Mathieu Renzo

Title

Clues from gravitational waves on (pulsational) pair instability

Abstract

Since the first direct detection in 2015, gravitational waves have completely changed the landscape of known stellar mass black holes (BH). This gives unprecedented constraints on the evolution and death of the most massive stars, which are otherwise hard to study due to their rarity. In particular, stellar evolution predicts the existence of a gap in the BH mass distribution, due to pair-instability evolution. Its location between ~45-125 Msun is one of the most robust predictions of stellar theory, primarily sensitive only to uncertain nuclear reaction rates. This will allow for the use of gravitational-wave detectors as nuclear astrophysics experiments. On the other hand, ~3% of the population of BHs inferred have masses within the pair-instability gap. Explaining these BHs requires either dynamics, gas accretion, or exotic physics.

Pair-instability should also produce visible electromagnetic transient, however, an uncontroversial detection is still lacking. Upcoming large time-domain surveys will soon be able to reveal even very rare transients and should identify these.

In this talk, I will review the physics of (pulsational) pair-instability in the context of the latest gravitational-wave and time-domain surveys. I will show the wide range of theoretical predictions and their trends with stellar mass, and highlight what we have already learned from the binary BH mergers detected. Finally, I will discuss possible ways to populate the pair-instability gap and potential open problems with some of the scenarios that have been

proposed.

Mathieu Renzo

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About me

I am a Flatiron Research Fellow at the Center for Computational Astrophysics in NY.
My research interests include massive stars and binary evolution, runaway stars, core-collapse supernovae, (pulsational) pair-instability supernovae, and gravitational wave astronomy. I address these combining stellar structure simulations (with MESA), population synthesis, and data analysis.

Language Skills

Mother tongue: Italian/French
Proficient: English (C1)

Computer Skills

Operating Systems: Unix, Windows
Programming languages:

Self-assessed skills

- python
- C – C++
- Fortran 90
- Bash
- LaTeX & TiKz
- perl
- html
- Emacs Lisp

References

Prof. S. E. de Mink — S.E.deMink@uva.nl
Prof. S. N. Shore — steven.neil.shore@unipi.it
Prof. I. Mandel — imandel@star.sr.bham.ac.uk
Prof. S. Justham — S.Justham@uva.nl

Curriculum vitae

Research experience

2019 - now	Flatiron research Fellow	Flatiron Institute, CCA
2015-2019	PhD candidate	University of Amsterdam
Dec 2017	Visiting researcher	University of Pisa
2017	Graduate Fellow (one semester)	KITP (UC Santa Barbara)
2014-2015	Recurrent visiting researcher	Caltech
2013	INFN/LIGO Summer student	Caltech

Education

2015-2019	Ph.D. advisor: S. E. de Mink	University of Amsterdam
2012-2015	MSc. in Physics advisors: S. N. Shore, C. D. Ott, grade: 110/110 cum laude	University of Pisa
2009-2012	BSc. in Physics advisor: G. Paffuti, grade: 110/110	University of Pisa

Grants & Awards

Jan 2017	KITP Graduate fellowship Kavli Institute for Theoretical Physics, advisor: L. Bildsten
2016-2018	PI of 3 Pilot Projects on the supercomputer Cartesius total **1.5 million CPU hours** used to compute MESA models to study stellar winds, pulsational pair instability supernovae, and gravitational wave progenitors.
Jul 2018	Co-I Muse proposal "MUSE WFM-AO observations of the Small Magellanic Cloud cluster NGC 330 as a benchmark for single and binary evolution of massive stars" (PI: J. Bodensteiner) 3.3h of VLT observational time
2015-2018	LKBF Travel funds total: 2200 €
Apr 2015	Travel funds for master thesis abroad, University of Pisa 2000 €

Teaching experience

Mar 2018	Guest lecture on neutrino cooling and core-collapse supernovae
Feb 2018	Guest lecture on the microphysics of nuclear reactions in stars
Jun 2018	TA Summer school "Simulating stars", UCAS, Beijing
2017-2018	Advising master thesis of D. Hendriks (now PhD student at U. Surrey)
Jan 2018	Guest lecture on nuclear reaction networks
2016-2017	Co-advising master thesis of W. van Rossem, L. Edstam
2016-2017	Co-advising bachelor thesis of F. Brooekgaarden
2016-2017	Instructor "Open Problems in Modern Astrophysics"
2016	Co-advising bachelor thesis of Mniversity of Briel
2016	Teaching Assistant "HEA: radiative processes and relativistic flows"
Jan 2016	Guest lecture on stellar evolution codes (MESA)
Aug 2015	TA "MESA Summer school", KITP (UCSB)
Sep 2015	I organized and held a MESA workshop, University of Pisa

Public Engagement experience

Feb 19	Astronomy on Tap Leiden, Talk
2017-now	Informal scientific advisor for science magazine KIJK
Oct 17	University of Amsterdam open day Q/A with public
Jul 17	Lunar Eclipse night in Pisa, telescopes setup and Q/A with public
Nov 2017	API Stargazing night, Q/A with public
Nov 2017	Guest writer of one post on Astrobites Did stripped stars re-ionize-the-universe?
2010-2014	Science demonstrator Ludoteca Scientifica LUS, Pisa

Other professional experience

Referee for ApJ and A&A
Translator (French→English) of the book " Successfully starting in astronomical spectroscopy, a practical guide", author: F. Cochard.
Main organizer bi-weekly "Massive Stars Meeting", University of Amsterdam

Publication list

Submitted and pending revision

1. **M. Renzo**, R. J. Farmer, S. Justham S. E. de Mink, Y. Götberg, P. Marchant P. Marchant, *Sensitivity of the lower-edge of the pair instability black hole mass gap to the treatment of time dependent convection*, submitted to MNRAS

Accepted and in press

2. R. J. Farmer, **M. Renzo**, S. E. de Mink, P. Marchant, S. Justham *Mind the gap: The location of the PISN black hole mass gap*, ApJ , 887, 53, Dec 19
3. E. Zapartas, S.E. de Mink, N. Smith, A. de Koter, S. Justham, I. Arcavi, R. Farmer, Y. Götberg **M. Renzo**, *The diverse lives of the progenitors of hydrogen-rich, type II, core-collapse supernovae: the importance of binary interaction*, , 631, A5, Nov 19.
4. P. Marchant, **M. Renzo**, R. Farmer, K. Pappas, R. Taam, S. E. de Mink, V. Kalogera *Pulsational Pair Instability in very close binaries*, *ApJ* , 882, 36, Sep 19.
5. **M. Renzo**, E. Zapartas, S. E. de Mink, Y. Götberg, S. Justham, R. J. Farmer, R. G. Izzard, S. Toonen, and H. Sana, *Massive runaways and walkaway stars*, , 624, A66, Apr 19.
6. A. Vigna-Gómez, C. J. Neijssel, S. Stevenson, J. W. Barrett, K. Belczynski, S. Justham, S. E. de Mink, B. Müller, P. Podsiadlowski, **M. Renzo**, D. Szécsi, and I. Mandel, *On the formation history of Galactic double neutron stars*, *ArXiv:1805.07974*, *Accepted by MNRAS*, Dec 18.
7. W. E. Kerzendorf, T. Do, S. E. de Mink, Y. Götberg, D. Millisaljevic, E. Zapartas, **M. Renzo**, S. Justham, P. Podsiadlowski, and R. A. Fesen, *No surviving stellar companion for Cassiopeia A*. *ArXiv:1711.00055*, *Accepted by A&A* , Oct 18.
8. **M. Renzo**, S. E. de Mink, D. J.Lennon, I. Platais, R. P. van der Marel, E. Laplace, J. M. Bestenlehner, C. J. Evans, V. Hénault-Brunet, S. Justham, A. de Koter, N. Langer, F. Najarro, F. R. N. Schneider, J. S. Vink, *Space astrometry of on the very massive* $\sim 150\,M_{\odot}$ *candidate runaway star VFTS682*, *ArXiv:1810.05650*, *Accepted by MNRAS Letters*, Oct 18
9. D. J. Lennon, C. J. Evans, R. P. van der Marel, J. Anderson, I. Platais, A. Herrero, S. E. de Mink, H. Sana, E. Sabbi, P. A. Crowther, N. Langer, M. Ramos Lerate, A. del Pino, **M. Renzo**, S. Simón-Díaz, and F. R. N. Schneider, *Gaia DR2 reveals a very massive runaway star ejected from R136*, *ArXiv:1805.08277*, *Accepted by A&A* , May 18.
10. J. Japelj, S. D. Vergani, R. Salvaterra, **M. Renzo**, E. Zapartas, S. E. de Mink, L. Kaper, and S. Zibetti, *Host galaxies of SNe Ic-BL with and without long gamma-ray bursts*, *ArXiv:1806.10613*, *Accepted by A&A* Jun 18.
11. Y. Götberg, S. E. de Mink, J. H. Groh, T. Kupfer, P. A. Crowther, E. Zapartas, and **M. Renzo**, *Spectral models for binary products: Unifying Subdwarfs and Wolf-Rayet stars as a sequence of stripped-envelope stars*, *A&A* 615:A78, Feb 18.
12. **M. Renzo**, C. D. Ott, S. N. Shore, and S. E. de Mink, *Systematic survey of the effects of wind mass loss algorithms on the evolution of single massive stars*, *A&A* 603:A118, Jul 17.
13. E. Zapartas, S. E. de Mink, S. D. Van Dyk, O. D. Fox, N. Smith, K. A. Bostroem, A. de Koter, A. V. Filippenko, R. G. Izzard, P. L. Kelly, C. J. Neijssel, **M. Renzo**, and S. Ryder, *Predicting the Presence of Companions for Stripped-envelope Supernovae: The Case of the Broad-lined Type Ic SN 2002ap*, *ApJ* 842:125, Jun 17.
14. E. Zapartas, S. E. de Mink, R. G. Izzard, S.-C. Yoon, C. Badenes, Y. Götberg, A. de Koter, C. J. Neijssel, **M. Renzo**, A. Schootemeijer, and T. S. Shrotriya, *Delay-time distribution of core-collapse supernovae with late events resulting from binary interaction*, *A&A* 601:A29, May 17.
15. V. Morozova, A. L. Piro, **M. Renzo**, and C. D. Ott, *Numerical Modeling of the Early Light Curves of Type IIP Supernovae*, *ApJ* 829:109, Oct 16.
16. V. Morozova, A. L. Piro, **M. Renzo**, C. D. Ott, D. Clausen, S. M. Couch, J. Ellis, and L. F. Roberts, *Light Curves of Core-collapse Supernovae with Substantial Mass Loss Using the New Open-source SuperNova Explosion Code (SNEC)*, *ApJ* 814:63, Nov 15.

Schools, conferences, and invited talks

Sep 19	Colloquium, Radbound University, Nijmegen, Netherlands	[**invited talk**]
Sep 19	Universe of binaries - binaries in the Universe, Telč, Czech Republic	[**invited talk**]
Aug 19	Massive widowed stars, Stars on the run II, Potsdam, Germany	[**invited talk**]
Mar 19	Seminar Institute of Astronomy and Astrophysics, Tuebingen	[**invited talk**]
Jan 19	Astrophysics seminar, ULB, Bruxelles	[**invited talk**]
Dec 18	STScI seminar, USA	[**invited talk**]
Nov 18	Contribution to CCA group meeting, Flatiron Institute, USA	[**invited talk**]
Nov 18	Informal talk at Columbia, USA	[**invited talk**]
Nov 18	Informal talk at NYU, USA	[**invited talk**]
Nov 18	McGill Space Institute seminar, Canada	[**invited talk**]
Nov 18	CITA Black Board seminar, Canada	[**invited talk**]
Sep 18	"A revolution in stellar physics with *Gaia* and large surveys", Poland	[**contributed talk**]
Jun 18	KIAA seminar at University of Peking, China	[**invited talk**]
Jun 18	"Simulating stars" summer school UCAS, China	[teaching assistant]
Jun 18	Shocking SNe, Stockholm, Sweden	[**contributed talk**]
Jun 18	"Brown bag" seminar at University of Pisa, Italy	[**invited talk**]
May 18	73$^{\mathrm{rd}}$ Netherlands Astronomy Conference (NAC), Netherlands	[**contributed talk**]
Apr 18	VFTS Collaboration Meeting, Puerto de la Cruz, Spain	[**contributed talk**]
Dec 17	Astro-seminar at University of Pisa, Italy	[**invited talk**]
Nov 17	Nova network 2 meeting, Netherlands	[**contributed talk**]
Oct 17	Blackgem collaboration meeting, Radbound University, Netherlands	
Sep 17	Lorentz Center Workshop on EM counterparts to BBH mergers, Netherlands	[**invited short talk**]
Jun 17	Caltech talk, USA	[**invited talk**]
Jun 17	Informal talk at UC Santa Cruz, USA	[**invited talk**]
Jun 17	Informal talk at Carnegie, USA	[**invited talk**]
May 17	UC Santa Barbara astro lunch, USA	[**invited talk**]
May 17	The Galaxy-Halo Connection, UC Santa Barbara, USA	
Mar 17	The Mysteries and Inner Workings of Massive Stars, KITP, USA	[2 posters]
Feb 17	Confronting MHD Accretion Theory with Observations, KITP, USA	
Oct 16	"Brown bag" seminar at University of Pisa, Italy	[**invited talk**]
Sep 16	MIAPP workshop conference "The physics of SNe", Germany	[**contributed talk**]
Aug 16	"Stars on the Run", Germany	[**contributed talk**]
Jul 16	Binary Stars in Cambridge, UK	[**contributed talk**]
Jun 16	Informal talk at University of Birmingham, UK	[**invited talk**]
Jun 16	Bridging the Gap: from Massive Stars to Supernovae, UK	[poster]
May 16	71$^{\mathrm{st}}$ Netherlands Astronomy Conference (NAC), Netherlands	[**contributed talk**]
May 16	VFTS Collaboration Meeting, Bulgaria	[**contributed talk**]
Nov 15	Nova network 3 meeting, Netherlands	
Oct 15	Nova Fall School at ASTRON, Netherlands	
Aug 15	MESA Summer school, KITP, USA	[teaching assistant]
Jul 15	Lorentz center workshop on Massive Binaries, Netherlands	[short talk]
Sep 14	Strangeness in Nuclei and in Neutron Stars, University of Pisa, Italy	
Aug 14	MESA Summer School, KITP, USA	
Jul 13	Caltech Gravitational Wave Astrophysics School, USA	