Tidally-induced thermonuclear Supernovae

Stephan Rosswog[1], **Enrico Ramirez-Ruiz**[2], **W. Raphael Hix**[3]
[1] School of Engineering & Science, Jacobs University Bremen, 28759 Bremen, Germany
[2] Dept. of Astronomy & Astrophysics, University of California, Santa Cruz, CA 95064, USA
[3] Physics Division, Oak Ridge National Laboratory, Oak Ridge, TN37831-6374, USA

E-mail: `srosswog@jacobs-university.de`

Abstract. We discuss the results of 3D simulations of tidal disruptions of white dwarfs by moderate-mass black holes as they may exist in the cores of globular clusters or dwarf galaxies. Our simulations follow self-consistently the hydrodynamic and nuclear evolution from the initial parabolic orbit over the disruption to the build-up of an accretion disk around the black hole. For strong enough encounters (pericentre distances smaller than about 1/3 of the tidal radius) the tidal compression is reversed by a shock and finally results in a thermonuclear explosion. These explosions are not restricted to progenitor masses close to the Chandrasekhar limit, we find exploding examples throughout the whole white dwarf mass range. There is, however, a restriction on the masses of the involved black holes: black holes more massive than 2×10^5 M$_\odot$ swallow a typical 0.6 M$_\odot$ white dwarf before their tidal forces can overwhelm the star's self-gravity. Therefore, this mechanism is characteristic for black holes of moderate masses. The material that remains bound to the black hole settles into an accretion disk and produces an X-ray flare close to the Eddington limit of $L_{\rm Edd} \simeq 10^{41}$erg/s $(M_{\rm bh}/1000 M_\odot)$, typically lasting for a few months. The combination of a peculiar thermonuclear supernova together with an X-ray flare thus whistle-blows the existence of such moderate-mass black holes. The next generation of wide field space-based instruments should be able to detect such events.

1. Introduction

Two classes of black holes are established beyond reasonable doubt: black holes of a few solar masses ("stellar-mass") make themselves known by interacting with a companion star [1] and "supermassive" black holes with masses of $10^6 - 10^{10}$ M$_\odot$ seem to lurk in the centres of most, if not all galaxies, see e.g. [2, 3]. A third class, so-called "intermediate-mass black holes" (IMBH) with masses of ~ 1000 M$_\odot$, represents a plausible, yet to date still missing link. The evidence for their existence is mounting, but to date it is not entirely conclusive. Based on kinematical studies Gerssen et al. [4, 5] have suggested the presence of a 3.9×10^3 M$_\odot$ black hole in the core of the globular cluster M15. More recently, there were further reports on IMBHs in the globular clusters NGC 2808 [6] and omegaCen [7]. Additional evidence comes from ultraluminous, compact X-ray sources in young star clusters [8, 9] and from n-body simulations [10] that indicate that runaway collisions in dense young star clusters can produce rapidly growing massive stars that should ultimately collapse to form IMBHs. None of the above arguments is strong enough to close the case, but their different nature gives this hypothesis credibility.

At the very large number densities in the environments that may habor such black holes stars are disrupted at a rate of $\sim 10^{-7}{\rm yr}^{-1}$ $M_{\rm bh,3}^{4/3}$ $n_{*,6}$ σ_{10}^{-1} $(R_{\rm per}/R_{\rm t})$, where $M_{\rm bh,3}$ is the black hole mass in units of 1000 M$_\odot$, $n_{*,6}$ is the central stellar density in units of 10^6 pc^{-3},

σ_{10} the velocity dispersion in 10 kms^{-1} and $R_{\rm per}$ is the distance of closest approach. The quantity $R_{\rm t} = (M_{\rm bh}/M_*)^{1/3} R_*$ is the tidal radius, the approximate separation where the hole's tidal field wins the battle against the star's self-gravity. It is proportional to the stellar radius R_*, but only grows $\propto M_{\rm bh}^{1/3}$, i.e. substantially slower than the gravitational radius, $R_{\rm S} = 2GM_{\rm bh}/c^2$, of the black hole. As a consequence, too massive black holes, $M_{\rm bh} > M_{\rm bh,lim} \simeq 2.5 \times 10^5 M_\odot \; R_{\rm wd,9}^{3/2} M_{\rm wd,0.6}^{-1/2}$ will swallow stars before disrupting them. Here, $R_{\rm wd,9}$ is the white dwarf radius in 10^9 cm and $M_{\rm wd,0.6}$ its mass in units of 0.6 $\mathrm{M}_\odot$. Thus, white dwarfs with their small radii and their (at least in principle) available nuclear fuel can only be tidally squeezed and disrupted by black holes of moderate masses. Therefore they are precious tools to probe the existence of this type of black hole.

Luminet and Pichon were the first to discuss the tidal disruption of white dwarfs by black holes [11] in the context of the affine star model [12, 13]. Wilson and Mathews [14] believe that general relativistic effects may lead to a tidal ignition even for supermassive black holes and at separations of many gravitational radii. A hydrodynamic simulation with a Newtonian Adaptive Lagrangian Eulerian (ALE) code was performed recently [15] where the gravitational constant was adjusted to mimic general relativistic effects. We have recently performed a large set of 3D hydrodynamic simulations [16, 17, 18] that incorporate the nuclear energy generation self-consistently with the hydrodynamics.

2. Ingredients for the simulations

Here we briefly summarize the ingredients of our simulations, both in terms of physics and numerical methods. We described the numerical aspects in [17] and in [18] we concentrated on the physics and the astrophysical implications of such tidal disruptions.

We use the smoothed particle hydrodynamics method (SPH) to follow the hydrodynamic evolution of the white dwarf matter. Being completely Lagrangian and conserving mass, energy, momentum and angular momentum by construction the method is ideal for the study of such a violent stellar disruption. General reviews on the method can be found in [19, 20, 21], our particular implementation is documented in [17]. We calculate the forces from self-gravity via a binary tree [22] and those from the central black hole via a relativistic pseudo potential [23], details of how the singularity is treated numerically are laid out in [24].We close the system of hydrodynamics equations via the HELMHOLTZ equation of state (EOS) [25]. It accepts an externally calculated chemical composition, facilitating the coupling to nuclear reaction networks. The electron-/positron equation of state makes no assumptions about the degree of degeneracy or relativity, the exact expressions are integrated numerically and are subsequently tabulated. The interpolation in this table enforces thermodynamic consistency by construction [25]. The nuclei in the gas are treated as a Maxwell-Boltzmann gas, the photons as blackbody radiation. Most importantly in this context, we couple a minimal nuclear reaction network [26] to the hydrodyamics. Throughout this simulation set we assume a uniform nuclear composition accross the white dwarfs. Stars with masses < 0.6 $\mathrm{M}_\odot$ are instantiated as pure helium, more massive stars are modeled with a mass fraction of 50% carbon and 50% oxygen. All simulations are started from parabolic orbits, the strength of an encounter is parametrized by the penetration factor $\beta = R_{\rm t}/R_{\rm per}$. For more details we refer the interested reader to [17, 18].

3. Results

3.1. Explosion mechanism

The tidal gravitational field is, to lowest order, determined by the second-order tidal tensor and the third-order deviation tensor. The latter determines the deviation of an extended body from a point particle trajectory of the same mass. The tidal tensor determines how the fluid will be shaped. It possesses one positive and two negative eigenvalues, see e.g. [27], and, as a consequence, the tidal field stretches the star in one eigen-direction and compresses it along the other two. Most severely, the star is compressed perpendicular to the orbital plane, this process halts when a shock forms [28, 27, 18] that reverts the compression into an expansion. For deep enough penetrations matter reaches nuclear statistical equilibrium, see Fig. 1, upper right panel. The star is squeezed through a point of maximum compression on a time scale of $\tau_{\rm comp} \sim R_{\rm wd}/v_{\rm p} \simeq 0.2{\rm s}\ (M_{\rm wd,0.6})^{-1/6} (R_{\rm wd,9})^{3/2} (M_{\rm bh,3})^{-1/3}$, where $v_{\rm p} \sim (R_{\rm g}/R_{\tau})^{1/2} c \simeq 5 \times 10^{9} {\rm cm\ s}^{-1}\ M_{\rm wd,0.6}^{1/6}\ R_{\rm wd,9}^{-1/2} M_{\rm bh,3}^{1/3}$ is the peri-centre passage velocity. This velocity exceeds thermonuclear flame speeds by orders of magnitude, therefore, flame propagation effects can be safely neglected. The compression time scale needs to be compared to the dynamical time scale of the star, $\tau_{\rm dyn} = (G\bar{\rho})^{-1/2} \simeq 7.2\ {\rm s}\ M_{\rm wd,0.6}^{-1/2}\ R_{\rm wd,9}^{3/2}$, with $\bar{\rho}$ being the average stellar density and to the nuclear reaction time scale, $\tau_{\rm nuc}$. Only for $\tau_{\rm nuc} \ll \tau_{\rm comp}, \tau_{\rm dyn}$ can a substantial nuclear energy release be expected. Our large simulation set [18] shows that white dwarfs of all masses can be thermonuclearly exploded provided that the penetration factor exceeds $\beta \simeq 3$. For definiteness, we illustrate here the results at the example of a typical 0.6 $M_{\odot}$ carbon-oxygen (CO) white dwarf that passes a 500 $M_{\odot}$ black hole with a penetration factor of $\beta = 5$, see Fig. 1.

3.2. Nucleosynthesis

Nucleosynthesis is triggered predominantly in the point of maximum compression, see Fig. 1, upper right panel, the concomitant nuclear energy release inflates a hot bubble in the debris centre, see Fig. 1, lower panels. The high-density centre of the star produces an iron-group core of 0.18 $M_{\odot}$[1], if mainly composed of ^{56}Ni this amount is comparable, but at the lower end of what is deduced for standard type Ia supernovae [29]. The iron core is surrounded by a 0.21 $M_{\odot}$ shell of silicon-group elements which in turn is covered by a sheath of unburned carbon-oxygen material, see Fig. 2. In reality, such a disruption would result in even stronger carbon-enhanced outer layers than shown in Fig. 2. For simplicity, we have instantiated our initial carbon oxygen white dwarf models ($M_{\rm WD} \geq 0.6\ M_{\odot}$) as homogeneously mixed stars with a 50% mass fraction of each nucleus. While such internal chemical profiles are likely accurately realized in nature in very massive white dwarfs ($\sim 1\ M_{\odot}$) [30], for lower masses the gravothermal adjustment of the interior during the cooling phase produces oxygen-enhanced stellar cores surrounded by very carbon-rich mantles ($X_C \sim 0.8$). The exact radial distribution depends on the exact value of $^{12}C(\alpha,\gamma)^{16}O$ rate and the details of how convection proceeds [30, 31, 32], but this general stratification tendency is well-established. Thus, the disruption of a standard 0.6 $M_{\odot}$ white dwarf should produce a highly carbon-enriched remnant atmosphere.

We found exploding examples throughout the whole white dwarf mass range. An extreme case is a low-mass white dwarf that can (due to its large stellar and correspondingly large tidal radius) be sent very deeply into the tidal radius of a black hole. A 0.2 $M_{\odot}$, pure helium white dwarf disrupted by a 1000 $M_{\odot}$ black hole ($\beta = 12$) produced an explosion with about 0.03 $M_{\odot}$ of iron-group elements. At the other extreme, a 1.2 $M_{\odot}$ CO white dwarf exploded with 0.66 $M_{\odot}$ of iron group elements after passing a 500 $M_{\odot}$ black hole with $\beta = 2.6$. For more details and examples, the interested reader should consult [18]. A detailed comparison of the lightcurves of tidally-induced supernovae and "normal" type Ia supernovae is currently being prepared [33].

3.3. Accompanying signatures

If the release of nuclear binding energy is disregarded, about half the stellar mass is ejected, the rest is still bound to the black hole and, in principle, available to be accreted. Nuclear energy release during pericentre passage can substantially increase the amount of unbound mass

---

[1] Note that our network uses element groups, individual isotopes would need to be recovered in a post-processing step with larger network.

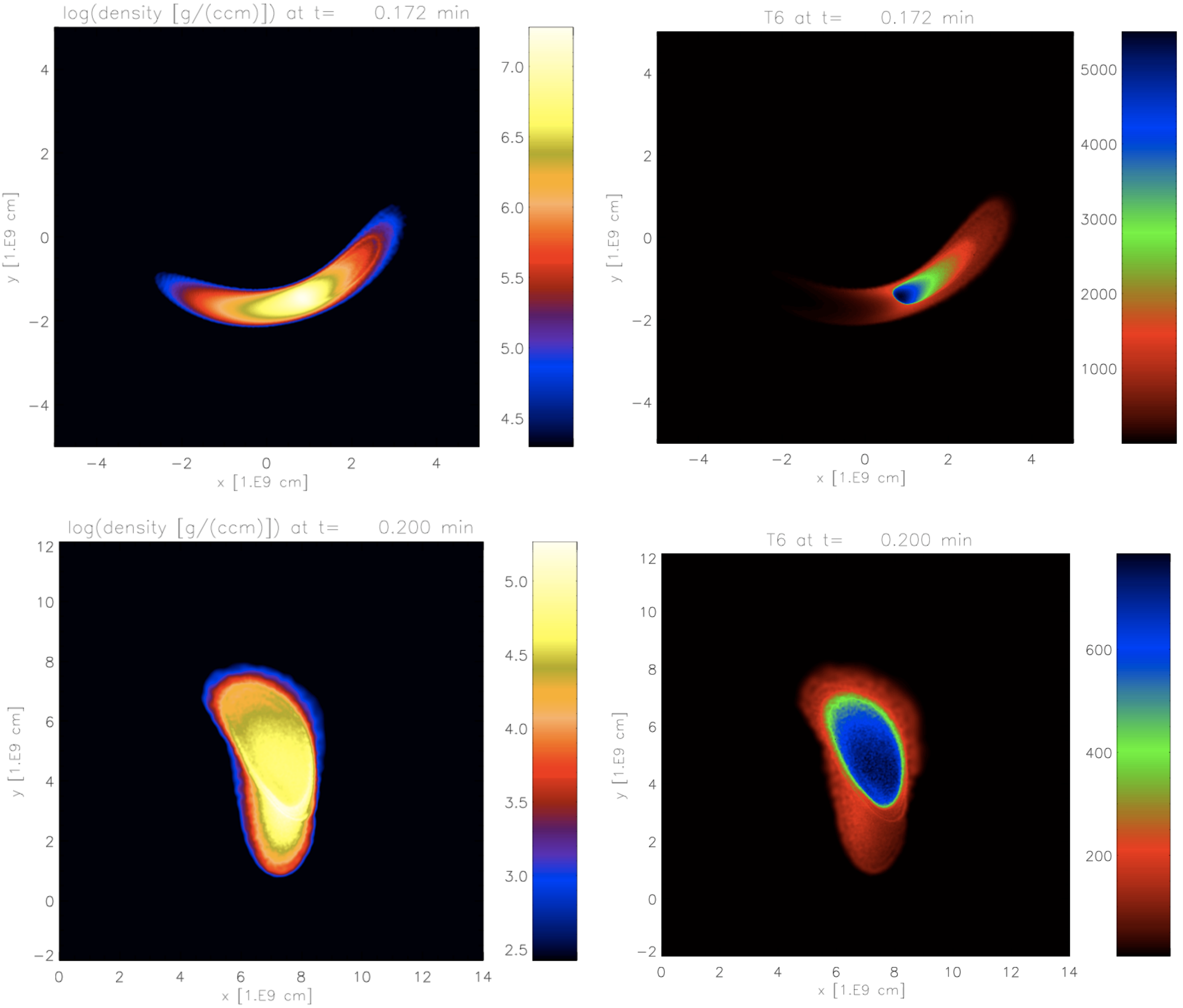

Figure 1. Density (left column) and temperature (right column) evolution during the disruption of 0.6 $M_\odot$ CO white dwarf by a 500 $M_\odot$ black hole. The distance of closest approach was 1/5 of the tidal radius.

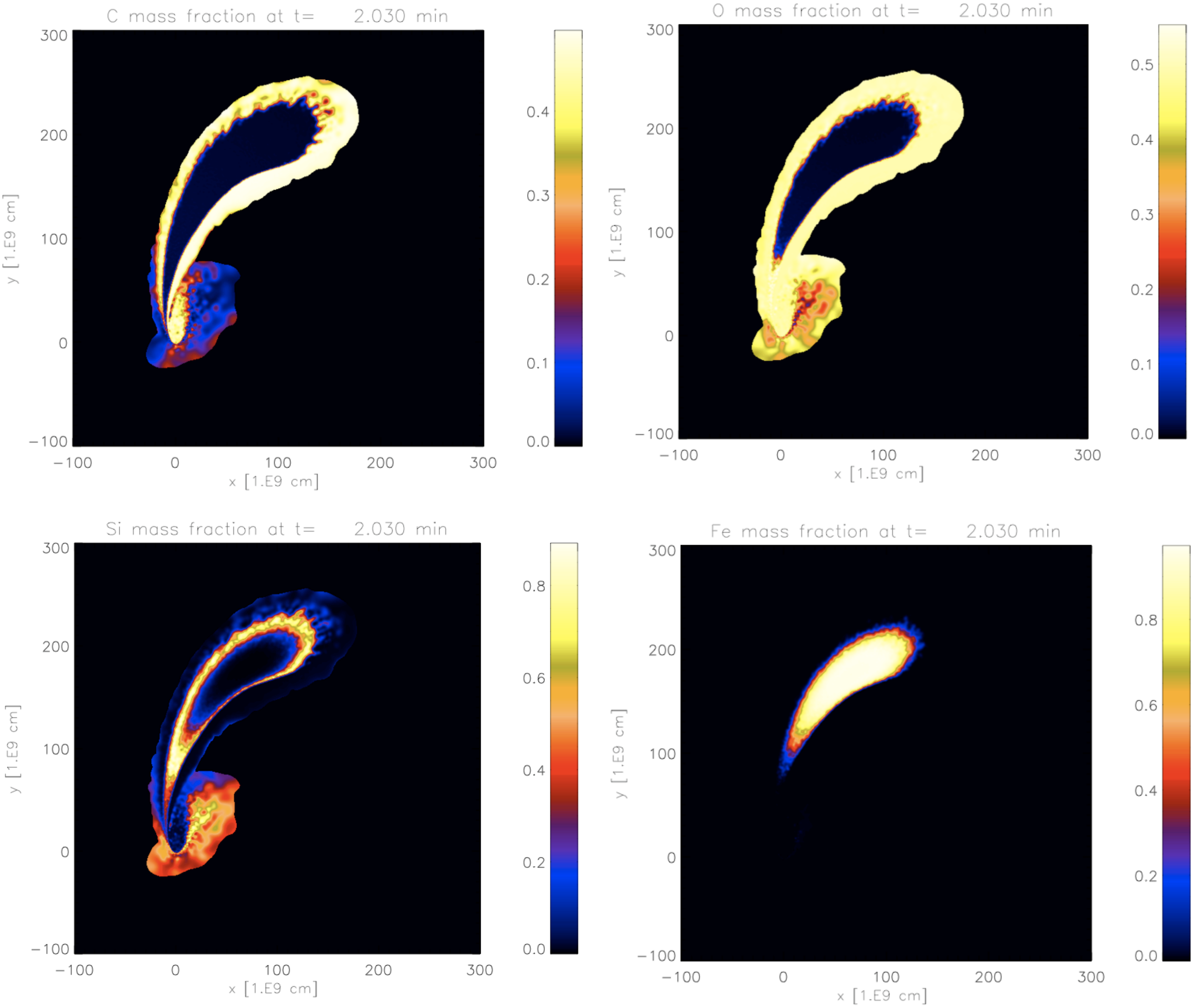

Figure 2. Mass fractions resulting from the disruption of 0.6 $M_\odot$ CO white dwarf by a 500 $M_\odot$ black hole. The distance of closest approach was 1/5 of the tidal radius.

to about $\sim 65\%$ [16]. Before the energy contained in the bound matter can be released, an accretion disk has to form. On returning to the black hole, the orbits of the bound matter become focussed once more towards peri-center. The spread of specific energies across the accretion stream is very large [34] so that matter that passes on the inside of the stream, i.e. closer to the black hole, is considerably stronger bound and subsequently only reaches moderate apocentre distances while matter on the outside track is relaunched into a substantially wider orbit. Thus, after having passed the hole for the second time, the matter stream spreads in a fan-like manner [34, 18]. It subsequently collides with the still infalling material and this self-interaction produces an angular momentum redistribution shock that circularizes the accretion flow, see e.g. Fig. 4 in [17]. In the early stages, mass is fed towards the black hole at a rate that carries the imprint of the internal structure of the star [35, 36], at later stages the rate falls off $\propto t^{-5/3}$ [34, 37]. Once a disk has formed, it evolves under the influence of viscosity, radiatively driven winds and the fallback rate by which it is fed. We expect a luminosity that is comparable to the Eddington value, $L_{\rm Edd} \simeq 10^{41}{\rm erg/s}\ (M_{\rm bh}/1000 M_\odot)$, typically lasting for a few months.

4. Summary and discussion

We have explored in detail the fate of white dwarfs that approach a moderately-massive black hole close enough to become tidally disrupted. Above a limiting mass of $\sim 10^5$ M$_\odot$, the detailed value depending on the white dwarf, the black hole swallows the star as a whole before disrupting it. Thus white dwarfs represent a precious tool to probe the existence of moderate-mass black holes. White dwarfs that penetrate the tidal radius deeply enough are heated by the tidal compression and ensuing shock to the temperatures of nuclear statistical equilibrium. In favorable cases more than the gravitational self-binding energy of the star can be released via nuclear reactions thus triggering a thermonuclear explosion of the white dwarf. The amount of iron-goup nuclei produced is rather sensitive to the densities at which nuclear burning occurs, and therefore to the white dwarf mass. The amount produced in the exploding cases of our simulation set [18] ranges from 0.03 M$_\odot$ for a 0.2 M$_\odot$ pure helium white dwarf to 0.66 M$_\odot$ for a 1.2 M$_\odot$ carbon-oxygen white dwarf, i.e. if composed of mainly ^{56}Ni the favorable cases produce amounts comparable to standard type Ia supernovae [29].

These tidally-induced supernovae are, however, in several respects different from what is considered a "normal" type Ia supernova. First, they are not restricted to progenitor masses close to the Chandrasekhar limit. We find exploding examples throughout the full explored mass range from 0.2 to 1.2 M$_\odot$. Typical examples of these explosions are close to the peak of the white dwarf mass distribution, i.e. near 0.6 M$_\odot$, or slightly above this value, since in the dense stellar environments around such black holes close encounters between stars may lead to mass segregation [38]. Thus the average progenitor will be less massive than for a normal type Ia. Second, and closely related to the first point, the progenitor composition is not restricted to carbon-oxygen. Also pure helium white dwarfs can explode via this mechanism, but since white dwarfs near and slightly beyond the peak of the mass distribution are thought to consist of carbon and oxygen this is the most common progenitor composition. Due to the initial chemical layering of the white dwarfs, the outer shells of the most common explosion remnants consist of unburned, highly carbon-enriched ($X_C \sim 0.8$) material. Third, the remnant geometry is most likely much less spherical than a standard type Ia, therefore the optical lightcurve should be rather unique as a result of the radiating material being highly squeezed into the orbital plane. The large velocities of the ejected debris ($> 10^4$ km/s) should produce large Doppler shifts. And last but not least, this peculiar type of thermonuclear supernova is accompanied by an X-ray flare close to the Eddington luminosity that lasts for a few months.

The estimated event rates for this type of transient are $\sim 10^{-3}$ of the type Ia supernova rate. Though being substantially less frequent, they occur often enough to warrant a search for this new class of optical transient. Upcoming supernova searches hope to discover several thousand to several hundred thousand type Ia-like events [39, 40] per year. Chances are promising to find examples of tidally-induced thermonuclear supernovae among them. Maybe, the recently detected carbon-rich transient SCP 06F6 accompanied by an X-ray signal [41] is already the first example for this class of object.

Acknowledgements We thank Holger Baumgardt, Peter Goldreich, Jim Gunn, Piet Hut, Dan Kasen, Bronson Messer and Martin Rees for very useful discussions. E. R. acknowledges support from the DOE Program for Scientific Discovery through Advanced Computing (SciDAC; DE-FC02-01ER41176). The simulations presented in this paper were performed on the JUMP computer of the Höchstleistungsrechenzentrum Jülich. Oak Ridge National Laboratory is managed by UT-Battelle, LLC, for the U.S. Department of Energy under contract DE-AC05-00OR22725.

References

[1] J. E. McClintock, R. A. Remillard, Black Hole Binaries, ArXiv Astrophysics e-prints.

[2] J. Kormendy, D. Richstone, Inward Bound—The Search For Supermassive Black Holes In Galactic Nuclei, Ann. Rev. Astron. Astrophys. 33 (1995) 581.

[3] L. Ferrarese, D. Merritt, A Fundamental Relation between Supermassive Black Holes and Their Host Galaxies, ApJL 539 (2000) L9–L12.

[4] J. Gerssen, R. P. van der Marel, K. Gebhardt, P. Guhathakurta, R. C. Peterson, C. Pryor, Hubble Space Telescope Evidence for an Intermediate-Mass Black Hole in the Globular Cluster M15. II. Kinematic Analysis and Dynamical Modeling, AJ 124 (2002) 3270–3288.

[5] J. Gerssen, R. P. van der Marel, K. Gebhardt, P. Guhathakurta, R. C. Peterson, C. Pryor, Addendum: Hubble Space Telescope Evidence for an Intermediate-Mass Black Hole in the Globular Cluster M15. II. Kinematic Analysis and Dynamical Modeling, AJ 125 (2003) 376–377.

[6] T. J. Maccarone, M. Servillat, Radio observations of NGC 2808 and other globular clusters: constraints on intermediate-mass black holes, MNRAS 389 (2008) 379–384.

[7] E. Noyola, K. Gebhardt, M. Bergmann, Gemini and Hubble Space Telescope Evidence for an Intermediate-Mass Black Hole in ω Centauri, ApJ 676 (2008) 1008–1015.

[8] A. Zezas, G. Fabbiano, A. H. Rots, S. S. Murray, Chandra Observations of "The Antennae" Galaxies (NGC 4038/4039). III. X-Ray Properties and Multiwavelength Associations of the X-Ray Source Population, ApJ 577 (2002) 710–725.

[9] D. Pooley, S. Rappaport, X-Rays from the Globular Cluster G1: Intermediate-Mass Black Hole or Low-Mass X-Ray Binary?, ApJL 644 (2006) L45–L48.

[10] S. F. Portegies Zwart, H. Baumgardt, P. Hut, J. Makino, S. L. W. McMillan, Formation of massive black holes through runaway collisions in dense young star clusters, Nature 428 (2004) 724–726.

[11] J.-P. Luminet, B. Pichon, Tidally-detonated nuclear reactions in main sequence stars passing near a large black hole, A&A 209 (1989) 85–102.

[12] B. Carter, J.-P. Luminet, Tidal compression of a star by a large black hole. I Mechanical evolution and nuclear energy release by proton capture, A&A 121 (1983) 97–113.

[13] B. Carter, J. P. Luminet, Mechanics of the affine star model, MNRAS 212 (1985) 23–55.

[14] J. R. Wilson, G. J. Mathews, White Dwarfs near Black Holes: A New Paradigm for Type I Supernovae, ApJ 610 (2004) 368–377.

[15] D. S. P. Dearborn, J. R. Wilson, G. J. Mathews, Relativistically Compressed Exploding White Dwarf Model for Sagittarius A East, ApJ 630 (2005) 309–320.

[16] S. Rosswog, E. Ramirez-Ruiz, R. Hix, Atypical thermonuclear supernovae from tidally crushed white dwarfs, ApJ 679 (2008) 1385.

[17] S. Rosswog, E. Ramirez-Ruiz, W. R. Hix, M. Dan, Simulating black hole white dwarf encounters, Computer Physics Communications 179 (2008) 184–189.

[18] S. Rosswog, E. Ramirez-Ruiz, R. Hix, Tidal disruption and ignition of white dwarfs by moderately massive black holes, submitted to ApJ.

[19] W. Benz, Smooth particle hydrodynamics: A review, in: J. Buchler (Ed.), Numerical Modeling of Stellar Pulsations, Kluwer Academic Publishers, Dordrecht, 1990, p. 269.

[20] J. J. Monaghan, Smoothed particle hydrodynamics, Ann. Rev. Astron. Astrophys. 30 (1992) 543.

[21] J. J. Monaghan, Smoothed particle hydrodynamics, Reports on Progress in Physics 68 (2005) 1703–1759.

[22] W. Benz, R. Bowers, A. Cameron, W. Press, Dynamic mass exchange in doubly degenerate binaries. i - 0.9 and 1.2 solar mass stars, ApJ 348 (1990) 647.

[23] B. Paczynski, P. J. Wiita, Thick accretion disks and supercritical luminosities, A & A 88 (1980) 23.

[24] S. Rosswog, Mergers of Neutron Star-Black Hole Binaries with Small Mass Ratios: Nucleosynthesis, Gamma-Ray Bursts, and Electromagnetic Transients, ApJ 634 (2005) 1202–1213.

[25] F. X. Timmes, F. D. Swesty, The Accuracy, Consistency, and Speed of an Electron-Positron Equation of State Based on Table Interpolation of the Helmholtz Free Energy, ApJS 126 (2000) 501–516.

[26] W. R. Hix, A. M. Khokhlov, J. C. Wheeler, F.-K. Thielemann, The Quasi-Equilibrium-reduced alpha - Network, ApJ 503 (1998) 332.

[27] M. Brassart, J. . Luminet, Shock waves in tidally compressed stars by massive black holes, A & A 481 (2008) 259–277.

[28] S. Kobayashi, P. Laguna, E. S. Phinney, P. Mészáros, Gravitational Waves and X-Ray Signals from Stellar Disruption by a Massive Black Hole, ApJ 615 (2004) 855–865.

[29] P. A. Mazzali, F. K. Röpke, S. Benetti, W. Hillebrandt, A Common Explosion Mechanism for Type Ia Supernovae, Science 315 (2007) 825–.

[30] I. Mazzitelli, F. Dantona, The relation between initial and minimum final white dwarf mass for Population I stars, ApJ 311 (1986) 762–773.

[31] M. Salaris, I. Dominguez, E. Garcia-Berro, M. Hernanz, J. Isern, R. Mochkovitch, The Cooling of CO White Dwarfs: Influence of the Internal Chemical Distribution, ApJ 486 (1997) 413–+.

[32] O. Straniero, I. Domínguez, G. Imbriani, L. Piersanti, The Chemical Composition of White Dwarfs as a Test of Convective Efficiency during Core Helium Burning, ApJ 583 (2003) 878–884.

[33] D. Kasen, E. Ramirez-Ruiz, S. Rosswog, in preparation.

[34] M. J. Rees, Tidal disruption of stars by black holes of 10 to the 6th-10 to the 8th solar masses in nearby galaxies, Nature 333 (1988) 523–528.

[35] G. Lodato, A. R. King, J. E. Pringle, Stellar disruption by a supermassive black hole: is the light curve really proportional to $t^{-5/3}$?, ArXiv e-prints.

[36] E. Ramirez-Ruiz, S. Rosswog, The star ingesting luminosity of intermediate mass black holes in globular clusters, ArXiv e-prints.

[37] E. S. Phinney, Manifestations of a Massive Black Hole in the Galactic Center, in: M. Morris (Ed.), IAU Symp. 136: The Center of the Galaxy, 1989, p. 543.

[38] J. Binney, S. Tremaine, Galactic Dynamics: Second Edition, Galactic Dynamics: Second Edition, by James Binney and Scott Tremaine. ISBN 978-0-691-13026-2 (HB). Published by Princeton University Press, Princeton, NJ USA, 2008., 2008.

[39] A. G. Riess, M. Livio, The First Type Ia Supernovae: An Empirical Approach to Taming Evolutionary Effects in Dark Energy Surveys from SNe Ia at z>2, ApJ 648 (2006) 884–889.

[40] G. Aldering, A. G. Kim, M. Kowalski, E. V. Linder, S. Perlmutter, Snapping supernovae at z > 1.7, Astroparticle Physics 27 (2007) 213–225.

[41] B. T. Gaensicke, A. J. Levan, T. R. Marsh, P. J. Wheatley, SCP06F6: A carbon-rich extragalactic transient at redshift z˜0.14, ArXiv e-prints.