Design of crystal-detector assemblies for ChemiX spectrometer aboard Interhelioprobe

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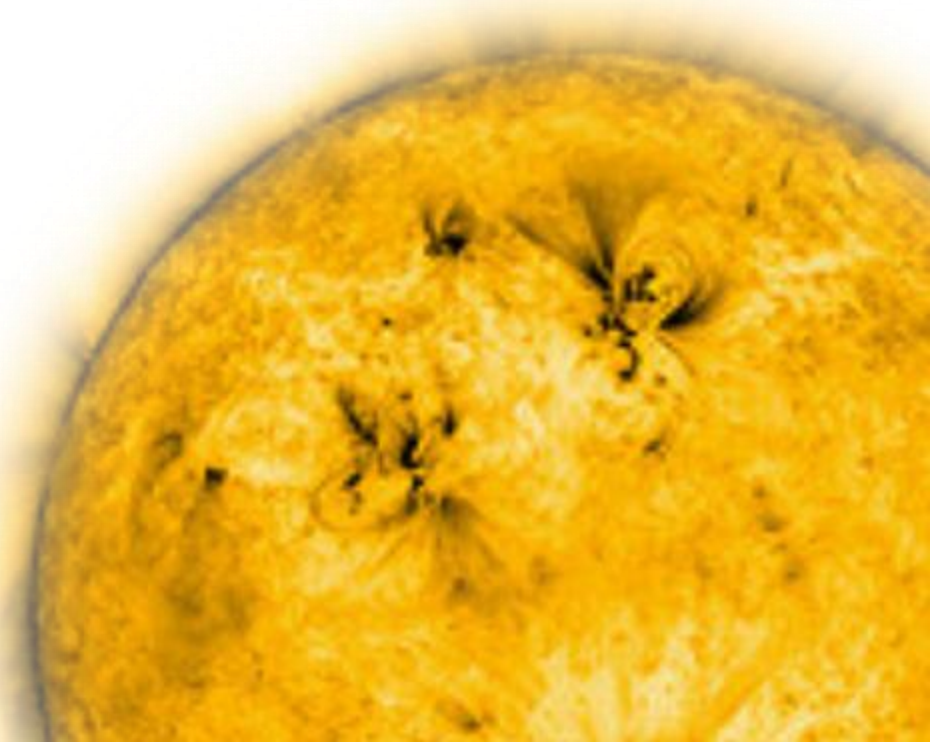
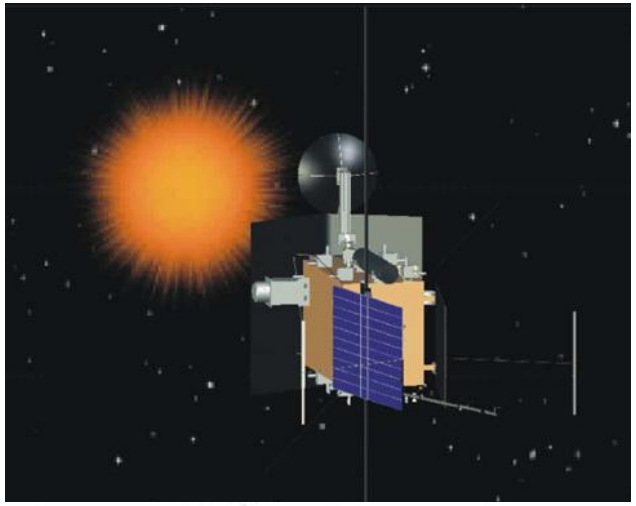
Overview

- General informations about ChemiX
- Design of crystal-detector assemblies
- Results
- Conclusions



Interhelioprobe

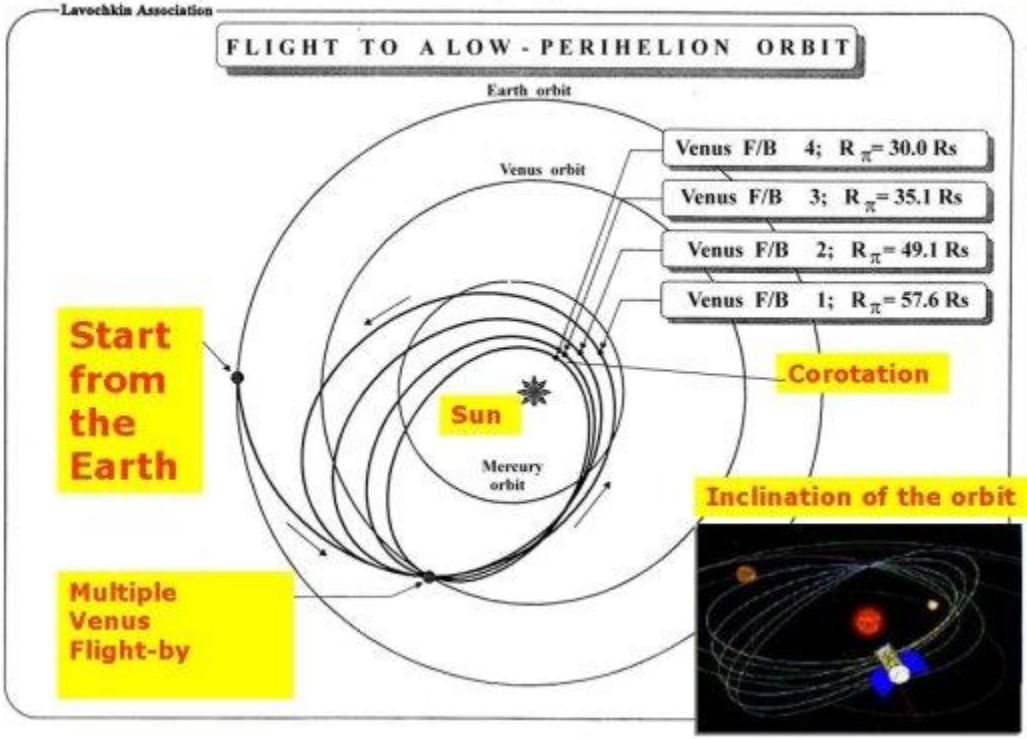


Investigation of an inner Heliosphere and the Sun from close distances and from out-of-ecliptic positions

Closest distance ~ 0.25 AU

Spatial resolution ~4 times better than from 1 AU

fluxes of the solar radiation ~15-20 times larger than in Earth vicinity.

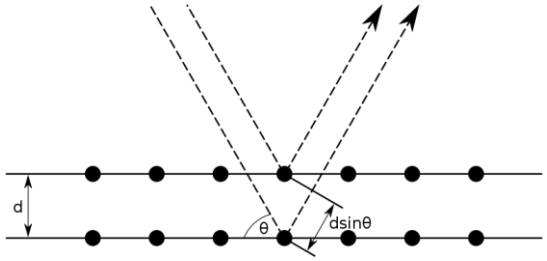


http://www.izmiran.ru

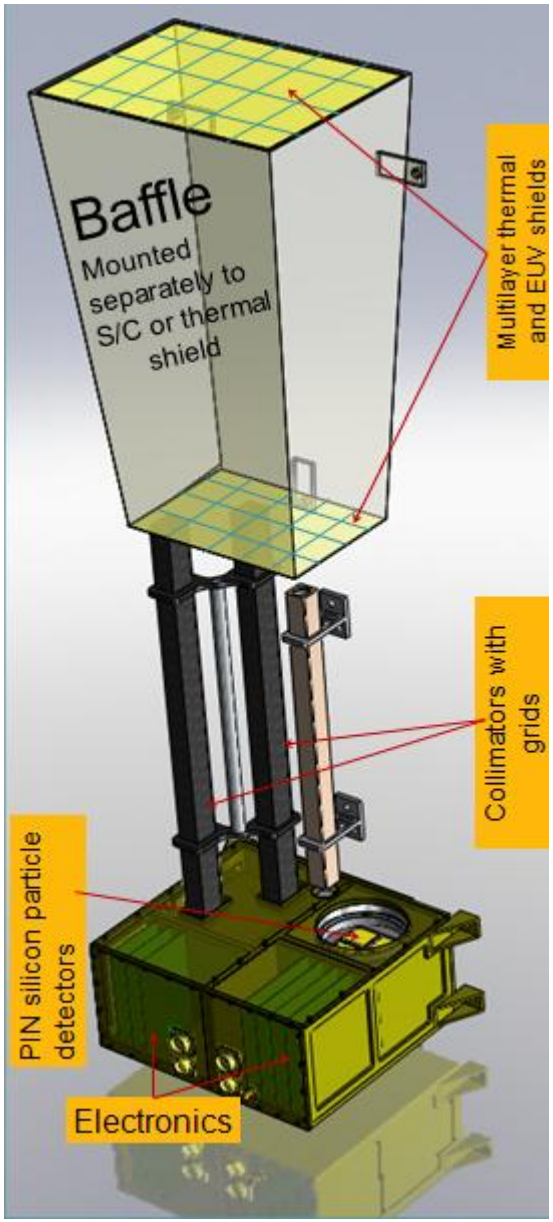
ChemiX

ChemiX is the Bragg crystal spectrometer for studies of Chemical composition of solar coronal plasmas based on measurements of X-ray spectra.

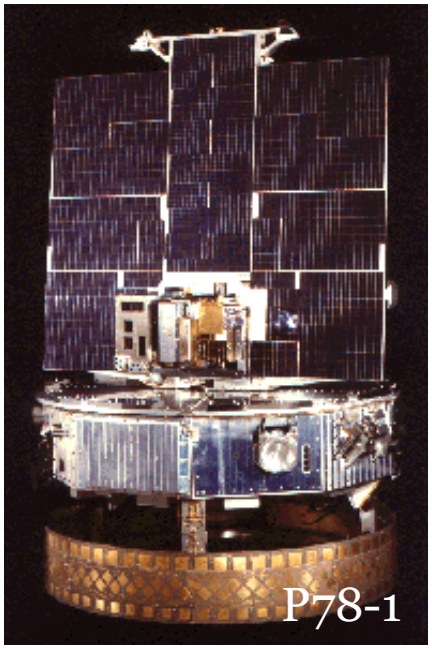
$$2\,d\sin\theta = n\lambda$$

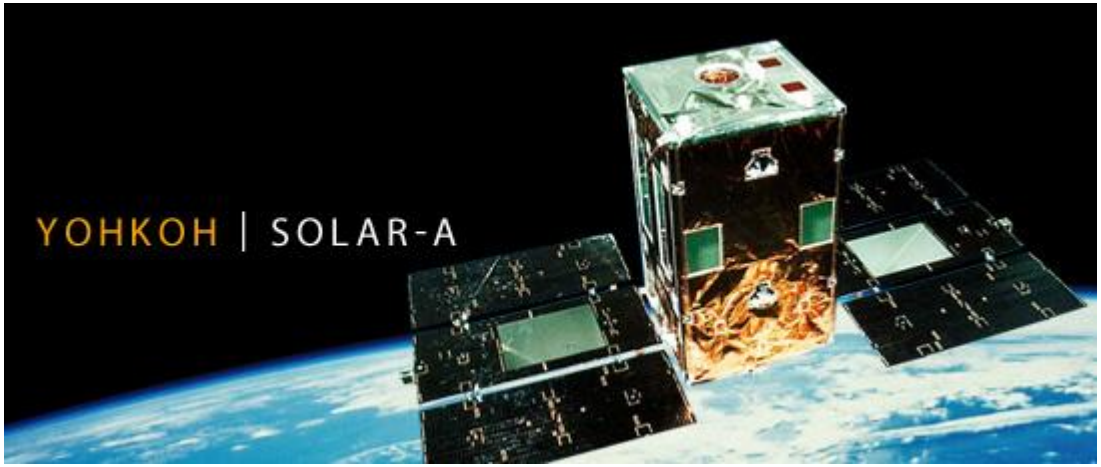


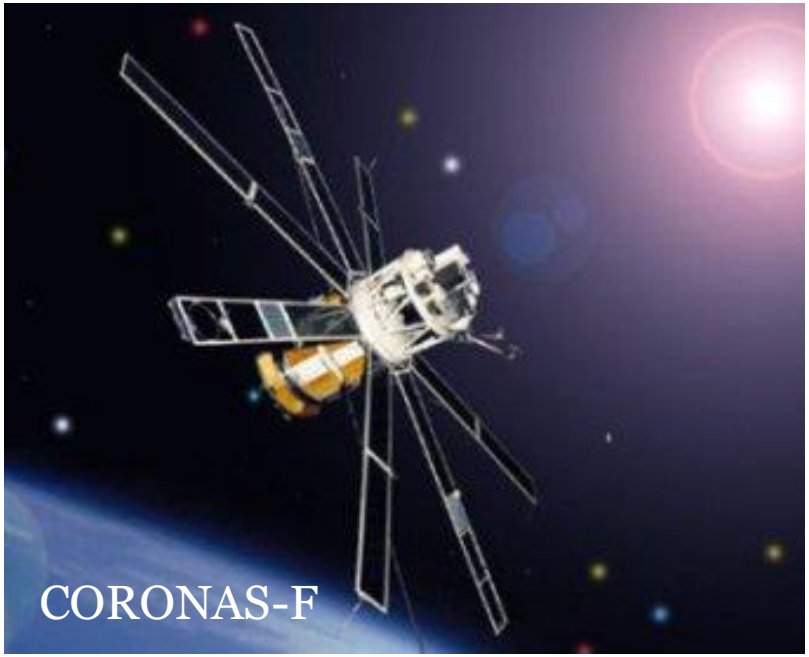
The use of bent crystals allows the wider wavelength range to be integrated simultaneously, whereas a flat crystal spectrometer must scan to cover its wavelength range



Prewious missions







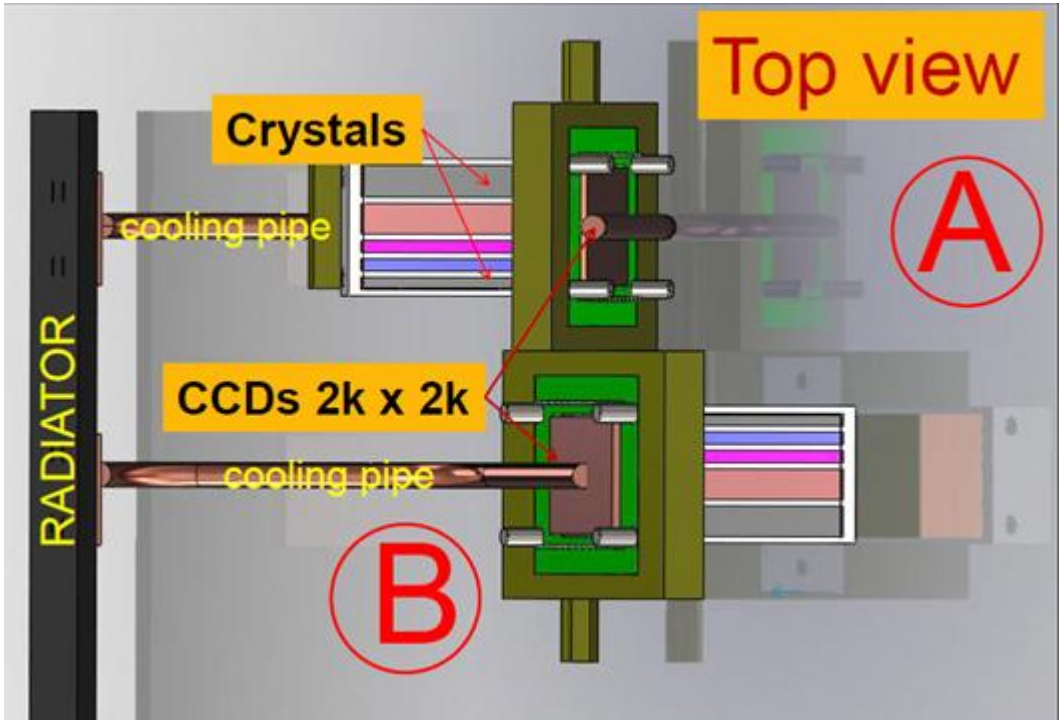
Prewious missions

launched on
31 July 2001

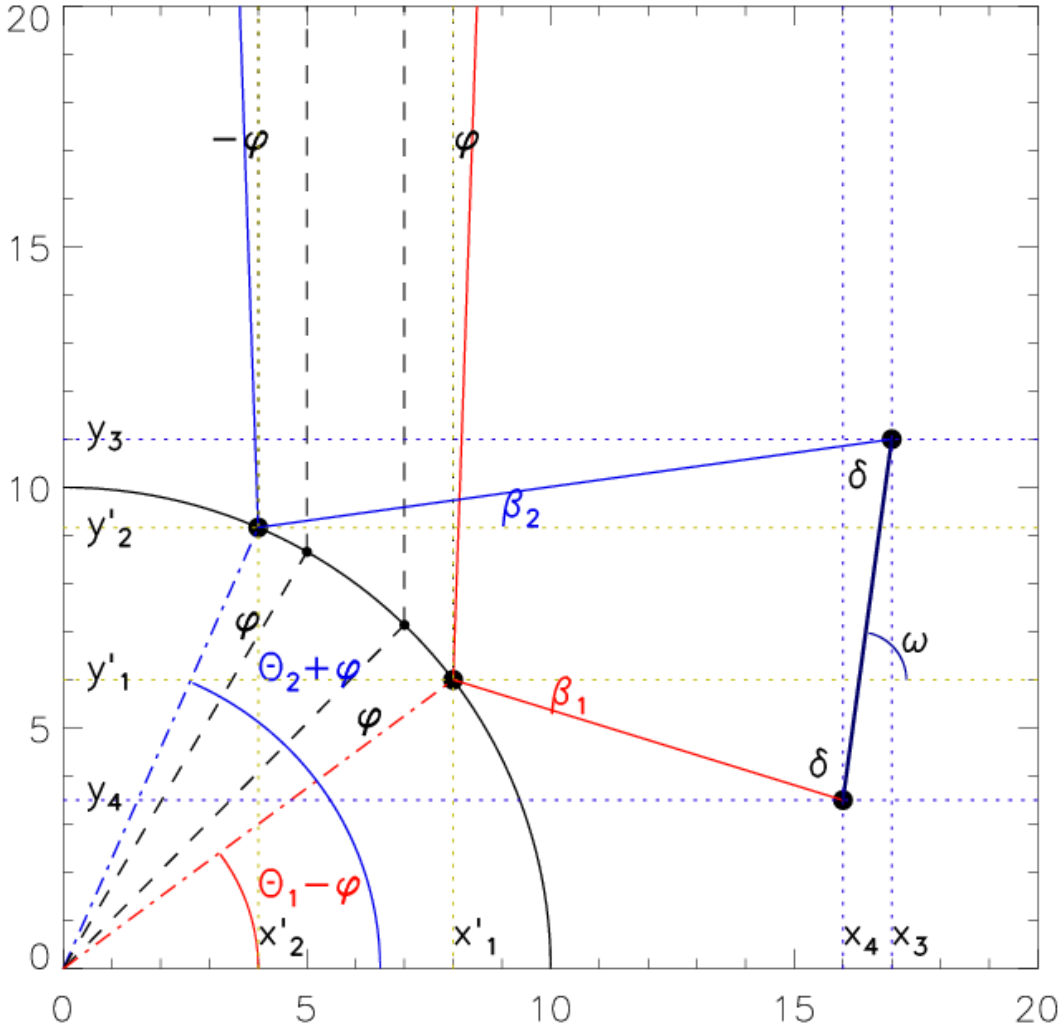
RESIK
Bent crystal spectrometer

Diogeness
Flat crystal spectrometer

Crystal-detector assembles



- two crystal-detector assemblies
- four wider mono-crystal wafers to cover the spectral range from approx. 1.5 A to 8.8 Å
- three dedicated crystal strips for the Dopplerometer in each crystal-detector assembly



(λ_1,λ_2) - wavelenght range we want to observe

(Θ_1,Θ_2) - Bragg angles corresponding to the above wavelength

φ - offset, due to the fact that the Sun is not a point obiect

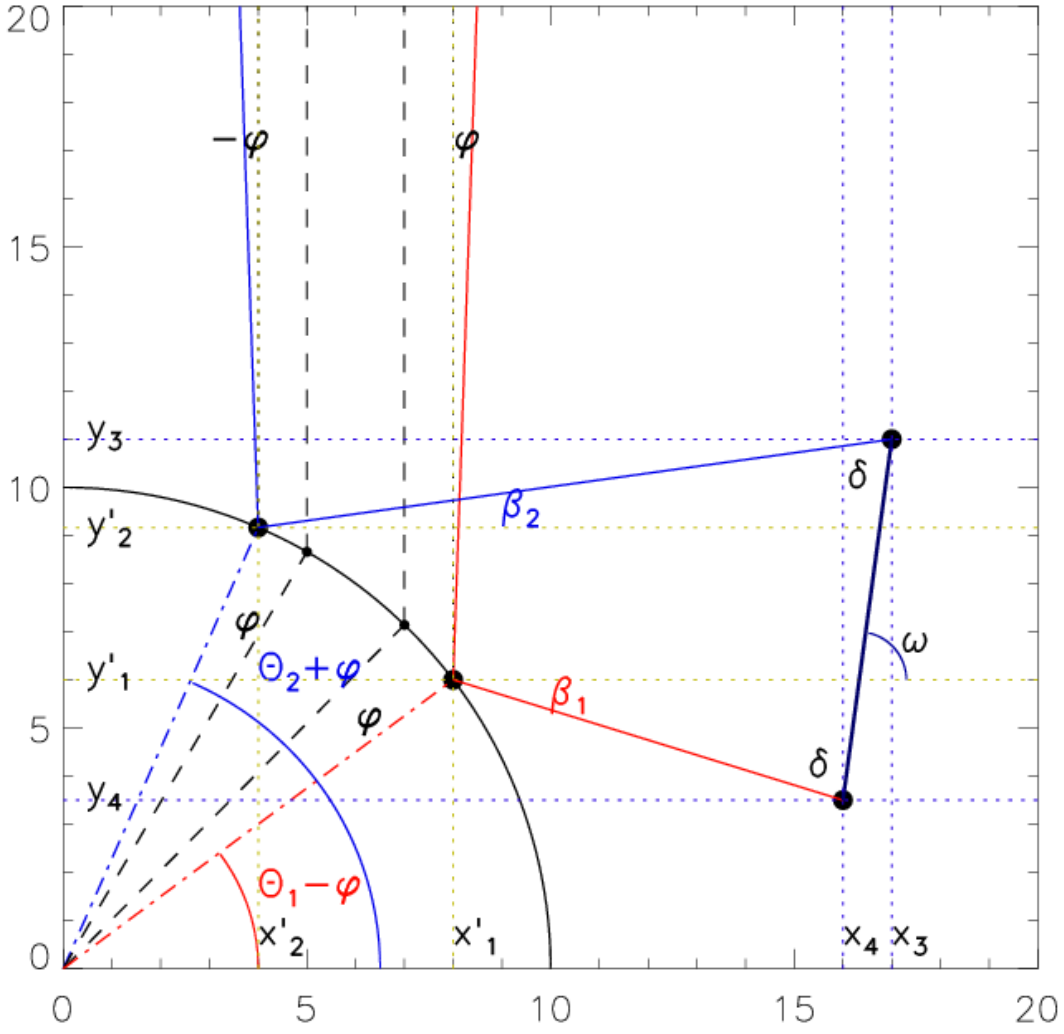
R - the radius of curvature of the crystal

$$x'_1 = Rcos(\Theta_1 - \varphi)$$

$$y'_1 = Rsin(\Theta_1 - \varphi)$$

$$x'_2 = Rcos(\Theta_2 - (-\varphi))$$

$$y'_2 = Rsin(\Theta_2 - (-\varphi))$$



$$\beta = 2\Theta - 90° - \varphi$$

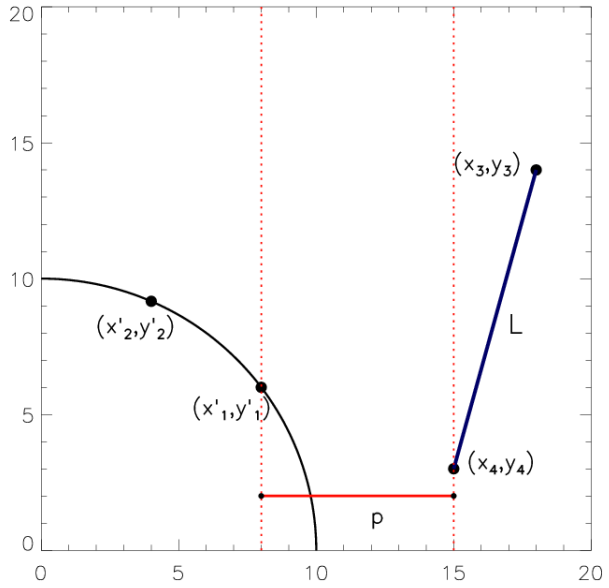
$$a_1 = tan(\beta_1) = tan(2\Theta_1 - 90° - \varphi)$$

$$a_2 = tan(\beta_2) = tan(2\Theta_2 - 90° - (-\varphi))$$

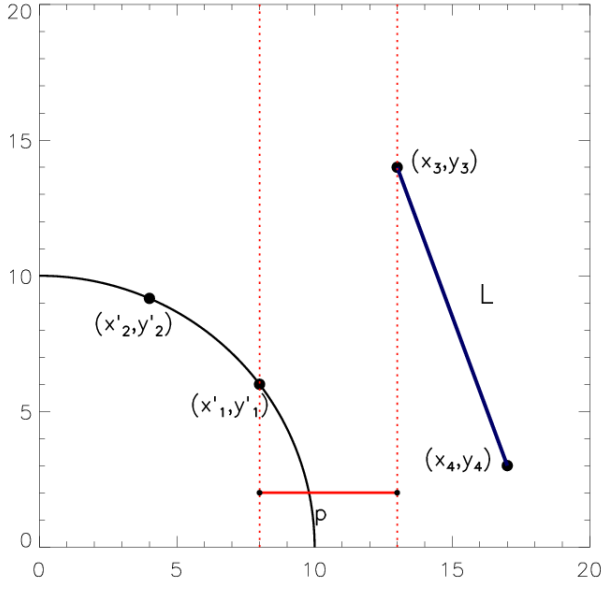
$$a_L = tan(\omega) = tan(\Theta_1 + \Theta_2)$$

L - detector lenght

p - minimum distance from the detector to the crystal



$$x_4 = x_1' + p$$



$$x_3 = x_1' + p$$

$$y_3 = a_2 x_3 + b_2$$

$$y_3 = a_L x_3 + b_L$$

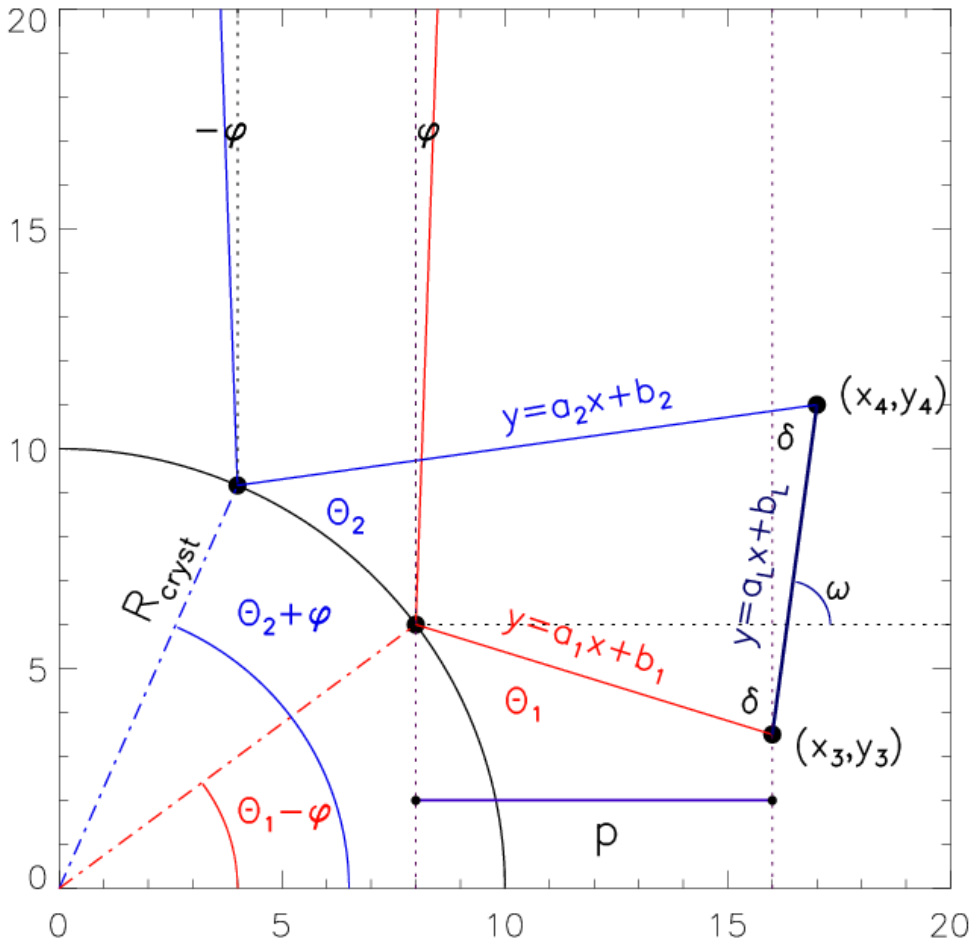
$$y_4 = a_1 x_4 + b_1$$

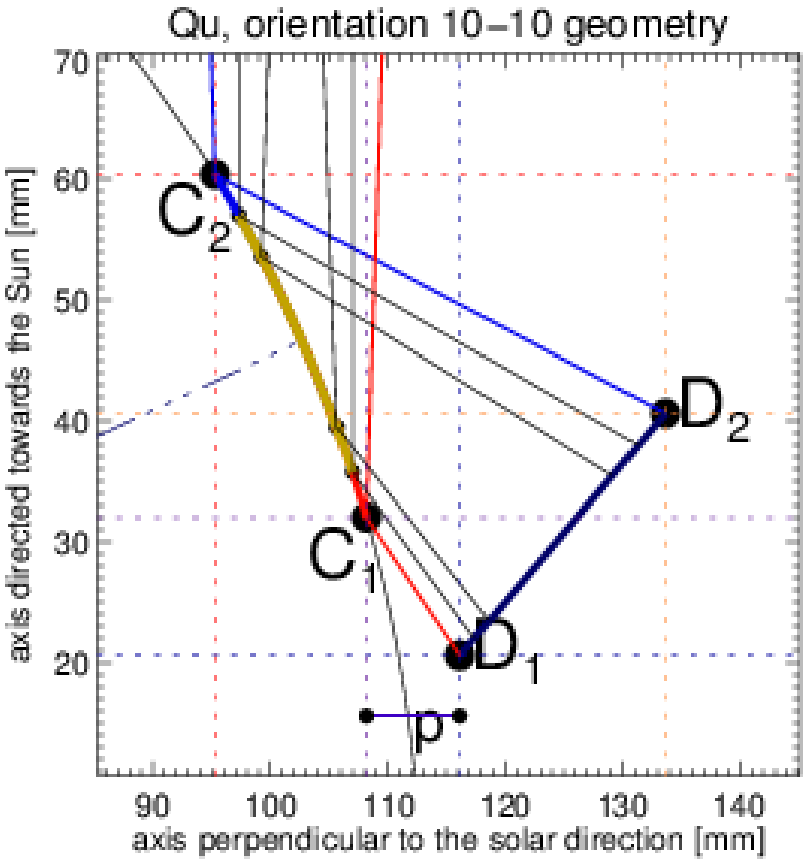
$$y_4 = a_L x_4 + b_L$$

$$L^2 = (x_4 - x_3)^2 + (y_4 - x_3)^2$$

$$a_L = tan(\omega) = tan(\Theta_1 + \Theta_2)$$

$$\begin{cases} x_4 = x_1' + p \\ x_3 = x_1' + p \end{cases}$$





Waverange: 2.700 - 4.304 Å
2d: 8.514 Å

Radius of curvature: 112.789 mm

Detector slope: 48.88

Now we want to know what wavelength falls on the individual pixels of the detector

We assume that we know: x, y, R, φ
We are looking for Θ

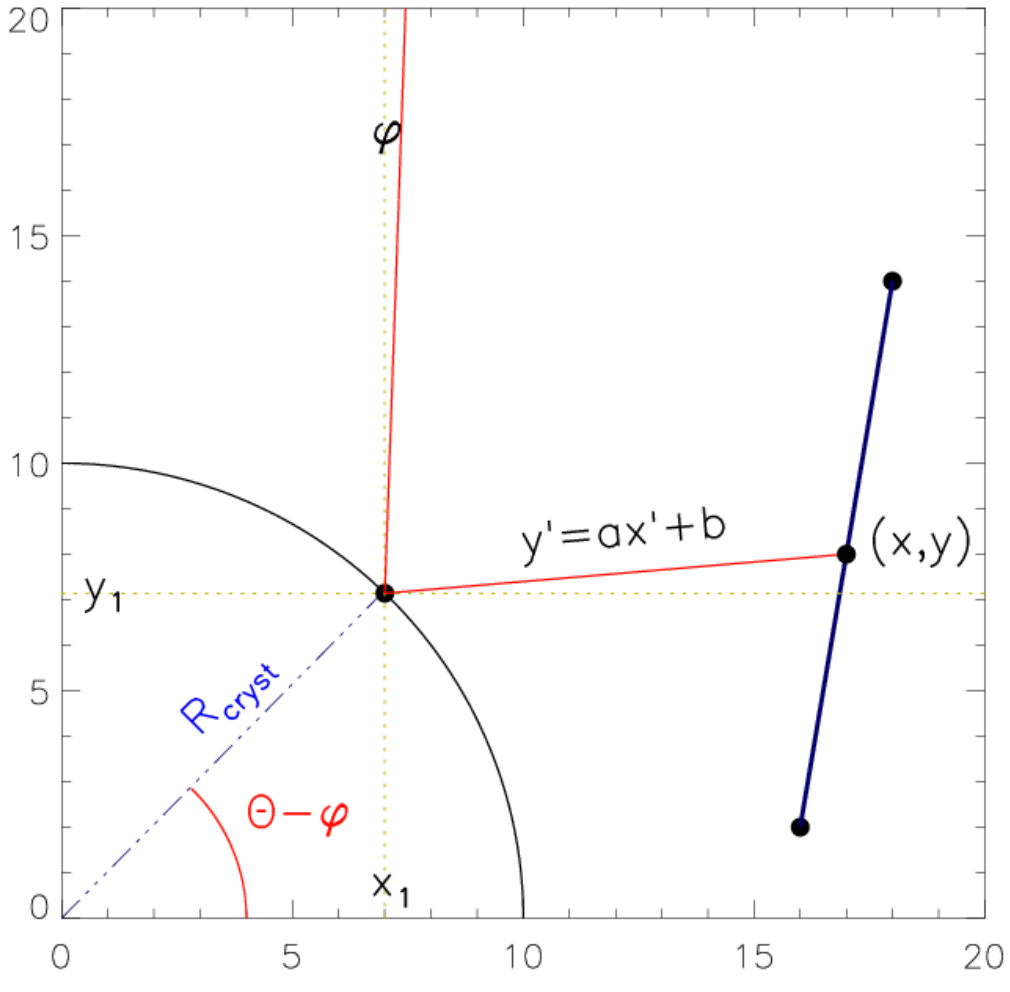
$$y = ax + b$$

$$y_1 = ax_1 + b$$

$$x_1 = Rcos(\Theta - \varphi)$$

$$y_1 = Rsin(\Theta - \varphi)$$

$$a = tan(2\Theta - \varphi - 90°) = -\frac{cos(2\Theta - \varphi)}{sin(2\Theta - \varphi)}$$



$$y - y_1 = a(x - x_1)$$

$$y - Rsin(\Theta - \varphi) = -\frac{cos(2\Theta - \varphi)}{sin(2\Theta - \varphi)}[x - Rcos(\Theta - \varphi)]$$

$$cos^4\Theta[4(A^2 + B^2)] + cos^3\Theta[-4RB] + cos^2\Theta[-4(A^2 + B^2) + R^2] + cos\Theta[2RB] + [B^2] = 0$$

$$A = ycos\varphi + xsin\varphi$$
$$B = xcos\varphi - ysin\varphi$$

We get the equation of the fourth degree that we have to solve.

We can do this by using FZ_ROOTS function in IDL.

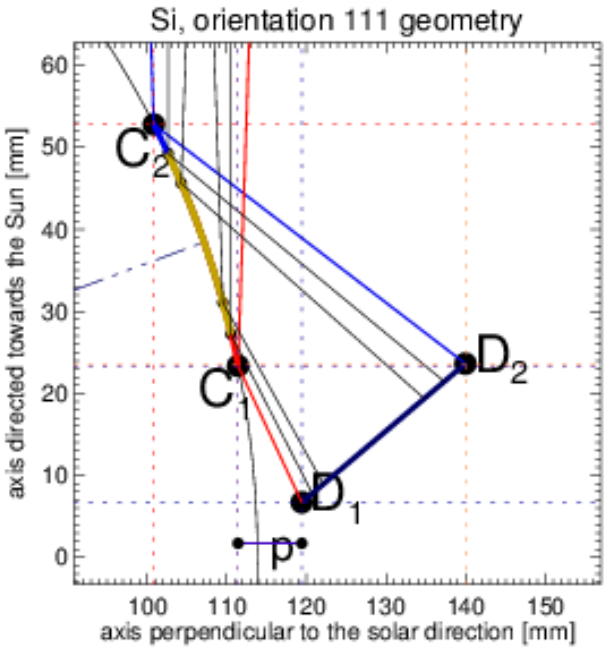
Selecting crystals

- we divide the observed wavelength range into four parts so that the bands overlap slightly
- we want to have some strong lines on those connecting areas
- we want to have most interesting lines on the middle of bands

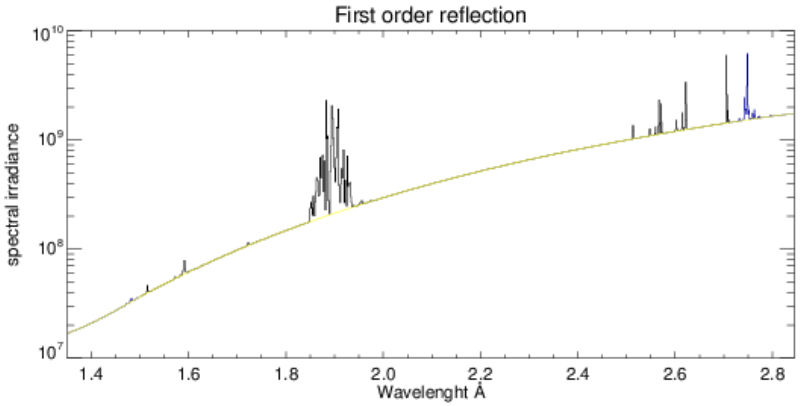
- we don't want to observe fluorescent lines from crystal
- the radius of curvature of crystal can’t be too small

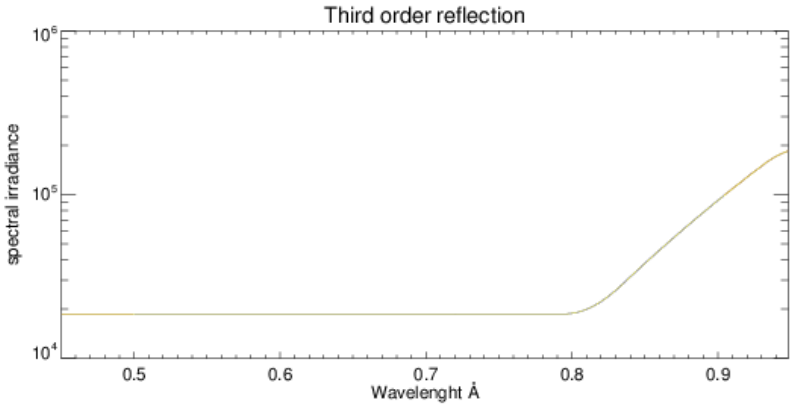
- in the case of dopplerometr we want to have the most interesting lines observed with the best resolution

Si 111

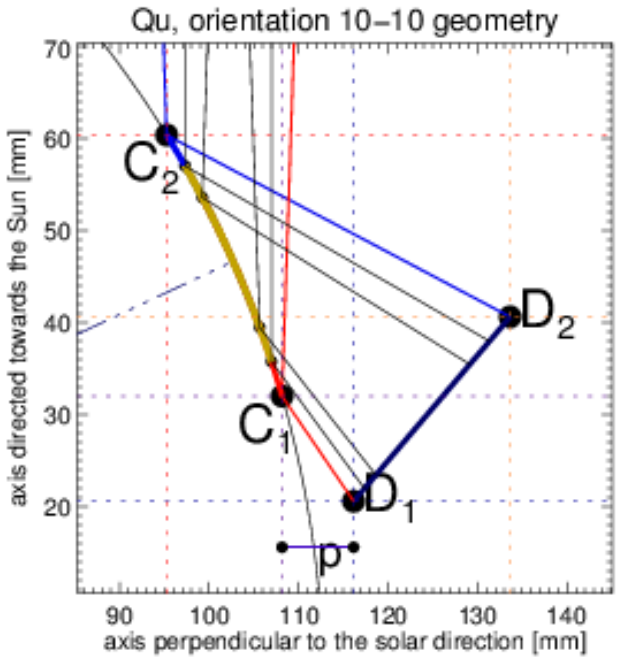


Waverange: 1.500 - 2.713 Å
2d: 6.271 Å
Radius of curvature: 113.84 mm
Detector slope: 39.47

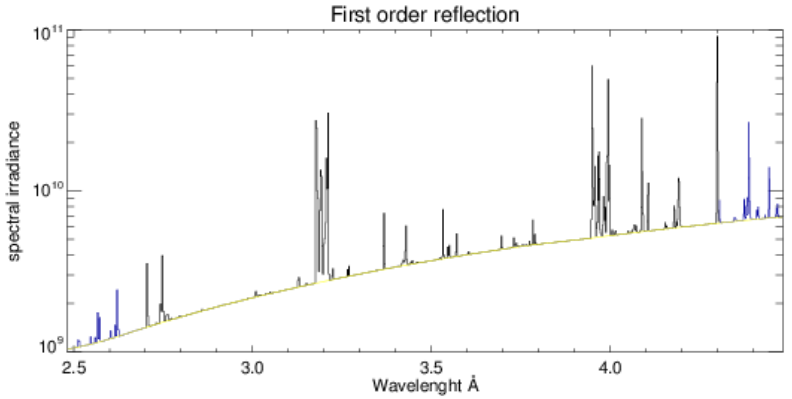


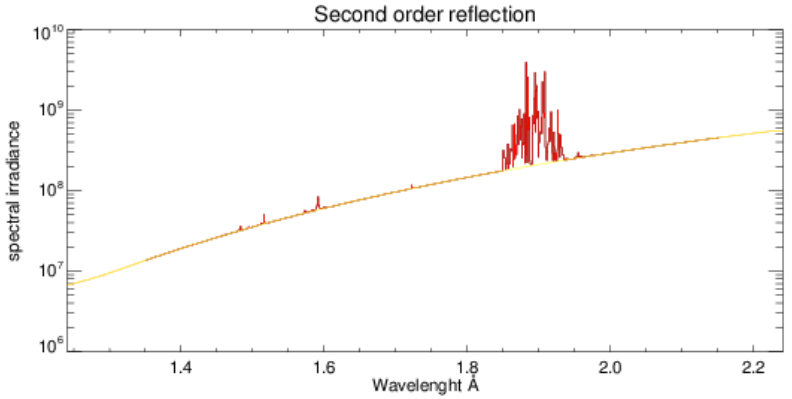


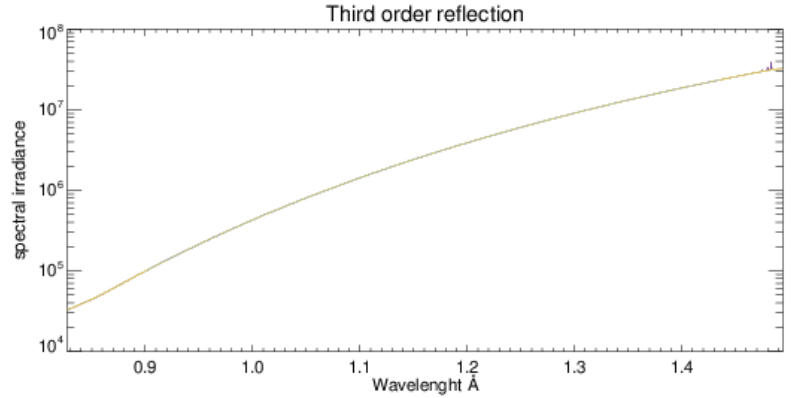
Quartz 10-10



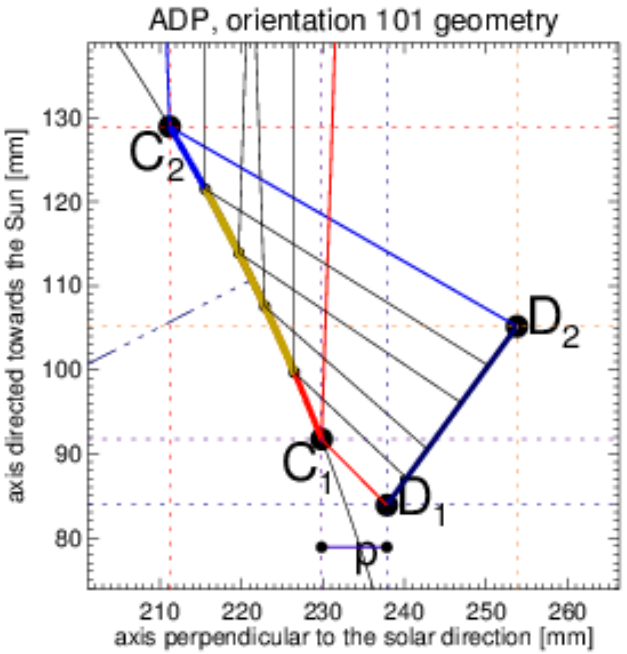
Waverange: 2.700 - 4.304 Å
2d: 8.514 Å
Radius of curvature: 112.789 mm
Detector slope: 48.88



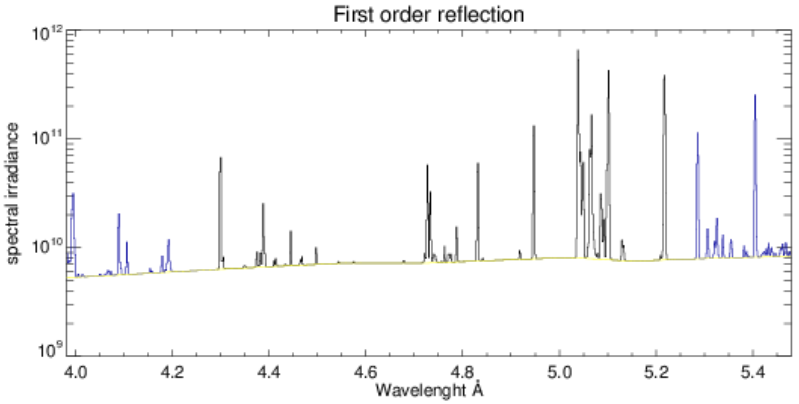


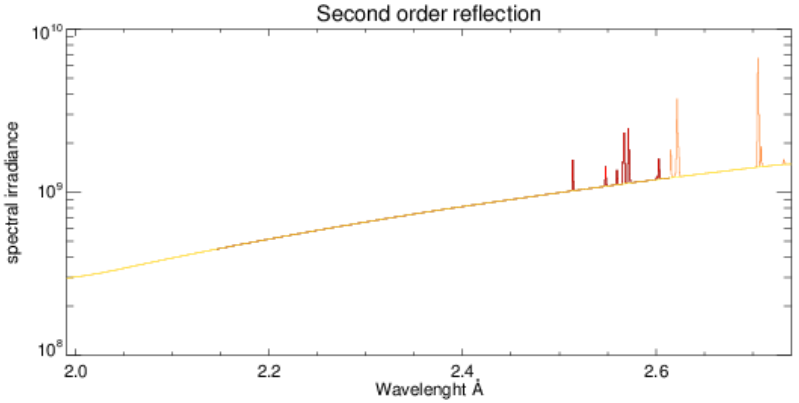


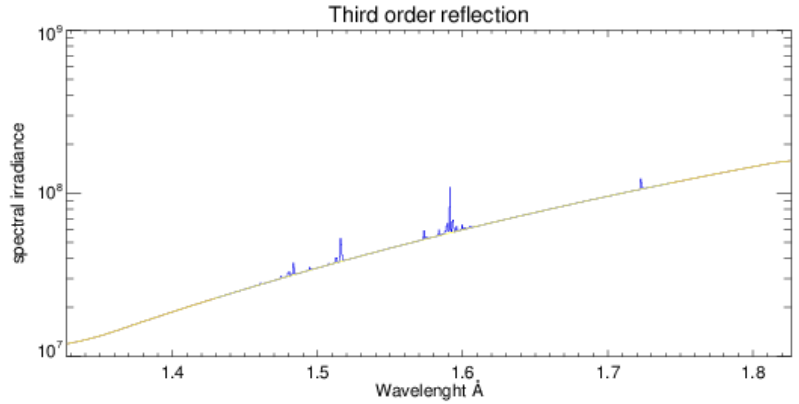
ADP 101



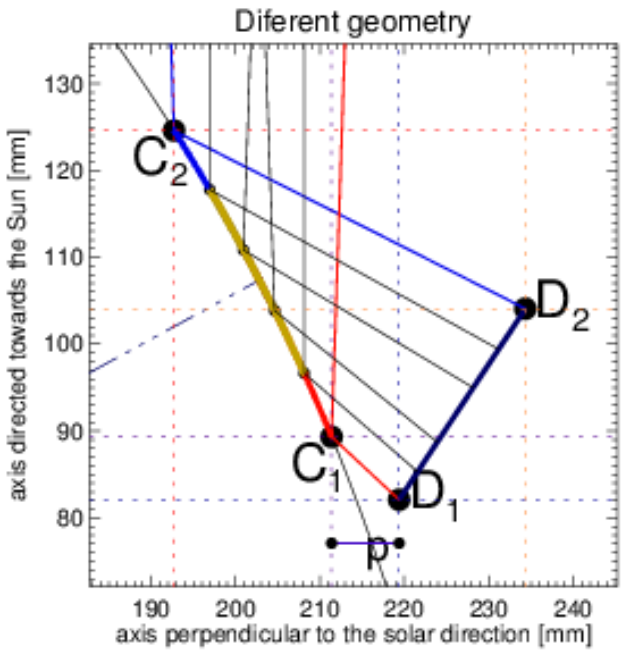
Waverange: 4.290 - 5.228 Å
2d: 10.648 Å
Radius of curvature: 247.45 mm
Detector slope: 53.16



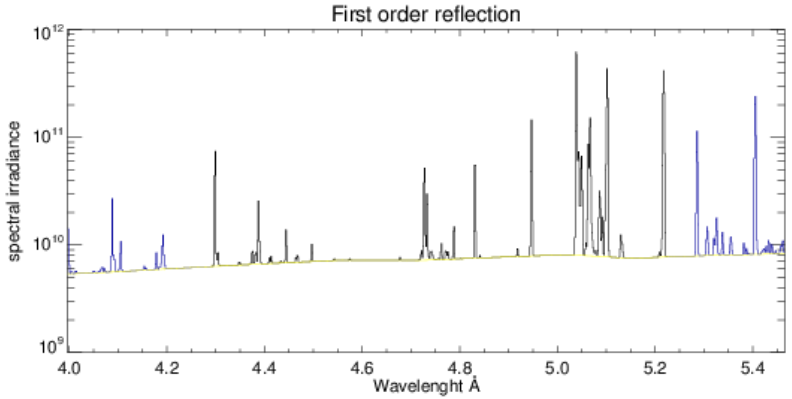


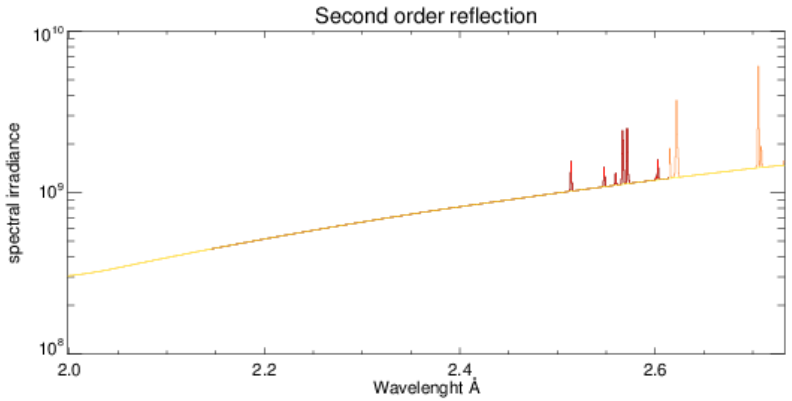


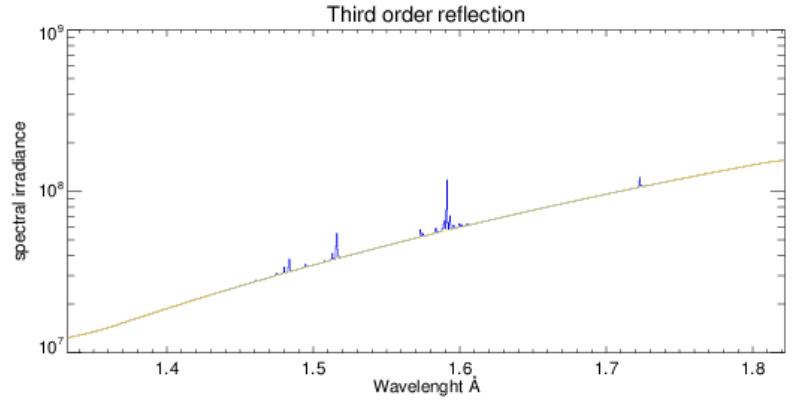
KDP 011



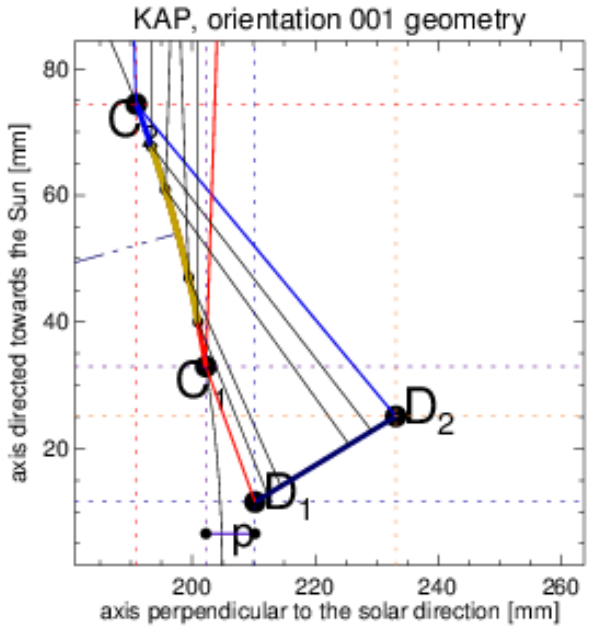
Waverange: 4.290 - 5.228 Å
2d: 10.185 Å
Radius of curvature: 229.484 mm
Detector slope: 56.52



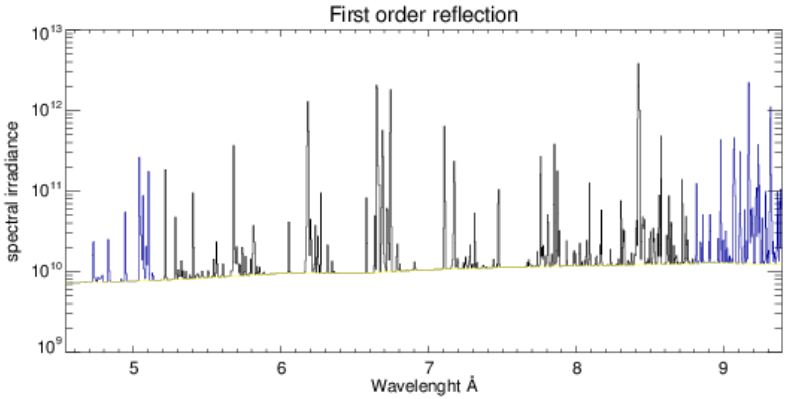


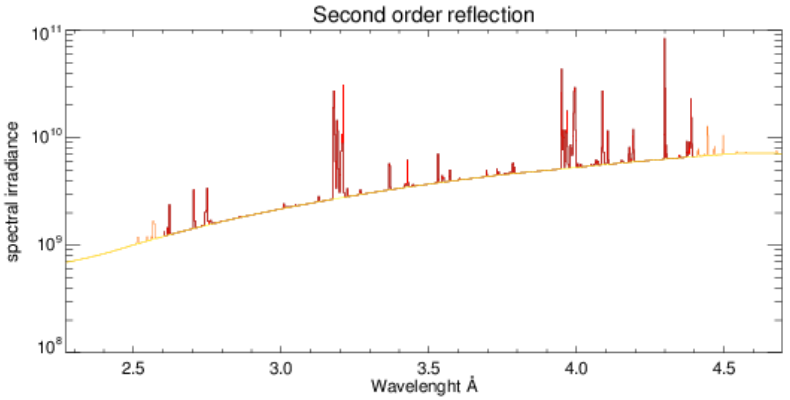


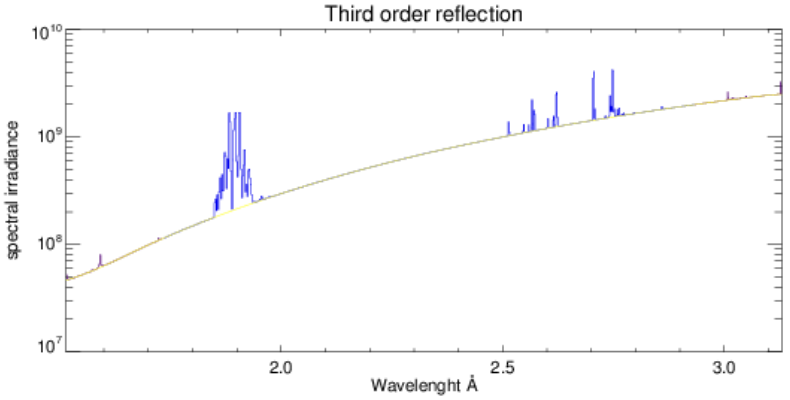
KAP 001



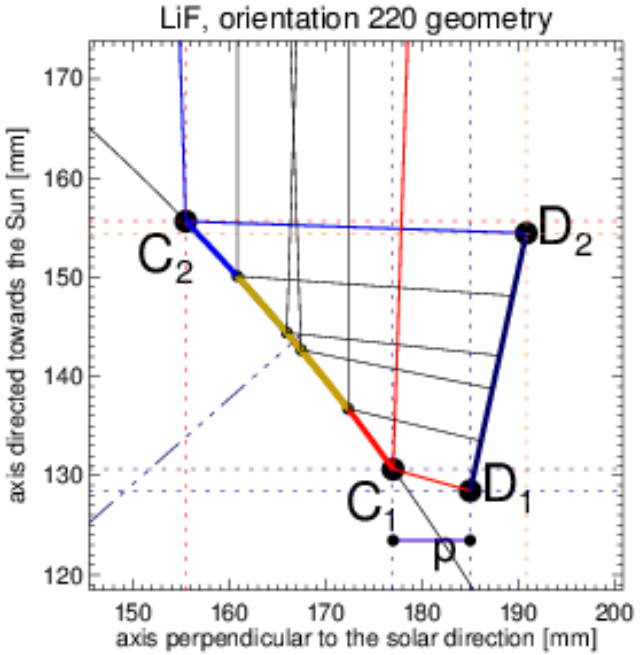
Waverange: 5.200 - 8.800 Å
2d: 26.64 Å
Radius of curvature: 204.909 mm
Detector slope:



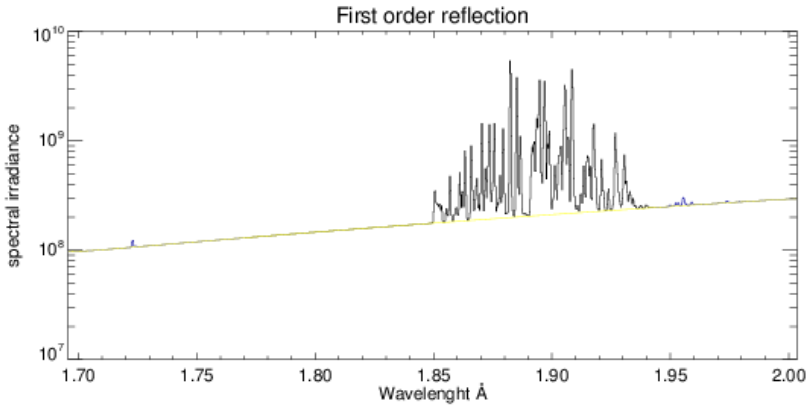


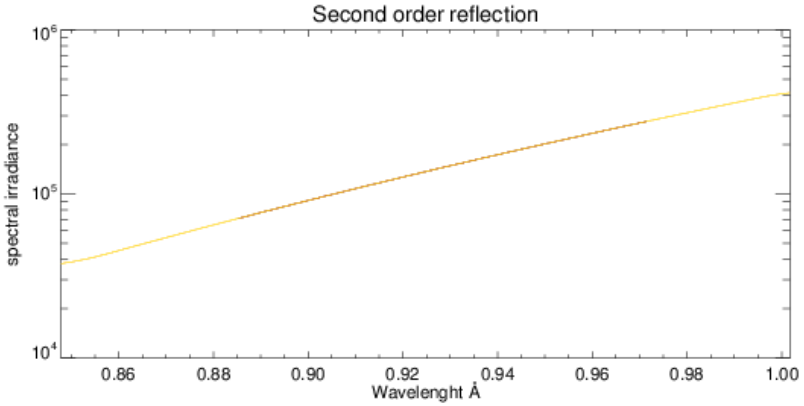


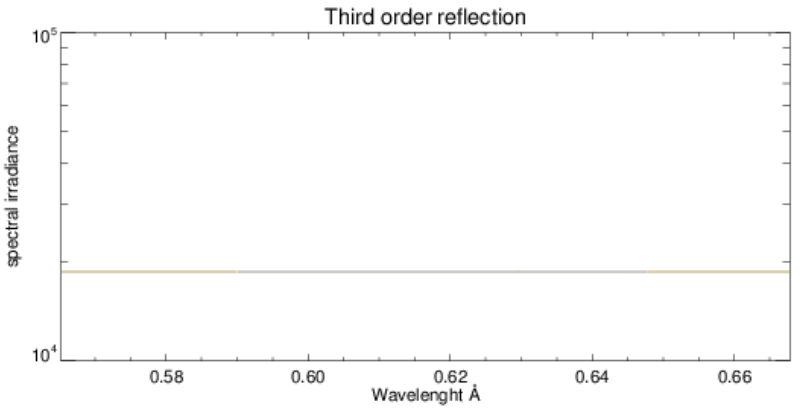
LiF 022



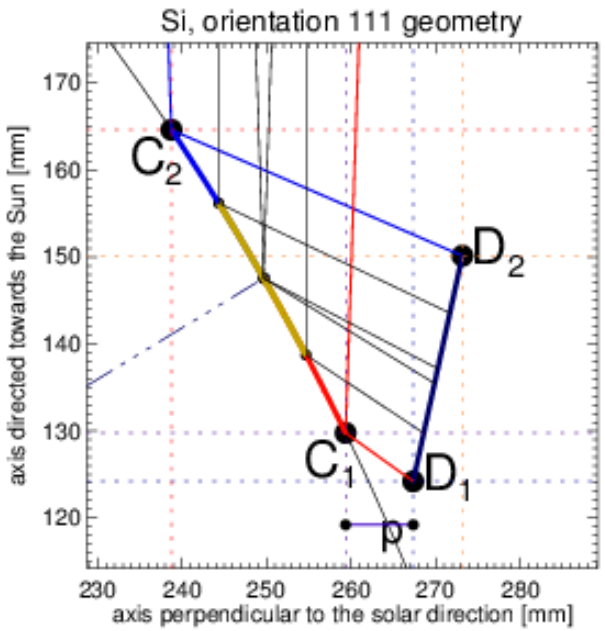
Waverange: 1.770 - 1.943 Å
2d: 2.848 Å
Radius of curvature: 220.0 mm
Detector slope: 77.35 (1.35 rad)



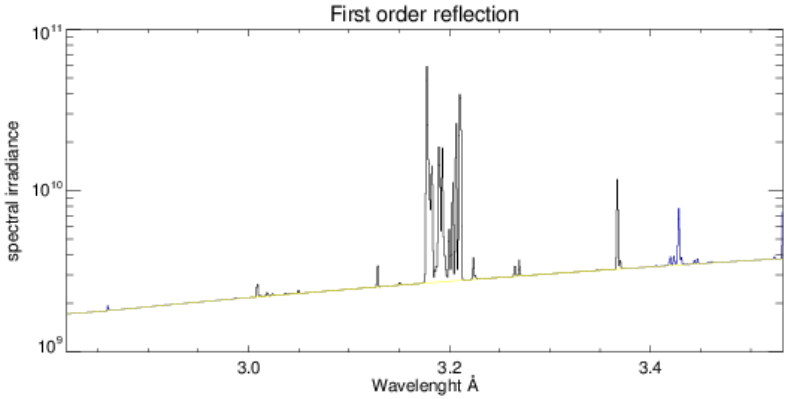


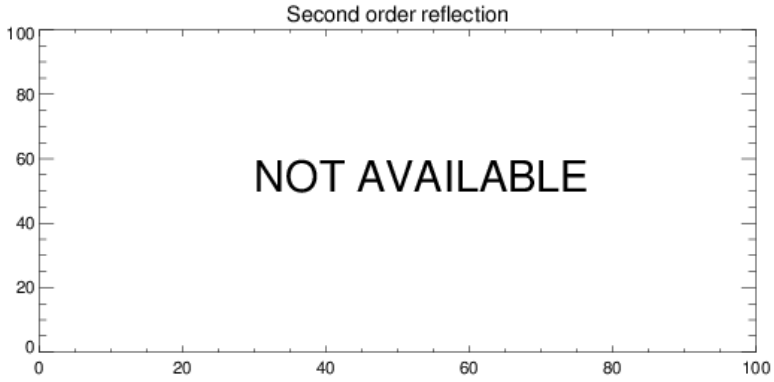


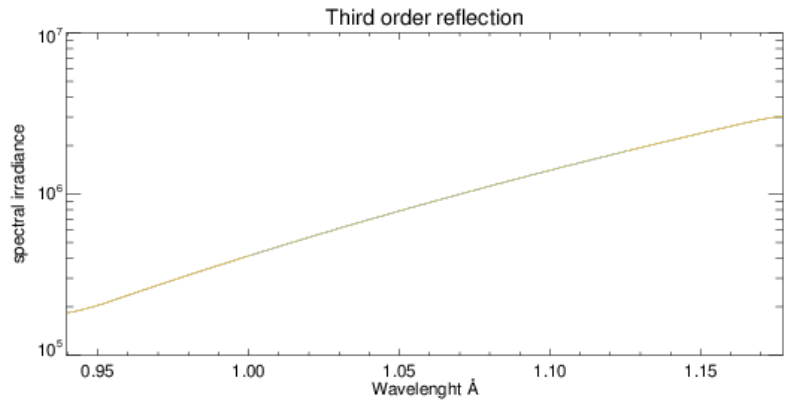
Si 111



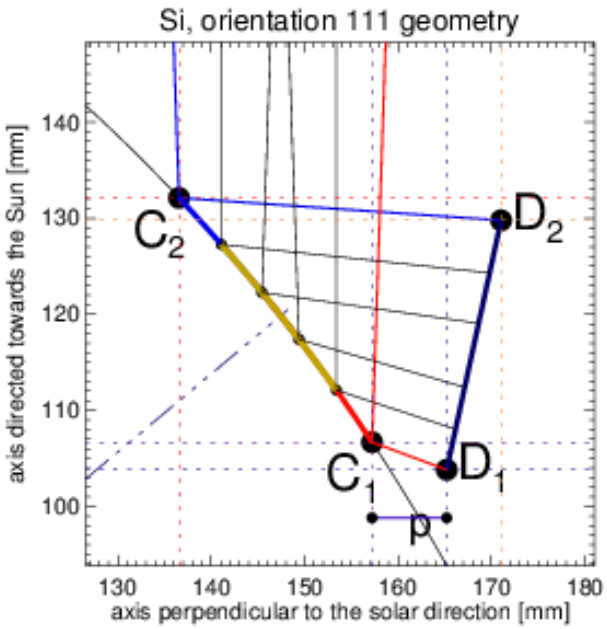
Waverange: 3.000 - 3.378 Å
2d: 6.271 Å
Radius of curvature: 290.0 mm
Detector slope: 77.35 (1.35 rad)



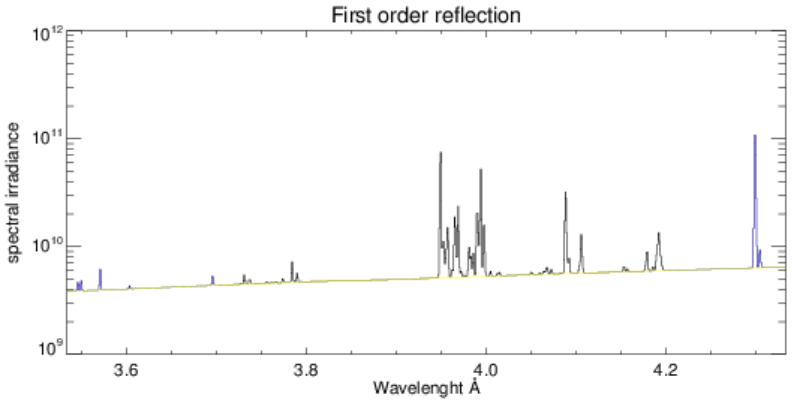


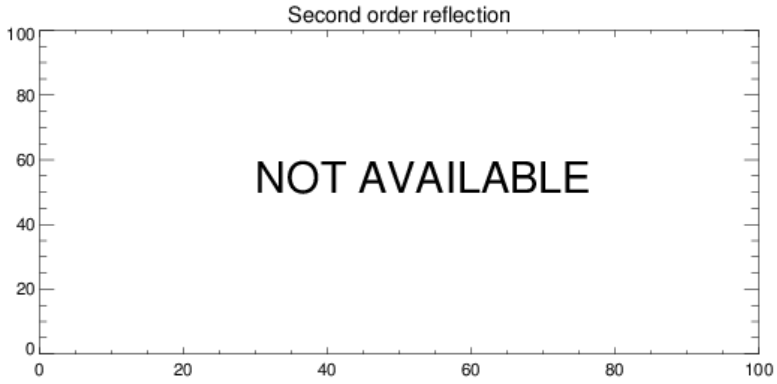


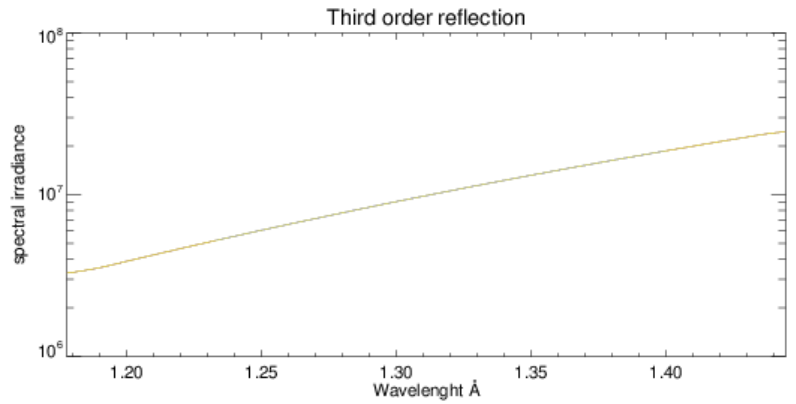
Si 111



Waverange: 3.700 - 4.201 Å
2d: 6.271 Å
Radius of curvature: 190 mm
Detector slope: 77.35 (1.35 rad)







No	crystal	orientation	2d	wavelenght range [Å]	curvature radius [mm]	total desired crystal lenght [mm]	working crystal lenght [mm]	crystal width [mm]	number of crystals
Spectrometer									
1	Si	111	6.271	1.500 - 2.713	113.844	41.3	31.29	10	1
2	Quartz	10-10	8.514	2.700 - 4.304	112.789	41.2	31.17	10	1
3	ADP	101	10.648	4.290 - 5.228	247.454	51.6	41.61	10	1
	KDP	011	10.185	4.290 - 5.228	229.484	49.9	39.90	10	1
4	KAP	001	26.64	5.200 - 8.800	204.909	52.95	42.95	10	1
Dopplerometer									
1	LiF	022	2.848	1.770 - 1.943	220.000	43.0	32.98	10	2
2	Si	111	6.271	3.000 - 3.378	290.000	50.5	40.51	10	2
3	Si	111	6.271	3.700 - 4.201	190.000	42.8	32.78	10	2

Conclusions

- ChemiX will constitute the most advencet solar X-ray Bragg spectrometer ever flown
- It will contained 10 crystals bent to desired radius of curvature
- It will allow to observe the spectral range from 1.5Å to 8.8Å with very good temporal and spatial resolution
- X-ray Doppleromerer will allow to study of line-of-sight plasma motion in absolute reference system