Exploration of Mass-Radius Relation for Low mass White Dwarfs

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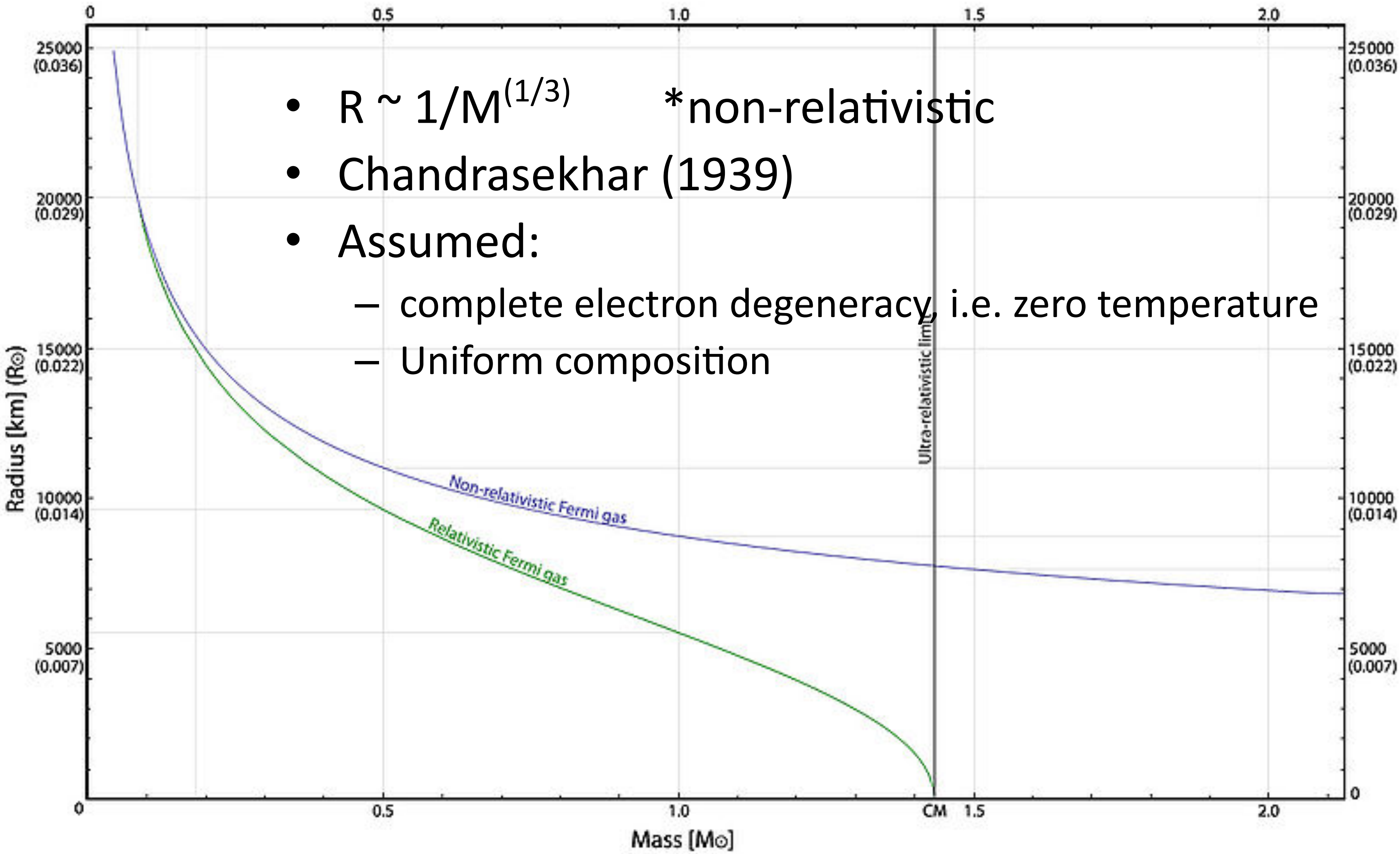
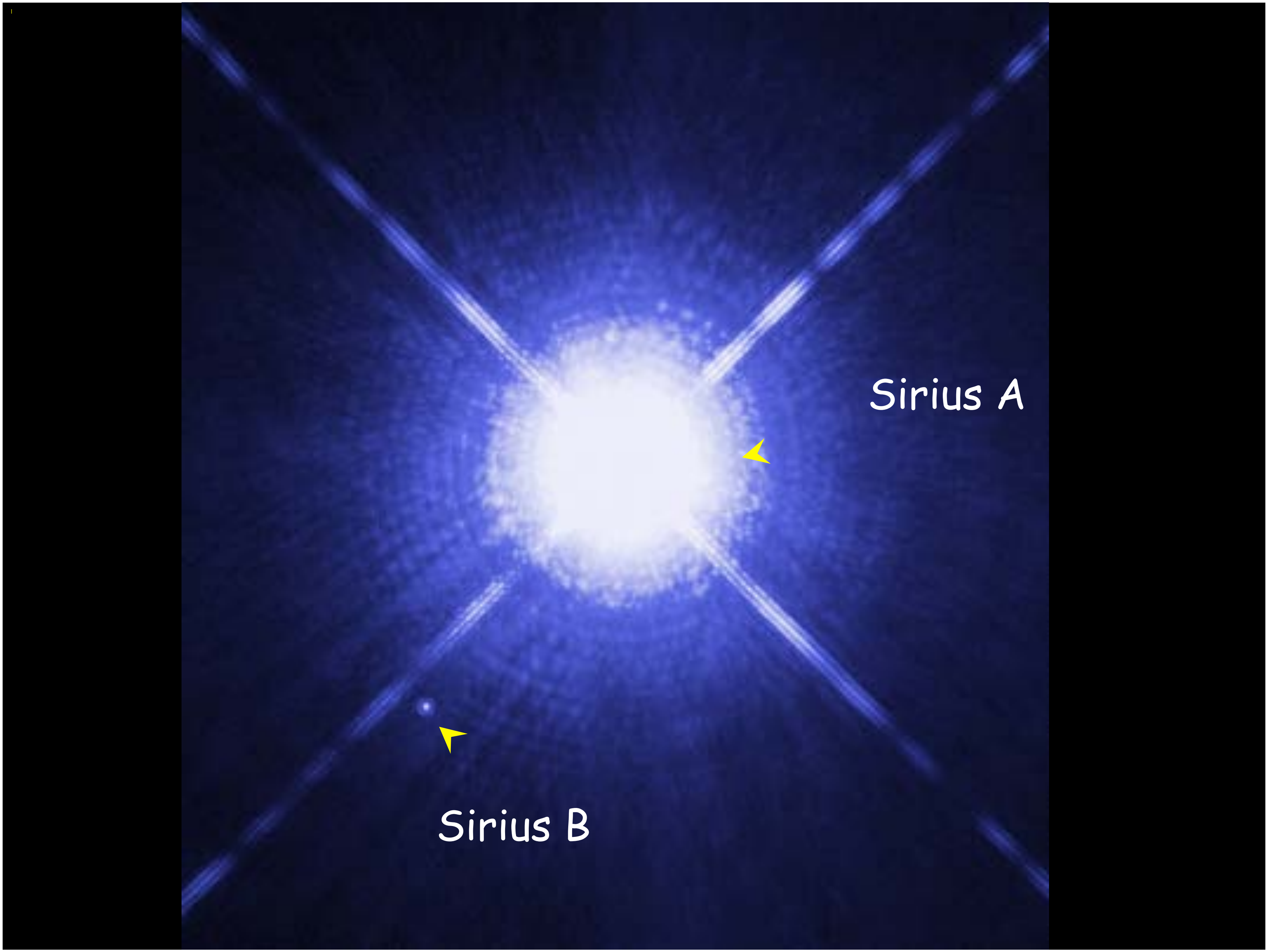
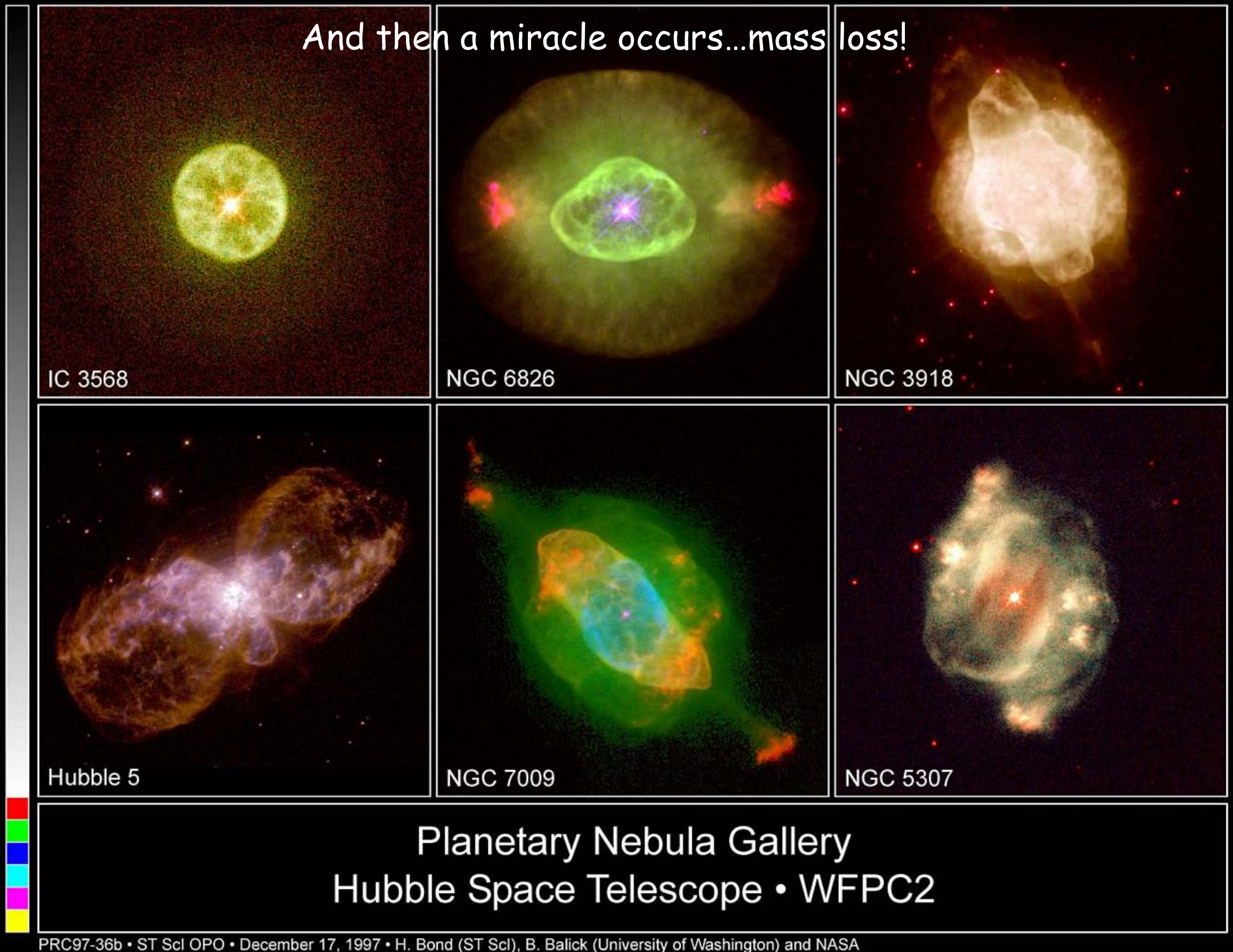
Mass-Radius relation for WD

- $R \sim 1/M^{(1/3)}$ *non-relativistic
- Chandrasekhar (1939)
- Assumed:
  - complete electron degeneracy, i.e. zero temperature
  - Uniform composition




Sirius A
Sirius B

And then a miracle occurs…mass loss!



More than 97% of stars in our galaxy are or will become White Dwarfs!

Wiagra

Normal Mass vs Low Mass White Dwarfs

Normal Mass	**Low Mass**
0.5 - 0.6 $M_\odot$	< 0.4 $M_\odot$
Carbon-Oxygen Core	Helium Core
High gravity: log_g=8.00	Lower Gravity: log_g= ~6.0 to 7.0
Dense envelope	“Fluffy” envelope

Low mass white dwarfs have a lot more hydrogen and thus they are considerably larger in radius!

Recent Discovery of very low-mass White Dwarfs

- If they are the product of single star evolution, then they would be over 100 billion years old.
- These White Dwarfs must be products of binary star evolution.
- We expect (and find!) many of these stars to still be in binary systems.

How accurate?

- “A 12 Minute Orbital Period Detached Eclipsing Binary”
- Two WD: 0.65 $M_{\odot}$ and 0.25 $M_{\odot}$
- Radius of 0.25 $M_{\odot}$ is known to ±5%

We would need to know the mass to ±0.001$M_{\odot}$ in order to test the M-R relation for low mass WD (lmwd)

Modules for Experiments in Stellar Astrophysics (MESA)

- MESA is an open-source code! You can download and install it onto your computer: http://mesa.sourceforge.net/
- MESA allows us to simulate the evolution of a star from its formation until it becomes a White Dwarf.

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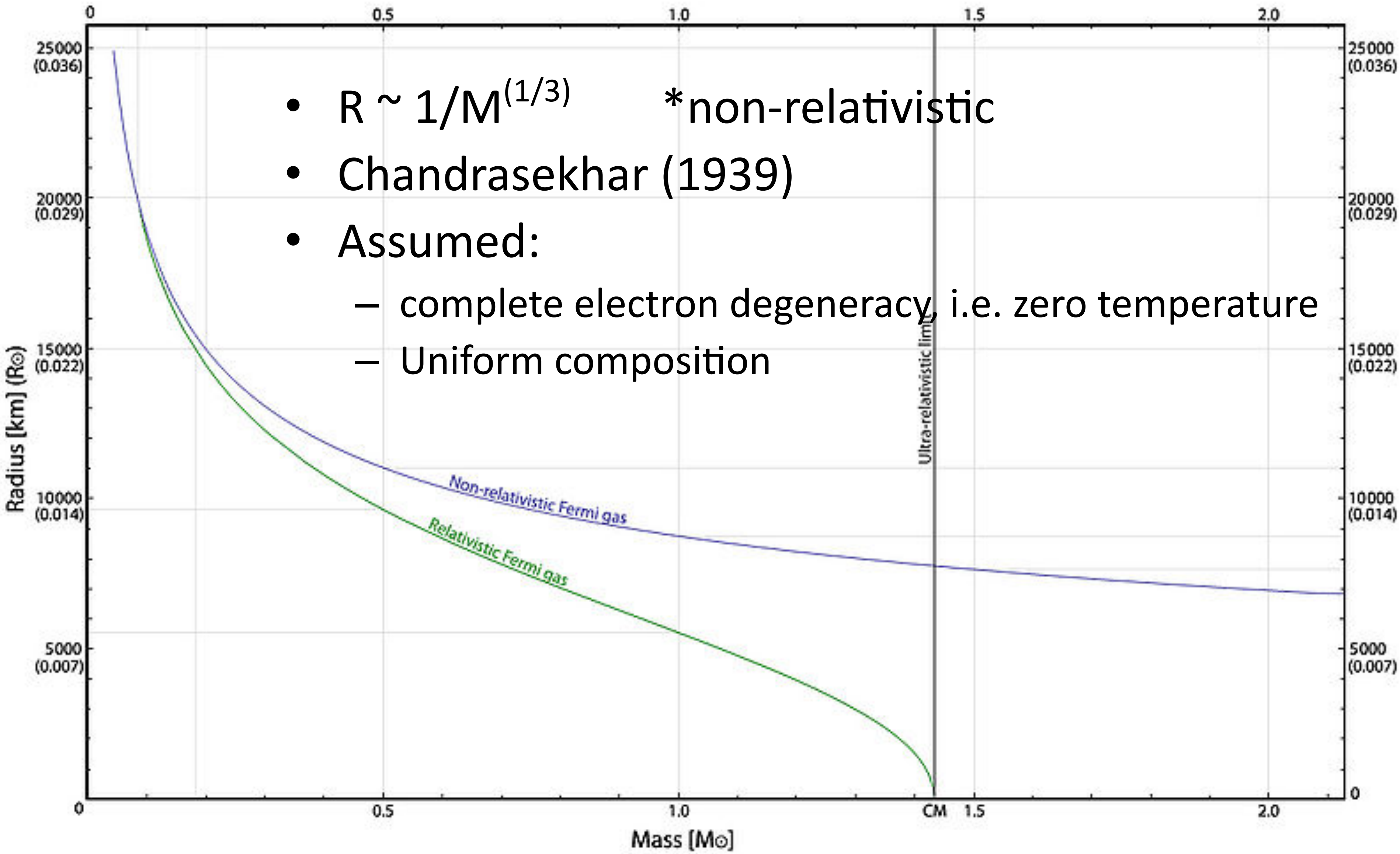
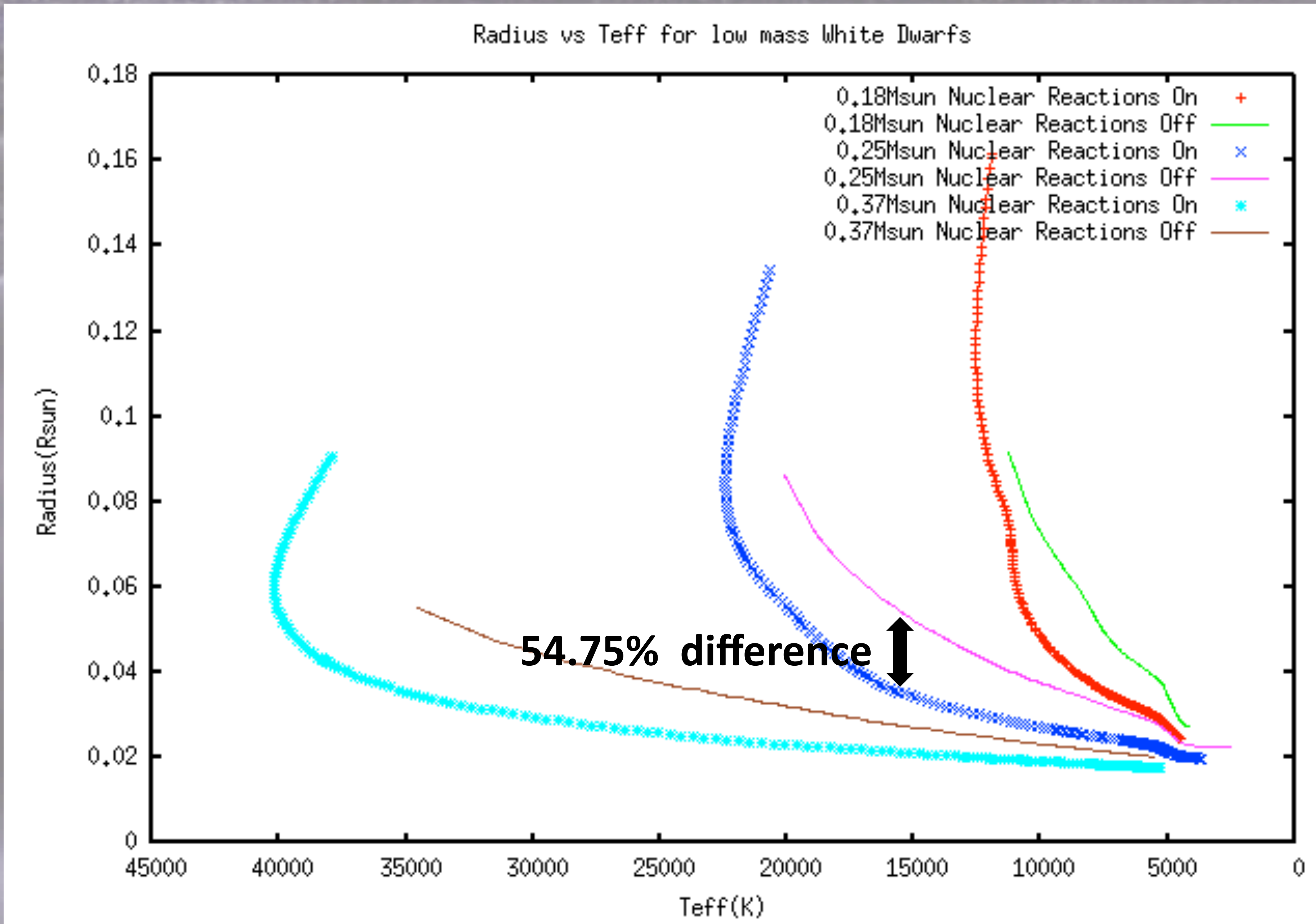
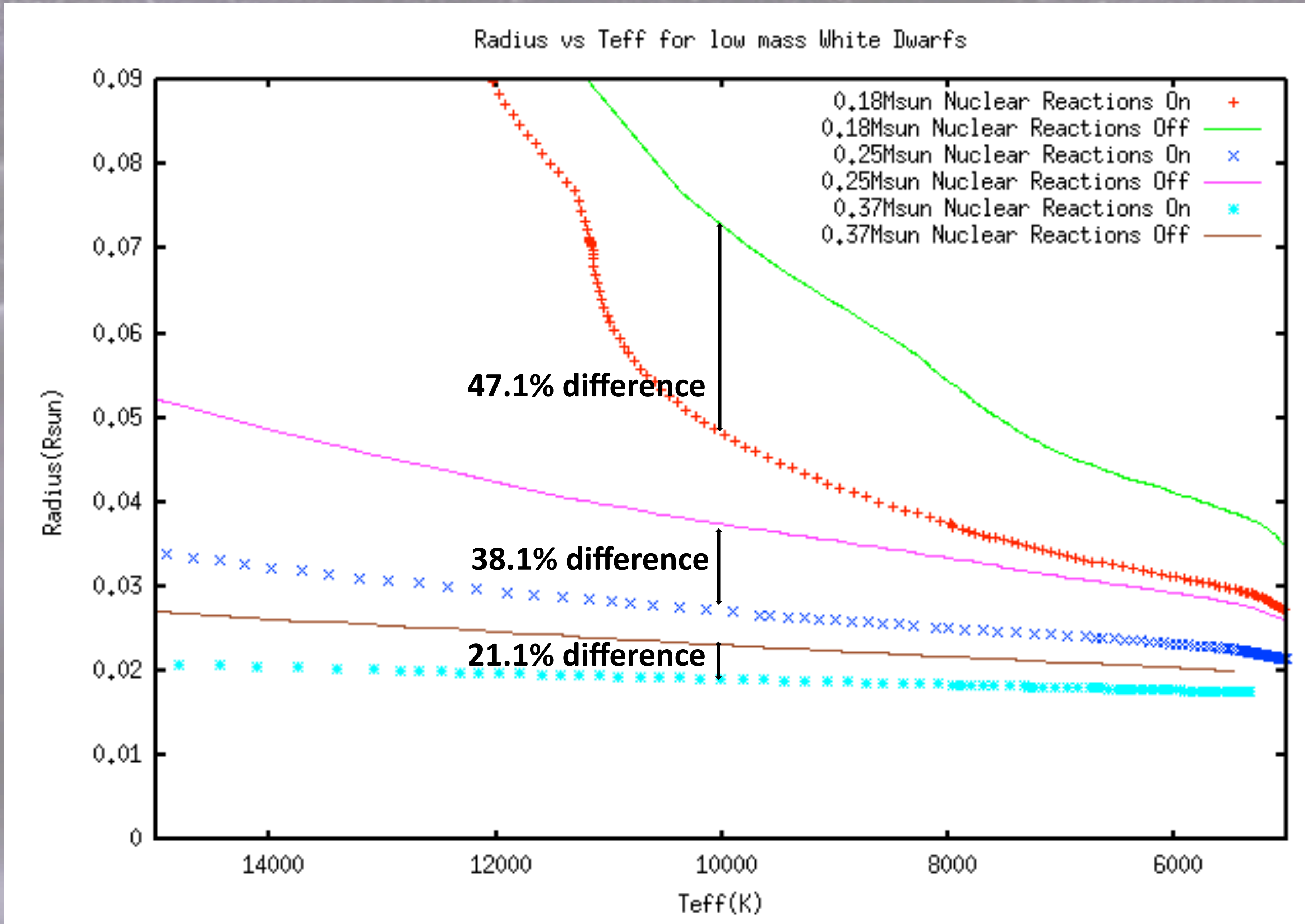


Influence of Hydrogen and residual nuclear burning on the radius of lmwd

- Questions:
  - Is residual nuclear burning present in lmwd?
  - If so, how significant is the effect it has on the radius of the star?
- Theory:
  - Nuclear reactions, if present, would make the star hotter, expanding the envelope and thus increasing the radius


Radius vs Teff for low mass White Dwarfs
0.18Msun Nuclear Reactions On
0.18Msun Nuclear Reactions Off
0.25Msun Nuclear Reactions On
0.25Msun Nuclear Reactions Off
0.37Msun Nuclear Reactions On
0.37Msun Nuclear Reactions Off
54.75% difference
Radius(Rsun)
Teff(K)
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
45000
40000
35000
30000
25000
20000
15000
10000
5000
0



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0.25Msun Nuclear Reactions On
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0.37Msun Nuclear Reactions On
0.37Msun Nuclear Reactions Off
47.1% difference
38.1% difference
21.1% difference
Radius(Rsun)
Teff(K)
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
14000
12000
10000
8000
6000

Conclusions, implications and future work

- Changes our views of properties of lmwd:
  - Residual Nuclear reactions play a significant role on the radius
  - While the extra heat does make the WD star expand, the hydrogen burns away faster, thus making it smaller.
- Better understanding of the mass-radius relation for lmwd.
- Hopefully, more accurate calculations of the relation will come too!

<u>Future work:</u>

- Using MESA, continue exploring properties of low mass and normal mass white dwarfs.