Empirically-Based Model for the Non-Axisymmetric Heliopause – An Outline

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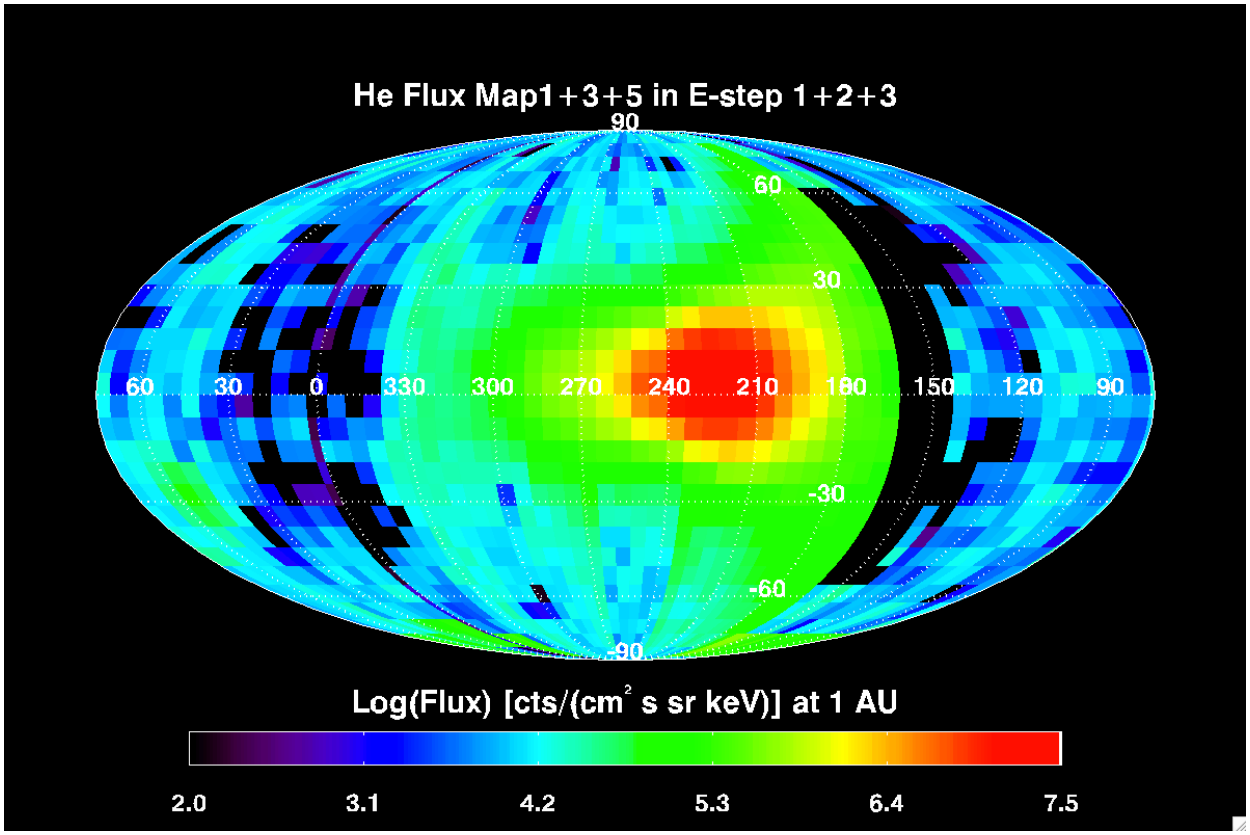
IBEX-Lo measurements enable a global sky-map of interstellar He.



Spring
2009 - 2011

Map shows primary flow and an irregular cloud of secondary atoms.

Distribution of flux carries information on the structure of the OHS.

→ How can we extract global information from this map?

- Primary beam: $N_o \sim 0.015$ cm^{-3}, $V_o \sim 26$ km/s, $T_o \sim 7000$ °K

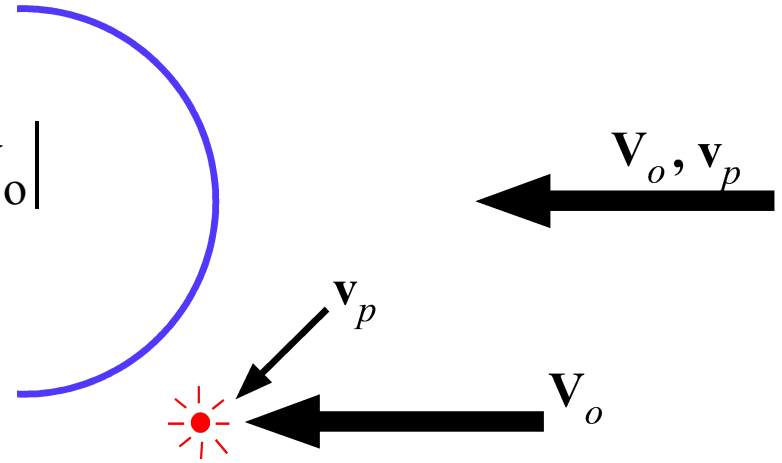
  Neutrals in equilibrium with distant ISM plasma

(Charge-exchange is taking place, but does not affect bulk properties.)

- Secondary cloud: plasma deflects around HP and

  charge-exchanges with primary neutral beam.

$$\text{He emission} \sim \sigma N_o \, n_{He+} \left| \mathbf{v}_p - \mathbf{V}_o \right|$$

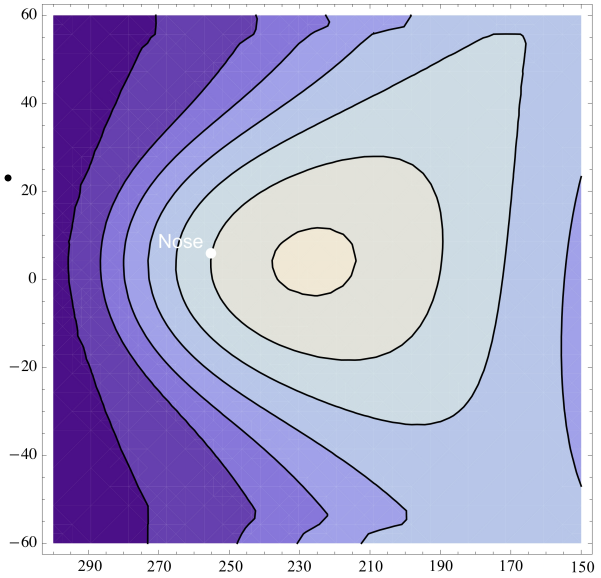


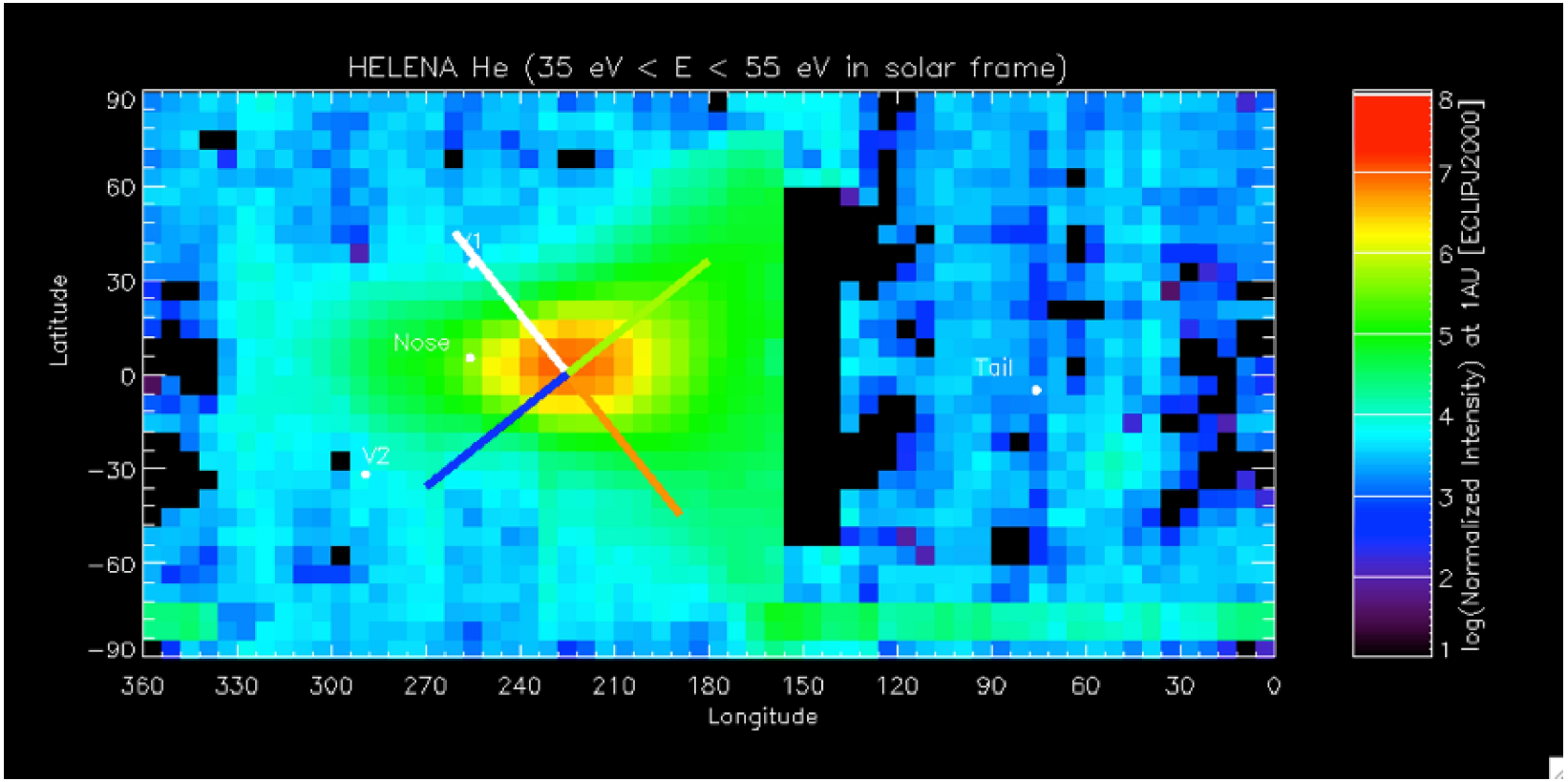
Interstellar neutral He is not strongly affected

by passage through the SW or inner heliosheath, so this cloud tells us about the plasma flow just outside the heliopause.

Basic idea:

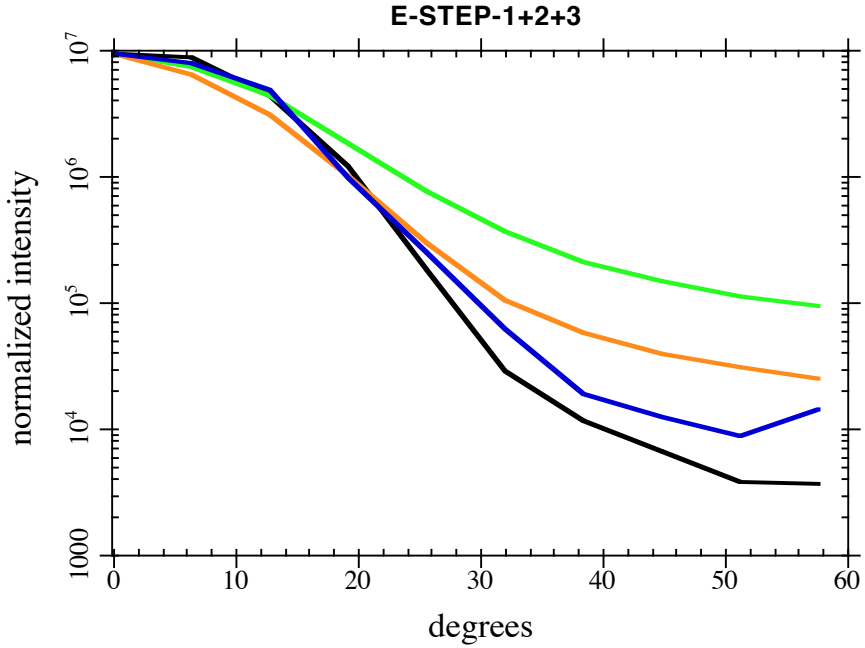
- Model plasma flow around 3-D obstacle representing the HP.
- Try to obtain obstacle shape such that
  secondary cloud matches the observations.
- Model should not be too complicated, since the
  observational data is not highly detailed:
  - Pixel size 6° x 6°
  - He is not directly measured, so
    energy of incident atoms is not well known.
  - Use total He counts in E1 + E2 + E3.
  - Cannot transform obs. to Sun's inertial frame.
    Treat map in IBEX frame,
    which contains inherent asymmetry.





Data:

- Flatten map
- Define cutlines for comparison with model results.



Deflected plasma flow:

- Simplify B-field forces – retain only isotropic "pressure" force.
- Take plasma number flux to be potential:

  If $n\mathbf{v} \equiv \nabla\varphi$, then $\nabla \bullet (n\mathbf{v}) = 0 \rightarrow \nabla^2\varphi = 0$

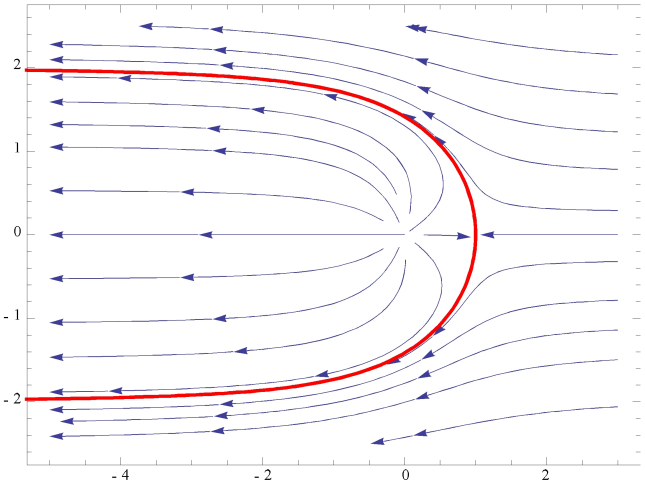
  flow obtained from solution of Laplace's equation.
- He^+ plasma is isotropic Maxwellian, evolving adiabatically, with effective "sound" speed = MHD fast speed

Incident neutral He at IBEX:

- Sum of primary beam and C-X secondaries.
- Secondary fluxes are obtained by integrating incident trajectories through region outside HP due to C-X interaction between deflected plasma and primary beam.

Define HP shape as an obstacle in the interstellar plasma flow:

- Extensions of Parker's [1961] method, which superposed
  a uniform interstellar flow with a point source at the Sun.



"Rankine half-body"

Point source has analytical form
in spherical coord. system

- Other coord. systems enable more elaborate analytical sources.

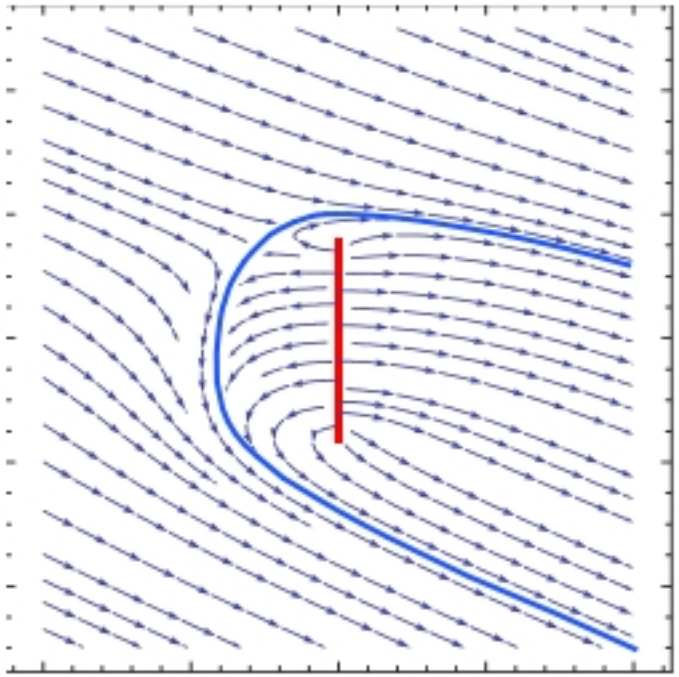
- Laplace's eq is linear, so any number of sources,
  with any size, strength and orientation, can be
  superimposed and treated analytically.

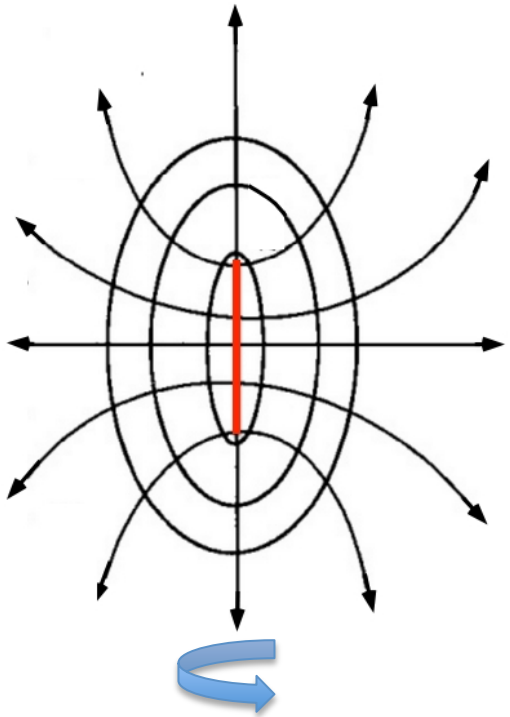
Consider orthonormal ellipical coordinates:

- Rotation in 3D about the vertical axis gives

Prolate spheriodal coords.

which can describe a line source





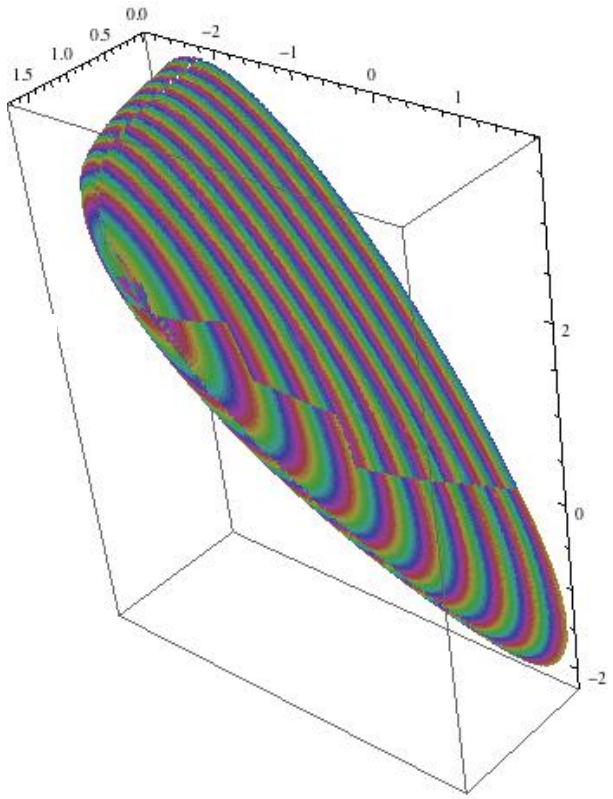
Example presented at the New Orleans AGU:

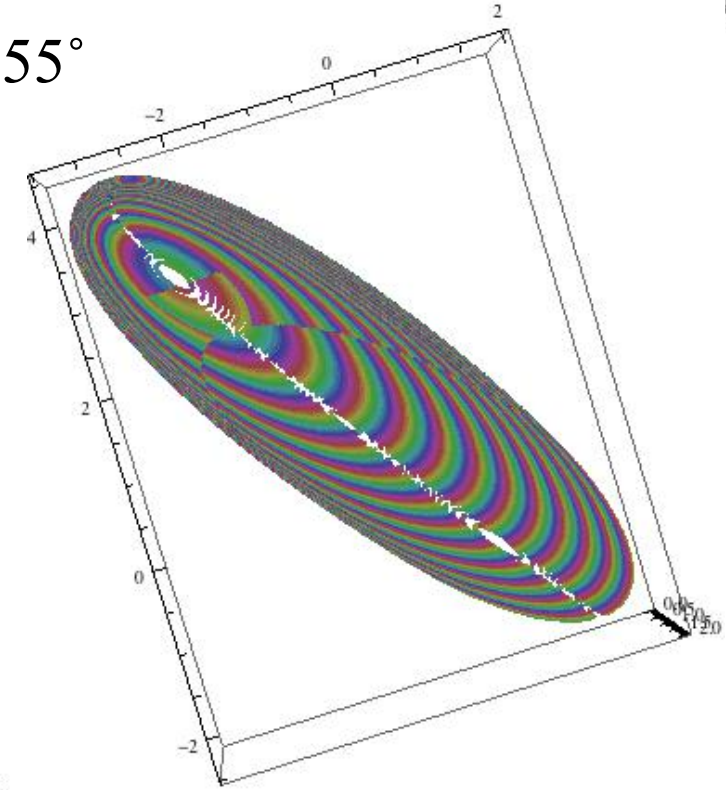
$d = 4.$

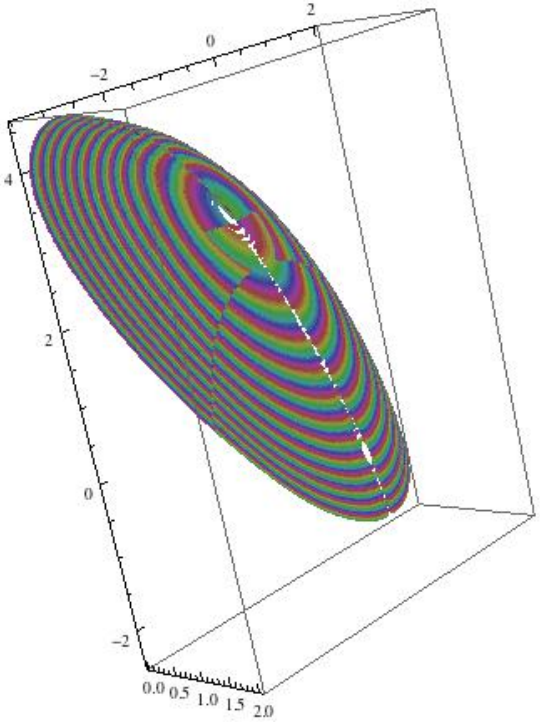
$\theta_{L\text{-}V} = 75^{\circ}$

$\alpha_{L\text{-}ecliptic} = 55^{\circ}$

$A/n\upsilon = 1.2$





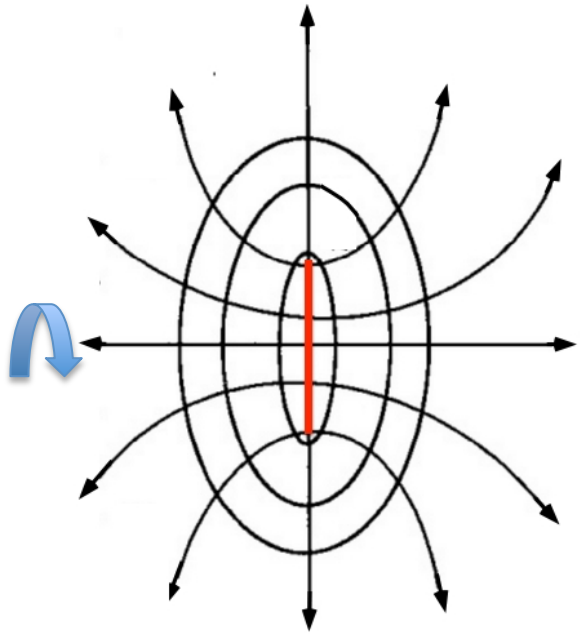


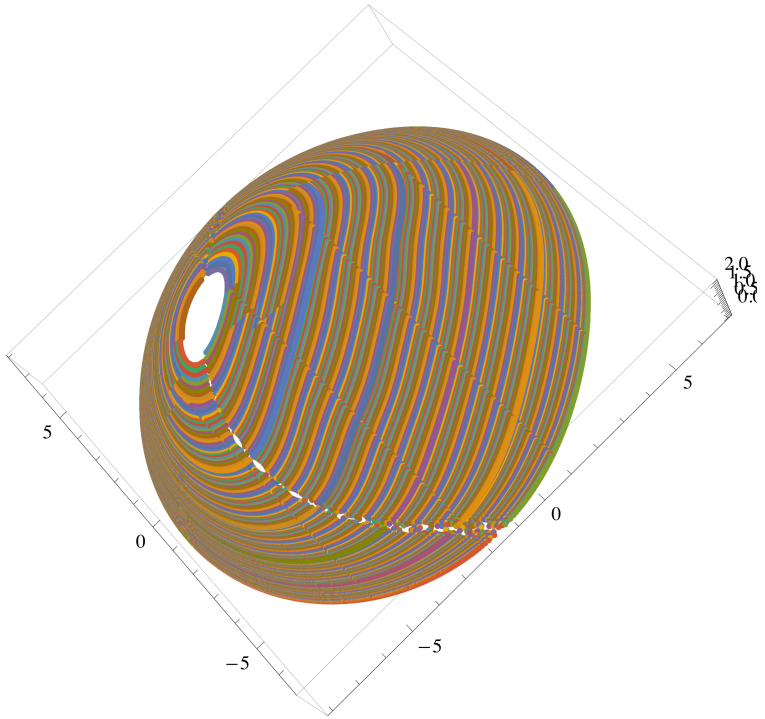
Back to ellipsoidal coordinates:

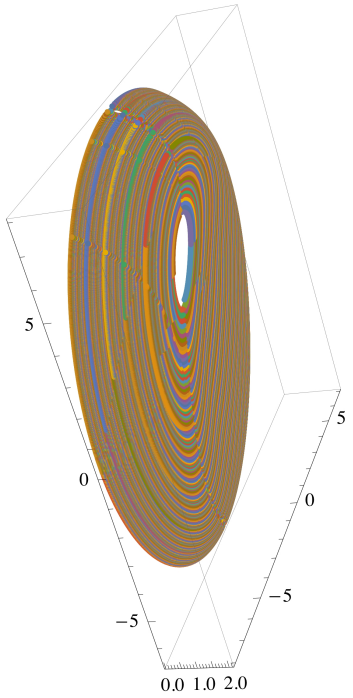
- Rotation in 3D about the horizontal axis gives

Oblate spheriodal coords.

which can describe a disc source







→ We want to assemble a set of point, line and disc sources

- centered on the Sun (probably)
- aligned with the *B*-*V* plane (probably)

which will result in a HP shape and OHS flow that reproduces the IBEX sky-map for Helium.

- Having obtained a HP shape and analytic representation of the deflected plasma flow, we can introduce:
  - higher-order C-X effects
  - contributions from the IHS

    → model the Hydrogen and Oxygen sky-maps.