

Improving the HART Simulation

Increasing Speed, Science, and Ease of Use

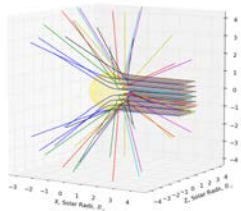
Mark Benjamin

MIT Haystack Observatory & Princeton University
`mbenjam@princeton.edu`

- 1 Introduction
 - Outline
 - HART
- 2 Scientific Improvements
 - Streamers
 - Scattering
- 3 Usability Improvements
 - GUI
 - FITS
- 4 Speed Improvements
 - Multi-Threading
 - CUDA
- 5 Conclusion
 - Examples
 - What Was Accomplished
 - Acknowledgments

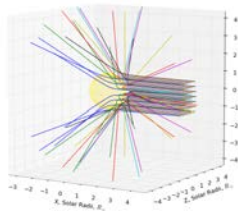
The HART Simulation

- H - Haystack
- A - AOSS
- R - Ray
- T - Tracer



The HART Simulation

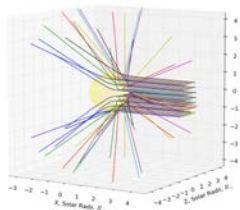
- H - Haystack
- A - AOSS
- R - Ray
- T - Tracer



Created by Leonid Benkevich in order to assemble a comprehensive package to perform raytracing of the Sun.

The HART Simulation

- H - Haystack
- A - AOSS
- R - Ray
- T - Tracer

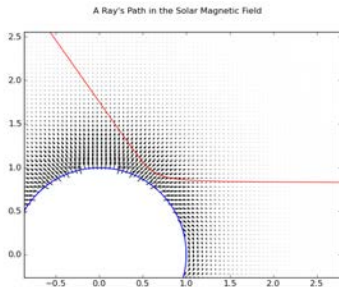


Created by Leonid Benkevich in order to assemble a comprehensive package to perform raytracing of the Sun.

Goal

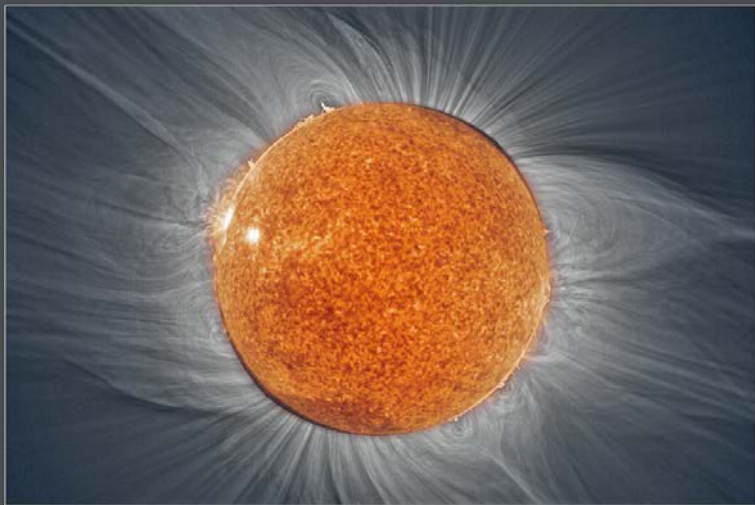
To improve this package in terms of speed, scientific capability, and usability.

HART Basics



HART makes changing the solar model easy, allowing a user to quickly compare his own model with actual results from MWA.

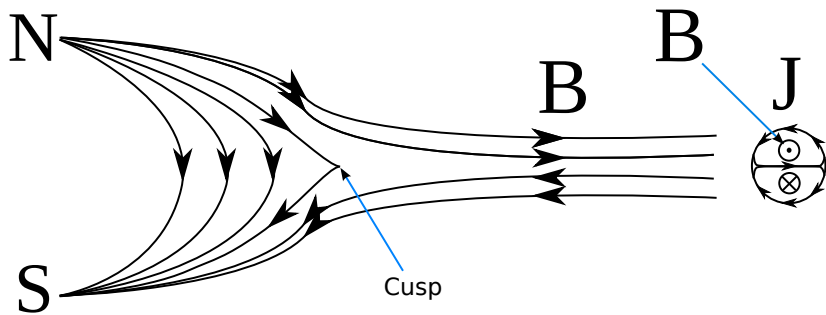
Helmet Streamers



Total Solar Eclipse 2006

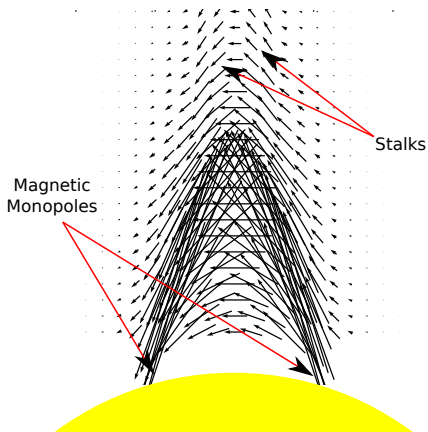
© 2006 Miloslav Druckmüller, Peter Aniol, ESA/NASA

Helmet Streamers



Helmet Streamers

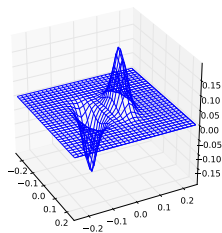
Magnetic Field of a Slice of a Solar Streamer



Magnetic Field of the Monopoles:

$$B \propto \frac{1}{r_+^3} - \frac{1}{r_-^3}$$

B-field in stalks falls off as a
Gaussian.



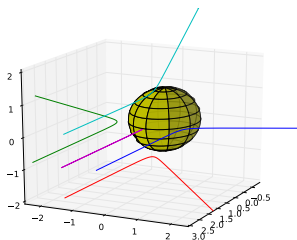
Scattering

In a paper by Thejappa and MacDowall, a computational approach to scattering is described. We then integrated this method with our simulation.

Scattering

In a paper by Thejappa and MacDowall, a computational approach to scattering is described. We then integrated this method with our simulation.

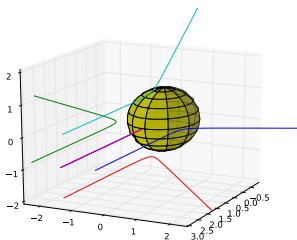
No Scattering



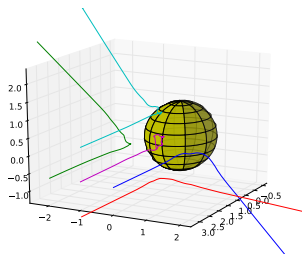
Scattering

In a paper by Thejappa and MacDowall, a computational approach to scattering is described. We then integrated this method with our simulation.

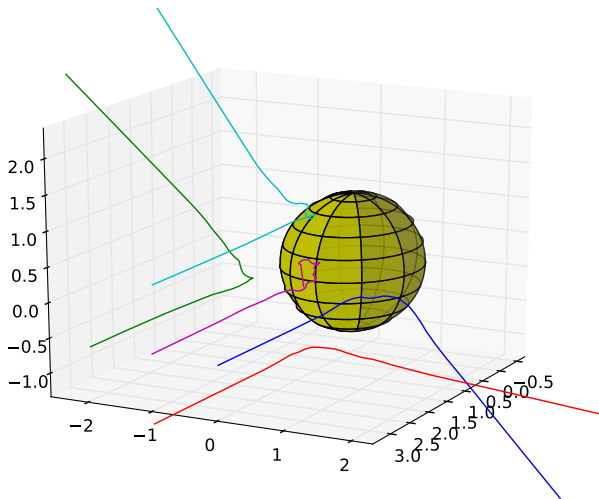
No Scattering



Scattering



Scattering



GUI

The standard GUI:

The screenshot displays the standard GUI for HART simulation, featuring a control panel on the left and a central visualization area.

File

Implane Coordinates:

xMin coordinate: -2.00 xMax coordinate: 2.00
yMin coordinate: -2.00 yMax coordinate: 2.00

Grid Size:

Grid Width: 10 Grid Height: 10

Observer Location: 215.0,0,0
Sphere Location: 25.0
Frequency: 80e6
cnu: 3.0
msun: 1.0

Mode: basic tbr tbriv

Units: Kelvin Jansky

Scattering: On Off

Buttons: Trace, Step Mode, Recompile, tbr Graph, tbriv Graph, Show Trajectories, Clear, Select All, Add streamers

The central visualization area shows a 2D grid with a yellow circle representing the Sun, centered at the origin (0,0).

GUI

Selecting Rays to Find Trajectories:

The screenshot displays the HART GUI interface. On the left, there are several control panels:

- File**: A menu option.
- Implane Coordinates**: Fields for xMin coordinate (-2.00), xMax coordinate (2.00), yMin coordinate (-2.00), and yMax coordinate (2.00).
- Grid Size**: Fields for Grid Width (10) and Grid Height (10).
- Observer Location**: A text field containing 215.0,0,0.
- Sphere Location**: A text field containing 25.0.
- Frequency**: A text field containing 80e5.
- cnu**: A text field containing 3.0.
- msun**: A text field containing 1.0.
- Mode**: Radio buttons for basic (selected), tbr, and tbriv.

At the bottom left, there are buttons for **Trace**, **Step Mode**, **Recompile**, **Tbr Graph**, **Tbriv Graph**, and **Show Trajectories**.

The central part of the GUI is a 10x10 grid. A yellow circle is centered on the grid, representing the sphere. Red squares are placed on the grid, indicating selected rays. The red squares are located at the following grid coordinates (row, column): (4, 3), (4, 7), (5, 2), (5, 4), (5, 6), (5, 8), (6, 3), (6, 5), (6, 7), (7, 3), (7, 7).

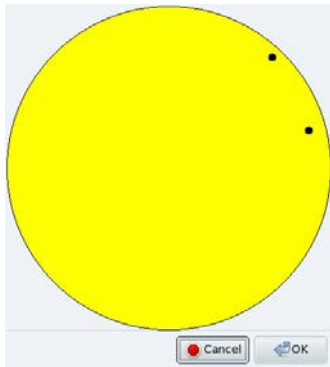
On the right side, there are two control panels:

- Units**: Radio buttons for Kelvin (selected) and Jansky.
- Scattering**: Radio buttons for On (selected) and Off.

At the bottom right, there are buttons for **Clear**, **Select All**, and **Add streamers**.

GUI

Adding Streamers:

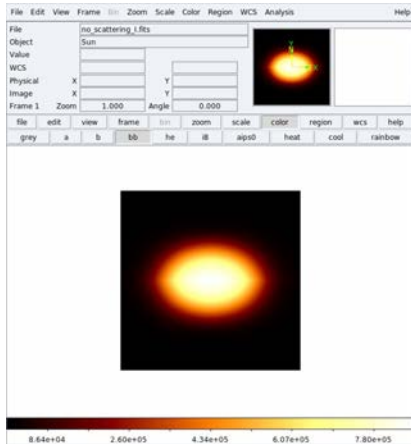


FITS Files

Because the FITS file format is so widely accepted in the astronomy community, the application must support its output. This facilitates the comparison of this model with real data.

FITS Files

Because the FITS file format is so widely accepted in the astronomy community, the application must support its output. This facilitates the comparison of this model with real data.

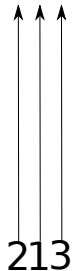
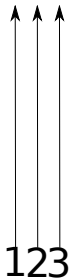


Multi-Threading

Raytracing algorithms are inherently parallelizable.

Multi-Threading

Raytracing algorithms are inherently parallelizable.



The order in which these rays finish is unimportant. We get the same answer either way.

CUDA

CUDA has become an incredibly popular way to see huge speed improvements at a relatively low cost.



CUDA

CUDA has become an incredibly popular way to see huge speed improvements at a relatively low ***monetary*** cost.



A CUDA Story

Carl Palmer Ulysses



A CUDA Story

Carl Palmer Ulysses



Greg Patrick Ulysses



A CUDA Story

Carl Palmer Ulysses



A.K.A. The Brains

Greg Patrick Ulysses

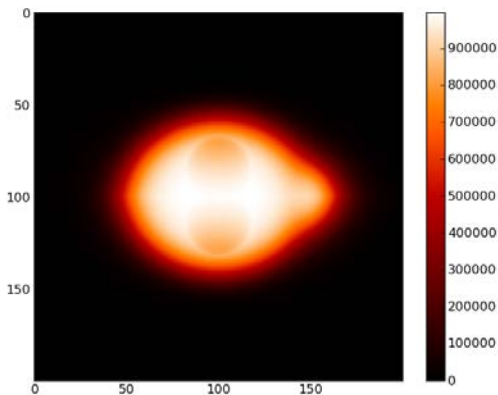


A.K.A. The Calculator

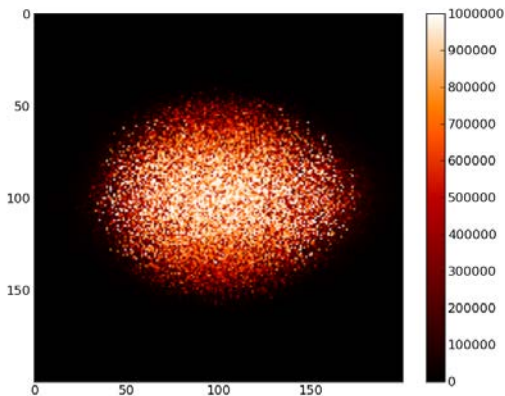
Speed Increase

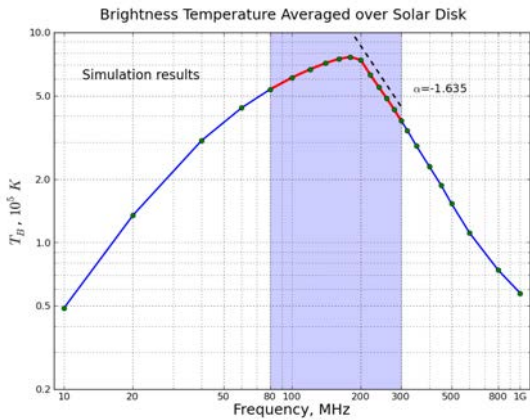


Brightness temperature at 180MHz with a helmet streamer at
(90°,90°)



Brightness temperature at 200MHz with scattering and a helmet streamer at $(90^\circ, 90^\circ)$





Conclusion

In these past ten weeks we have:

- Improved the scientific capabilities of the raytracer by adding solar streamers and scattering.
- Improved the usability of the program by adding a GUI and enabling output to FITS files.
- Improved the speed by integrating multi-threading and CUDA.

These improvements have moved HART towards its ultimate goal, a powerful raytracer that can be easily used to test solar hypotheses.

Acknowledgments

I'd like to give my thanks to:

- Leonid Benkevitch
- Divya Oberoi
- Lynn Matthews
- Mark McCurry
- David Packard

