HIGH-ENERGY NEUTRINO GENERATION AT JETS FROM SUPERMASSIVE BLACK HOLES

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Fundamental problems and applications
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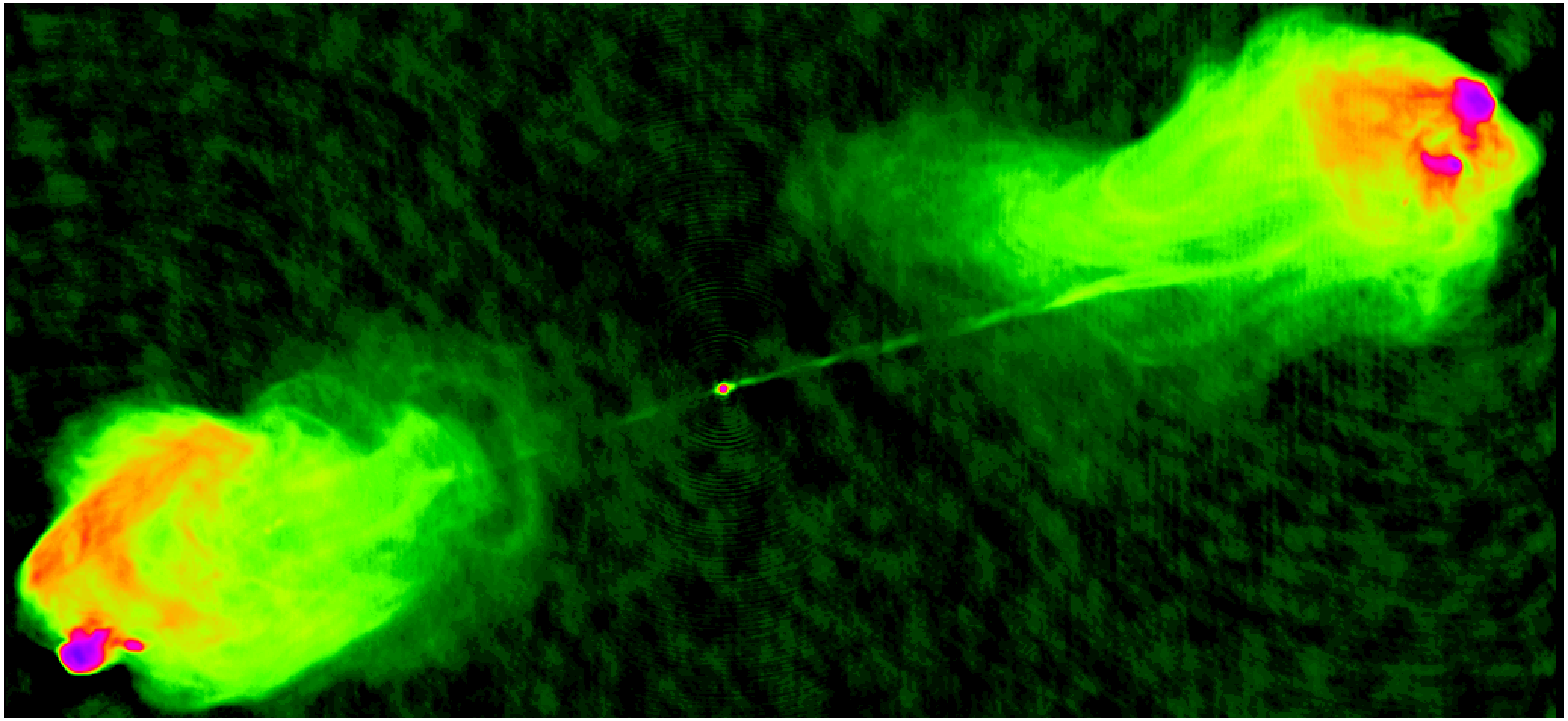
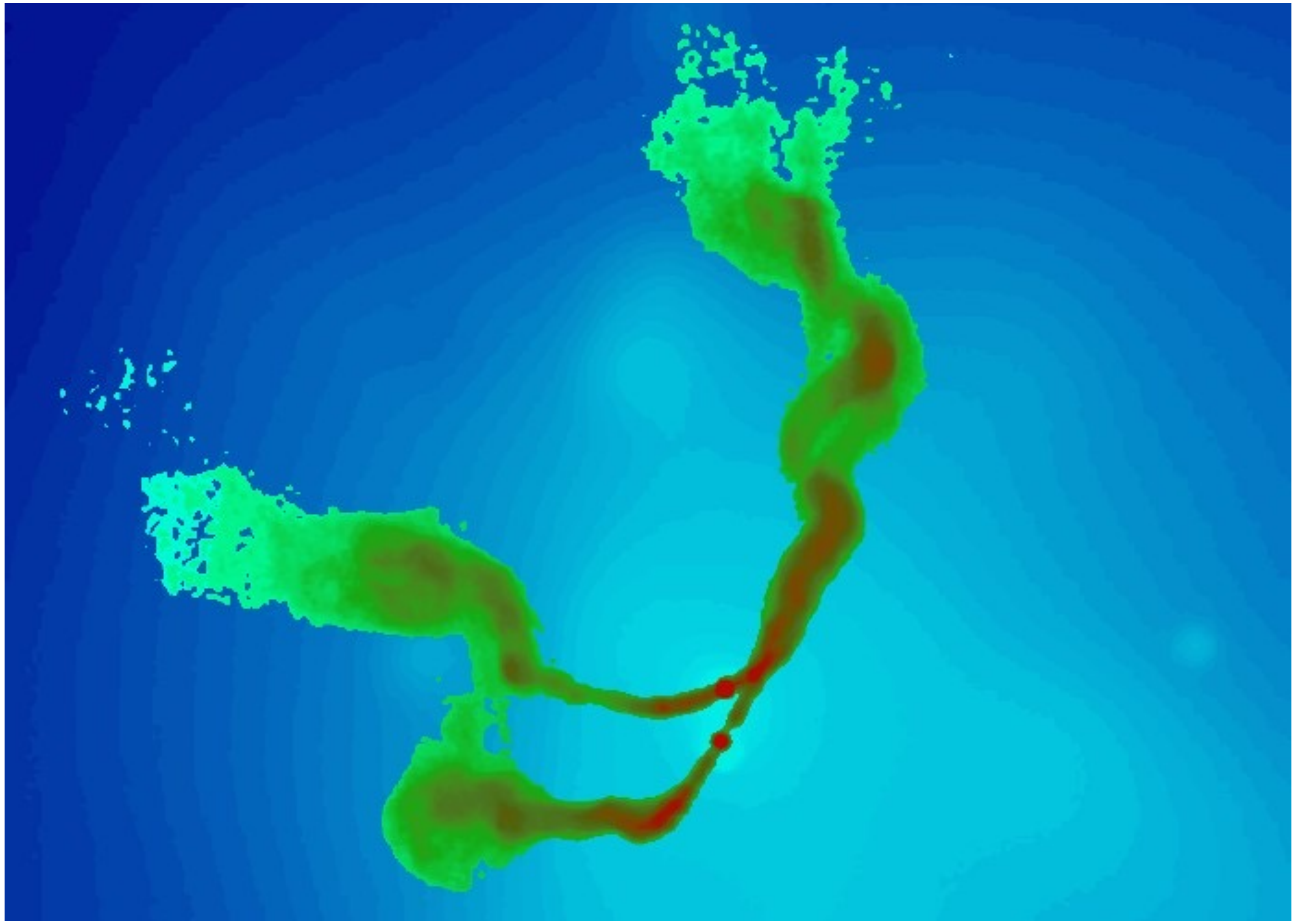
CANONICAL BLACK HOLES AT THE CENTRES OF GALAXIES AND IN THE BINARY STELLAR SYSTEMS

Supermassive black holes: $M \sim 10^6 - 10^{10} M_\odot$
Black holes of star mass: $M \gtrsim 3M_\odot$
Cygnus A: quasar, relativistic jets



STANDARD ASTROPHYSICAL MODEL: ACTIVE GALACTIC NUCLEI (AGN)

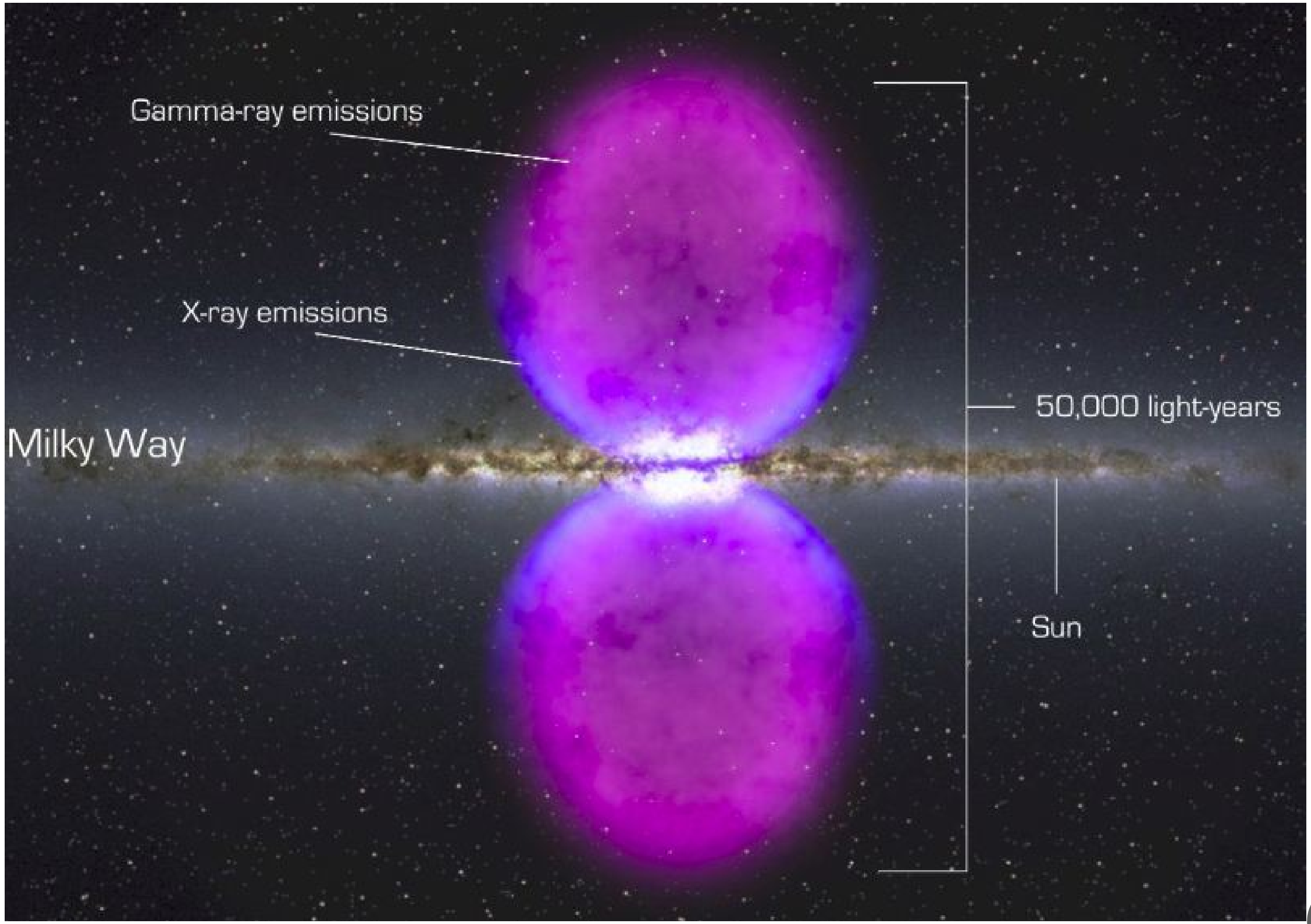
3C 75: binary black holes, VLA, CHANDRA



STANDARD ASTROPHYSICAL MODEL: DORMANT QUASAR

Milky Way galaxy: normal galaxy and “Fermi bubbles”

Supermassive black hole SgrA* at the center of our native Milky Way galaxy at an everage 10 thousand years tidally disrupts falling stars from the central stellar cluster. The matter of disrupted star forms an accretion disk with the Eddington luminosity, which is absorbed by black hole during 5–10 years.



ACTIVE GALAXY M87:
RELATIVISTIC JET

Optical jet from black hole M87* (Hubble Space Telescope)

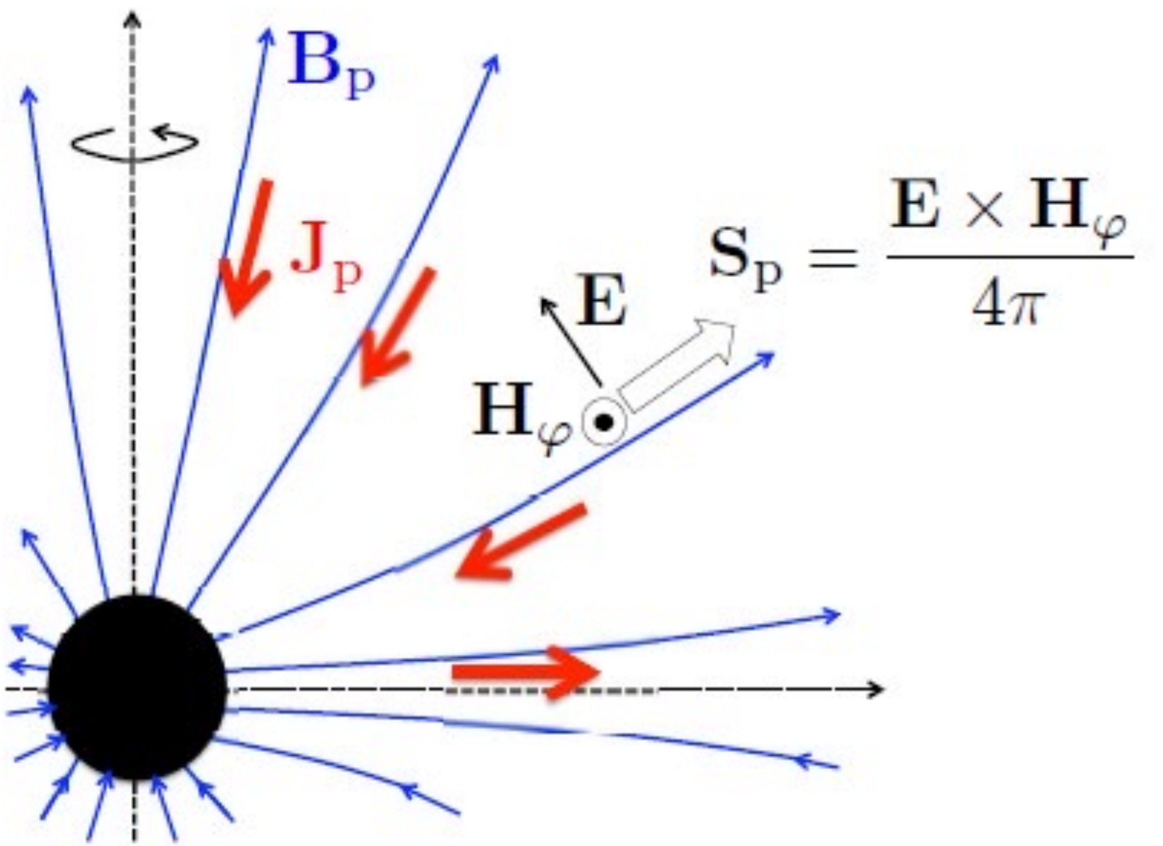
GENERAL RELATIVISTIC MAGNETO-HYDRODYNAMICS

Powerful luminosity of accretion disk in the very vicinity of the black hole event horizon due to Blanford-Znajec process (mechanism)

Blanford-Znajec process:

Generation of electromugnetic field flux Sp along the magnetized Kerr black hole rotating axis, when the radial electric current is flowing through the black hole event horizon.

This electric current generates relativistic jets along the black hole rotation axis and strongly heats the accretion disk up very vicinity of the black hole event horizon.



Blandford R.D., Znajek R.L. MNRAS 179 433 (1977)

GENERAL RELATIVISTIC MAGNETO-HYDRODYNAMICS

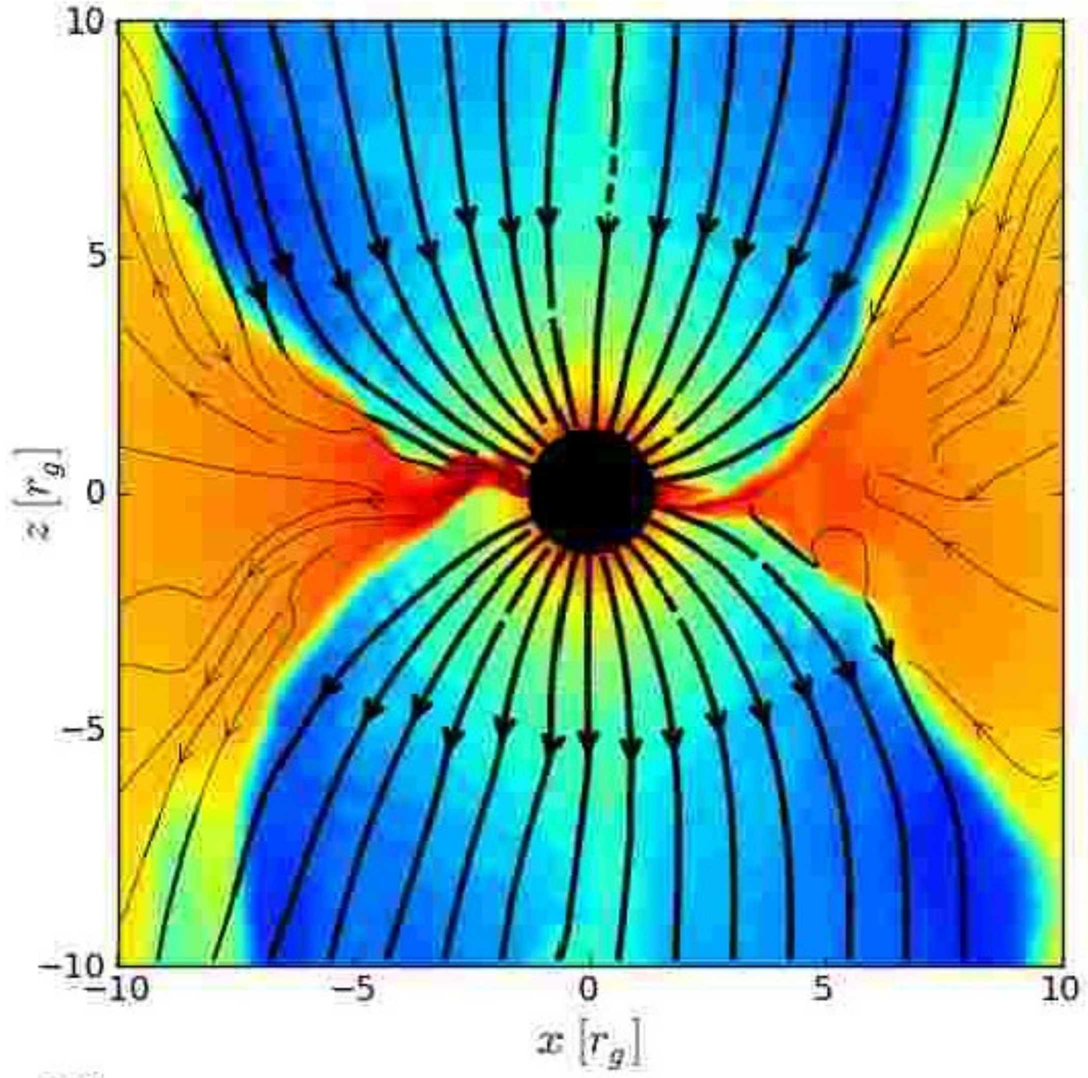
The high efficiency of Blandford–Znajec mechanism is confirmed nowadays by numerical simulations at the most powerful supercomputers in the world at framework of the general relativistic magneto-hydrodynamics in the Kerr metric.

By means of Blanford-Znajec process two relativistic jets are generated along the Kerr black hole rotation axis. These jets are carrying on electromagnetic energy density flux in the form of the Umov-Pointing vector

$$W = \frac{c}{4\pi}[E\times H]$$

E и H – respectively, vectors of electric and magnetic field strength in the jet.

It must be again stressed that high efficiency of Blanford-Znajec process is confirmed nowadays by numerical simulations at the most powerful supercomputers in the world at framework of the general relativistic magneto-hydrodynamics in the Kerr metric.



J.C.McKinney, A.Tchekhovskoy, R.D.Blandford (2012)

ACCRETING SUPERMASSIVE BLACK HOLES ARE THE SOURCES OF HIGH-ENERGY COSMIC NEUTRINO

Energy of large scale relativistic jets is taken from the rotational energy of black hole. The strong shock waves are generated due to turbulence instabilities inside the jets and also in collision of expanding jet with the dense gas clouds. The protons (and also the more heavy nuclei) are effectively accelerated up to the high energies by multiple intersections of these shock waves. The high-energy neutrino are the inevitable secondary particles in these conditions.

In result, the supermassive black holes are the suitable sources for high-energy cosmic neutrinos. Generation of relativistic jets are confirmed also by observations of the so-called Fermi-bubbles, detected by the Gamma Space Observatory Fermi.

The maximal energy of generated secondary neutrino particles may be estimated by using the classical Hillas criteria (Hillas A.M. Annu. Rev. Astron. Astrophys. 22 425 (1984)), when Larmor radius (gyroradius) of the particle with an electric charge q does not exceeds the linear size of the acceleration region R with the magnetic field strength H, or, in supposition of energy equipartition between the turbulence motions and the electromagnetic field energyH):

$$E_{max} = qRH.$$

In the considered case of the supermassive black hole SgrA* at the center of our Galaxy $E_{max} \approx 10^{17}$эВ. The corresponding maximal energy of the secondary neutrino particles would by an order of magnitude less.

CONCLUSIONS

- Blanford-Znajec process explains the physical origin of the large scale relativistic jets from accreting supermassive black holes
- The suitable place for the acceleration of cosmic electrically charged particles (and for generation of the secondary high-energy neutrinos) are the relativistic jets from the accreting supermassive black holes. This acceleration takes place far enough from the black hole event horizon, where the photon energy flux from accretion disc is weak enough for preventing the energy losses by acceleration charged particles (at the distance ≥ 1 pc).
- In result, the supermassive black holes are the suitable sources for high-energy cosmic neutrinos.
- The high-neutrinos, generated by the accreting supermassive black holes may be observed by the large volume detectors, such as IceCube at the South Pole and Baikal Neutrino Telescope (Baikal Gigaton Volume Detector, Baikal-GVD).

THANK YOU FOR ATTENTION!