



# Study of Formation and Evolution double PBHs in the early universe

Vorobyev Grigory
NRNU Mephi, M21-115
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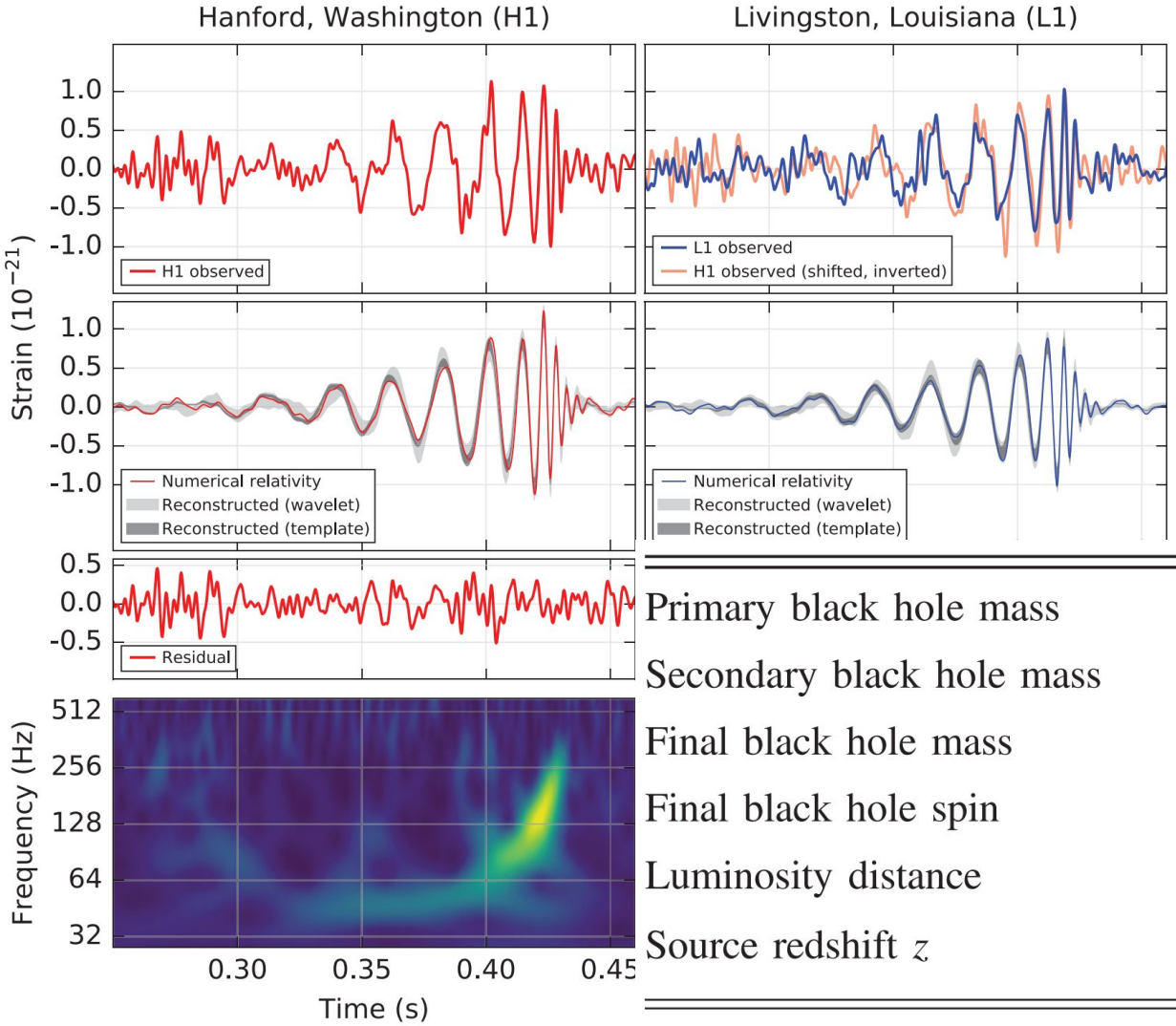


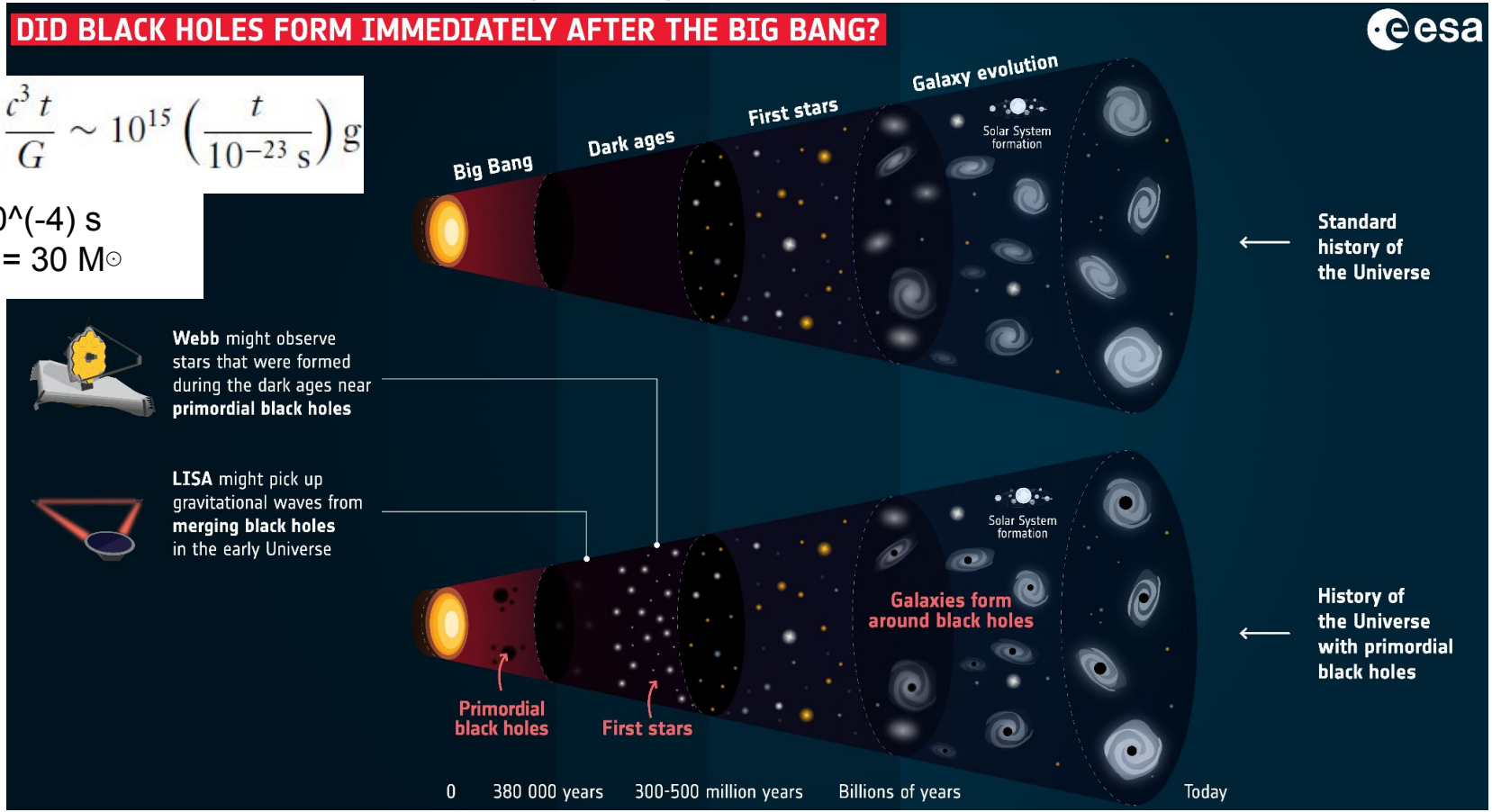

# GW150914

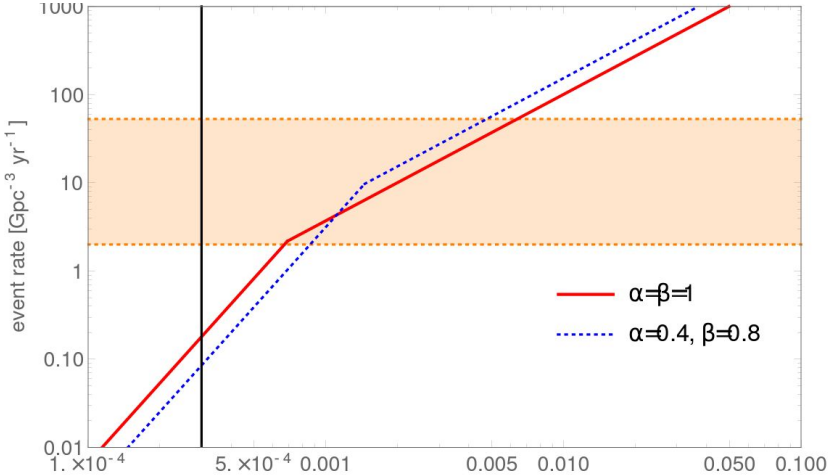
arXiv:1602.03837 Observation of Gravitational Waves from a Binary Black Hole Merger LIGO

B. P. Abbott et al. (LIGO Scientific Collaboration and Virgo Collaboration) "Properties of the Binary Black Hole Merger GW150914" 2016

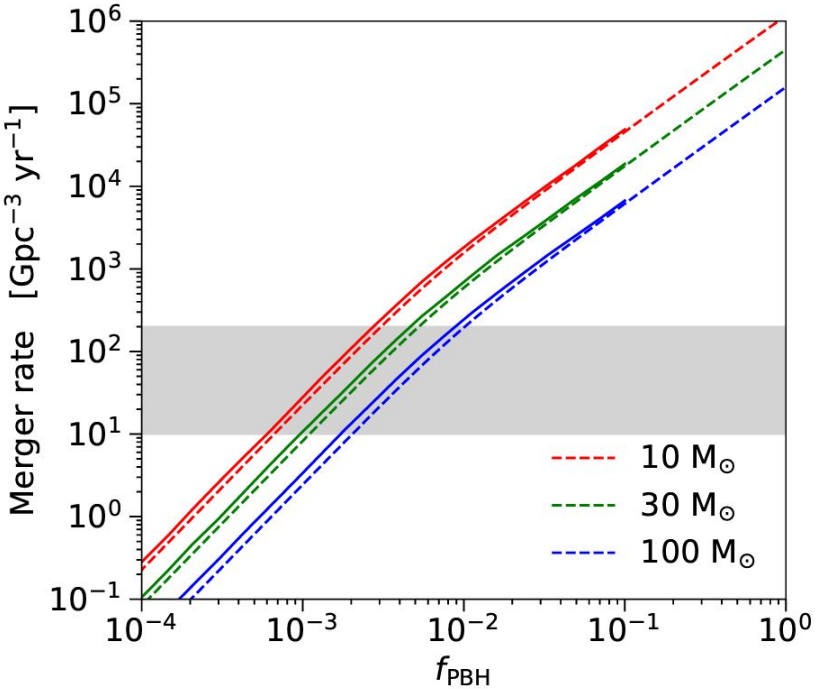
| | |
|---|---|
| Primary black hole mass | $36^{+5}_{-4} M_\odot$ |
| Secondary black hole mass | $29^{+4}_{-4} M_\odot$ |
| Final black hole mass | $62^{+4}_{-4} M_\odot$ |
| Final black hole spin | $0.67^{+0.05}_{-0.07}$ |
| Luminosity distance | $410^{+160}_{-180}$ Mpc |
| Source redshift $z$ | $0.09^{+0.03}_{-0.04}$ |

# Primordial black holes (PBH)






Misao Sasaki "Primordial Black Hole Scenario for the Gravitational-Wave Event GW150914"




Bradley J. Kavanagh “Black Holes' Dark Dress: On the merger rate of a subdominant population of primordial black holes”

# Merger rate

Number of GW signals per year and Gpc^3.

**Shaded bar** - observed merger rate measured by LIGO

**Black line** - the upper limit on rate from the nondetection of the CMB spectral distortion

The *solid lines* on the right graph are the merger rate of PBHs in the *halo of dark* matter particles, the *dotted lines* are without a halo.

# Programm realisation

P **PyGra**
Project ID: 43381994

☆ Star 0

**20** Commits **4** Branches **1** Tag **4.5 MB** Project Storage **1** Release

Merge branch 'pygra_dev' into 'main'
Gregory Vorobyev authored 2 days ago

37b7700c

main pygra Find file Clone

README

| Name | Last commit | Last update |
|---|---|---|
| .devcontainer | Initial commit | 2 weeks ago |
| debug | First release with some examples. Simulation... | 2 days ago |
| lib | First release with some examples. Simulation... | 2 days ago |
| output | First release with some examples. Simulation... | 2 days ago |
| scripts | First release with some examples. Simulation... | 2 days ago |
| .gitignore | First release with some examples. Simulation... | 2 days ago |
| Dockerfile | Initial commit | 2 weeks ago |
| README.md | Update README.md | 2 days ago |

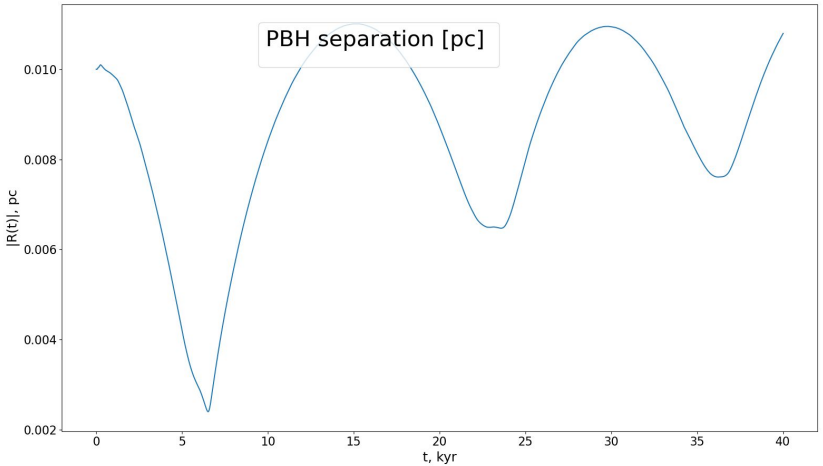
Numba + python™

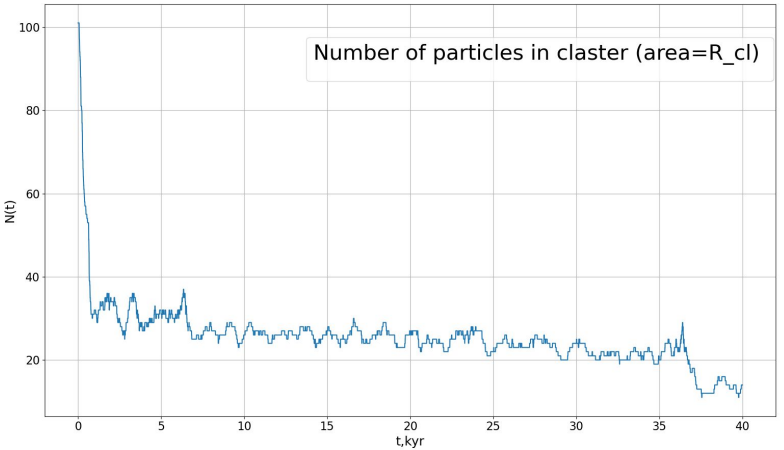
docker

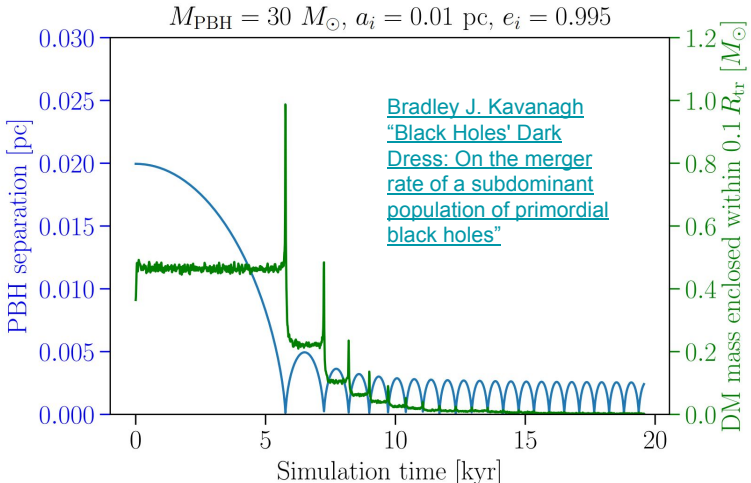
NBODY6++

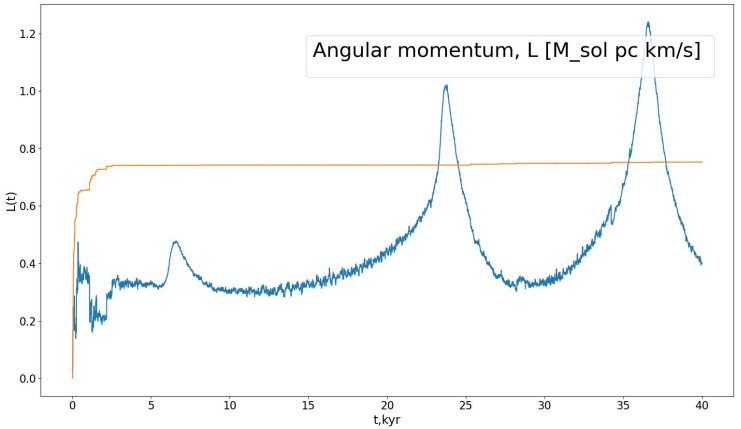
G.Vorobyev
gitlab.com/MirumeYato/pygra

# Merger of binaries surrounded by clusters



# Conclusion

In this presentation, we discussed issues of modern cosmology, the successes of gravitational-wave astronomy and the concept of primary black holes (PBHs). The gravitational wave signal GW150914 and hypotheses about the nature of the black holes that gave rise to it are considered. One of the hypotheses noted the possibility of the existence of PBH clusters with central massive BHs at the epoch of the RD-MD transition, the merging of which will also affect the rate of mergers observed by the experiments of the LIGO, Virgo, and KaGra collaborations.

A Python script for N-body simulations was developed. Clusters simulations was provided and next step will be estimating of merger rate for cluster coalescence.

As result with this work we will understand more about nature of binaries systems and maybe give more gravitational wave samples for collaborations like LIGO, Virgo and KaGra.

# Thank you for your attention