Week 14 Report

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Vector Field Correction

Background:

- Data files created by the PLUTO code I've written are configured to write the B-field in terms of spherical coordinates.
- However, VisIt, the visualization software I use, defaults to assigning vector-valued variables to cartesian components.
    - This means we must use transformations to convert the B-field from spherical coordinates to cartesian coordinates so that we can create proper visualizations.

VisIt_Spherical_to_Cartesian.txt

- Text file for documenting transformations and various variables necessary for converting from vector components from spherical to cartesian coordinates.

$$\begin{bmatrix} \hat{\mathbf{x}} \\ \hat{\mathbf{y}} \\ \hat{\mathbf{z}} \end{bmatrix} = \begin{bmatrix} \sin\theta\cos\phi & \cos\theta\cos\phi & -\sin\phi \\ \sin\theta\sin\phi & \cos\theta\sin\phi & \cos\phi \\ \cos\theta & -\sin\theta & 0 \end{bmatrix} \begin{bmatrix} \hat{\boldsymbol{\rho}} \\ \hat{\boldsymbol{\theta}} \\ \hat{\boldsymbol{\phi}} \end{bmatrix}$$

Transformation matrix via https://en.wikipedia.org/wiki/Vector_fields_in_cylindrical_and_spherical_coordinates

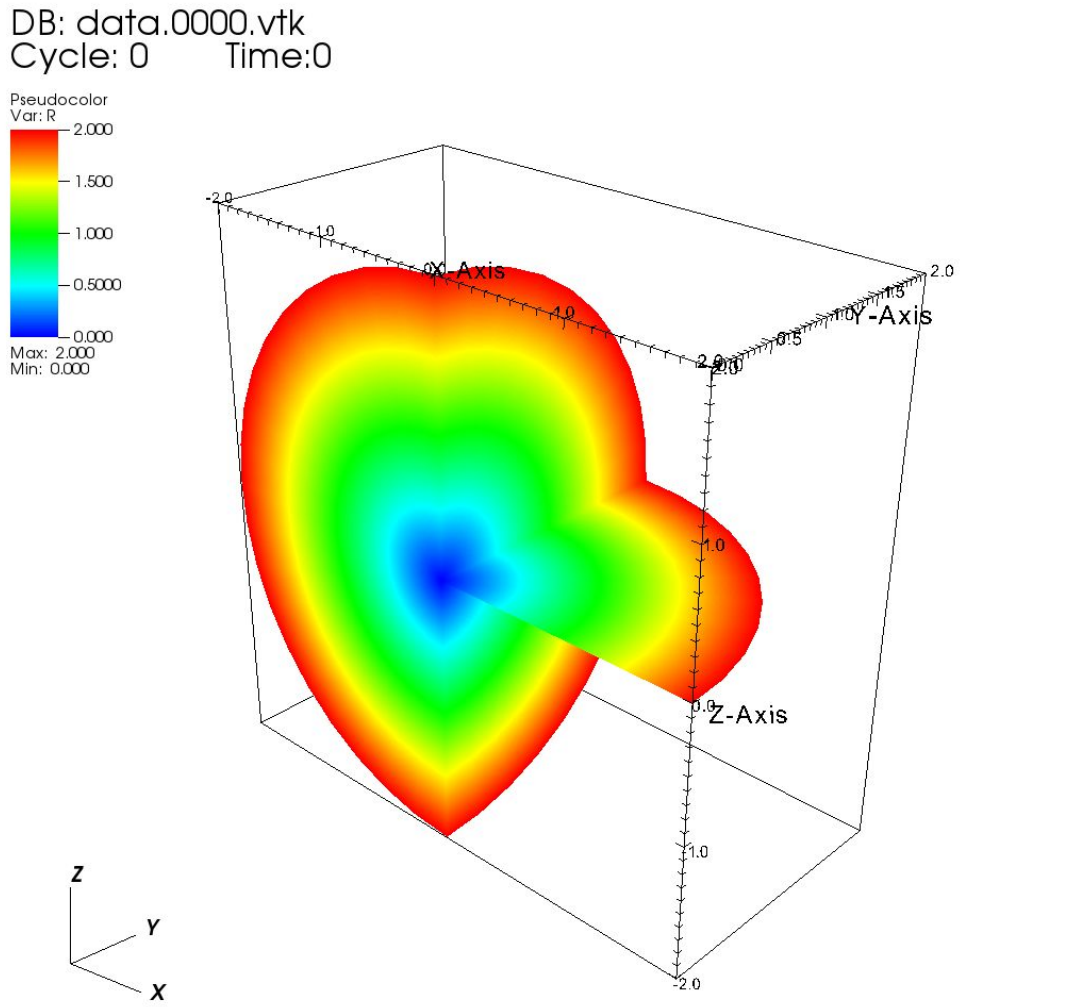
Expressions as they appear in VisIt:

```
 **Expressions**

Coords:
coord(mesh) // defines coordinate mesh as a Vector Mesh Variable

X:
Coords[0] // defines X-direction as Scalar Mesh Variable

Y:
Coords[1] // defines Y-direction as Scalar Mesh Variable

Z:
Coords[2] // defines Z-direction as Scalar Mesh Variable

R:
sqrt(X*X+Y*Y+Z*Z) // defines R, radius, as a Scalar Mesh Variable

theta:
acos(Z/(R+.001)) // defines theta as a Scalar Mesh Variable

phi:
acos(X/(R*sin(theta))) // defines phi as a Scalar Mesh Variable

Bx:
Mr*sin(theta)*cos(phi)+Mt*cos(theta)*cos(phi)-Mp*sin(phi) // Magnitude of B-field in x-direction

By:
Mr*sin(theta)*sin(phi)+Mt*cos(theta)*sin(phi)+Mp*cos(phi) //  Magnitude of B-field in y-direction

Bz:
Mr*cos(theta)-Mt*sin(theta) // Magnitude of B-field in z-direction

Magnetic_Field:
{Bx,By,Bz}  // The magnetic field itself in vector form
```

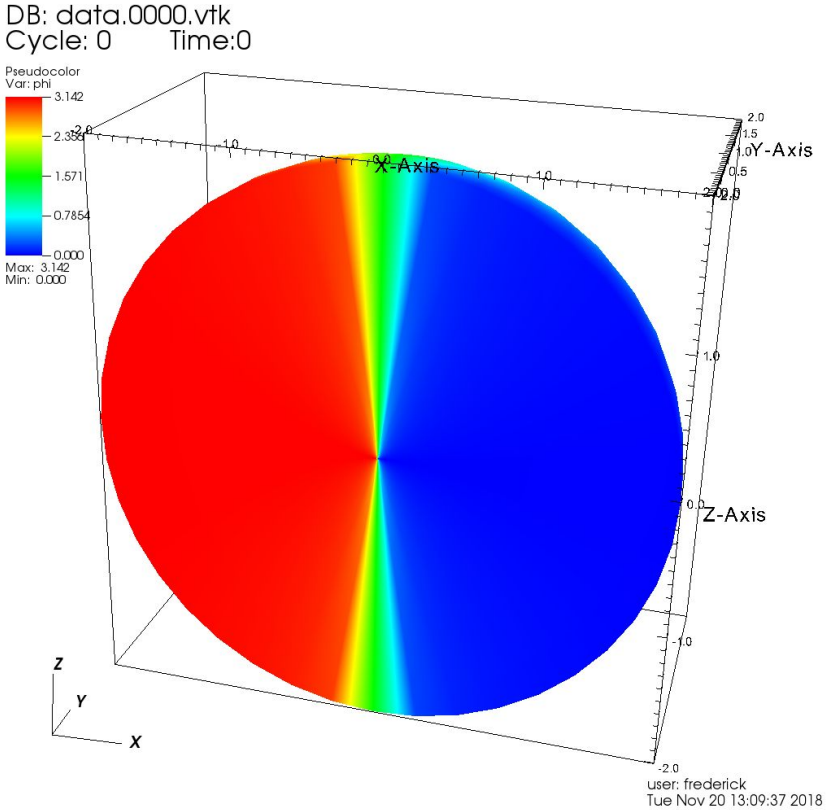
Verifying these transformations

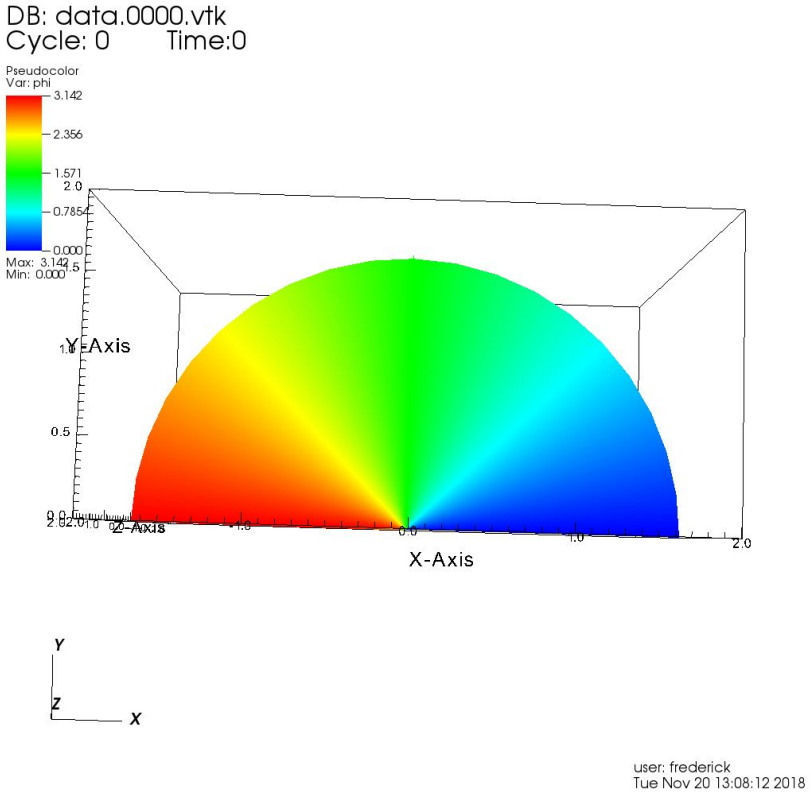
- We can verify these expressions and transformations by first checking that our definitions of `R`, `theta`, and `phi` are consistent with the regions for which we wish these expressions to point.
  - Since our expressions for `R, theta,` and `phi` are scalar-valued variables, we can plot each in 3-D pseudocolor plots showing the computational domain where each grid-cell is assigned the value the specified variable.

"R"


DB: data.0000.vtk
Cycle: 0 Time:0
Pseudocolor
Var: R
2.000
1.500
1.000
0.5000
0.000
Max: 2.000
Min: 0.000
X-Axis
Y-Axis
Z-Axis
Z
Y
X
user: frederick
Tue Nov 20 12:46:08 2018

“phi” expression. Notice the slight error in phi localized about the central axis of the star.





Despite this slight discrepancy, it doesn’t appear to have a significant impact for most vectors.

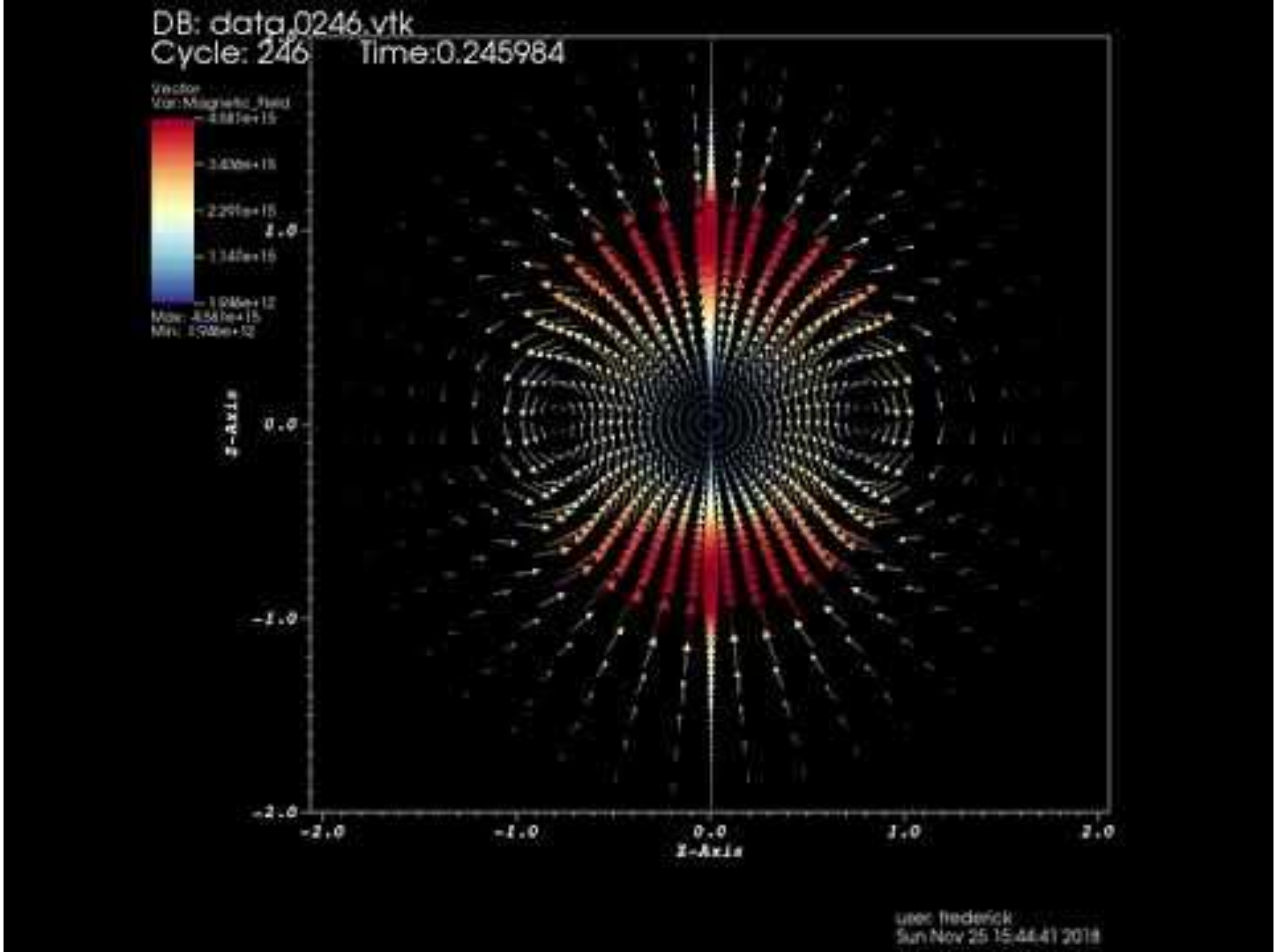
I forgot to take a picture of
“theta”, but it’s pretty much what
we’d expect.

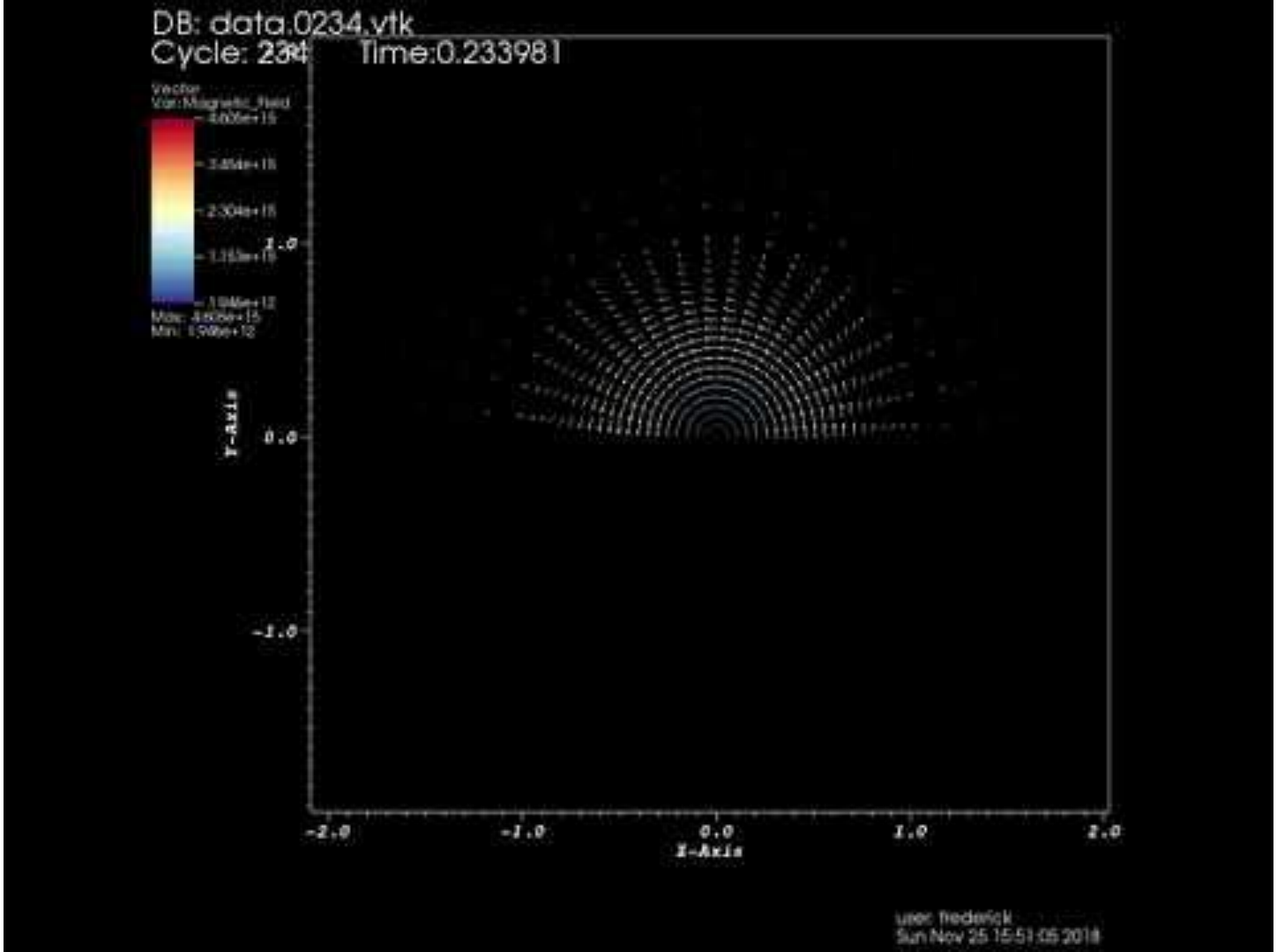
Results

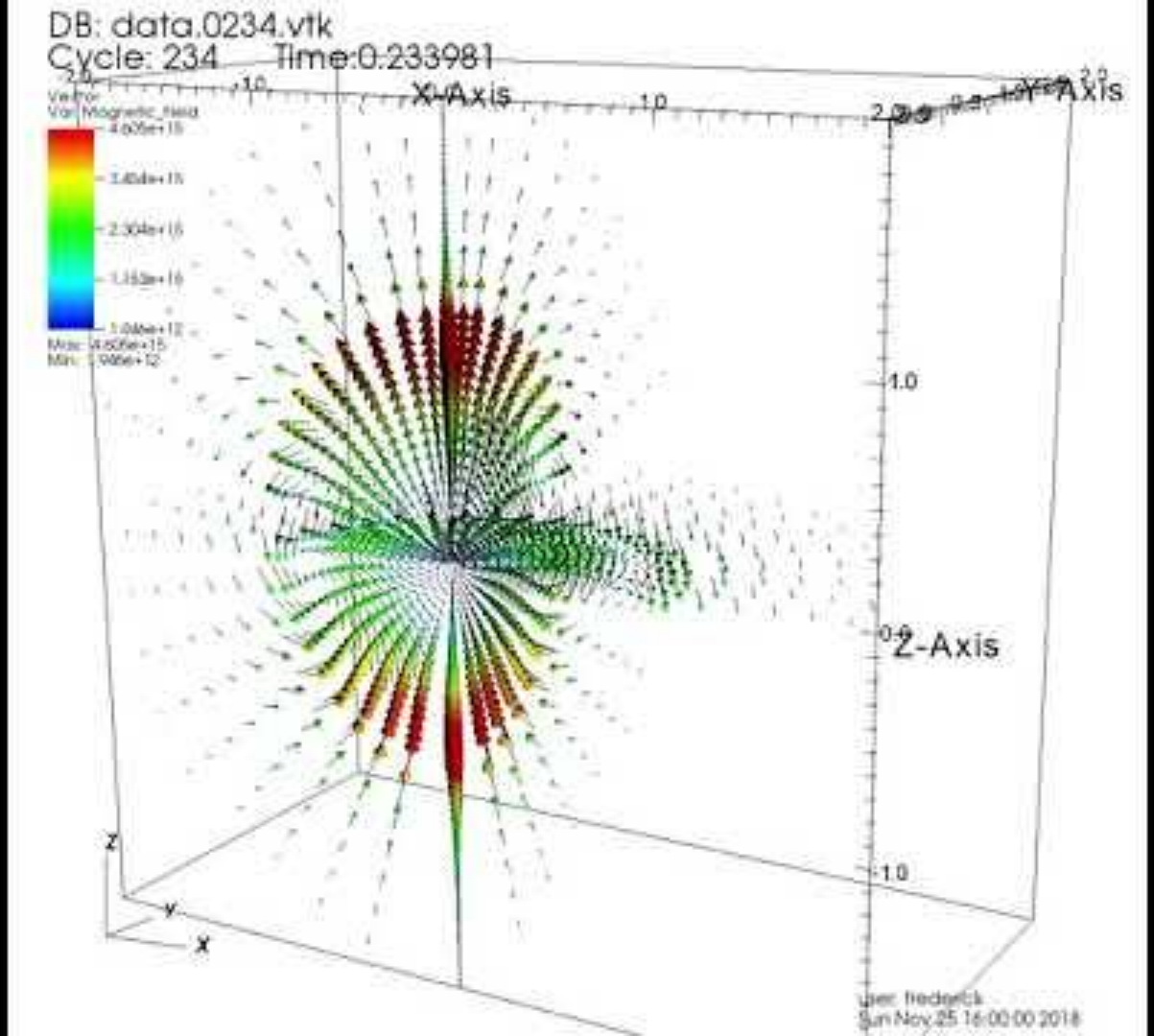
- The end result is that we can represent the B-field (or any vector such as velocity) accurately in VisIt.

The following animations:

- A slice from the XZ-plane displaying the b-field with proper visualization.
- A slice from the XY-plane displaying similar results.
- A 3-D plot showing a “three-slice” of the XZ, XY, and YZ planes

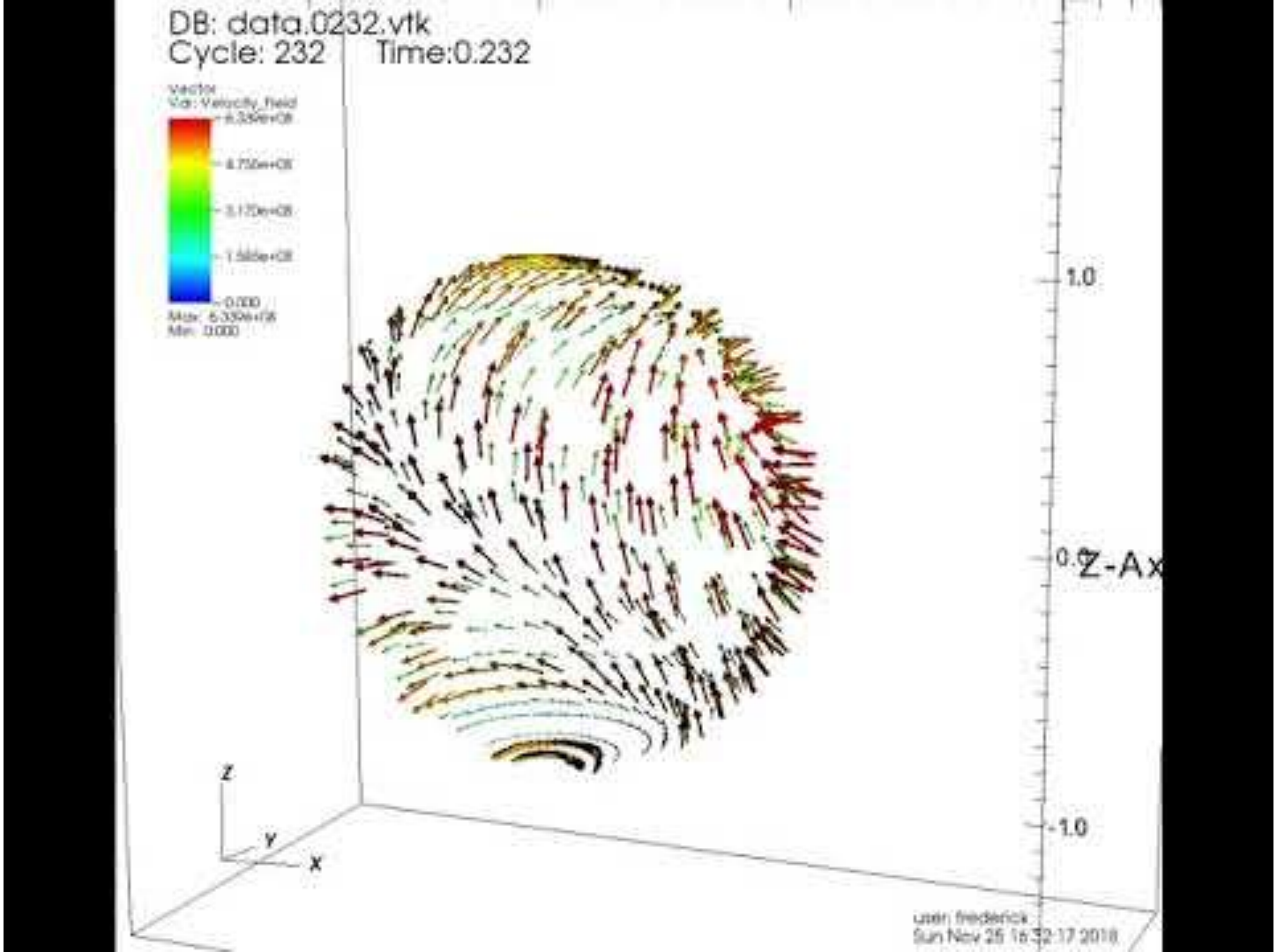

DB: data.0246.vtk
Cycle: 246 Time:0.245984
Vector
Var: Magnetic_Field
Max: 4.581e+15
Min: 1.998e+12
1.0
0.0
-1.0
-2.0
Z-Axis
-2.0
-1.0
0.0
1.0
2.0
X-Axis
user frederick
Sun Nov 25 15:44:41 2018


DB: data.0234.vtk
Cycle: 234
Time:0.233981
Vector
Var: Magnetic_Field
Max: 4.605e+15
Min: 1.948e+12
1.0
0.0
-1.0
Y-Axis
-2.0
-1.0
0.0
1.0
2.0
X-Axis
user: frederick
Sun Nov 25 15:51:05 2018

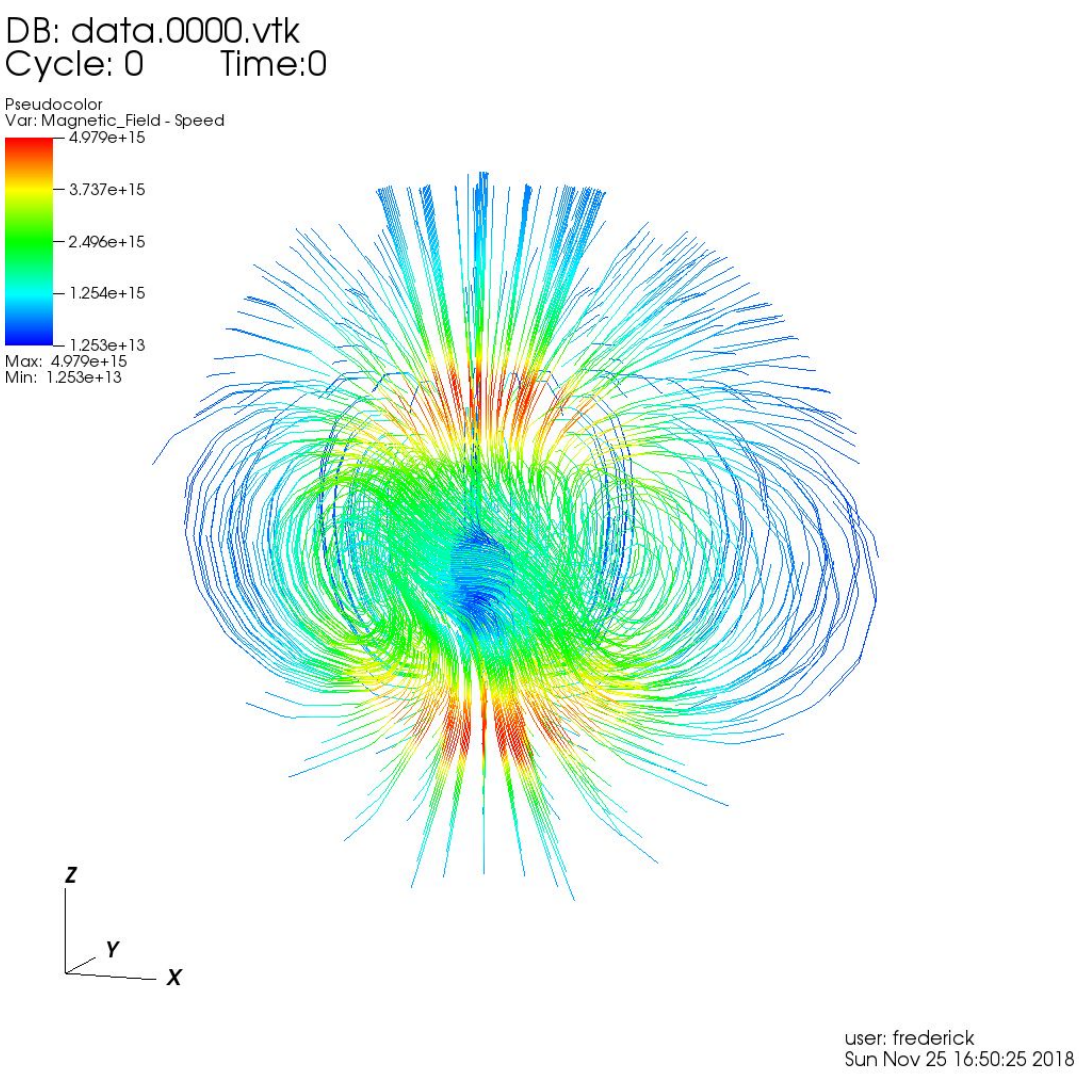

DB: data.0234.vtk
Cycle: 234 Time:0.233981
X-Axis
Y-Axis
Z-Axis
1.0
z
y
x
user: frederick
Sun Nov 25 16:00:00 2018

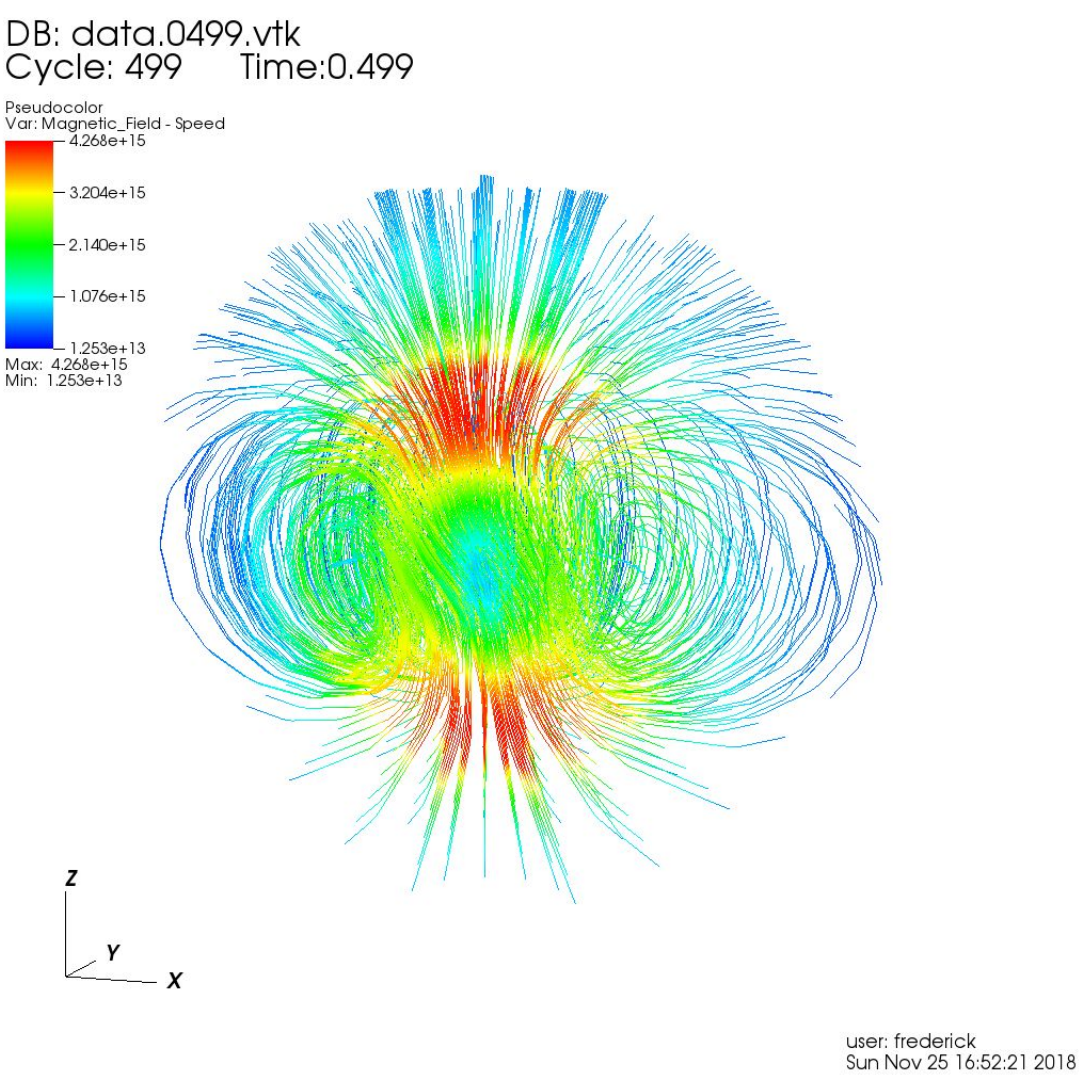
Interesting Results

- I performed the same transformation procedure for the velocity vector field and noticed an intriguing behavior:
  - The following animation shows a spherical “slice” of the the velocity vector field at r = 0.5. We notice that at roughly t = 0.3 s, vectors near the south pole reverse direction triggering high velocity regions to briefly increase in magnitude followed by a dramatic global decrease in velocity magnitude.


DB: data.0232.vtk
Cycle: 232 Time:0.232
Vector
Var: Velocity_Field
Max: 6.336e+08
Min: 0.000
1.0
0.0
Z-Ax
-1.0
Z
Y
X
user: frederick
Sun Nov 25 16:32:17 2018

Following Slides: Nice streamline images using the properly transformed B-field


DB: data.0000.vtk
Cycle: 0 Time:0
Pseudocolor
Var: Magnetic_Field - Speed
4.979e+15
3.737e+15
2.496e+15
1.254e+15
1.253e+13
Max: 4.979e+15
Min: 1.253e+13
Z
Y
X
user: frederick
Sun Nov 25 16:50:25 2018


DB: data.0499.vtk
Cycle: 499 Time:0.499
Pseudocolor
Var: Magnetic_Field - Speed
4.268e+15
3.204e+15
2.140e+15
1.076e+15
1.253e+13
Max: 4.268e+15
Min: 1.253e+13
Z
Y
X
user: frederick
Sun Nov 25 16:52:21 2018