# GRATINGS

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What is a grating?

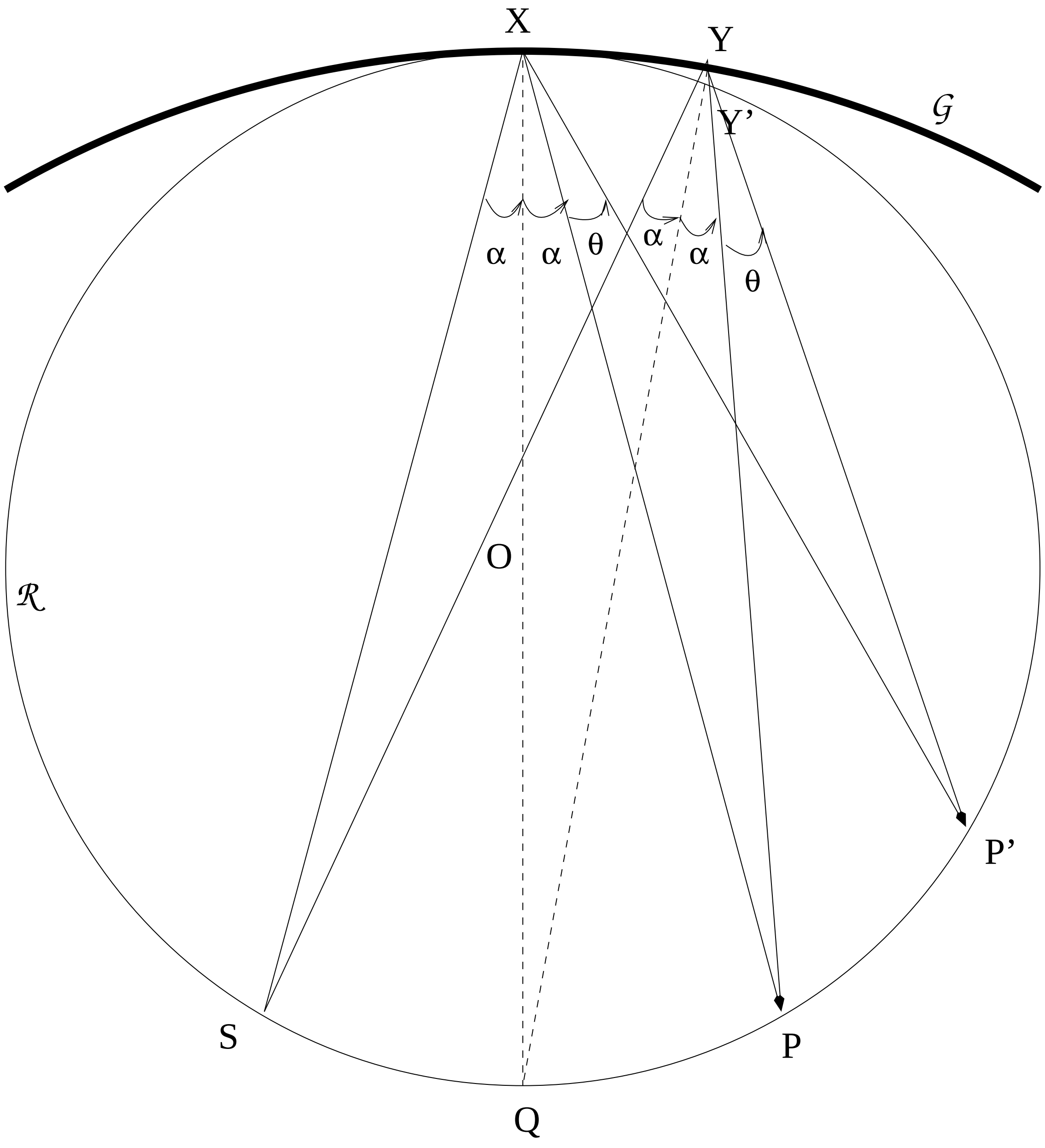
Why use gratings?

How do gratings work?

- In Theory
  - Dispersion
  - Rowland Circle
- In Practice
  - Current X-ray Gratings
  - Order Separation
  - Wavelength scale
  - Line Spread Function
  - Flux Spectra (when to and when not to)
  - Response Matrices
  - Fitting Issues

Examples

# The Rowland Circle Geometry




OQ = OX = radius of Rowland circle $\mathcal{R}$
XQ = radius of curvature of concave grating $\mathcal{G}$
angle of reflection SXQ = QXP = $\alpha$ = XYQ = QYP
angle of dispersion PXP' = $\theta$ = PYP'
YY' assumed to be small

# DISPERSION

- The grating equation relates the wavelength of dispersion $\lambda$ at any given order $m$ to the grating period $d$ and the angles of incidence ($\theta_0$) and dispersion ($\theta$):

$$m\lambda = d(\sin\theta - \sin\theta_0)$$

- The grating focus is on the Rowland circle of diameter $\mathcal{D} = 2\mathcal{R}$, so for a detector shaped to follow the Rowland circle, photons of wavelength $\lambda$ come to a focus at a distance

$$x = \mathcal{D}(\theta - \theta_0) = \mathcal{D}\Delta\theta \approx m\lambda\frac{\mathcal{D}}{d}$$

- The resolving power, $\frac{\lambda}{\delta\lambda} \approx \left[\left(\frac{\delta d}{d}\right)^2 + \left(\frac{\delta x}{x}\right)^2\right]^{-\frac{1}{2}}$, and because the error in the grating period is usually small, is generally detemined by the width of telescope PSF. Also note that $\lambda/\delta\lambda \sim x/\delta x$, i.e., the resolving power increases for higher wavelengths.

- **Example:** Consider the LETGS, which has a Rowland diameter $\mathcal{D} = 8637$ mm, and a grating period $d = 0.99125 \pm 0.000087$ $\mu$m. At say 100 Å in the $1^{st}$ order, $\Delta\theta \approx 0.0100883^c \sim 37.4'$, $x = 87.1324$ mm, for a plate scale of 1.148 Å mm$^{-1}$. The HRMA on-axis PSF is approximately 5 HRC pixels (0.032 mm) wide, so the resolving power is $\approx 2700$.

## Line Spread Function

- The response of the instrument to a $\delta$-function line is the Line Spread Function (LSF)
- Chandra LSFs usually well described by a "Beta profile,"

$$I(\lambda) = \frac{1}{\left[1 + \left(\frac{\lambda - \lambda_0}{\lambda_c}\right)^2\right]^\beta}$$

  ($\beta = 1$ is the Lorentzian function)
- Response matrices include multiple Gaussian and Lorentzian components
- Do you *really* need to use a response matrix for grating data?
  – yes, if you cannot separate the orders and have significant continuum
  – no, if you are analyzing individual lines and are confident of the model