



Dai modelli scientifici all'Universo: esplorare il cosmo con 3D MAP - VR

*The Art and Science of Visualizing
Computational Scientific Models*

Salvatore Orlando
INAF - Osservatorio Astronomico di Palermo

NELL'AMBITO DELLA
XXII SCUOLA
DI COMPUTER GRAFICA E AI
PER I BENI CULTURALI E LA SCIENZA

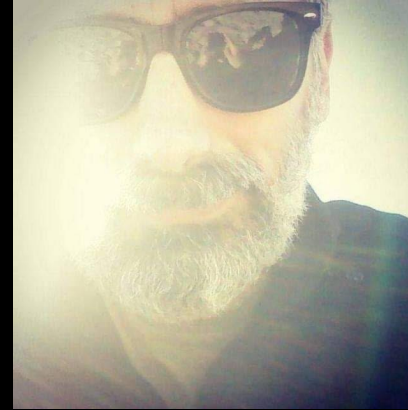
Principali Membri del Team 3DMAP-VR



Laura Daricello



Laura Leonardi

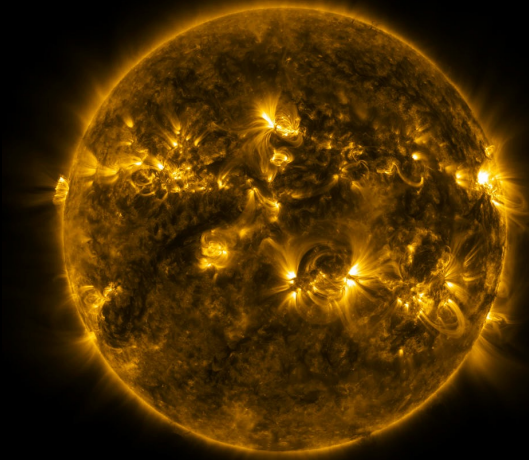


Ignazio Pillitteri

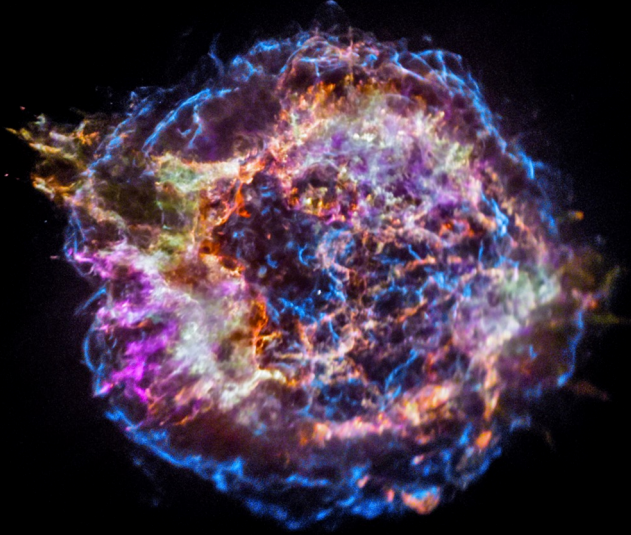


Sabina Ustamujic

Astronomical Observations



SDO/AIA 171 2013-04-09 14:15:12 UT



$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{v}) = 0$$

$$\frac{\partial m}{\partial t} + \nabla \cdot (m \mathbf{v}) = 0$$

$$\frac{\partial \mathbf{B}}{\partial t} + \nabla \times \mathbf{E} = 0$$

$$\frac{\partial (E_t + \rho \Phi)}{\partial t} + \nabla \cdot (\mathbf{v} (E_t + \rho \Phi)) = 0$$

$$E_t = \rho e + \frac{m^2}{2\rho}$$

$$c\mathbf{E} = -\mathbf{v} \times \mathbf{B} + \nabla \Phi$$

```

/* -----
2. Obtain conservative vector Uc
----- */

PrimToCons3D(d->Vc, d->Uc, &box);

/* -----
3. Compute the parabolic time step by calling
the RHS function once outside the main loop.
----- */

g_intStage = 1;
Boundary(d, ALL_DIR, grid);

Dts->invDt_par = ParabolicRHS(d, MY_0, &box, NULL, RK_LEGENDRE, 1.0, grid);
Dts->invDt_par /= (double) dimensions;
#ifdef PARALLEL
MPI_Allreduce (&Dts->invDt_par, &scrh, 1, MPI_DOUBLE, MPI_MAX, MPI_COMM_WORLD);
Dts->invDt_par = scrh;
#endif

dt_par = Dts->cfl_par/(2.0*Dts->invDt_par); /* -- explicit parabolic time step -- */

/* -----
4. Compute number of RKL steps from Dts->inv_dta
----- */

#ifdef RKL_ORDER == 1
scrh = tau/dt_par; /* Solution of quadratic Eq. */
s_st = 4.0*scrh/(1.0 + sqrt(1.0 + 8.0*scrh)); /* 2*tau/dt_exp = s^2 + s */

```

Numerical codes for
astrophysical plasmas

hundreds of files
thousands of lines of text

SETUP

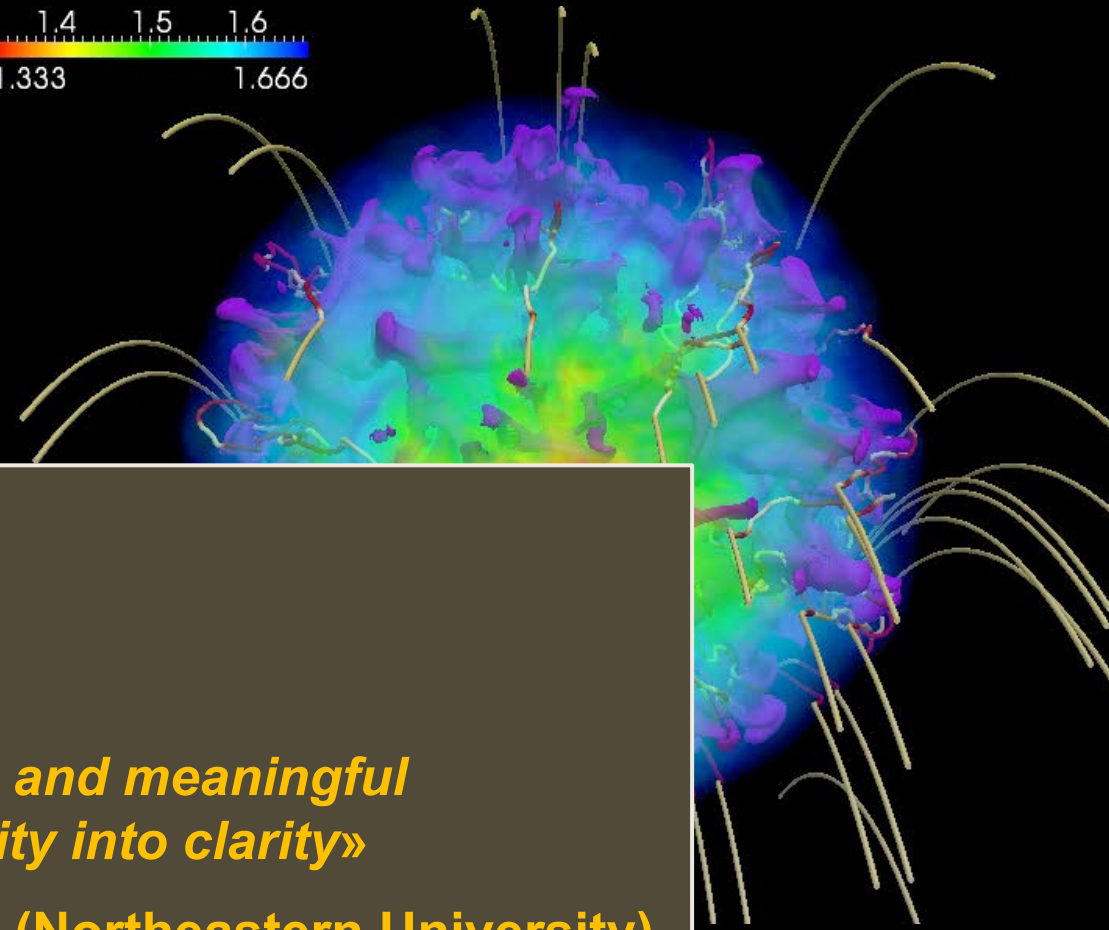
- Geometry
- Physics
- Chemistry
- etc.

High Performance Computing



Model Visualization

```
ianachel:NOVA orlando$ fg  
/Applications/harris/id186/bin/idl  
  
IDL> █
```



visualization as an interpreter
formal transformation process

*«It bridges the gap between raw data and meaningful
comprehension, unraveling complexity into clarity»*

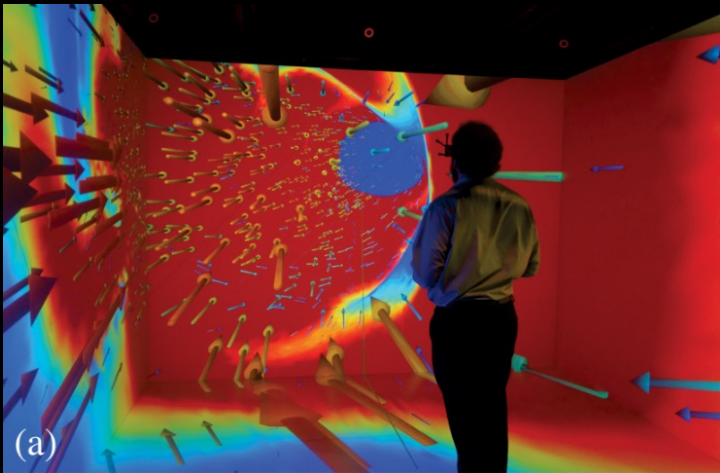
Lace Padilla (Northeastern University)

3-Dimensional Modeling of Astrophysical Phenomena in Virtual Reality

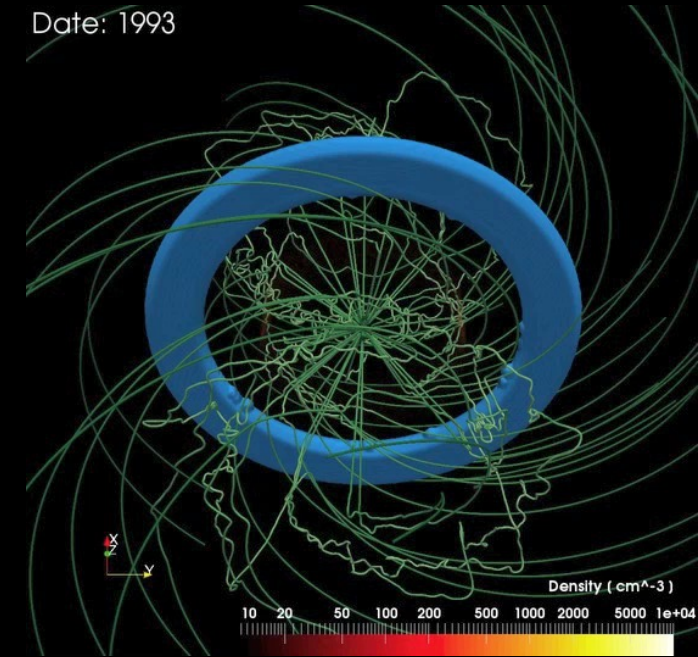
Simulazioni 3D MHD di fenomeni astrofisici

challenge nella visualizzazione tradizionale di modelli per studi scientifici

per la quantità di dati da processare
e la mole di informazioni scientifiche che essi contengono



Date: 1993



Sfruttamento delle potenzialità della realtà virtuale (VR) - hardware e software – per l'analisi dei dati scientifici

L'adozione di ambienti VR per l'analisi di routine di dati scientifici
è ancora in fase embrionale
ancora necessario lo sviluppo ad-hoc di tecniche e metodologie

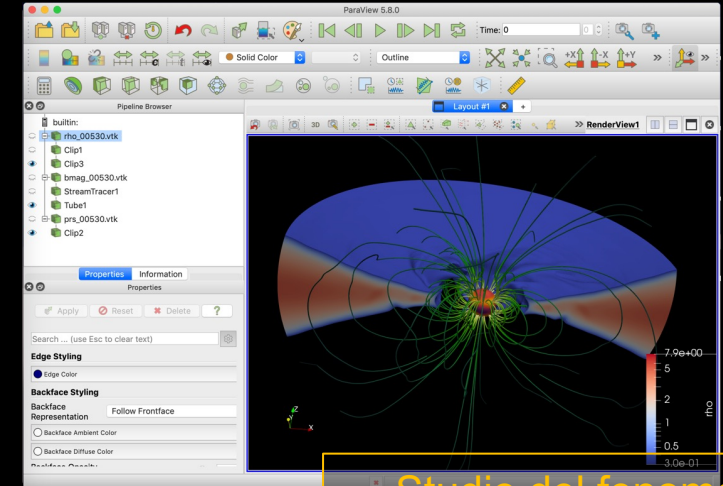
Il Progetto 3DMAP-VR



supercomputer

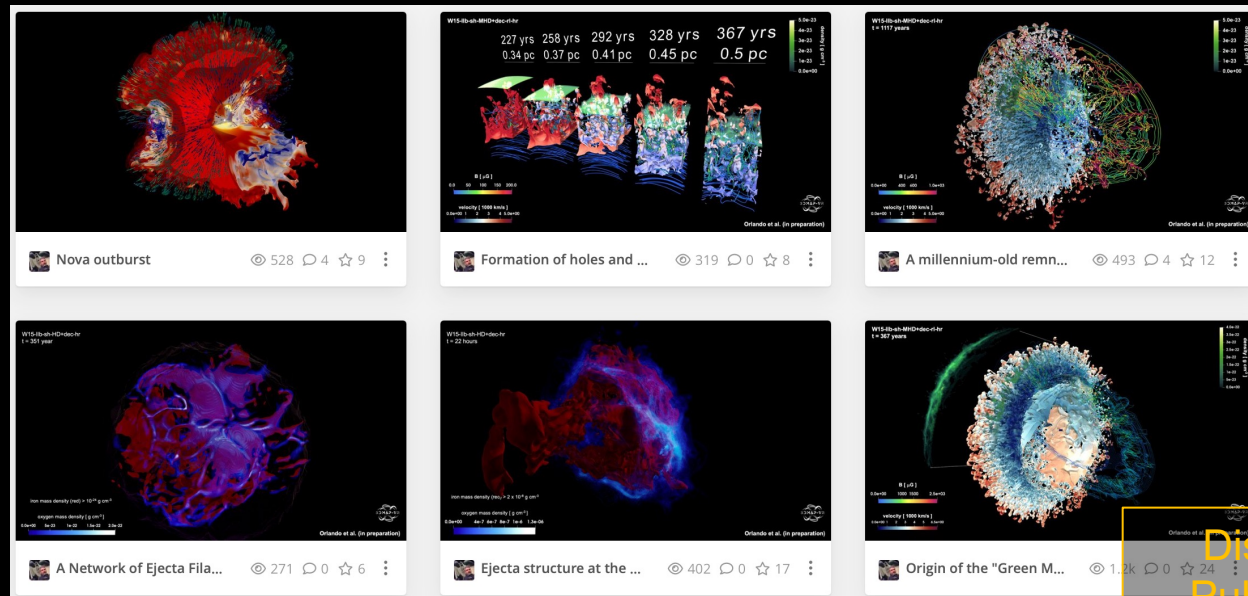


Analisi dati e
visualizzazione dei modelli



Studio del fenomeno
Estrazione di informazioni

Gallerie pubbliche di
grafiche interattive, VR, AR



Dissemination
Public outreach

The 3DMAP-VR project



Phase I — PRODUCE *(from physical models to numerical simulations)*

- Develop the physical model and numerical setup
- Perform high-resolution numerical simulations on HPC systems
- Generate multidimensional datasets describing the evolution of the system

Phase II — EXPLORE *(from simulations to physical understanding)*

- Analyze the numerical datasets and identify structures, patterns, and physical processes
- Extract relevant physical quantities and diagnostics
- Connect simulation results with theoretical predictions and observations

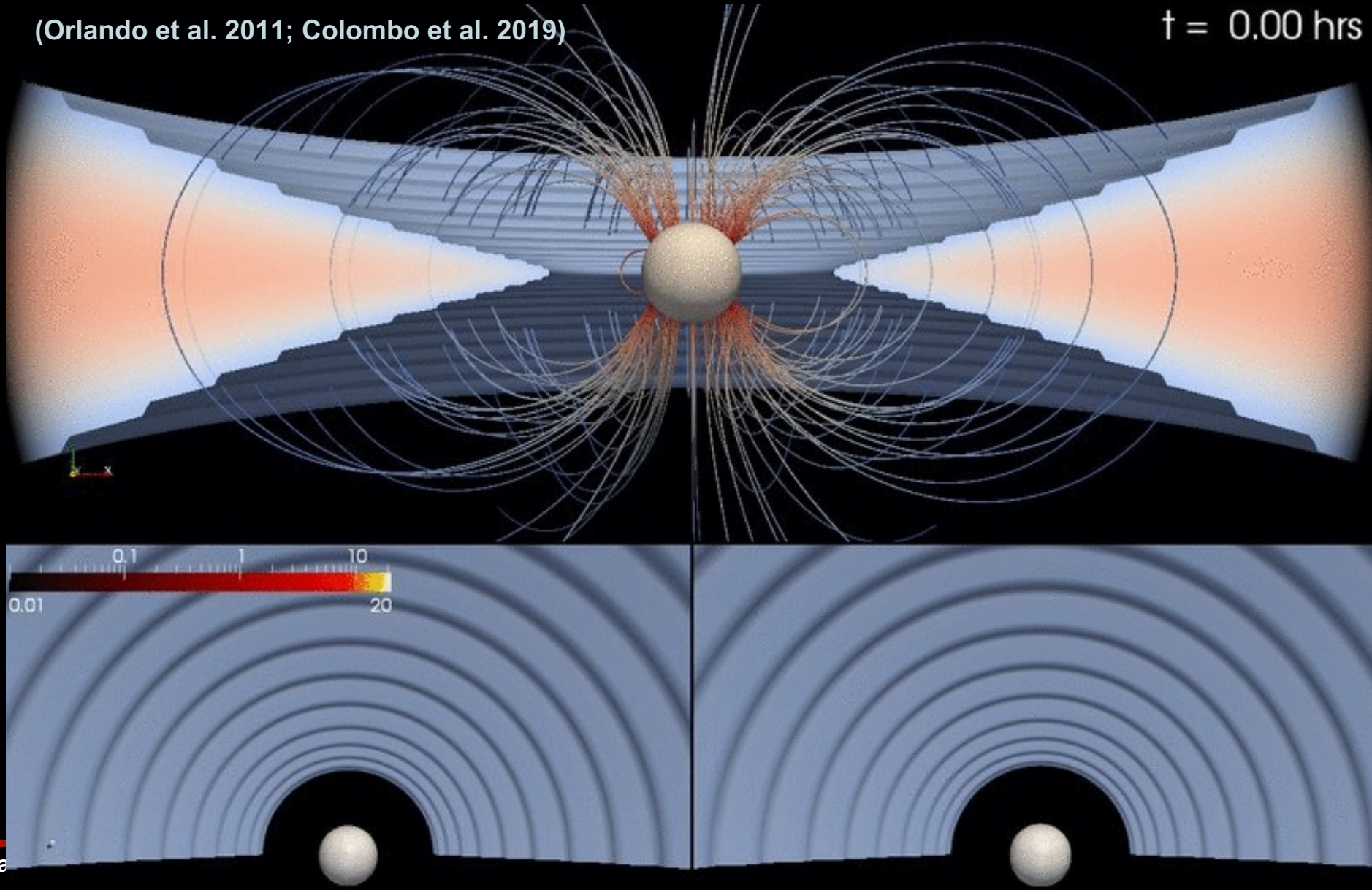
Phase III — EXPLAIN / COMMUNICATE *(from scientific visualization to scientific storytelling)*

- Translate complex multidimensional data into intuitive visual representations
- Design figures, animations, and movies to highlight key processes and phenomena
- Communicate the physical interpretation clearly and effectively
- Make complex physical processes accessible to different audiences (experts, students, amateurs)

Visualization is Storytelling for Models

(Orlando et al. 2011; Colombo et al. 2019)

$t = 0.00$ hrs

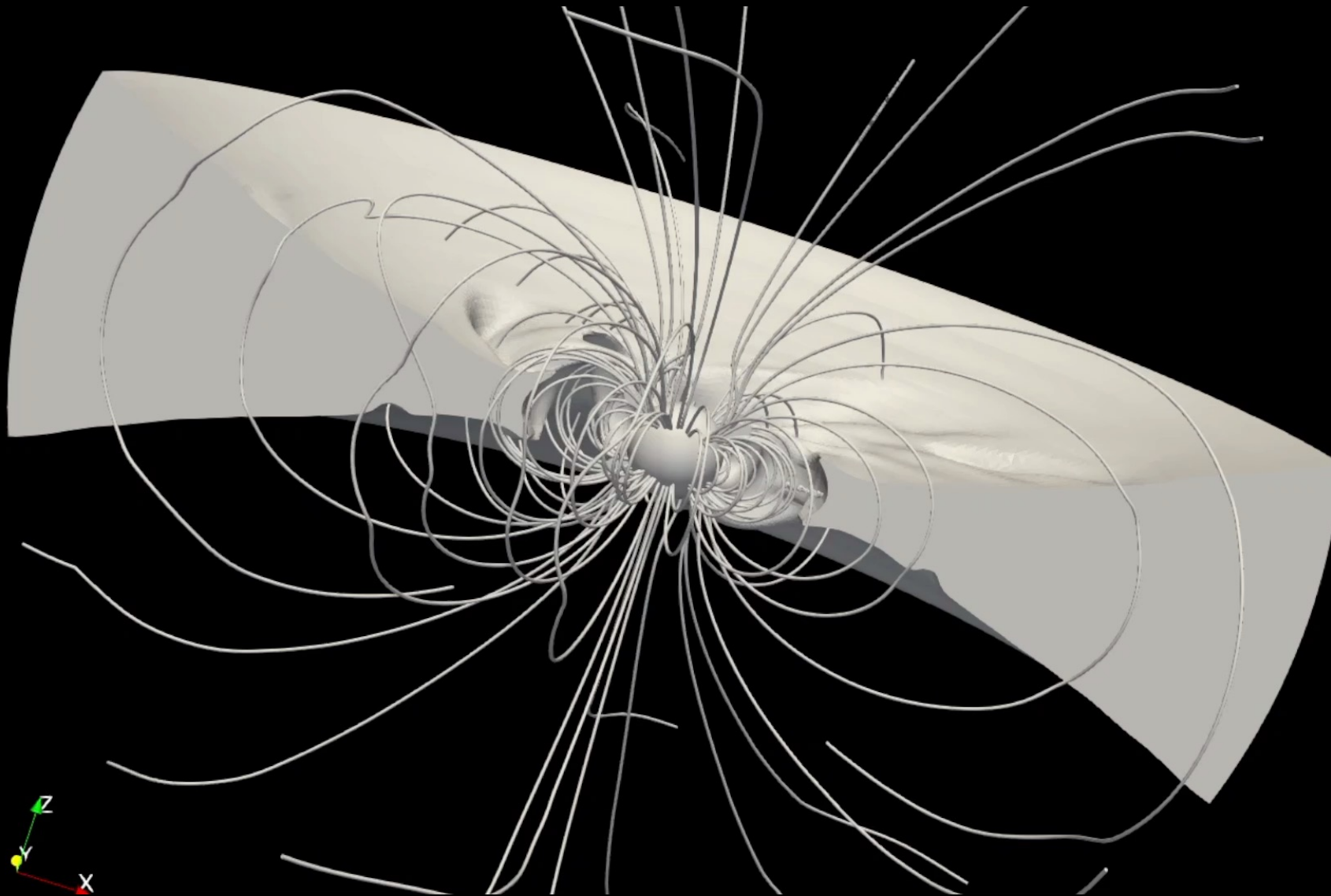


Translating
Complex Data



Visually
Engaging Stories

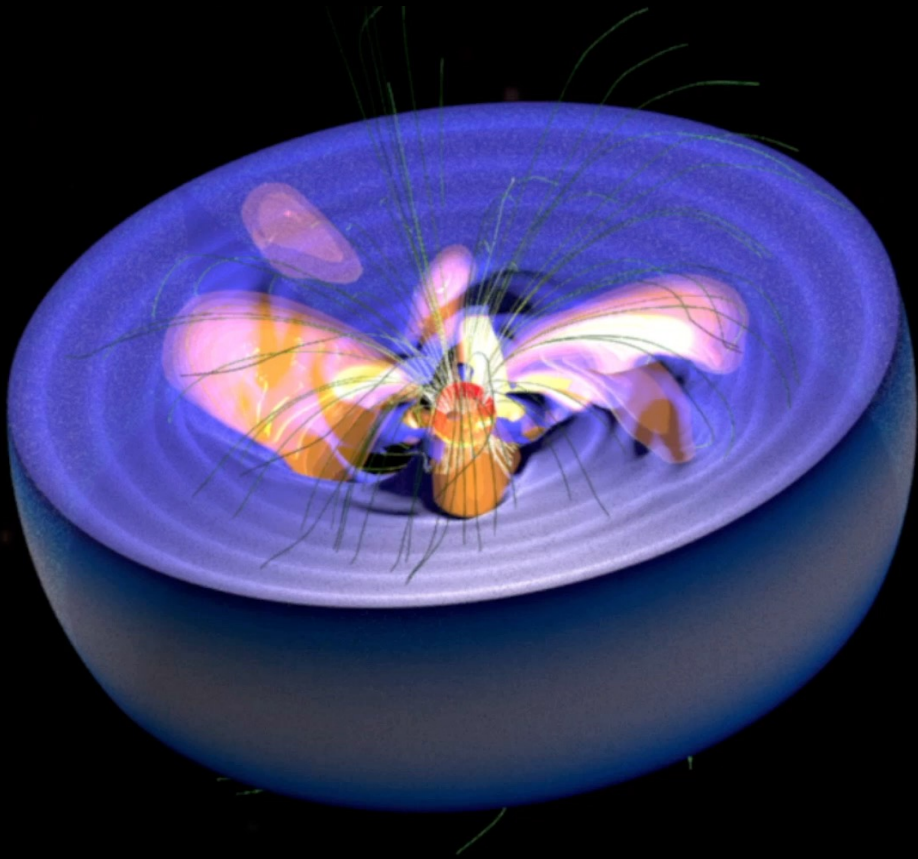
The Model Visualization Design Process



3D MHD simulation
describing mass accretion
in a classical T Tauri star

(Orlando et al. 2011;
Colombo et al. 2019)

The Model Visualization Design Process



Different representations

- Scientific representation

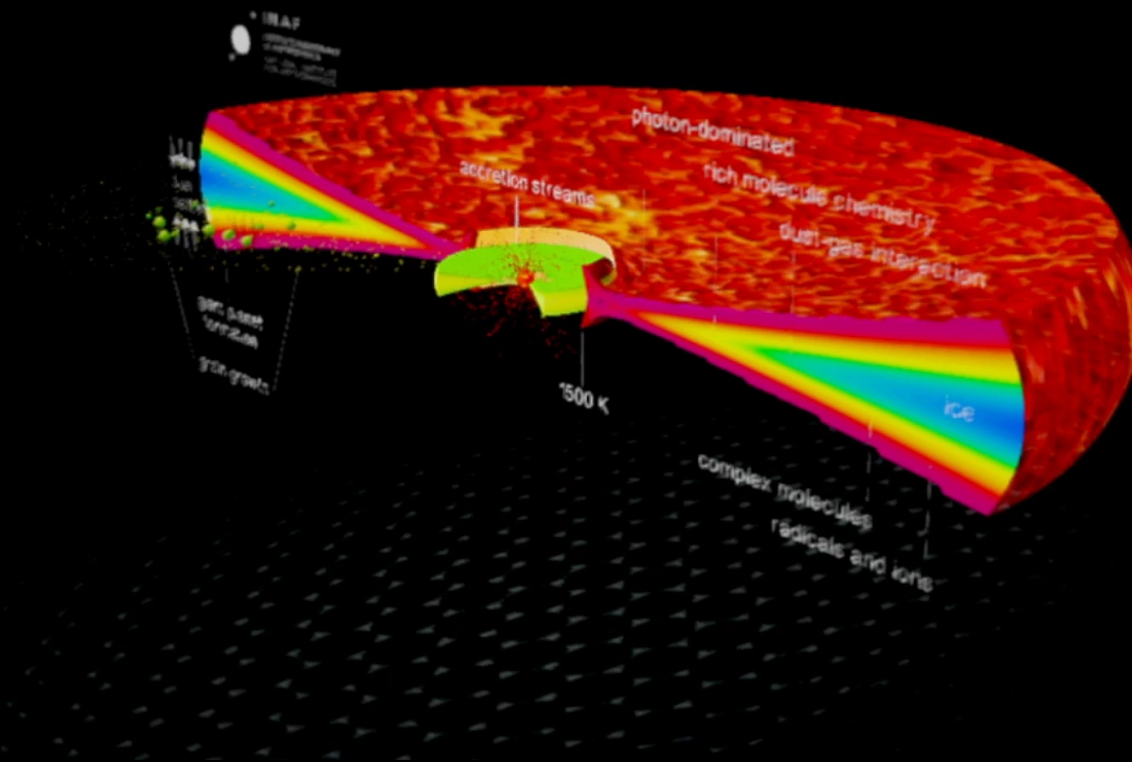
AIM:

- highlight specific features/structures
- Discuss specific processes

The Model Visualization Design Process

Different representations

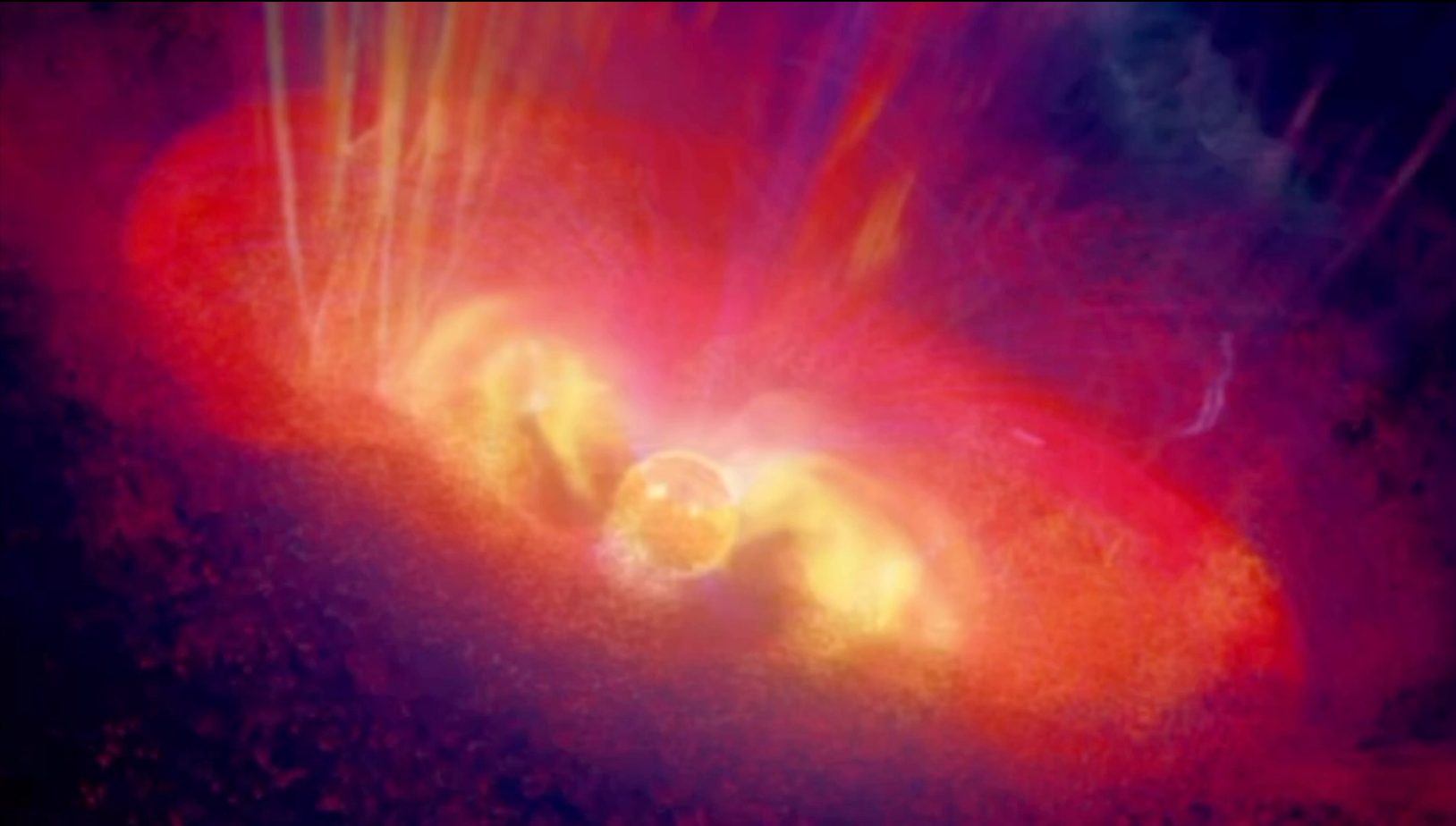
- Scientific representation
- Sketch ideas (education)



AIM:

- Basic representation (schemes)
- Train students

The Model Visualization Design Process



Different representations

- Scientific representation
- Sketch ideas (education)
- Artist's impression

AIM:

- Attract people interest (wow effect)
- Show basic facts

Analisi e visualizzazione di fenomeni astrofisici con HPC e VR

- Analysis & Visualization of Scientific Data
- How to Design an Effective Visualization
- Immersive Horizons
A Semi-Serious Guide to Finding Your Way in Virtual Data Space
- Possible Applications