Science Results from GTC-Subaru Collaboration

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Abstract

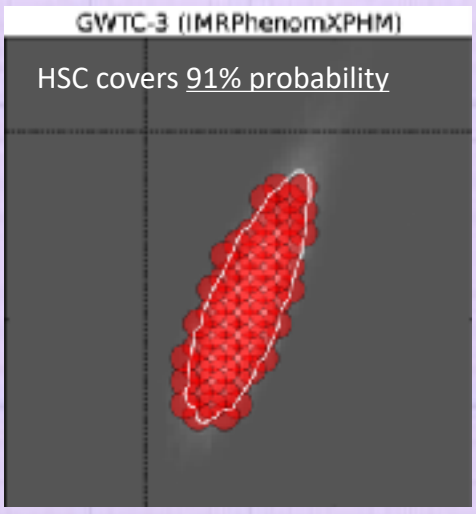
We here summarize science results obtained based on the GTC-Subaru Collaboration since 2019. Taking advantage of the unique features of both the telescopes, we have conducted (1) imaging surveys with Subaru/Hyper Supreme-Cam (HSC) and (2) imaging and spectroscopic follow-up observations of HSC-discovered transient/variable phenomena with GTC. The science results we have obtained include (a) a search for electromagnetic counterpart of the binary black hole GW200224_222234 (Ohgami+2023), (b) a rapidly fading quasar by a factor of 20 over 20 years, and (c) rapid transients. In addition to the instrument suites and different operation styles (classical+queue vs queue), the most unique feature in this collaboration is the time difference (10 hours) between the two telescopes, which is powerful especially for studies on rapid transients including kilonovae as a counterpart of gravitational wave source with neutron stars in the merger system. We are discussing about continuing this powerful unique collaboration.

(1) Science Case 1: Follow-Up for Gravitational Wave Sources (Ohgami+2023, ApJ, 947, 9)

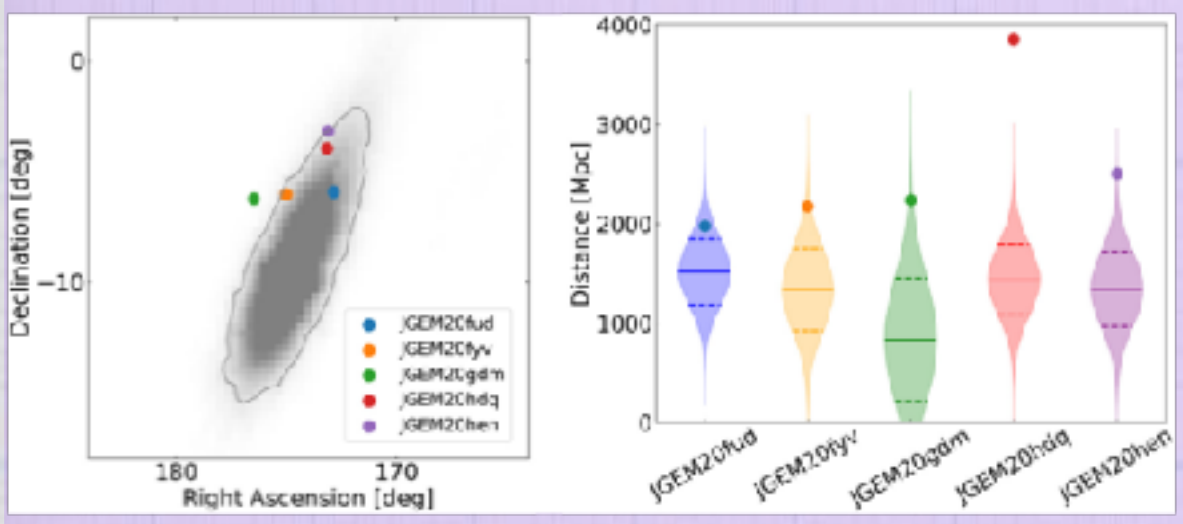
- GW200224_222234 (S200224ca)
  - Binary Black Hole merger
  - 90% area: 50 deg² (narrow!!!)
  - Distance: 1710 Mpc (z~0.30)
  - only a few BBHs w/ ~>90% coverage (e.g., Doctor+2019)
- Subaru/HSC follow-up observations
  - started 12.3 hours (~0.5 days) after GW detection
  - 3-times ToO observations
  - Observation area: 56.6 deg² (91% cumulative probability)
- GTC/OSIRIS follow-up: 3.12 hours (incl. overhead)
  - 5 host galaxies of counterpart

Results

- 2 candidates likely be outside the 3D skymap (P_{assoc} < 0.01)
- **Other 3 candidates remain as the candidates of the GW counterpart.**

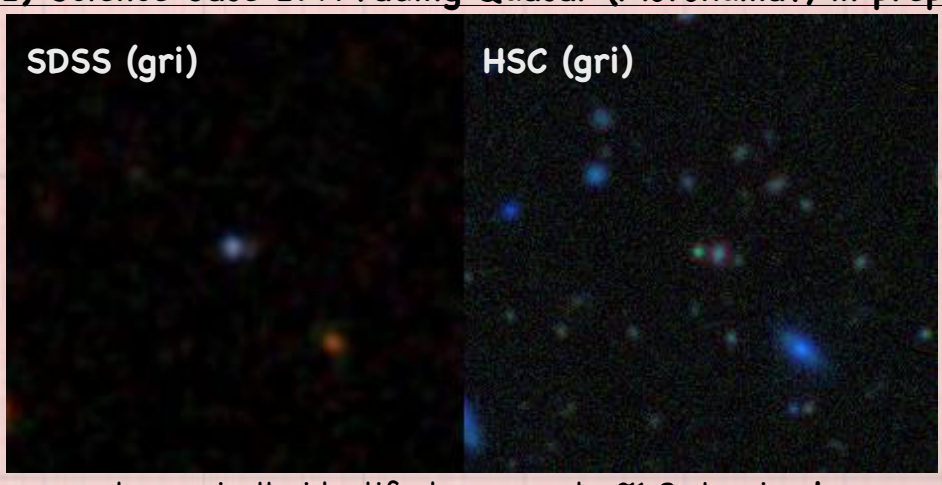


Observation pointings with the Subaru/HSC (filled red circles) overlaid on the refined skymap using the IMRPhenomXPHM model (GWTC-3 catalog; The LIGO Scientific Collaboration et al. 2021). The white contour lines indicate the 90% credible regions.



(Left) 2D location of the five candidates observed with the GTC/OSIRIS and the localization skymap (IMRPhenomXPHM model) released in the GWTC-3 catalog. The dots are the locations of the candidates. The gray contour line indicates the 90% credible region. (Right) Distance to each candidate and probability distribution at their location as a function of distance. The dots are the distances of the candidates. The horizontal solid and dashed lines indicate the mean and standard deviation of the probability distribution, respectively.

(2) Science Case 2: A Fading Quasar (Morokuma+, in prep.)



- a spectroscopically identified quasar at z~1.8 showing **large brightness decline (by a factor of ~20),** found by comparing the SDSS and HSC magnitudes of ~30,000 quasars.
- **OSIRIS (optical) & EMIR (NIR) imaging follow-up** observations were done immediately after we found the dramatic SDSS-HSC decline. ==> further follow-up observations w/ Subaru, Keck, etc.
- The reason of the large decline is likely to be **a large decline in mass accretion rate** rather than obscuration of moving clouds.

(3) Science Case 3: Rapid Transients (Tominaga+, in prep.)

- Scientific motivations for studying rapid transients include "**How high is the fraction of massive stars having the confined dense CSM?**", "**How widely is the dense CSM extended?**", "**How high is the mass loss rate realized just before the core collapse?**", leading physical questions about "What is **the mechanism of the enhanced mass loss**?", "How does it change **the metal enrichment and cosmic reionization by the massive stars**?"
- For these purposes, **immediate spectroscopic follow-ups** right after the discovery of transients would be essential.
- A rapid transient **MUSSES2020A at z=0.0535** discovered in our HSC high-cadence transient survey (PI: N. Tominaga)
  - Intranight flux increase: >1.5 mag over 4 "hours"
  - Successfully obtained **GTC/OSIRIS spectra 1.5 days & 2.5 days after** the first detection => variable H-alpha detected
  - Found to be Type II-P supernova w/ dense CSM
- 2 more objects triggered for follow-ups w/ GTC/OSIRIS

Summary & Future

Collaborative observations with GTC and Subaru are powerful especially for transient object science, including follow-up observations for gravitational wave sources. We are now seriously discussing how to proceed more with the collaboration.

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