	AB Dor	2002-12-30	560	48800	90	-2	0
1345221	R2S002	AB Dor	2002-12-30	560	48800	90	-2	0
1345222	R1S001	AB Dor	2003-01-23	572	51200	89	-2	0
1345222	R2S002	AB Dor	2003-01-23	572	51200	89	-2	0
1345223	R1S001	AB Dor	2003-03-30	605	48700	87	0	0
1345223	R2S002	AB Dor	2003-03-30	605	48700	87	0	0
1345224	R1S001	AB Dor	2003-05-31	636	19200	88	1	0
1345224	R2S002	AB Dor	2003-05-31	636	19200	88	1	0
1603625	R1U002	AB Dor	2003-08-02	668	13100	91	2	0
1603625	R2U002	AB Dor	2003-08-02	668	13100	91	2	0
1603626	R1S001	AB Dor	2003-08-02	668	23600	91	2	0
1603626	R2S002	AB Dor	2003-08-02	668	23600	91	2	0
1603627	R1S001	AB Dor	2003-10-23	709	24400	93	0	0
1603627	R1S014	AB Dor	2003-10-24	709	26400	93	0	0
1603627	R2S015	AB Dor	2003-10-23	709	24700	93	0	0
1603627	R2S016	AB Dor	2003-10-24	709	26100	93	0	0
1603628	R1S001	AB Dor	2003-12-08	732	53200	92	-2	0
1603628	R2S016	AB Dor	2003-12-08	732	53200	92	-2	0
1345407	R1S001	HR 1099	2004-02-14	766	40200	87	-29	0
1345407	R2S002	HR 1099	2004-02-14	766	40200	87	-29	0
1347208	R1S007	Capella	2004-04-01	790	62600	71	-26	2
1347208	R2S008	Capella	2004-04-01	790	1700	71	-26	2
1347208	R2U002	Capella	2004-04-01	790	60600	71	-26	2
1345408	R1S001	HR 1099	2004-08-13	857	51700	89	28	1
1345408	R2S002	HR 1099	2004-08-13	857	51600	89	28	1
1347215	R1S007	Capella	2004-09-10	871	67900	87	28	2
1347215	R2S008	Capella	2004-09-10	871	67800	87	28	2
1345409	R1S001	HR 1099	2005-01-29	942	55300	101	-28	1
1345409	R2S002	HR 1099	2005-01-29	942	55300	101	-28	1
1347216	R1S007	Capella	2005-03-28	971	23800	75	-27	2
1347216	R2S008	Capella	2005-03-28	971	23800	75	-27	2
1347217	R1S007	Capella	2005-03-31	972	16700	73	-26	2
1347217	R2S008	Capella	2005-03-31	972	16700	73	-26	2
1603630	R1S001	AB Dor	2005-04-18	981	51700	87	0	0
1603630	R2S016	AB Dor	2005-04-18	981	51600	87	0	0
1603632	R1S001	AB Dor	2005-10-16	1072	49700	93	0	0
1603632	R2S016	AB Dor	2005-10-16	1072	49600	93	0	0
1347220	R1S007	Capella	2006-03-20	1150	59300	82	-27	3
1347220	R2S008	Capella	2006-03-20	1150	59300	82	-27	3
4125801	R1S004	AB Dor	2006-12-31	1293	44900	90	-2	0
4125801	R2S005	AB Dor	2006-12-31	1293	44800	90	-2	0
1347221	R1S007	Capella	2007-02-20	1319	63800	108	-26	3
1347221	R2S008	Capella	2007-02-20	1319	59300	108	-26	3
4155801	R1S001	Procyon	2007-04-07	1342	44500	98	-28	16
4155801	R2S002	Procyon	2007-04-07	1342	44500	98	-28	16
4155802	R1S001	Procyon	2007-04-08	1342	33800	98	-28	9
4155802	R2S002	Procyon	2007-04-08	1342	33800	98	-28	9
4155803	R1S001	Procyon	2007-04-08	1342	38800	97	-28	10
4155803	R2S002	Procyon	2007-04-08	1342	38800	97	-28	10
4125802	R1S004	AB Dor	2007-07-19	1393	48700	91	2	0
4125802	R2S005	AB Dor	2007-07-19	1393	48700	91	2	0
5107801	R1S007	Capella	2007-08-27	1413	59900	74	26	4
5107801	R2S008	Capella	2007-08-27	1413	60000	74	26	4
4125803	R1S004	AB Dor	2008-01-03	1478	48700	90	-2	0

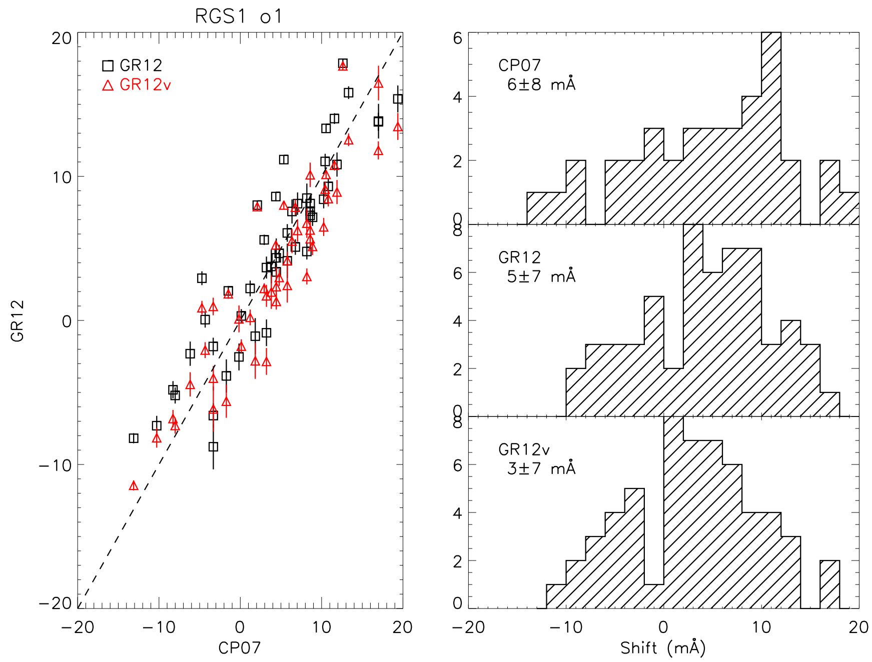

Figure 6: Line shifts: RGS1 Order 1. Comparison of the shifts measured by CP07 with this work, with and without velocity correction. Numbers given in the plots are the median and the standard deviation of the distributions.

Table 6 – continued from previous page

Obsid	Expid	Target	Date	Rev	Texp (sec)	Beta	V_{bary}	Offset
4125803	R2S005	AB Dor	2008-01-03	1478	48700	90	-2	0
5107802	R1S007	Capella	2008-09-17	1607	54000	93	27	4
5107802	R2S008	Capella	2008-09-17	1607	54100	93	27	4
4125804	R1S004	AB Dor	2009-01-04	1662	47300	90	-2	0
4125804	R2S005	AB Dor	2009-01-04	1662	47000	90	-2	0
5107804	R1S007	Capella	2009-09-29	1796	61500	103	26	5
5107804	R2S008	Capella	2009-09-29	1796	61600	103	26	5
4125806	R1S004	AB Dor	2010-01-11	1848	49700	90	-2	0
4125806	R2S005	AB Dor	2010-01-11	1848	49800	90	-2	0
5107805	R1S007	Capella	2010-08-24	1961	59500	71	25	5
5107805	R2S008	Capella	2010-08-24	1961	59600	71	25	5
4125807	R1S004	AB Dor	2011-01-02	2027	1400	90	-2	0
4125807	R1U002	AB Dor	2011-01-02	2027	55900	90	-2	0
4125807	R2S005	AB Dor	2011-01-02	2027	1400	90	-2	0
4125807	R2U002	AB Dor	2011-01-02	2027	55500	90	-2	0

V_{bary}: Barycentric velocity correction (km s^{-1})
Offset: Offset from boresight (arcsec)

Table 7: Line shifts: RGS1 Order 1

Obsid	Target	Rev	CP07	GR12	GR12v	nl
01219201	Capella	54	4.4	8.6±0.3 (2.8)	5.2±0.3 (3.5)	8
01237202	AB Dor	72	8.2	4.8±0.6 (4.5)	3.1±0.6 (5.1)	7
01261302	AB Dor	91	4.8	4.7±0.6 (4.1)	3.0±0.6 (4.6)	7
01239401	Procyon	160	-0.2	-2.5±0.9 (5.0)	0.1±0.9 (4.3)	4
01239402	Procyon	160	-3.3	-6.6±0.9 (5.6)	-4.0±0.9 (5.1)	4

Table 7 – continued from previous page

Obsid	Target	Rev	CP07	GR12	GR12v	nl
01237203	AB Dor	162	1.2	2.2±0.5 (4.5)	0.2±0.5 (5.2)	6
01331201	AB Dor	185	0.1	0.3±0.5 (3.7)	-1.8±0.5 (4.3)	7
01331207	AB Dor	185	4.4	4.3±1.3 (6.0)	2.3±1.3 (6.1)	3
01345203	AB Dor	205	-4.3	0.1±0.6 (4.5)	-2.1±0.6 (5.1)	6
01345401	HR 1099	221	10.8	9.3±0.5 (2.3)	8.5±0.5 (2.6)	6
01347201	Capella	232	2.9	5.6±0.4 (4.1)	2.2±0.4 (4.7)	7
01345207	AB Dor	266	8.6	7.6±0.7 (5.0)	5.7±0.7 (5.4)	6
01345404	HR 1099	310	8.6	7.3±0.8 (3.5)	10.1±0.8 (3.1)	6
01345405	HR 1099	310	17.0	13.8±1.2 (3.8)	16.5±1.2 (3.9)	4
01345213	AB Dor	338	17.0	13.8±0.6 (4.3)	11.8±0.6 (4.7)	6
01345215	AB Dor	429	10.4	11.0±0.5 (5.3)	9.1±0.5 (5.7)	6
01345216	AB Dor	462	8.6	8.1±0.6 (2.4)	6.3±0.6 (2.9)	6
01345406	HR 1099	495	-3.3	-1.8±0.6 (6.9)	1.0±0.6 (6.0)	6
01347204	Capella	517	-1.5	2.1±0.3 (3.9)	1.8±0.3 (4.0)	7
01345218	AB Dor	532	11.9	10.8±0.8 (2.1)	8.9±0.8 (2.2)	4
01345217	AB Dor	537	6.4	7.6±0.8 (6.0)	5.5±0.8 (5.3)	6
01345220	AB Dor	546	-6.2	-2.3±0.8 (3.3)	-4.4±0.8 (2.7)	6
01345221	AB Dor	560	-4.7	2.9±0.5 (4.9)	0.9±0.5 (5.2)	6
01345222	AB Dor	572	4.4	3.4±0.6 (2.6)	1.3±0.6 (3.1)	6
01345223	AB Dor	605	8.9	7.2±0.6 (2.7)	5.1±0.6 (2.4)	6
01345224	AB Dor	636	19.4	15.4±0.9 (6.9)	13.5±0.9 (7.2)	5
01603625	AB Dor	668	3.8	3.7±1.2 (3.6)	2.0±1.2 (3.7)	4
01603626	AB Dor	668	7.0	8.1±0.8 (3.3)	6.2±0.8 (3.0)	6
01603627	AB Dor	709	3.2	3.7±0.8 (3.1)	1.7±0.8 (3.0)	6
01603628	AB Dor	732	-8.0	-5.2±0.6 (1.4)	-7.3±0.6 (1.4)	6
01345407	HR 1099	766		3.8±0.6 (2.3)	2.9±0.6 (2.1)	6
01347208	Capella	790	10.5	13.3±0.3 (4.0)	10.1±0.3 (2.7)	8
01345408	HR 1099	857	6.8	5.1±0.5 (5.5)	7.9±0.5 (5.9)	7
01347215	Capella	871	2.1	8.0±0.3 (4.3)	7.9±0.3 (4.3)	7
01345409	HR 1099	942	-10.3	-7.3±0.7 (5.0)	-8.1±0.7 (4.9)	7
01347216	Capella	971	11.6	14.0±0.4 (4.1)	10.8±0.4 (3.4)	7
01347217	Capella	972	13.3	15.8±0.4 (7.0)	12.5±0.4 (5.7)	7
01603630	AB Dor	981	10.3	8.4±0.6 (2.0)	6.5±0.6 (1.6)	6
01603632	AB Dor	1072	5.8	6.1±0.6 (1.2)	4.2±0.6 (1.6)	6
01347220	Capella	1150	5.3	11.2±0.3 (3.0)	8.0±0.3 (2.0)	5
04125801	AB Dor	1293	-8.3	-4.8±0.6 (2.2)	-6.8±0.6 (2.2)	5
01347221	Capella	1319	-13.1	-8.2±0.3 (1.8)	-11.5±0.3 (1.2)	5
04155801	Procyon	1342	5.8	4.1±1.2 (2.1)	2.4±1.2 (2.1)	3
04155802	Procyon	1342	1.8	-1.1±1.3 (0.7)	-2.8±1.3 (0.8)	3
04155803	Procyon	1342	-1.7	-3.9±1.1 (5.2)	-5.6±1.1 (4.8)	4
04125802	AB Dor	1393		7.4±0.5 (1.8)	5.6±0.5 (1.7)	5
05107801	Capella	1413	12.6	17.9±0.3 (5.0)	17.7±0.3 (4.9)	7
04125803	AB Dor	1478		-6.1±0.6 (3.3)	-8.2±0.6 (3.2)	6
05107802	Capella	1607		2.7±0.3 (1.8)	2.6±0.3 (1.9)	6
04125804	AB Dor	1662		-1.7±0.6 (2.3)	-3.7±0.6 (2.3)	6
05107804	Capella	1796		-4.6±0.3 (2.5)	-4.8±0.3 (2.5)	7
04125806	AB Dor	1848		-1.5±0.6 (3.4)	-3.5±0.6 (2.7)	6
05107805	Capella	1961		13.0±0.3 (3.0)	12.8±0.3 (2.9)	7
04125807	AB Dor	2027		6.9±0.5 (3.6)	4.9±0.5 (4.0)	6

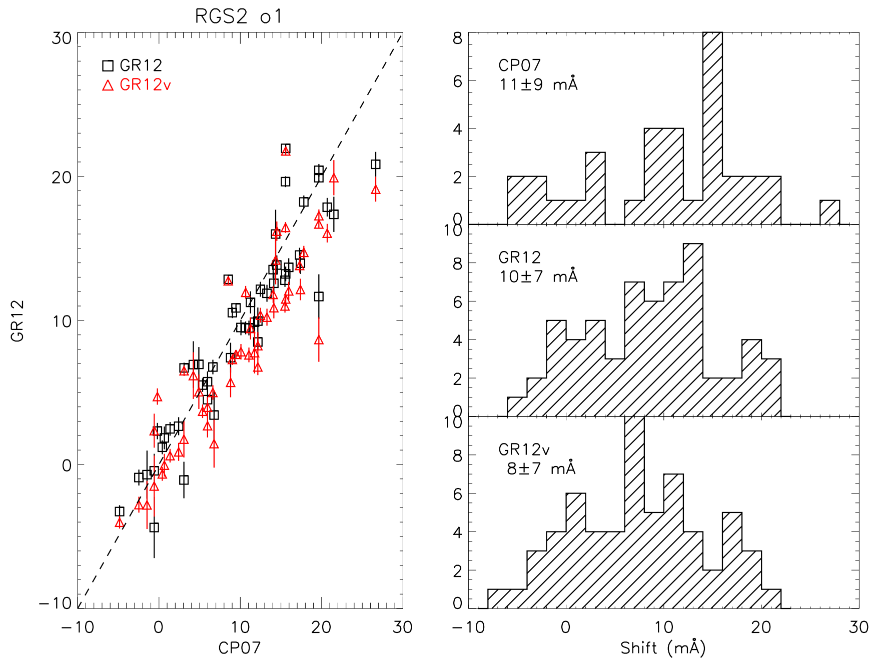

Figure 7: As Fig. 6 for RGS2 Order 1.

Table 8: Line shifts: RGS2 Order 1

Obsid	Target	Rev	CP07	GR12	GR12v	nl
01219201	Capella	54	9.5	10.9±0.3 (2.9)	7.6±0.3 (3.7)	7
01237202	AB Dor	72	12.2	8.5±0.6 (5.0)	6.8±0.6 (5.8)	6
01261302	AB Dor	91	10.1	9.5±0.5 (4.6)	7.8±0.5 (5.2)	6
01239401	Procyon	160	3.1	-1.1±1.3 (7.0)	1.8±1.3 (6.2)	3
01239402	Procyon	160	-0.6	-0.4±1.2 (8.5)	2.3±1.2 (7.7)	3
01239402	Procyon	160	-0.6	-4.4±2.1 (4.9)	-1.5±2.1 (3.8)	2
01237203	AB Dor	162	6.6	6.8±0.5 (2.0)	5.0±0.5 (2.6)	6
01331201	AB Dor	185	5.4	5.5±0.5 (2.3)	3.7±0.5 (2.7)	6
01331207	AB Dor	185	4.9	7.0±1.2 (6.4)	5.0±1.2 (7.2)	5
01345203	AB Dor	205	2.4	2.7±0.6 (4.0)	0.9±0.6 (4.7)	6
01345403	HR 1099	214	4.2	6.9±1.6 (1.6)	6.2±1.6 (1.5)	3
01345401	HR 1099	221	17.3	14.5±0.5 (3.0)	13.8±0.5 (3.1)	6
01347201	Capella	232	9.0	10.5±0.4 (1.6)	7.3±0.4 (2.9)	6
01345207	AB Dor	266	13.3	11.9±0.6 (4.5)	10.2±0.6 (5.0)	6
01345404	HR 1099	310	14.5	13.8±0.7 (4.5)	16.2±0.7 (4.1)	6
01345405	HR 1099	310	21.5	17.4±1.2 (4.7)	19.9±1.2 (3.1)	3
01345213	AB Dor	338	20.7	17.9±0.6 (4.0)	16.1±0.6 (4.4)	6
01345214	AB Dor	375	14.3	16.0±1.7 (1.0)	14.2±1.7 (1.5)	2
01345215	AB Dor	429	14.0	13.5±0.6 (4.4)	11.8±0.6 (5.2)	6
01345216	AB Dor	462	16.0	13.7±0.6 (4.0)	12.0±0.6 (4.7)	6
01345406	HR 1099	495	-0.2	2.3±0.6 (5.2)	4.7±0.6 (4.2)	6
01347204	Capella	517	3.1	6.7±0.4 (4.4)	6.5±0.4 (4.5)	7
01345218	AB Dor	532	17.4	14.0±0.7 (5.9)	12.1±0.7 (5.5)	5
01345217	AB Dor	537	11.3	11.3±0.8 (2.5)	9.4±0.8 (2.8)	6
01345220	AB Dor	546	0.7	1.8±0.8 (5.2)	-0.1±0.8 (5.0)	6
01345221	AB Dor	560	1.4	2.5±0.5 (5.1)	0.6±0.5 (4.8)	6
01345222	AB Dor	572	11.1	9.5±0.5 (4.2)	7.6±0.5 (3.5)	6
01345223	AB Dor	605	15.5	12.8±0.5 (4.2)	11.0±0.5 (3.6)	6
01345224	AB Dor	636	26.7	20.8±0.9 (3.5)	19.1±0.9 (2.9)	6

Table 8 – continued from previous page

Obsid	Target	Rev	CP07	GR12	GR12v	nl
01603625	AB Dor	668	8.8	7.4±1.0 (4.7)	5.7±1.0 (4.2)	4
01603626	AB Dor	668	14.1	12.6±0.7 (6.2)	10.9±0.7 (5.7)	6
01603627	AB Dor	709	6.0	5.7±0.7 (3.8)	4.0±0.7 (3.7)	6
01603628	AB Dor	732	0.4	1.2±0.5 (2.9)	-0.7±0.5 (2.2)	6
01345407	HR 1099	766		7.5±0.5 (4.8)	6.8±0.5 (4.5)	6
01347208	Capella	790	19.7	19.9±0.3 (7.3)	16.7±0.3 (5.8)	6
01345408	HR 1099	857	10.7	9.5±0.4 (3.3)	11.9±0.4 (3.0)	7
01347215	Capella	871	8.5	12.9±0.3 (2.4)	12.7±0.3 (2.3)	6
01345409	HR 1099	942	-4.8	-3.3±0.4 (3.2)	-4.0±0.4 (3.3)	7
01347216	Capella	971	15.6	19.6±0.4 (4.9)	16.5±0.4 (3.4)	7
01347217	Capella	972	19.7	20.4±0.4 (2.9)	17.3±0.4 (1.8)	6
01603630	AB Dor	981	15.6	13.2±0.5 (3.3)	11.5±0.5 (3.1)	6
01603632	AB Dor	1072	12.5	12.2±0.5 (2.9)	10.4±0.5 (2.1)	6
01347220	Capella	1150	17.8	18.2±0.4 (5.3)	14.7±0.4 (3.4)	5
04125801	AB Dor	1293	-2.5	-0.9±0.6 (1.5)	-2.8±0.6 (1.9)	6
01347221	Capella	1319	-11.3	-3.7±0.4 (1.8)	-7.0±0.4 (1.9)	6
04155801	Procyon	1342	11.8	9.9±1.4 (2.8)	7.8±1.4 (2.2)	3
04155802	Procyon	1342	6.8	3.4±1.7 (2.9)	1.4±1.7 (3.3)	3
04155803	Procyon	1342	-1.5	-0.7±1.7 (6.2)	-2.8±1.7 (6.7)	3
04125802	AB Dor	1393		11.3±0.5 (3.1)	9.6±0.5 (2.9)	6
05107801	Capella	1413	15.6	21.9±0.3 (2.6)	21.8±0.3 (2.5)	6
04125803	AB Dor	1478		-1.5±0.6 (2.1)	-3.4±0.6 (1.6)	6
05107802	Capella	1607		7.4±0.3 (1.7)	7.3±0.3 (1.7)	6
04125804	AB Dor	1662		3.3±0.6 (3.3)	1.5±0.6 (2.7)	6
05107804	Capella	1796		1.8±0.3 (2.1)	1.7±0.3 (2.0)	6
04125806	AB Dor	1848		1.3±0.6 (3.4)	-0.6±0.6 (2.7)	6
05107805	Capella	1961		18.5±0.3 (3.1)	18.3±0.3 (3.0)	7
04125807	AB Dor	2027		10.5±0.6 (4.3)	8.6±0.6 (3.6)	6

Table 9: Line shifts: RGS1 Order 2

Obsid	Target	Rev	CP07	GR12	GR12v	nl
01219201	Capella	54	1.7	2.4±0.4 (5.3)	-0.5±0.4 (5.0)	5
01237202	AB Dor	72	2.6	2.4±0.9 (2.7)	1.0±0.9 (3.0)	3
01261302	AB Dor	91	-0.2	0.9±0.9 (4.4)	-0.6±0.9 (4.5)	3
01237203	AB Dor	162	0.3	1.9±0.8 (3.0)	0.3±0.8 (3.2)	3
01331201	AB Dor	185	-0.7	0.9±0.7 (2.1)	-0.7±0.7 (2.3)	4
01331207	AB Dor	185	-0.2	1.3±2.1 (0.8)	-0.2±2.1 (0.3)	2
01345203	AB Dor	205	-4.3	-1.6±0.7 (2.2)	-3.2±0.7 (2.5)	3
01345401	HR 1099	221	4.4	4.8±0.7 (2.6)	4.1±0.7 (2.5)	4
01347201	Capella	232	0.2	1.0±0.6 (2.9)	-1.9±0.6 (3.5)	5
01345207	AB Dor	266	2.2	3.9±0.8 (1.8)	2.4±0.8 (2.1)	3
01345404	HR 1099	310	2.4	3.8±1.0 (6.9)	5.9±1.0 (6.7)	3
01345405	HR 1099	310	8.1	10.0±1.6 (4.6)	12.0±1.6 (3.9)	2
01345213	AB Dor	338	6.2	5.4±0.9 (1.5)	3.9±0.9 (1.9)	3
01345214	AB Dor	375	1.1	2.1±3.2 (3.8)	0.4±3.2 (4.4)	2
01345215	AB Dor	429	1.4	4.1±0.8 (3.9)	2.6±0.8 (4.1)	3
01345216	AB Dor	462	3.8	3.9±0.8 (2.7)	2.5±0.8 (3.0)	3
01345406	HR 1099	495	-4.8	-3.2±0.8 (4.5)	-1.0±0.8 (4.1)	3
01347204	Capella	517	-3.5	-1.8±0.6 (5.9)	-2.0±0.6 (5.9)	5
01345218	AB Dor	532	1.2	3.7±1.3 (2.0)	2.1±1.3 (2.5)	2

Table 9 – continued from previous page

Obsid	Target	Rev	CP07	GR12	GR12v	nl
01345217	AB Dor	537	6.3	6.8±1.2 (3.1)	5.2±1.2 (2.7)	3
01345220	AB Dor	546	0.7	2.6±1.3 (4.5)	1.1±1.3 (4.3)	3
01345221	AB Dor	560	0.4	1.7±0.7 (1.9)	0.0±0.7 (1.8)	4
01345222	AB Dor	572	6.6	5.5±0.8 (2.4)	3.9±0.8 (2.4)	4
01345223	AB Dor	605	8.6	8.2±0.7 (3.7)	6.6±0.7 (3.6)	3
01345224	AB Dor	636	9.9	8.9±1.3 (1.5)	7.4±1.3 (1.7)	3
01603625	AB Dor	668		4.1±1.6 (3.7)	2.7±1.6 (3.2)	2
01603626	AB Dor	668	8.1	7.9±1.2 (0.6)	6.5±1.2 (0.7)	3
01603627	AB Dor	709	3.8	4.9±1.1 (2.6)	3.3±1.1 (2.2)	3
01603628	AB Dor	732	-0.7	0.1±0.7 (1.6)	-1.5±0.7 (1.8)	3
01345407	HR 1099	766		4.7±0.7 (5.4)	4.1±0.7 (5.3)	4
01347208	Capella	790	8.4	9.9±0.4 (3.2)	7.1±0.4 (2.5)	5
01345408	HR 1099	857	5.8	4.3±0.7 (3.2)	6.4±0.7 (2.8)	4
01347215	Capella	871	3.9	3.9±0.4 (4.0)	3.8±0.4 (4.0)	5
01345409	HR 1099	942	-3.5	-1.8±0.7 (1.0)	-2.3±0.7 (1.1)	3
01347216	Capella	971	9.5	9.8±0.7 (3.3)	7.1±0.7 (3.1)	5
01347217	Capella	972	8.6	10.9±0.8 (5.3)	8.2±0.8 (4.7)	5
01603630	AB Dor	981	7.9	7.0±0.8 (3.2)	5.5±0.8 (3.2)	3
01603632	AB Dor	1072	6.6	5.8±0.8 (1.4)	4.3±0.8 (1.3)	4
01347220	Capella	1150	7.2	8.4±0.5 (6.9)	5.8±0.5 (6.4)	3
04125801	AB Dor	1293	-2.5	1.2±1.1 (4.4)	-0.3±1.1 (4.1)	3
01347221	Capella	1319	-4.2	-2.6±0.4 (2.2)	-5.3±0.4 (1.6)	4
04125802	AB Dor	1393		4.2±1.2 (1.7)	3.0±1.2 (1.5)	2
05107801	Capella	1413	6.3	8.9±0.5 (2.6)	8.7±0.5 (2.6)	3
04125803	AB Dor	1478		-2.2±0.9 (2.7)	-3.9±0.9 (2.7)	3
05107802	Capella	1607		1.6±0.4 (4.1)	1.5±0.4 (4.1)	5
04125804	AB Dor	1662		2.2±0.8 (0.4)	0.6±0.8 (0.3)	3
05107804	Capella	1796		-1.5±0.4 (4.1)	-1.7±0.4 (4.1)	5
04125806	AB Dor	1848		1.3±0.9 (1.3)	-0.4±0.9 (0.9)	3
05107805	Capella	1961		8.1±0.5 (3.5)	7.9±0.5 (3.5)	5

Table 10: Line shifts: RGS2 Order 2

Obsid	Target	Rev	CP07	GR12	GR12v	nl
01219201	Capella	54	1.1	2.3±0.5 (3.0)	-0.4±0.5 (2.8)	4
01237202	AB Dor	72	7.1	2.0±1.1 (4.9)	0.7±1.1 (5.0)	3
01261302	AB Dor	91	2.5	3.7±1.1 (2.0)	2.5±1.1 (2.2)	2
01237203	AB Dor	162	2.1	2.6±1.0 (1.2)	1.3±1.0 (0.9)	2
01331201	AB Dor	185	1.9	2.3±0.9 (2.1)	1.0±0.9 (2.3)	3
01345203	AB Dor	205	-0.7	0.2±0.9 (1.5)	-1.2±0.9 (1.7)	3
01345401	HR 1099	221	5.8	6.6±0.9 (2.1)	6.0±0.9 (2.1)	3
01347201	Capella	232	1.7	3.1±0.7 (2.7)	0.4±0.7 (2.3)	4
01345207	AB Dor	266	4.9	5.8±1.1 (3.8)	4.5±1.1 (4.0)	3
01345404	HR 1099	310	2.9	3.7±1.2 (2.4)	5.4±1.2 (2.7)	2
01345213	AB Dor	338	8.5	6.9±1.3 (2.3)	5.6±1.3 (2.5)	3
01345215	AB Dor	429	4.1	5.0±1.0 (1.2)	3.8±1.0 (1.0)	3
01345216	AB Dor	462	8.1	8.2±1.0 (1.0)	7.0±1.0 (1.2)	2
01345406	HR 1099	495	-1.6	-0.4±1.0 (1.4)	1.4±1.0 (1.2)	4
01347204	Capella	517	-1.6	-1.0±0.6 (5.3)	-1.2±0.6 (5.4)	4
01345218	AB Dor	532	7.5	8.5±1.6 (3.1)	7.3±1.6 (3.3)	2
01345217	AB Dor	537	8.2	7.7±1.7 (4.2)	6.4±1.7 (4.0)	2

Table 10 – continued from previous page

Obsid	Target	Rev	CP07	GR12	GR12v	nl
01345220	AB Dor	546	-0.5	3.0±1.7 (2.1)	1.7±1.7 (1.9)	2
01345221	AB Dor	560	2.6	2.4±0.9 (0.4)	1.0±0.9 (0.4)	3
01345222	AB Dor	572	6.8	5.4±1.1 (1.7)	4.1±1.1 (1.5)	2
01345223	AB Dor	605	7.8	7.9±0.9 (5.1)	6.6±0.9 (5.2)	3
01345224	AB Dor	636	8.5	10.7±1.7 (2.4)	9.5±1.7 (2.6)	2
01603625	AB Dor	668		5.0±2.0 (0.8)	3.8±2.0 (0.6)	2
01603626	AB Dor	668	9.0	9.0±1.4 (1.4)	7.8±1.4 (1.6)	3
01603627	AB Dor	709	4.4	3.0±1.6 (0.3)	1.7±1.6 (0.1)	2
01603628	AB Dor	732	2.0	2.4±0.9 (2.9)	1.1±0.9 (3.1)	3
01345407	HR 1099	766		5.5±0.9 (4.9)	4.9±0.9 (5.0)	3
01347208	Capella	790	10.7	12.2±0.4 (1.8)	9.5±0.4 (1.4)	3
01345408	HR 1099	857	5.7	6.1±0.8 (4.1)	7.9±0.8 (3.8)	2
01347215	Capella	871	5.0	6.9±0.4 (1.4)	6.9±0.4 (1.4)	4
01345409	HR 1099	942	-1.6	-0.7±0.7 (3.1)	-1.2±0.7 (3.1)	4
01347216	Capella	971	11.8	12.2±0.7 (2.6)	9.5±0.7 (2.7)	3
01347217	Capella	972	11.8	12.3±0.8 (2.2)	9.6±0.8 (2.3)	3
01603630	AB Dor	981	8.2	8.3±1.1 (5.0)	7.0±1.1 (5.2)	3
01603632	AB Dor	1072	8.1	5.8±1.0 (0.5)	4.5±1.0 (0.4)	3
01347220	Capella	1150	9.3	9.8±0.4 (1.3)	7.1±0.4 (1.3)	3
04125801	AB Dor	1293	0.1	0.5±1.1 (2.4)	-0.8±1.1 (2.2)	2
01347221	Capella	1319	-3.4	-2.5±0.4 (2.1)	-5.2±0.4 (1.6)	4
04125802	AB Dor	1393		7.0±1.1 (2.1)	5.8±1.1 (1.9)	2
05107801	Capella	1413	9.5	11.2±0.4 (5.5)	11.1±0.4 (5.5)	4
04125803	AB Dor	1478		1.0±1.1 (1.2)	-0.4±1.1 (0.9)	3
05107802	Capella	1607		3.4±0.5 (3.3)	3.3±0.5 (3.3)	4
04125804	AB Dor	1662		2.1±1.1 (1.0)	0.8±1.1 (1.3)	3
05107804	Capella	1796		-0.0±0.5 (3.6)	-0.2±0.5 (3.5)	4
04125806	AB Dor	1848		2.7±1.2 (0.6)	1.4±1.2 (0.8)	3
05107805	Capella	1961		9.8±0.5 (1.8)	9.6±0.5 (1.8)	3

shifts in mÅ, given as average±error (rms)
nl: number of lines measured in the spectrum.
CP07: Data from Coia and Pollock 2007.
GR12: This work without velocity correction.
GR12v:This work, with star+barycenter velocity correction..

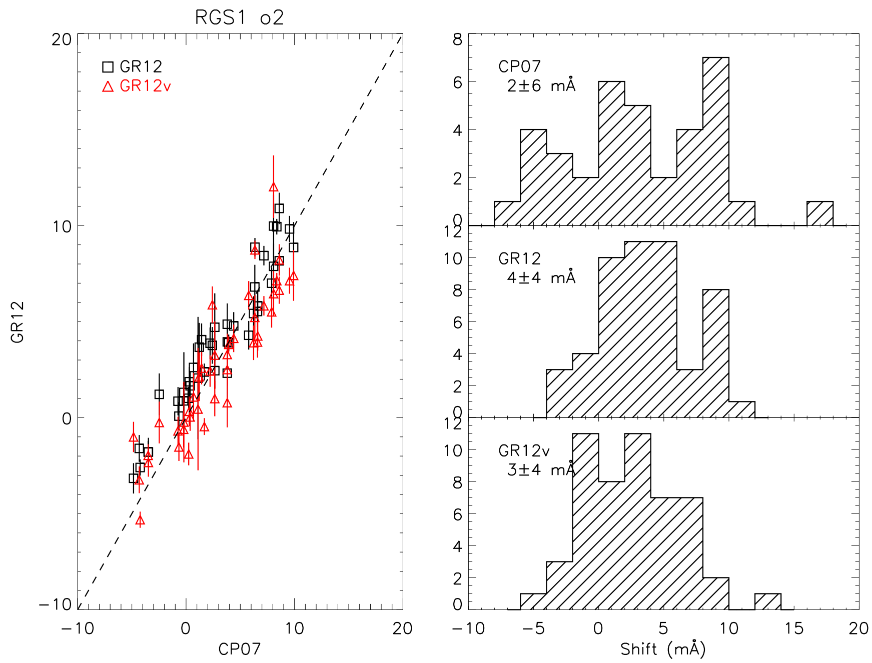

Figure 8: As Fig. 6 for RGS1 Order 2.

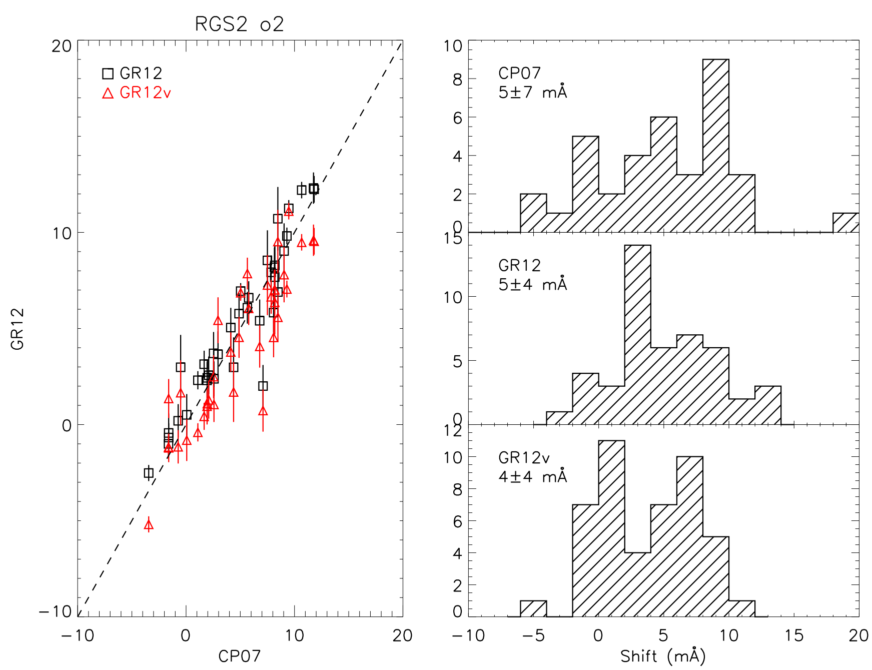

Figure 9: As Fig. 6 for RGS2 Order 2.