

# Common Envelope Evolution Involving a Jet

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## 1 INTRODUCTION

Chamandy et al. (2018) as Paper I  
Blackman & Lucchini (2014)  
Federrath et al. (2014)

This document summarizes runs simulating CEE involving a red giant branch (RGB) primary star and a secondary companion star that is launching a bipolar jet. The runs that will be performed with the remainder of the allocation (about 75,000 SUs) are detailed in Table 1.

The current run plan was built when preparing the 2019 XSEDE supplemental proposal. Planned runs are listed in Table 1.

The actual runs on Stampede2 are listed in Table 2

### 1.0.1 Common Envelope Evolution Involving a Jet

We are presently modeling CEE with a jet emanating from the companion star (represented by a point particle in the simulation owing to its relatively small size as compared to the primary giant star). Thus far, we have performed one complete jet run. The orbital evolution is shown in Figure 1.

### 1.1 Background

From Paper I:

- high accretion rate at  $\sim 0.2 - 2 M_{\odot} \text{yr}^{-1}$ 
  - for MS, this is  $10^2 - 10^2$  times Eddington rate, and
  - for WD, this is  $10^4 - 10^5$  times Eddington rate

Questions to answer for jet project:

- How does the jet affect the morphology of the envelope?
- How does the jet affect the ejection of the envelope?
- How does the jet evolve, does it get quenched?
- What is the dependence of these questions on when the jet gets turned on?
  - What is the dependence on accretion rate?
  - Opening angle?

## 2 METHOD

### 2.1 simulation parameters

In `problem.f90`, the following parameters affect the jet:

- `jet_radius`: size of the outflow region, radius of the cones where jet is initialized. in unit of finest level cells = 64 (5d12 cm, or 70.4  $R_{\odot}$ )
- `jet_collimation`: half-angle of the jet cone in radians =  $0.2618 = \pi/12$

- `jet_temp` = 30000 Kelvin
- `jet_index` = 1. exponent of collimation (never changed yet)
- `jet_masslossrate` = 2. in solar mass per year
- `lcorrect` = F Apply conservative correction
- `jet_vrad` = 1000 in km/s (1d8 cm/s), radial velocity of jet
  - *Amy: look for an offset parameter in the source code, which should determine how far from the center point does the jet initialization region actually start.*
  - *Amy: look into the algorithm on how density gets initialized inside the jet initialization region*

### 2.2 setup

Simulation domain is a cubic box with 8d13 cm (1143  $R_{\odot}$ ) on each side. Base grid is 64 per each side. Base grid length is then 1.25d12 cm (17.8  $R_{\odot}$ ).

So a 4-level AMR has its finest grid cell at 7.8d10 cm, about 1  $R_{\odot}$ .

Primary:  $M = 7.298d32$ , starts at the center of the simulation. Initial velocity is calculated from Keplerian velocity for circular orbit (2-body problem). `rc` = 1.676d11.

Secondary:  $M = 1.945d33$  (0.978  $M_{\odot}$ ). `rc` = 1.676d11.

**Do this!!!!** Choices of initial separation and velocity: see table 3.

## 3 CE JET ON STAMPEDE2 - STATUS UPDATE FROM OCTOBER 28, 2019

### 3.1

Submit job, `run_dir_002_second`, linked to source code `/HOME/astrobear_1008`.

Recompiled to use `scrambler.f90` to restart every 5 frames.

### 3.2

Submit job, `run_dir_003_ptclbuff`, linked to code `/HOME/astrobear_1014_C`.

Recompiled to use `scrambler.f90` to restart every 2 frames. Restart from frame 11 (till frame 46, on refinement 4d12). This run has particle buffer around P1, AMR=4. Check mesh in VisIT!

- NOTE: no particle buffer version has 8 frames, in `run_003_run_dir`, linked to `/HOME/astrobear_1008` as well. Run completed last week, so not using `scrambler` restart feature. Need to check mesh in this version as well!!

**Table 1.** Proposed runs in Stampede Supplement 2019-12. Remaining simulation runs and projected node-hours assuming an average of 50 node-hours per frame. Quantities are:  $M_2$ : Mass of secondary;  $\dot{M}/\dot{M}_{\text{Edd}}$ : Accretion rate relative to Eddington value for a  $1 R_{\odot}$  main sequence, if a jet is present; *Initial separation*: Separation between primary and secondary at the beginning of the simulation; *Restart frame*: Frame at which the simulation is restarted from the fiducial RGB simulation or the AGB simulation with no jet; *SUs*: Projected number of service units (node hours); *Data*: Projected storage requirement for simulation output.

|                                   |         | $M_2$           | $\dot{M}/\dot{M}_{\text{Edd}}$ | Initial separation      | Restart frame | Number of frames | SUs    | Data |
|-----------------------------------|---------|-----------------|--------------------------------|-------------------------|---------------|------------------|--------|------|
|                                   |         | ( $M_{\odot}$ ) | ( $M_{\odot}$ )                | ( $R_{\odot}$ )         |               |                  |        | (TB) |
| 1                                 | RGB+Jet | 1               | 1000                           | 73.5                    | 0             | 400              | 20,000 | 20   |
| 2                                 | RGB     | 1               | –                              | 73.5                    | 0             | 400              | 20,000 | 20   |
| 3                                 | RGB+Jet | 1               | 1                              | 49.0                    | 0             | 200              | 10,000 | 10   |
| 4                                 | RGB+Jet | 1               | 1                              | $a(t_{\text{restart}})$ | 50            | 150              | 7,500  | 7.5  |
| 5                                 | RGB+Jet | 1               | 1                              | $a(t_{\text{restart}})$ | 150           | 50               | 2,500  | 2.5  |
| 6                                 | RGB+Jet | 1/2             | 1                              | 49.0                    | 0             | 200              | 10,000 | 10   |
| Test runs and convergence studies |         |                 |                                |                         |               | 100              | 5,000  | –    |
| Totals                            |         |                 |                                |                         |               | 1500             | 75,000 | 70   |

**Table 2.** Status of the planned runs.

| Model | Stp run |         | $M_2$           | $\dot{M}/\dot{M}_{\text{Edd}}$ | $a_i$                   | Restart frame | End frame | Status              | Ambient |
|-------|---------|---------|-----------------|--------------------------------|-------------------------|---------------|-----------|---------------------|---------|
|       | #       |         | ( $M_{\odot}$ ) | ( $M_{\odot}$ )                | ( $R_{\odot}$ )         |               |           |                     |         |
| 0     | 2       | RGB+Jet | 1               | 1000                           | 49.0                    | 0             | 173       | completed           | high    |
| 1     |         | RGB+Jet | 1               | 1                              | 73.5                    | 0             |           | running             | low     |
| 2     |         | RGB     | 1               | –                              | 73.5                    | 0             |           | running             | low     |
| 3     | 6       | RGB+Jet | 1               | 1                              | 49.0                    | 0             | 142       | completed           | high    |
| 4     | 7       | RGB+Jet | 1               | 1                              | $a(t_{\text{restart}})$ | 50            |           | working on the code | high    |
| 5     | 8       | RGB+Jet | 1               | 1                              | $a(t_{\text{restart}})$ | 150           |           | working on the code | high    |
| 6     | 9       | RGB+Jet | 1/2             | 1                              | 49.0                    | 0             | 73        | completed           | high    |
| 7     |         | RGB+Jet | 1               | 10                             | $a(t_{\text{restart}})$ | 50            |           | working on the code | high    |
| 8     |         | RGB+Jet | 1               | 10                             | $a(t_{\text{restart}})$ | 150           |           | working on the code | high    |

| $a_0$    | $a_0$ ( $R_{\odot}$ ) | vy1      | vy2     |
|----------|-----------------------|----------|---------|
| 6.818d12 | 98                    | -2.519d6 | 5.039d6 |
|          | 49                    |          |         |

**Table 3.** combination of initial separations and velocities.

### 3.3

`astrobear_1212_CEJet_run_on_stp2`: Last major modification to the problem module use Shape object to define regions of refinement. The routine of refining has been moved from `ProblemSetErrFlag(Info)` to `ProblemBeforeGlobalStep(n)`.

Both `run_dir_004` and `run_dir_005` are linked to this version. Two runs were set up for the super jet ( $2 M_{\odot}/\text{yr}$ ) starting from  $73.5 R_{\odot}$ , and comparing between jet versus no-jet situations. Killed because wall time was too long on 64 nodes.

### 3.4

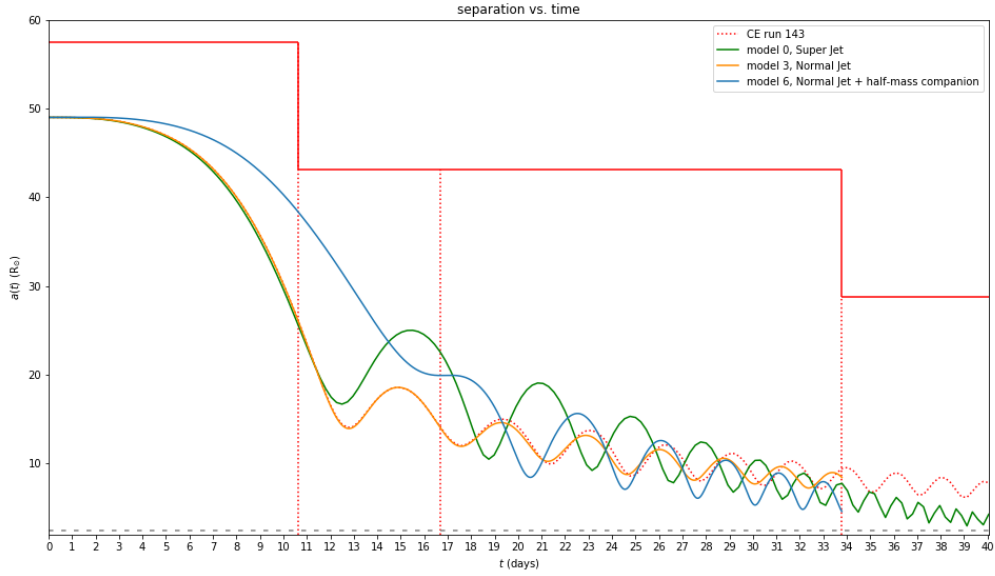
`run_dir_006` and `run_dir_009` use the older version of `astrobear_1008`, with restart every 2 frames. The problem module has been fixed to reattach tracers after restart. See table 2 models 3 and 6.

### 3.5

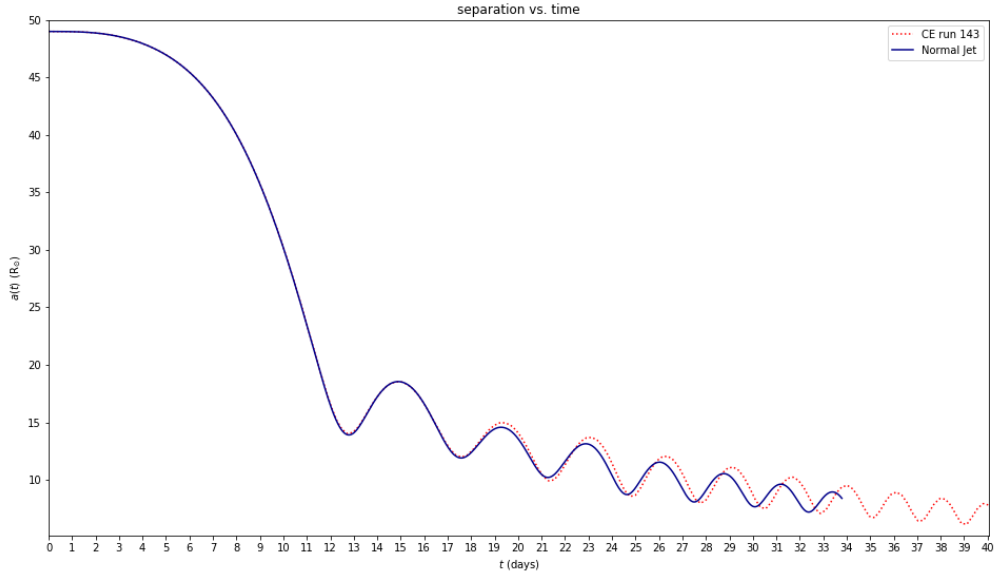
`run_dir_010` and `run_dir_011` linked to code version `astrobear_0112`. Modified from version `astrobear_1212` with added refine-on-density criteria. Submitted to stampede.

## REFERENCES

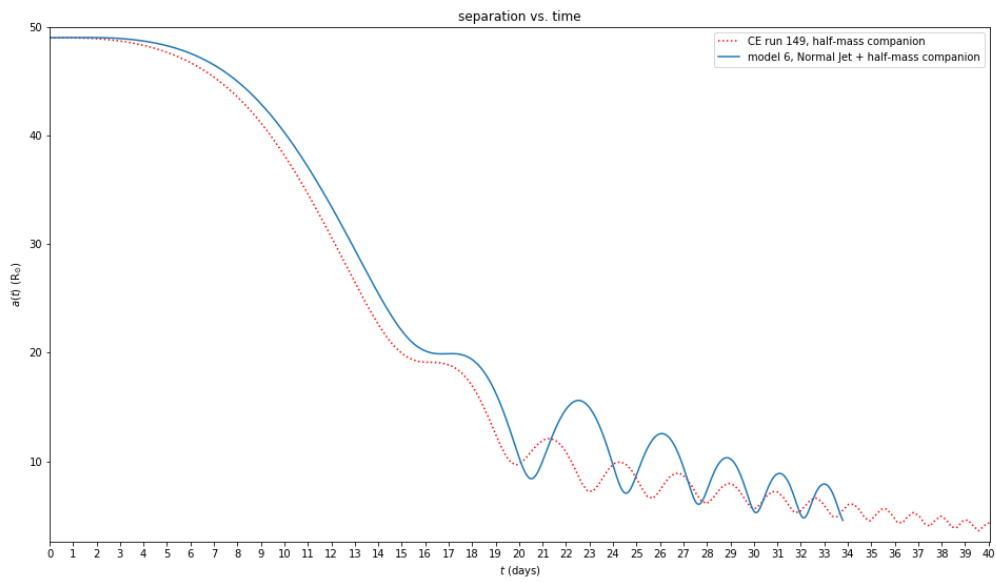
- Blackman E. G., Lucchini S., 2014, *MNRAS*, **440**, L16  
 Chamandy L., et al., 2018, *MNRAS*, **480**, 1898  
 Federrath C., Schrön M., Banerjee R., Klessen R. S., 2014, *ApJ*, **790**, 128



**Figure 1.** Separation between primary core and secondary for runs with (green) and without (orange) jet. The jagged red line shows the radius of the volume refined at the highest AMR level. The jet run has initial separation at  $49 R_{\odot}$  and mass loss rate at  $2 M_{\odot}/\text{year}$ . This figure is preliminary and the curves will become smoother once the full data set (which has higher time-sampling) is incorporated.



**Figure 2.** Compare CE run 143 with Jet model 3.



**Figure 3.** Compare CE run 149 with Jet model 6.