Data Visualisation - 1

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I. Introduction

This report contains the visualisations and findings for the IEEE Visualization 2008 Design Contest. It explains the use of color maps as compared to contour maps with reasoning for which is a better visualisation.It further explains how combining different visualisations can help. It explains the approach used to be able to generate a quiver plot for the curl of velocity field.

II. Data

The dataset consists of two types of data, multifield and velocity data. All the data points are from a fixed space of 0.6*0.25*0.25 parsecs taken at 200 timesteps.

A. Multifield Data

This data consists of 10 different properties to choose from. I have explored five of these properties- density, temperature, H_2 mass abundance, H^- mass abundance and H_2+ mass abundance.

What is your rationale for the selection of variables? All of these properties are important to be able to analyse the formation of thin-shell and shadow instabilities, as mentioned by the authors of [1]. As one can easily understand, there must exist a relationship between density of gas and the temperature. So an obvious experiment that I performed was to see how the density changed with the temperature. Furthermore, as explained in [1] - *Free electron abundances at temperatures of a few thousand K in the finite width of the front rapidly catalyze H_2 production by the H^- and H_2^+ channels.* So I wanted to visualise this feature as well.

B. Plane Selection

How did you arrive at which plane you are going to explore? As can be seen in the Fig 1, the YZ plane slices were symmetrical for the two properties(Temperature and Density), and as I discovered for other properties as well. So, even though this can tell us about what is called as a D-Front but not enough about shadow instabilities.

Now, since the YZ plane had circular plots, I looked at the XZ and XY planes. Both of these planes showed almost similar structures [2], which led me to believe that the pertubations are all symmetric with multiple peaks.

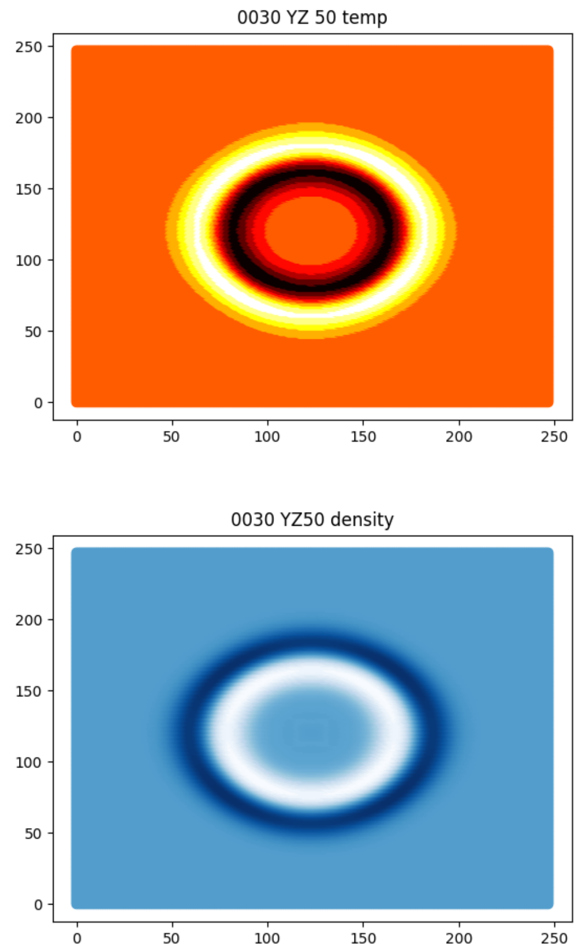

Fig. 1. X=50 at timestep 30

C. Time Steps

What is your rationale for the selection of variables? The dataset consists of 200 timesteps for both the multifield and the velocity data. My approach to selection of timesteps was based on a binary search. The goal was to first find a time step where I could see the pertubation in the field, or the **shadow instability**. I found that these instabilities were visible(with changing shapes) near the 100 timestamp. So, I backtraced to find the start of this instability. At the timestamp 0, I was

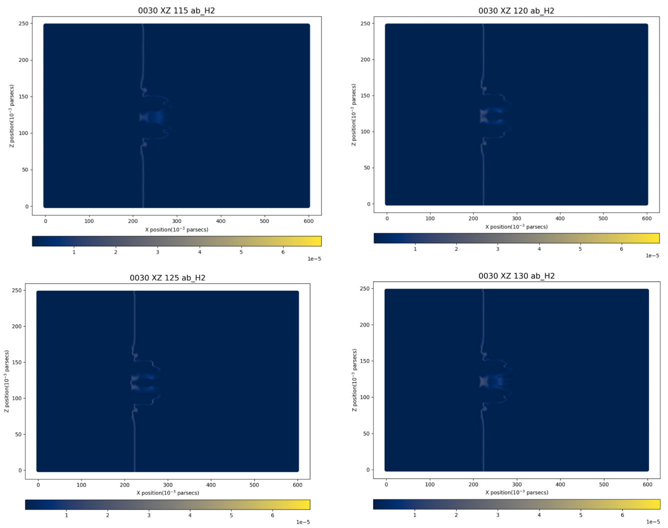

Fig. 2. Colormap of H2 abundance at different Y values

able to see a small circular region in the XZ plane at the selected slice. Exploring timestep 5, I saw small pertubation, so I decided to select timesteps at a gap of 5 - which turned out to be perfect for showing the changes.

1) Slice selection: After realising that the data is present in such a way that it creates a symmetric artifact, my goal was to find the slice which shows the cross section of the exact center. So, I started from Y=0 and looked at slices at a gap of 10 units. Y=80 you can notice slight perturbations which I understood to be boundary of the artifact. So moving ahead, I started seeing the two peaks. Now, at Y=115 I saw similar patterns to that present at Y=130 (Fig 2). So, the center had to lie somewhere in between. At Y=125 I found pattern exactly similar to Y=124 which implied this could be the center. Hence I chose **Y=125** as the center of the artifact.

III. Visualisations

Now, after having identified the proper plane for these visualisations, selecting a colormap that could clearly portray the information was an important task. Now, I calculated the minimum and maximum of all the values for all the different properties. All the values that I looked at were positive values. And none of these properties portrayed reaching an extrema, hence a diverging colormap was not a favourable option. The best option was a Sequential colormap because I wanted to be able to see the points where the pertubations reach an upper limit, compare regions with different values.

The next choice I had to make was between contour plots and scatter plots. The visualisations generated by the contour plots were very similar to the scatter plots, with no additional information(Fig 3). The only place where it helped to generate contour lines was with a combination of temperature and density as I've explained.

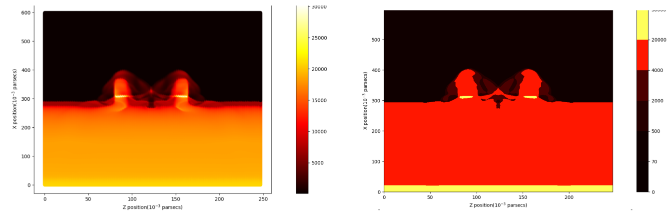

Fig. 3. Contour Plot on the right, Scatter plot on Left of Temperature at time=60

A. Multifield Data

1) Density: For density I chose *Blues_r* colormapping by setting the limits to the minimum and the maximum of the values. A scatter plot for timestep = 60 can be seen in Fig 4. Now, this front can be seen moving along the timesteps and the plane that I have chosen. The selection of the colormap was based on the fact that white spots/ lighter spots will be clearly show high density points in space.

For all the timesteps, I iterated over all the values in the XZ plane at Y=125 slice and found the minimum and the maximum density values, which I what I used for the colormapping. Now, initially I had calculated individual minmum and maximum for the different timesteps and used those on the colormaps, but when I played the animation, it would seem like higher densities have been achieved much earlier and at different places, obviously because the mapping was different for each time step. Keeping the **same min-max across timesteps** allowed me to counter this problem and see the actual growth in the density over time.

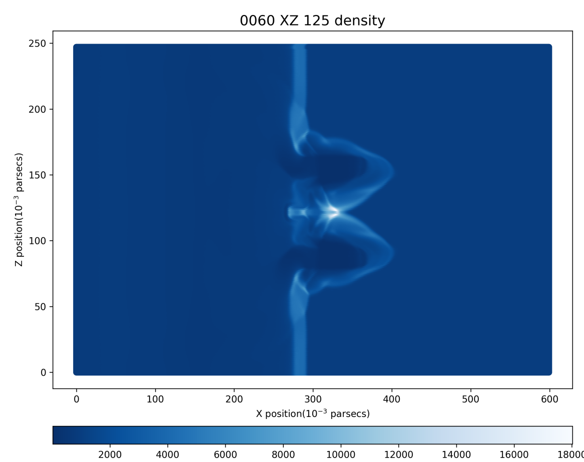

Fig. 4. Density Plot at time step 60

2) Temperature: For temperature an obvious selection of colormapping was **hot** since it clearly represents the common perception of temperature. Now, for this too I calculated the minimum and maximum across all timesteps like in density. One of the plots at timestep=60 can be seen in Fig 5. Now, as the temperature increases the density reduces. This concept helped me further verify the validity of the available data. As you can see, the regions where the temperature is higher, that is dark red to yellow, the corresponding density is low - darker shades of Blue.

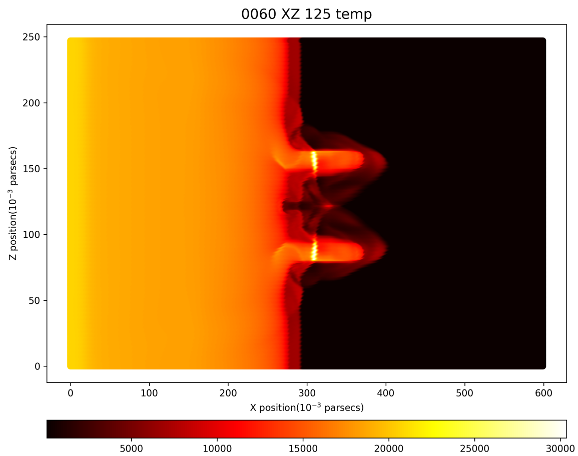

Fig. 5. Temperature Plot at time step 60

Even though this conclusion can be made visually, I wanted to get a combined view of the same. This is where I utilised **contour plots**. Now, we know that ambient gas is very cool (72 K), shocked gas is around 2000-3000 K and ionized gas is much hotter(20,000 K). So this is what I used to set my contour levels for the temperature - [0, 70, 500, 2000, 4000, 20000, 30000]. The combined plot can be seen in Fig 6.

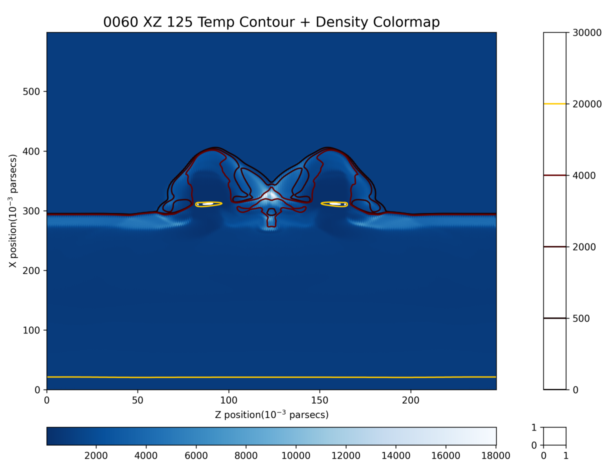

Fig. 6. Density colormap with Temperature Contour lines at time=60

Using this animation we can see that the extremely high temperature region is very dark, all the way to the dark red coloured contour region which represents the lowest temperature and consequently lightly coloured density points implying higher density.

3) Chemical Species: The reason for the selection of H_2, H^- and H_2+ was based on the following reactions from [1]:

$$
\begin{aligned}
H + e^- \rightarrow H^- + \gamma \quad & H^- + H \rightarrow H_2 + e^- \\
H + H^+ \rightarrow H_2^+ + \gamma \quad & H_2^+ + H \rightarrow H_2 + H^+
\end{aligned} \tag{1}
$$

These equations imply that the H_2 production is catalyzed by abundance of free electrons at few thousand Kelvins using H^- and H_2^- channels. So, the regions where there is a peak in the H^- and H_2^+, there will also be a peak in H_2. So to be able to see an output which depicts this feature, I tried using the same colormap across the three properties with the min-max value formed by values of all the three properties. This result can be seen in Fig 7. I went through all the selected timesteps, but the values of the H^- and H_2^+ was very low in comparision to the H_2 values that they weren't visible. I thought a different colormap which had multiple colours could be a way in which even the small values could become visible, so I tried *flag*, *prism*, *tab20c* all of which have high variations in small ranges, but the domain of these properties was too small to be differentiated by these.

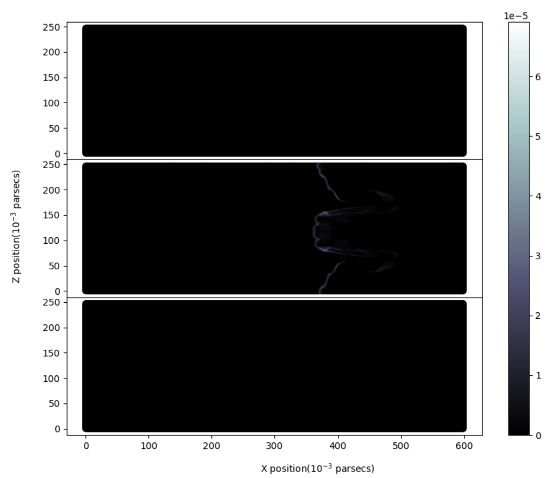

Fig. 7. H^-, H_2, H_2^+ mass abundances plotted against same min-max values at time=60

Hence, I decided to plot the plots like that of density and temperature with respective minimum and maximum values defining the limits of the colormaps as can be seen in Fig 8. Here, we can clearly see that the plot of H_2 is almost a copy of the other two plots $\rightarrow$ the peak of H_2 is achieved along with that of H_2^+ and H^-, which verifies the proposed output from the reactions.

B. Velocity field

So since I have considered the XZ plane, the Curl_X and Curl_Z will be the two which I will have to consider for the plot. So, a curl vector will basically be useful in showing how the gases will be ”rotating” or moving in space. So,

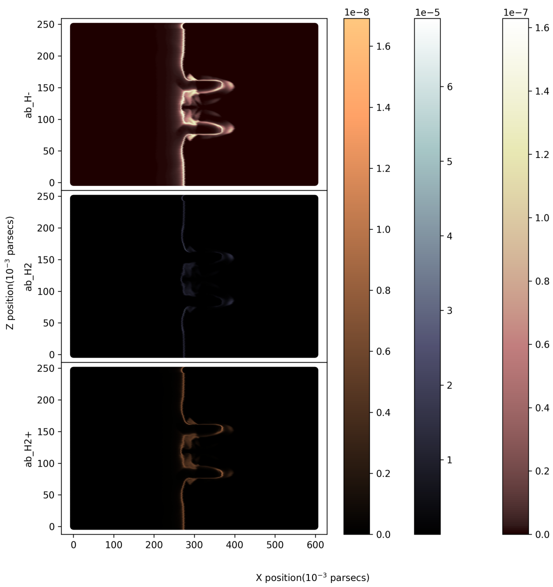

Fig. 8. H^-, H_2, H_2^+ mass abundances plotted against respective min-max values at time=60

from intuition I expected to see some curl vectors which would show turbulence of sort in high temperature regions. Plotting a simple quiver plot without any other property, we just can't understand what it would imply. So, I combined it with temperature property.

The quiver plot has been colormapped based on the temperature. So what we see in Fig 9 are the arrows turning inwards as they reach the peaks and temperature decreases. Furthermore, the domain of the curls was very big(-7000 to 7000 approx.) which resulted in quiver plots with extremely large arrows with a lot of variations. To counter this problem I applied ***tanh*** to the values to bring the domain from -1 to 1. Now, notice that a normalisation would not be ideal since it would remove the negative values, but in a vector field, it is important.

IV. Results

Overall, for the given data sets, Sequential Colormaps have outperformed other colormaps, owing to the data. I found a scatter plot being able to showcase better information than a contour plot. I was able to visually provide correlation between density and temperature of the gas and animate the shadow instability. The comparision between the different chemicals- H^-, H_2 and H_2^+ helped in verifying the creation of H_2 as the temperature increases. The curl of the velocity field, combined with the temperature property was instrumental in visualising how the movement of the gas changes when the temperature changes.

References

[1] D. Whalen and M. L. Norman, "Ionization front instabilities in primordial hiiregions," *The Astrophysical Journal*, vol. 673, no. 2, p. 664–675, Feb 2008. [Online]. Available: http://dx.doi.org/10.1086/524400

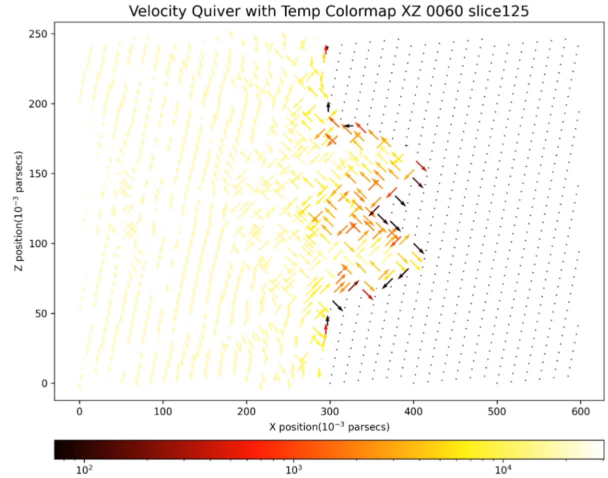

Fig. 9. Curl of Velocity field in XZ plane at timestep 60 with colormapping based on temperature

[2] L. Linsen, T. Long, and P. Rosenthal, "Linking multidimensional feature space cluster visualization to multifield surface extraction," *IEEE computer graphics and applications*, vol. 29, pp. 85–9, 05 2009.