Targets of Innovative Area Gravitational Wave Physics and Astronomy: Genesis (2017-2011)

PI: Takahiro Tanaka

Kyoto University

What did we promise to do?

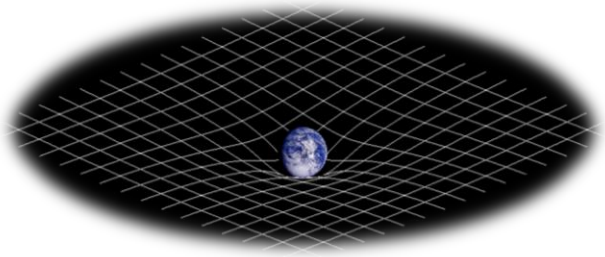
from the interview
(hearing) at MEXT

Announcement of the first direct detection of GWs by LIGO：2016 Feb.

GWs：The final homework of Einstein

1915：proposal of general relativity

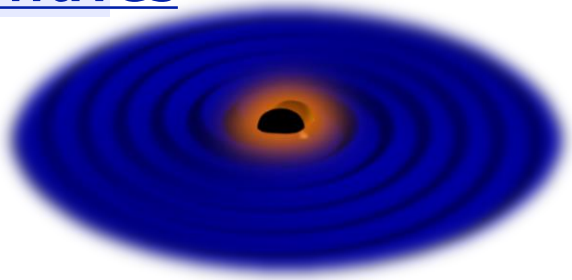
Gravity is described by a straight motion
on curved spacetime.



Predictions of General Relativity

・Periherion advance ・light bending
・gravitational redshift ・**Gravitational waves**

GWs : propagating waves of the curvature of spacetime



GWs were finally observed directly

Direction of【This Innovative Area】

Leading the "Genesis" of
GW Physics and Astronomy

Scientific achievement

Training of young researchers

Developing focused subjects: GW data analysis, Follow-up observations, Theoretical work ⇒ Strong Synergy

Chance of new discovery

Testing strong gravity, Uncovering origin of gold/Platinum, History of formation of BHs, Mechanism of SN explosion, Mechanism of generating GRB

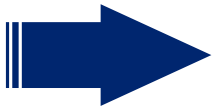
First direct detection of GW

Construction of km-scale GW detectors
LIGO, VIRGO, **KAGRA**

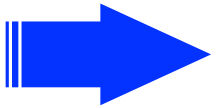
Success and development from the previous innovative area

"New development in astrophysics through multi-messenger observations of gravitational wave sources (PI: Takashi Nakamura)"

- Preparation of multi-wavelength follow-up organization for the first detection of gravitational waves
  ⇒ Follow-up observation paper on the LIGO events
- Preparation for the fundamental GW data analysis
  ⇒ Demonstration using the real data from iKAGRA
- Development of neutrino detectors to identify supernova neutrinos
  ⇒ Demonstration of anti-neutrino discrimination using small scale detector EGADS
- Theoretical research of GW sources
  ⇒ Prediction of 30Msun BH binaries etc.



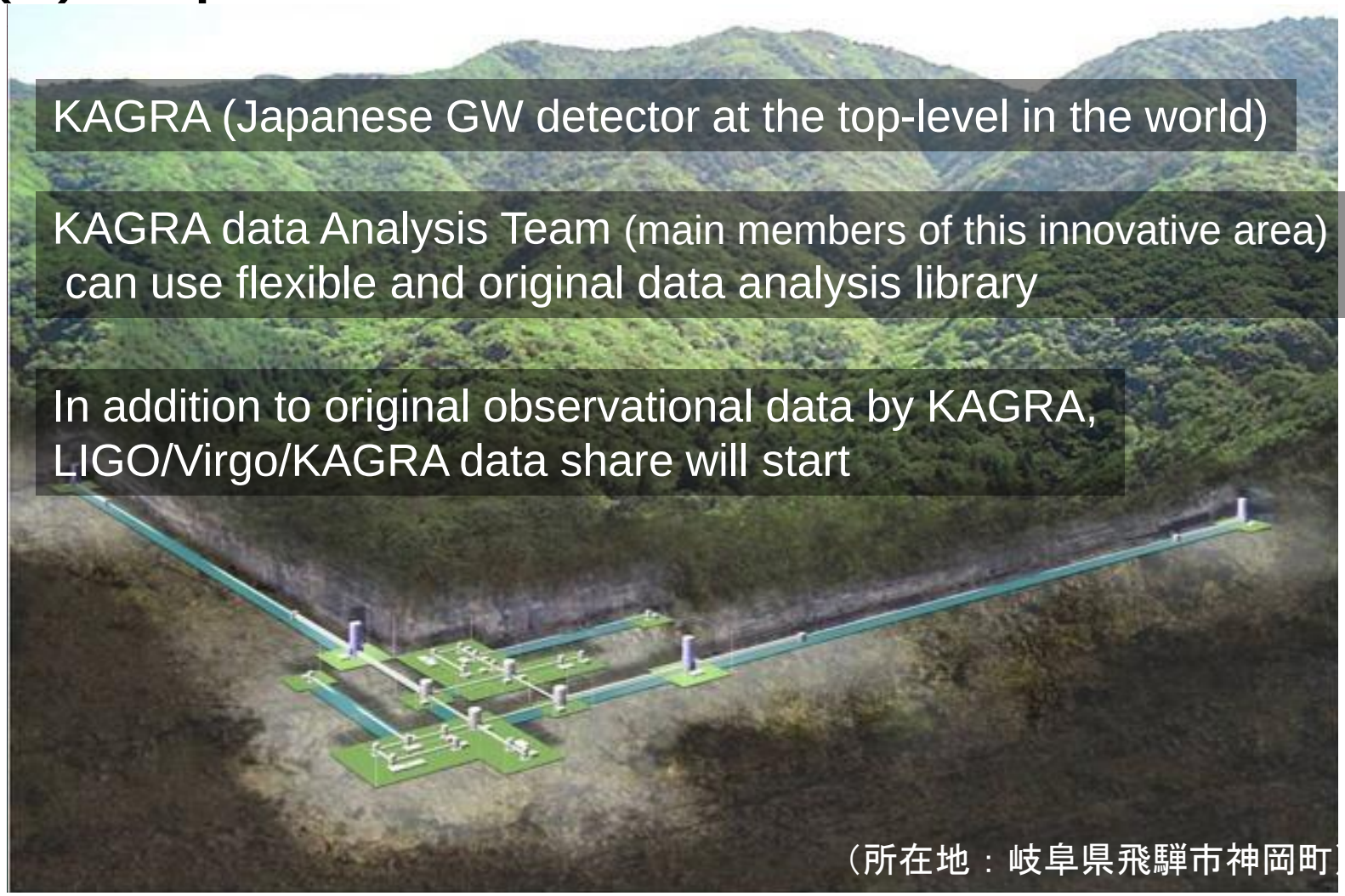
In response to the first GW detection



It's time for a new challenge !

Advantage in developing GW physics/astronomy

(1) Japanese own observation device

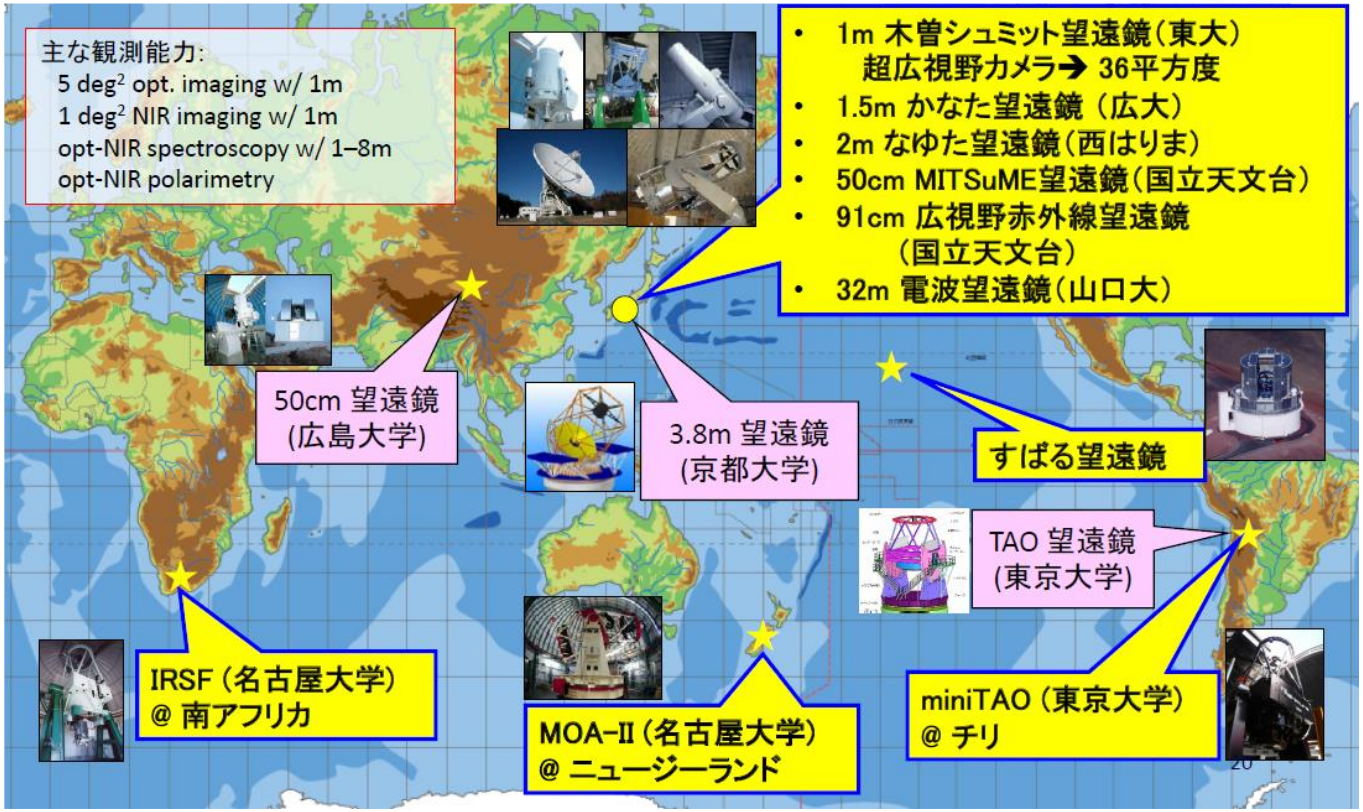


Advantage in developing GW physics/astronomy

(2) organized follow-up observations

Participation in international GW follow-up observation network

J-GEM: Organization connecting telescopes



X-ray · γ ray monitors

for gamma ray bursts

"Super Kamiokande"

The world's highest sensitive neutrino detector

Big impact on study of supernova explosion

Advantage in developing GW physics/astronomy

(3) Outstanding achievements in theoretical research

Lead by theory groups having long history of outstanding achievement

27th JGRG workshops (Tanaka,Oohara, Mukohyama, Maeda, Asada, Soda, Tagoshi, Shibata, Ioka et al. are organizers)

International workshop of general relativity and gravitation

Large scale numerical simulations :

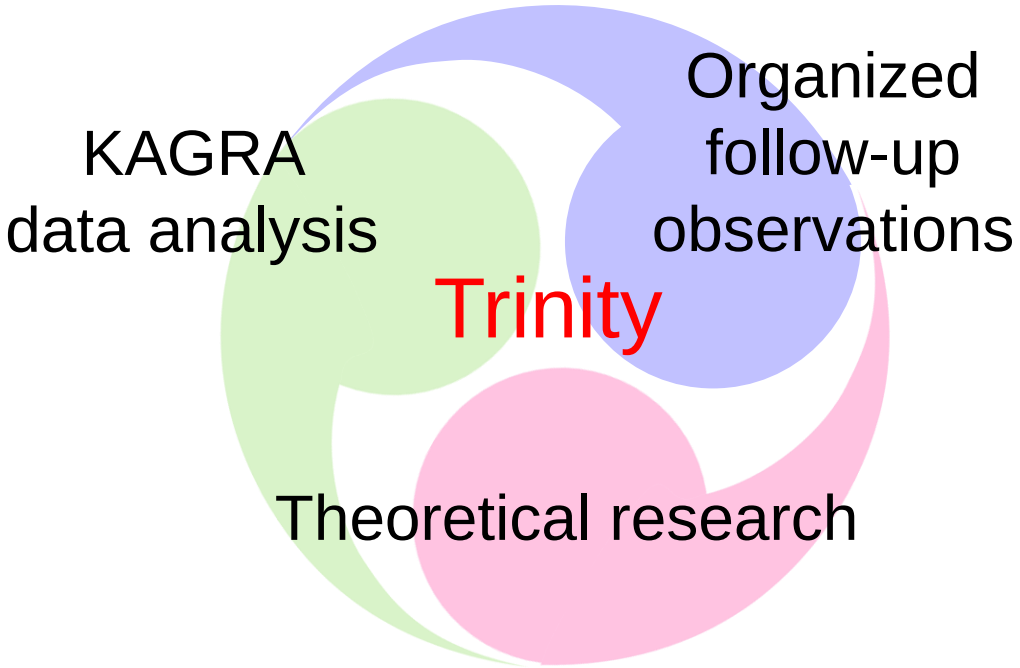
Numerical relativity : State-of-art NS-NS binary simulations

Supernovae : Three-dimensional radiative hydrodynamics ahead of the world

Star formation : Achievement of radiative/magnetic HD simulations

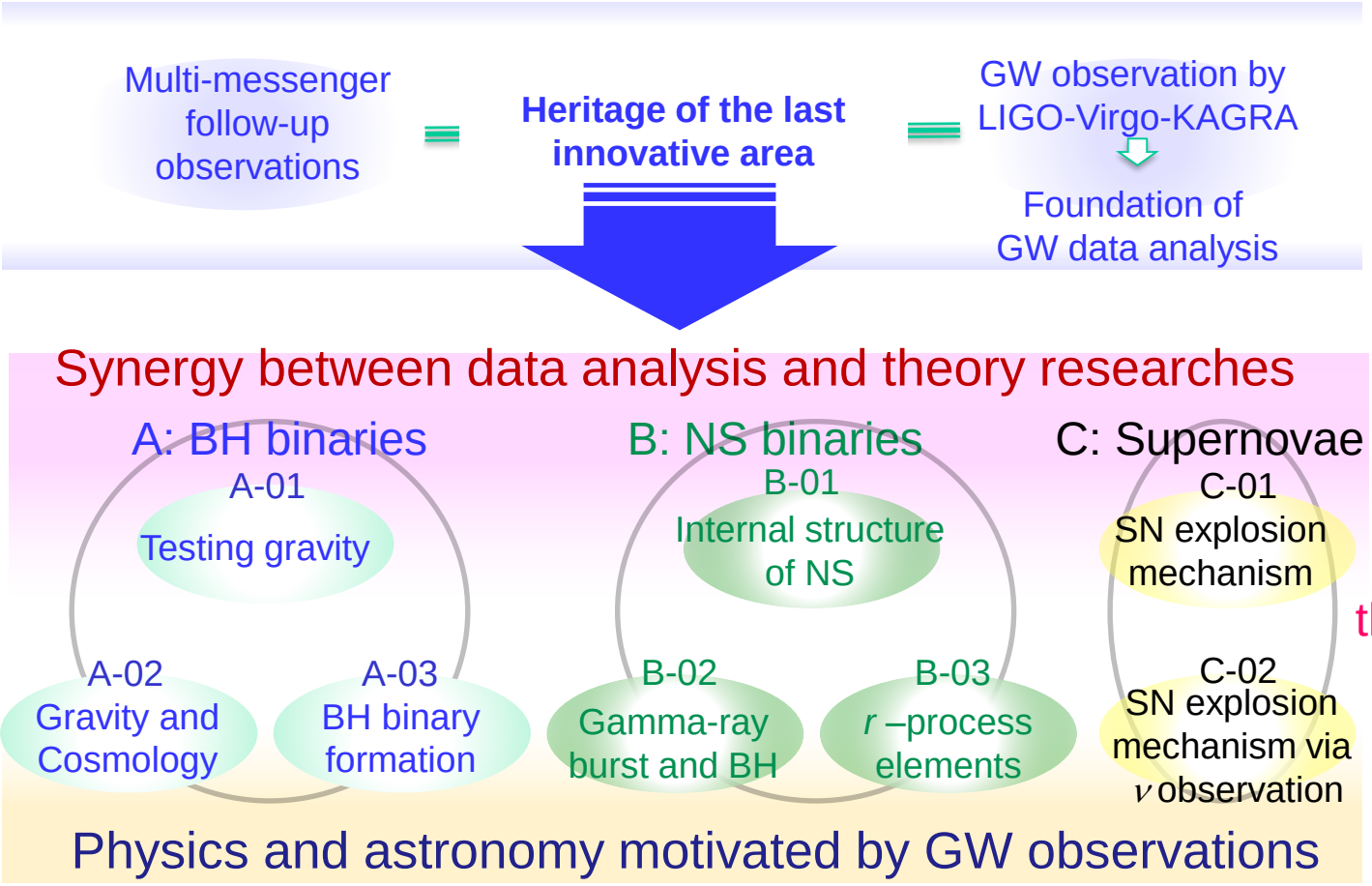
Integrating three advantages

In order to contribute to the genesis of GW physics and astronomy under the world-wide competition,



Research Projects

To extract deep science, theoretical researchers participate in all projects.



Double layer structure

First layer

Strategic data analysis aided by theoretical predictions

Second Layer

Selected 5 topics among those driven by GW observations

Goal of each research project

A01	**Testing various models of gravity, using GW data**
A02	**Leading a new paradigm**, in the understanding of quantum gravity and the accelerated expansion of the universe
A03	Establishing sufficiently precise theoretical prediction, **to test the various BH binary formation scenarios**
B01	Detecting GWs from NS binaries and deriving constraints on high energy phenomena and **neutron star physics**
B02	**Clarifying the process of NS and/or BH mergers**, through the analysis of radiation from BHs and neutron stars
B03	**Estimating the production of r –process elements**, by detecting optical and NIR radiation from NS binary mergers
C01	Unveiling SN explosion mechanism from **gravitational wave data and numerical simulations**
C02	Testing the SN and BH formation scenarios **at the best sensitivity in the world** through the observation of the background SN neutrino radiation using SK-Gd

Activities of Sokatsu-han

Sokatsu-han

- Monthly head-quarter meeting
  - TV conf. of PIs
  - Mutual evaluation
- Kick-off meeting
- Area workshop(3/year)
  - Use of TV conf. system
  - Organized by each A, B, C group
- International symposia (1/year)
  ICRR⇒Tohoku U.⇒…
- Small workshop/school（1/year）
- Dispatching to domestic workshops (10/year)
- Large international workshop at the last year
- Transmission of information through area HP

International activities

- Monthly meeting
- Selecting who and which conference we send (10/year)
  - Report on the information obtained by the conference at the area workshop
  - Promoting international collaborations
  - Sending young researcher for a long period（4/year）
    ⇒ Writing a report article (for outreach)
- Invitation of outstanding researchers(10/year)
- Co-organization of international workshops (1/year)

Subscription research(公募研究)

① Extension of research to wider area
② New directions motivated by the latest development

400Myen/year: 3
200Myen/year: 6
100Myen/year:12

Budgetary Plan

- Employment of more than 20 young postdocs
  - Realizing trinity
  - Training researchers who have a wide scope

- To strengthen existing equipment capabilities with small-scale development that brings out science by maximizing the ability of equipment that has been developed so far
  - Data analysis server for Subaru telescope/ HSC to observe gravity wave counterparts
  - Development of a high-speed data processing system to extract the performance of SK-Gd
  - Maintenance of servers for gravitational wave data analysis pipeline development

Questions by referees

Should researchers in nuclear physics be incorporated seriously?

- Strong relationship already established with nuclear physics group
  - Prof. M. Shibata (B01) is a representative of the integrated group of the lattice QCD, nuclear physics, and astrophysics of the post-K project.
  - Long-term workshop connecting these fields has been organized:

NPCSM 2016: YIPQS long-term and Nishinomiya-Yukawa memorial workshop on "Nuclear Physics, Compact Stars, and Compact Star Mergers 2016", Oct.17 (Mon) - Nov.18 (Fri), 2016, YITP, Kyoto, Japan

- We plan to adopt nuclear physics researchers interested in Gravitational wave physics and astronomy in subscription research.

Risk management in response to possible delay in KAGRA's sensitivity improvement

The negative impact is limited, outstanding achievements can be expected

Delay by 6 months

⇒ Fully prepare data analysis pipeline and accelerate research after data acquisition

Delay by 1 year

⇒ Focus on the following researches that do not require KAGRA data

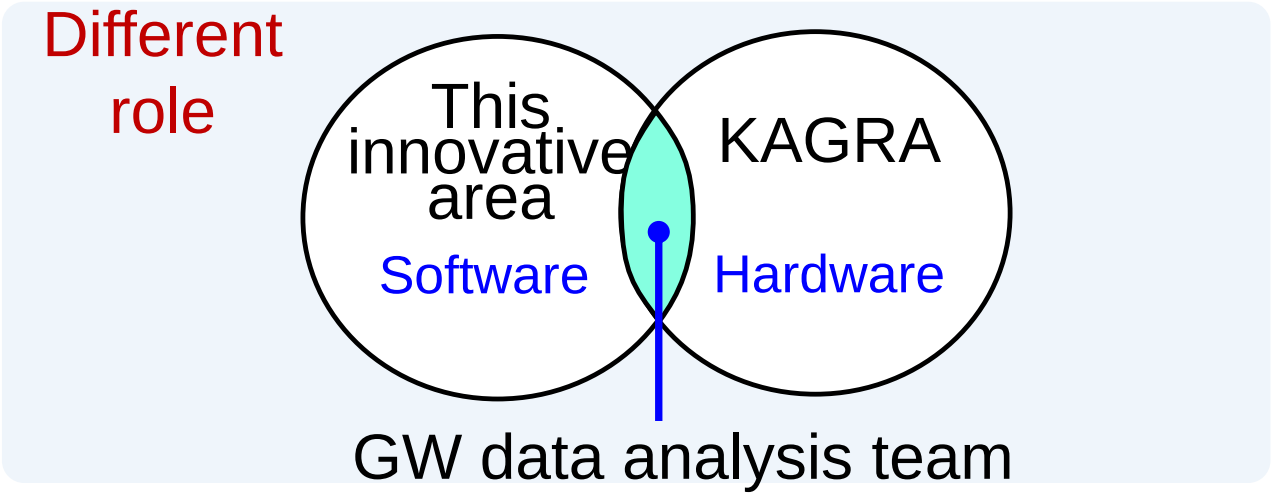
Science spreading from follow-up observations

- Advance research based on alert of GW events

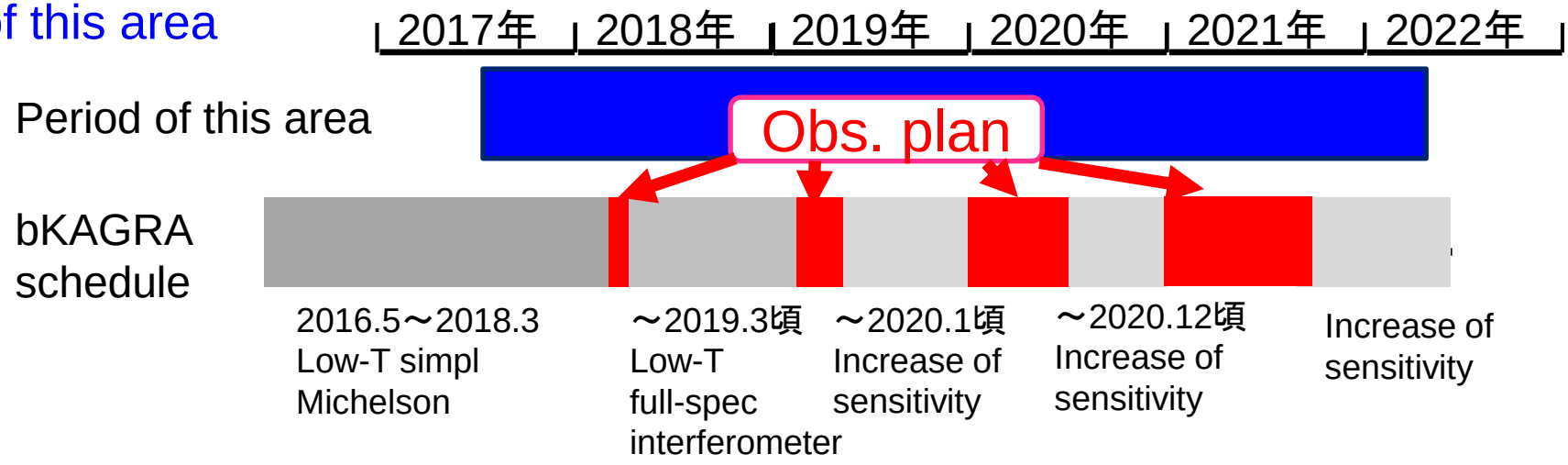
Science spreading from GW data analysis

- Advance analysis using LIGO/Virgo's open GW data
- Develop original analysis methods

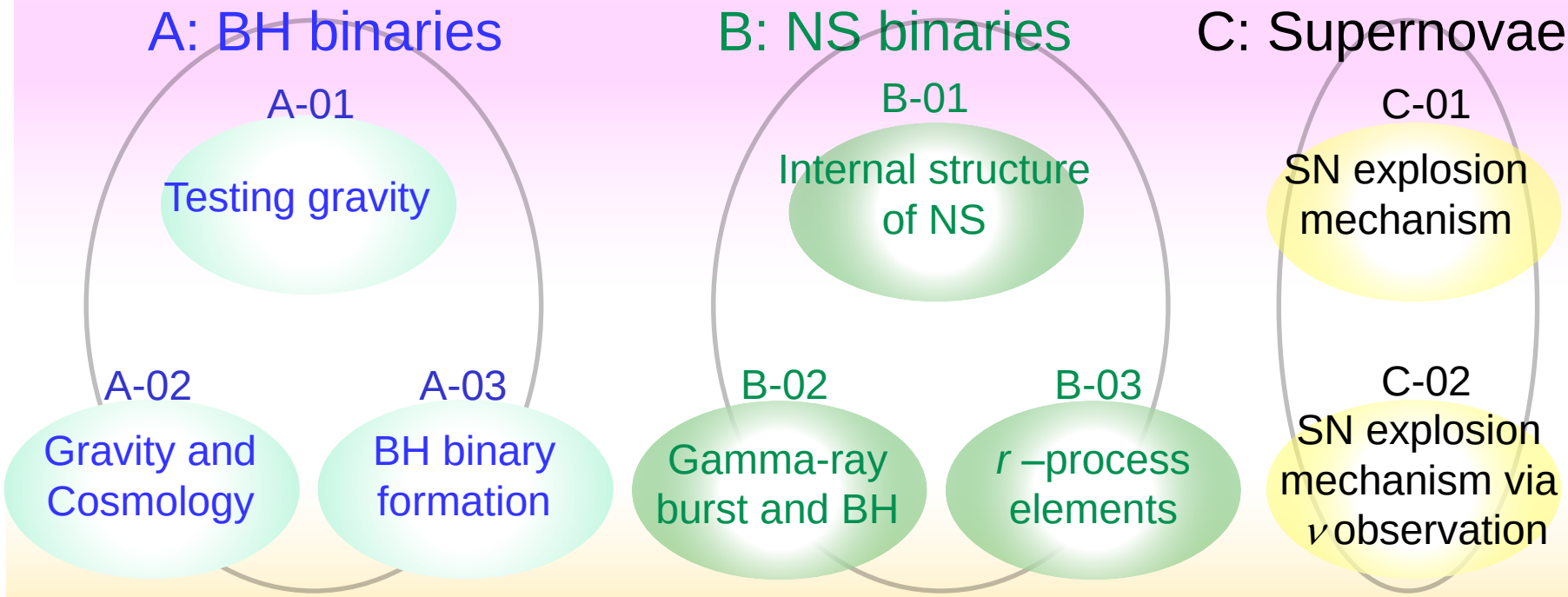
Relationship between 'bKAGRA' and this area



GW observation by bKAGRA has sufficient overlap with the research period of this area



Synergy between data analysis and theory researches



Physics and astronomy motivated by GW observations

A01:Testing gravity theories using gravitational waves

- 代表者: Takahiro Tanaka
- 分担者: Kenichi Ohara
- 分担者: Hisaaki Shinkai
- 分担者: Hirotaka Takahashi
- 分担者: Naoki Seto
- 連携　: Atsushi Nishizawa
- 連携　: Hiroyuki Nakano
- 連携　: Norichika Sago
- 協力者: Shigeyoshi Aoki
- 協力者: Kent Yagi
- 協力者: Kazuki Sakai
- 協力者: Takahiro Yamamoto

- GW waveform prediction for possible modification of GR, in collaboration with A02 group.
- For such models that allow us to have reliable theoretical GW templates. GW data analysis codes are systematically developed: *e.g.*
  - Massive scalar-tensor theory
  - String axion clouds
  - Modified GW propagation
  - also Environmental effects.
- Extracting spin/eccentricity information to identify the origin of BBHs.
- Mock data challenge to test various methods proposed to extract the BH QNM frequency and the decay rate.

A02 “New developments of gravity theory research in gravitational wave physics / astronomy”

代表者: Shinji Mukohyama (YITP)
分担者: Kei-ichi Maeda (Waseda)
分担者: Hideki Asada (Hirosaki)
分担者: Teruaki Suyama (RESCEU)

連携 : Jiro Soda (Kobe)
連携 : Kazuhiro Yamamoto (Hiroshima)
連携 : Atsushi Taruya (YITP)
連携 : Kazunori Kohri (KEK)
連携 : Tsutomu Kobayashi (Rikkyo)
連携 : Masaki Shigemori (QML)
連携 : Kazunori Nakayama (Tokyo)

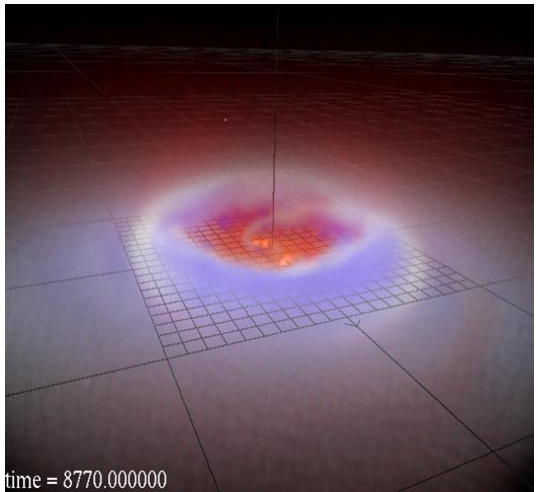
- The aim is to develop theories of gravity at short and long distances.
- GR at short distances less than 0.01 mm is untested.
- Modification of GR is required for quantum gravity.
- Modification at cosmological distance may explain dark energy or/and dark matter.
- A02 group explores various possibilities to approach these issues in view of GW physics/astronomy: the effective field theory approach, methods of testing gravity theories, detection perspective of stochastic GWs, etc.

A03:BH binary formation/evolution

PI:
Kazuyuki Omukai（Tohoku）
co-PI:
Hajime Susa（Konan）
Masahiro Machida（Kyushu）
Takashi Hosokawa（Kyoto）
Ataru Tanikawa（Tokyo）
Michiko Fujii（Tokyo）
連携:
Tomoaki Matsumoto (Hosei)
Naoki Yoshida (Tokyo)

- Theoretically studying binary star formation and evolution from the early to present-day universe:
  - Thermal processes and resulting magnetic resistivity
  - 3D radiation-resistive MHD (RRMHD) + protostellar evolution simulations
  - Binary evolution
- Predict properties of BH binaries which can be GW sources and compare them with GW observation

Constrain binary formation/evolution in the high-redshift universe



Susa + 2014

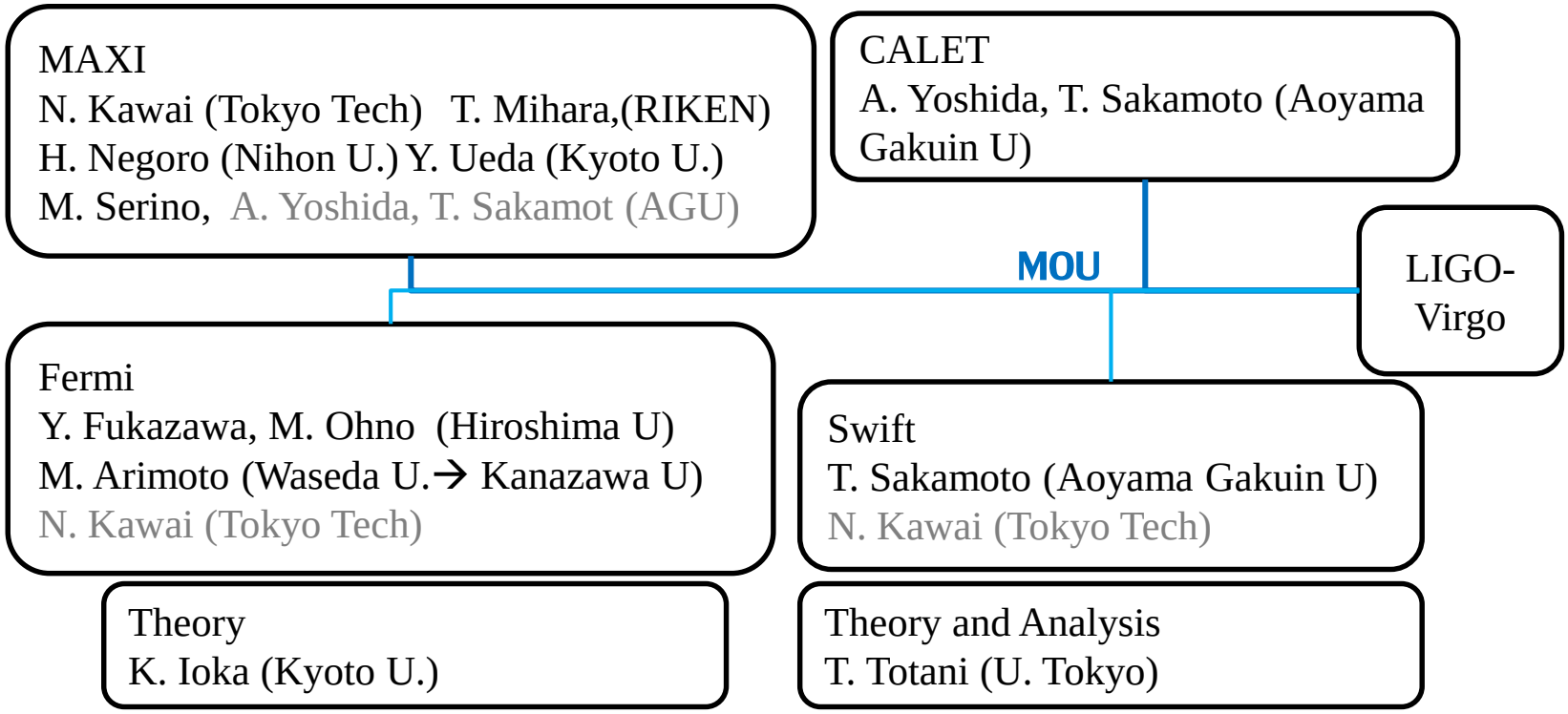
B01
"Physics and Astrophysics with Gravitational waves from Binary Neutron star Coalescences, Black Hole Neutron star Coalescences, Pulsars and Magnetars"

Data Analysis:
H. Tagoshi: CBC Analysis
K. Cannon: CBC Analysis (LIGO tools)
Y. Itoh: Continuous Wave Analysis
Narikawa, Uchikata,
Numerical Relativity:
K. Kiuchi, K. Kyutoku, M. Shibata,
K. Kawaguchi, K. Hotokezaka
Neutron star Astrophysics:
Y.Kojima

The main science target is to detect GWs from coalescences of binary NSs and BH-NS, and constrain the property of high density nuclear matter through the tidal interaction, and post-merger hypermassive NSs.
The detection of other targets containing NSs are also pursued.

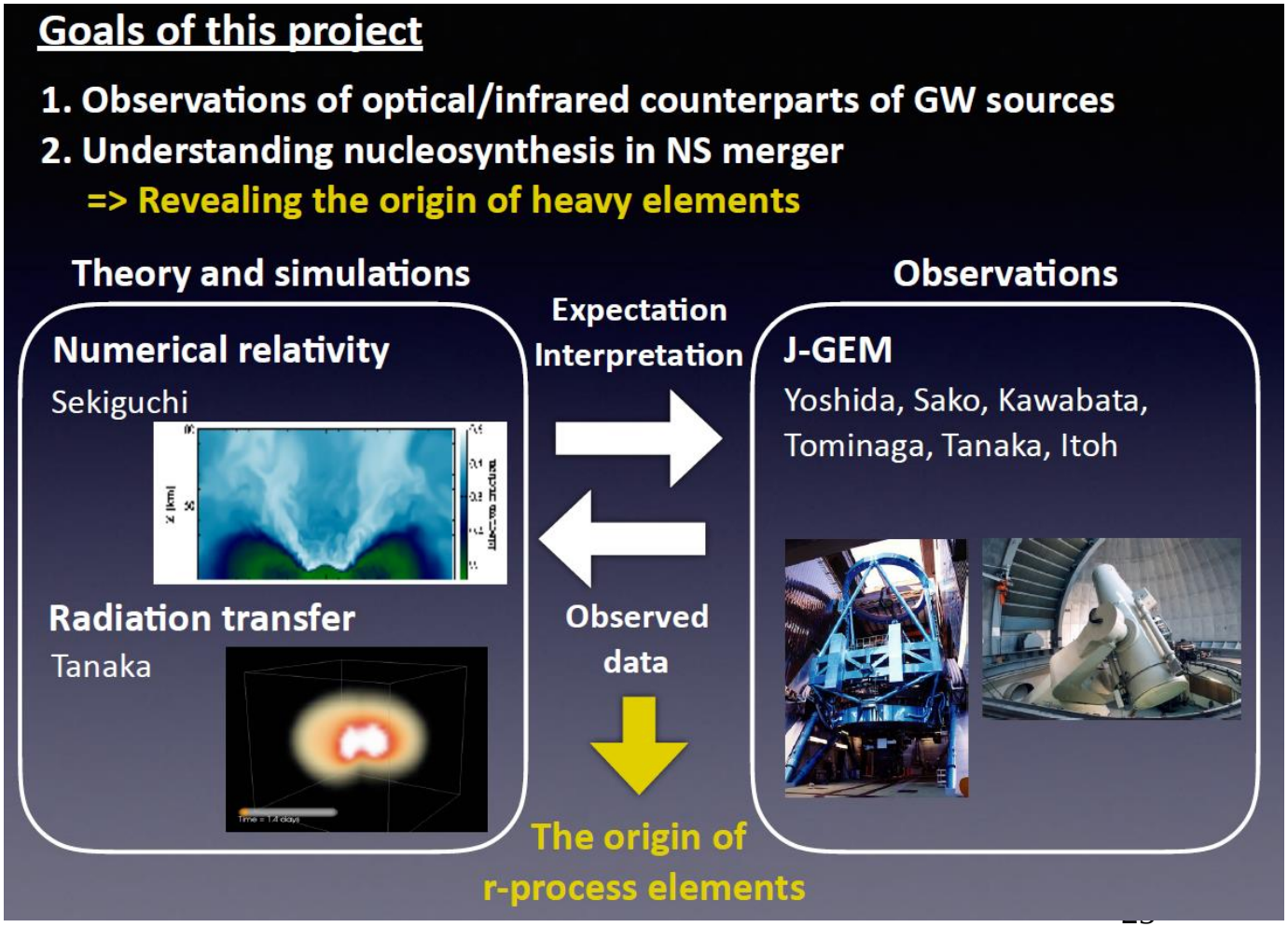
B02 Gravitational Wave Sources Probed with High Energy Observations (PI: N. Kawai)

1. **Search for X/γ radiation from GW events**（⇔A01）
2. **Physics of NS-NS merger**（⇔ B01, B03）
3. **History and frequency of NS mergers and BH formation**（⇔ A03）
4. **EM emission mechanism of NS merger**（⇔ B01, B03）
5. **Origin of short GRBs**（⇔ B01）



B03 Revealing Nucleosynthesis in NS Merger by Optical/Near-Infrared Observations of GW Sources

PI: Michitoshi Yoshida
(NAOJ)
Co-I:
Masaomi Tanaka
(NAOJ)
Yuichiro Sekiguchi
(Toho)
Shigeyuki Sako
(U. Tokyo)
Nozomu Tominaga
(Konan U.)
Koji Kawabata
(Hiroshima)
Yoichi Itoh (U. Hyogo)
Renkei:
Wako Aoki (NAOJ)
Satoshi Honda
(U. Hyogo)



C01: Investigation of Supernova Mechanisms via Gravitational Waves : via Gravitational Waves

PI: Kei Kotake
（Fukuoka University)
Co-PI's :
N. Kanda(Osaka-city Univ.)
T. Takiwaki(NAOJ)
K. Hayama (ICRR)
Collaborators ：
K. Nakamura (Fukuoka Univ.)
Y. Suwa (YITP),
S. Mano(Tousuken)
T.Yokozawa (Osaka-city, Univ.)
T. Kuroda (TU Darmstadt)

The team consists of experts on supernova theory and numerical modeling, and on the GW detection and data analysis dedicated to core-collapse supernova events.

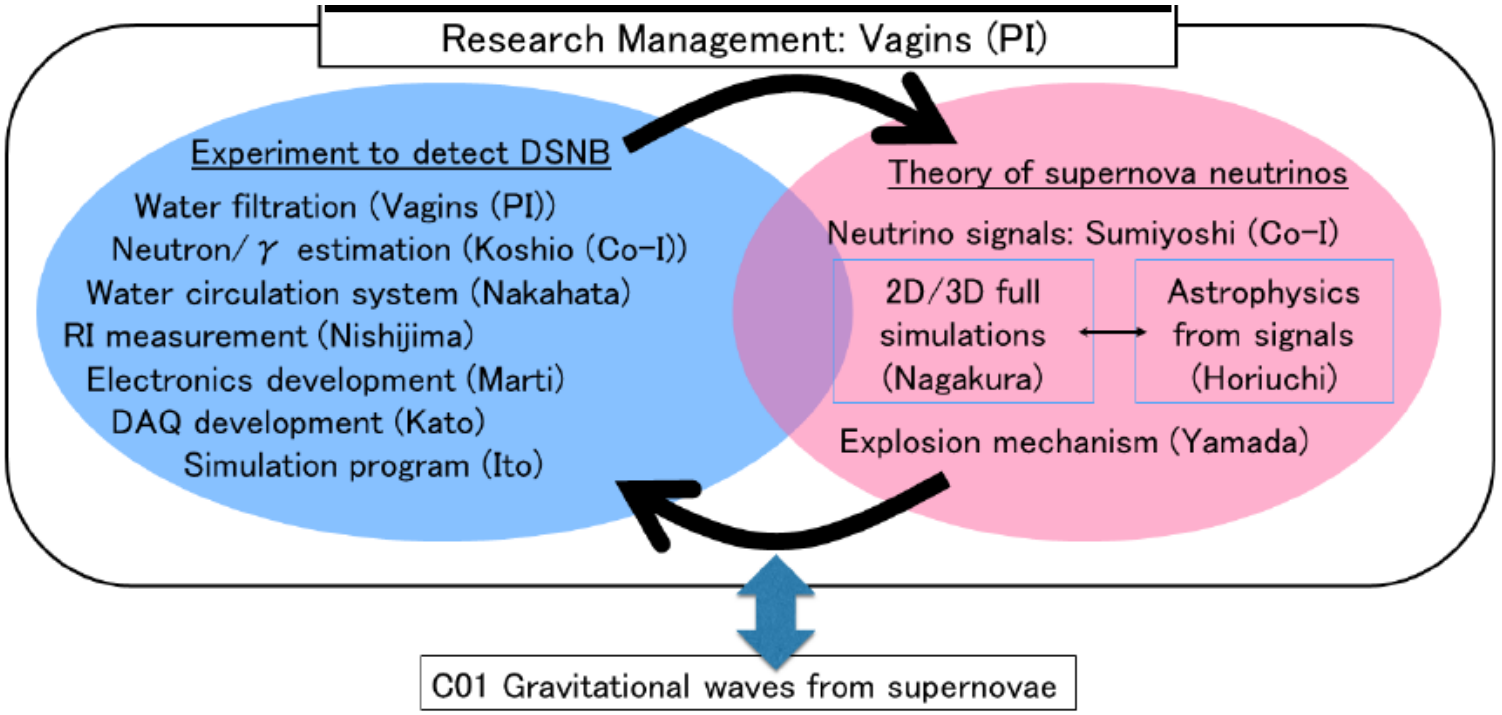
GW signals could provide us the signature of the shock instability in the SN core (aka SASI), which is one of the keys to trigger explosions.

Code update: 3D longer simulation with accurate transfer, rotation, B-field

New data analysis schemes: signal extraction, correlation analysis with neutrinos, GW polarization from rotation and SASI

⇒ CCSN drill, Search using real data

C02: Investigation of Supernova Mechanism via Neutrinos



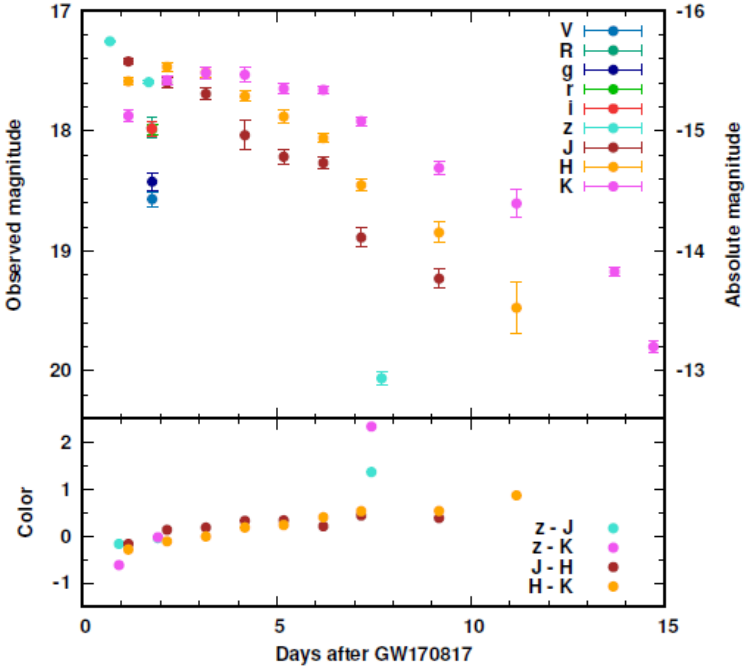
Super-Kamiokande, is soon to undergo a major upgrade via doping gadolinium salt. This upgrade, invented and driven by members of C02, should allow the first detection of the Diffuse SN Neutrino Background flux, the neutrinos emitted by all past core collapse SN explosions.

The information on the average temperature of these explosions, along with insight on the rate of optically failed explosions, will help improve the advanced modeling of explosions conducted by the theoretical members using 6D Boltzmann transport in close co-operation with the C01. Their world-leading simulations will then be used by the experimental members to best prepare their detector for the next galactic supernova.

Many papers related to GW170817 (not complete at all)

"Multi-messenger Observations of a Binary Neutron Star Merger" 1710.05833
J-GEM, MAXI, Fermi-LAT, CALET

"J-GEM observations of an electromagnetic counterpart to the neutron star merger GW170817"1710.05848
Follow-up observations have been done in various color bands by J-GEM members



"Kilonova from post-merger ejecta as an optical and near-infrared counterpart of GW170817" 1710.05850
Interpretation by the kilonova model. Requesting larger ejecta mass and high Ye component

"Subaru Hyper Suprime-Cam Survey for An Optical Counterpart of GW170817" 1710.05865

"Can an Off-axis Gamma-Ray Burst Jet in GW170817 Explain All the Electromagnetic Counterparts?" 1710.05905
Kunihito Ioka, Takashi Nakamura

"Scattered Short Gamma-Ray Bursts as Electromagnetic Counterparts to Gravitational Waves and Implications of GW170817 and GRB 170817A" 1711.00243
Shota Kisaka, Kunihito Ioka, Kazumi Kashiyama, Takashi Nakamura

"GW170817: Modeling based on numerical relativity and its implications" 1710.07579
Masaru Shibata, Sho Fujibayashi, Kenta Hotokezaka, Kenta Kiuchi, Koutarou Kyutoku, Yuichiro Sekiguchi, Masaomi Tanaka
Long-lived massive NS and the new mass bound on the maximum mass of non-rotating NS 2.15-2.25

"Mass Ejection from the Remnant of Binary Neutron Star Merger: Viscous-Radiation Hydrodynamics Study" 1711.02093
Sho Fujibayashi, Kenta Kiuchi, Nobuya Nishimura, Yuichiro Sekiguchi, Masaru Shibata

Type of ejecta	Mass ($M_\odot$)	$V_{\rm ej}/c$	Y_e	Direction	Duration
Dynamical ejecta	$O(10^{-3})$	~ 0.2	0.05–0.5	$\theta \gtrsim 45°$	$t - t_{\rm merge} \lesssim 10\,{\rm ms}$
Early viscosity-driven ejecta	$\sim 10^{-2}(\alpha_{\rm vis}/0.02)$	$\sim 0.15 - 0.2$	0.2–0.5	$\theta \gtrsim 30°$	$t - t_{\rm merge} \lesssim 0.1\,{\rm s}$
Late-time viscosity-driven ejecta (polar)	$\sim 10^{-3}(t_\nu/{\rm s})$	~ 0.15	0.4–0.5[a]	$\theta \lesssim 30°$	$t - t_{\rm merge} \sim t_\nu \sim 10\,{\rm s}$
Late-time viscosity-driven ejecta (equatorial)	$\gtrsim 10^{-2}$	~ 0.05	0.3–0.4[a]	$\theta \gtrsim 30°$	$t - t_{\rm merge} \sim 1$–$10\,{\rm s}$

"Prompt emission from the counter jet of a short gamma-ray burst"
Ryo Yamazaki, Kunihito Ioka, Takashi Nakamura. 1711.05848
Counter jet can be brighter than the early macronova emission and detectable by LSST.

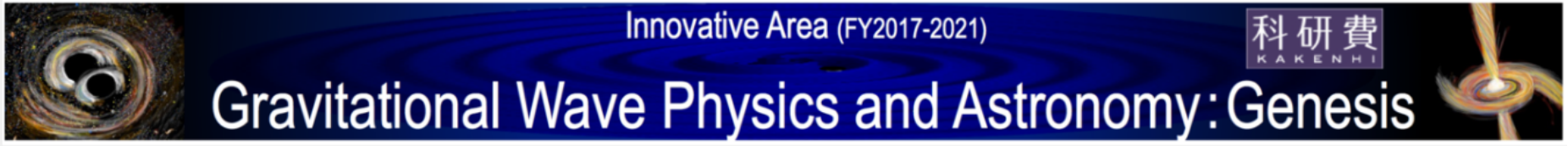
"Prospects of the local Hubble parameter measurement using gravitational waves from double neutron stars" 1710.06424
Naoki Seto, Koutarou Kyutoku

"Generalized framework for testing gravity with gravitational-wave propagation. I. Formulation"
1710.04825 Atsushi Nishizawa
"Generalized framework for testing gravity with gravitational-wave propagation. II. Constraints on Horndeski theory" 1711.03776
Shun Arai, Atsushi Nishizawa.

https://gw-genesis.scphys.kyoto-u.ac.jp/ilias/ilias.php?baseClass=ilrepositorygui&reloadpublic=1&cmd=frameset&ref_id=1&lang=en

ILIAS

gw-genesis.scphys.Kyoto-u.ac.jp



文部科学省 科学研究費助成事業 新学術領域（研究領域提案型）平成29～33年度　Gravitational wave physics and astronomy: Genesis（重力波物理学・天文学：創世記） 領域番号：2905

- Message from leader
  領域代表挨拶
- Organization
  Project Overview, Organization,
- Conference
- Documents
  Document of Research Projects and Sub-Projects
- Links
  related organizations/institutions
- Publications
  一般向け出版物等のお知らせ

Gravitational Wave Physics and Astronomy Genesis

Newsletters

- Postdoc position
- 諏訪雄大さんが物理学会若手奨励賞を受賞しました
- Gravitational wave detection from neutron star binary
  Thtere is a press conference by J-GEM
- 2017年度のノーベル物理学賞が「LIGO検出器と重力波検出への決定的に重要な貢献」の功績に対してレイナー・ワイス氏、バーリー・C・バリッシュ氏、キップ・ソーン氏の3氏に贈られました
- Report of Kickoff workshop at Kyoto University (September 22-23, 2017)
  9月23日から22日に京都大学で行われたKickoff workshopのレポートがアップされました。

Event information

Former Release

Planed workshops and meetings

Area workshop + Boot camp of A group

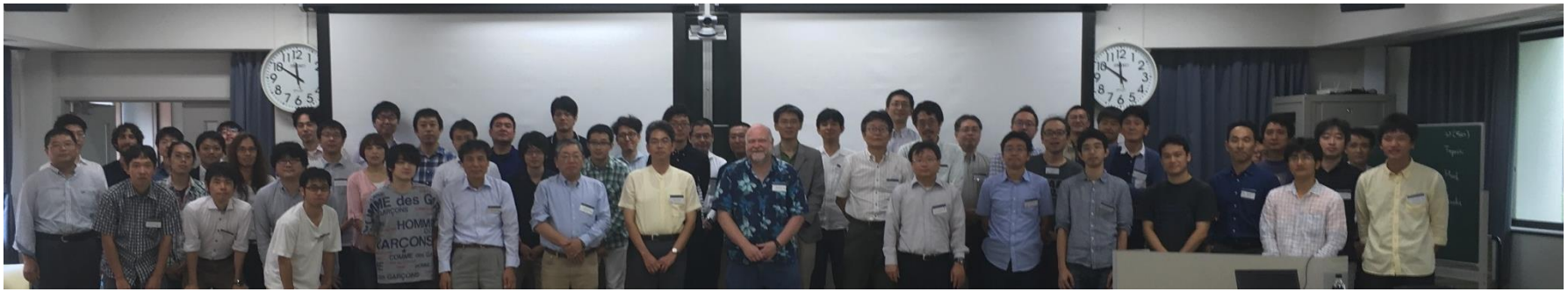
Dec. 7(Thu), 2017 (Area workshop), Tohoku University
Dec. 8(Fri)-9(Sat), 2017 (Boot camp), around Tohoku University

Annual Area Symposium

March 5(Mon)-7(Wed), 2018, Kashiwa campus of the University of Tokyo

- 2018/03/05-07, **Annual Area Symposium**
  @Kashiwa campus of the University of Tokyo
- 2018/01/29-30 **GWASNe2018 organized by C01@NAOJ**
- 2017/12/08-09 **Group A boot camp**
- 2017/12/07 **Area Workshop 2017 Autumn**
  (KEK mcu: 906)
- 2017/11/27-12/01
  JGRG27@Hiroshima
  (co-organization)

- 2017/09/22-23
  KICKOFF workshop



Summary

Gravitational Wave Physics and Astronomy : Genesis

GW detection has started
KAGRA is developing

Chance of big scientific discovery

Focus on important subjects:
Tight and wide collaboration network taking advantages in
GW data analysis, Follow-up observations, Theoretical work

Important results in
GW physics/astronomy

Fostering young researchers
who lead the future development
of GW physics/astronomy