An Empirical 3-D Reconstruction of a CIR: The 2008 January 31 CIR example
Building a 3-D CIR

The following equations define the shape of a 2-D CIR shape in cylindrical coordinates in 3-D space, where $\psi \in [0,2\pi]$ and $\eta \in [-1,1]$.

\[
\begin{align*}
    r &= \alpha(2\pi - \psi) \\
    \theta &= \psi - 2\pi + \phi_C - \gamma \eta^2 \\
    z &= \beta \eta r.
\end{align*}
\]

A 3-D density distribution is then derived by assuming a Gaussian density profile normal to the 2-D CIR shape, such that if $\delta(r,\theta,z)$ is the distance of a point from the CIR midplane, then

\[
n_e(r, \theta, z) = n_{\text{max}} \exp \left[ -\frac{1}{2} \left( \frac{\delta(r, \theta, z)}{\sigma_n} \right)^2 \right]
\]

For our morphological purposes, we simply set $n_{\text{max}} = 1$. For the 2008 January 31 CIR, our best fit has the following parameters:

\[
\begin{align*}
    \alpha &= 0.802 \text{ AU/rad} \\
    \phi_C &= 6.091 \text{ rad} \\
    \beta &= 0.7 \\
    \gamma &= 1.48 \text{ rad} \\
    \sigma_n &= 0.0098 \text{ AU}
\end{align*}
\]

This CIR maps back to a bifurcated streamer near the Sun, which surrounds a coronal hole (see right).
The curvature of the model CIR can be related to the velocity of the slow wind barrier against which fast wind is impinging by:

\[ V_{\text{eff}} = \frac{2\pi \alpha}{T_C} \]

This equation yields \( V_{\text{eff}} = 345 \) km/s, consistent with the observed velocity at the time of the CIR density pulse (see right).

The duration of the CIR density pulse (particularly at STEREO-B) can be related to the CIR model parameters via:

\[ \Delta t = \frac{2.355 \sigma_n}{V_{\text{eff}} \cos[\arctan(\frac{\alpha}{r})]} \]

This equation yields \( \Delta t = 0.15 \) days, roughly consistent with the observed density pulse (see right).