A Tribute to Gerry@2013.11.26

Neutron Star Mass Distribution in Binaries

Chang-Hwan Lee @ PUSAN NATIONAL UNIVERSITY

Sabbatical Year@Stony Brook (2013.8~2014.8)

Life of THB inspired by Drs. Brown & Bethe (My Life in HR Diagram)

95.4.21 (Fri) : Star Trek - First Contact

Finally I met Dr. Brown after a few years collaboration since 1992, he called me as "Thin & Hungry Boy" (THB), I liked it. Still I do like "THB", and remain as a "THB", really thin and hungry boy.

- 96.3.25 (Mon) : Star Wars - Return of Jedi
  After Ph.D. degree, THB joined Stony Brook Group

Dr. Brown and "Thin and Hungry Boy" (Picture of Brown & Lee)

- Dr. Brown's prejudice : Prejudice saves time to think.
  We believe our friends.
- Dr. Brown's Dracula : "I live off blood of young people"
  In his 73rd birthday party (July 22, 1999), he told us how his research had been going on with young people.
- Dr. Brown's formalism : Formalism is like "sex". Do it at home and do not show anybody else.
  Then, the result is a "baby" ?
- Your intelligence : Your intelligence is propotional to the time you spent to find Dr. Brown's office.
  Dr. Bailyn (Yale) was visiting Dr. Brown & THB, and he was late to find Dr. Brown's office. Dr. Brown turned the situation into a joke.
- Dr. Brown's new idea : He who laughs last laughs best.
  Usually, Dr. Brown's new ideas with (too?) simple arguments brought a lot of "hot" discussion during the lunch time. Oneday, after long fight(?) with other people, Gerry wanted to add one more item in this list.
- Dr. Brown's new idea II: Why should I bother by the nonsense which I talked yesterday.
  Dr. Brown has much more ideas than the criticisms, and he is already(?) in tenure track. Why should he

Gerry's Three Questions

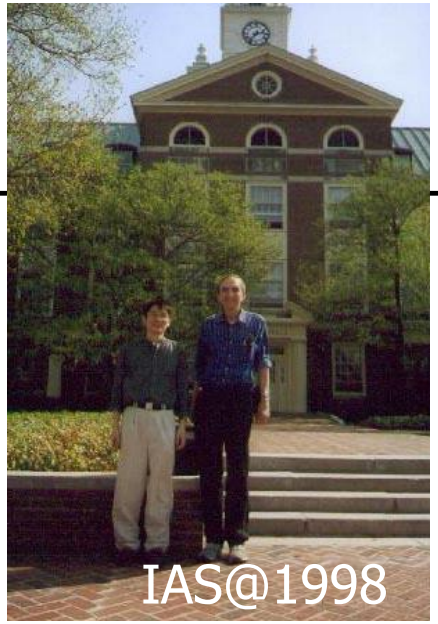
The Future

The Life

The Science

20 years with Gerry since 1992

1996~2000@Stony Brook



34 papers with Gerry

1st paper : Kaon condensation in `nuclear star` matter
Lee, Brown, Rho (PLB 335, 266, 1994)

… …

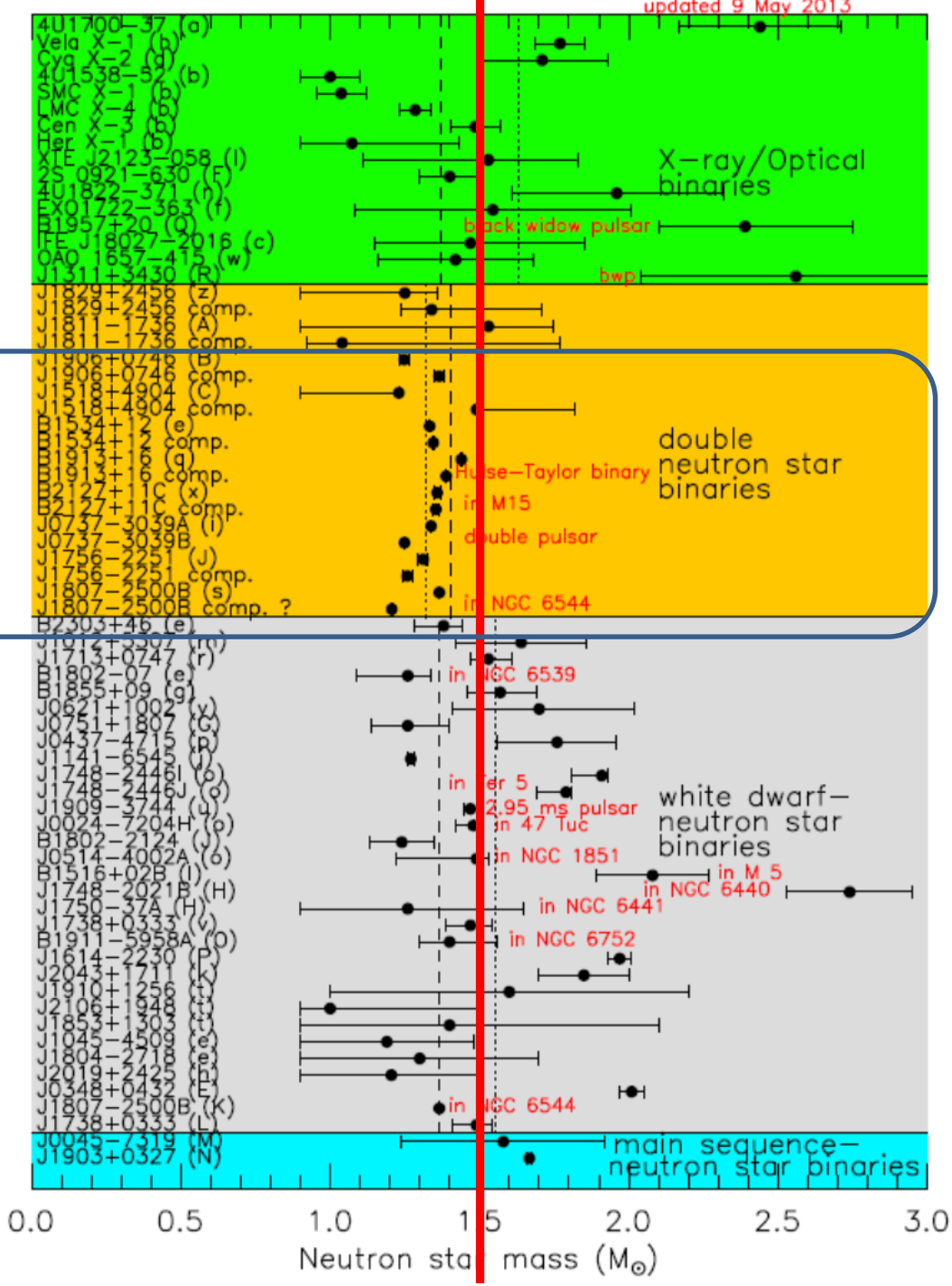
14th paper: Discovery of Black Hole Mass-Period Correlation in Soft X-ray Transients and its implication for GRB and Hypernova mechanisms
Lee, Brown, Wijers (ApJ 575, 996, 2002)

… …

34th paper: Kerr parameters for stellar mass black holes and their consequences for GRBs and hypernovae
Moreno Mendez, Brown, Lee, Walter (ApJ 727:29, 2011)

Gerry's favorite

All well measured NS masses in NS-NS binaries are < 1.5 Msun



Prakash (2013)

Our open questions

High-mass neutron stars in NS-White Dwarf binaries
1.97 solar mass NS : Nature 467 (2010) 1081
2.01 solar mass NS : Science 340 (2013) 6131

- 1.97 & 2.01 Msun NS were observed in NS-WD binaries
- Why all well-measured NS masses in NS-NS binaries are less than 1.5 Msun?

→ NS mass may/should depend on the evolution process

THE ASTROPHYSICAL JOURNAL, 670:741–746, 2007 November 20

MERGERS OF BINARY COMPACT OBJECTS

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Department of Physics, Pusan National University, Busan 609-735, South Korea; clee@pusan.ac.kr

AND

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Received 2006 September 15; accepted 2007 July 26

In 2007

- ✓ we discussed that NS masses in NS-NS binaries may be the result of evolution, not an indication of maximum NS mass.
- ✓ Gerry accepted the possibility that the maximum mass of NS can be significantly higher than 1.5 solar mass.

- Dr. Brown's new idea II: Why should I bother by the nonsense which I talked yesterday.

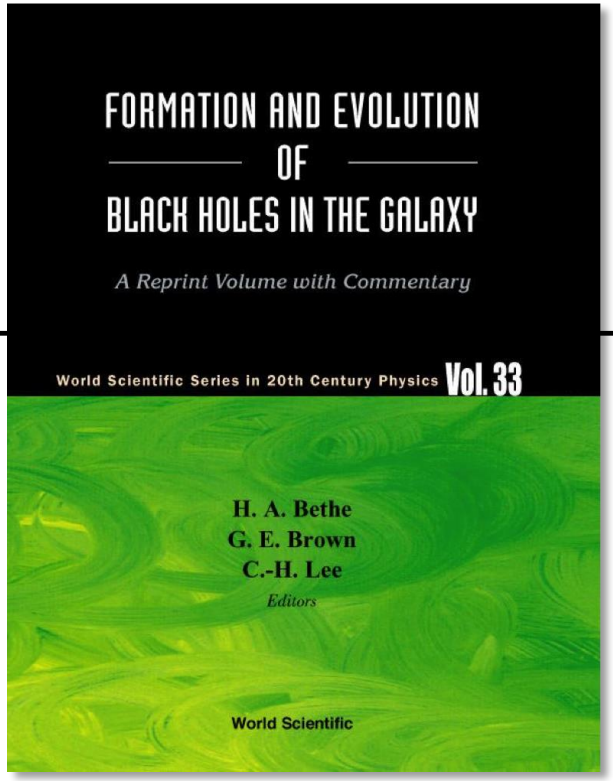
Contents

Part I : What we discovered in BH binaries

Part II : What if we apply the same evolution process
to neutron star binaries ?

Part I. What we discovered in BH binaries

Collection of Gerry's contributions to Astrophysics until 2002



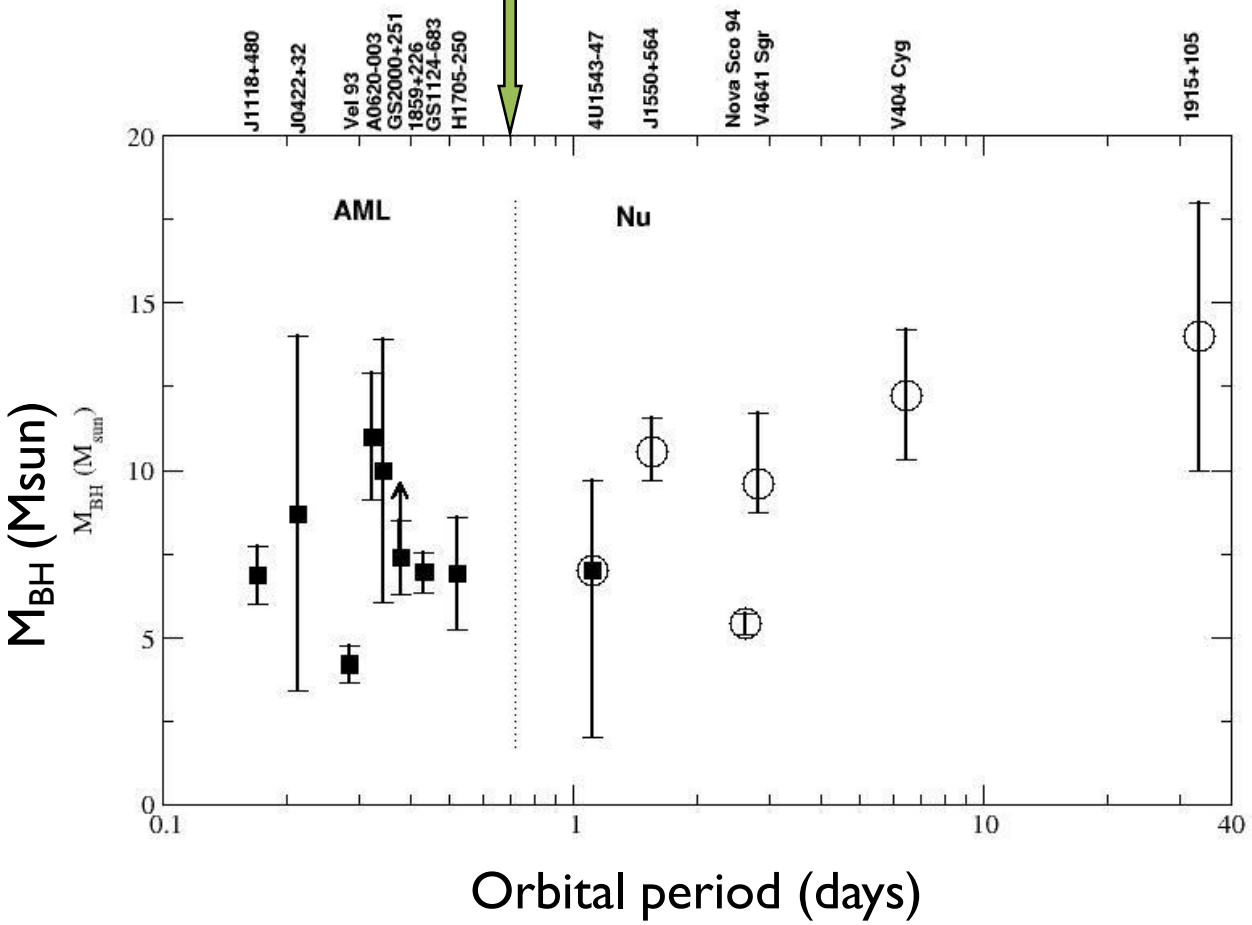
THE ASTROPHYSICAL JOURNAL, 575:996–1006, 2002 August 20

DISCOVERY OF A BLACK HOLE MASS-PERIOD CORRELATION IN SOFT X-RAY TRANSIENTS AND ITS IMPLICATION FOR GAMMA-RAY BURST AND HYPERNOVA MECHANISMS

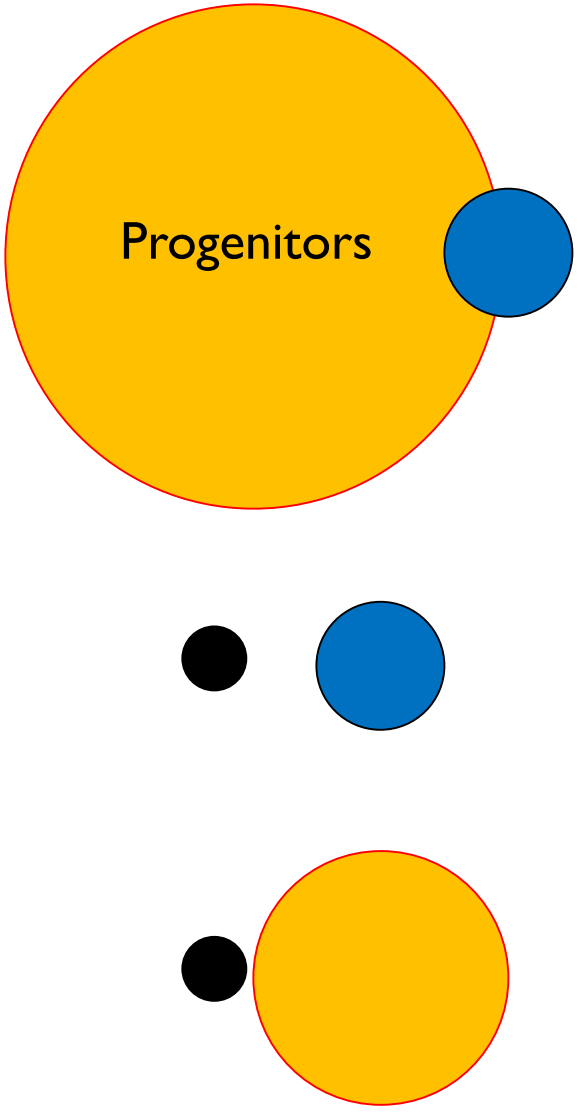
C.-H. LEE,[1,2,3] G. E. BROWN,[3] AND R. A. M. J. WIJERS[3,4]
Received 2001 October 17; accepted 2002 April 23

Black Hole Binaries (Soft X-ray Transients)

Main Sequence companion ← → Evolved companion



Q) How can we understand the population of SXTs ?

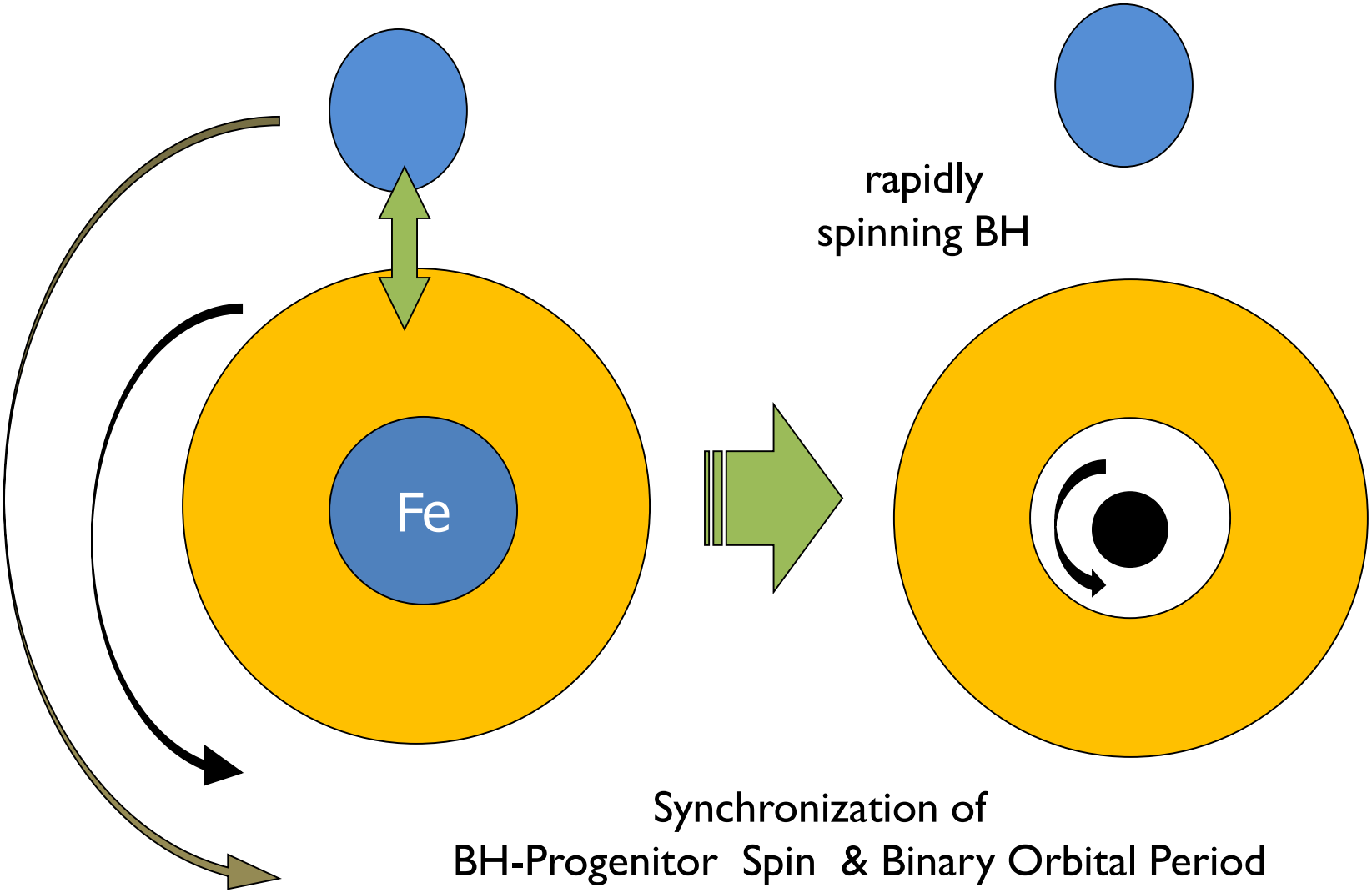


Q1) Evolution of BH/NS Progenitor

Q2) What happens at birth ?

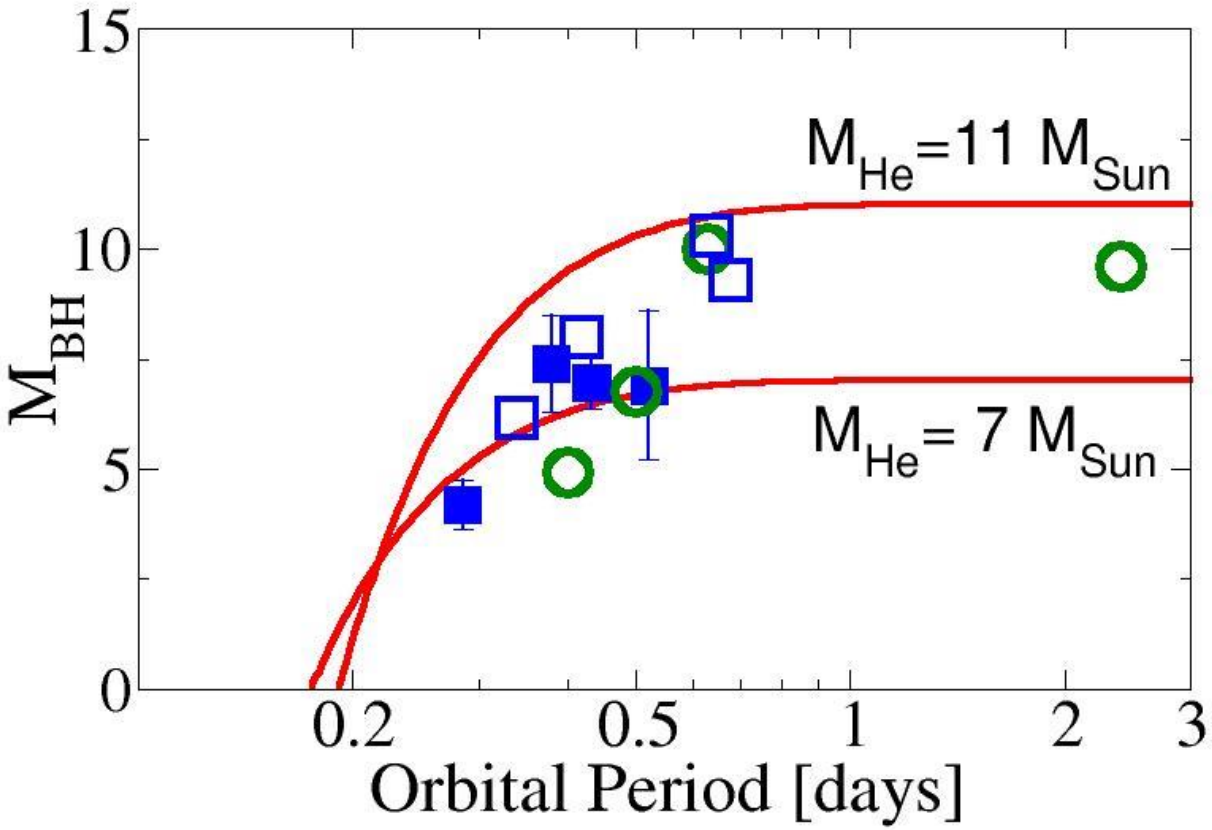
Q3) Evolution of Donor Star

Tidal interaction just before BH formation

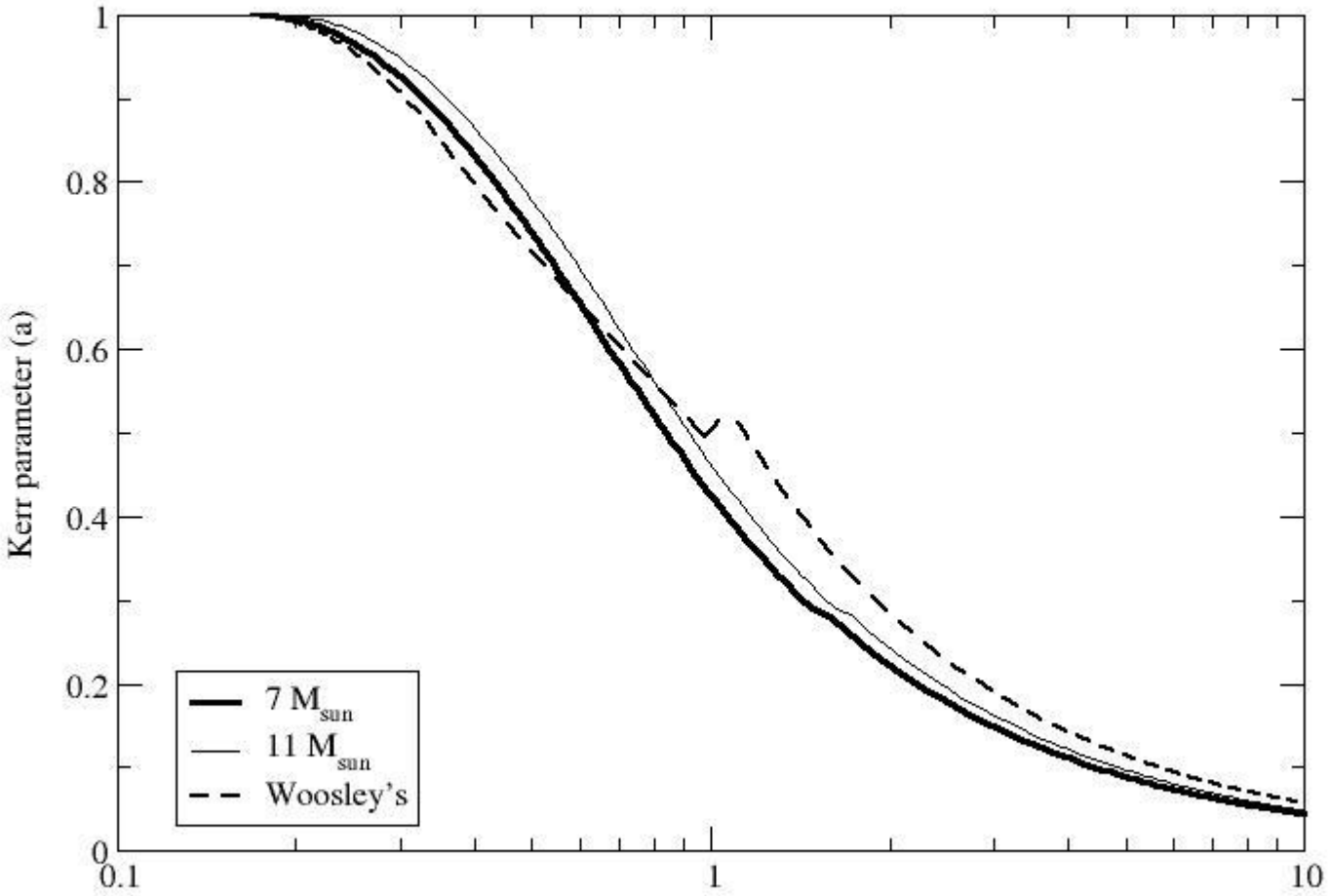


Synchronization of
BH-Progenitor Spin & Binary Orbital Period

Reconstructed BH Binaries at Birth

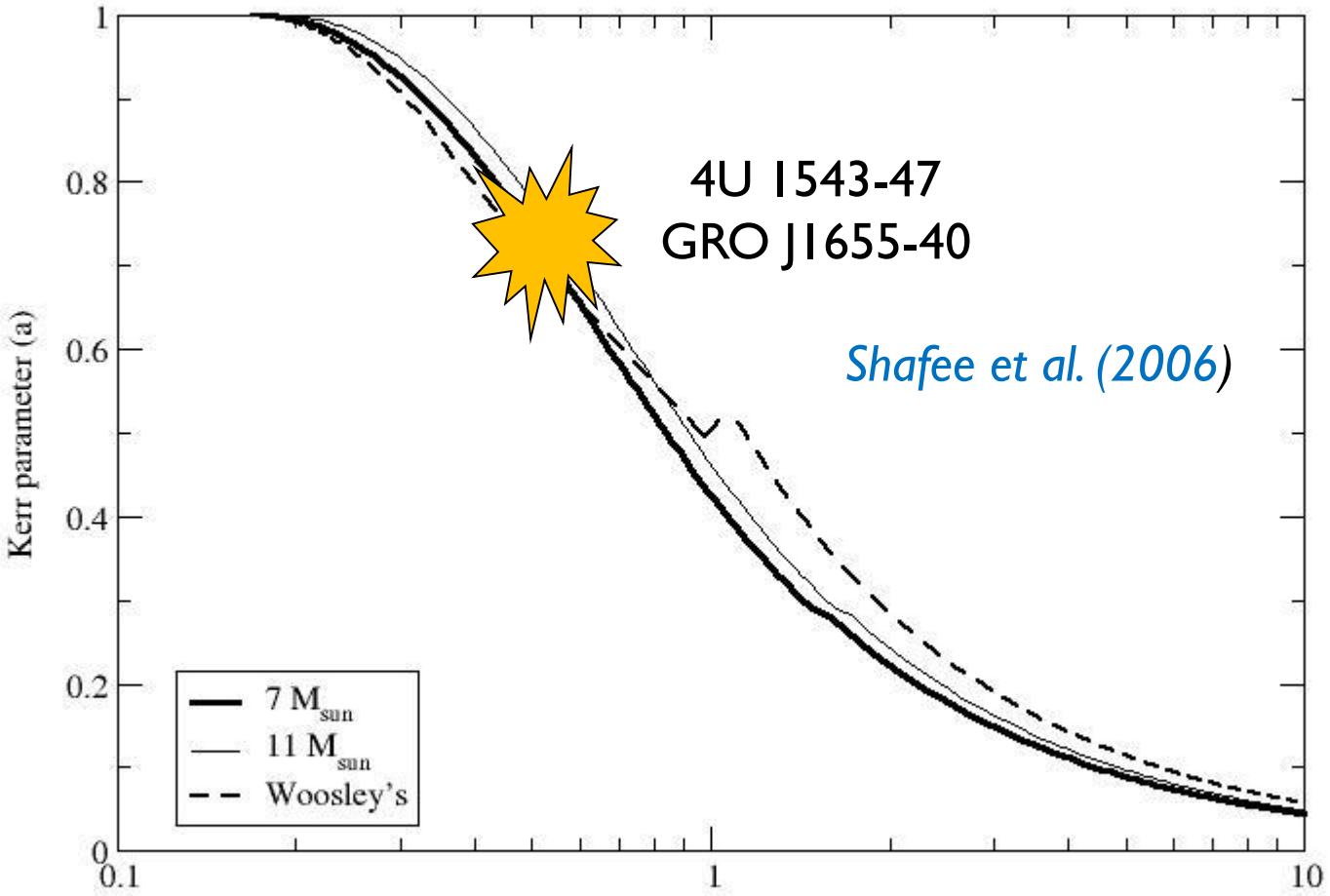


Rapidly spinning black holes at birth

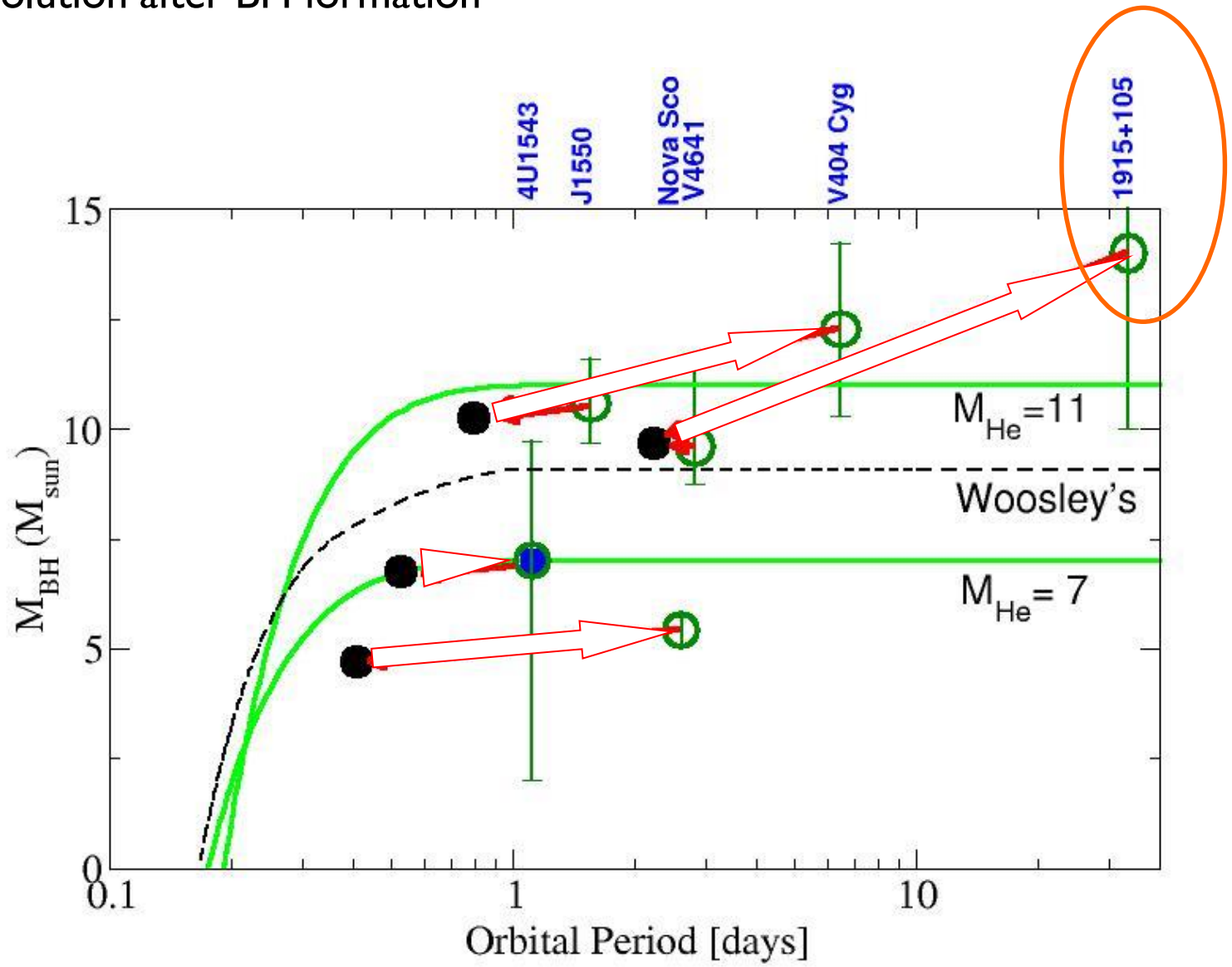


Pre-explosion orbital period (days)

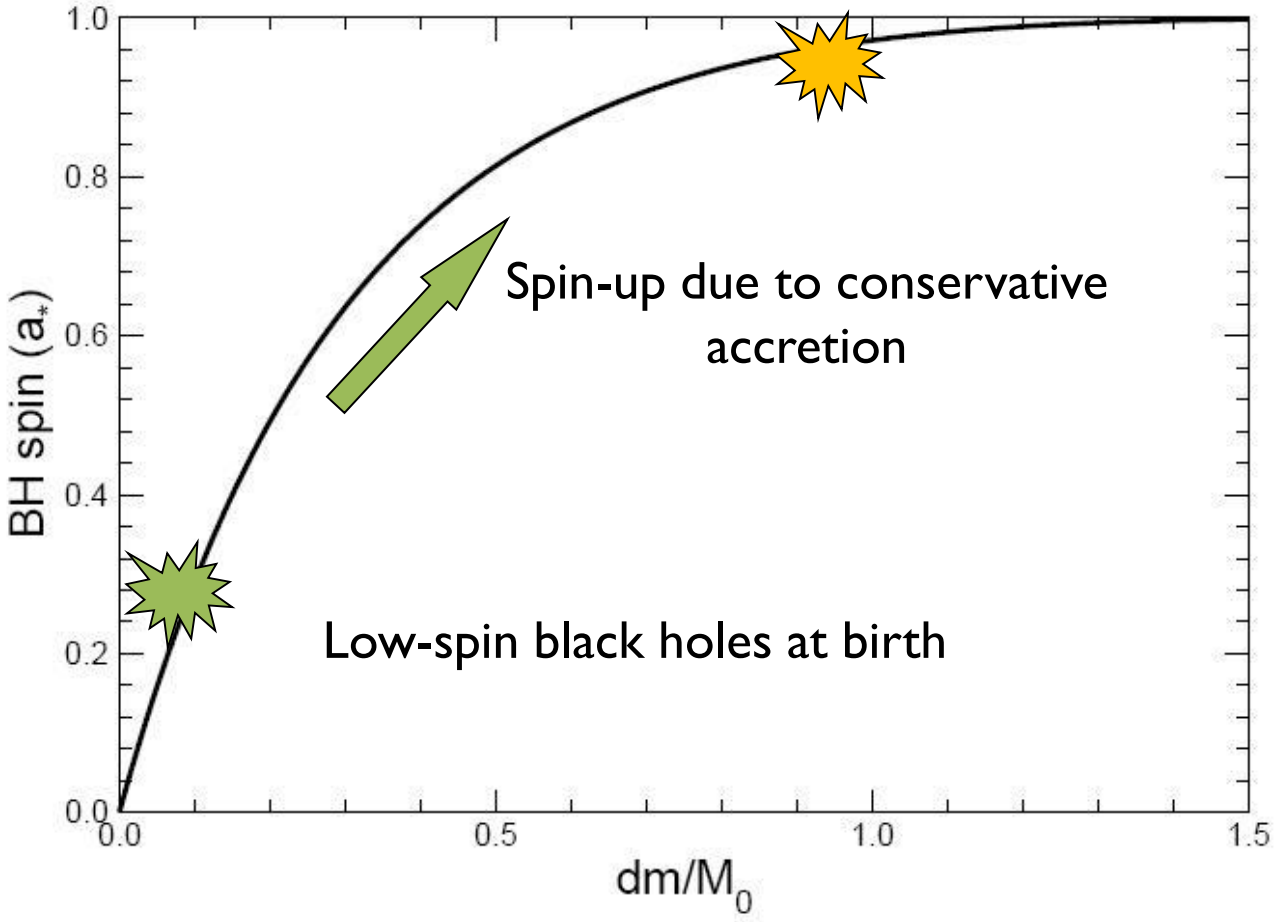
Rapidly spinning black holes at birth



Evolution after BH formation



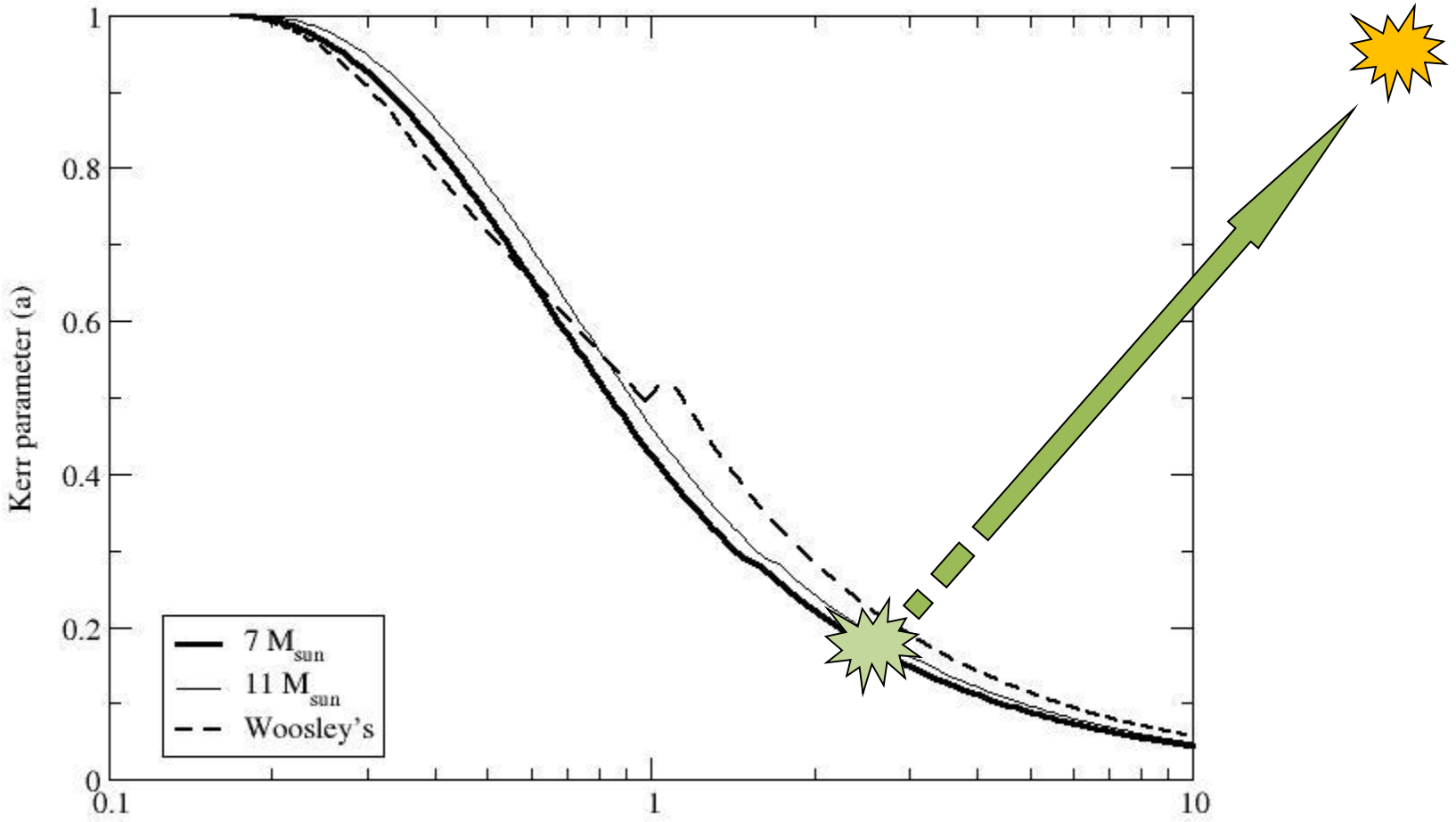
GRS 1915+105


1.0
0.8
0.6
0.4
0.2
0.0
BH spin (a_*)
0.0
0.5
1.0
1.5
dm/M_0
Spin-up due to conservative accretion
Low-spin black holes at birth

McClintock et al. (2006)

GRS 1915+105

$a^* > 0.98$



Pre-explosion orbital period (days)

Gerry's last paper

by Enrique Moreno Mendez, Brown, Lee, Walter (ApJ 727:29)

submitted 2009 May 11, accepted 2010 Nov 8, published 2011 Jan

THE ASTROPHYSICAL JOURNAL, 727:29 (9pp), 2011 January 20 doi:10.1088/0004-637X/727/1/29

KERR PARAMETERS FOR STELLAR MASS BLACK HOLES AND THEIR CONSEQUENCES FOR GAMMA-RAY BURSTS AND HYPERNOVAE

ENRIQUE MORENO MÉNDEZ[1,2], GERALD E. BROWN[1], CHANG-HWAN LEE[3], AND FREDERICK M. WALTER[1]
[1] Department of Physics and Astronomy, State University of New York, Stony Brook, NY 11794, USA; moreno@astro.uni-bonn.de
[2] Argelander Institute for Astronomy, University of Bonn, Auf dem Hügel 71, 53121 Bonn, Germany
[3] Department of Physics, Pusan National University, Busan 609-735, Republic of Korea; clee@pusan.ac.kr
Received 2009 May 11; accepted 2010 November 8; published 2010 December 29

ABSTRACT

Recent measurements of the Kerr parameters $a_\star$ for two black hole binaries in our Galaxy, GRO J1655−40 and 4U 1543−47, of $a_\star = 0.65$–0.75 and $a_\star = 0.75$–0.85, respectively, fit the predictions of Lee et al. of $a_\star \cong 0.8$. They predicted $a_\star > 0.5$ for 80% of the soft X-ray transient (SXT) sources. The maximum available energy in the Blandford–Znajek formalism for $a_\star > 0.5$ gives $E > 3 \times 10^{53}$ erg, orders of magnitude larger than the energy needed for the gamma-ray burst (GRB) and hypernova explosion. We interpret the SXTs to be relics of GRBs and hypernovae. We find that most galactic SXTs were subluminous given that they could use only a small part of the available rotational energy.

Key words: binaries: close – black hole physics – gamma-ray burst: general – supernovae: general – X-rays: binaries

Part II

What if we apply the same evolution process to neutron star binaries ?

- Supercritical accretion in NS binaries
- Possibilities of `NS + high-mass NS/BH` binaries

[Lee,Park,Brown, ApJ 670,741(2007)]

Supercritical Accretion onto first-born NS

- Eddington Accretion Rate : photon pressure balances the gravitation attraction
- If this limit holds, neutron star cannot be formed from the beginning (e.g. SN1987A; 10^8 Eddington Limit).
- Neutrinos can take the pressure out of the system allowing the supercritical accretion when accretion rate is bigger than 10^4 Eddington limit !
  (T > 1 MeV : Thermal neutrinos dominates !)

Q) What is the implications of supercritical accretion, if it works ?

Fresh NS mass from Fe core collapse

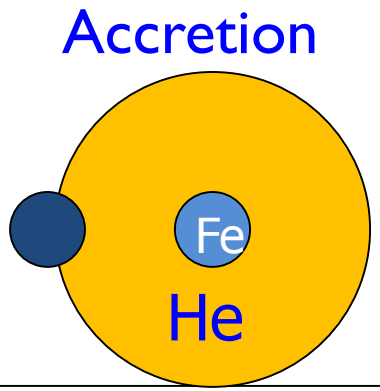
In close binaries (evolution without H envelope)

low Fe core mass  NS mass = 1.3 - 1.5 Msun

This value is independent of NS equation of state.

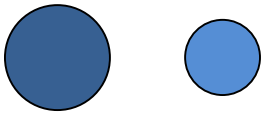
Q) What is the fate of primary (first-born) NS in binaries ?

Final fate of first-born NS



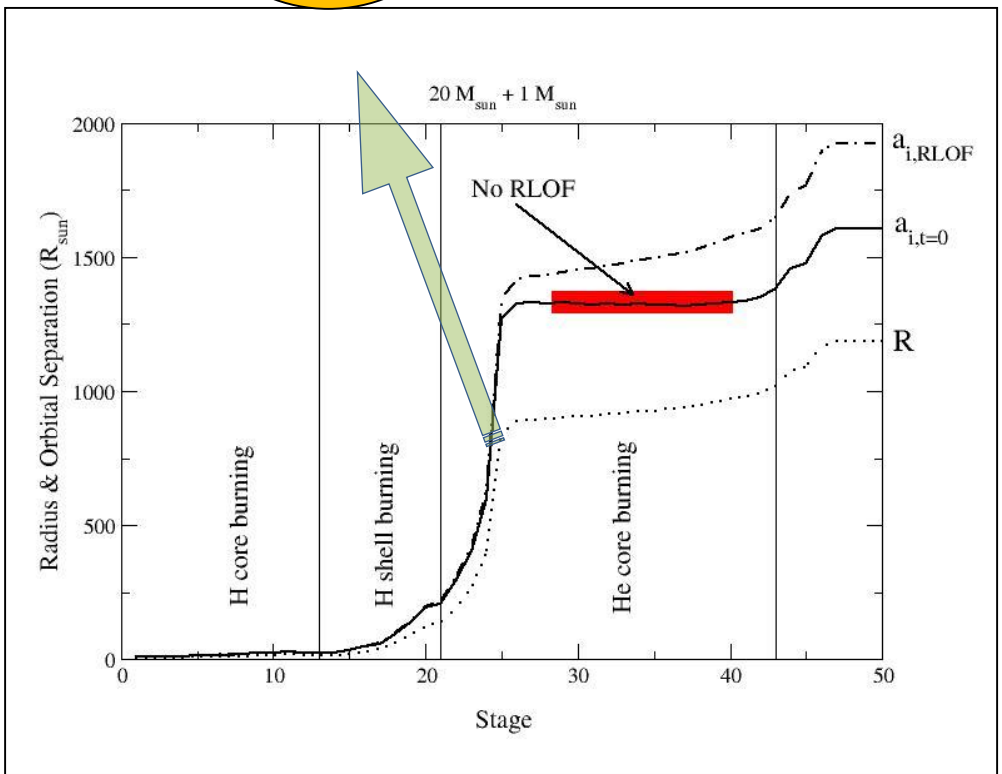
1st-born NS

NS + accretion

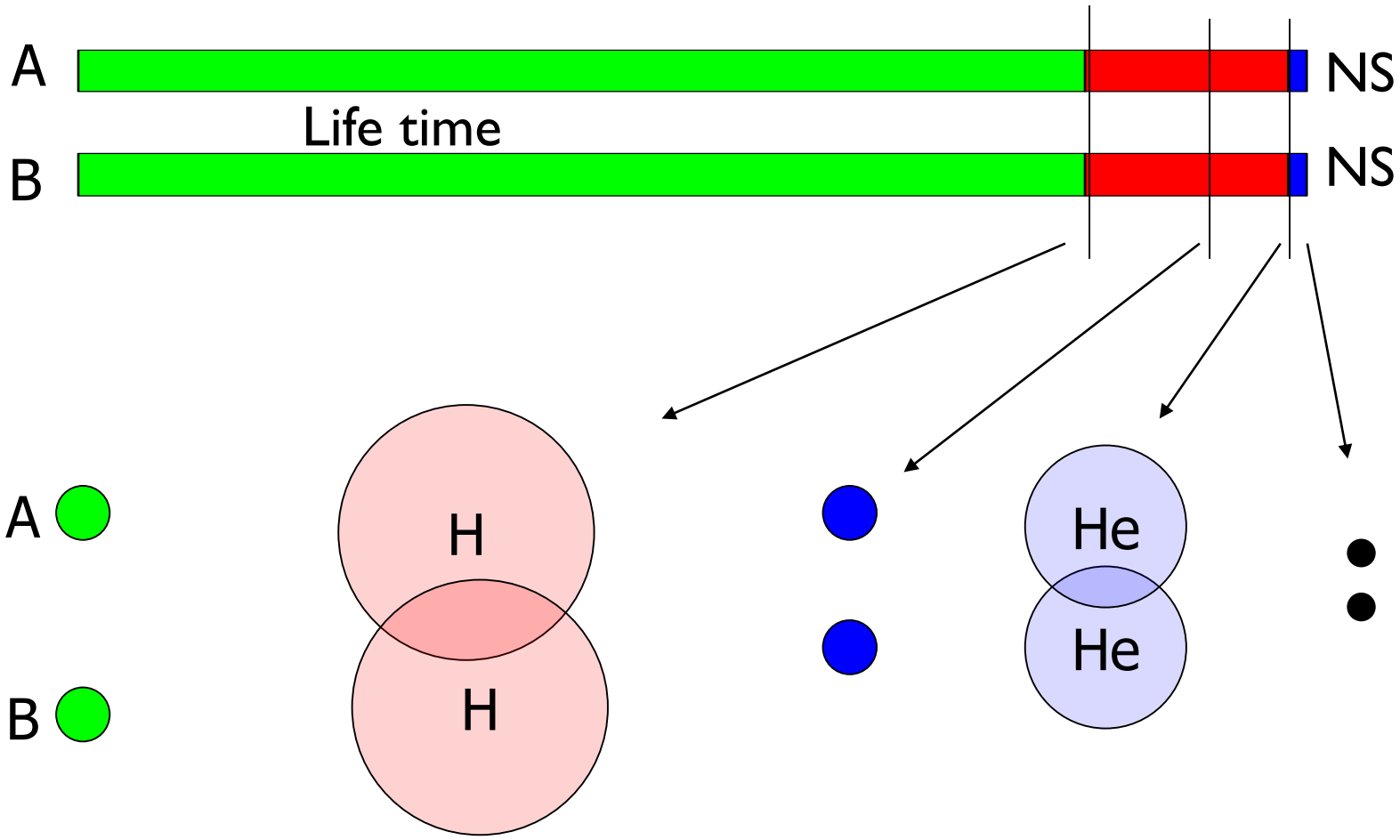


2nd NS/WD

Evolution of Companion

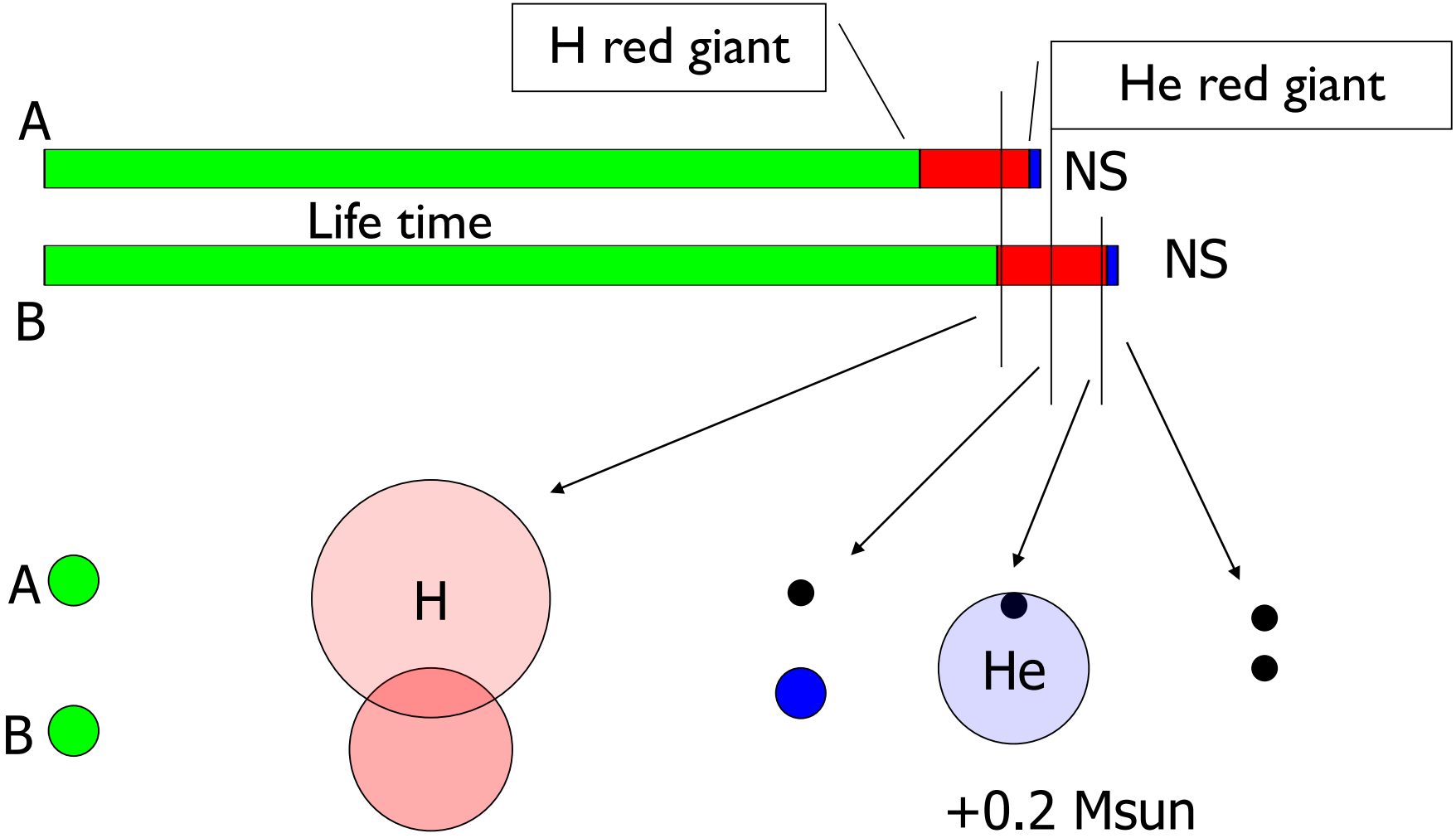


Case 1



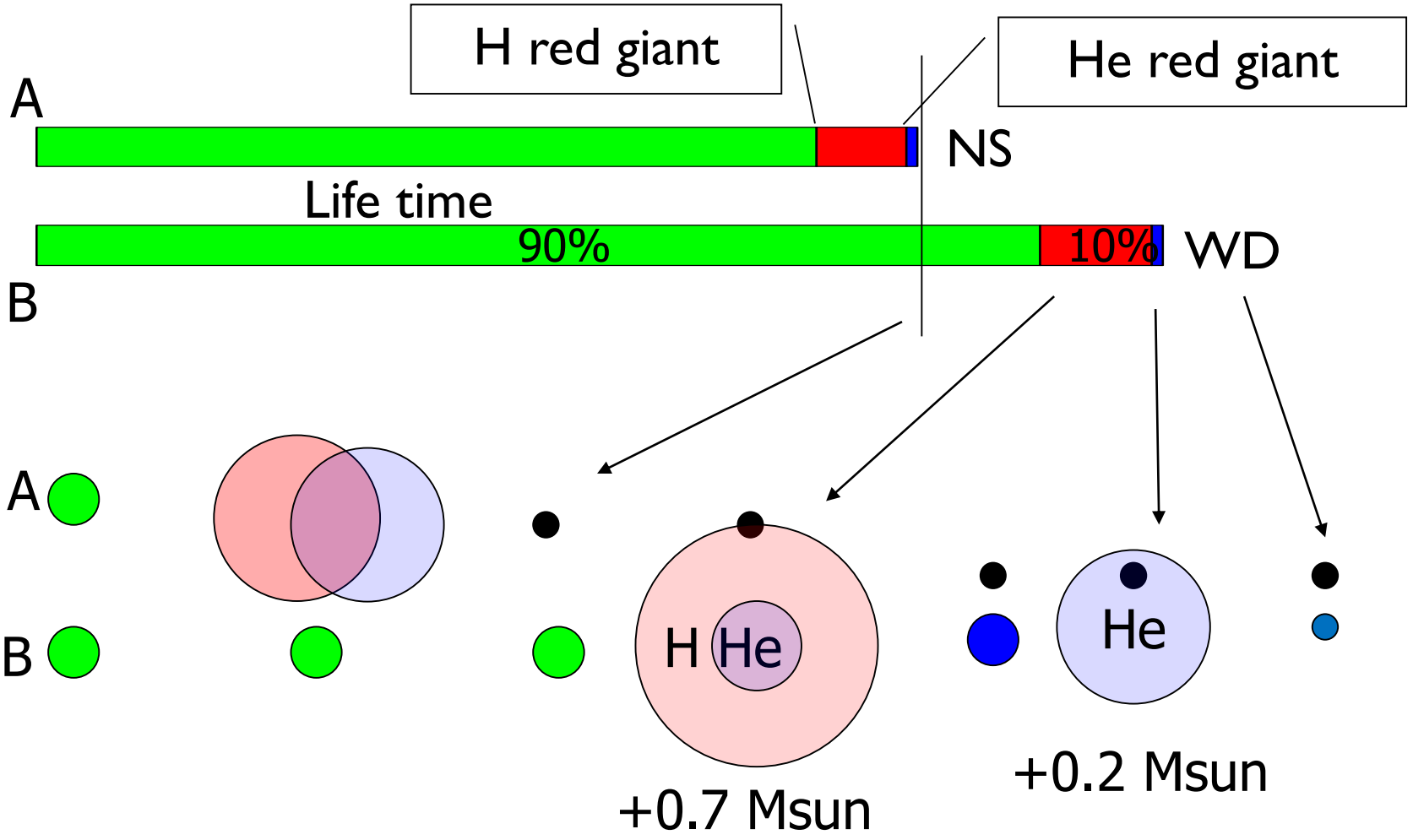
No accretion : nearly equal mass NS-NS binary!

Case 2



First born NS should accrete only < 0.2 $M_\odot$!

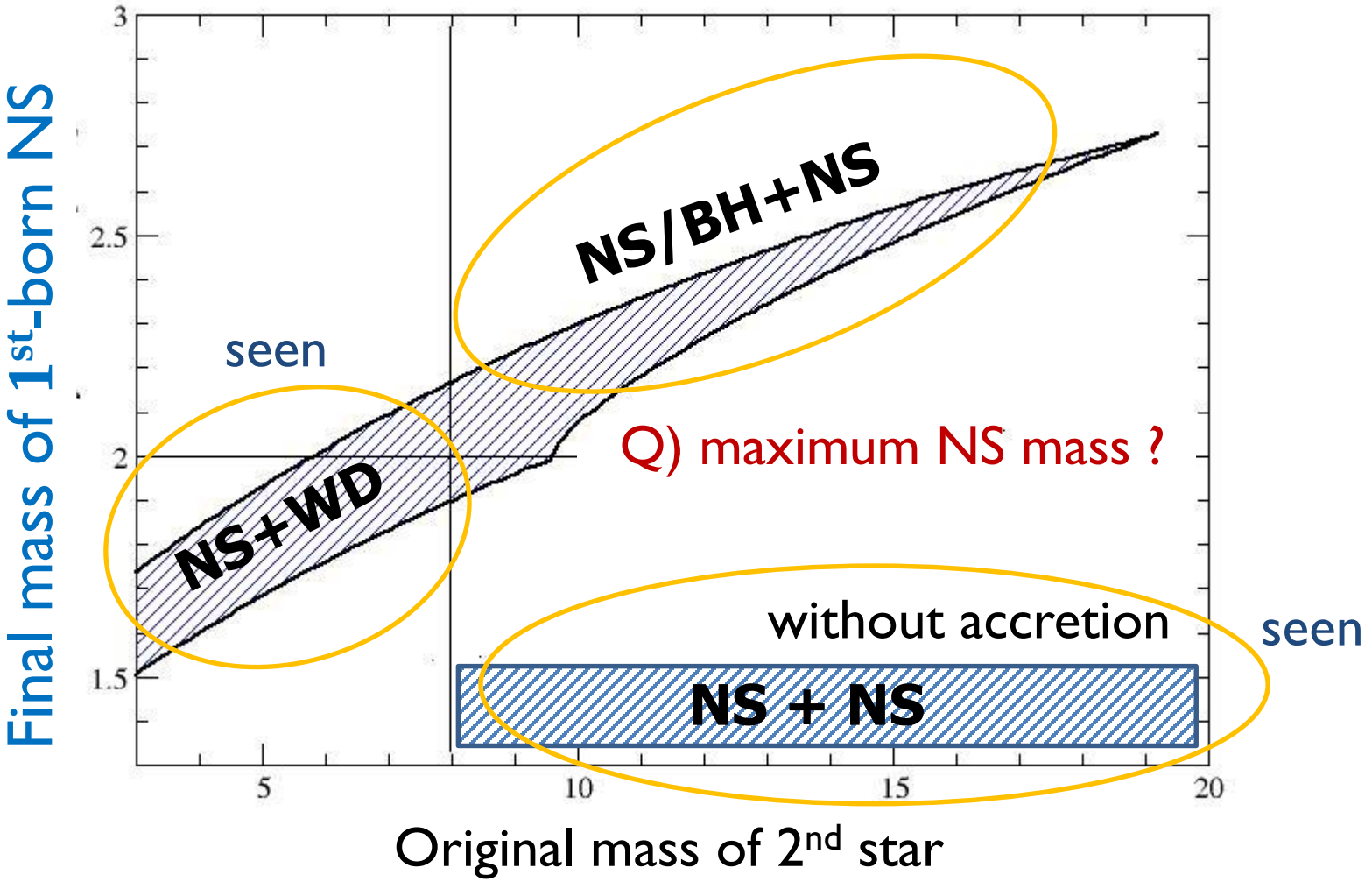
Case 3



Supercritical Accretion: First born NS can accrete up to 0.9 $M_\odot$!

Possibilities of `NS + high-mass NS/BH` binaries

Final mass of first-born NS with supercritical accretion



Can we see BH-NS binaries as pulsars even if they exist ?

Pulsar life time : 1/B

Fresh pulsar : $B \sim 10^{12}$ G

- NS-NS
  → if first-born NS is recycled by accretion
  → longer pulsar life time ($B \sim 10^{8}$ G)
  → larger beaming angle
  → bigger chances to be observed
- BH-NS
  → no recycled pulsar
  → much smaller chances to be observed

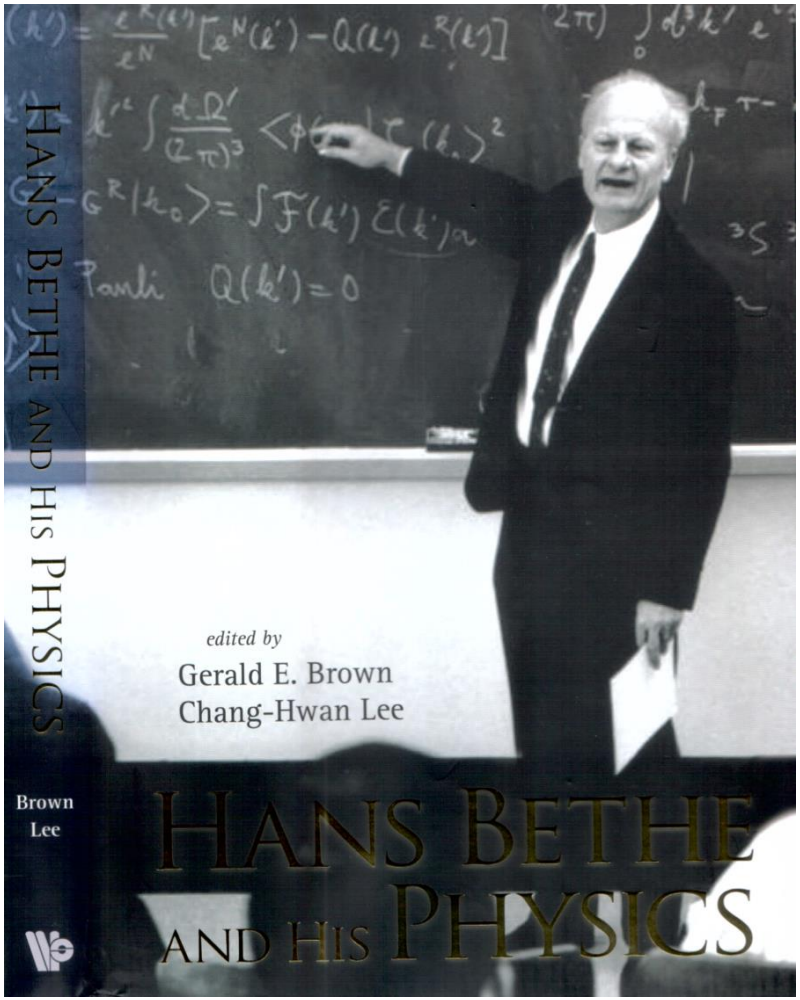
GW sources with NS

- NS-NS
  – already seen
- NS-BH
  – no evidence yet
  – can contribute to GW if exist

Consequences of supercritical accretion, if it works

- different class of NS binaries may exist
  high mass NS/BH (> 2 solar mass) + typical NS
- could be hidden GW sources

Fly with Eagles



2006

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Gerry's contribution to my HR diagram ?

Yeji papa's home

him.phys.pusan.ac.kr/~clee

Papa's life
- myself
- as a husband
- as a father

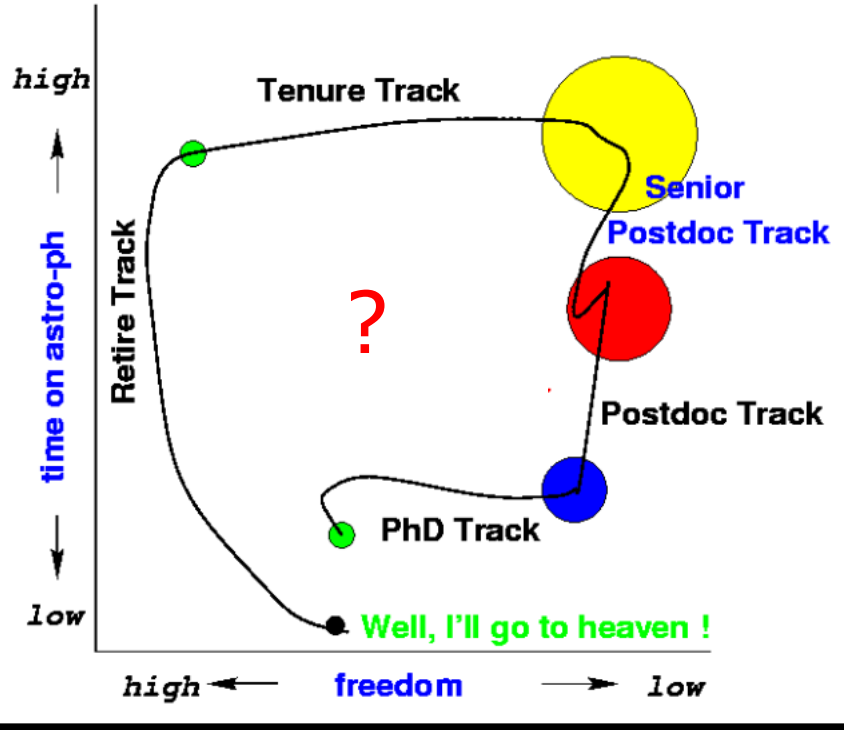
Experiences
- dr.Brown&THB
- as a physicist
- @stonybrook
- jokes@talks

Physicist's life
- black holes
- neutron stars
- dense matter

Activities
- astro@kps
- him@korea

How to contact

back



Yeji papa's home

him.phys.pusan.ac.kr/~clee

- Papa's life
  - myself
  - as a husband
  - as a father
- Experiences
  - dr.Brown&THB
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  - @stonybrook
  - jokes@talks
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  - black holes
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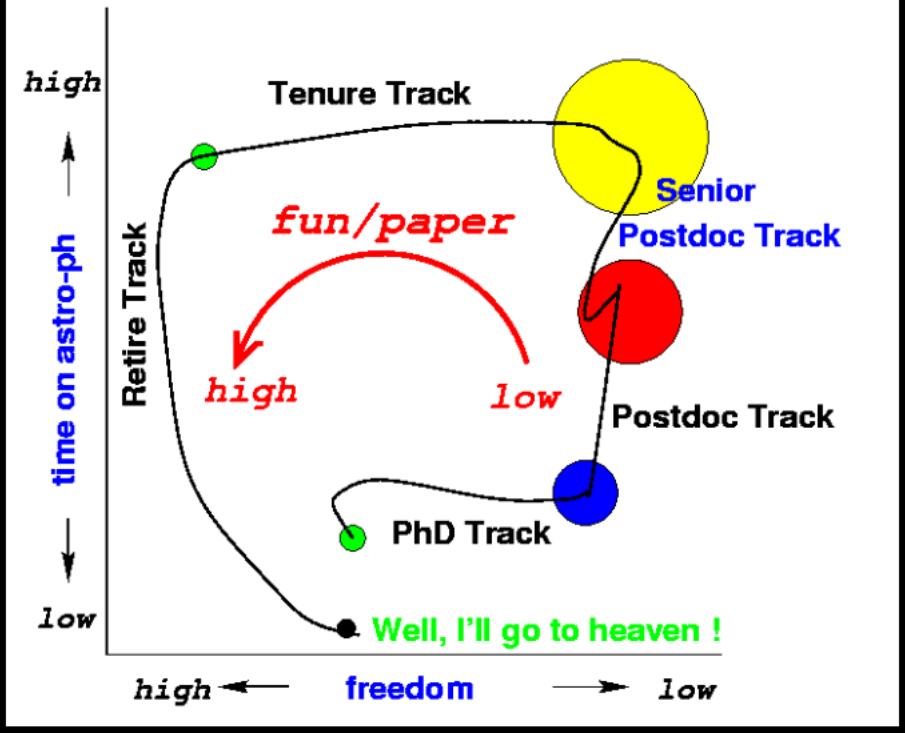

I really enjoyed working with Gerry