Part I: Consequences of Mass Loss on the Final Fates of Massive Stars

Part II: The BEC Interface

Dorottya Szécsi

Argelander-Institut für Astronomie

Group Meeting, Bonn

12. June 2014

Stellar evolution + mass loss recipes

Stellar evolutionary tracks

- hydrodynamic simulation of an isolated, rotating gas sphere (= star)
- nuclear burning, 1D

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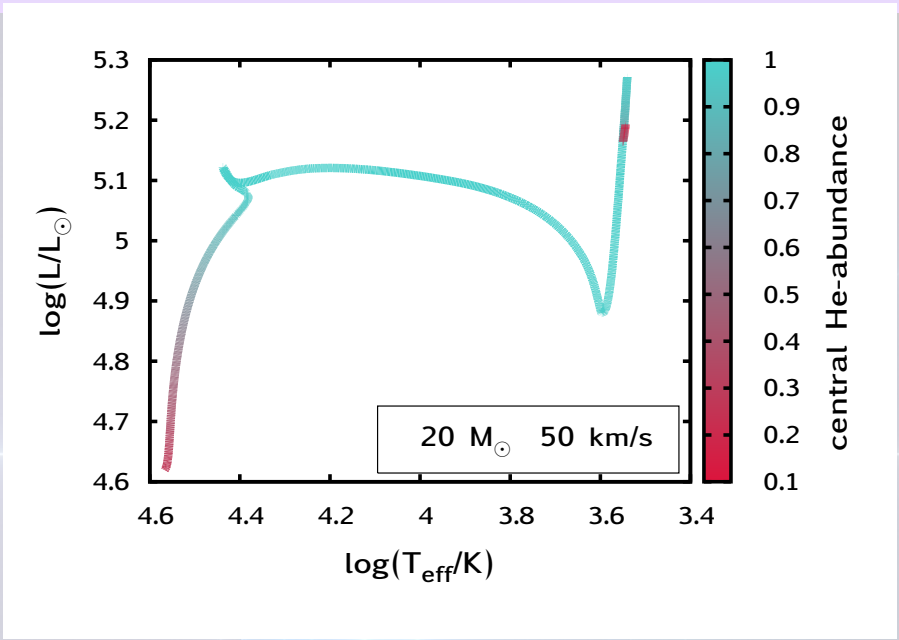

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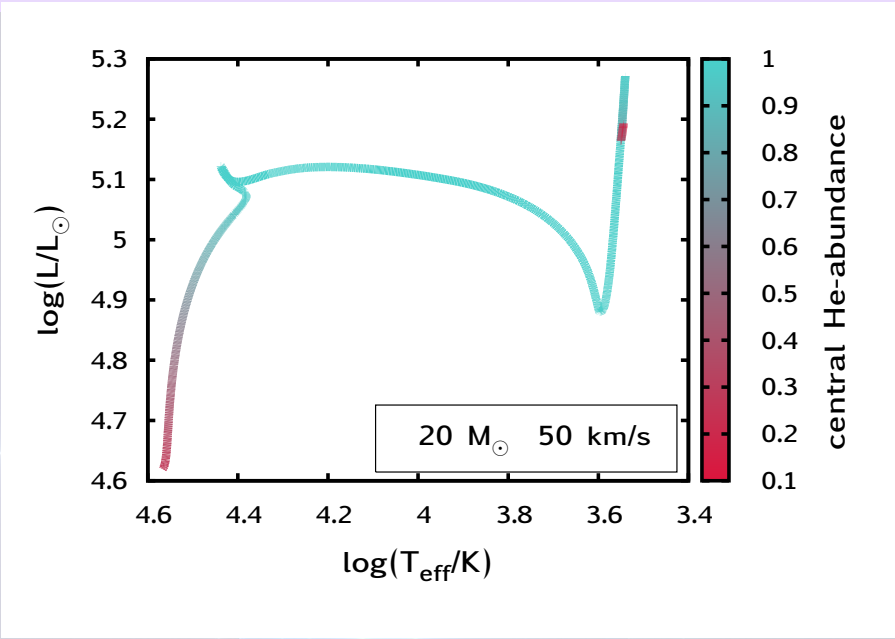

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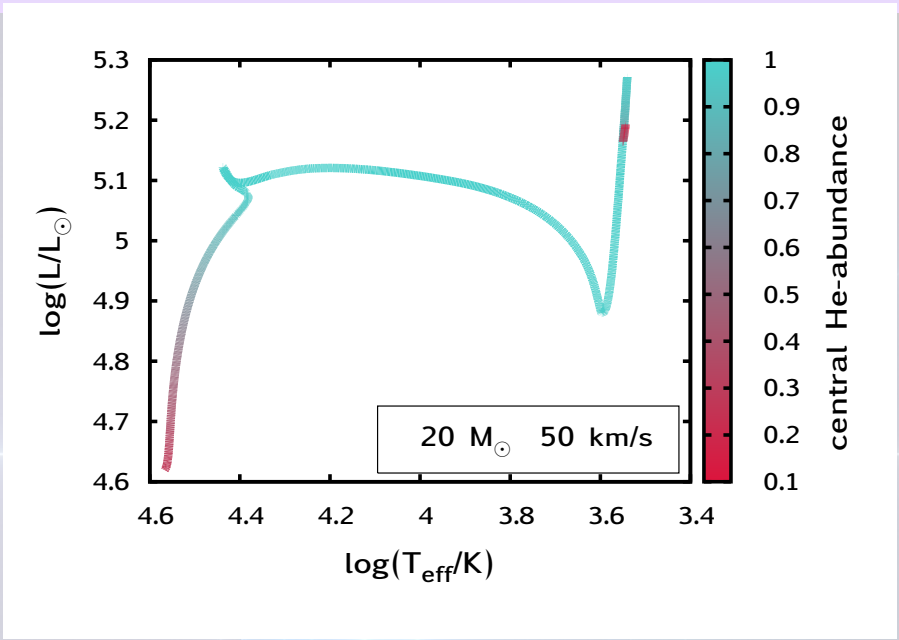

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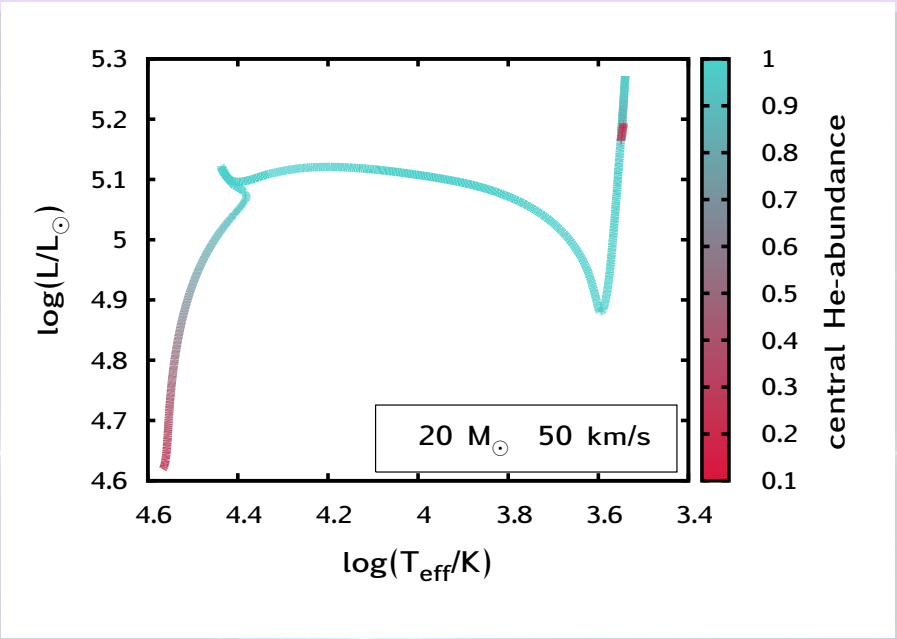

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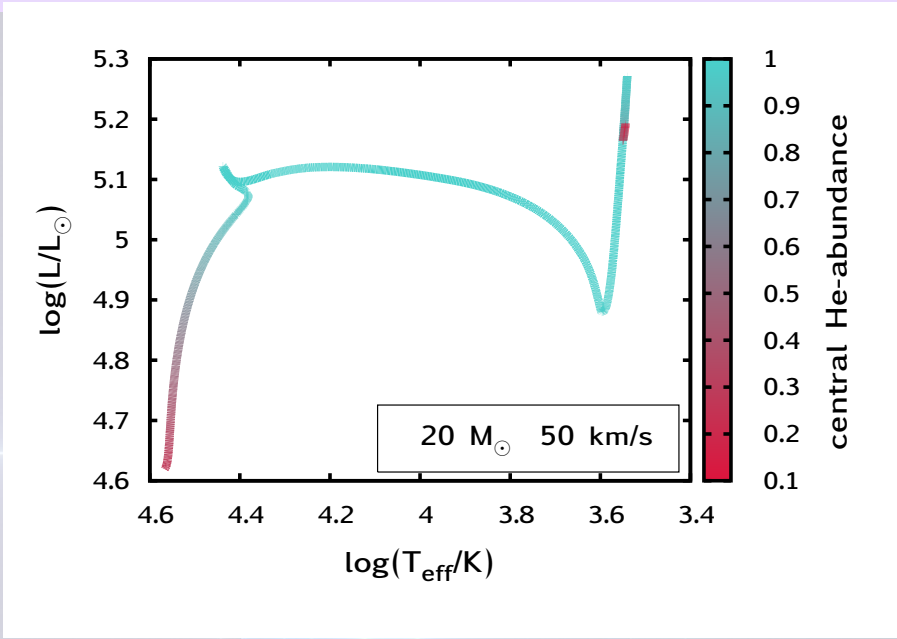

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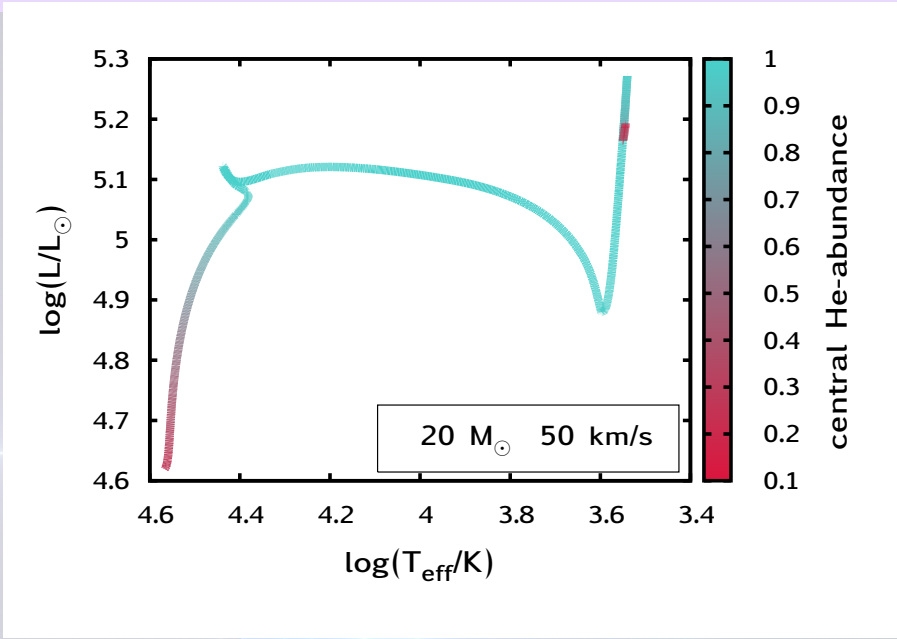

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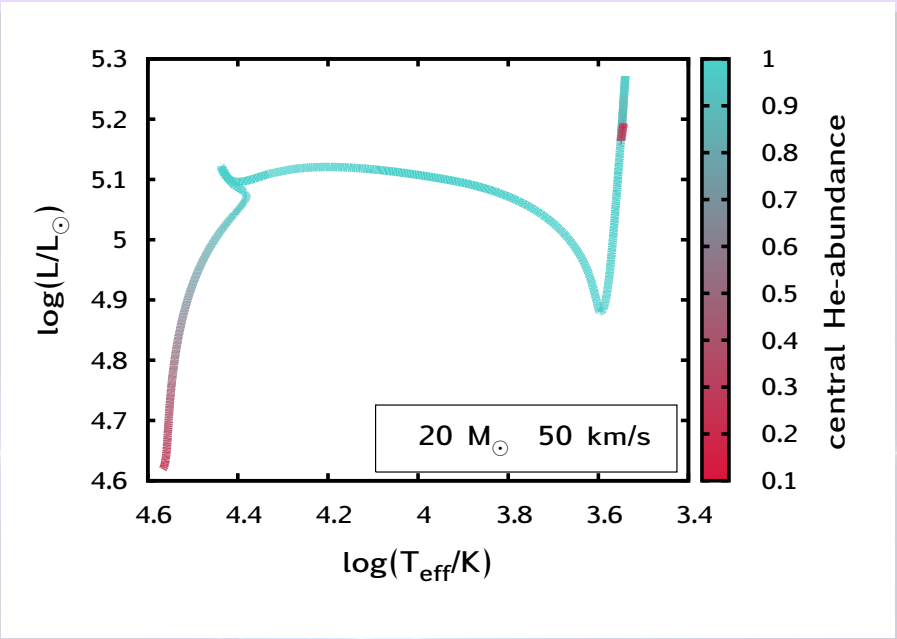

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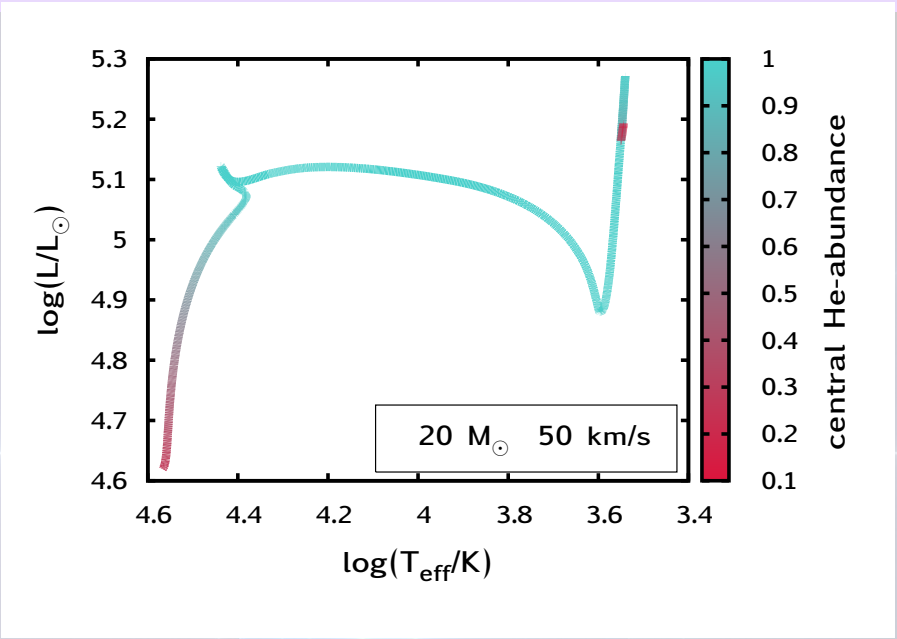

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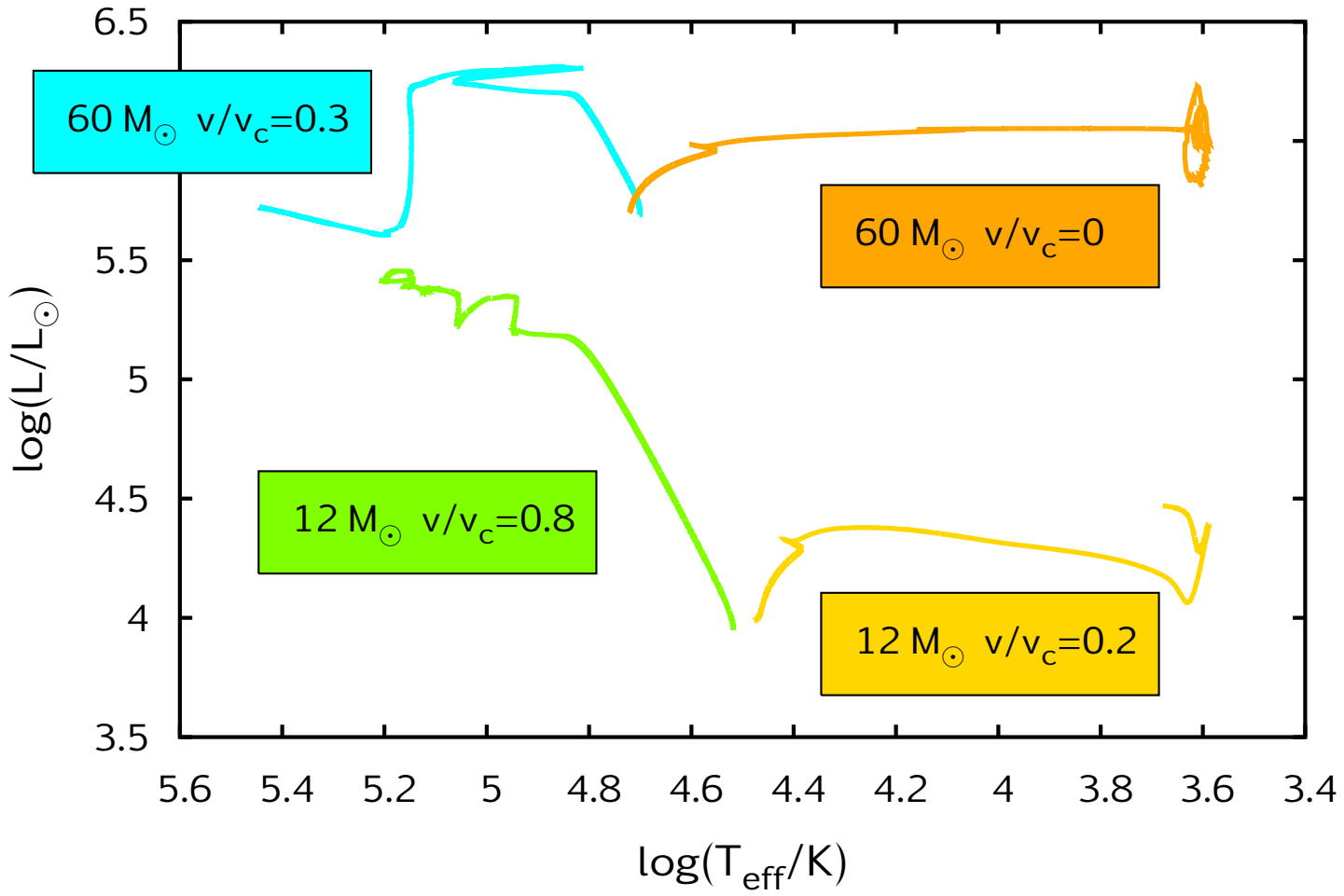
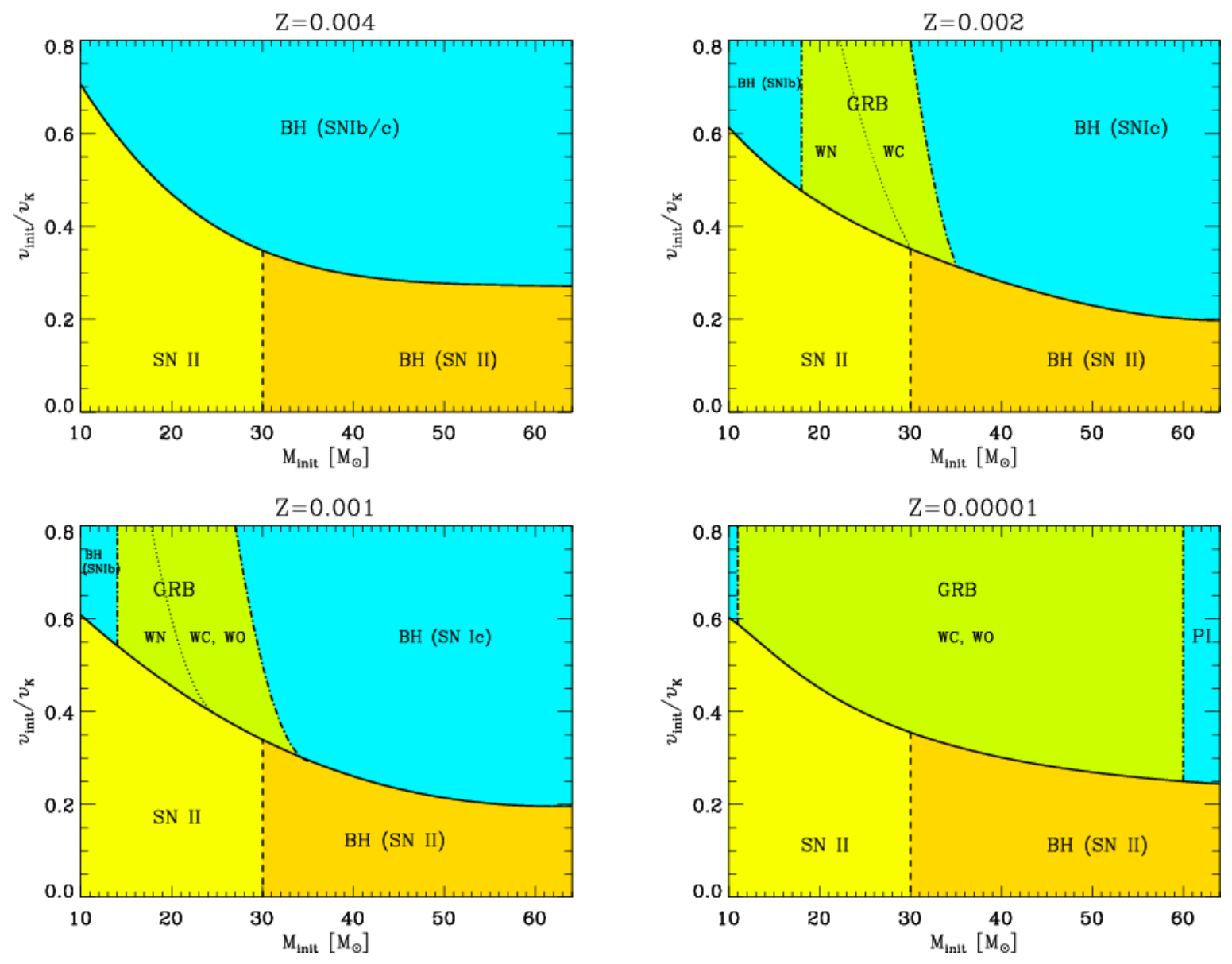
→ fast but approximate
→ mass loss rate has a feedback on the evolution!

Yoon et al. 2006: low Z tracks on the HRD



Yoon'06: lGRB and SN progenitors at different Z



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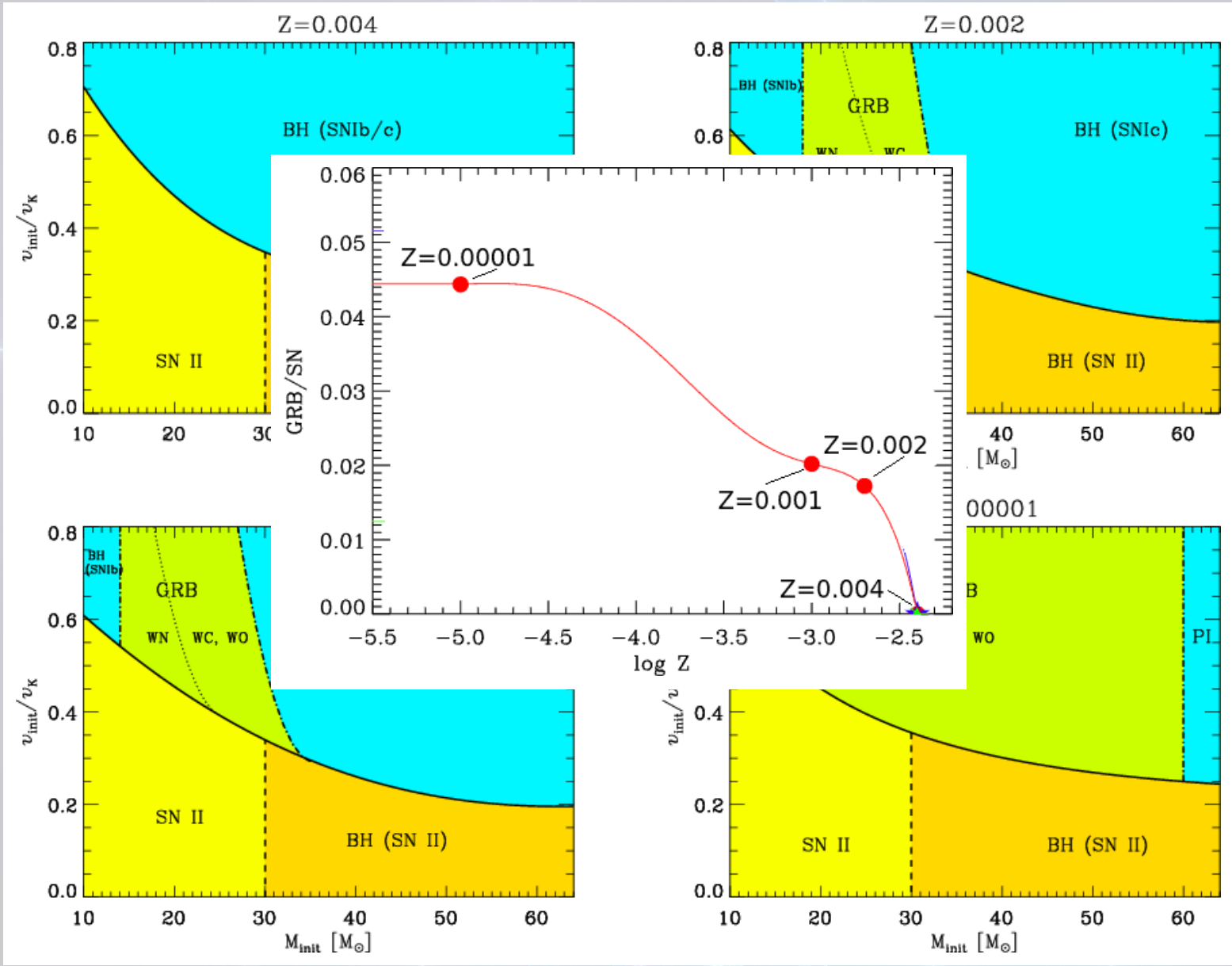

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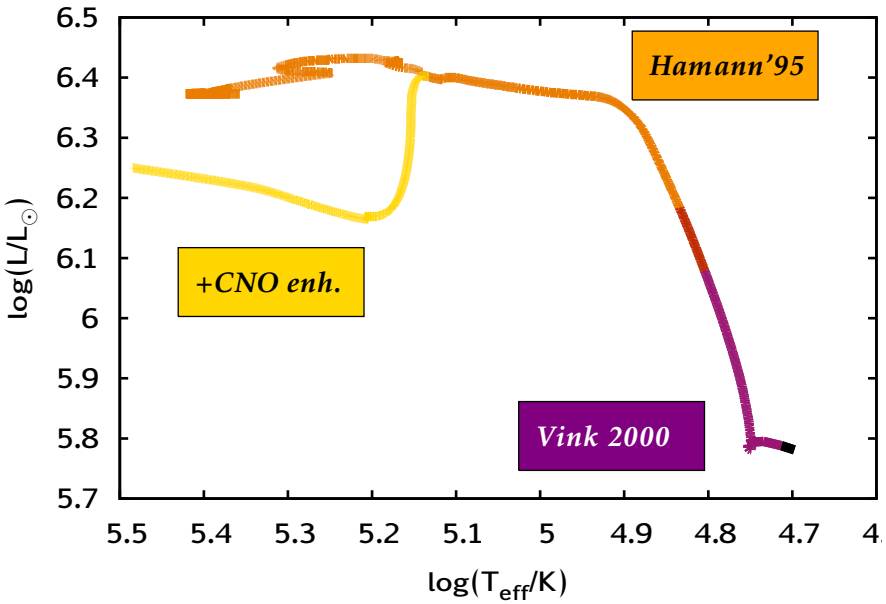
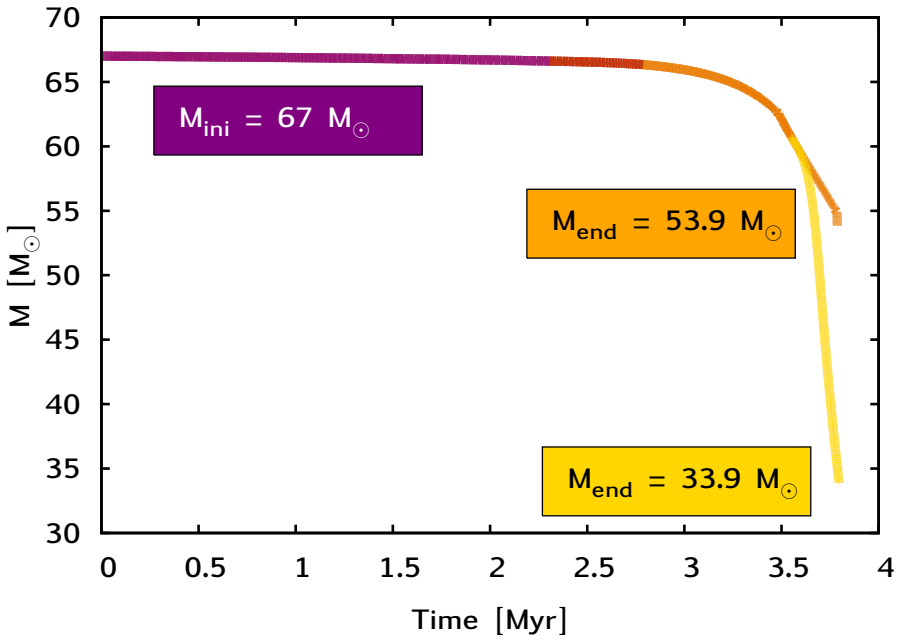
  - How much does it effect the final fate predictions?

With and without CNO enhanced mass loss

67 $M_\odot$ v/v_c=0.3 tracks from *Szécsi et al. 2014*





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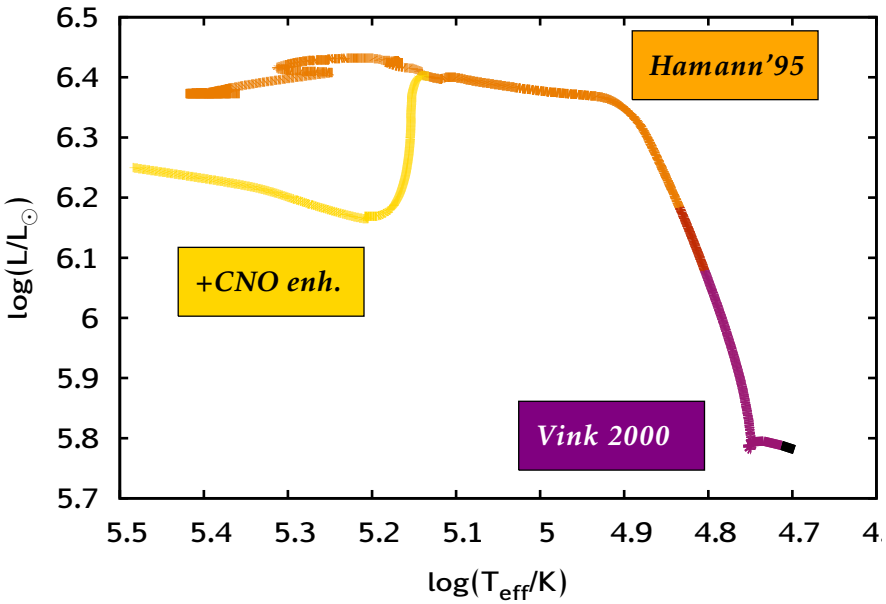

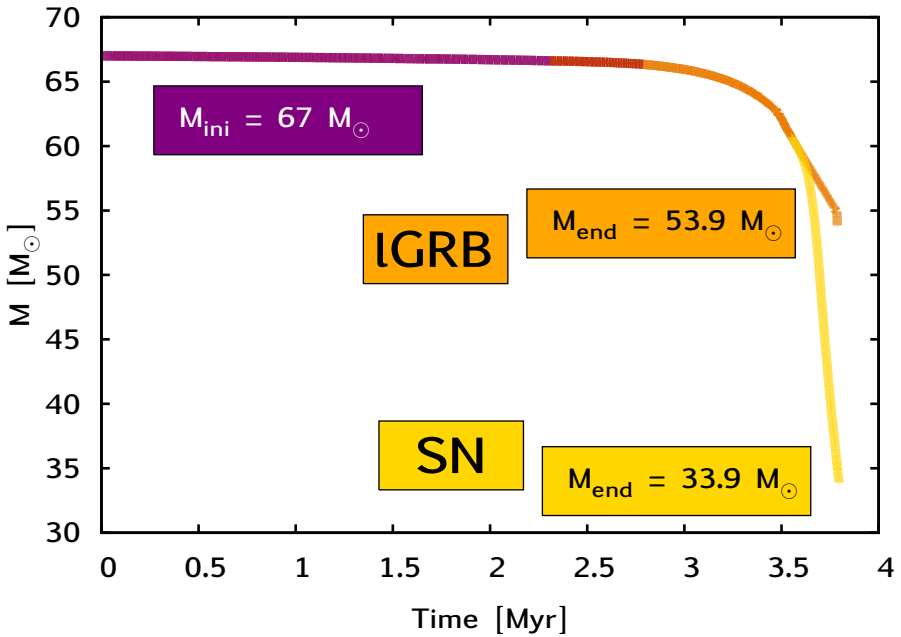

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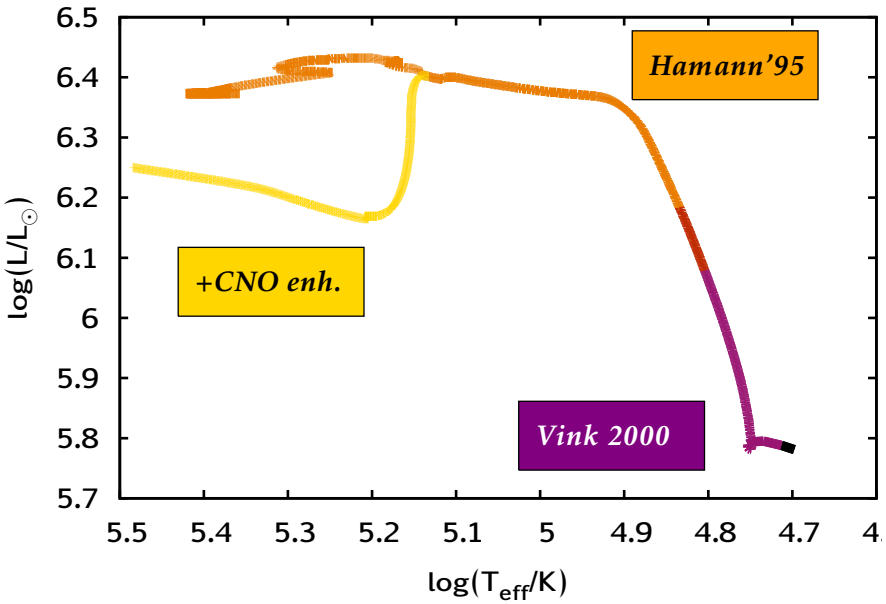

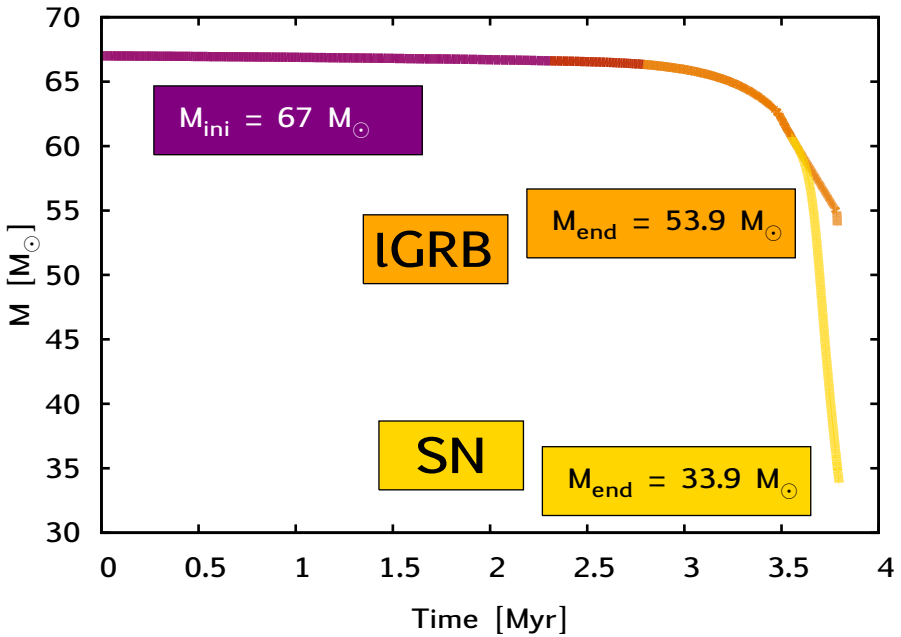

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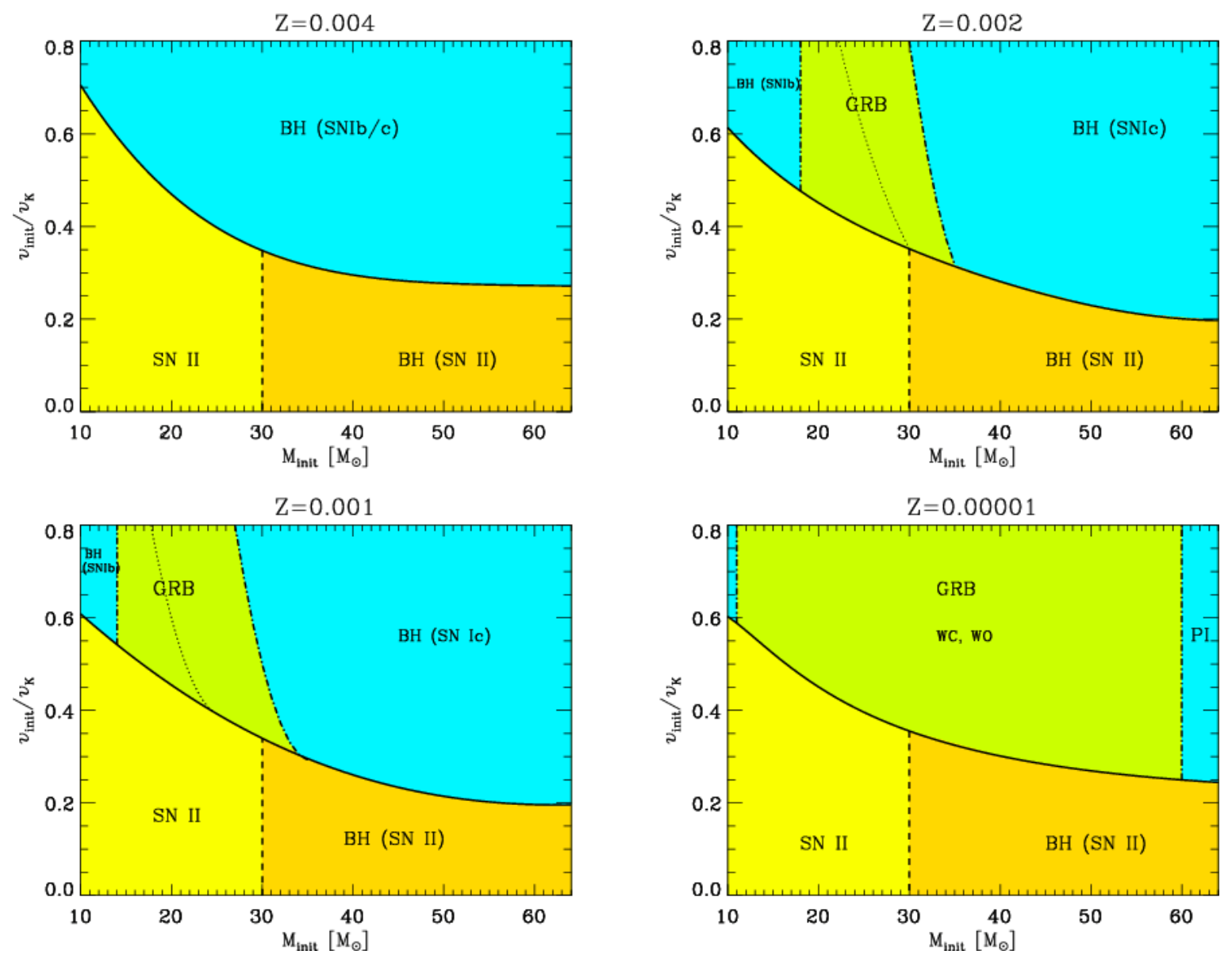
lGRB rate of Yoon'06 – *REVISED*



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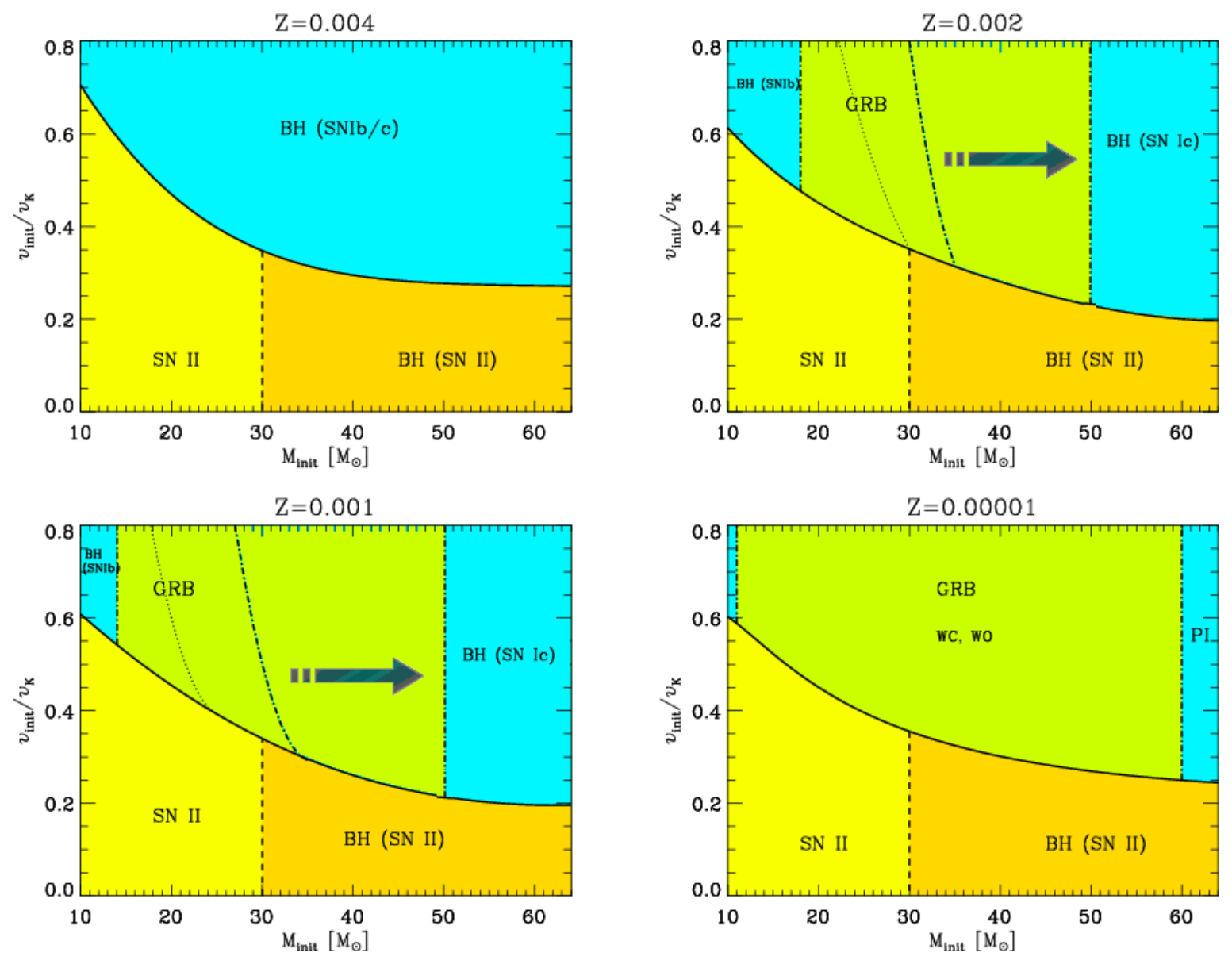

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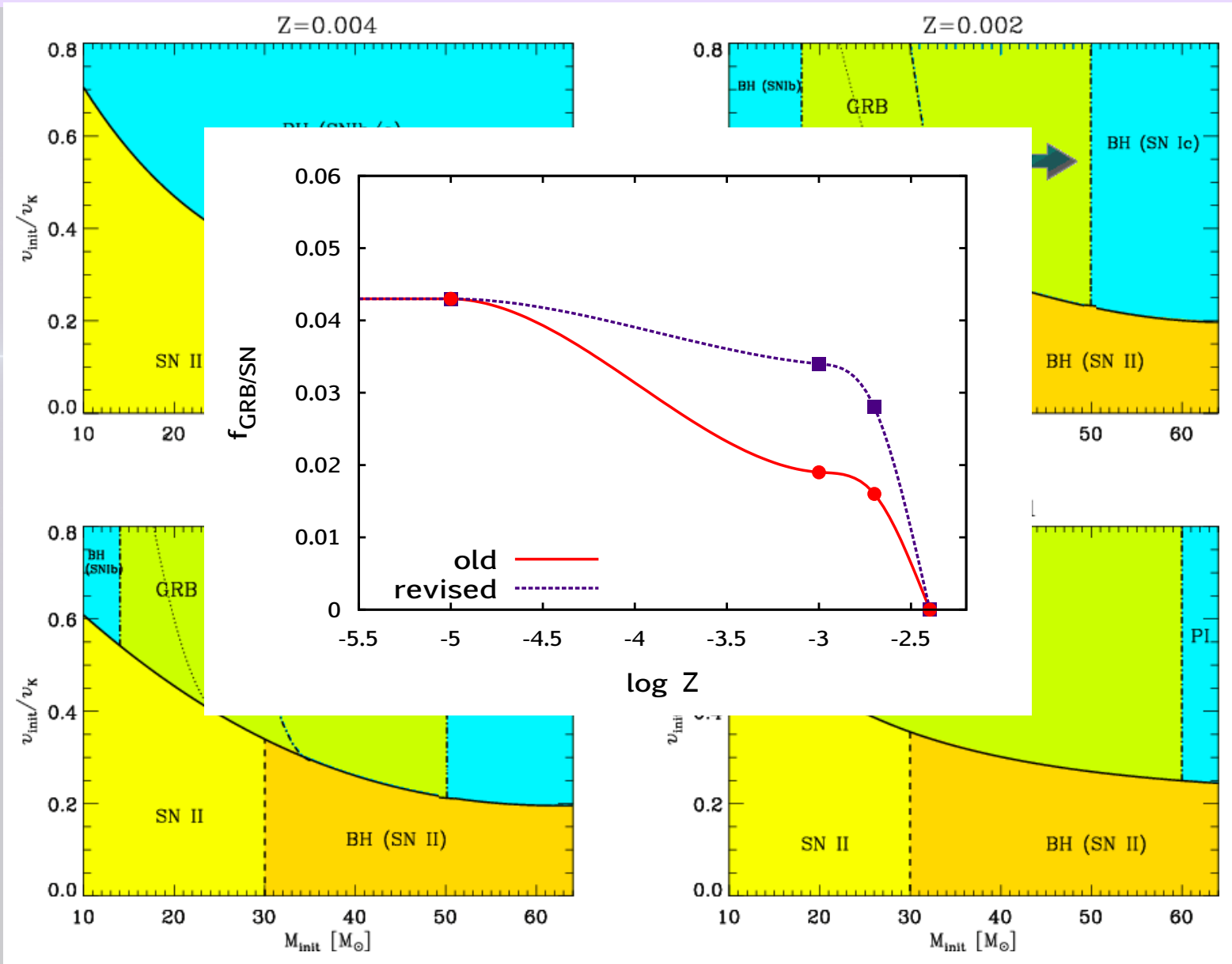

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- Waiting for comments and questions!

WR wind mass loss rates

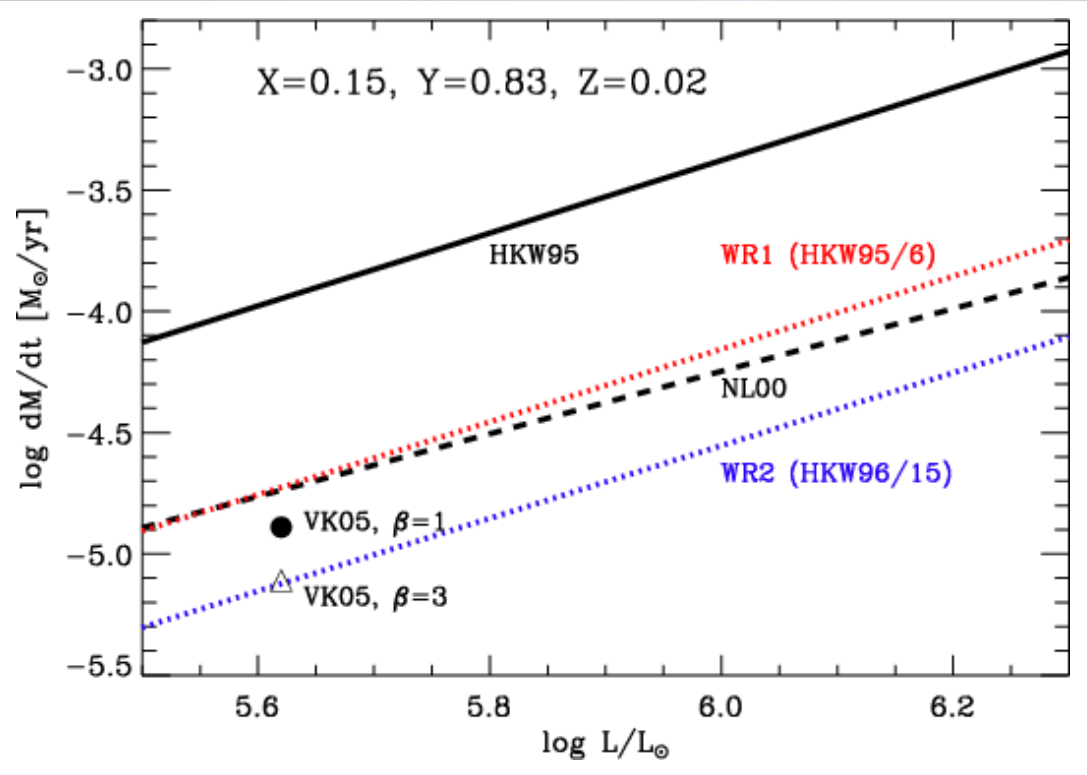

Fig. 1. of *Yoon & Langer 2005*

Wolf-Rayet wind mass loss rates as a function of the stellar luminosity for a given surface composition.

Hamann et al. 1995: HKW95 (solid)
Nugis & Lamers 2000: NL00 (dashed)

HKW/6
HKW/15

Vink & de Koter 2005: VK05
(mass loss rate for WN stars)

The BEC interface

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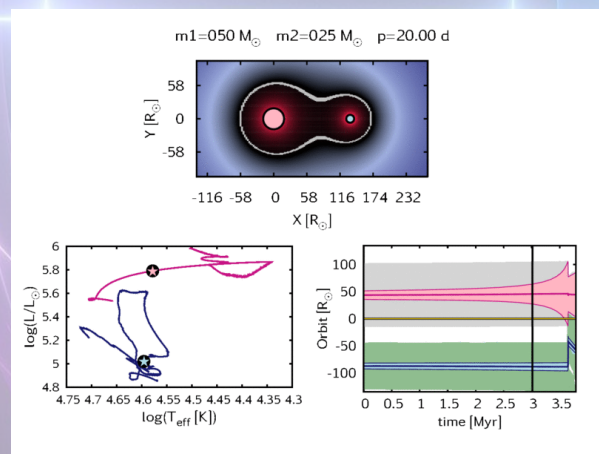


June 12, 2014

The BEC interface: `beci`

BEC = Binary Evolutionary Code

- single and binary stellar systems
- with or without rotation
- developed since the 1970s in Fortran
- very powerful!
- ...but difficult to use

`beci` = the interface for BEC

- automatized + documented
- easy to learn and use
- transferable, extensible
- and more...

Basic commands 1.

Run a new single stellar evolutionary model

```
WORKDIR/BEC$ ./beci -single 20 0.8 50 lmc -run
```

M_{ini}=20 $M_{\odot}$ Z=0.8*Z_{LMC} v_{ini}=50 km/s

Check its status

```
./beci -single 20 0.8 50 lmc -v1
```

Create a HRD

```
./beci -single 20 0.8 50 lmc -visualize -HRD
```

Create a Kippenhahn diagram

```
./beci -single 20 0.8 50 lmc -visualize -kippenhahn
```

Basic commands 2.

Get help any time

```
./beci -help
./beci -help -run
```

Modify the `m.dat` from the command line

```
./beci -single 20 0.8 50 lmc -mdat IOUT=20 DTMIN_1=1.0d0
```

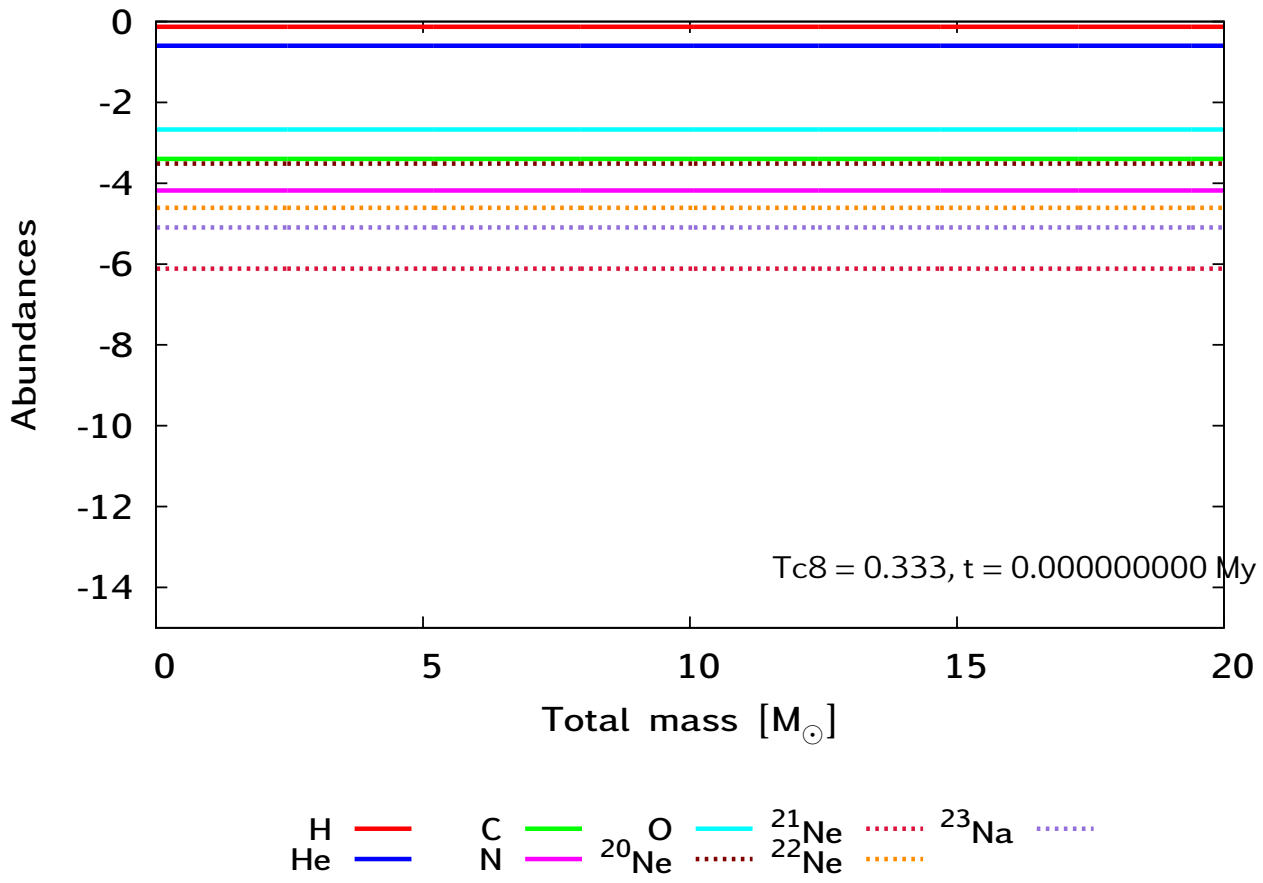
Continue a stopped calculation

```
./beci -single 20 0.8 50 lmc -continue
```

Create an animation of the composition change

```
./beci -single 20 0.8 50 lmc -visualize -composition
```

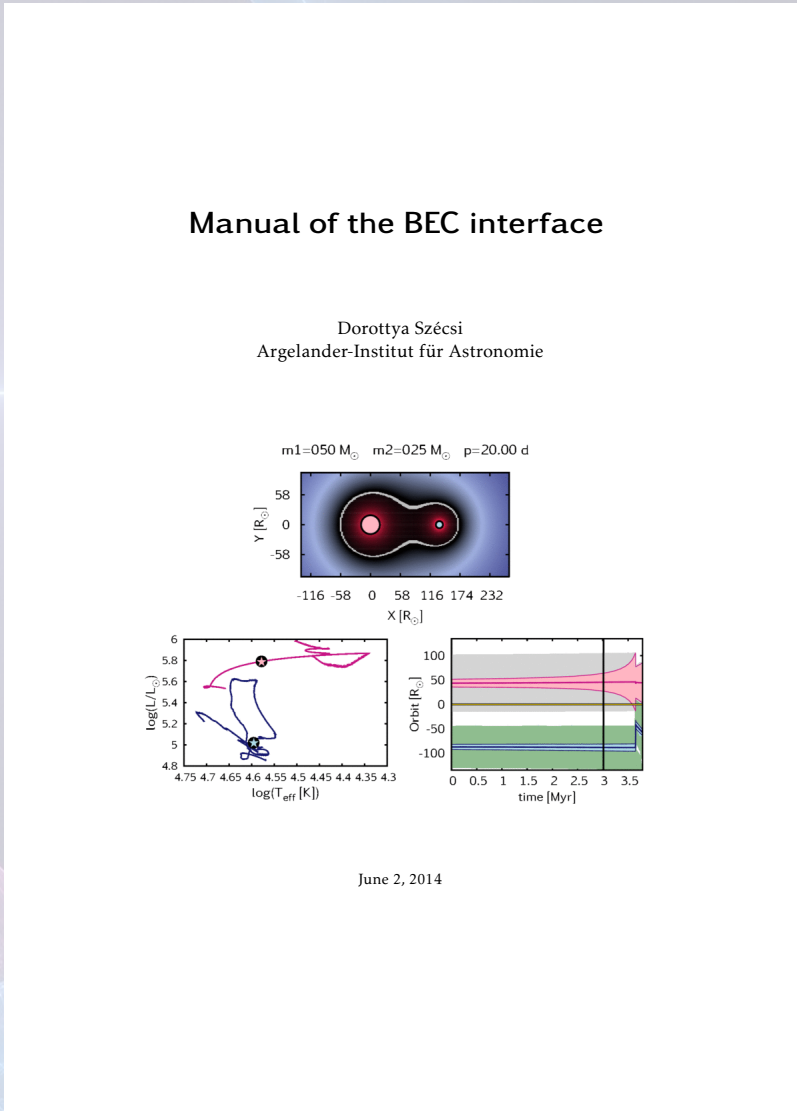
Basic commands: -composition



More options for single stars in the Manual

- `-normal`
- `-extended`
- `-savetozams`
- `-comeclean`
- `-obsHRD`
- `-recipes`
- `-structure`
- `-elements`
- `-YcYs`
- `-yield`
- `-angmom`
- `-PISN`

Also see the `-help` command!



Manual of the BEC interface

Dorottya Szécsi
Argelander-Institut für Astronomie

June 2, 2014

So what about binaries?

Run a new binary stellar evolutionary model

```
./beci -binary 050 025 1.0 20.00 smc -run
```

M^{P}_{ini}=50 $M_{\odot}$ M^{S}_{ini}=25 $M_{\odot}$ Z=1.0*Z_{SMC} p_{ini}=20 days

Check their status

```
./beci -binary 050 025 1.0 20.00 smc -v1 -v2 -v3
```

Visualize them on the HRD and Orbit diagram

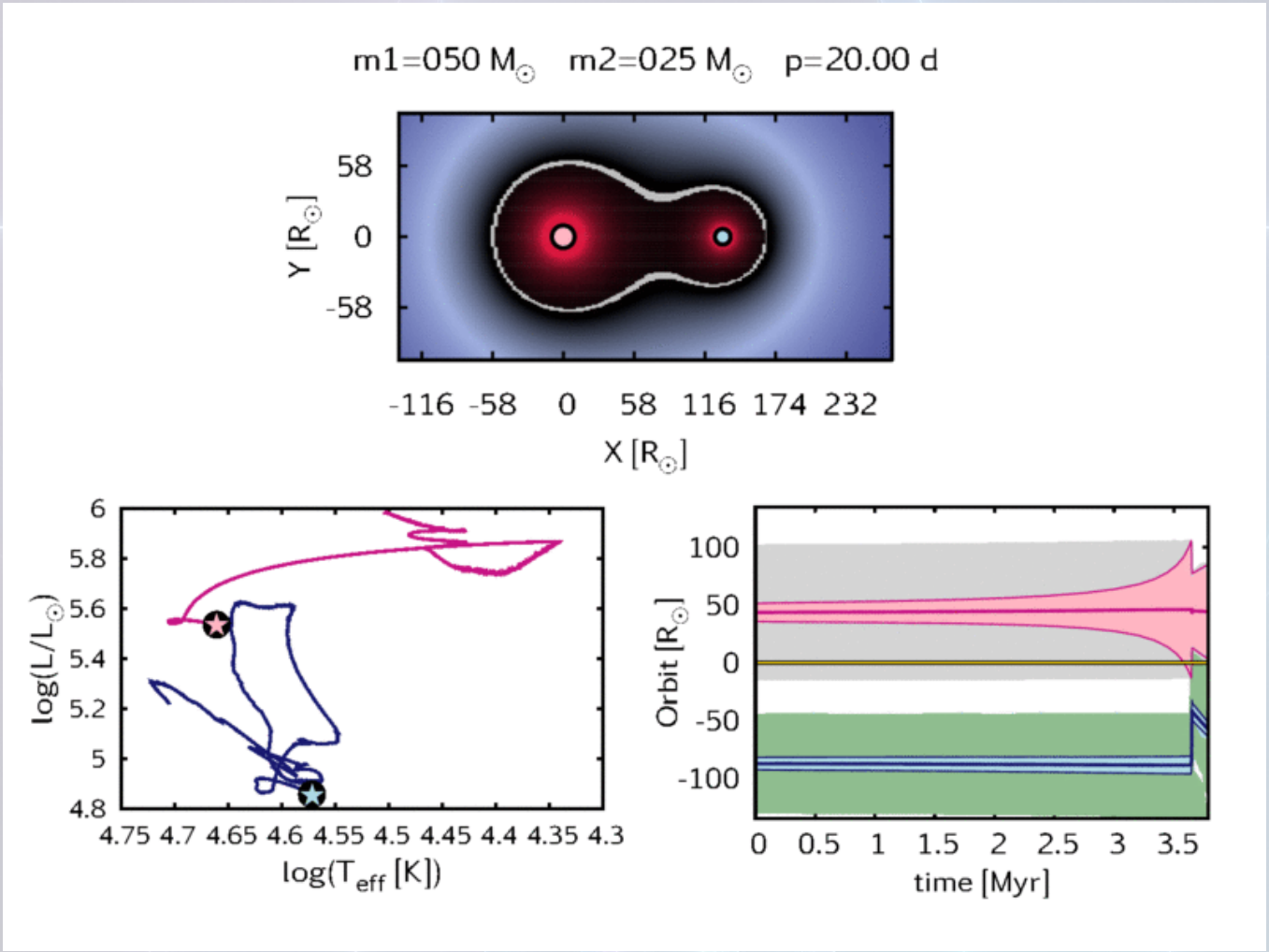
```
./beci -binary 050 025 1.0 20.00 smc -visualize
```

More options for binary stars in the Manual:

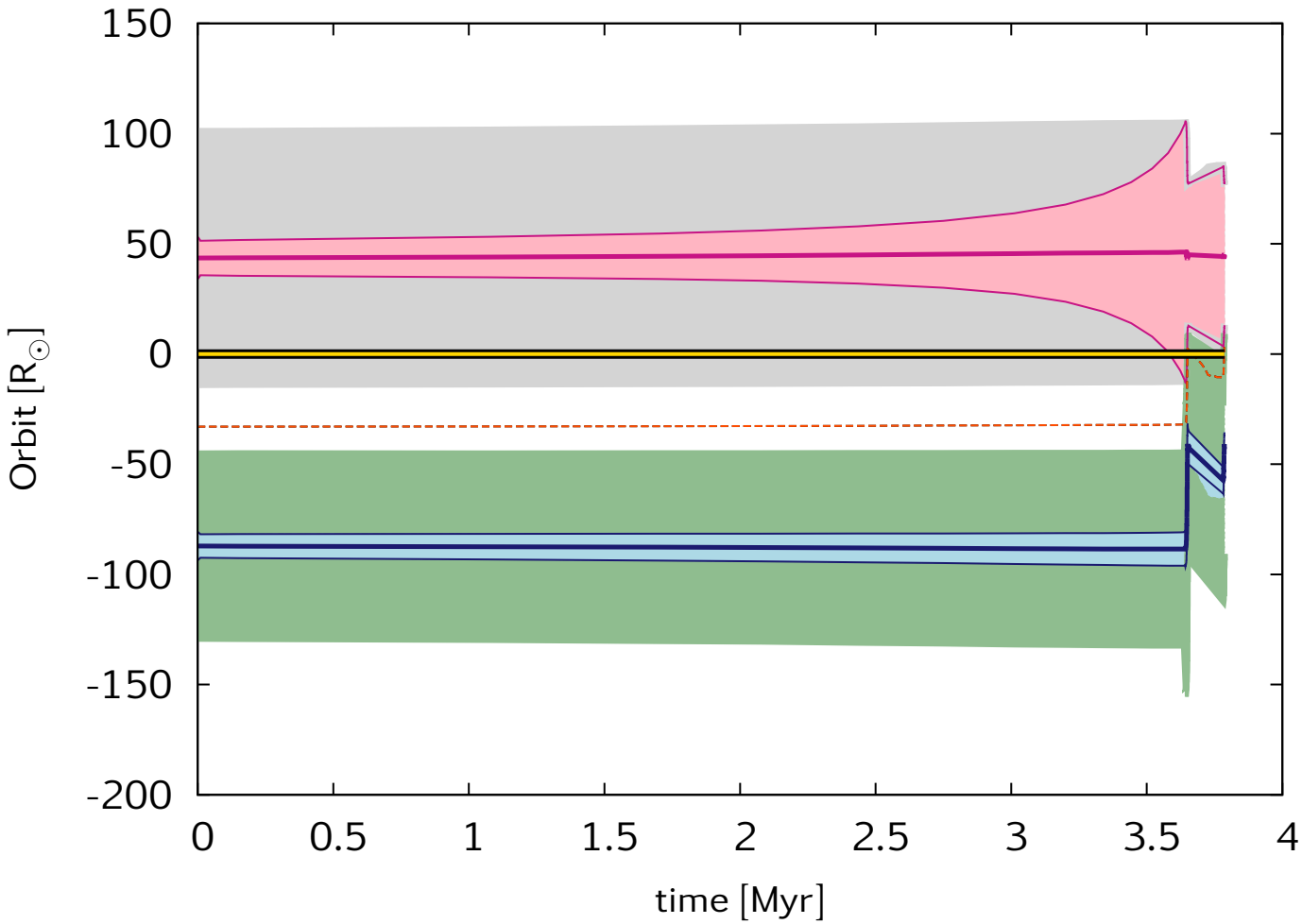
- `-mdat -continue -normal -kippenhahn -composition -recipes -structure -help`

...and more

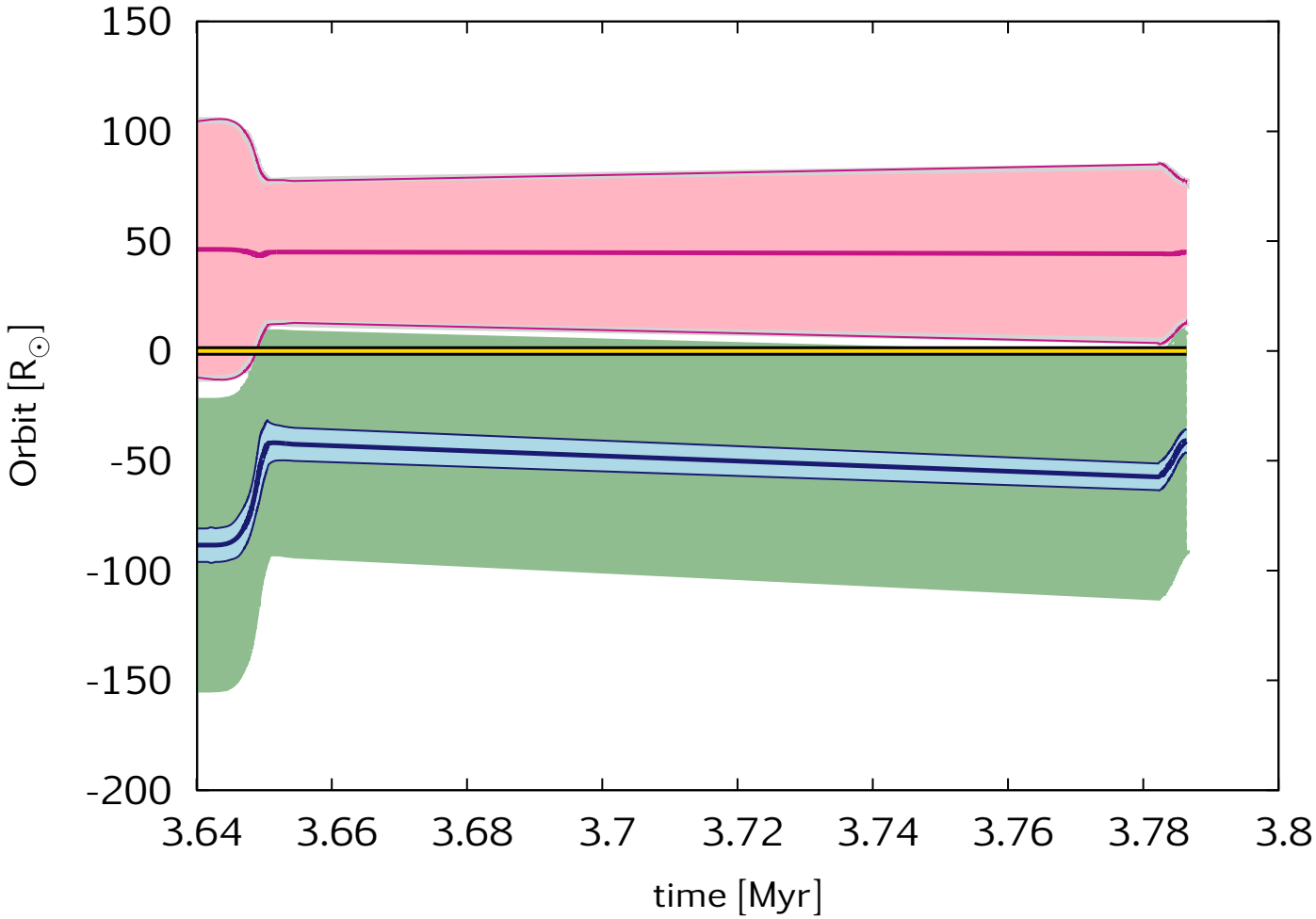
```
./beci -binary 050 025 1.0 20.00 smc -visualize -anim
```



The 'Orbit' diagram



The 'Orbit' diagram - after RLOF



Handling large grids of stars

Grids created by BEC:

- Yoon et al. 2006, 2012 (low Z, Pop.III)
- Brott et al. 2011 (MW, LMC, SMC)
- Köhler et al. 2014 (LMC)
- Szécsi et al. 2014 (IZw18)

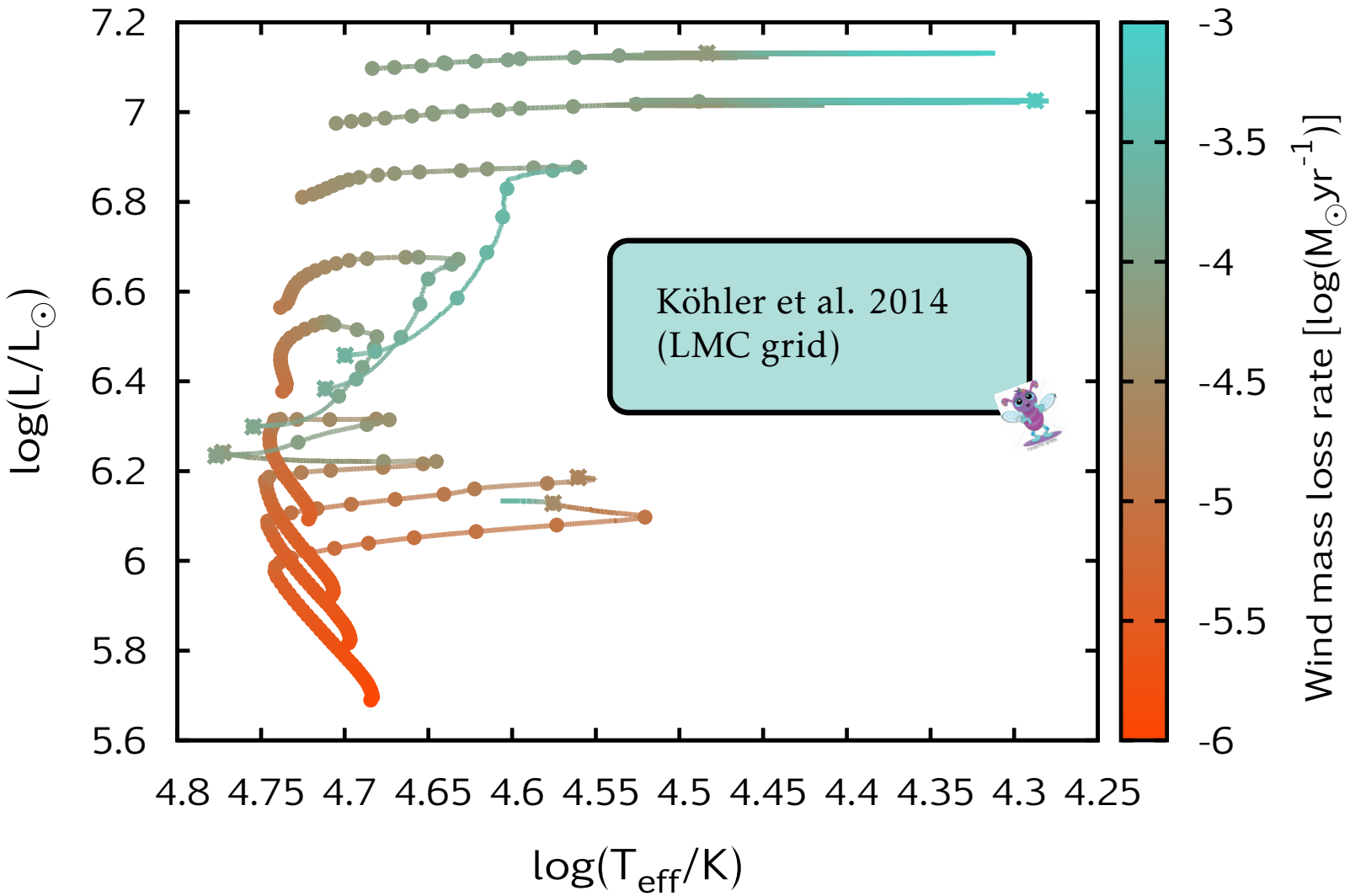
Common HRD of all stars in the grid

```
./beci -grid NameOfGrid -gridHRD
```

More grid commands are available, see the Manual or call

```
./beci -help -grid
```

Handling large grids of stars: -gridHRD



Write your own script!

```
./beci -single 20 0.8 50 lmc -myscript -coolscript Dori
```

```
##coolscript.sh
echo "Hi dear friend $1!"
echo "You are working with the star
M=$m Msun - z=$z x Z_$g - v=$v km/s in $path_BEC/bin"
endMS=`cat ./m$m-z$z-v$v.$g/$m-$z.plot1 | sed 's/D/E/g' | awk '
BEGIN{max=0}{if($3>max){max=$3;tmax=$1}} END{print tmax}'`
endMSMyr=`echo $endMS | awk '{printf "%1.3f", $1/1000000 }'`
echo "Main sequence lifetime:  $endMSMyr Myr"
echo "Bye!  :)"
```

Result

```
Hi dear friend Dori!
You are working with the star
M=20 Msun - z=0.8 x Z_lmc - v=50 km/s in $WORKDIR/BEC/bin
Main sequence lifetime:  7.886 Myr
Bye!  :)
```

Thank you for your attention!

Program files are available here:

`/vol/cstorage/raid18/dorottya/BECinterface`

Copy the files in your $WORKDIR and call

```
./beci -setup
```

Please try it and find bugs!