Studies of black hole accretion flows

Astroparticle Physics in Poland

Agnieszka Janiuk
Petra Suková
Szymon Charzyński

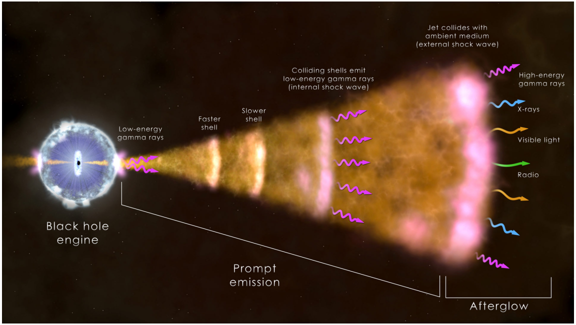
Center for Theoretical Physics
Polish Academy of Sciences
Warsaw

13.8.2015

Astrophysics group in Center for Theoretical Physics

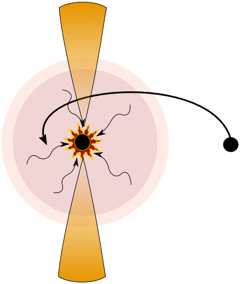
- The NCN grant *Astrophysics of processes around compact objects* - prof. Janiuk, 2013–2018
- Grant goals - study the relation between the observable variability of outcoming radiation from systems containing compact object (neutron star or black hole) and the physical processes going on in the accretion flow on these objects
- Study of BHs in different situations - formation of BH in collapsar/merger connected with GRB, properties of accretion disc of stellar mass BH in binaries, properties of corona in stellar mass/supermassive BHs
- Postdocs:
  - dr Petra Suková
  - dr Szymon Charzyński (CFT PAN / FUW)
- PhDs:
  - Mikołaj Grzedzielski
  - Bartłomiej Kamiński (until September 2014)

- GRB - extremely energetic, transient events
- possible mechanism - collapse of massive star (long GRB) or merge of 2 compact objects (short GRB) $\rightarrow$ new BH
- engine of the process - hot and dense accretion disc with hyper-Eddington accretion rate (up to 1 $M_{\odot} s^{-1}$) triggers powerful, ultra-relativistic jets, which produce gamma ray radiation far away from the central region



Binary black hole merger simulations

- combination of the two scenarios (close binary of massive OB star + BH) can yield the longest GRBs
- simulations of such scenario very complicated, consists of several steps:

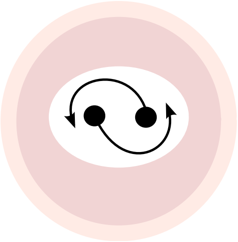


- spinning up the massive star, common envelope phase
- core collapse and accretion of inner envelope, primary BH mass and spin evolution, possible jet launch
- binary BH merger in vacuum
- accretion of the envelope onto the merged product

A. Janiuk, S. Charzyński, M. Bejger, *Long gamma ray bursts from binary black holes*, *Astronomy & Astrophysics*, A25, **560** arXiv:1310.4869 [astro-ph.HE]

Binary black hole merger simulations

- combination of the two scenarios (close binary of massive OB star + BH) can yield the longest GRBs
- simulations of such scenario very complicated, consists of several steps:

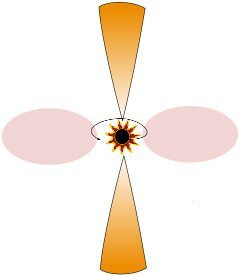


  - spinning up the massive star, common envelope phase
  - core collapse and accretion of inner envelope, primary BH mass and spin evolution, possible jet launch
  - binary BH merger in vacuum
  - accretion of the envelope onto the merged product

A. Janiuk, S. Charzyński, M. Bejger, *Long gamma ray bursts from binary black holes*, *Astronomy & Astrophysics*, A25, **560**
arXiv:1310.4869 [astro-ph.HE]

Binary black hole merger simulations

- combination of the two scenarios (close binary of massive OB star + BH) can yield the longest GRBs
- simulations of such scenario very complicated, consists of several steps:



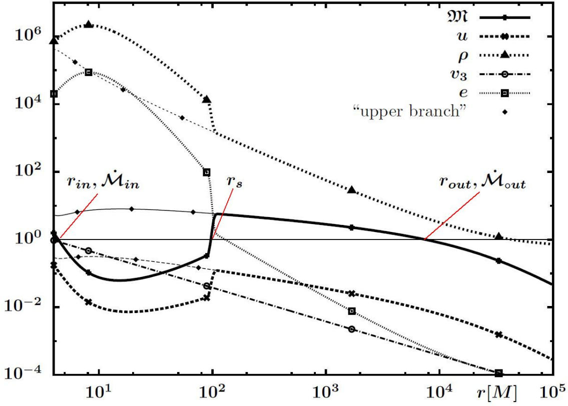
  - spinning up the massive star, common envelope phase
  - core collapse and accretion of inner envelope, primary BH mass and spin evolution, possible jet launch
  - binary BH merger in vacuum
  - accretion of the envelope onto the spinning merged product

A. Janiuk, S. Charzyński, M. Bejger, *Long gamma ray bursts from binary black holes*, *Astronomy & Astrophysics*, A25, **560**
arXiv:1310.4869 [astro-ph.HE]

Shocks in low angular momentum flows

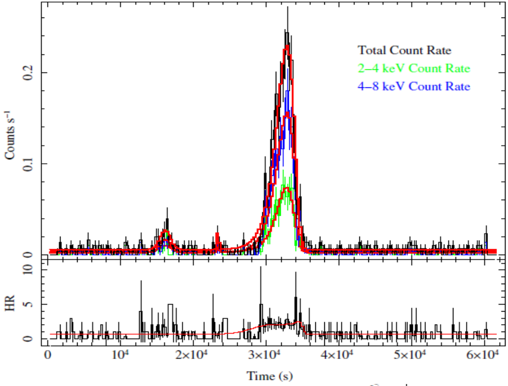
- Study the variability of low luminous X-ray sources or the part of the variability of high luminous sources connected with the hot corona
- Low luminous galactic nuclei including Sgr A* $\rightarrow$ quasi-periodic oscillations (QPOs) and flares observed
- Stellar black hole binaries in the quiescent state bright flares (change of count rate by a factor of 5-8)
- In some stellar black hole candidates QPOs with changing frequency have been observed (e.g. GX 339-4)
- Possible explanation – quasi-spherical accretion flow with shocks forms instead of an evaporated Keplerian accretion disc or around it
- Influence on velocity and density profiles, time dependence of mass accretion rate

- semi-analytical treatment of shocks in quasispherical flow (1D)
- position of critical points and shock front found for the steady state in dependence on several parameters - specific energy ε, specific angular momentum λ and adiabatic index γ



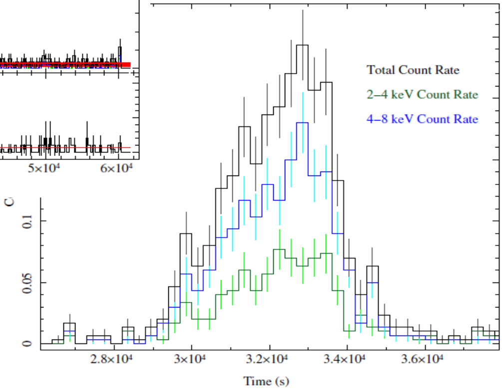
$\gamma = 4/3$,
$\varepsilon = 0.0001$,
$\lambda = 3.78M$,
$r_{\rm in} = 4.39M$,
$r_{\rm out} = 7482.81M$,
$r_s = 110.57M$

Bright flare of Sgr A*



Nowak et al., 2012, ApJ, 759, 95

Sgr A* observation



Sgr A* $M \sim 4.3 \cdot 10^6 M_\odot$

$[t] = 1\mathrm{M} \approx 21.5\mathrm{s}$

$5\mathrm{ks} \approx 230\mathrm{M}$