Illinois Relativity Group Data Location

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This document specifies the location of the selected simulation data produced by the Illinois Relativity Group. Most of our data are in HDF5 format – this includes magnetic field (Bx.file_*.h5, By.file_*.h5, and Bz.file_*.h5), matter density (rho_b.file_*.h5), velocity (vx.file_*.h5, vy.file_*.h5, and vz.file_*.h5), pressure (P.file_*.h5), and magnetic field magnitude $B^2/4\pi$ (smallb2.file_*.h5). All of the HDF5 files are stored in folders with the name in pattern of 3d_data_XXXXXX, where "XXXXXX" indicates the date data was generated. Black hole horizon data and gravitational wave data are not in HDF5 format. Black hole data are in .gp files. Particle data are in bhns-particles.mon files. Gravitational wave data are in Psi4_rad.mon.* files, which will require Zack's code to extract h_+ and $h_\times$ data. Zack's code can be found at
`Nearline: /projects/sciteam/bakp/Zack_code.tar.gz`.
You will need the extraction radii for each Psi4 files, which can be found in the parameter files (*.par).

1 Working with time

In our simulations, we will refer to the time in code units (t) and iteration number (it). The time step between each frame in the visualization will be limited by the output frequency of the HDF5 files, which can be checked by reading any HDF5 file with the command "`h5ls <filename>`". The HDF5 output frequency is usually every it=256. The output frequency of black hole's horizon data (.gp files) is different and will be more frequent than HDF5 files. The time for each horizon data can be easily determined from the filename. For example, the file `h.t135200.ah2.gp` is the horizon data for 2nd black hole at it=135200. The time used in the particle data will be in code units. The content of the bhns-particles.mon file is listed in four tab-separated columns: t, x, y, and z position of the particles. The relationship between code unit time and iteration number is found using the first and second columns in `BH_diagnostics.ah1.gp`. Alternatively, we can find the relation between t and it by loading a HDF5 file into VisIt and checking the time in the file information window.

In our visualization, we represent the time in t/M. The relation between t/M and code unit time (t) is

$$t/M = t/M_{ADM},$$

where M_{ADM} is the ADM mass of the system. The value of M_{ADM} for each simulation will be listed in the following sections.

2 Binary Black Hole Merger Simulations: LIGO Source GW150914 (2016)

Website: `http://research.physics.illinois.edu/cta/movies/bhbh_sim/`
$M_{ADM} = 1.000$

2.1 Data Location

Here are the main directories to the data. I will refer to these paths as `<rootdir>`.
Estimated total size is 5 TB.

Case A: No Spin
`Nearline: /projects/sciteam/bakp/joh/vpaschal/BHBH_vac/GW150914_large_sep_nospin/`

Case B: Aligned Spin
`Nearline: /projects/sciteam/bakp/joh/vpaschal/BHBH_vac/GW150914_large_sep_aligned/`

Case C: Unaligned Spin
`Nearline: /projects/sciteam/bakp/joh/vpaschal/BHBH_vac/GW150914_large_sep_misaligned/`

Black holes horizon data (h.t*.ah1.gp files for the 1st BH and h.t*.ah2.gp files for the 2nd BH) are located in
`<rootdir>/ABE-bbh-output/`
Gravitational wave data are in the files
`<rootdir>/Psi4_rad.mon.*`
Parameter values are in the file
`<rootdir>/carptest1-lr.par`
More details can be found in the files
`<rootdir>/ABE-bbh-output/BH_diagnostics.ah*.gp`

2.2 Correlation with the Movies

Case A: No Spin

BHBH Evolution Movie
url: `http://research.physics.illinois.edu/cta/movies/bhbh_sim/intro_a.html`

Time	Data Using
0:00 - 2:20	Black holes horizon

Gravitational Wave Movie

url: http://research.physics.illinois.edu/cta/movies/bhbh_sim/gw_a.html

Time	Data Using
0:00 - 0:52	Black holes horizon, gravitational wave($h_\times$)

Case B: Aligned Spin

BHBH Evolution Movie
url: http://research.physics.illinois.edu/cta/movies/bhbh_sim/intro_b.html

Time	Data Using
0:00 - 3:05	Black holes horizon

Gravitational Wave Movie
url: http://research.physics.illinois.edu/cta/movies/bhbh_sim/gw_b.html

Time	Data Using
0:00 - 0:54	Black holes horizon, gravitational wave($h_\times$)

Case C: Unaligned Spin

BHBH Evolution Movie
url: http://research.physics.illinois.edu/cta/movies/bhbh_sim/intro_c.html

Time	Data Using
0:00 - 2:51	Black holes horizon

Gravitational Wave Movie
url: http://research.physics.illinois.edu/cta/movies/bhbh_sim/gw_c.html

Time	Data Using
0:00 - 0:55	Black holes horizon, gravitational wave($h_\times$)

3 Magnetorotational Collapse of Supermassive Stars: Black Hole Formation and Jets (2017)

Website: `http://research.physics.illinois.edu/cta/movies/SMS_2016/`
Paper: `https://arxiv.org/pdf/1704.04502.pdf`
$M_{ADM} = 4.572$
$\rho_{max}(0) = 0.0000000077539552478$

The maximum density at the beginning, $\rho_{max}(0)$, is used for normalization in our density movies.

3.1 Data Location

Estimated total size is 6 TB.

3.1.1 Zero B-field Case

Here are the main directories to the data. I will refer to these paths as `<rootdir>`.

Before BH (Level 0-5) – Total size 0.5TB:

```
Nearline: /projects/sciteam/bakp/lsun11/evolve/run1/
Nearline: /projects/sciteam/bakp/lsun11/8nodes_first/SMS_regrid_1_8nodes/
Nearline: /projects/sciteam/bakp/lsun11/second/SMS_regrid_2/
Nearline: /projects/sciteam/bakp/lsun11/third/SMS_regrid_3/
Nearline: /projects/sciteam/bakp/lsun11/fourth/SMS_regrid_4/
Nearline: /projects/sciteam/bakp/lsun11/fifth/SMS_regrid_5/
```

After BH – Total size 1.5TB:

```
Nearline: /projects/sciteam/bakp/lsun11/PURE_HYDRO_TEST_Speed_Limit_25_20M_escaping_mass/
```

Level indicates different regridding runs. Higher numbers correspond to later times in the run, which have more refined meshes. The data for density, B-field, and velocity (.h5 files) are located in

`<rootdir>/3d_data_XXXXXX/`

where `<rootdir>` is the directory indicated above. The black hole horizon data (h.t*.ah1.gp files) are located in

`<rootdir>/`

The data for particles (for B-field seeding points or fluid elements tracking) are in the file

`<rootdir>/bhns-particles.mon`

Parameter values are in the files

`<rootdir>/nsnstest2_hr.par`

Gravitational wave data are in the files

`<rootdir>/Psi4_rad.mon.*`

3.1.2 Interior-Only B-field Case

Here are the main directories to the data. I will refer to these paths as `<rootdir>`. Estimated total size is 2 TB

Before BH (Level 0-4) – Total size 0.5TB:

```
Nearline: /projects/sciteam/bakp/wongsutt/Lunan/before_collapse_int/0/
Nearline: /projects/sciteam/bakp/wongsutt/Lunan/before_collapse_int/1/
Nearline: /projects/sciteam/bakp/wongsutt/Lunan/before_collapse_int/2/
Nearline: /projects/sciteam/bakp/wongsutt/Lunan/before_collapse_int/3/
Nearline: /projects/sciteam/bakp/wongsutt/Lunan/before_collapse_int/4/
```

After BH – Total size 1.7TB:

```
Nearline: /projects/sciteam/bakp/wongsutt/Lunan/int/
```

For before BH, level indicates different regridding runs. Higher numbers correspond to later times in the run, which have more refined meshes. The data for density, B-field, and velocity (.h5 files) are located in

`<rootdir>/beta100/3d_data_XXXXXX/`

where `<rootdir>` is the directory indicated above for each level.

For after BH, the data for density, B-field, and velocity (*.h5 files) are located in

`<rootdir>/h5data/`

The black hole horizon data (h.t*.ah1.gp files) are located in

`<rootdir>/h5data/horizon/all_horizon/`

For both before BH and after BH, the data for particles (for B-field seeding points or fluid elements tracking) are in the file

`<rootdir>/particle_code/bhns-particles.mon`

Parameter values are in the files

`<rootdir>/nsnstest2_hr.par`

Gravitational wave data are in the files

`<rootdir>/Psi4.mon.sort.*`

Alternatively, we extract the gravitational wave data into .vtk files for both h_+ and $h_\times$ mode. They can be found in the directory:

```
Nearline: /projects/sciteam/bakp/wongsutt/Lunan/int_GW/
```

3.1.3 Interior and Exterior B-field Case

Here are the main directories to the data. I will refer to these paths as `<rootdir>`. Estimated total size is 2 TB

Before BH (Level 0-5) – Total size 0.5TB:

```
Nearline: /projects/sciteam/bakp/wongsutt/Lunan/before_collapse/0/
```

`Nearline: /projects/sciteam/bakp/wongsutt/Lunan/before_collapse/1/`
`Nearline: /projects/sciteam/bakp/wongsutt/Lunan/before_collapse/2/`
`Nearline: /projects/sciteam/bakp/wongsutt/Lunan/before_collapse/3/`
`Nearline: /projects/sciteam/bakp/wongsutt/Lunan/before_collapse/4/`
`Nearline: /projects/sciteam/bakp/wongsutt/Lunan/before_collapse/5/`

After BH – Total size 1.5TB:
`Nearline: /projects/sciteam/bakp/wongsutt/Lunan/ext_int/`

For before BH, level indicates different regridding runs. Higher numbers correspond to later times in the run, which have more refined meshes. The data for density, B-field, and velocity (.h5 files) are located in

`<rootdir>/beta100/3d_data_XXXXXX/`

where `<rootdir>` is the directory indicated above for each level.

For after BH, the data for density, B-field, and velocity (*.h5 files) are located in

`<rootdir>/h5data/`

The black hole horizon data (h.t*.ah1.gp files) are located in

`<rootdir>/h5data/horizon/all_horizon/`

For both before BH and after BH, the data for particles (for B-field seeding points or fluid elements tracking) are in the file

`<rootdir>/particle_code/bhns-particles.mon`

Parameter values are in the files

`<rootdir>/nsnstest2_hr.par`

Gravitational wave data are in the files

`<rootdir>/Psi4.mon.sort.*`

Alternatively, we extract the gravitational wave data into .vtk files for both h_+ and $h_\times$ mode. They can be found in the directory:
`Nearline: /projects/sciteam/bakp/wongsutt/Lunan/ext_int_GW/`

3.2 Starting Time

In this simulation, after each regridding the time will be reset and start at zero again. To get the cumulative time from the beginning, we need to add the time in current regridding level with the starting time of the current level. The starting times are provided below. The time increment dt (in code units) between each output is also different between two levels.

3.2.1 Zero B-field Case

Level	dt (over 256 it)	Starting time (code units)
0	1600	0
1	800	76393.548
2	400	99120.960
3	200	116590.572
4	50	126173.484
5	6.25	130393.440
After BH	6.25	130832.352

3.2.2 Interior-Only B-field Case

Level	dt (over 256 it)	Starting time (code units)
0	1600	0
1	800	106897.265
2	400	116995.898
3	200	127733.398
4	50	136889.648
After BH	6.25	137627.148 *

* After it=133632 in this level, we halved HDF5 output frequency to output every 512 iterations. Therefore, the time increment between each frame is doubled, i.e. dt (over 512 it) = 12.5.

3.2.3 Interior and Exterior B-field Case

Level	dt (over 256 it)	Starting time (code units)
0	1600	0
1	800	108800
2	400	119000
3	200	122800
4	50	140400
5	6.25	141160 *
After BH	6.25	141335 **

* This level is not used in the movie we created, since level 4 completely covers the time during level 5. We provide this data just in case it is needed for higher time resolution.
** Note that the iteration number of the first frame in after bh folder in this case is not zero, but at it=7168. The time at which it=0 for this level corresponds to t=141160.

3.3 Correlation with the Movies

3.3.1 Zero B-field Case

Density Evolution Movie
url: `http://research.physics.illinois.edu/cta/movies/SMS_2016/density_hydro.html`

Time	Data Using
0:00 - 0:26	Level 0 - density
0:26 - 0:31	Level 1 - density
0:31 - 0:38	Level 2 - density
0:38 - 0:55	Level 3 - density
0:55 - 1:25	Level 4 - density
1:25 - 1:26	Level 5 - density
1:26 - 2:35	After BH - density, BH horizon
2:35 - 2:54	After BH - density, velocity, BH horizon
2:54 - 3:44	After BH - density(sliced), BH horizon
3:44 - 3:53	After BH - density(sliced), velocity, BH horizon

Lagrangian Matter Tracer Movie
url: `http://research.physics.illinois.edu/cta/movies/SMS_2016/particles_hydro.html`

Time	Data Using
0:00 - 0:08	After BH - density(sliced), particles, BH horizon

3.3.2 Interior-Only B-field Case

Density and Magnetic Field Movie
url: `http://research.physics.illinois.edu/cta/movies/SMS_2016/density_int.html`

Time	Data Using
0:00 - 0:25	Level 0 - density, magnetic field, particles(B-field seeding points)
0:25 - 0:34	Level 1 - density, magnetic field, particles(B-field seeding points)
0:34 - 0:44	Level 2 - density, magnetic field, particles(B-field seeding points)
0:44 - 1:00	Level 3 - density, magnetic field, particles(B-field seeding points)
1:00 - 1:18	Level 4 - density, magnetic field, particles(B-field seeding points)
1:18 - 2:33	After BH - density, magnetic field, BH horizon
2:33 - 2:49	After BH - density, magnetic field, velocity, BH horizon
2:49 - 3:46	After BH - density(sliced), magnetic field, BH horizon
3:46 - 3:56	After BH - density(sliced), magnetic field, velocity, BH horizon

Lagrangian Matter Tracer Movie
url: `http://research.physics.illinois.edu/cta/movies/SMS_2016/particles_int.html`

Time	Data Using
0:00 - 0:24	After BH - density(sliced), magnetic field, particles, BH horizon

Gravitational Wave Movie
url: `http://research.physics.illinois.edu/cta/movies/SMS_2016/gw_int.html`

Time	Data Using
0:00 - 0:56	gravitational wave(h_+), After BH - density, BH horizon

3.3.3 Interior and Exterior B-field Case

Density and Magnetic Field Movie
url: `http://research.physics.illinois.edu/cta/movies/SMS_2016/density_ext.html`

Time	Data Using
0:00 - 0:30	Level 0 - density, magnetic field, particles(B-field seeding points)
0:30 - 0:40	Level 1 - density, magnetic field, particles(B-field seeding points)
0:40 - 0:49	Level 2 - density, magnetic field, particles(B-field seeding points)
0:49 - 1:12	Level 3 - density, magnetic field, particles(B-field seeding points)
1:12 - 1:36	Level 4 - density, magnetic field, particles(B-field seeding points)
1:36 - 2:42	After BH - density, magnetic field, BH horizon
2:42 - 3:01	After BH - density, magnetic field, velocity, BH horizon
3:01 - 3:51	After BH - density(sliced), magnetic field, BH horizon
3:51 - 4:02	After BH - density(sliced), magnetic field, velocity, BH horizon

Lagrangian Matter Tracer Movie
url: `http://research.physics.illinois.edu/cta/movies/SMS_2016/particles_ext.html`

Time	Data using
0:00 - 0:22	After BH - density(sliced), magnetic field, particles, BH horizon