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Common Envelope Evolution Involving a Jet

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Table 1. Eddington accretion rate ($\dot{m}_{\rm Edd}$) and Eddington luminosity ($L_{\rm Edd}$) for a 1 $M_\odot$ star. ϵ is the fraction of rest mass energy that gets radiated away and is proportional to m/R.

	MS	WD
M_* ($M_\odot$)	1	
R_* ($R_\odot$)	1.0	0.01
$\dot{m}_{\rm Edd}$ ($M_\odot$/ yr)	2×10^{-3}	2×10^{-5}
$L_{\rm Edd}$ (erg/s)	1.257×10^{38}	
ϵ	1×10^{-6}	1×10^{-4}

1 INTRODUCTION

This document summarize runs simulating CEE involving a red giant branch (RGB) primary star and a secondary companion star that is launching a bipolar jet.

1.1 Background

Chamandy et al. (2018) shows high accretion rate in CE simulations at $\sim$ 0.2 – 2 $M_\odot\,{\rm yr}^{-1}$. For MS star, this is 10^2 – 10^2 times the Eddington rate, and for WD, this is 10^4 – 10^5 times the Eddington rate. Table 1 summarize the Eddington accretion rate and the Eddington luminosity for a 1 $M_\odot$ companion star.

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 on when the jet gets turned on?
- What is the dependence on accretion rate?

2 LIST OF RUNS

A reduced set of runs is listed in Table 2.

3 RESULTS

REFERENCES

Blackman E. G., Lucchini S., 2014, MNRAS, 440, L16
Chamandy L., et al., 2018, MNRAS, 480, 1898
Chamandy L., Tu Y., Blackman E. G., Carroll-Nellenback J., Frank A., Liu B., Nordhaus J., 2019a, Monthly Notices of the Royal Astronomical Society, 486, 1070–1085
Chamandy L., Blackman E. G., Frank A., Carroll-Nellenback J., Zou Y., Tu Y., 2019b, MNRAS, 490, 3727
Federrath C., Schrön M., Banerjee R., Klessen R. S., 2014, ApJ, 790, 128

4 LEGACY RUNS

This is for book keeping. Match legacy model names to the new run numbers:

We used to have 4 models, all with super high mass loss jets:
- A: 2 $M_\odot$/ yr jet, higher ambient, a_0 = 49 $R_\odot$
- B: 2 $M_\odot$/ yr jet, lower ambient, a_0 = 49 $R_\odot$
- C: 2 $M_\odot$/ yr jet, lower ambient, a_0 = 73.5 $R_\odot$
- D: 2 $M_\odot$/ yr jet, lower ambient, a_0 = 73.5 $R_\odot$

The above names were in use last year since 2019-10-21. Model A has Stp run 002, amd model C has Stp run 003 which failed after the primary became unstable. No more lower ambient run has been planned since then.

For the Stampede proposal, we decided on 8 runs in Table 3. The model numbers are listed in the first column, and they also appear in file names as “SS #".

Runs also carry a sequential number on Stampede2, which are listed in the second column as “Stampede run ###".

We canceled runs planned to start with larger separation. Luke has been working to fix the RLOF problem in CEE simulations.

5 METHOD

5.1 simulation parameters

In `problem.f90`, the following parameters affects 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 radius = 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 starts.*
- *Amy: look into the algorithm on how density gets initialized inside the jet initialization region*

5.2 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.

Table 2. Planned runs.

Model name	Stp run #		M_2 ($M_\odot$)	$\dot{m}_j$ ($M_\odot$/ yr)	$\dot{M}/\dot{M}_{Edd}$	a_i ($R_\odot$)	End frame	Status	Ambient
Super jet	2	RGB+Jet	1	2	1000	49.0	173	completed	high
Normal jet	6	RGB+Jet	1	2×10^{-3}	1	49.0	142	completed	high
Half-mass companion	9	RGB+Jet	1/2	2×10^{-3}	1	49.0	73	completed	high
Rerun super jet	10	RGB+Jet	1	2	1000	49.0	173		high
Rerun fiducial	11	RGB	1	-	-	49.0	173		high
Half-mass fiducial	12	RGB	1/2	-	-	49.0	73		high

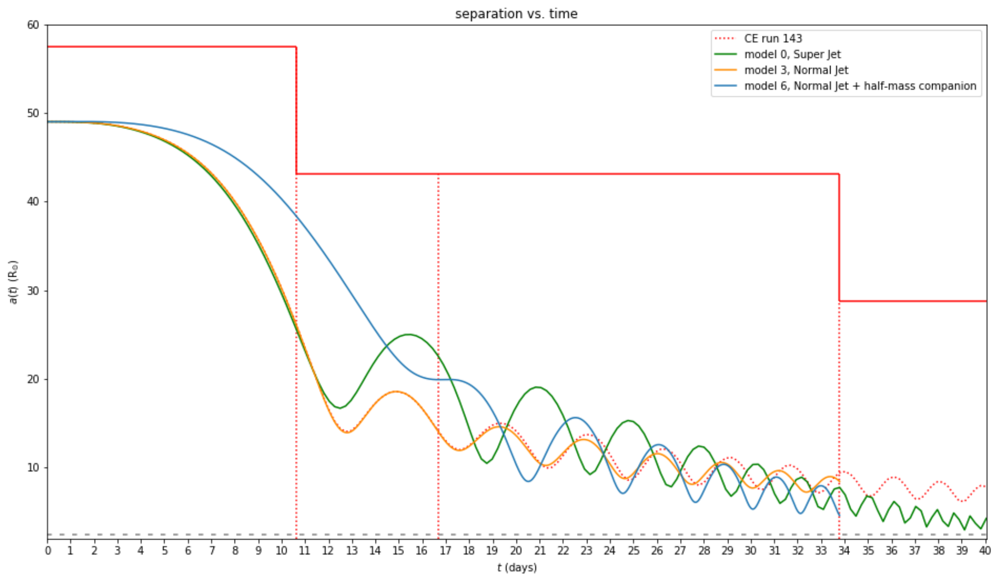

Figure 1. Separation between primary core and secondary for runs with (green) and without (orange) jet. The jagged red line shows the radius of the volume refined at the highest AMR level. The jet run has initial separation at 49 $R_\odot$ and mass loss rate at 2 $M_\odot$/year. This figure is preliminary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

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 4. See my local Jupyter notebook `CEJet-init_two_body_velc`

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

6.1

Submit job, run_dir_002_second, linked to source code `/HOME/astrobear_1008`.
Recompiled to use scrambler.f90 to restart every 5 frames.

6.2

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!!

6.3

`astrobear_1212_CEJet_run_on_stp2`: Last major modification to the problem module use Shape object to define regions of refine-

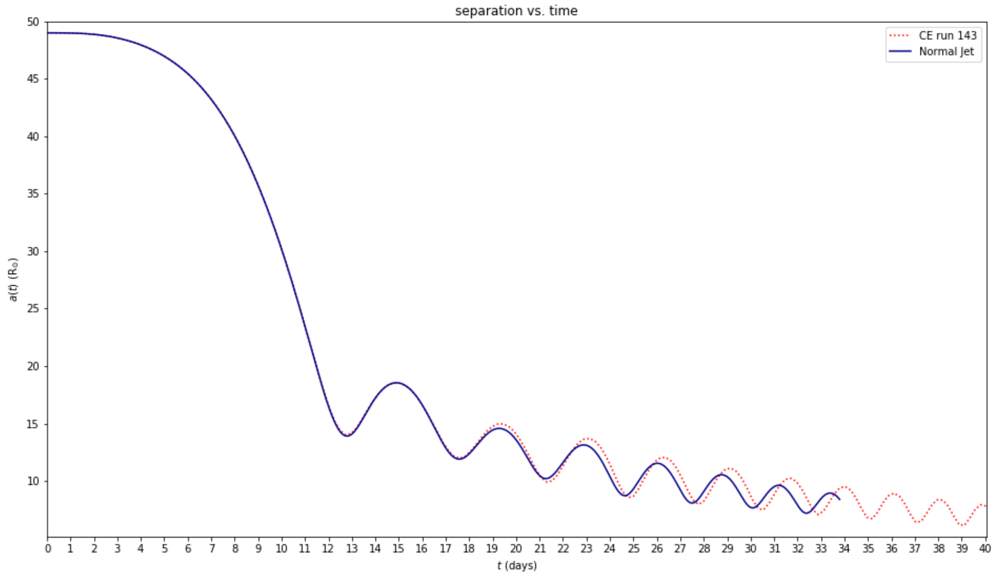

Figure 2. Compare CE run 143 with Jet model 3.

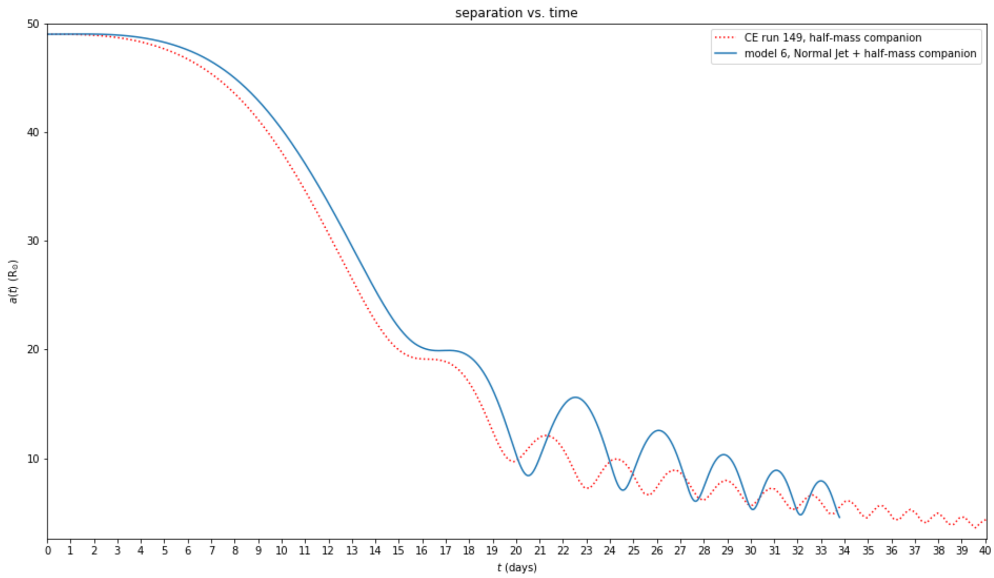

Figure 3. Compare CE run 149 with Jet model 6.

ment. 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 $M_\odot$/ 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.

6.4

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 3 models 3 and 6.

Table 3. Status of the planned runs.

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

Table 4. combination of initial separations and velocities.

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

6.5

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.

KEEP A LIST OF REFERENCES

Chamandy et al. (2018) Paper I
Chamandy et al. (2019a) Paper II, also as the energy paper
Chamandy et al. (2019b) Paper III, also as the force paper
Blackman & Lucchini (2014)
Federrath et al. (2014)