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Scisim / Columbia Raytrace Benchmark Test Suite

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1 Introduction

Having arrived at a successful, fully representative physical model, the modeling of the processes has been confirmed to within measurement uncertainties. Now that the development of the numerical modeling and incorporation of all measured, relevant physical parameters have been completed, the Columbia raytrace may serve as a convenient benchmark for other physical models.

The following tables present a suite of cross-checks between the Columbia raytrace and the Scisim raytrace, for the most part developed by Christian Erd, with some input from Joshua Spodek.

Before discussing each series of tests, we list the common properties for all tests, except where otherwise noted:

- In flight geometry
- 15 Å
- m=0, -1, -3
- Ideal mirror model, no scatter
- Ideal Grating model, no scatter
- output: ascii table: z(mm), y(mm), i, order (where z and y are coordinates along the Rowland circle)
- at least 20 000 rays per order

The output from each simulation will be a list of photon positions along the Rowland circle/torus/sphere, their weight in scisim, and their orders. These photon lists will then be used to generate line profiles in the dispersion and cross dispersion directions, as well as two-dimensional scatter plots.

2 Series 1: RGA Mechanical Alignment

The first series of test, "Testing the RGA Mechanical Alignment," tests the modeling of departures from an ideal RGA box in a schematic way, with no reference to the actual, as-built boxes, or to the individually measured gratings.

The baseline for this series of tests is the error budget of February 1996 (undocumented memo provided by Frits Paerls), adapted from the ISVR, and prepared prior to the start of the Panter campaigns. This original purpose of the error budget was as an upper limit for deviations from an ideal RGA. But for our purposes, it serves as a convenient reference of modelable deviations that have been observed in the as-built models.

In the following table, all errors except the named one are set to zero. Each named source of error is modeled independently of each other source in order that small effects be observable without being dwarfed by larger effects. Furthermore, the magnitudes of the deviations are generally larger then those of the error budget by up to an order of magnitude. This increase is designed to maximize the effect of the deviation in the given parameter to allow calibration by a longer lever arm.

Some terms in the error budget are not modeled in this series, notably the grating bow and grating twist. Since more detailed information on these properties was collected during assembly at Nevis, tests of these parameters are made in subsequent series.

Test Number	Test Name	Output Directory	Test Error	Error Budget Magnitude	Test Suite Magnitude
1.1	Intrinsic	intrinsic/	None	0.0	0.0
1.2	Boss	boss/	Boss error	FW = 1.2×10^{-3}mm	12.3×10^{-3} mm
1.3	Rail	rail/	Rail error	FW = 0.15×10^{-3} mm	3.0×10^{-3} mm
1.4	Embedment	embed/	Abs. Embed.	FW = 0.5–2.5×10^{-3} mm	0.5–2.5×10^{-3} mm
			Diff. Embed.	FW = 1.5×10^{-3} mm	0.15×10^{-3} mm
1.5	Grating Bow (R_x, cross disp.)	bowx/	Grating R_x	FW = 20 arcsec	20 arcsec
1.6	Line Spacing	line_space/	Line spacing	$\sigma = 3.0 \times 10^{-7}$	$\sigma = 3.0 \times 10^{-6}$
1.7	Shift X (along optical axis)	tx/	Grating T_x	FW = 0.4 mm	FW = 1 mm
1.8	Shift Y (cross disp.)	ty/	Grating T_y	FW = 1.0 mm	FW = 3 mm
1.9	Z rotation (R_z)	rz/	Grating R_z	FW = 0.01×10^{-6} rad	0.1×10^{-6} rad
1.10	All	all/	All	N/A	All errors at error budget magnitude

3 Series 2: Intrinsic Grating Scattering Properties

The tests in this series test the modeling of the individual grating properties that were measured during the grating calibration phase at Nevis Labs. These tests include multiple wavelengths since the line broadening effects of these grating properties scale with wavelength. The exit angle dependence is tested in the multiple orders.

Since the values of the physical parameters are well constrained by external measurement, these exact values are used, not larger ones, as in the previous section.

Test Number	Test Name	Output Directory	Test Error	Error Budget Magnitude	Test Suite Magnitude
2.1	RGA1 Scatter at 15 Å	scat_rga1_15A/	Grating Scatter, 15 Å	Nevis Values	Nevis Values
2.2	RGA1 Scatter at 7Å	scat_rga1_7A/	Grating Scatter, 7 Å	Nevis Values	Nevis Values
2.3	RGA2 Scatter at 15 Å	scat_rga2_15A/	Grating Scatter, 15 Å	Nevis Values	Nevis Values
2.4	RGA2 Scatter at 7Å	scat_rga2_7A/	Grating Scatter, 7 Å	Nevis Values	Nevis Values

4 Series 3: Grating Mechanical Alignment

The tests in this series test the modeling of misalignments that occured during assembly of each grating array at Nevis Labs as well as the individual grating bows that were measured at the same time.

As in the previous section, the values of the parameters are well constrained by external measurements, so the exact values are used. Since the wavelength dependence of these properties is weak, the tests are performed at one wavelength. The exit angle dependence is tested in the multiple orders.

Test Number	Test Name	Output Directory	Test Error	Error Budget Magnitude	Test Suite Magnitude
3.1	RGA1 Grating Corners	grat_corner_rga1/	Corner Alignment	Nevis Values	Nevis Values
3.2	RGA2 Grating Corners	grat_corner_rga2/	Corner Alignment	Nevis Values	Nevis Values
3.3	RGA1 Bow at 15 Å	bow_rga1_15A/	Grating Bow, 15 Å	Nevis Values	Nevis Values
3.4	RGA2 Bow at 15 Å	bow_rga2_7A/	Grating Bow, 7 Å	Nevis Values	Nevis Values
3.5	RGA1 Bow at 7 Å	bow_rga1_15A/	Grating Bow, 15 Å	Nevis Values	Nevis Values
3.6	RGA2 Bow at 7 Å	bow_rga2_7A/	Grating Bow, 7 Å	Nevis Values	Nevis Values

5 Series 4: Mirror Model

This section tests the modeling of the mirror model. The photons are collected at the EPIC focal plane. No RGA modeling is performed.

Test Number	Test Name	Output Directory	Test Error	Error Budget Magnitude	Test Suite Magnitude
4.1	MM PSF at 5 Å	mmpsf_5/	None	Nominal MM	Nominal MM
4.2	MM PSF at 15 Å	mmpsf_15/	None	Nominal MM	Nominal MM
4.3	MM PSF at 30 Å	mmpsf_30/	None	Nominal MM	Nominal MM

6 Series 5: Comprehensive End Results

This series tests the combined effects of all the above contributions to deviations from the ideal RGS.

Test Number	Test Name	Output Directory	Test Error	Error Budget Magnitude	Test Suite Magnitude
5.1	RGA 1 LSF at 7 Å	lsf_rga1_7/	None	All Nominal	All Nominal
5.2	RGA 1 LSF at 15 Å	lsf_rga1_15/	None	All Nominal	All Nominal
5.3	RGA 1 LSF at 30 Å	lsf_rga1_30/	None	All Nominal	All Nominal
5.4	RGA 2 LSF at 7 Å	lsf_rga2_7/	None	All Nominal	All Nominal
5.5	RGA 2 LSF at 15 Å	lsf_rga2_15/	None	All Nominal	All Nominal
5.6	RGA 2 LSF at 30 Å	lsf_rga2_30/	None	All Nominal	All Nominal