Growing Black Holes in Stellar Clusters
CAMK Annual Meeting 2024

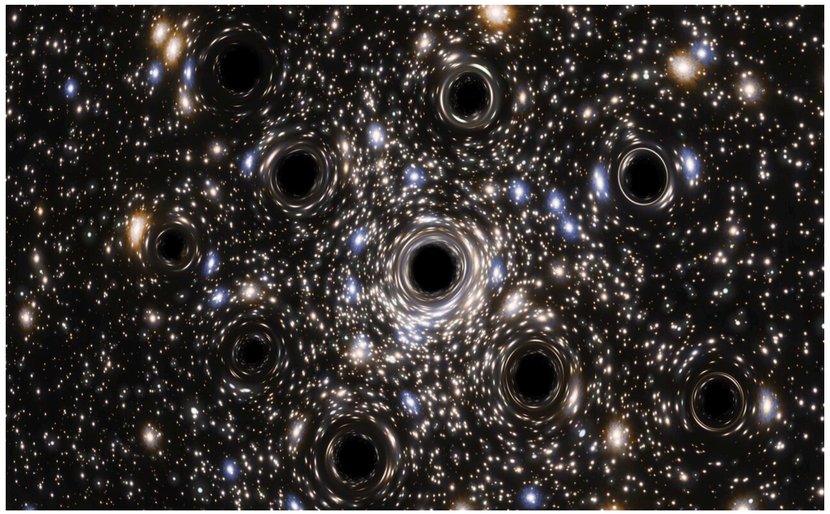


Image Credit: ESA/Hubble, N. Bartmann

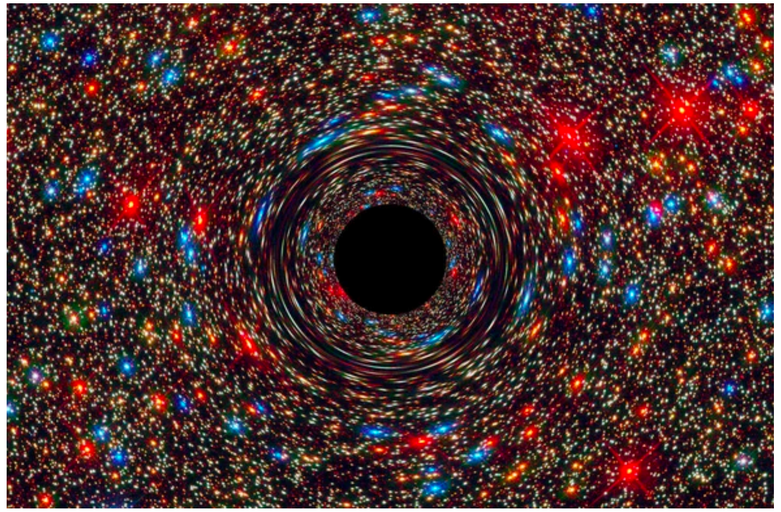


Image Credit: NASA, ESA, and D. Coe, J. Anderson, and R. van der Marel (STScI)

POLONEZ BIS

NATIONAL SCIENCE CENTRE POLAND

MARIE CURIE ACTIONS

CAMK PAN

Abbas Askar

POLONEZ Fellow (2 year project: BHGrowth)

Nicolaus Copernicus Astronomical Center

Warsaw, Poland

askar@camk.edu.pl

BH GROWTH

Growing Black Holes in Star Clusters

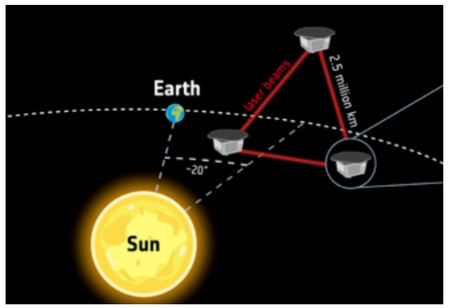
https://bhg.camk.edu.pl/

MOCCA

Updates and scientific activities in 2023

- Resigned from my position as researcher at Lund Observatory in Sweden at the end of August 2023
- Gave talks at 2 conferences (including an invited review talk at EAS 2023)
- Gave lecture in 2 masters courses at Lund Observatory, supervised 3 student projects and gave 2 popular talks to high school students
- **Papers/monographs published or accepted in 2023:**
  - A. Leveque, M. Giersz, **A. Askar**, M. Arca-Sedda, A. Olejak: ***"MOCCA-Survey Database: Extra Galactic Globular Clusters. III. The population of black holes in Milky Way and Andromeda - like galaxies"*** (MNRAS, 2023: https://arxiv.org/abs/2209.01564)
  - P. Amaro-Seoane, J. Andrews, M. Arca Sedda, **A. Askar** and 154 co-authors: ***"Astrophysics with the Laser Interferometer Space Antenna"*** (Living Reviews In Relativity, 2023: https://arxiv.org/abs/2203.06016)
    - Coordinated writing of section 1.4 and contributed to section 1.7 (Stellar compact binaries and multiples)
    - Contributed to section 2.3 (massive BH seeds and their formation mechanism)
  - M. Pasquato, P. Trevisan, **A. Askar**, P. Lemos, G. Carenini, M. Mapelli, Y. Hezaveh: ***"Interpretable machine learning for finding intermediate-mass black holes"*** (Accepted in ApJ: https://arxiv.org/abs/2310.18560)
  - **A. Askar**, V.F. Baldassare, M. Mezcua: ***"Intermediate-Mass Black Holes in Star Clusters and Dwarf Galaxies"*** (To appear in Chapter 2 in the book, ***"Black Holes in the Era of Gravitational Wave Astronomy"***, ed. Arca Sedda, Bortolas, Spera, pub. Elsevier. in print; June 2024: https://arxiv.org/abs/2311.12118)
    - Author of Part I on Formation pathways of IMBHs and GWs from IMBH mergers with other BHs

LISA CONSORTIUM



Launch Date: 2035 (planned)

BHGrowth: Investigating black hole growth in stellar clusters

Basic Idea: Carry out MOCCA simulations of hundreds of realistic dense star clusters

- Inclusion of physical processes relevant for studying BH growth:
  • Improved Stellar/binary evolution prescriptions for BH progenitors • **Energy losses due to gravitational wave radiation and tides during close encounters** • Gravitational wave recoil kicks

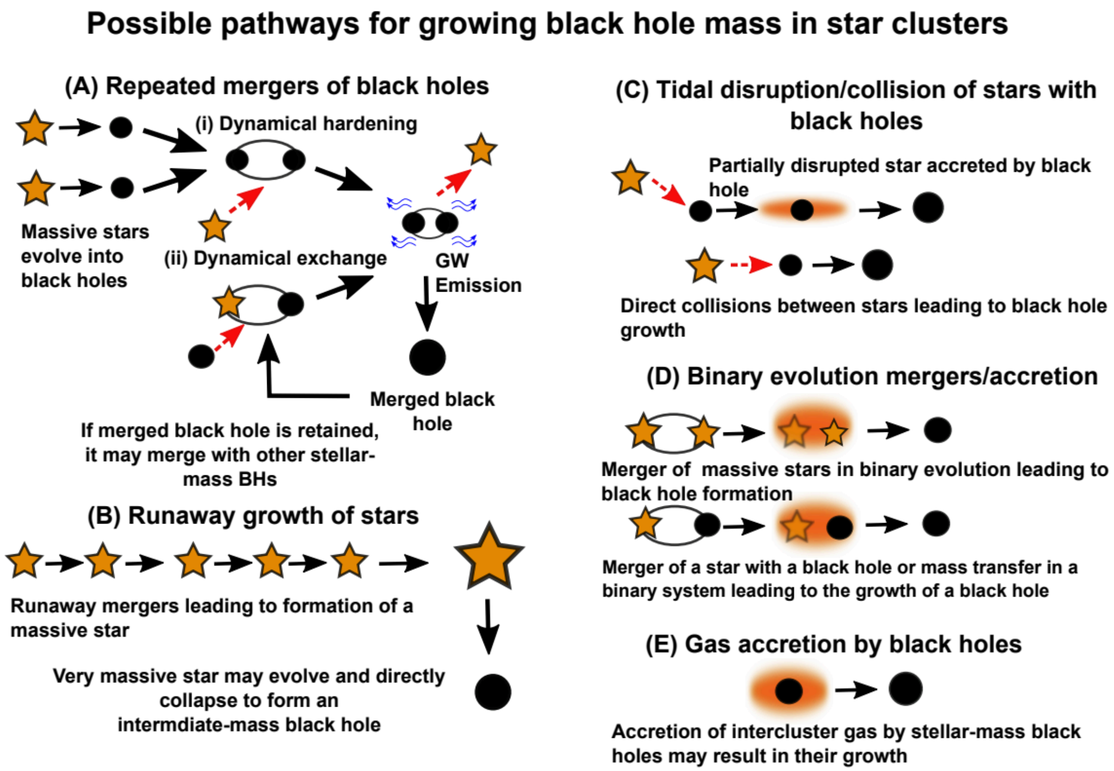
Goals:

– Identify predominant pathway for forming and growing IMBHs in stellar clusters

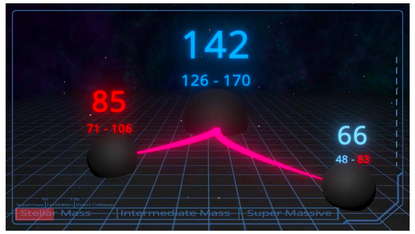
- Dependence on cluster initial properties and uncertain parameters that can influence BH growth
- Calculate how efficiently dense star clusters form merging binary BHs similar to GW190521

– Use simulations to provide observational constraints on the presence of IMBHs in stellar clusters

- Estimate rates and properties of high-energy transient events (tidal disruption events and gravitational wave mergers) involving IMBHs to make predictions for existing and planned observations
- Identify unique observable properties of clusters that host an IMBH and compare with observations



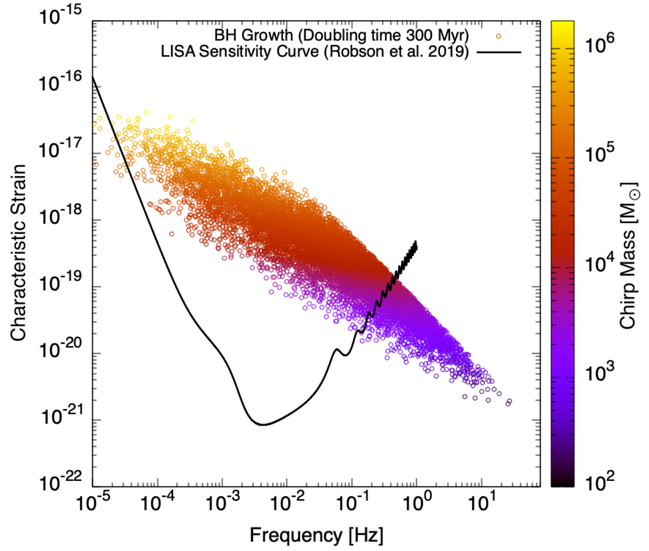
Askar et al. 2023



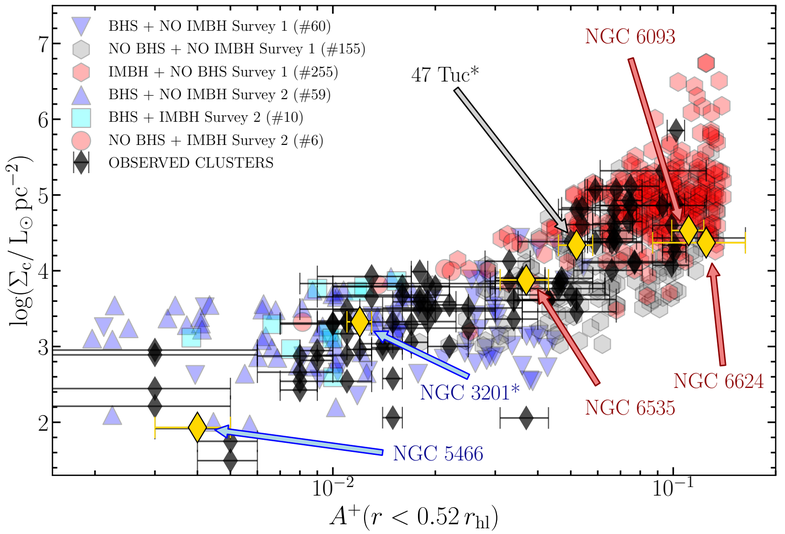
GW190521: Observed merger of 2 BHs that produced an IMBH (LVK 2020)

Other ongoing projects and highlights

- ***LISA sources originating in galactic nuclei: Mergers of SMBHs and IMBHs in galactic nuclei: binary properties and intermediate-mass ratio inspiral merger rates*** (based on Askar, Davies & Church 2021; 2022)
- ***Mass segregation in globular clusters harbouring an IMBH or a subsystem of stellar-mass BHs*** (led by former master student Markus Strickert)
- ***Growth of nuclear star cluster and SMBH in Milky Way and M31*** (in collaboration with Agostino and Mirek using results from their previous papers)
- ***Stellar collisions in the Galactic center with N-body simulations*** (in collaboration with Ross Church, Alessandra Mastrobuono-Battisti, Markus Strickert)
- ***Multi-messenger study for the evolution of binary populations in the Milky Way star clusters*** (project led by Xiaoying Pang)
- ***Binary IMBH evolution due to dynamical encounters*** (with Alessandro Trani)
- ***Creating mock star cluster observations from N-body/Monte Carlo simulations*** (in collaboration with Paolo Bianchini, continuation of the development of the COCOA code; Askar et al. 2018)



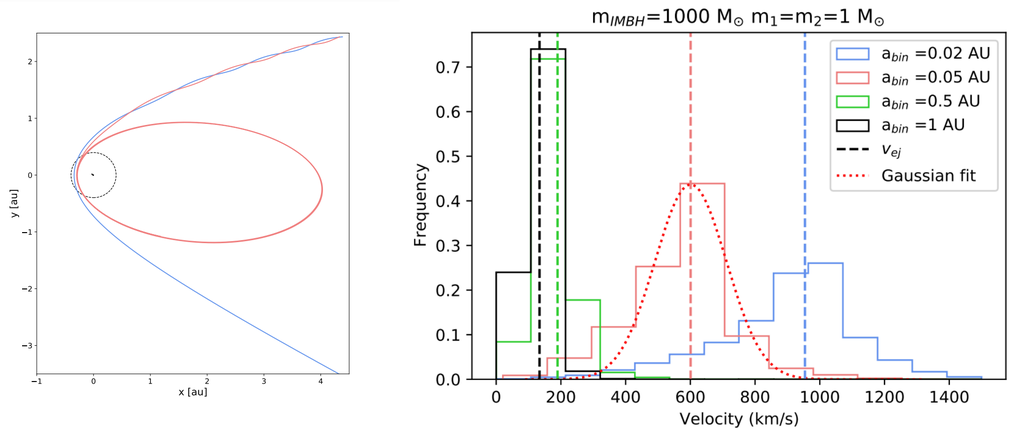
Askar in prep.



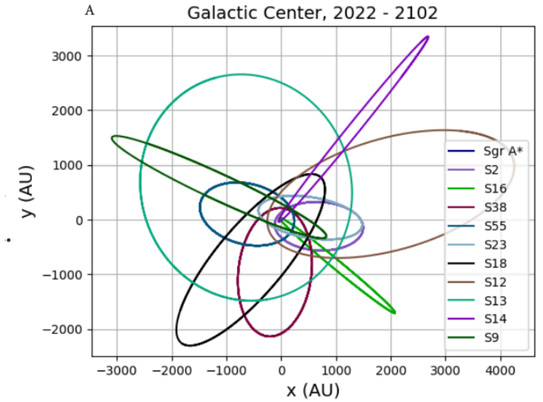
Strickert et al. in prep.

Other ongoing projects and highlights (2)

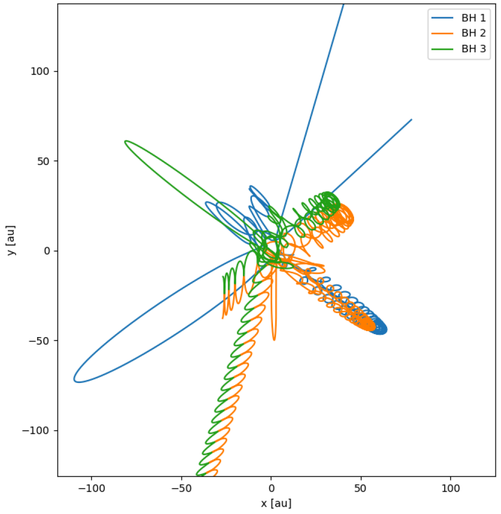
- Student projects supervised in 2023:
  - ***Hyper-velocity stars from globular clusters hosting intermediate-mass black holes*** (Bachelor project of Matilda Skantz at Lund University defended in June 2023)
    - Carried out 3-body binary-single encounters (using the Tsunami code) between a binary star system and an IMBH → HVS produced via Hill's mechanism → possible mechanism for producing hypervelocity white dwarfs (https://lup.lub.lu.se/student-papers/search/publication/9132033)
  - ***Measuring the mass of Sagittarius A* and simulating the orbits of S-stars in the Galactic center*** (Final year high school research project by Viktor Wellander from Orebro, Sweden)
    - Semi-finalist in the Swedish competition for Young Researchers (Unga Forskare)
  - ***3-body gravitational scattering experiments: Merging stellar-mass binary black holes*** (Ongoing final year high school research project by Amanda Skog, Aron Andrén & Alexander Andersson from Ystad, Sweden)



Skantz 2023



Wellander 2023



Skog et al. In prep