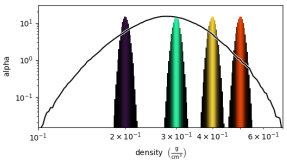
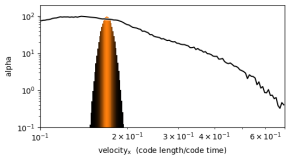
Appendix A: Supplementary Material

Nyx and Castro Transfer Functions

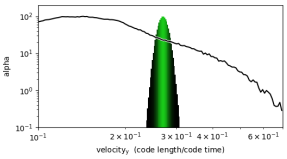
In Fig. 8 and Fig. 9 we present transfer functions for visualizing the density and velocity components of the Nyx and Castro ensembles, respectively. These are applied to the density field and the x, y, and z components of the flow field, offering an intuitive means to explore and analyze the spatial and dynamic characteristics of the simulation data. The utilized transfer functions help to better understand the structural patterns and flow dynamics inherent to each ensemble.



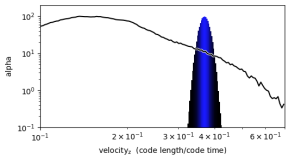
(a) *TF for density field.*



(b) *TF for flow field in x direction.*

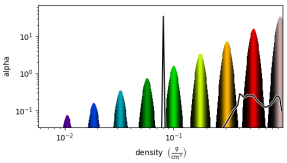


(c) *TF for flow field in y direction.*

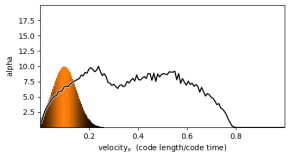


(d) *TF for flow field in z direction.*

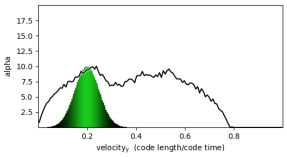
Figure 8: *Nyx ensemble: transfer function for density and x, y, z components of the flow field.*



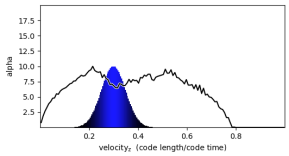
(a) *TF for density field.*



(b) *TF for flow field in x direction.*



(c) *TF for flow field in y direction.*



(d) *TF for flow field in z direction.*

Figure 9: *Castro ensemble: transfer function for density and x, y, z components of the flow field.*

3D Flow Estimation and Density Interpolation Results

This subsection presents the complete results for 3D flow estimation and temporal interpolation tasks on the Nyx (Fig. 10) and Castro (Fig. 11) datasets. The figures include visualizations of the estimated flow fields and interpolated density fields. Additionally, the results highlight comparisons with baseline methods, including FLINT and STSR-INR.

The 3D PSNR metric used in our evaluation is computed after normalizing the scalar data to [0,1], using the following formulation:

$$\mathrm{MSE} = \frac{1}{mno}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}\sum_{k=0}^{o-1}(D^{GT}_{t,i,j,k} - \hat{D}_{t,i,j,k})^2, \tag{5}$$

$$\mathrm{PSNR} = 20\log_{10}(1.0) - 10\log_{10}(\mathrm{MSE}), \tag{6}$$

where the mean squared error (MSE) is calculated over the entire 3D volume, with m,n,o representing the spatial dimensions of the volume along the x-, y-, and z-axes, respectively.

For flow estimation, we compute the 3D endpoint error (EPE) as:

$$\mathrm{EPE} = \frac{1}{mno}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}\sum_{k=0}^{o-1}\left\|F^{GT}_{t,i,j,k} - \hat{F}_{t,i,j,k}\right\|_2. \tag{7}$$

Here, F^{GT} and $\hat{F}$ represent the ground-truth and predicted flow fields, respectively, with components along the x-, y-, and z-axes. The EPE measures the Euclidean distance between the predicted and true flow vectors across the entire 3D volume.

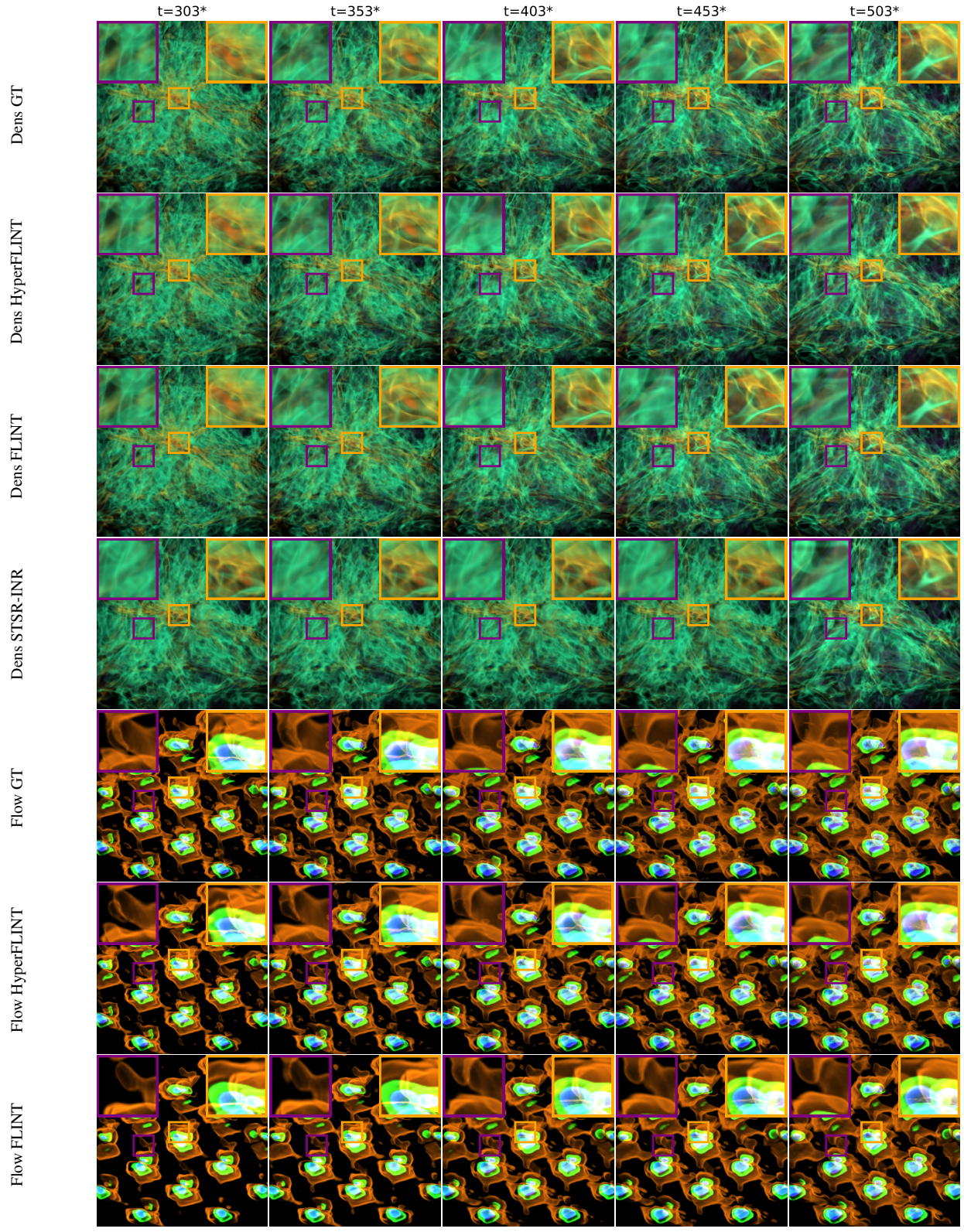


Figure 10: *Nyx: HyperFLINT flow field estimation and temporal density interpolation, 5×. From top to bottom, the rows show GT density, HyperFLINT interpolated density, FLINT interpolation, STSR-INR interpolation, GT flow, HyperFLINT flow estimation, and FLINT flow estimation. 3D rendering was used for the density and flow visualization (● ● ● colors representing x, y, and z flow directions respectively).*

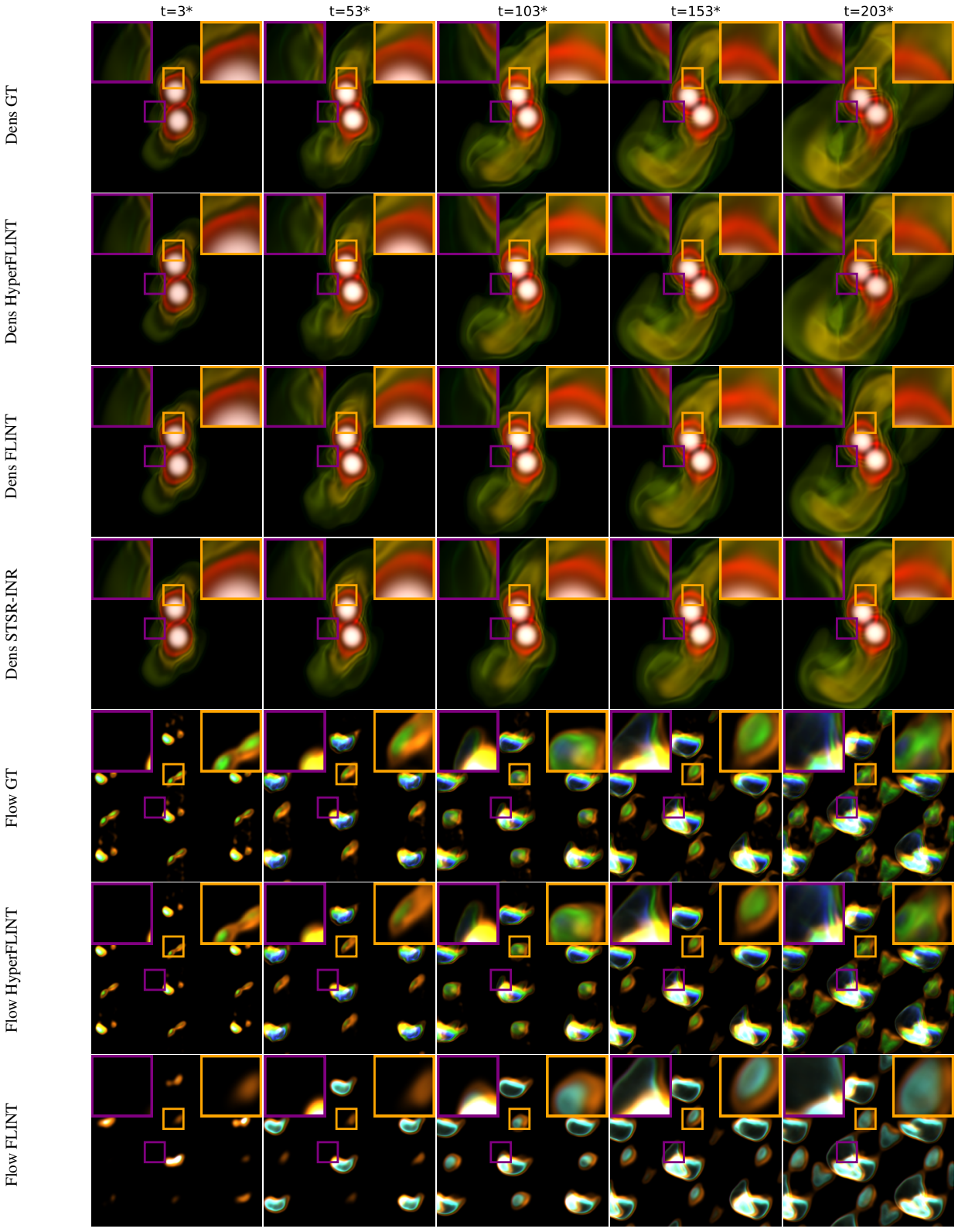


Figure 11: *Castro: HyperFLINT flow field estimation and temporal density interpolation, 5×. From top to bottom, the rows show GT density, HyperFLINT interpolated density, FLINT interpolation, STSR-INR interpolation, GT flow, HyperFLINT flow estimation, and FLINT flow estimation. 3D rendering was used for the density and flow visualization (● ● ● colors representing x, y, and z flow directions respectively).*