# Light curve simulation of X-Ray Binaries in presence of stellar wind

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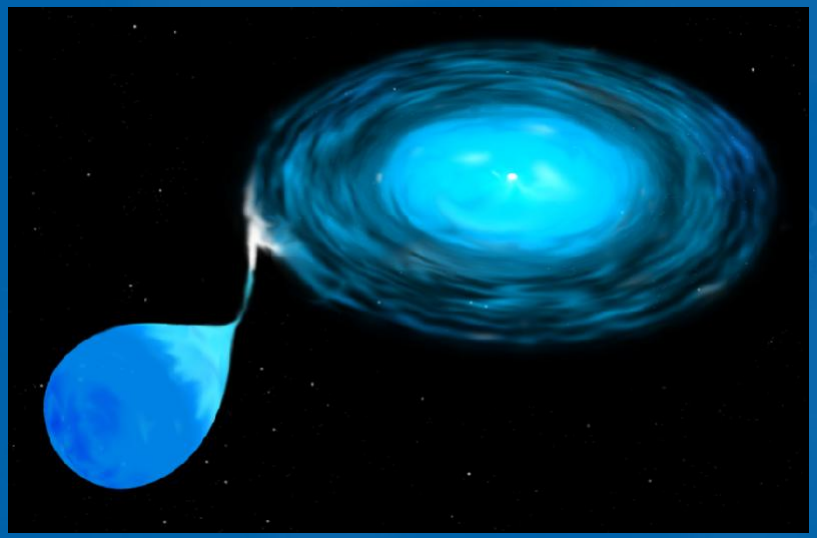
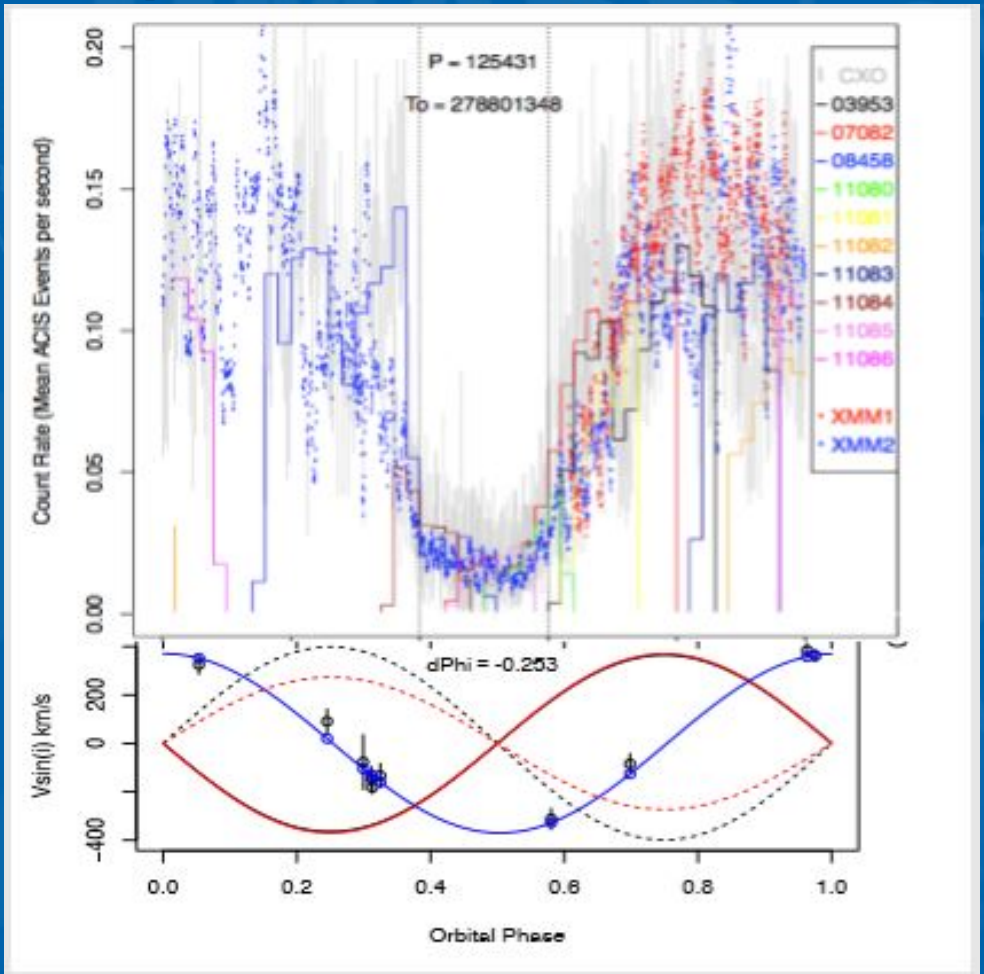
# X-Ray Binaries

- Accretor : Compact object (NS or BH)
- Donor : Normal star
- Accretion region
- Luminous in X-Rays



http://hubblesite.org/newscenter/newsdesk/archive/releases/1995/23/image/a

# IC10 X-1 LC and RV curves Laycock et al. 2014

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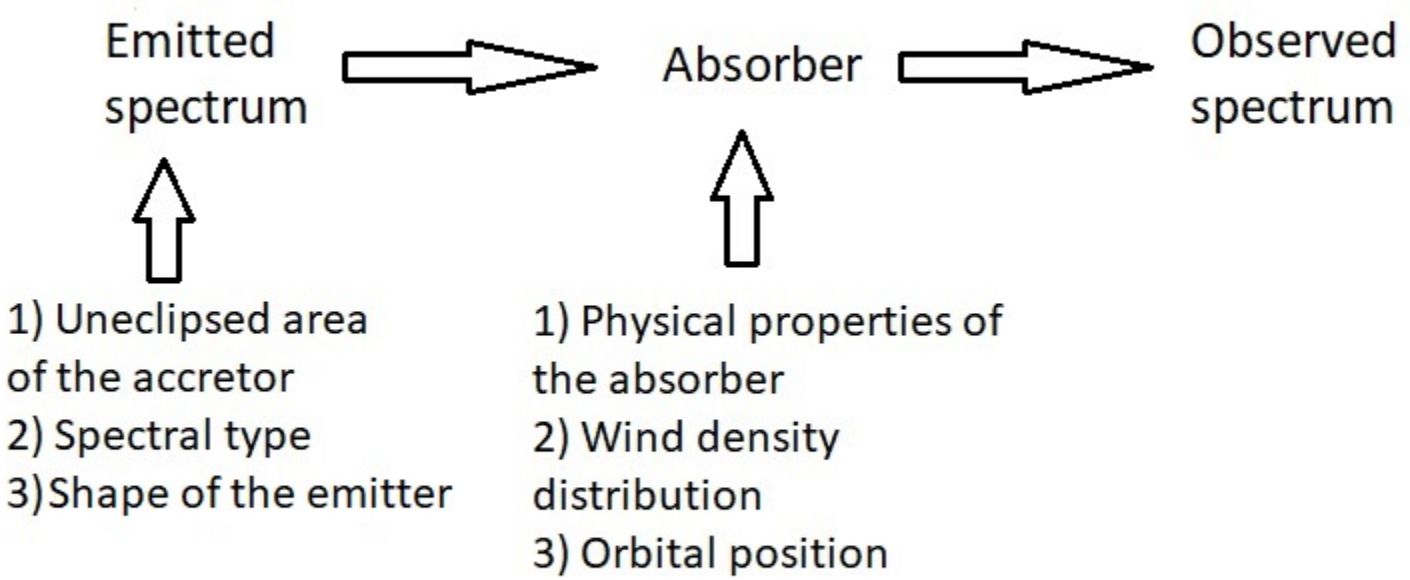
# Extended Emitter

- Supported by Barnard et al. 2014
- Partial covering at mid-eclipse

# WR wind absorption

- Hard Evidence for energy-dependence (Barnard et al. 2014, Steiner et al. 2015)
- WR wind suspected to contain traces of Neutrals (Laycock et al. 2015)

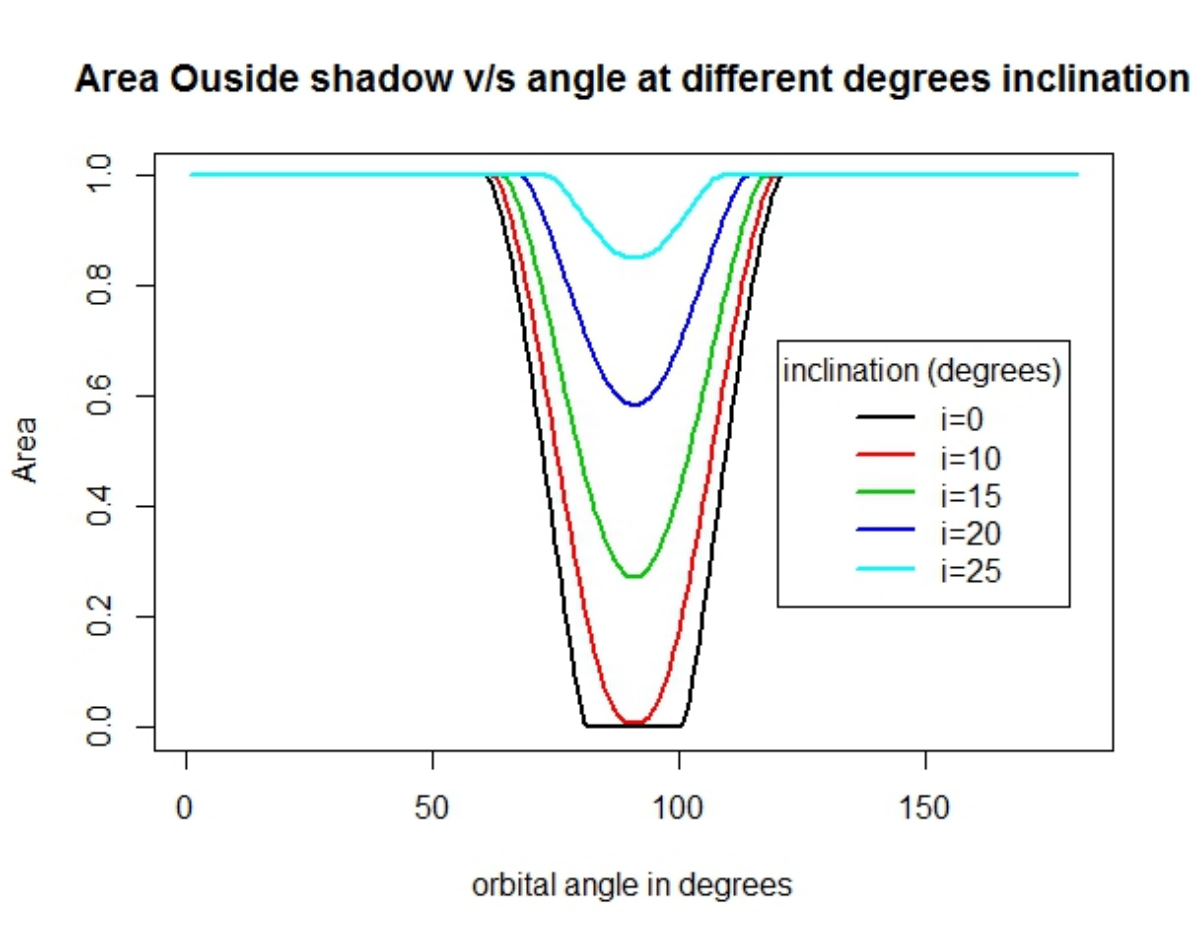
# Approach


Emitted spectrum
Absorber
Observed spectrum
1) Uneclipsed area of the accretor
2) Spectral type
3) Shape of the emitter
1) Physical properties of the absorber
2) Wind density distribution
3) Orbital position

# Assumptions

- Circular orbit
- Spherically symmetric emitter
- Spherically symmetric Wind
- Neutral Hydrogen Absorber in Wind
- Ignore Scattering and Wind Ionization

# Preliminary Results



# Stellar Wind

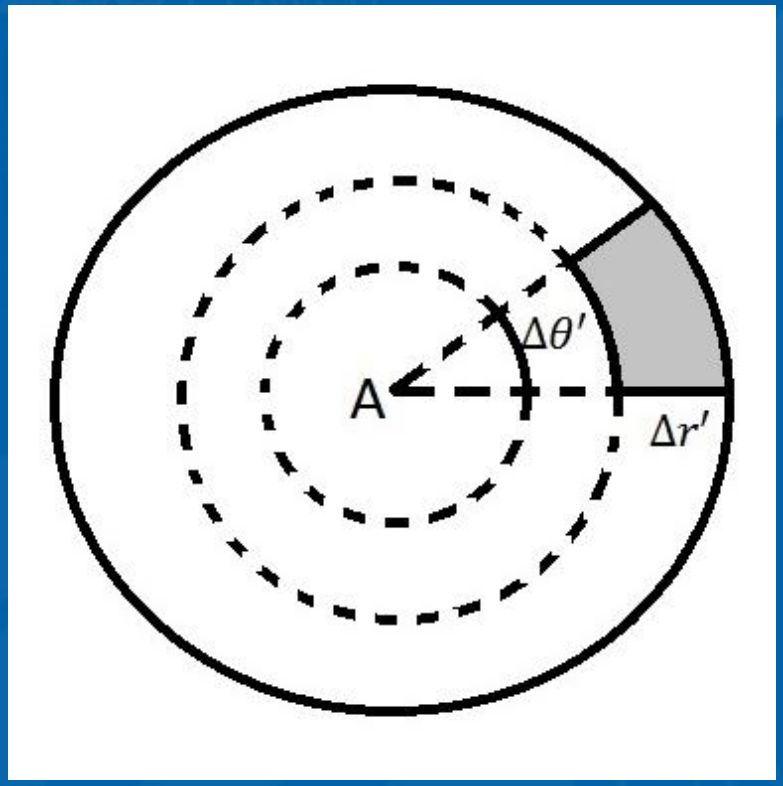
- Spherically Symmetric Radiation-Driven
- Constant Outflow Velocity $(V_0 = constant)$

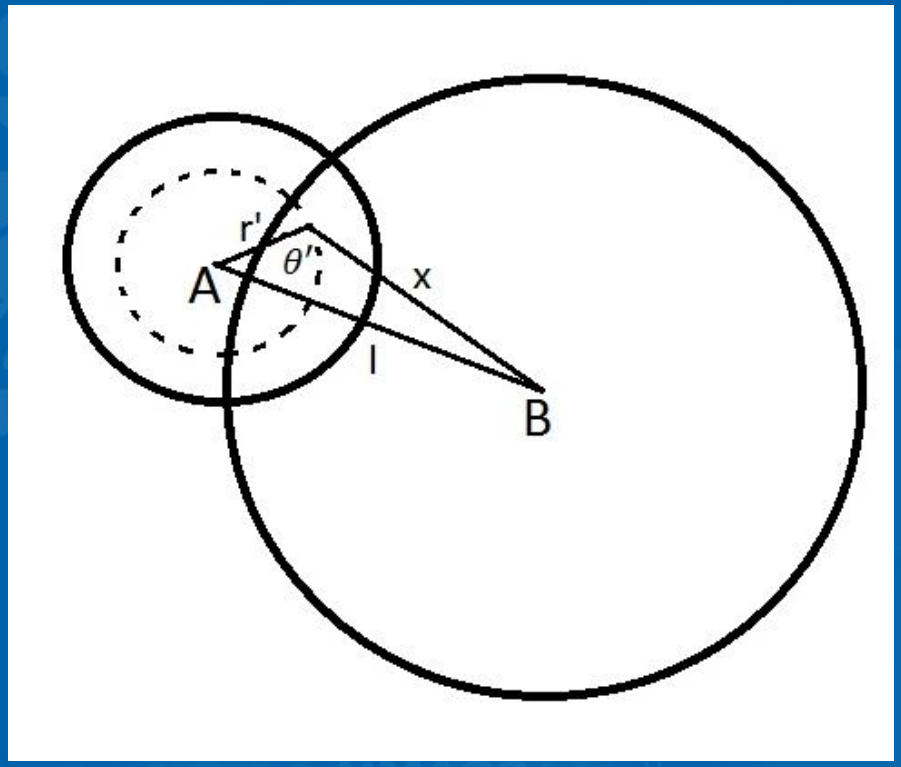
$$\rho \propto \frac{1}{r^2}$$

- Assuming constant acceleration
- Density variation with distance

$$\rho \propto \frac{1}{r^{5/2}}$$

# Emitter Grid




$$\Delta A = \frac{1}{2}(\Delta r')^2 \Delta\theta'$$

- Column Integral of a cell

$$I_{cell} = \sum_i \frac{1}{d_i^2} dz$$

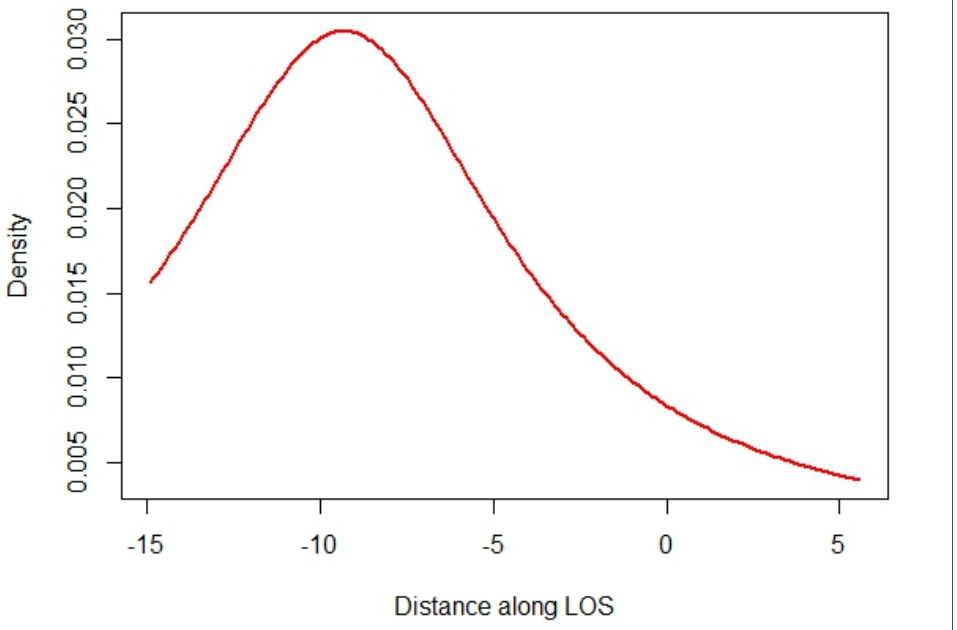
- Total Column Integral

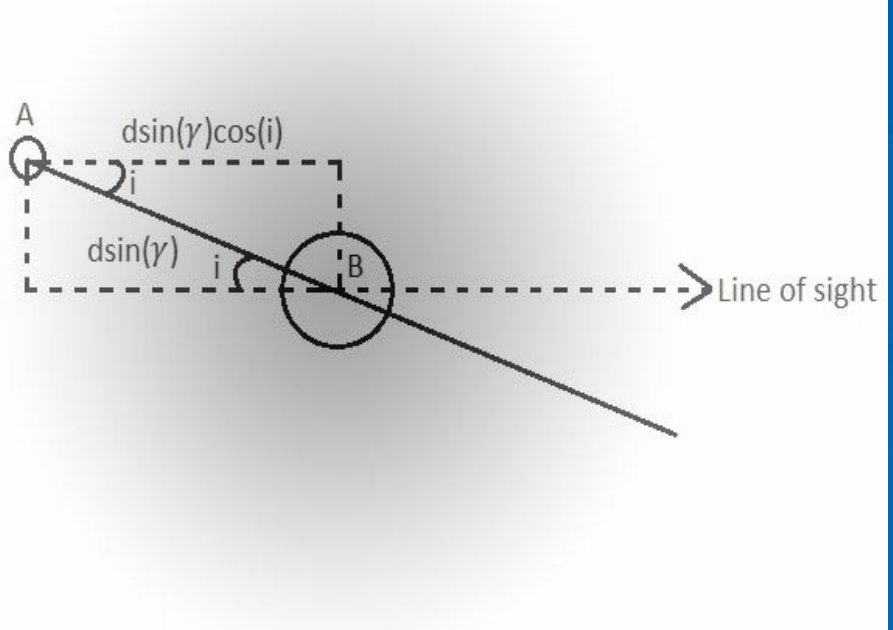
$$I_{total} = \sum_j I_j da_j$$

- Average Column Integral

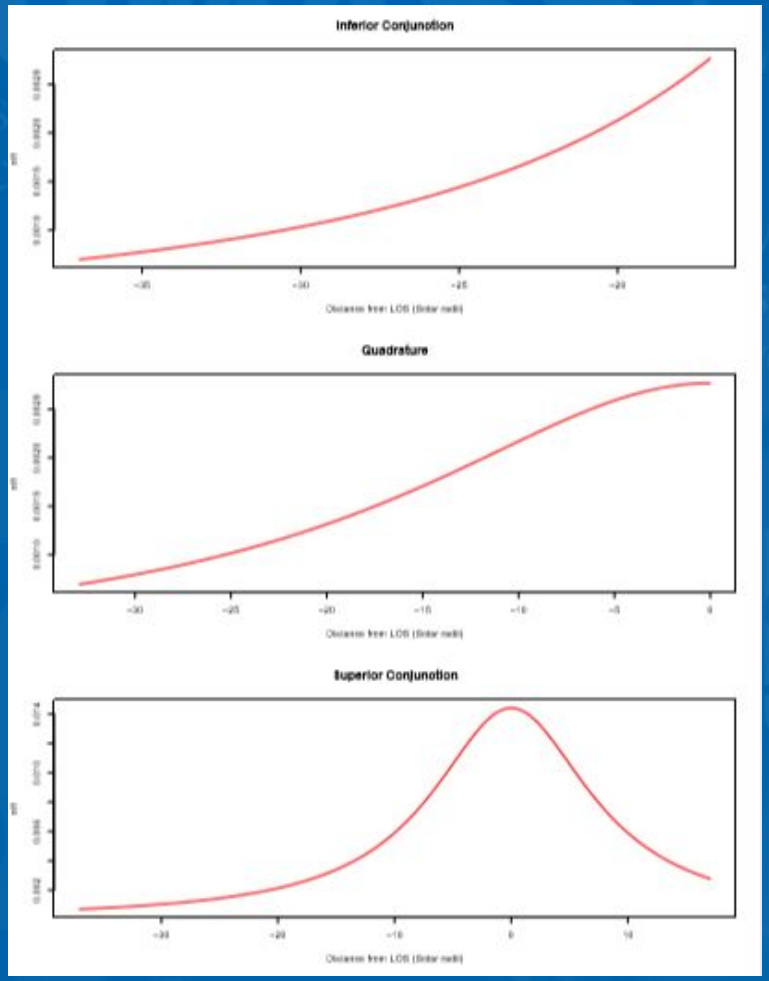
$$I_{av} = \frac{\sum_j I_j da_j}{\sum_j da_j}$$

# Column Integral

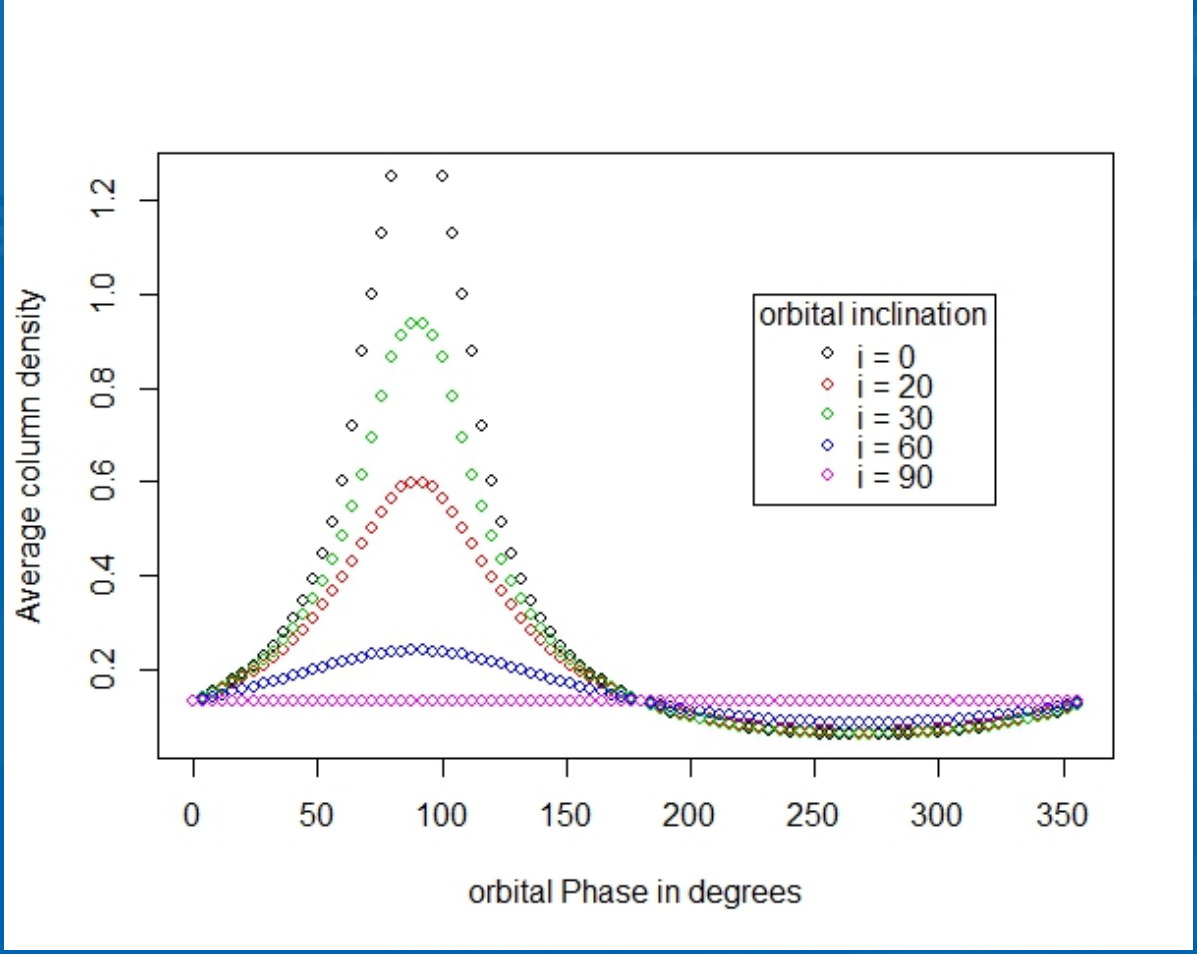


# Column lines with phase

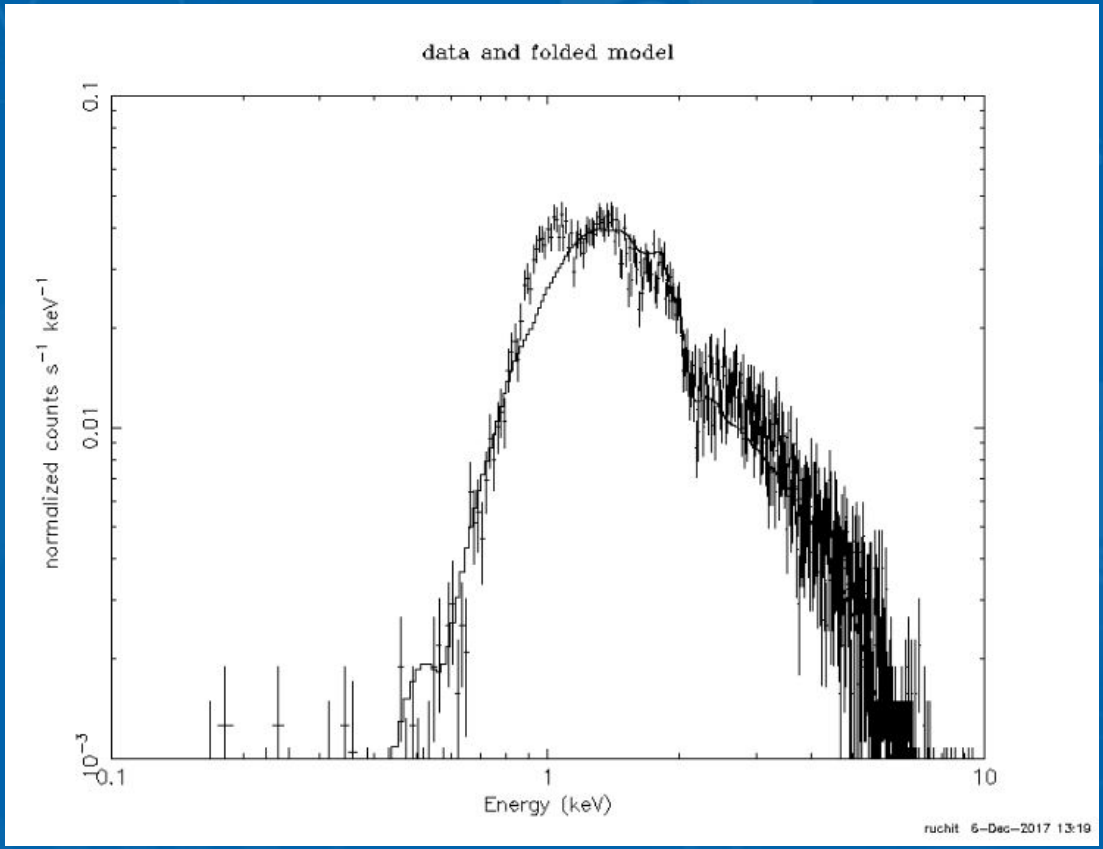


# Phase connected nH



# Spectral Model

## Xspec model : absorbed Power law



# Flux Variation

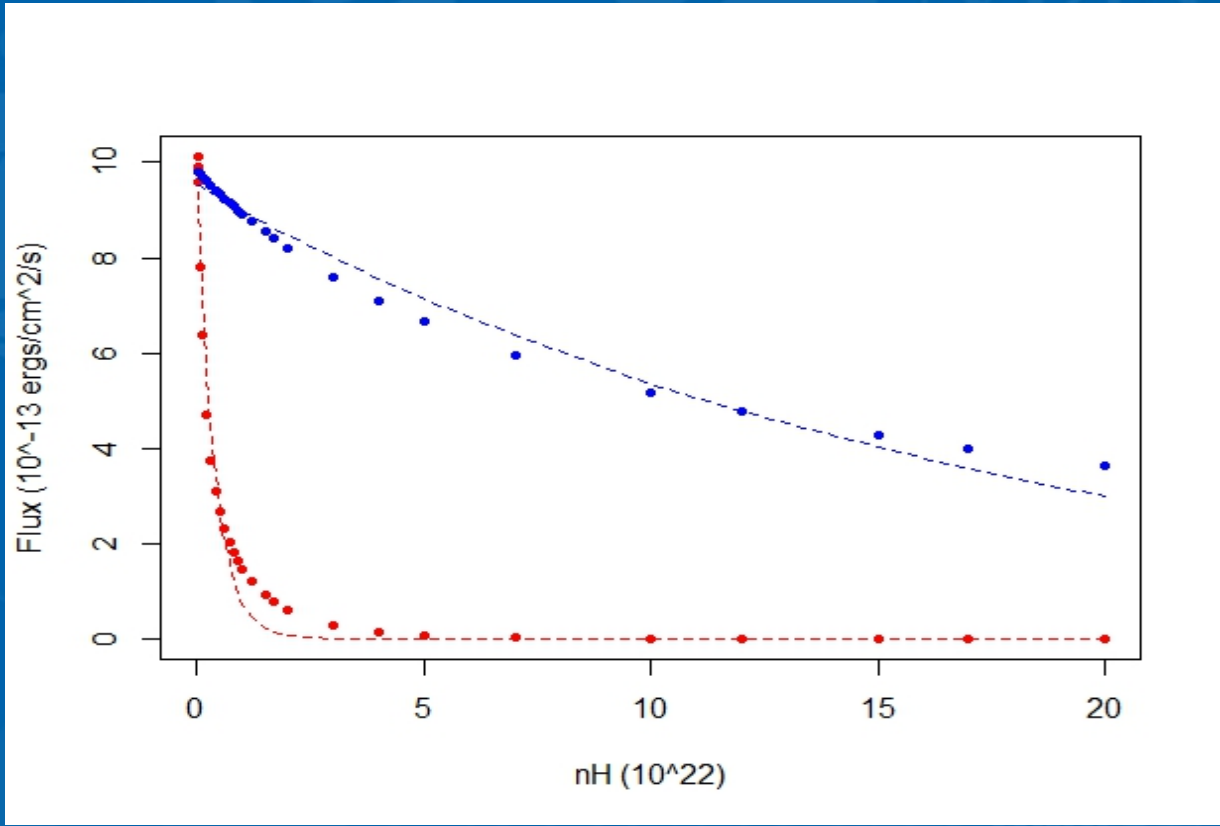
- Equation of Radiative Transfer
  - Equation of Radiative Transfer

$$\frac{dI_\nu}{ds} = -\alpha_\nu I_\nu + j_\nu$$

- Absorption case
  - Absorption case

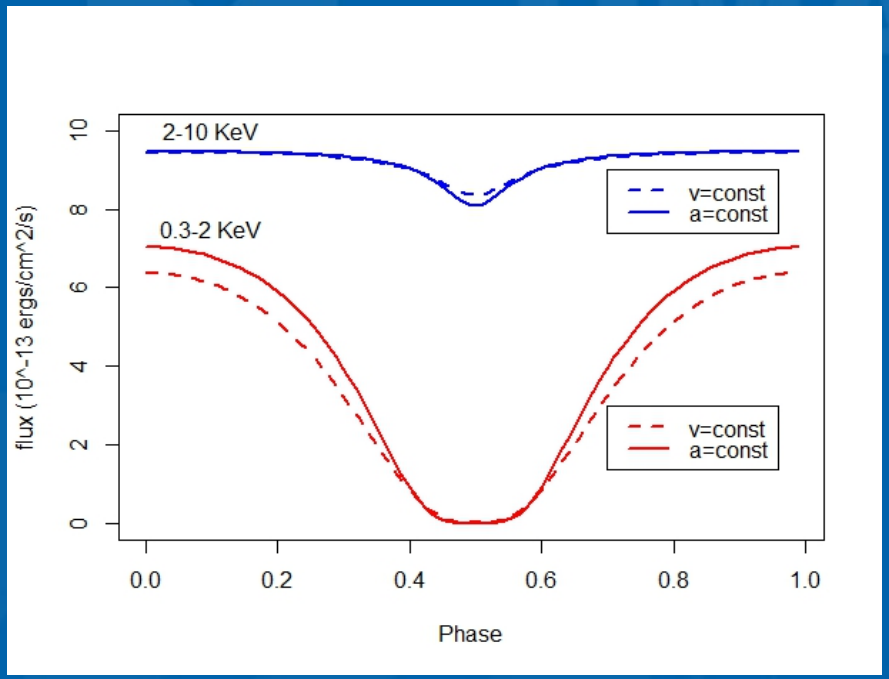
$$I_\nu(s) = I_\nu(s_0)\exp\left[-\int_{s_0}^{s}\alpha_\nu(s')ds'\right]$$

# Flux Variation

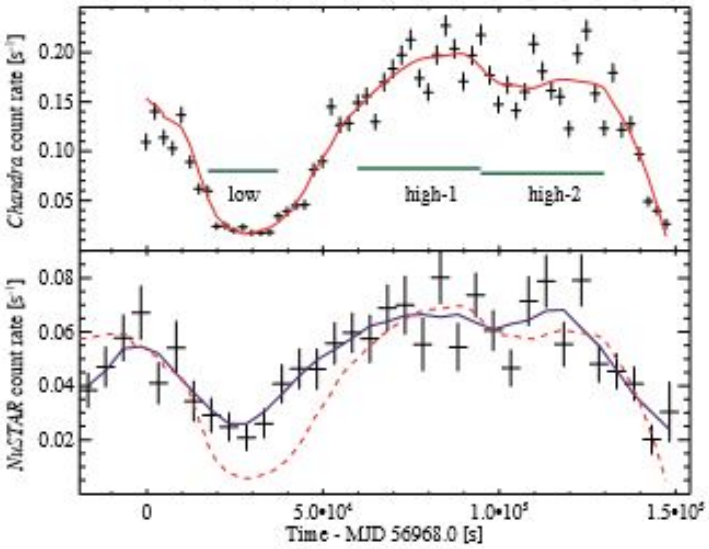



- Hard Band (blue) (2–10KeV) : $9.5e^{-0.057x}$
- Soft Band (red) (0.3–2KeV) : $9.4e^{-2.506x}$

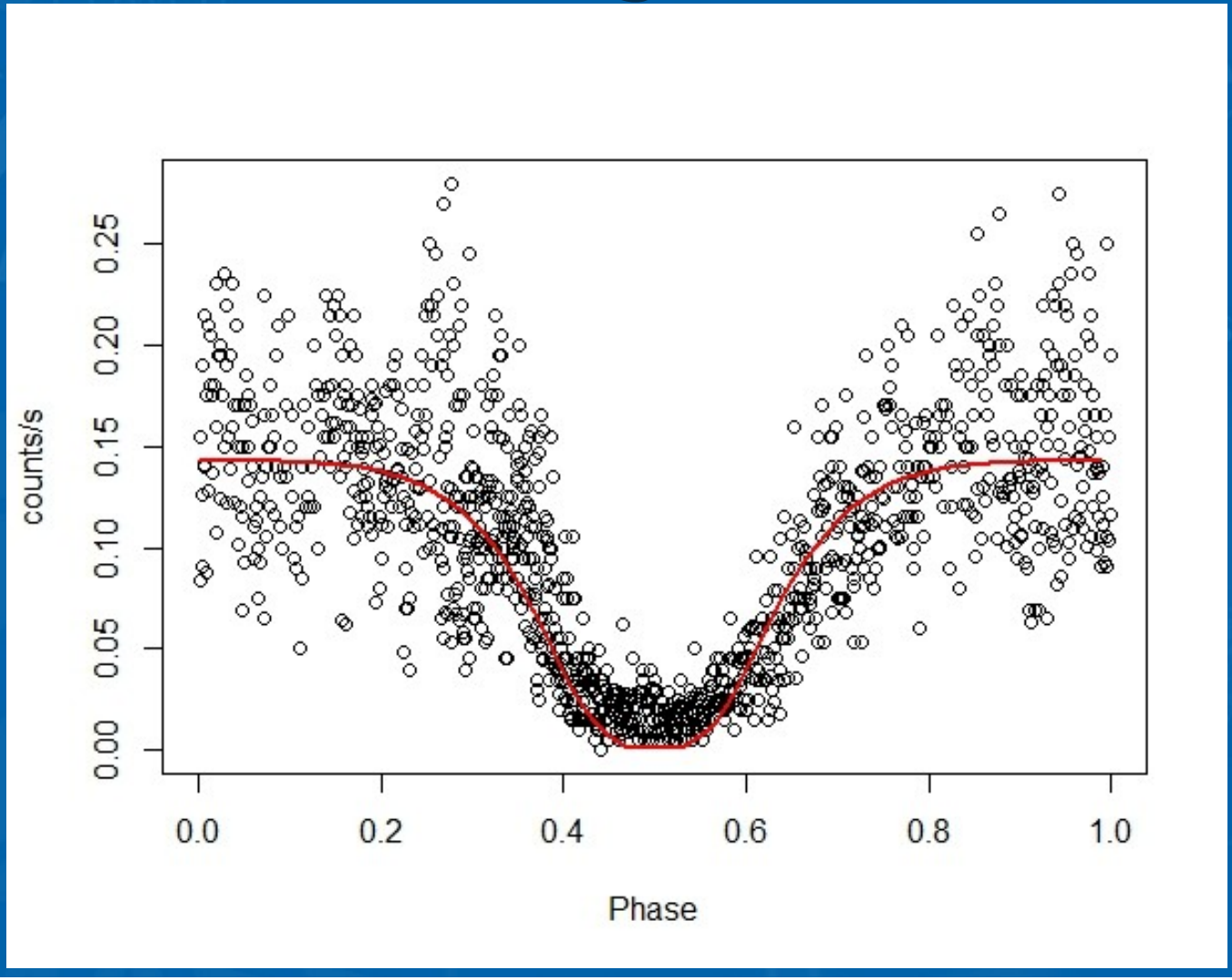
# Energy Dependence




# NuStar Data (Steiner et al.



# Fitting Data



# Estimating Wind parameters

- Density for constant velocity wind
  - Density for constant velocity wind

$$\rho_r = \frac{\rho_0}{v_0 r^2}$$

- Density for constant accelerated wind
  - Density for constant accelerated wind

$$\rho_r = \frac{\rho_0}{\sqrt{2a}r^{5/2}}$$

# Conclusions

- Model calculates line of sight column integrals at each phase point of the orbit in any inclination
- Model flux values show energy dependence
- Reflects different types of wind distribution (constant velocity and constant acceleration)
- Appears to confirm the idea that the eclipse of IC 10 X-1 is a result of absorption rather than occultation
- Provided initial $\rho_0$ an estimate of the wind velocities and acceleration can be made.

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http://www2.lowell.edu/users/massey/lgsurvey/IC10_BVHa.jpg

# Thank You !

# Scaling column Integral lines

- Scaling factor ($\lambda$)
- From Spectrum fitting

$$nH_{scaled} = \lambda \times nH_{unscaled}$$

$$\lambda = \frac{nH_{avg}^{xspec}}{nH_{avg}^{model}}$$

# Estimating Wind parameters

- Integrating

$$\int \rho_r dz = \frac{\rho_0}{v_0} \int \frac{1}{r^2} dz$$

$$nH_{scaled} = \frac{\rho_0}{v_0} nH_{unscaled}$$

$$nH_{scaled} = \lambda \times nH_{unscaled}$$

# Estimating Wind parametes

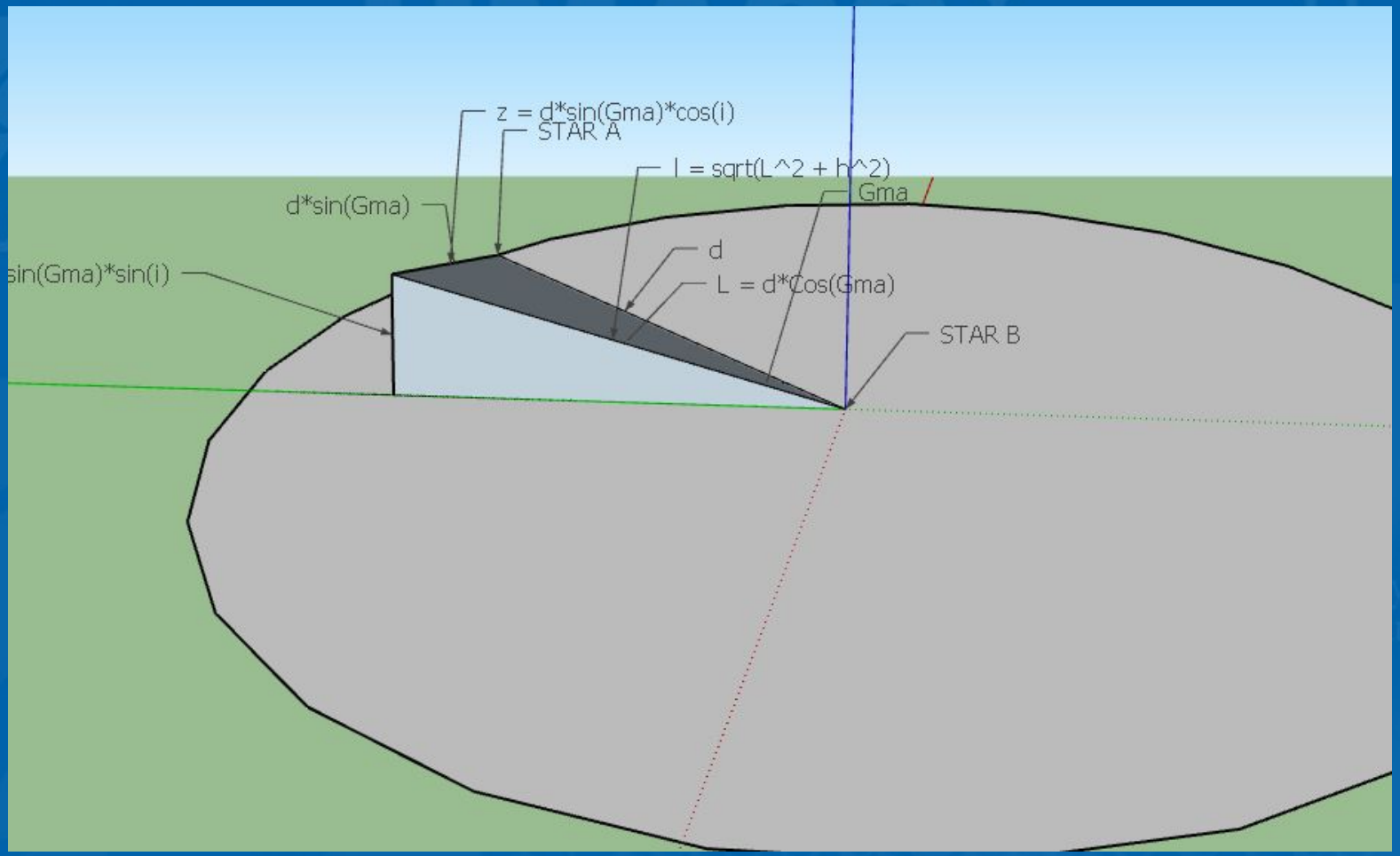
- Constant velocity
  - Constant velocity

$$v_0 = \frac{1}{\lambda_v}\rho_0$$

- Constant acceleration
  - Constant acceleration

$$\sqrt{2a} = \frac{1}{\lambda_a}\rho_0$$

# Geometry


z = d*sin(Gma)*cos(i)
STAR A
l = sqrt(L^2 + h^2)
Gma
d*sin(Gma)
d
sin(Gma)*sin(i)
L = d*Cos(Gma)
STAR B