UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

IEEC

The core degenerate scenario: an alternative pathway to SNIa

Enrique García-Berro

Supernovae, hypernovae and binary driven hypernovae

An Adriatic Workshop – Pescara 2016

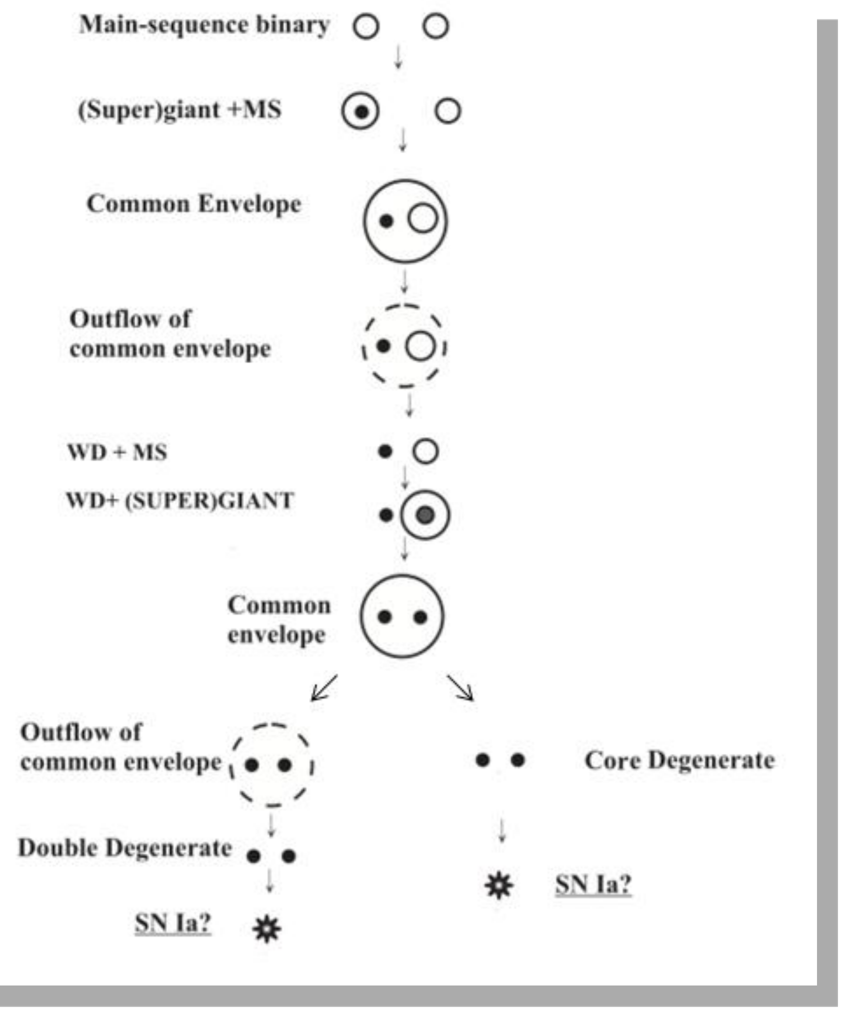
CONTENTS

1. Astrophysical framework.
2. Initial conditions.
3. Time evolution.
4. The merged remnant.
5. Observables.
6. Discussion and conclusions.

CONTENTS

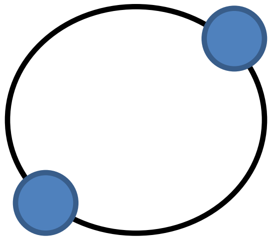
1. Astrophysical framework.
2. Initial conditions.
3. Time evolution.
4. The merged remnant.
5. Observables.
6. Discussion and conclusions.

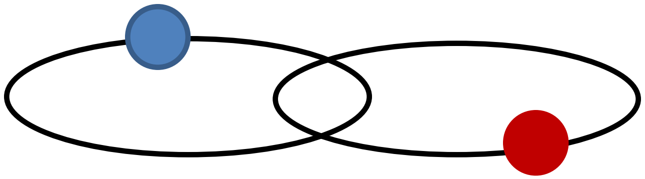
1. ASTROPHYSICAL FRAMEWORK



1. ASTROPHYSICAL FRAMEWORK

- In a double degenerate merger the orbit is expected to be nearly circular and with synchronized and cool white dwarfs.
- In the core degenerate a broader range of orbital eccentricities and temperatures for the core component are expected.





CONTENTS

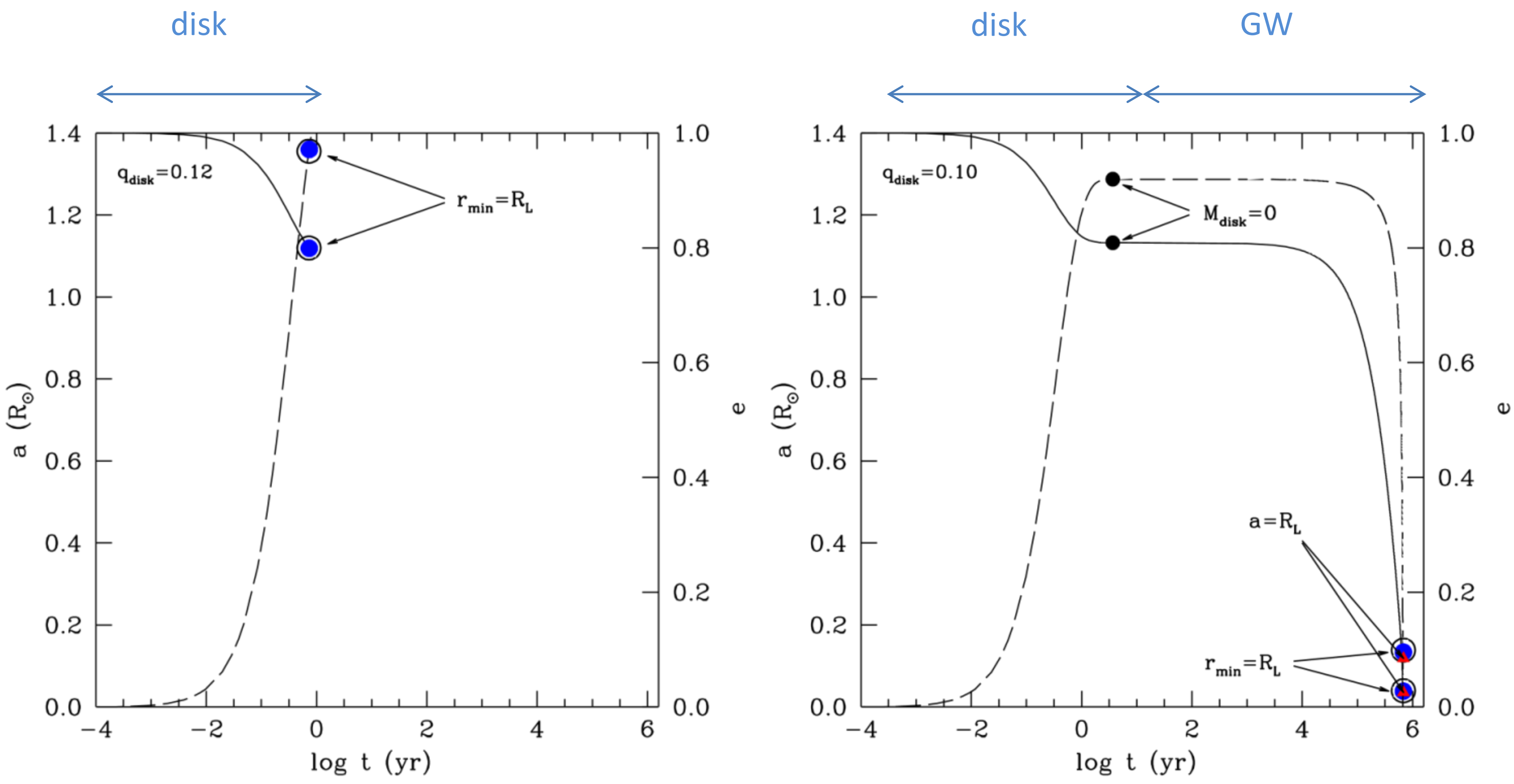
1. Astrophysical framework.
2. Initial conditions.
3. Time evolution.
4. The merged remnant.
5. Observables.
6. Discussion and conclusions.

2. INITIAL CONDITIONS

- M_{AGB}=0.77 $M_\odot$, M_{WD}=0.60 $M_\odot$.
- T_{AGB}=10^6 K (CC) and 10^8 K (HC).
- T_{WD}=10^6 K.
- Two different disk masses:

$$q_{disk} = \frac{M_{disk}}{M_{AGB} + M_{WD}} = 0.10,\ \ 0.12.$$

2. INITIAL CONDITIONS

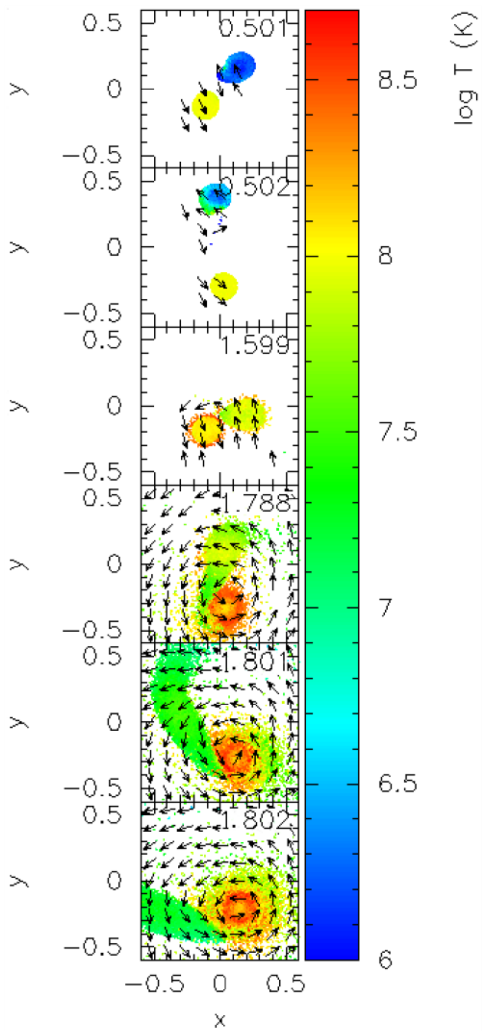


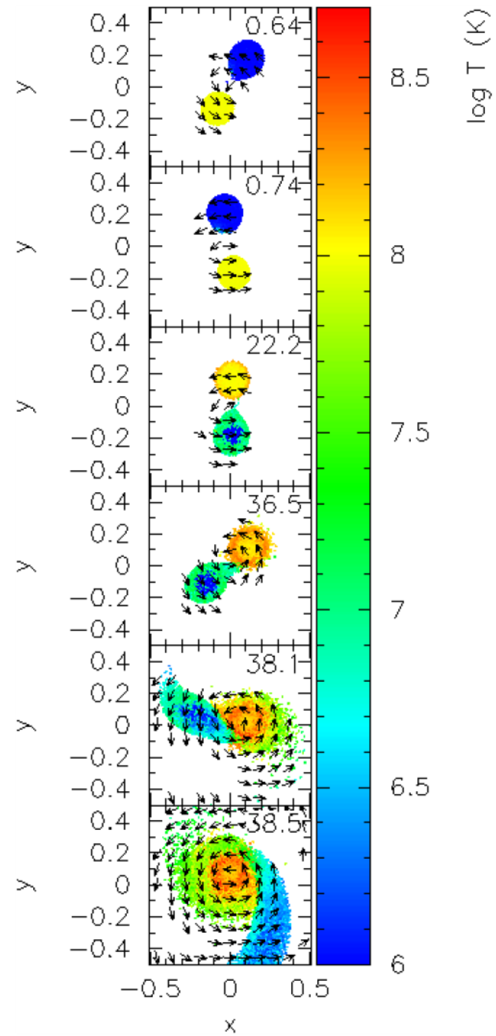
CONTENTS

1. Astrophysical framework.
2. Initial conditions.
3. Time evolution.
4. The merged remnant.
5. Observables.
6. Discussion and conclusions.

3. TIME EVOLUTION

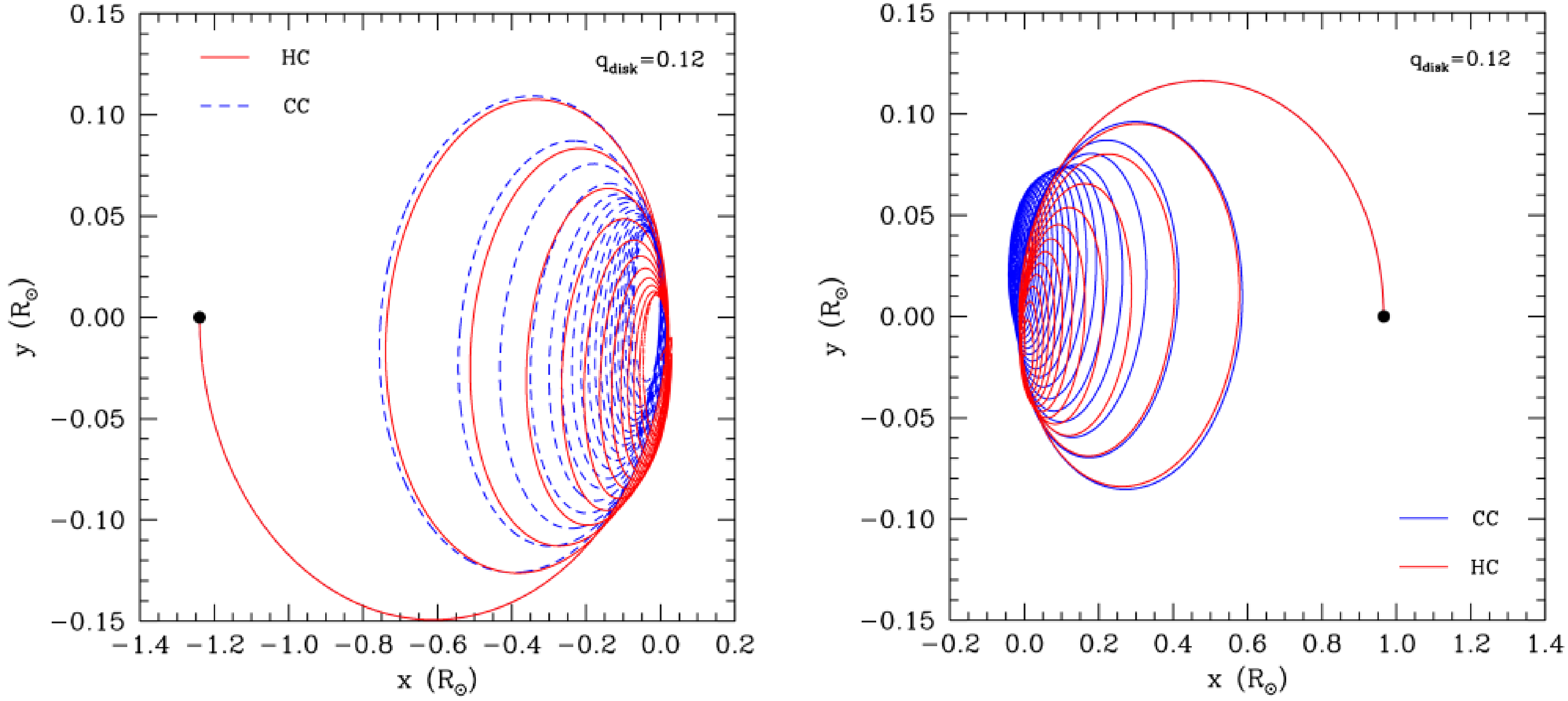
$q_{disk} = 0.12$



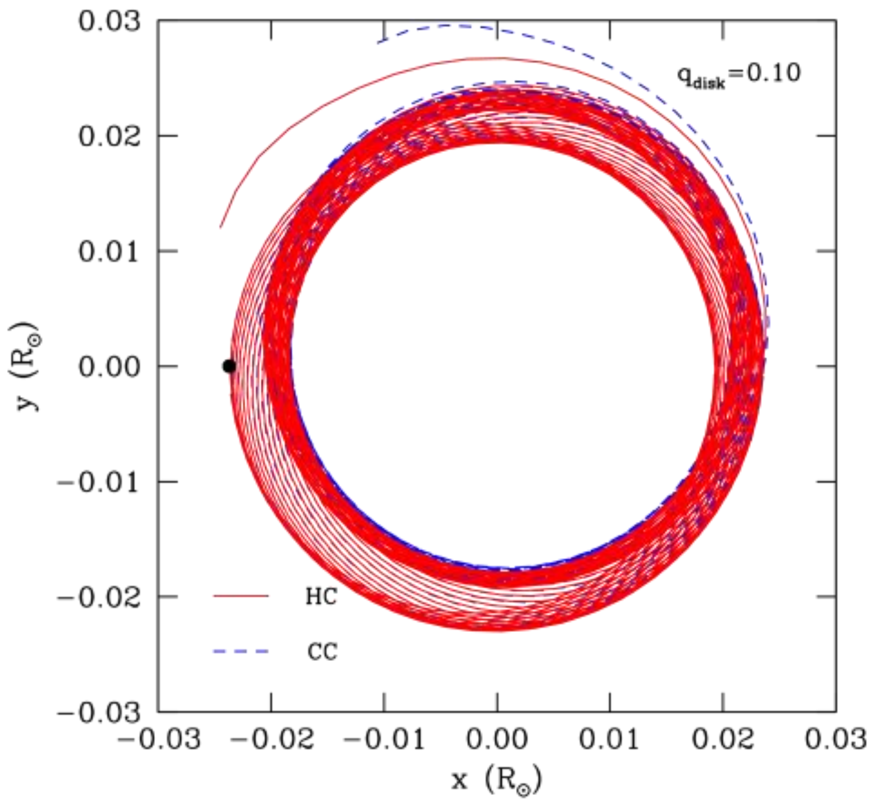


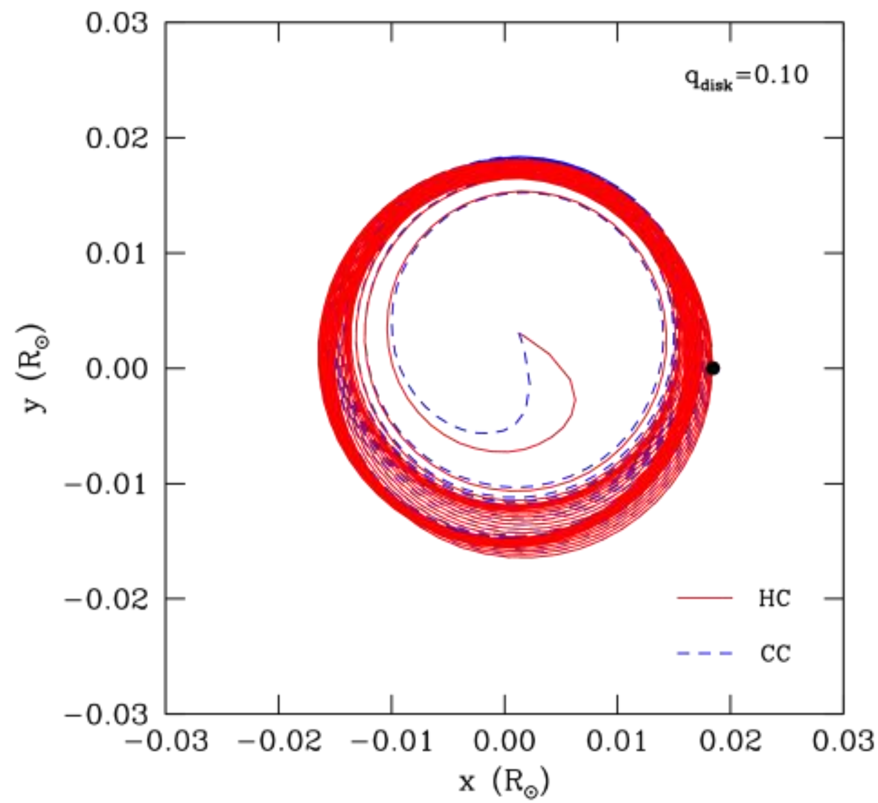
$q_{disk} = 0.10$

3. TIME EVOLUTION

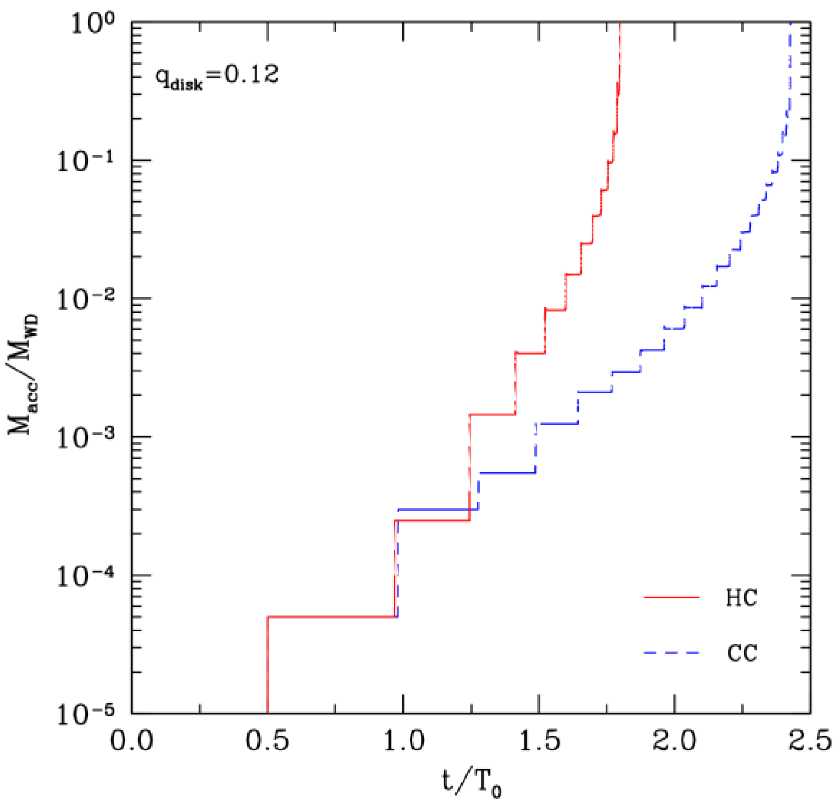


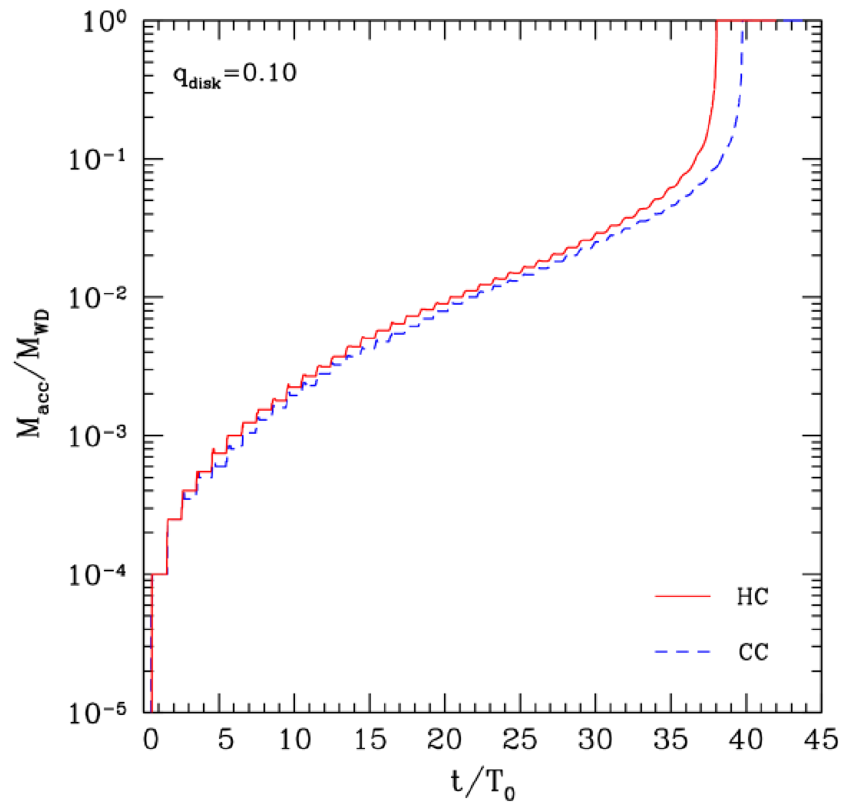
3. TIME EVOLUTION





3. TIME EVOLUTION





3. TIME EVOLUTION

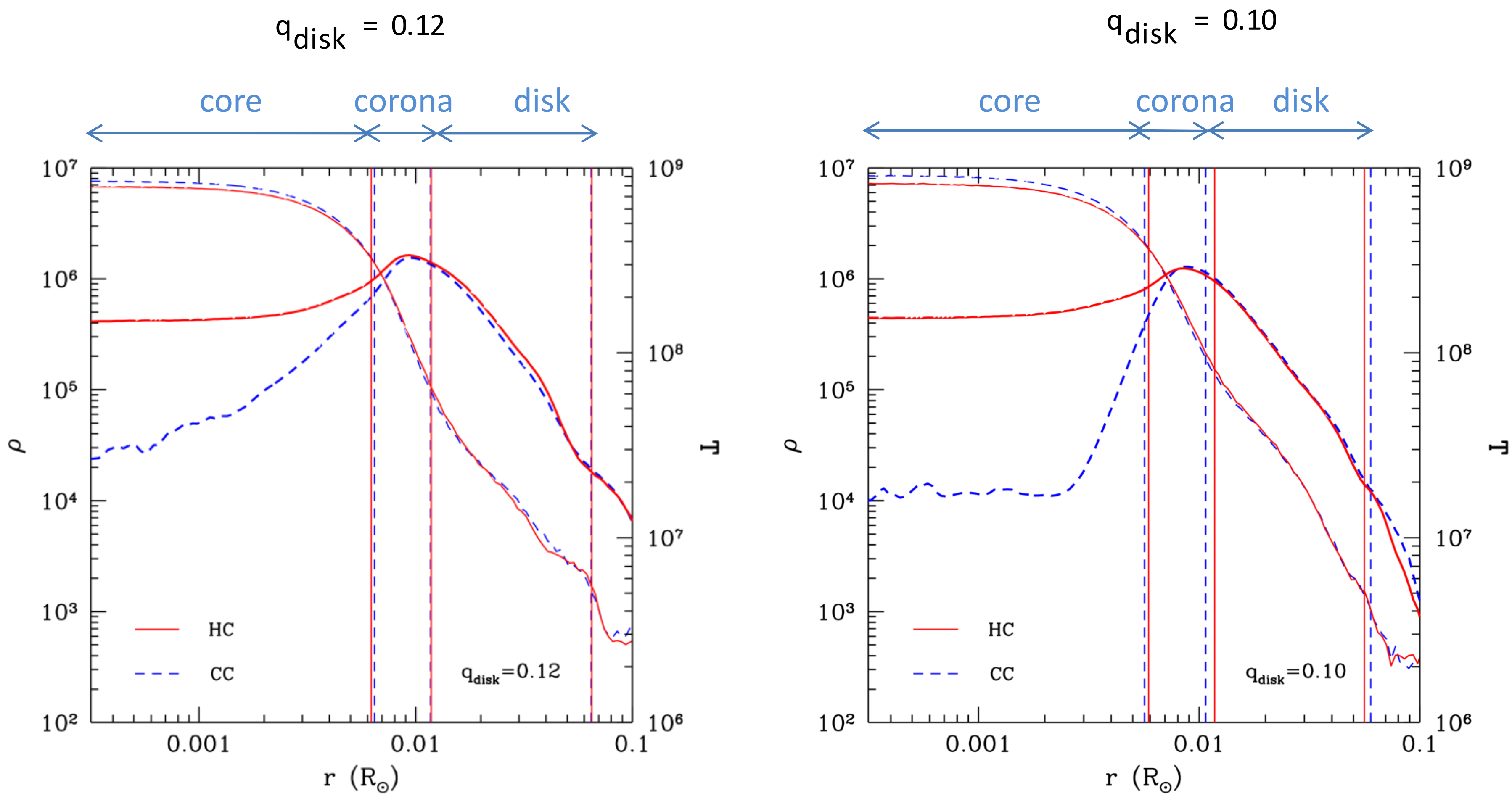
- In eccentric mergers the peak temperatures are slightly larger.
- In the CC case, the nuclear energy release is smaller.
- Eccentric mergers coalesce in a couple of orbital periods, although the elapsed time is larger.

$q_{\rm disk}$	Run	$T_{\rm peak}$ (K)	$E_{\rm nuc}$ (erg)	Δt (s)
0.12	HC	9.23×10^{8}	1.13×10^{39}	18343
	CC	8.55×10^{8}	3.54×10^{37}	24784
0.10	HC	8.74×10^{8}	1.12×10^{39}	2599
	CC	8.18×10^{8}	4.77×10^{37}	2710

CONTENTS

1. Astrophysical framework.
2. Initial conditions.
3. Time evolution.
4. The merged remnant.
5. Observables.
6. Discussion and conclusions.

4. THE MERGED REMNANT

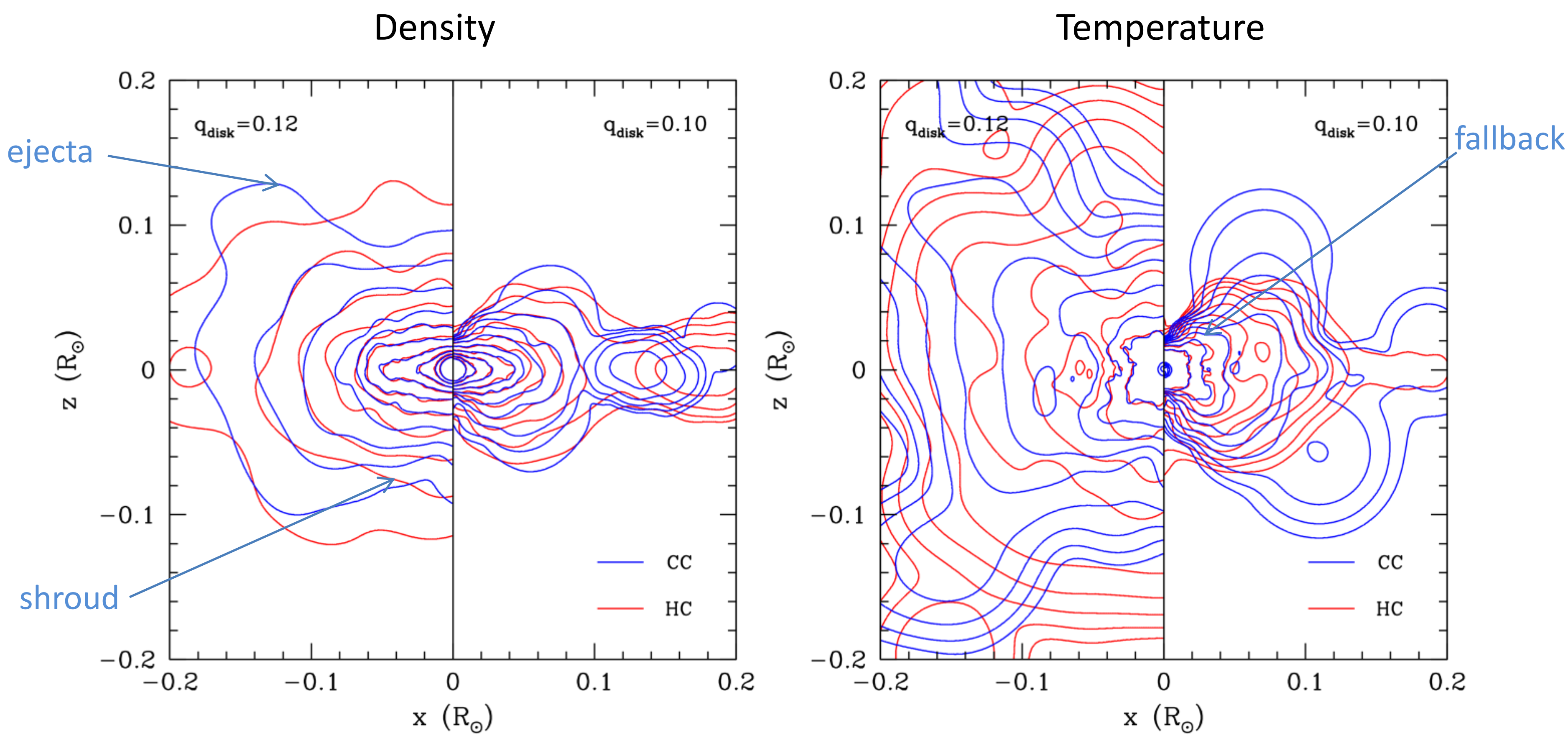


4. THE MERGED REMNANT

- The remnant is similar to that of the double degenerate scenario.
- The stronger interactions of the eccentric merger leave imprints on the accreted mass and the rotational velocities.

$q_{\rm disk}$	Run	$M_{\rm mr}$ ($M_\odot$)	$M_{\rm disk}$ ($M_\odot$)	$T_{\rm max}$ (K)	$\omega_{\rm max}$ (s^{-1})
0.12	HC	0.88	0.36	3.56×10^8	0.23
	CC	0.88	0.35	3.53×10^8	0.25
0.10	HC	0.93	0.39	2.97×10^8	0.30
	CC	0.91	0.41	3.10×10^8	0.32

4. THE MERGED REMNANT



CONTENTS

1. Astrophysical framework.
2. Initial conditions.
3. Time evolution.
4. The merged remnant.
5. Observables.
6. Discussion and conclusions.

CONTENTS

5. Observables.
    5.1 Gravitational wave radiation.
    5.2 Neutrinos.
    5.3 Fall-back luminosities.
    5.4 Nebular emission.

CONTENTS

5. Observables.

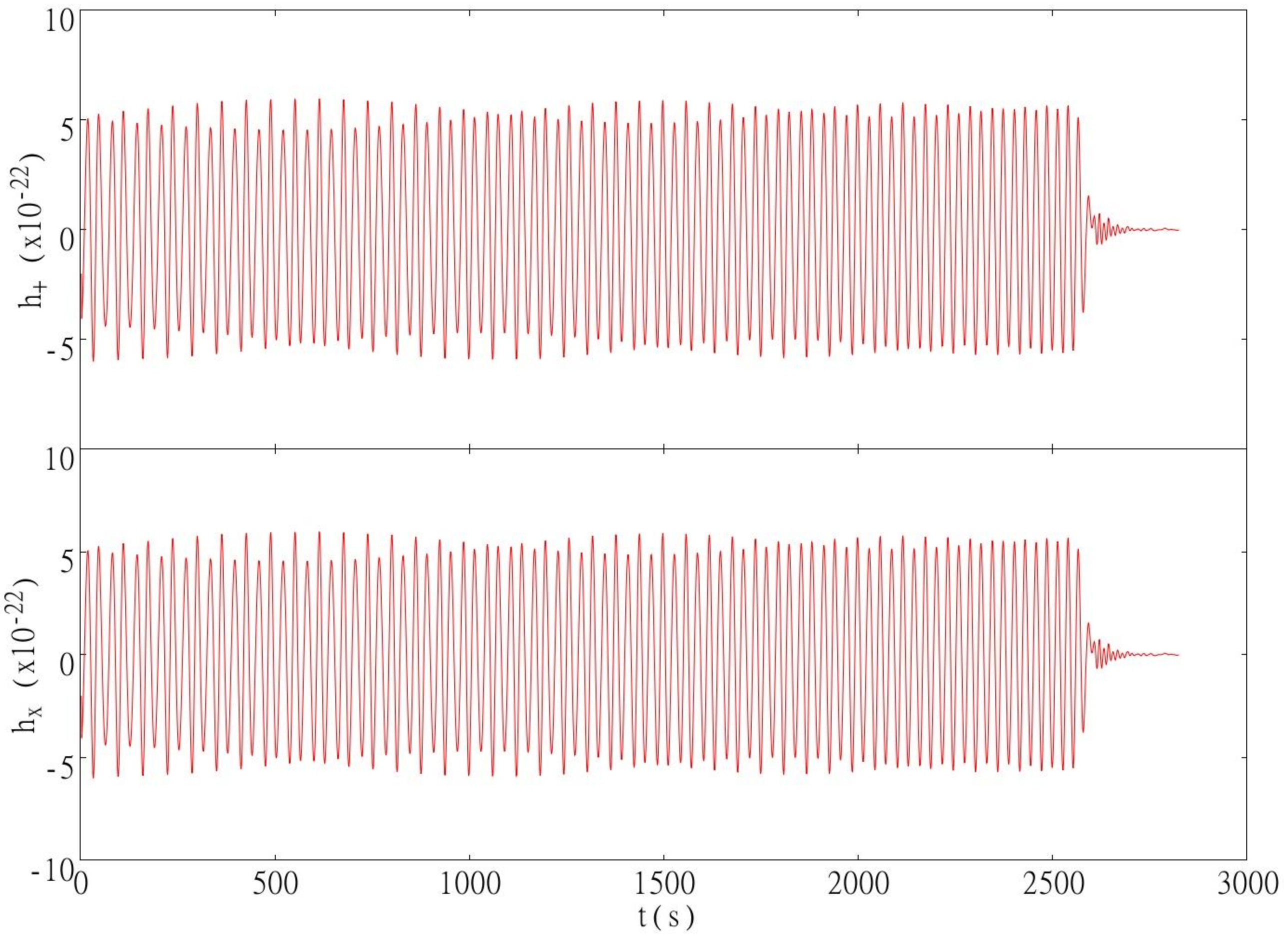
5.1 Gravitational wave radiation.

5.2 Neutrinos.

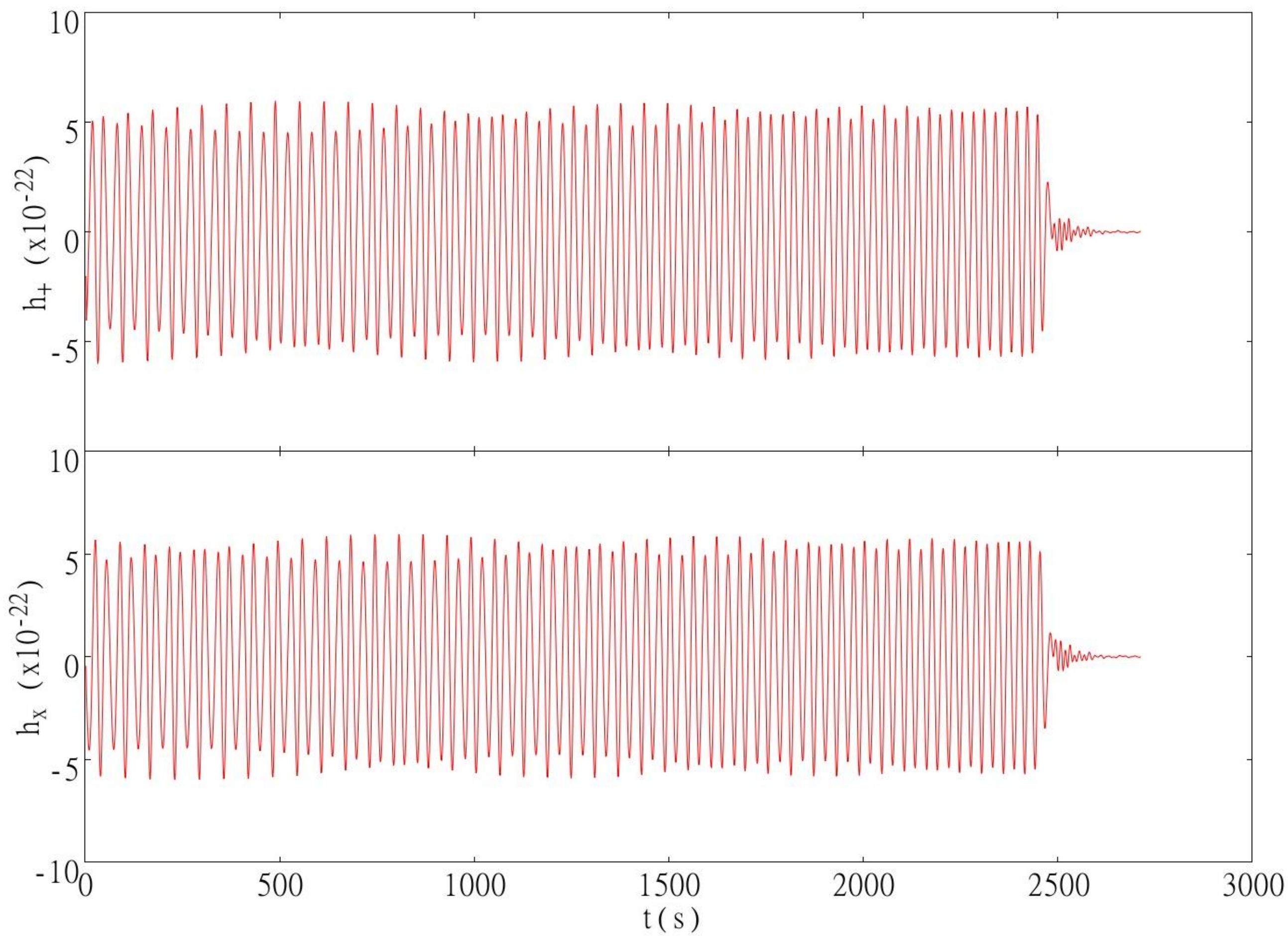
5.3 Fall-back luminosities.

5.4 Nebular emission.

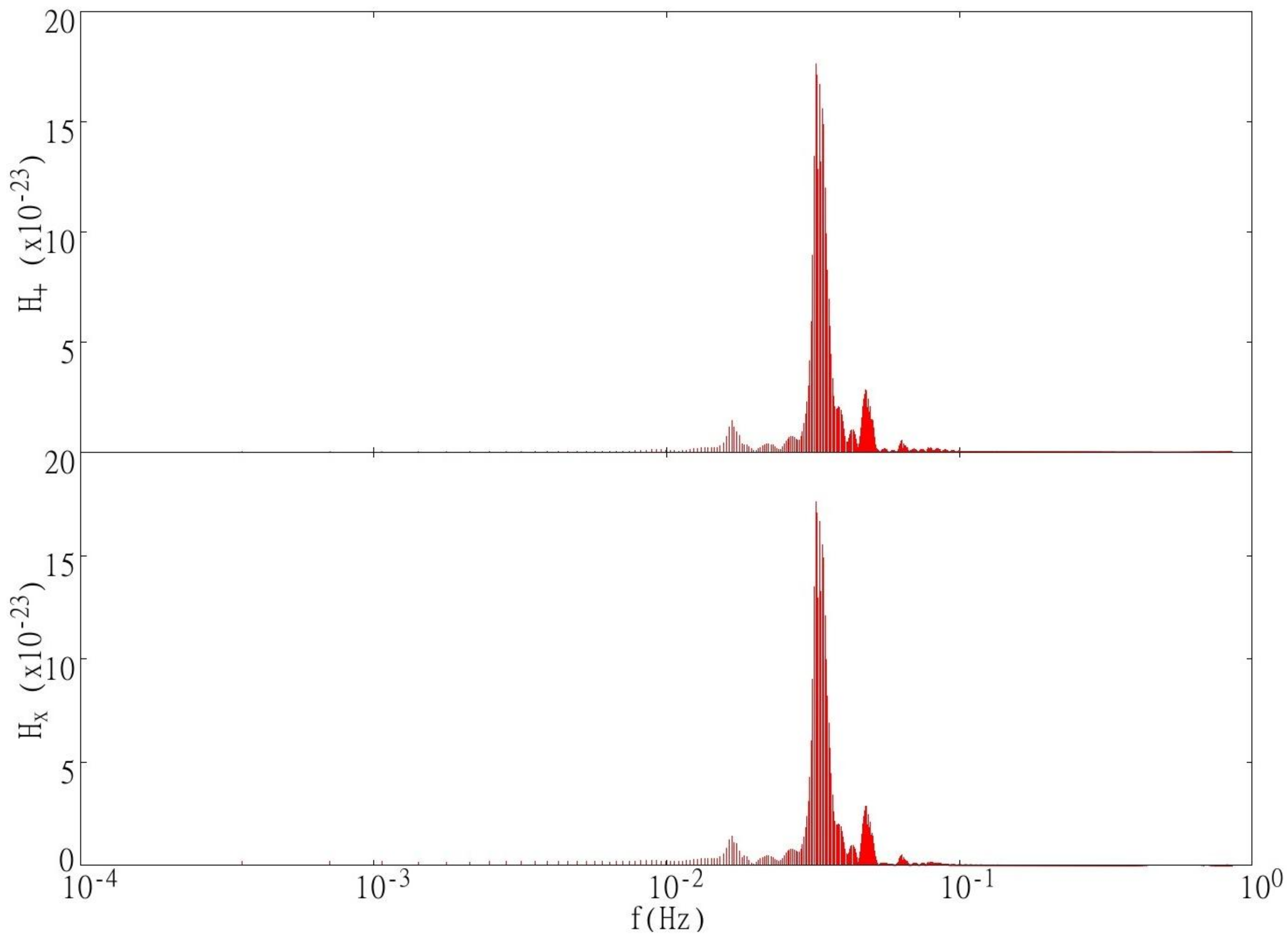
5.1 GRAVITATIONAL WAVE RADIATION CC *q*=0.10



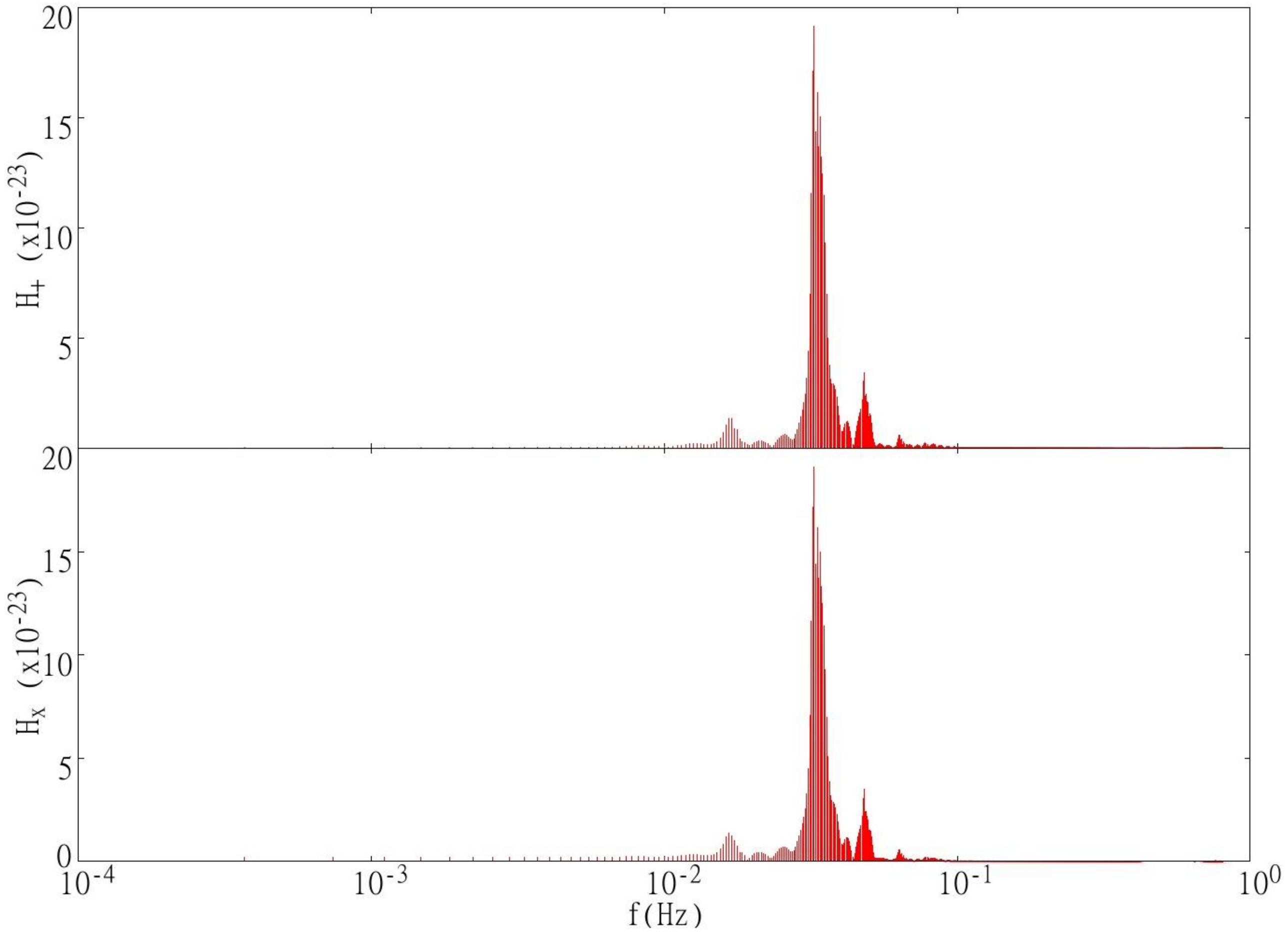
5.1 GRAVITATIONAL WAVE RADIATION
HC q=0.10



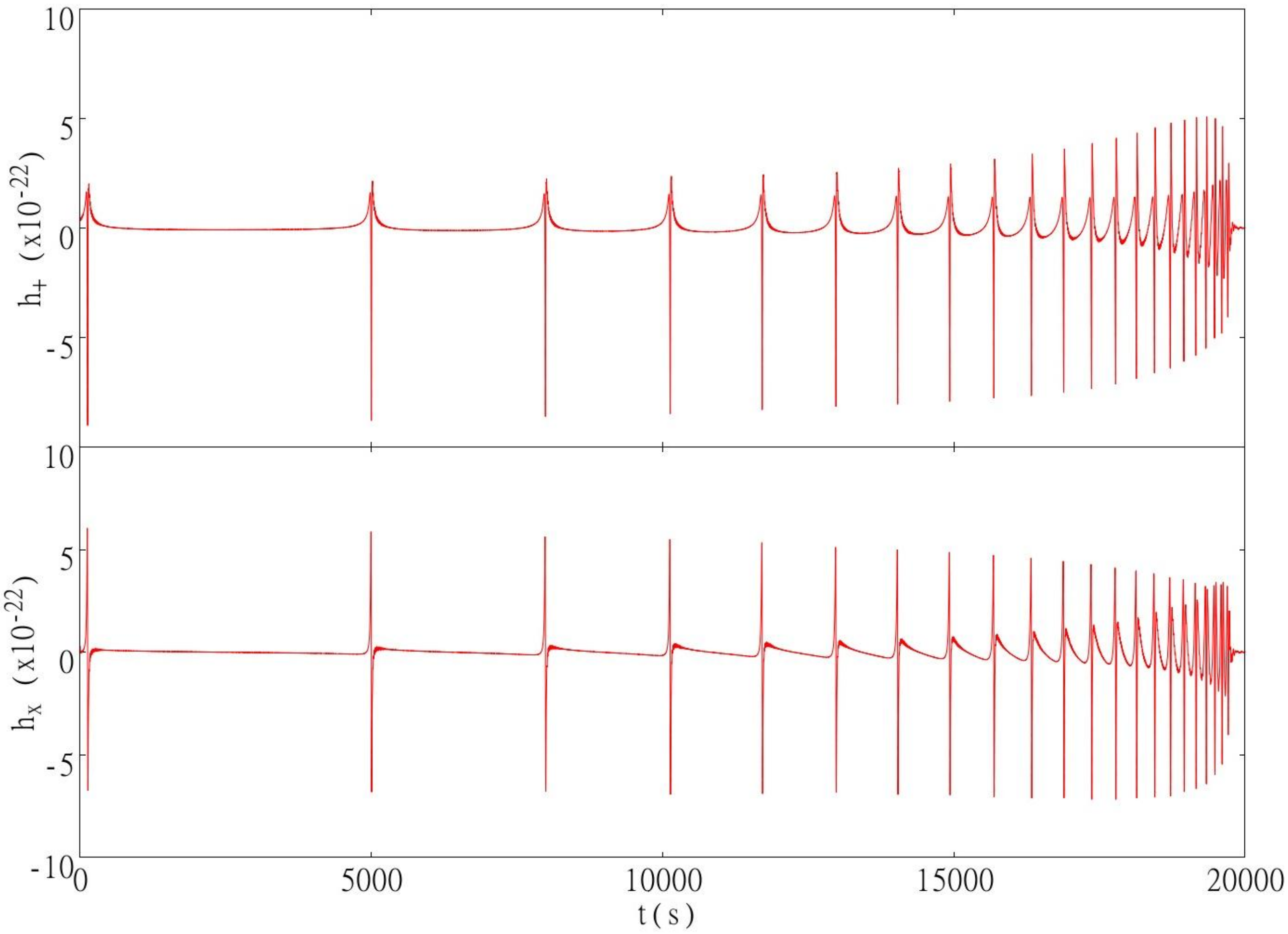
5.1 GRAVITATIONAL WAVE RADIATION CC q=0.10



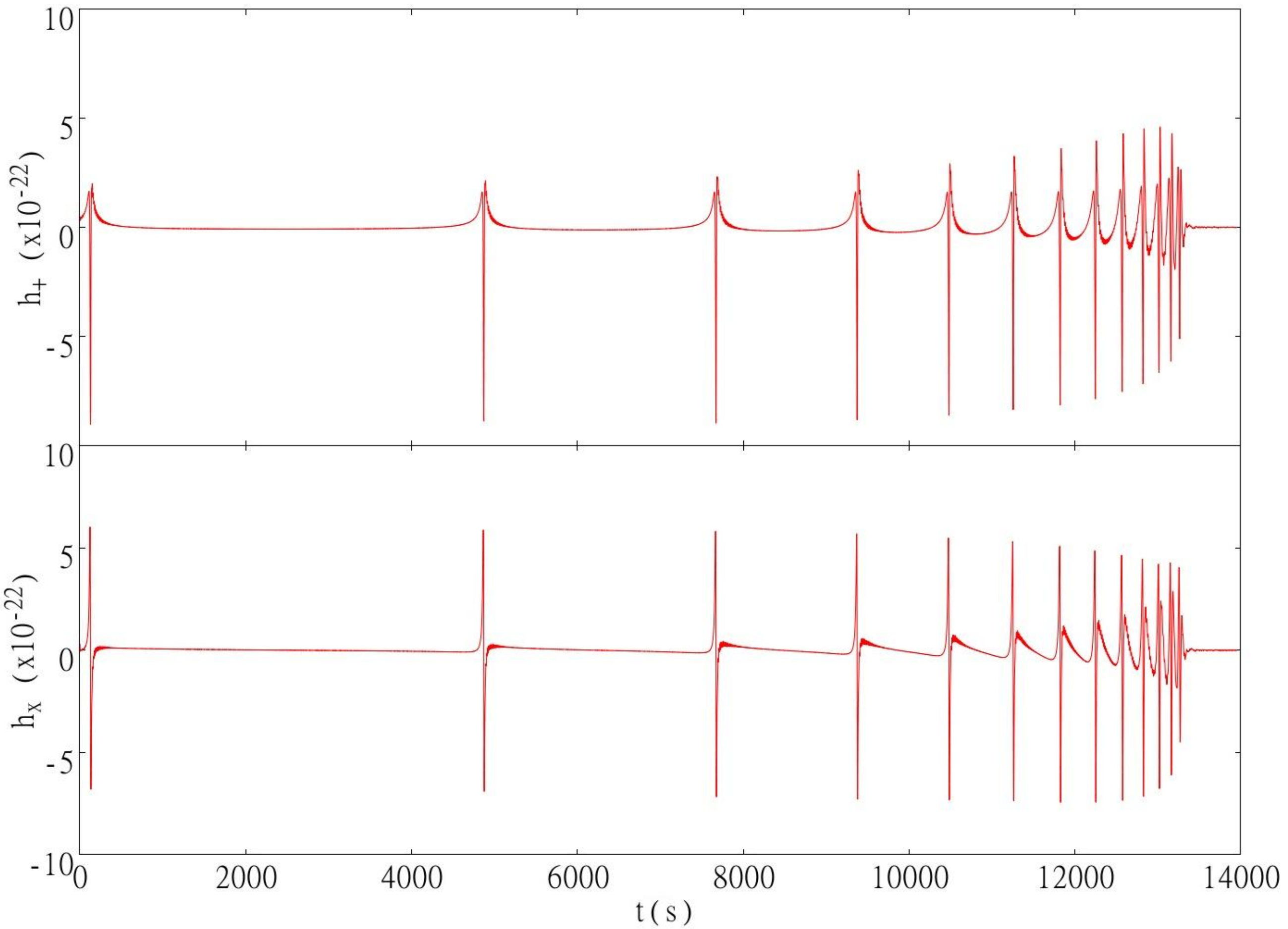
5.1 GRAVITATIONAL WAVE RADIATION HC q=0.10



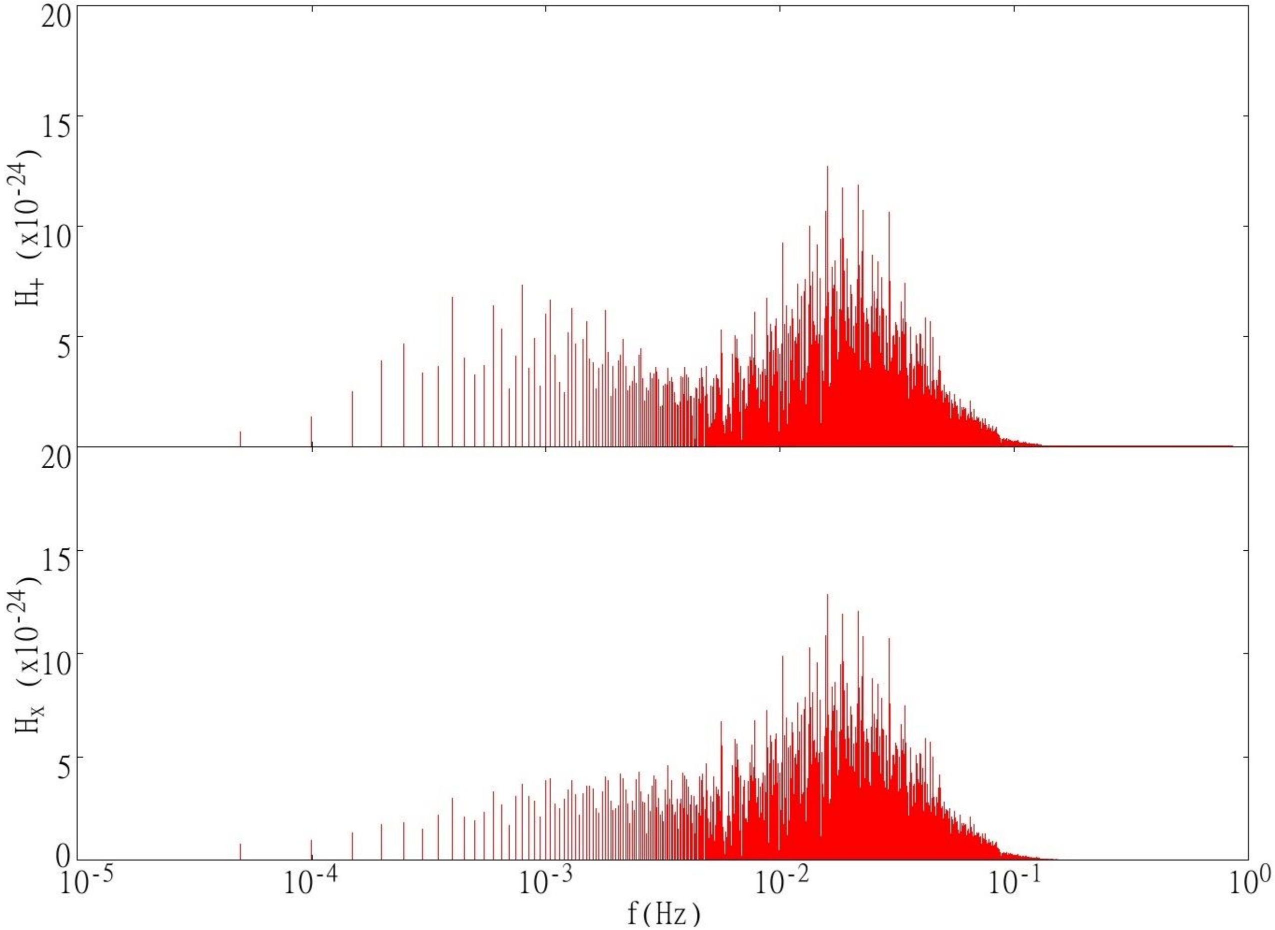
5.1 GRAVITATIONAL WAVE RADIATION CC *q*=0.12



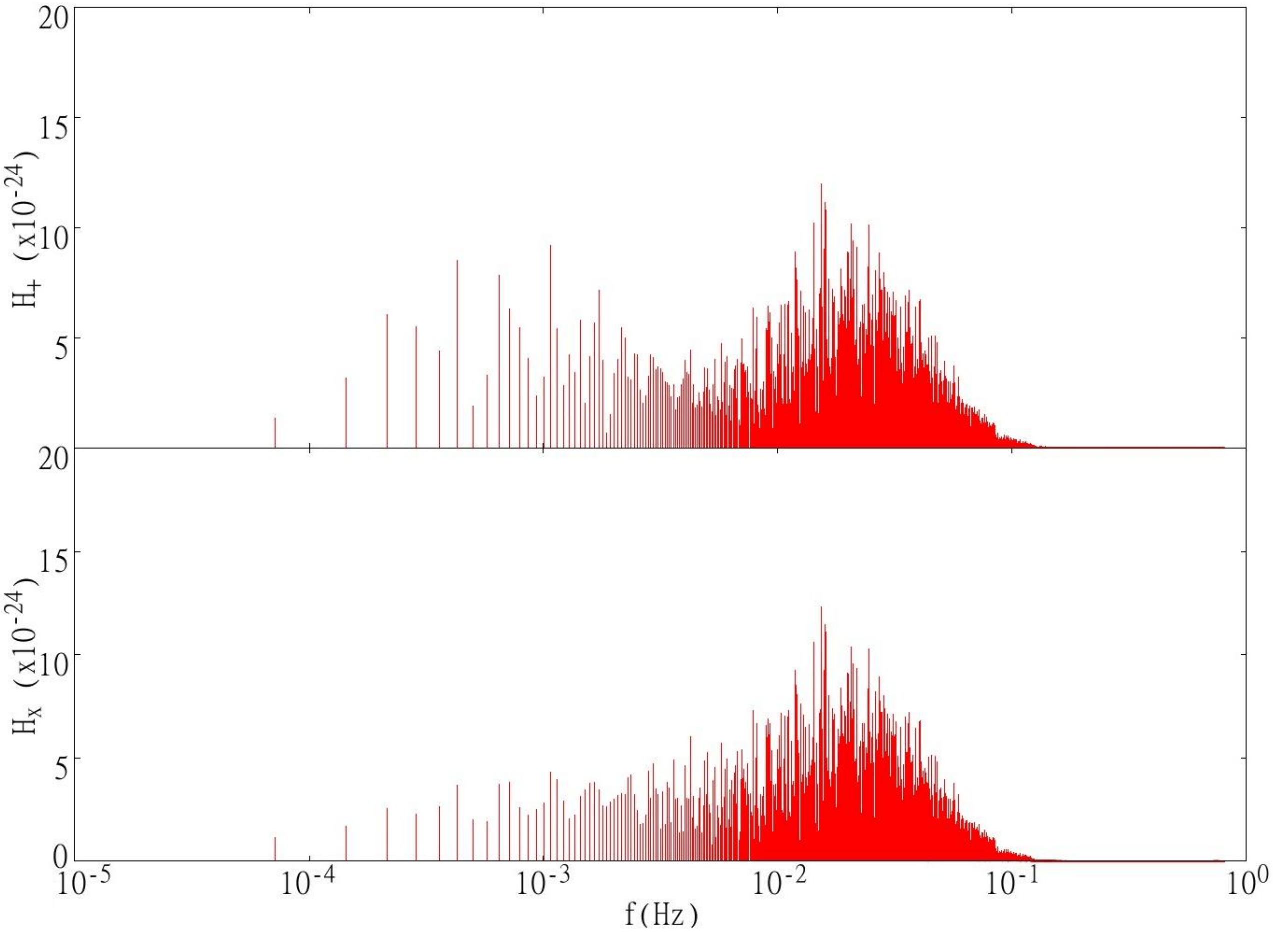
5.1 GRAVITATIONAL WAVE RADIATION
HC q=0.12



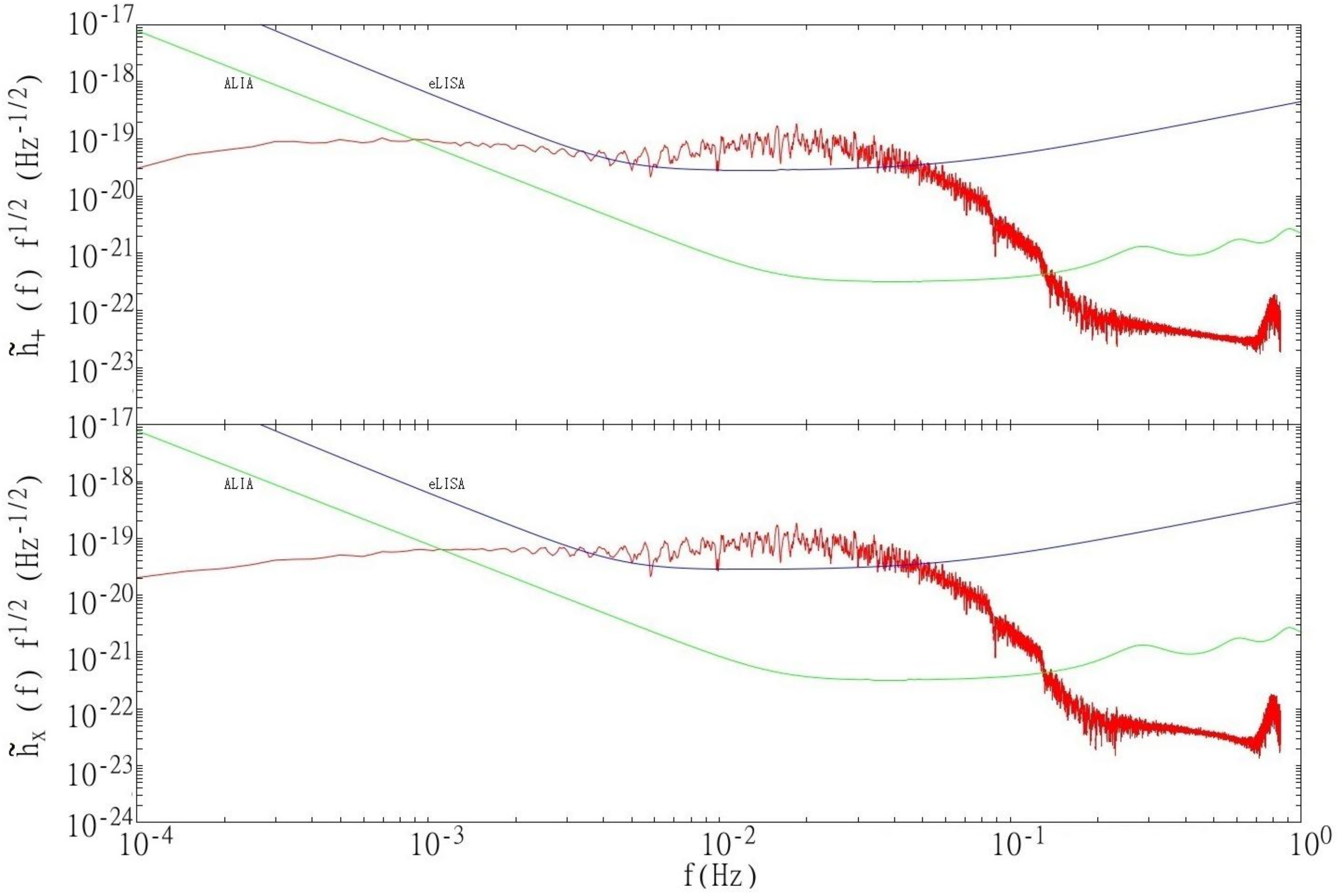
5.1 GRAVITATIONAL WAVE RADIATION
CC q=0.12



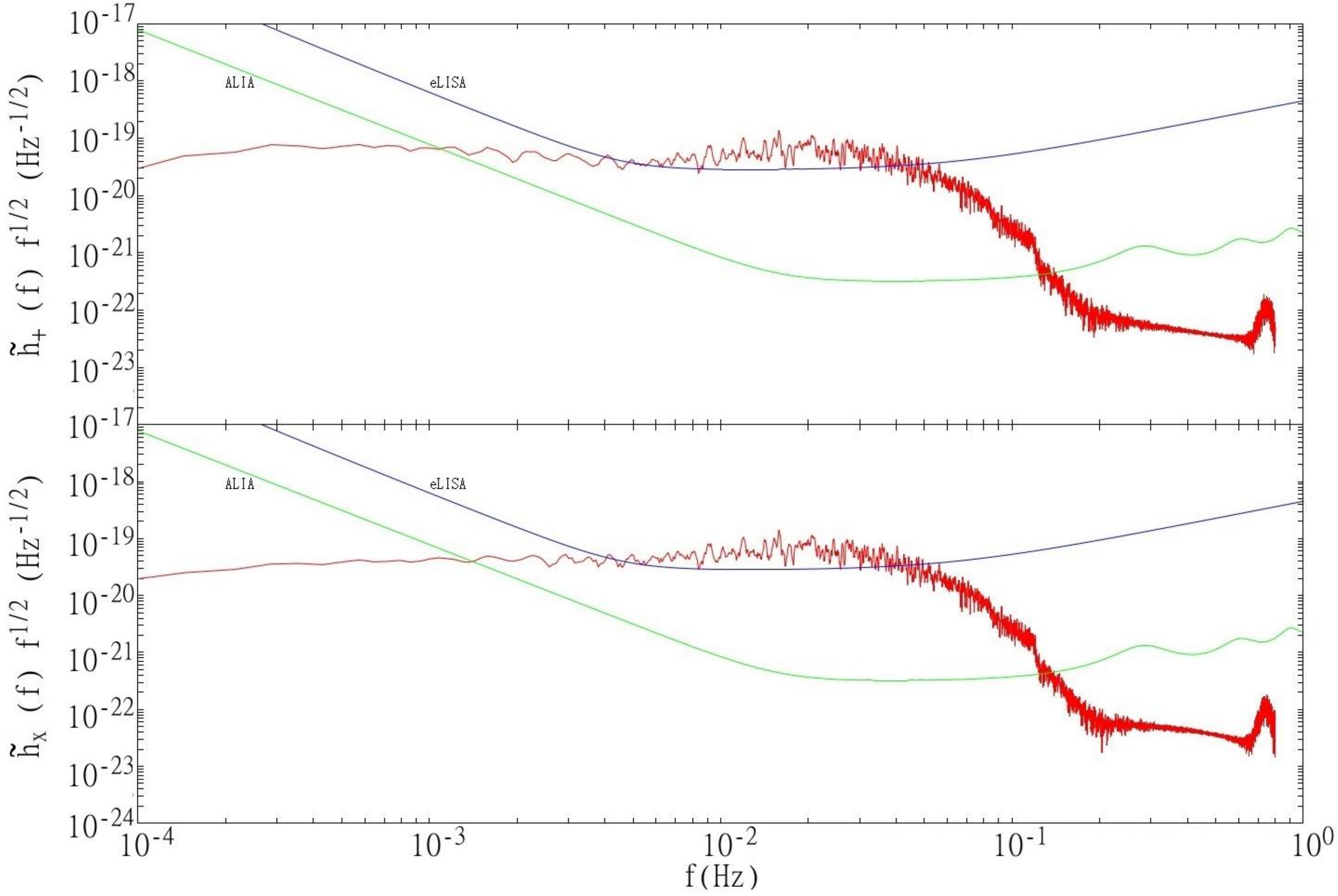
5.1 GRAVITATIONAL WAVE RADIATION HC q=0.12



5.1 GRAVITATIONAL WAVE RADIATION q=0.10



5.1 GRAVITATIONAL WAVE RADIATION q=0.12



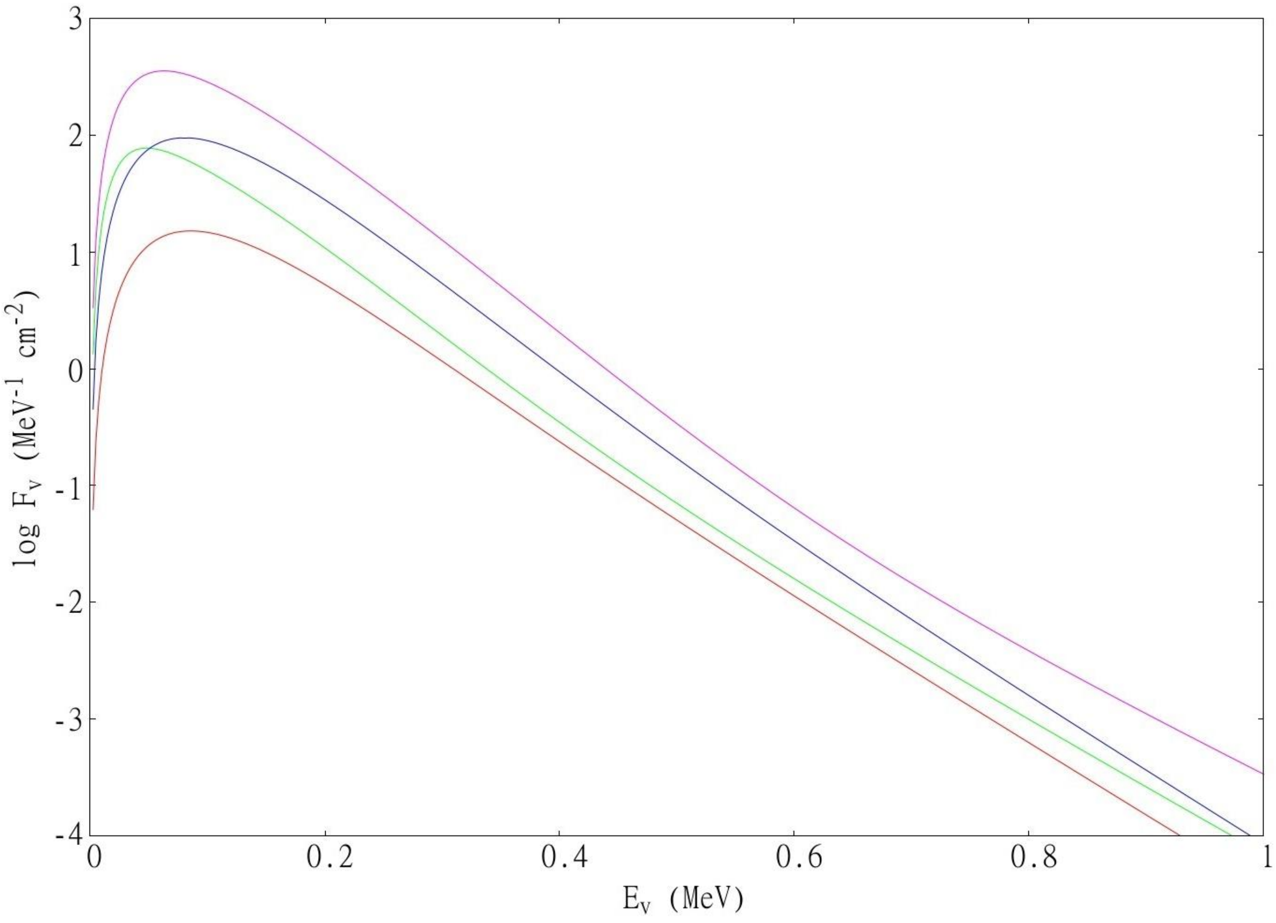
UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

IEEC

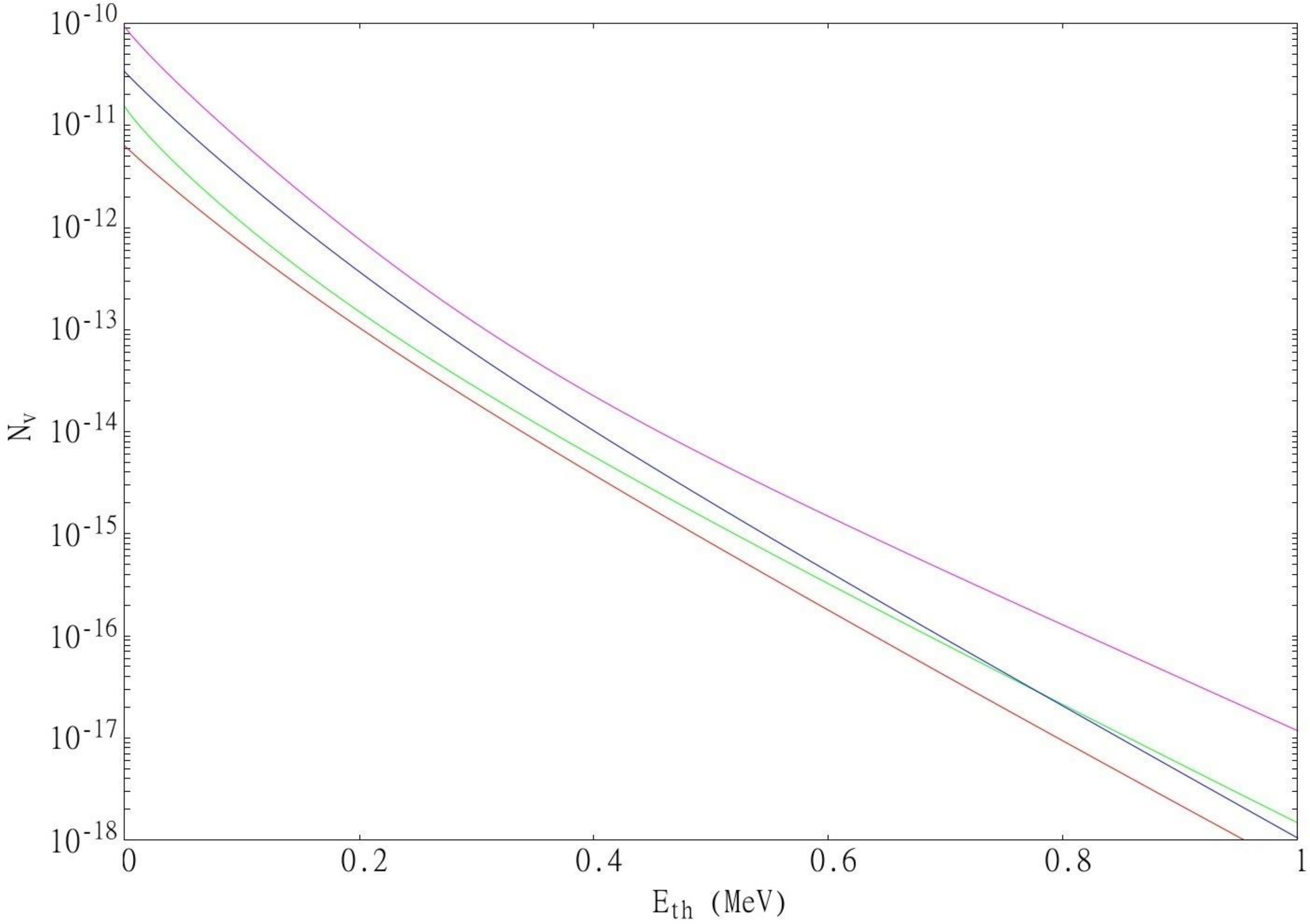
CONTENTS

5. Observables.
- 5.1 Gravitational wave radiation.
- 5.2 Neutrinos.
- 5.3 Fall-back luminosities.
- 5.4 Nebular emission.

5.2 NEUTRINOS



5.2 NEUTRINOS



CONTENTS

5. Observables.

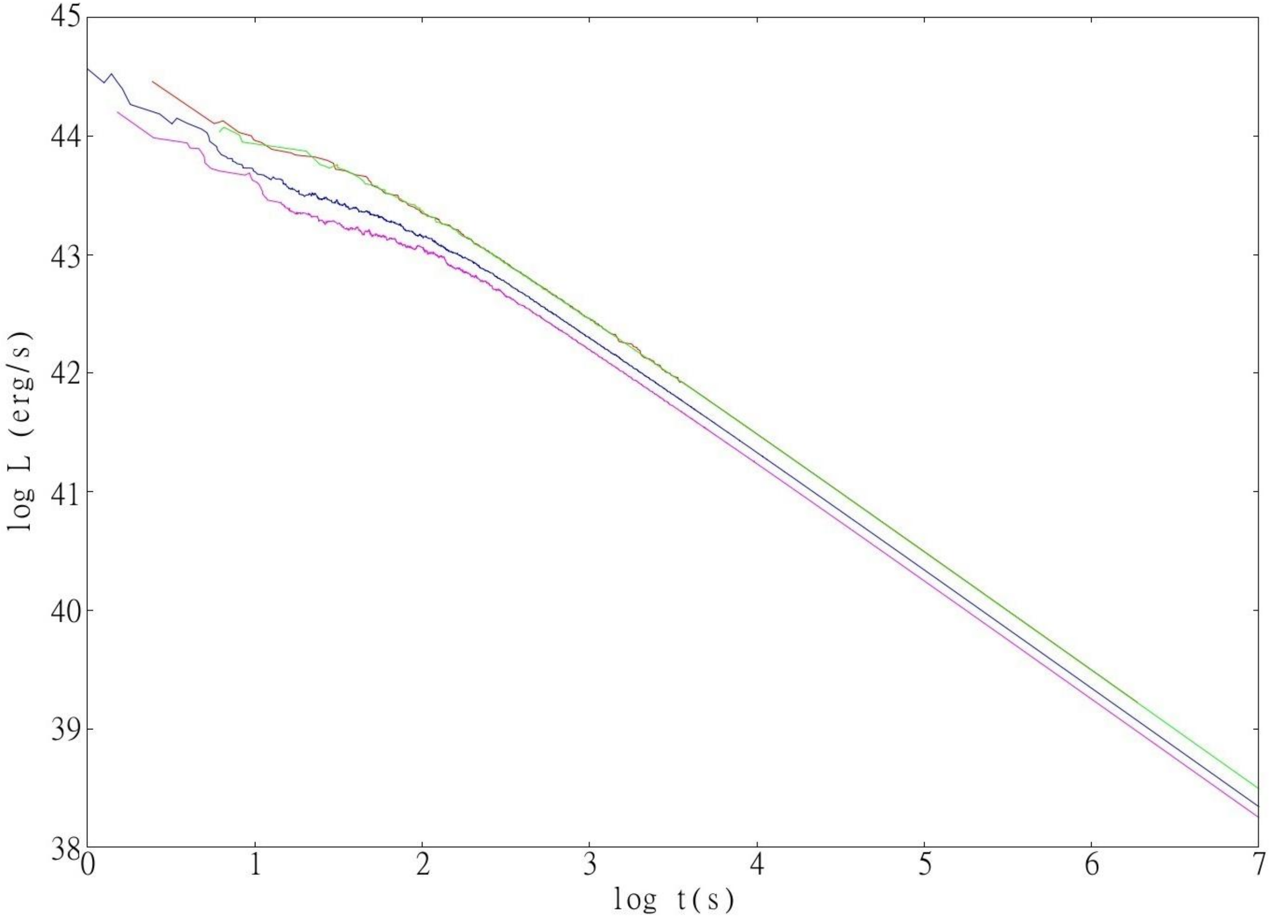
5.1 Gravitational wave radiation.

5.2 Neutrinos.

5.3 Fall-back luminosities.

5.4 Nebular emission.

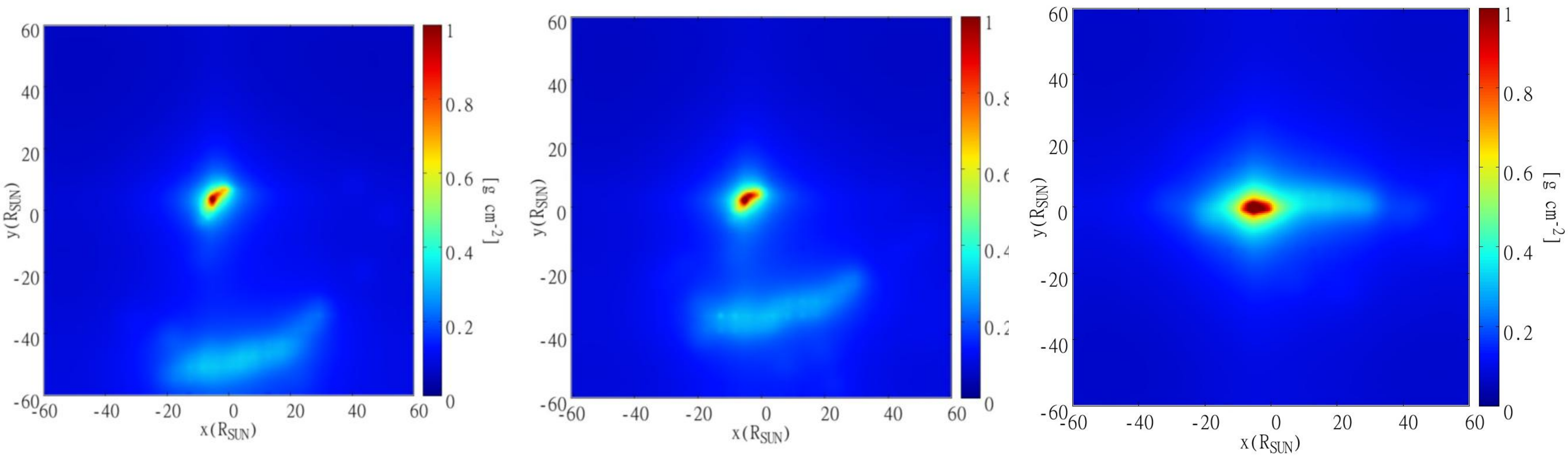
5.3 FALL-BACK LUMINOSITIES



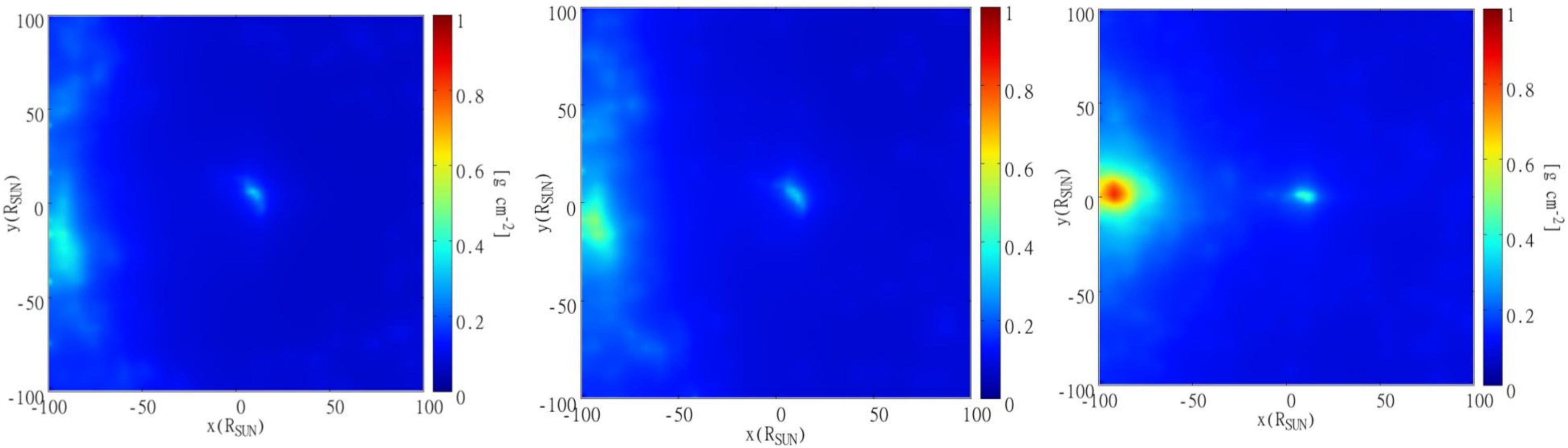
CONTENTS

5. Observables.
    - 5.1 Gravitational wave radiation.
    - 5.2 Neutrinos.
    - 5.3 Fall-back luminosities.
    - 5.4 Nebular emission.

5.4 NEBULAR EMISSION
q=0.10 CC (0°, 45°, 90°)



5.4 NEBULAR EMISSION
q=0.12 CC (0°, 45°, 90°)



CONTENTS

1. Astrophysical framework.
2. Initial conditions.
3. Time evolution.
4. The merged remnant.
5. Observables.
6. Discussion and conclusions.

6. DISCUSSION AND CONCLUSIONS

- Although the core-degenerate scenario is viable, a prompt explosion does not occur.
- A type Ia supernova can be produced upon accretion of the debris.
- The gravitational waves radiated during the merger would be detectable by future space-borne advanced detectors, like eLISA.
- Although many neutrinos are emitted the probability of detecting them is negligible.
- Fallback luminosities are large and follow a power-law of index 5/3.
- The thermal emission depends on the eccentricity.

6. DISCUSSION AND CONCLUSIONS

- Although the core-degenerate scenario is viable, a prompt explosion does not occur.
- Density and temperature conditions for a detonation to develop are not met.
- The temperature peaks off-center.
- The density is too low to produce an accretion induced collapse (Saio & Nomoto 2004).
- The initial temperature of the core has little influence on the merging process and the remnant. The initial eccentricity has a larger impact.
- A type Ia supernova can be produced upon accretion of the debris.

6. DISCUSSION AND CONCLUSIONS

- The structure of the debris region near the poles for less eccentric mergers might lead to jets and disk winds that might be detectable if an explosion occurs shortly after merger (Levanon et al. 2015).
- The emission of gravitational waves could be eventually detected by eLISA.
- There are no hopes to detect the emission of thermal neutrinos.
- The fallback luminosities follow a power law with index -5/3, and could be easily observed, as it occurs in mergers or collisions of white dwarfs.

6. DISCUSSION AND CONCLUSIONS

- For those case in which a detonation does not occur a bound remnant can help in explaining some objects for which we do not have yet a satisfactory explanation:

  - High-field magnetic white dwarfs.
  - Anomalous X-ray pulsars (4U 0142+61).
  - R Corona Borealis stars.

UNIVERSITAT POLITÈCNICA
DE CATALUNYA
BARCELONATECH

IEEC

The core degenerate scenario: an alternative pathway to SNIa

Enrique García-Berro

Supernovae, hypernovae and binary driven hypernovae

An Adriatic Workshop – Pescara 2016