RayPC: Interactive Ray Tracing Meets Parallel Coordinates

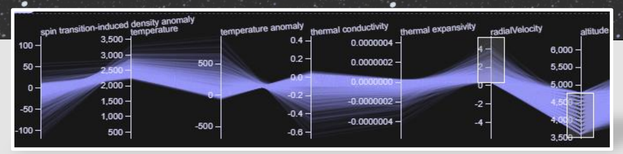
Jonathan Fritsch, Markus Flatken, Simon Schneegans,
Andreas Gerndt, Ana-Catalina Plesa, and Christian Hüttig

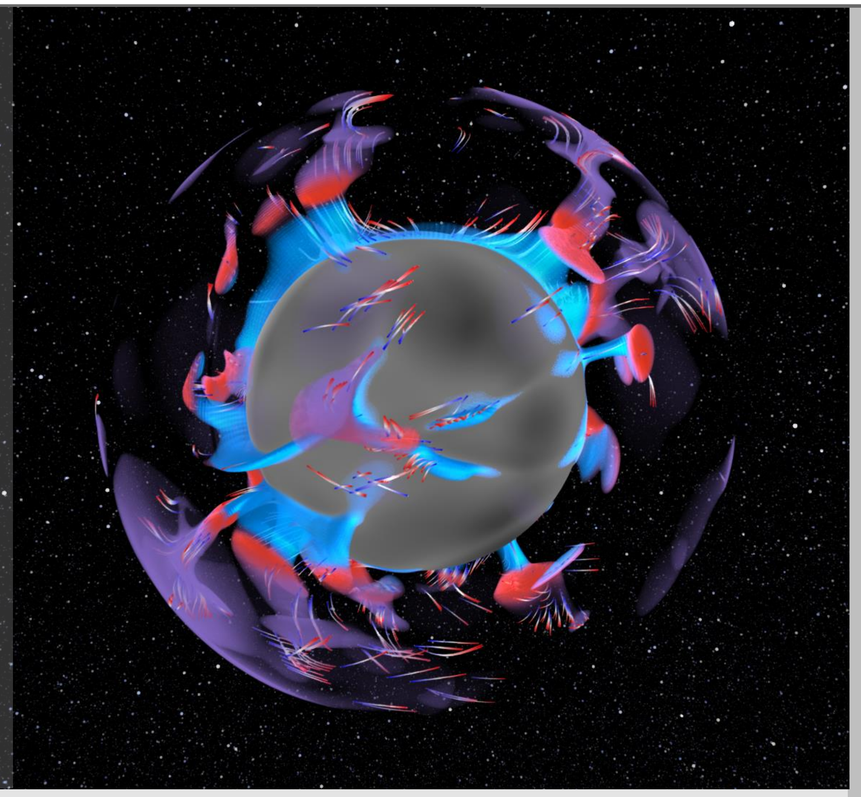
We present a plugin for CosmoScout VR [1] which can be used for interactive visualization of large-scale fluid dynamics data.

It combines asynchronous volume rendering, pathline visualization, and parallel coordinates and can be used to explore features, patterns, and correlations between variables in real-time.

MIT-licensed source code:
https://github.com/cosmoscout

Contact:
Jonathan.Fritsch@dlr.de

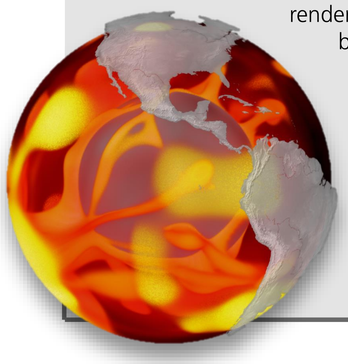




A parallel coordinates plot (PCP) enables efficient data selection and visual exploration of correlations. To create the image above, the PCP was used to remove all cells with a negative temperature anomaly. The remaining cells are colored according to the spin transition-induced density anomaly. Positive values (red) cause the hot material to stagnate and move laterally at mid-mantle depth. Pathlines visualize where the selected material will move in future time steps (from blue to red).

Interactive Asynchronous Volume Rendering

- Based on the open-source ray tracing engine OSPRay from Intel [2].
- Asynchronous Rendering: Raytracing is performed in a separate thread.
- Therefore, the application always stays interactive and runs at high frame rates.
- Missing frames are extrapolated by using image-warping of the most recent frame.
- Allows using the tool in Virtual Reality.
- Progressive Rendering: While the virtual camera is stationary, the previously rendered image is enhanced by running additional render passes.



As a plugin of the open source space simulation CosmoScout VR, the data can be contextualized with geographical information.

Feature Selection with a Parallel Coordinates Plot (PCP)

- Can be used to limit the drawn cells based on their scalar values, and to explore correlations between variables of the data set.
- OSPRay renderer was extended to discard cells during ray-marching.
- This results in low latency during interaction with the PCP as the volume data is not modified.

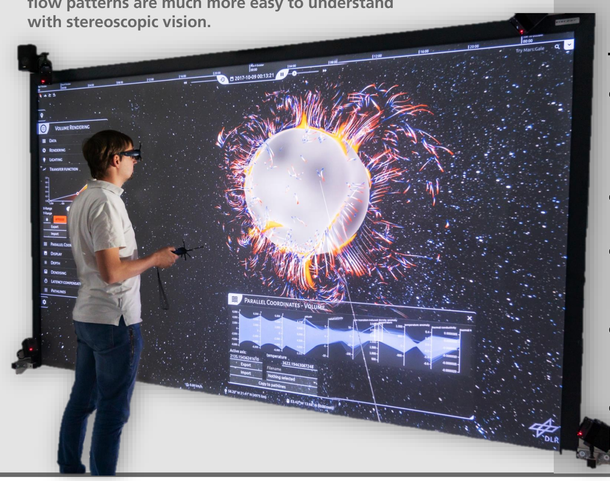
Preprocessing

- An octree-based level-of-detail data structure is generated to reduce I/O requirements during animations.
- Pathlines are seeded at critical points of the temperature anomaly field using TTK [3] and each traced for 10 time steps (20 Myrs).
- 100.000 cells are randomly selected to later progressively draw the lines of the PCP.

Flow Visualization with Pathlines

- Pathlines are filtered by the PCP according to their starting point and the current time step.
- They visualize where the selected material will move to in the upcoming 20 Myrs.

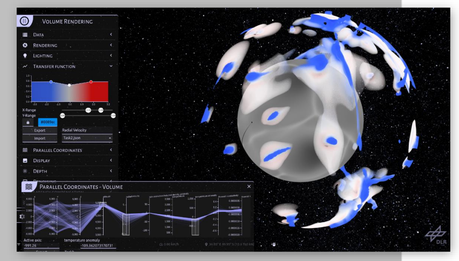
High frame rates allow using the system in Virtual Reality. Complex flow patterns are much more easy to understand with stereoscopic vision.



The Five Tasks of the SciVis Contest

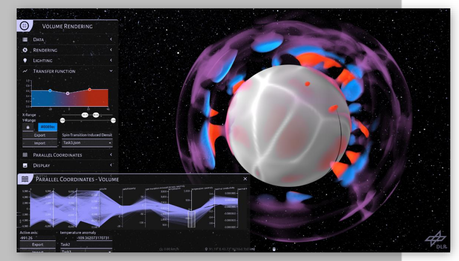
Task 1: Cold Slabs at 660 km

- The PCP is used to select cells with a non-positive radial velocity, a negative temperature anomaly, and a depth around 660 km.
- The transfer function uses the radial velocity: Stagnating slabs are shown in white while sinking slabs are colored blue.



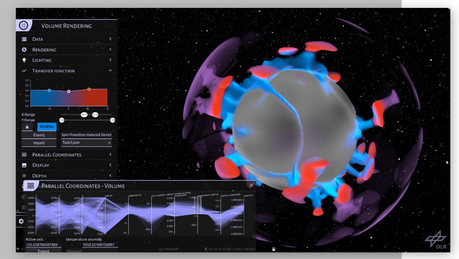
Task 2: Cold Slabs at 1600 km

- The PCP is used to select cells with a negative temperature anomaly.
- Data is colored according to the spin transition-induced density anomaly.
- Especially in the upper left, we can see how cold material slows down (blue color) as it approaches the iron-spin transition.



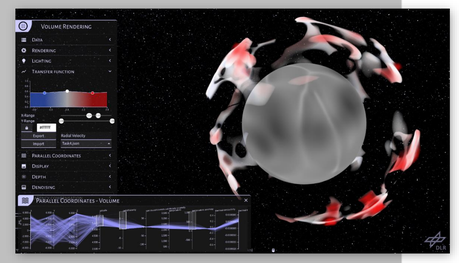
Task 3: Hot Plumes at 1600 km

- The PCP is used to select cells with a positive temperature anomaly.
- Data is colored according to the spin transition-induced density anomaly.
- A positive density anomaly (red color) causes the plumes to stagnate and move laterally at mid-mantle depth.



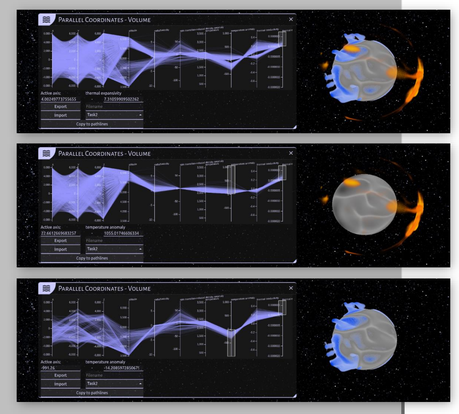
Task 4: Hot Plumes at 660 km

- The PCP is used to select cells with a non-negative radial velocity, a positive temperature anomaly, and a depth around 660 km.
- The transfer function uses the radial velocity: Rising material is shown in red while stagnating material is colored white.



Task 5: Data Correlations

- Correlations between the variables and the flow patterns can be identified in our framework through the parallel coordinates.
- As an example, we select a positive thermal expansivity.
- The lines of the parallel coordinates plot clearly show a separation of the data into two distinct regions.
- We can use further selections in the parallel coordinates to choose the individual regions.
- In this example, the transfer function uses the temperature anomaly.



[1] S. Schneegans, M. Flatken, and A. Gerndt. “CosmoScout VR 1.4.0”, Mar.2021. doi: 10.5281/zenodo.4646924
[2] I. Wald et al. "Ospray – a CPU ray tracing framework for scientific visualization." IEEE Transactions on Visualization and Computer Graphics 23.1 (2016): 931-940.
[3] J. Tierny, G. Favelier, J. A. Levine, C. Gueunet, and M. Michaux. “The topology toolkit.” IEEE Transactions on Visualization and Computer Graphics, 24.1 (2018) :832–842.

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