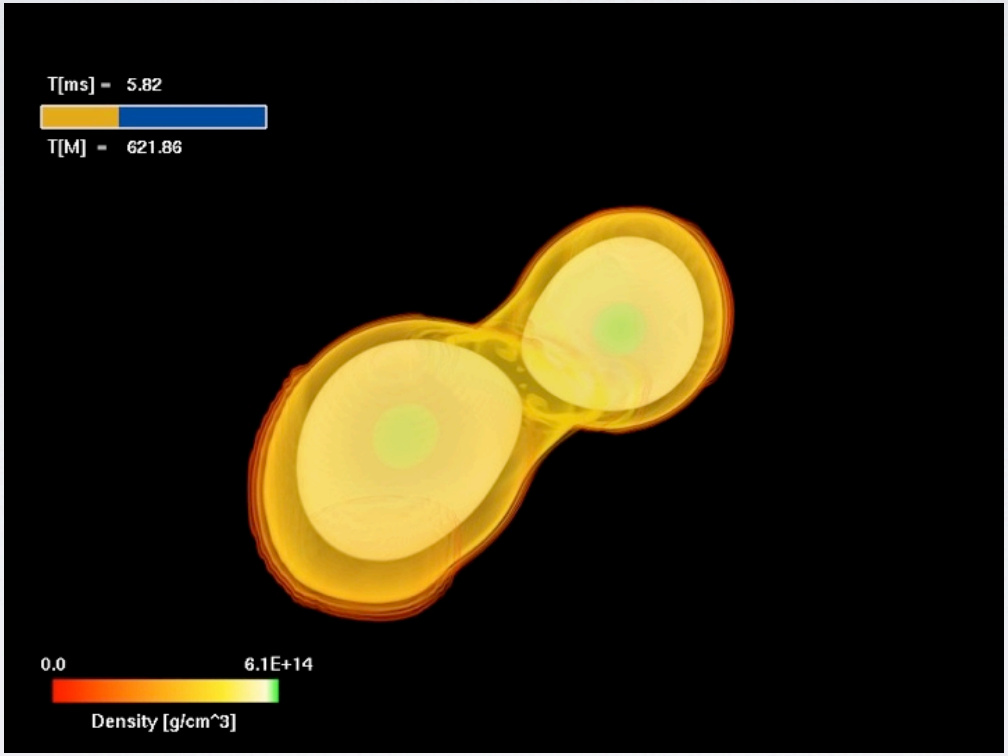
GR SIMULATIONS OF BINARY NEUTRON STAR MERGERS



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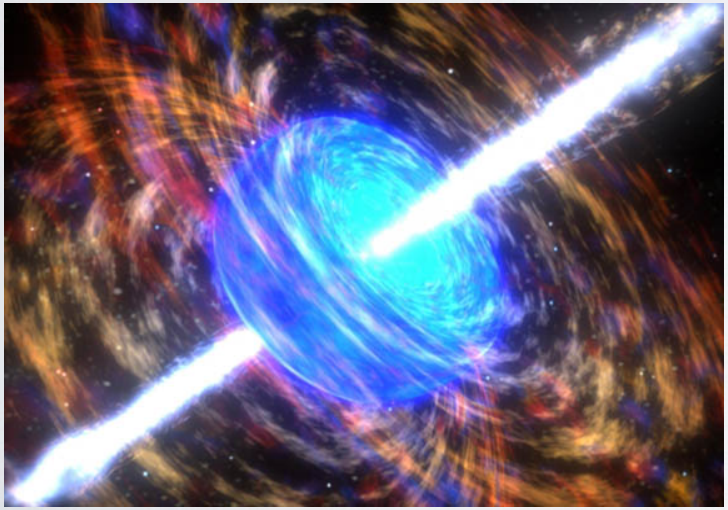
WHY SO INTERESTING?

Due to their duration and dynamics, Binary Neutron Stars are very good sources for gravitational wave detectors such as Virgo (Italy) and LIGO (USA)

Virgo (Pisa, Italy)



Credit: NASA/SkyWorks Digital

Tori formed after the merger of BNSs could power short-GRBs via neutrino or magnetic fields. Contemporary detection of GWs and gamma-rays could unveil the source of short-GRBs.

To study these sources we use our GRMHD code **Whisky**

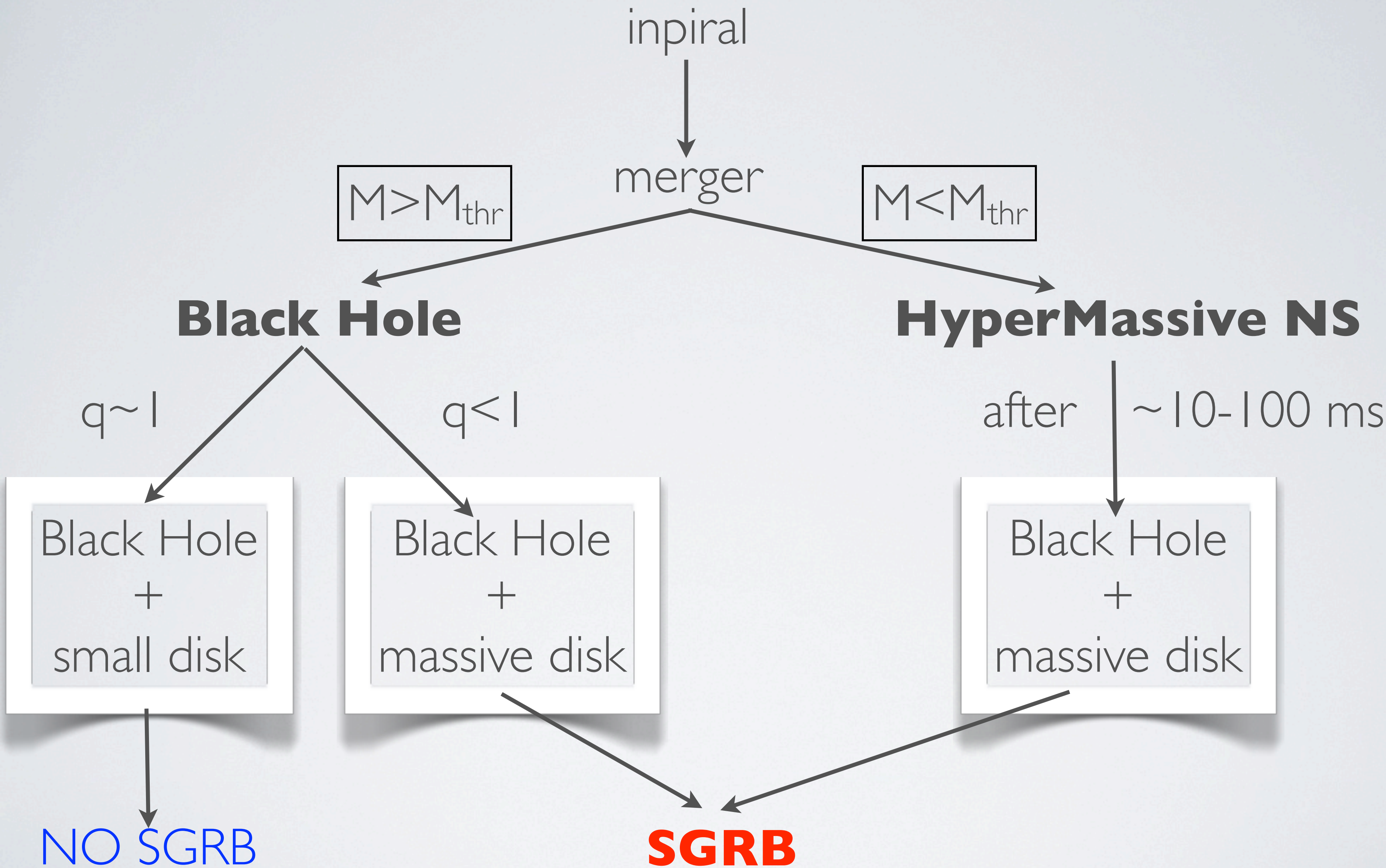
GR BNS SIMULATIONS: STATE OF THE ART

(for a recent review see: Duez 2010, CQG 27, 114002)

- GRHD (only most recent papers listed)
  - Shibata et al 2005: FOS and SLy EOS
  - Shibata & Taniguchi 2006: APR and SLy EOS
  - Anderson et al 2008: first with AMR, ideal-fluid EOS
  - Baiotti et al 2008: AMR, ideal-fluid EOS, first complete GWs
  - Yamamoto et al 2008: AMR, ideal-fluid
  - Read et al 2009: investigated cold realistic EOS and GW inspiral signals
  - Baiotti et al 2009: first study of the accuracy of GR computed GWs
  - Kiuchi et al 2009: long-term inspiral, APR EOS
  - Rezzolla et al 2010: studied tori and long HMNS evolutions
  - Kiuchi et al 2010: connection between short-GRBs and GWs

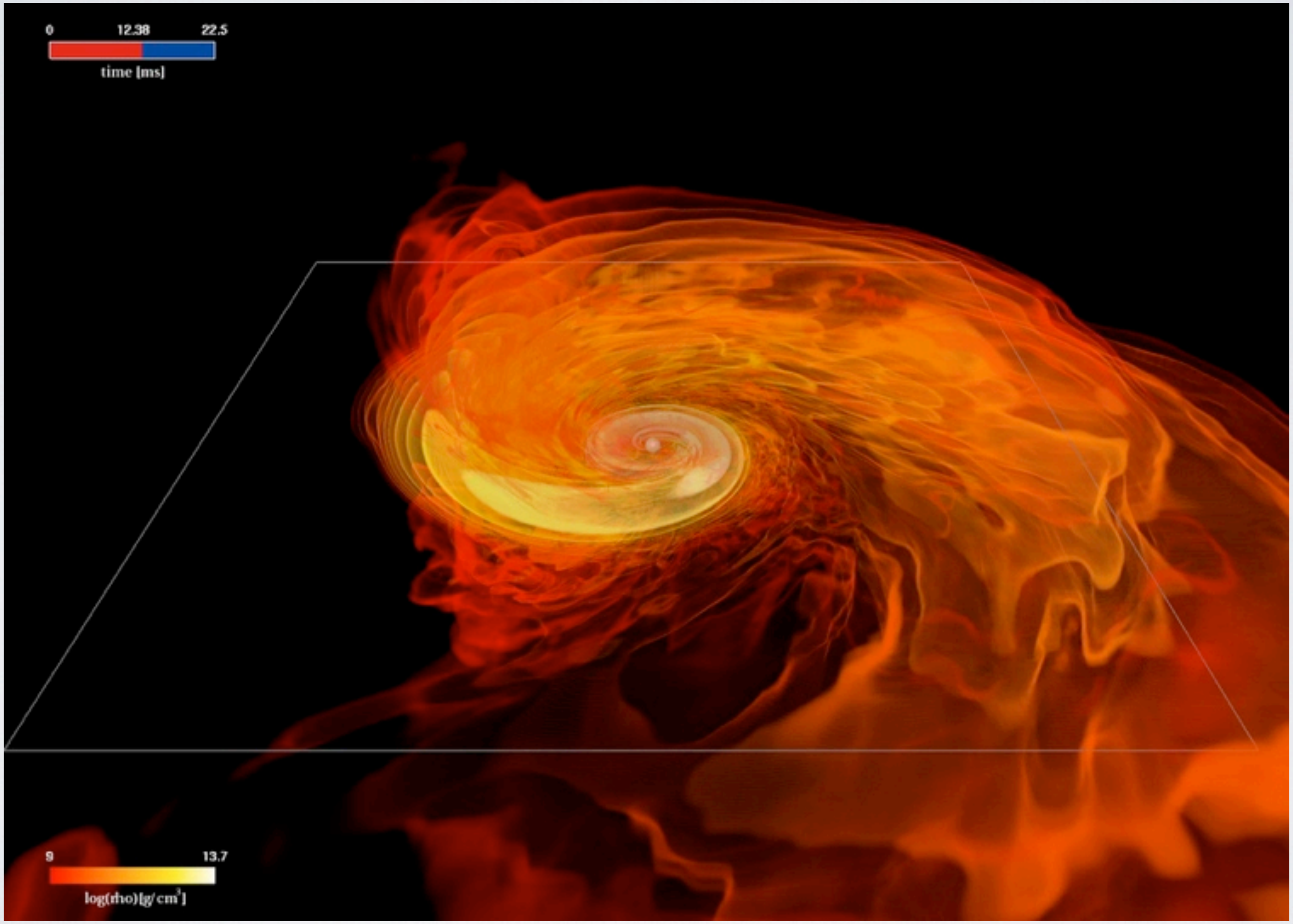
- GRMHD (all the papers listed)
  - Anderson et al 2008: first run of magnetized BNS ($B \sim 10^{16}$G)
  - Liu et al 2008: magnetized BNS ($B \sim 10^{16}$G), followed collapse to BH
  - Giacomazzo et al 2009: first study of amplification of magnetic field
  - Giacomazzo et al 2010: first study of "realistic" configurations ($B \sim 10^{8}$-10^{12}G)

EVOLUTION OF BNS MERGERS



All these 3 cases were studied for the first time in Rezzolla et al 2010

UNEQUAL-MASS BNS: TORUS FORMATION AND GWS



Rezzolla, Baiotti, Giacomazzo, Link, Font 2010, CQG 27, 114105

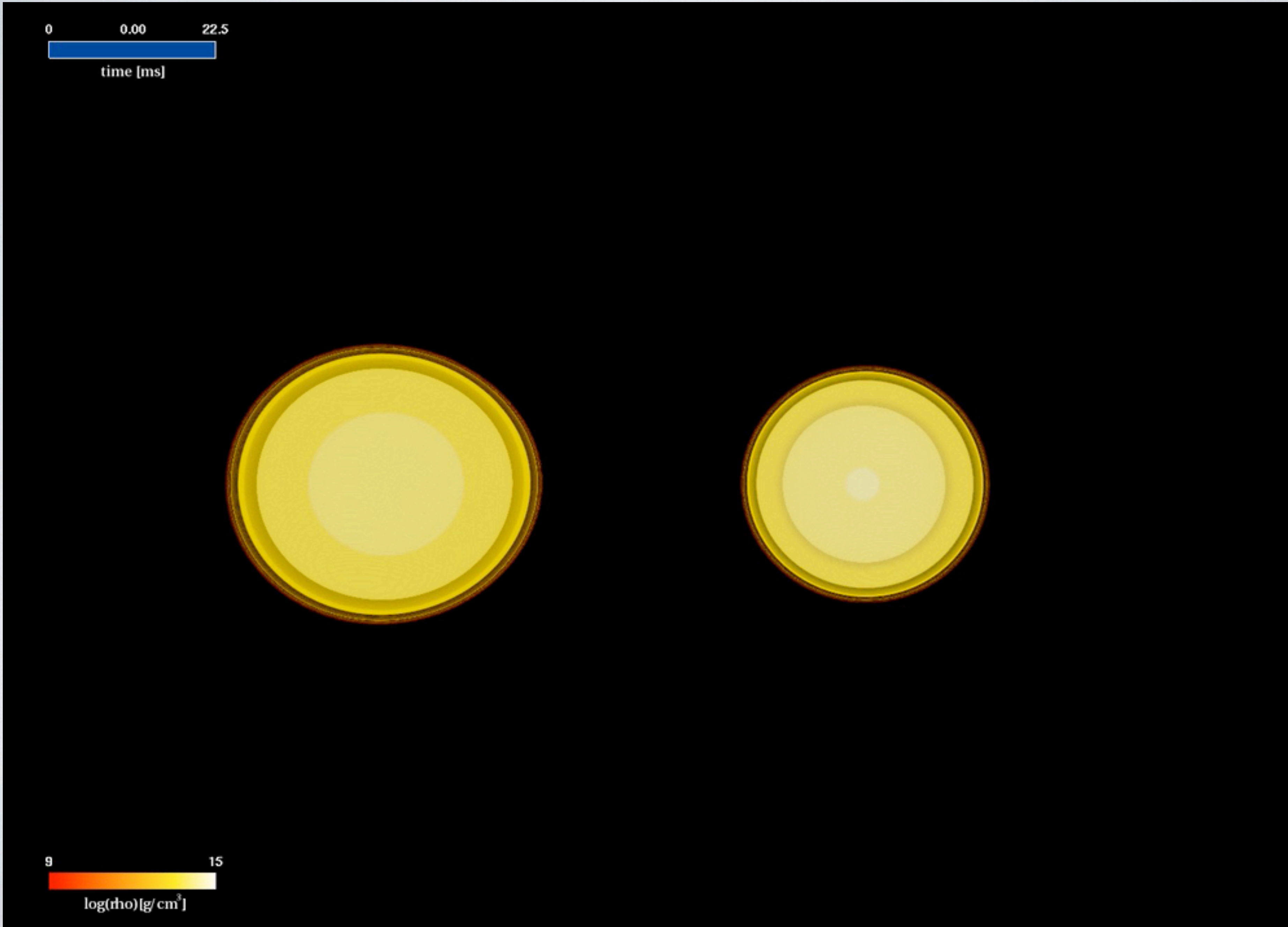
TORUS PROPERTIES: UNEQUAL-MASS CASE

We have considered the inspiral and merger of 6 irrotational binaries with variable total mass and mass ratio

Model	Total ADM Mass	M1, M2
M3.6q1.00	3.23	1.64, 1.64
M3.7q0.94	3.33	1.64, 1.74
M3.4q0.91	3.11	1.51, 1.64
M3.4q0.80	3.08	1.40, 1.72
M3.5q0.75	3.14	1.39, 1.80
M3.4q0.70	3.07	1.30, 1.81

Total initial mass chosen to have prompt collapse to BH

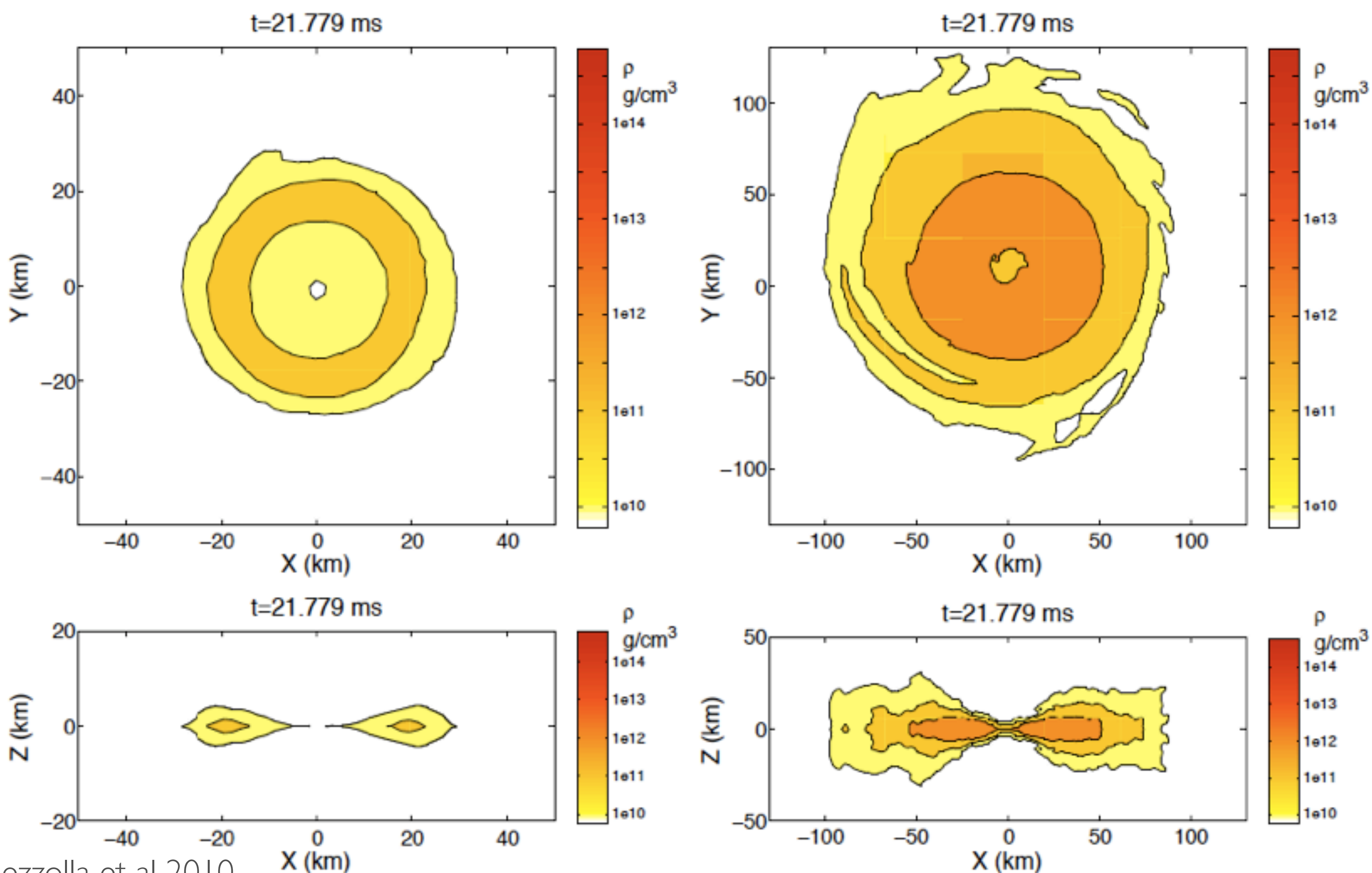
M3.4q0.80



Visualization by Giacomazzo, Koppitz, Rezzolla

TORUS PROPERTIES: UNEQUAL-MASS CASE

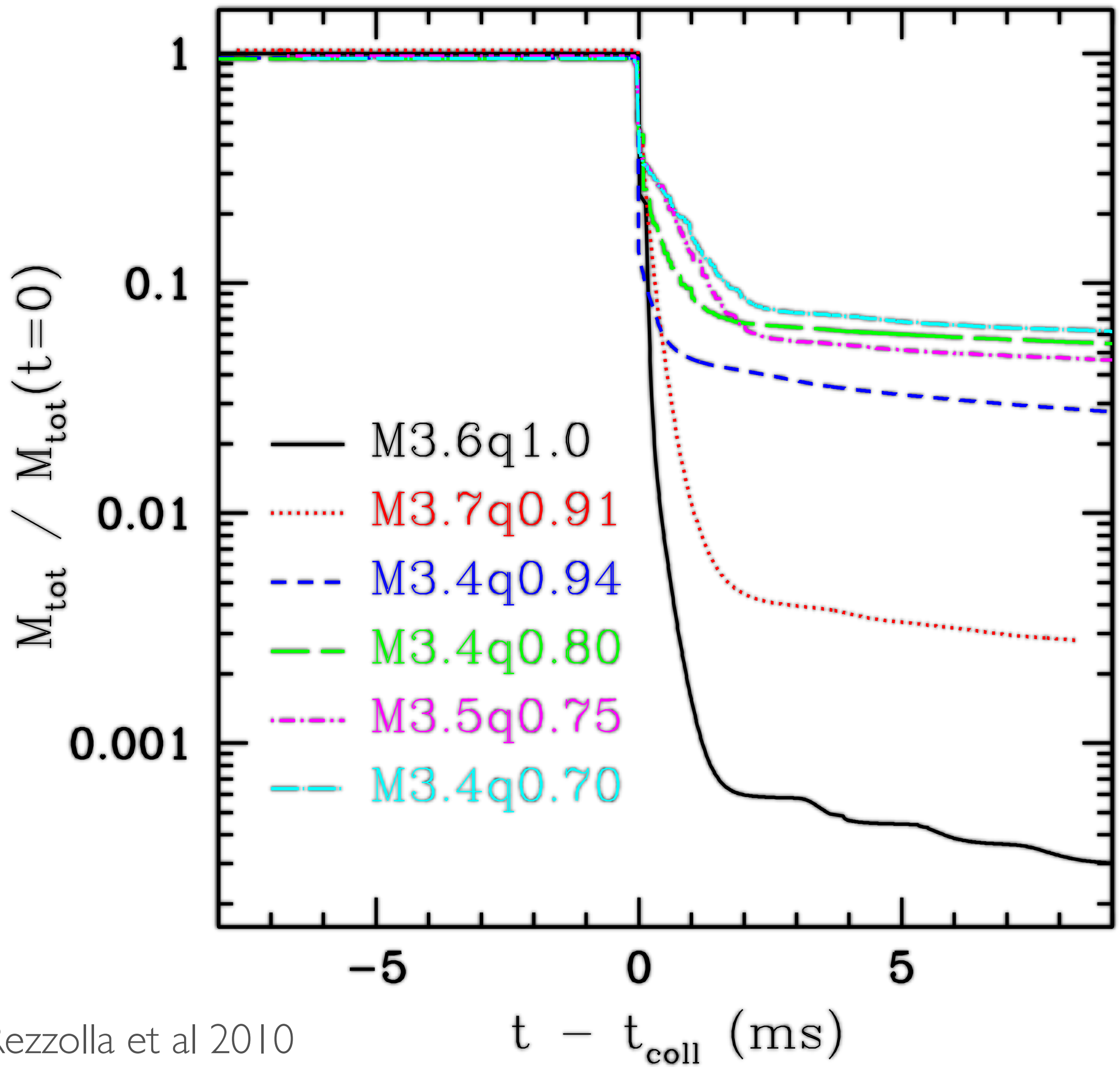
M3.6q1.0 | M3.4q0.7



Rezzolla et al 2010

Note the different length scales!

TORUS PROPERTIES: MASS OF THE TORUS



Rezzolla et al 2010

For smaller $q=M_2/M_1$ the less massive star is tidally disrupted producing a massive tail.

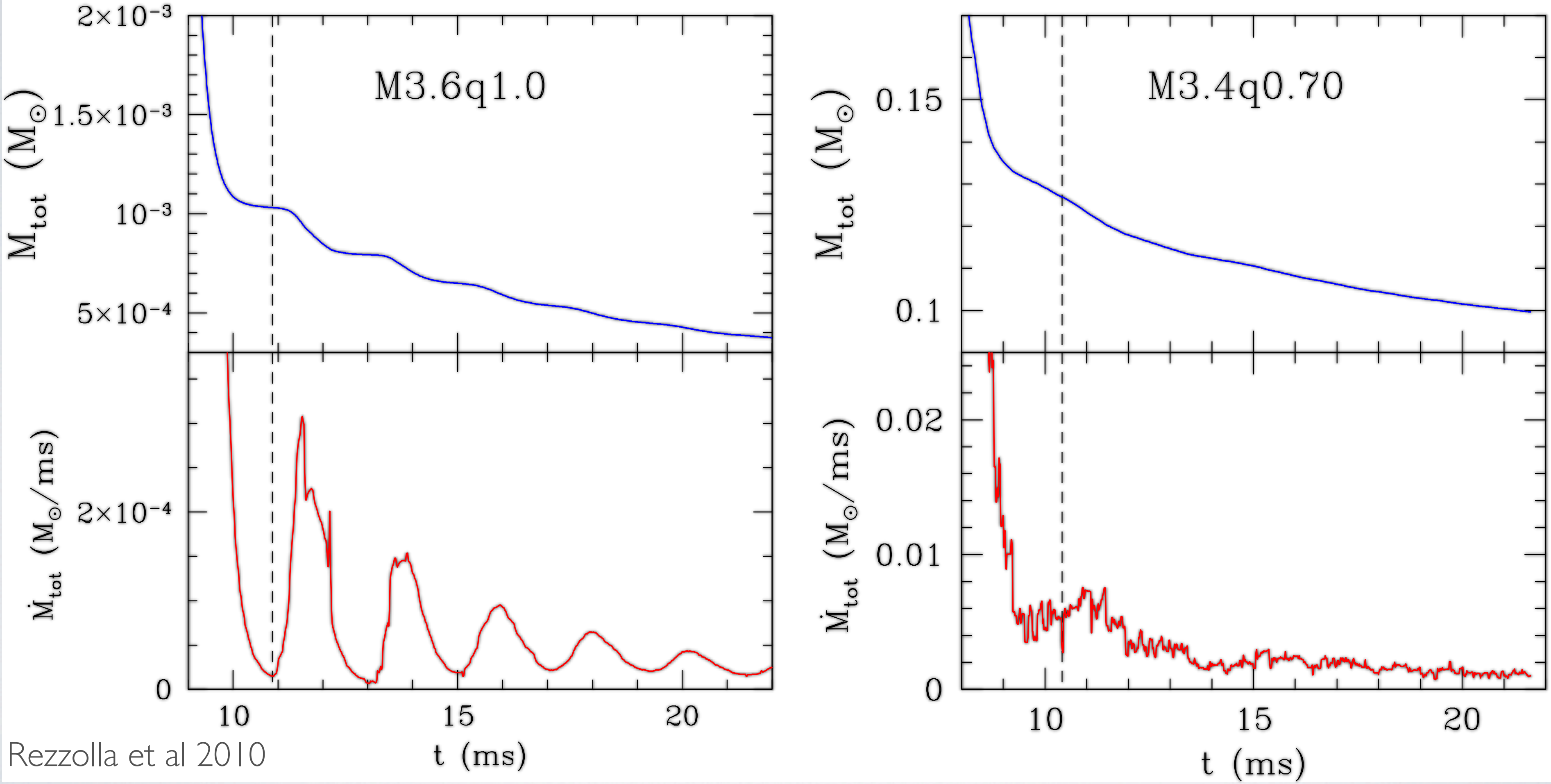
Smaller q produce then larger tori with masses up to $\sim 0.1 M_{\odot}$.

This tori could power short-GRBs.

These tori are MRI unstable and can also lead to the formation of jets (work currently in progress...).

TORUS PROPERTIES: ACCRETION RATES

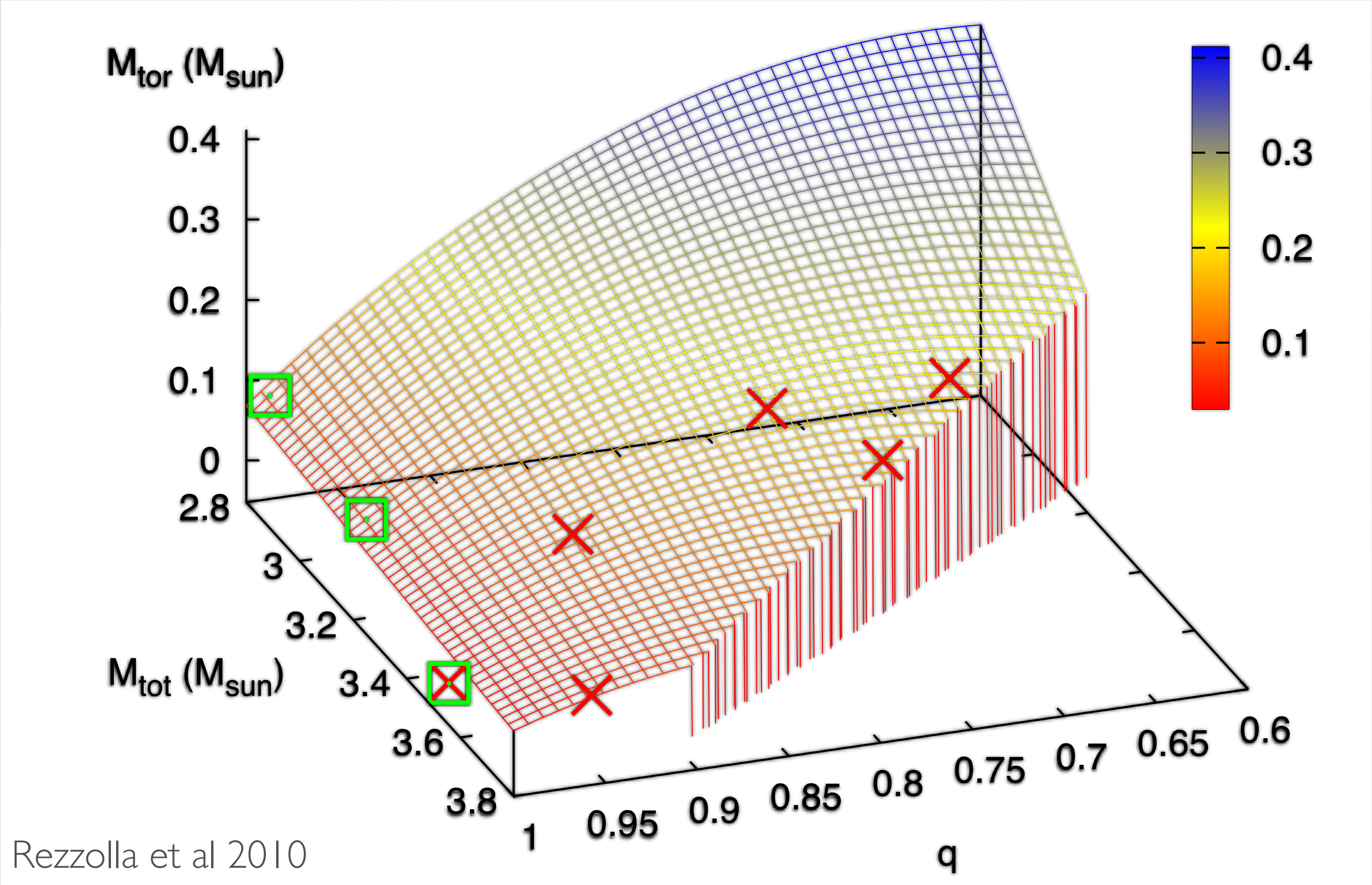
The equal mass case shows periodic oscillations while the unequal-mass cases show a steady accretion rate.



Rezzolla et al 2010

Note the 2 order-of-magnitude difference between q=1 and q=0.7!

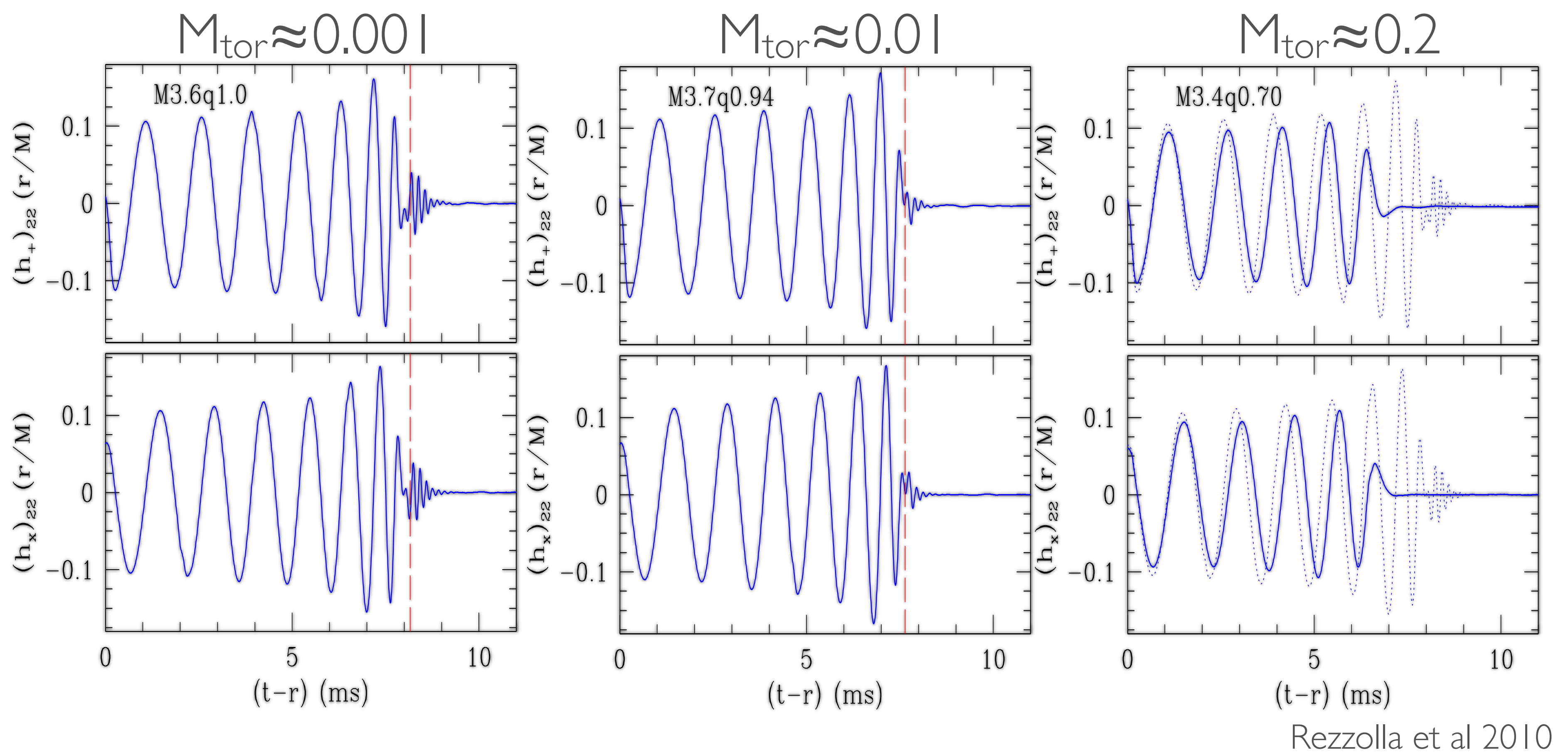
TORUS PROPERTIES: MASS FIT



A systematic investigation shows that: the torus mass increases with the mass ratio and decreases with the total mass

$$\widetilde{M}_{\rm tor}(q, M_{\rm tot}) \;=\; [c_3(1+q)M_* - M_{\rm tot}]\,[c_1(1-q)+c_2]$$

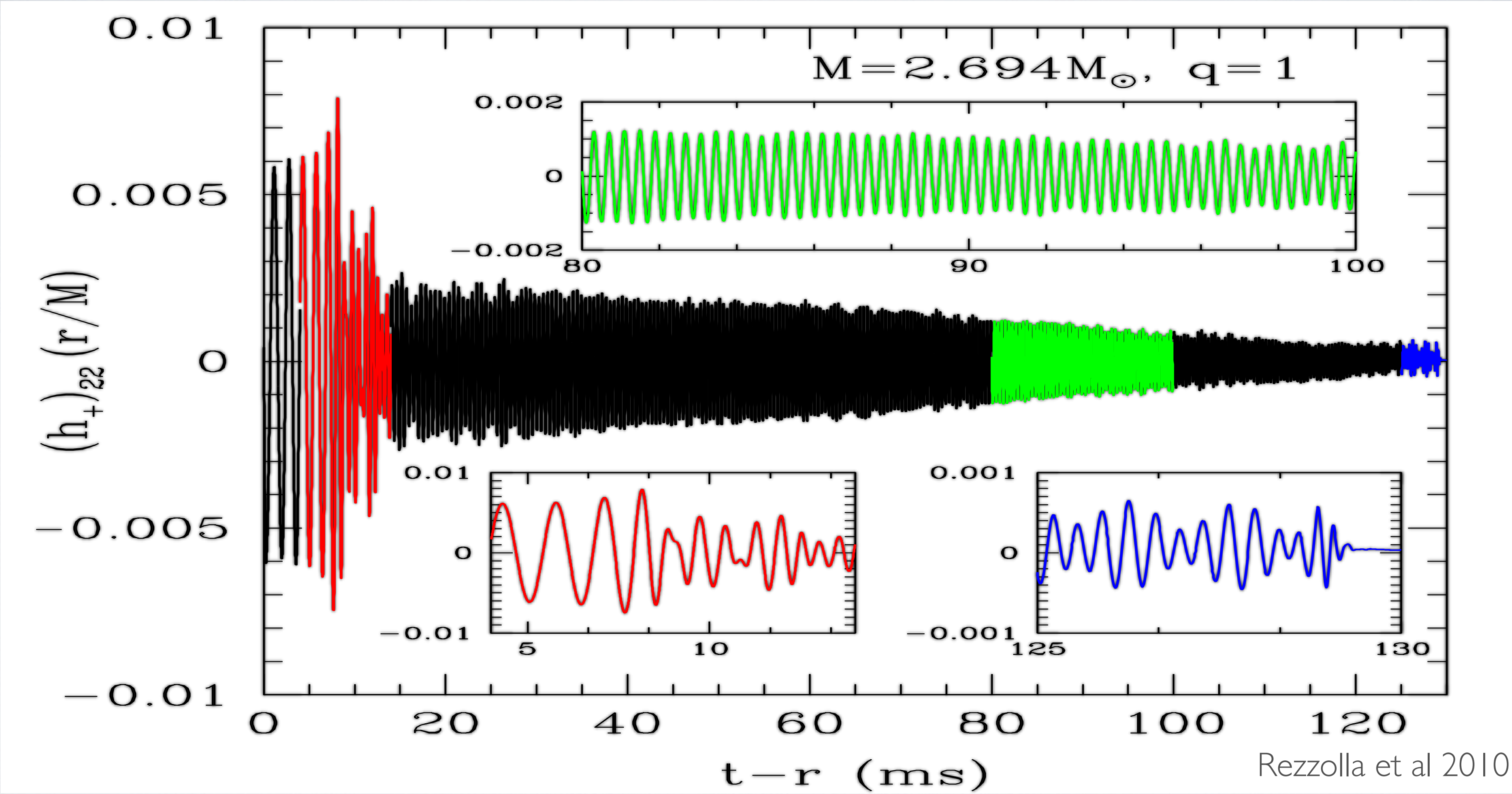
GWs AND GRBs: TORUS MASS



The different mass of the torus has an effect on the GWs. Larger tori suppress the QNM part of the signal.

This is an example of how GWs contain information about the possible central engine of GRBs.

GWs AND GRBs: DELAYED COLLAPSE



Rezzolla et al 2010

GW emitted by a system with $M<M_{thr}$

Torus formed after the HMNS collapses to BH: $M_{tor}\approx 0.11$

SUMMARY

- Able to simulate in full GR the evolution of BNSs during all the phases of inspiral, merger and up to formation of tori around spinning BHs
- Studied the effect of different mass ratio on the production of tori sufficiently massive to power short-GRBs
- Studied in details the properties of the tori formed from BNS mergers
- Evolved for the first time an HMNS up to its collapse to BH after ~120ms
- Computed the GW signal and its correlation with the mass of the torus
- Currently investigating the emission of relativistic jets from these systems