# Manifestations of Quark-less Baryonium Dark Matter states

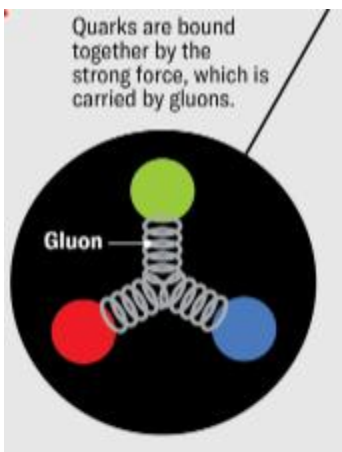
Olga I. Piskounova,

P.N. Lebedev Physical Institute, Moscow

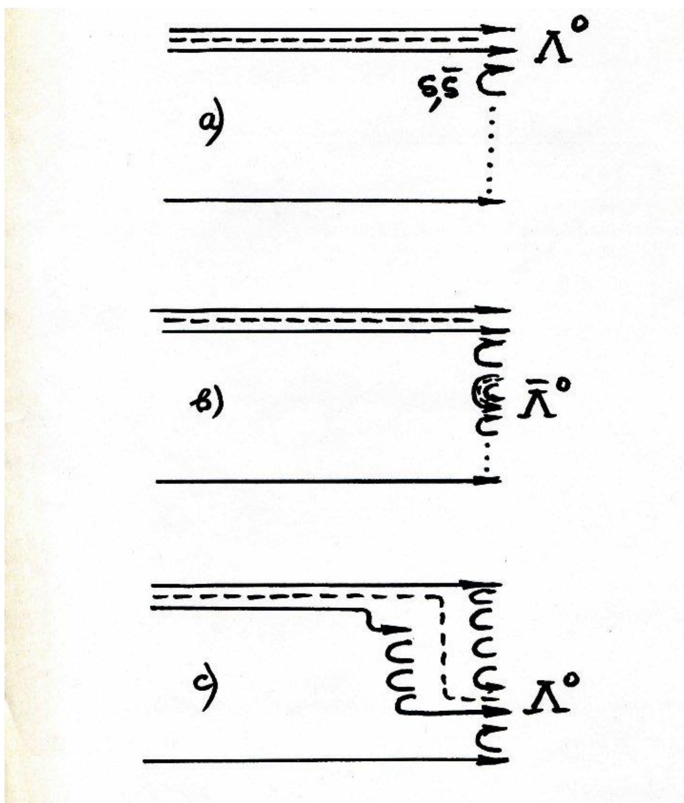
Abstract
Quark-less baryonium resonance has been expected in the old paper on string QCD phenomenology (G.Veneziano et al. 1980). This idea can be expanded to the multi baryon-antibaryon states of Baryonium Dark Matter (BDM), (O.Piskounova, 2017). The structure of BDM conglomerates and their masses are investigated on the basis of achievements of QCD string phenomenology. The masses of expected BDM states go with exponential sequence and correspond to the medial mass of each hadron generation. If take into account the hidden mass of BDM, it is suggested that heavy neutral BDM state is progenitor of mesons, baryons and resonances of corresponding generation. This assumption has been checked up on charmed generation of hadrons. The heavy Baryonium Dark Matter conglomerates should be stable in space and fulfill important functions in the Universe.

# Baryon string junction

Baryonic string junctions bring asymmetry into the central rapidity baryon-antibaryon production rate at the high energies.




String Junction



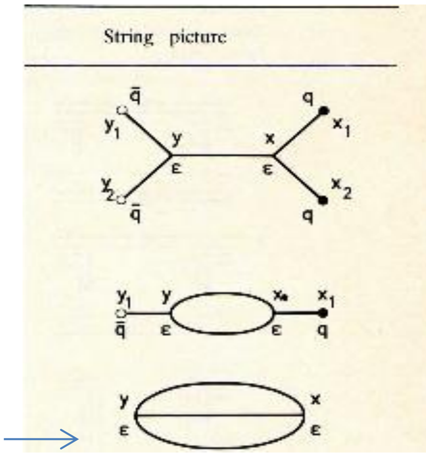

**Leading production brings asymmetry in forward region of spectra**

**Baryon-antibaryon production in central region is symmetrical**

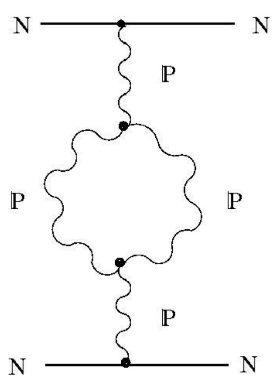
**Extra baryon production is brought to central region by proton String Junction**

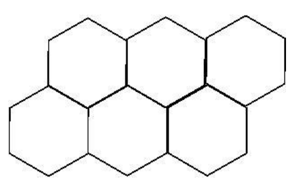
# Introduction into BDM

Baryonium Dark Matter (BDM) is possible because of baryonium resonances that have been invented in L. Montanet, G.C. Rossi and G. Veneziano, *Baryonium Physics*, Phys. Rep. 63 (1980) 153. They are multi-quark resonances: tetraquark, gluon loop and quark-less baryonium. All of them are decaying into baryon and antibaryon. The quark-less diagram is actually the first lightest state of Baryonium Dark Matter.

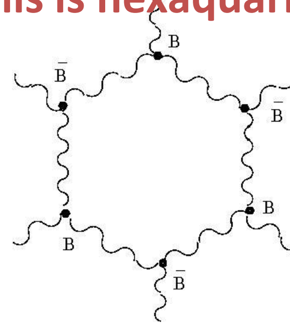



BDM has been built with the same principles: multiple String Junctions (SJ) are self connected on the surface of torus with no quarks and of zero baryon charge.



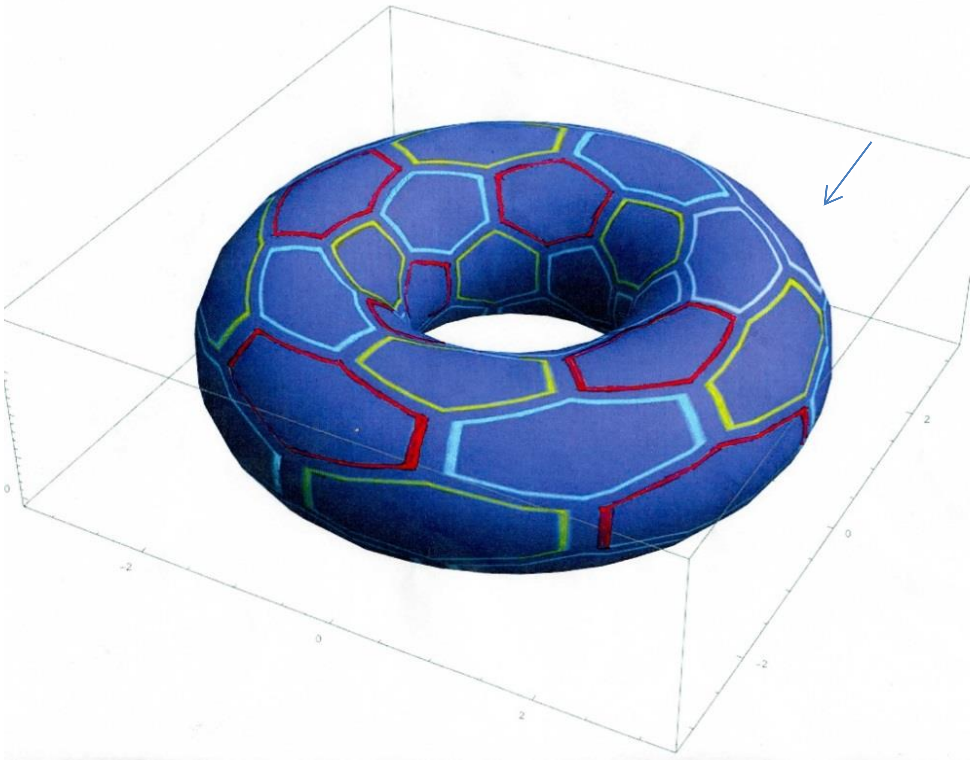



This is hexaquark (gr.)




# Discrete masses of BDM

Since the BDM particles are the objects of QCD, they should obey the symmetry rules. These rules are manifested in SJ anti-SJ hexagons and gluon color confinement inside each of them. It leads to the following sequence of the number of hexagons along the big radius R of torus: 3, 6, 12, 24, 48…, while the number of hexagons around small radius r of torus has to be even.



It is shown in the figure that 7 hexagons around radius R don't allow us to close the hexagon net with color confinement.

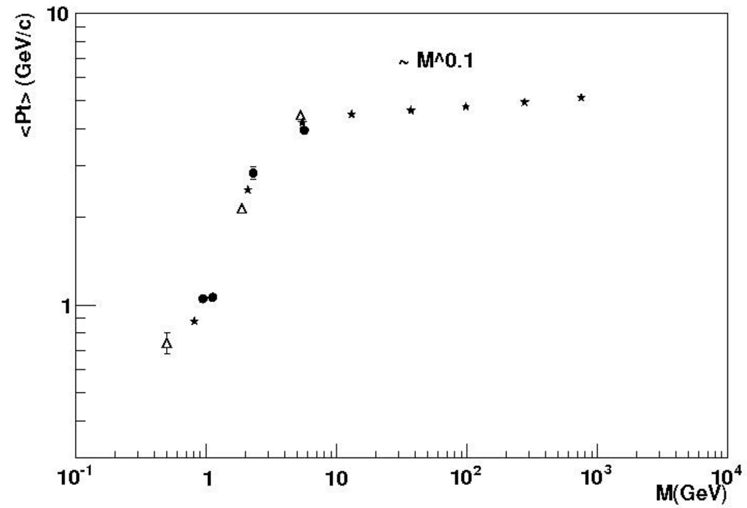
# Suggestion about mass values of BDM

In QGSM it was expected that hadrons are the results of the disintegration of quark-gluon string. The Pomeron exchange is only string which is working at high energy QCD phenomena. The  baryon-antibaryon torus is a third order in pomeron exchange expansion. In the paper on mass dependence of average transverse momenta of hadrons, the hadron generations are shown on logarithmic scale of mass. It is seen that generations go with exponential dependence from mass, which is natural for QCD variables.

If we suggest that hadrons are the results of BDM states disintegration, the BDM mass dependence can be described with an expression

$$M_n = 0{,}25 * \exp(n-1) \text{ (GeV)}.$$

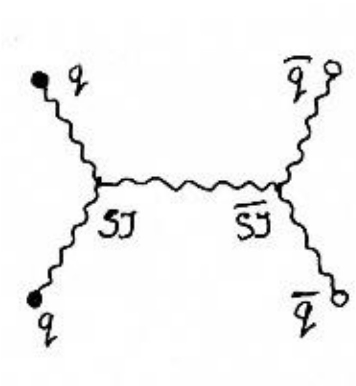
The sequence is able to be extrapolated to the giant mass values. The slope of average Pt vs M will be also work for the detailed investigation of BDM disintegration. E.Fermi and C.N.Yang have been proposed in 1949 that pion should be the baryonium (proton-antiproton state). In this approach a mass of first state is 250 MeV.



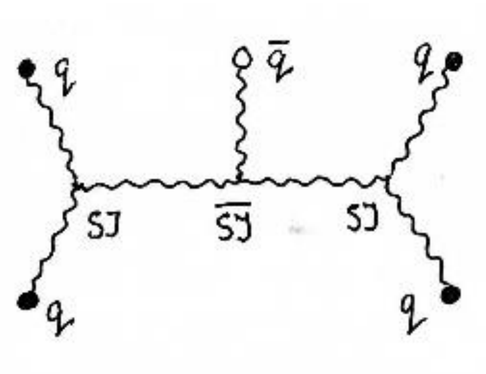

* Important notice: the lowest mass BDM state is 8 times less massive than p+antip.

# Tetraquarks and pentaquarks as baryon-antibaryon string objects

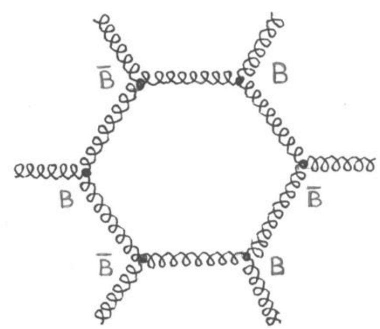
The BDM structure is seen in the diagrams of multi quarks QCD conglomerates: tetraquark and pentaquark. We see the obvious presence of baryon antimatter: the anti-baryon anti-String Junction is included into all diagrams. These states are the debris of BDM.




**Tetraquark**



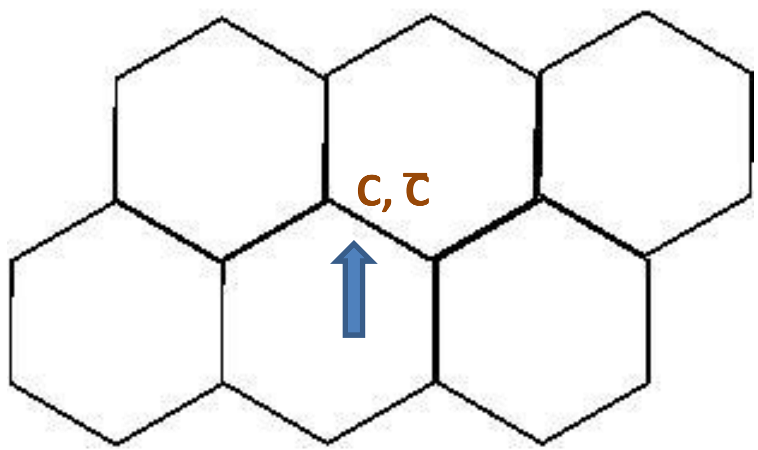

**Pentaquark**




**Hexaquark**

# Charmed resonances as offspring from third-order 3x2 BDM state

If we pull gluon line in the 3x2 diagram, the cut line gives two heavy quarks (c, anti-c) that are connected to baryon SJ and antibaryon anti-SJ. That are two charmed resonances. Deconstruction of other hexagons has to be resulted with more light baryons and mesons. For charm production it is necessary to have enough mass and energy concentrated in one gluon string. There are 6 protons and 6 antiprotons on the torus, that means that the mass of BDM conglomerate is less than included baryons by 6.5 times. Hidden mass gives the possibility to produce c-anti c quark pair. There could be baryon resonances or two charmed penta-quarks plus few light baryons-antibaryons with dozen of pions and photons.




Experimental achievements gave the charmed resonances with masses: 1835, 1851 and 1859 MeV. The mass of third order BDM is 1855+-15 MeV, see Piskounova, arXiv: 1908.10759.

# More expectations on Baryonium Dark Matter

Concept of Dark Matter is changing. Dark Matter particles used to be imagined as mysterious species of light exotic undiscovered particles that are just flying in space and somehow capturing almost entire mass of the Universe. DM even was recently suggested to be primordial Black Holes (see Cuadrat-Grzybowski et al, Phys. Rev. D 110 (2024) 06029) that are also just moving in space. But Dark Matter particles, first of all, must be functional constituents of Universe. Starting from fundamental features of living nature to expand and to propagate itself as more as possible, it may be approved that Baryonium Dark Matter should exist in order to stockpile the condensed baryon-antibaryon matter, to transport materials into empty places of Universe, and to multiply new stars and galaxies. It is also nutrition for Super Massive Black Holes (SMBH). In our Galaxy the waves of BDM from central SMBH may transfer the energy and matter to the periphery and even can modulate the climate variations. In such a way, BDM particles are very necessary matter constituents of the Universe.

# Conclusions I

Baryonium Dark Matter particles are long-living constituents of Universe, whose functional role begins to be more and more appreciated.  It should be called the fundamental state of matter in the Universe.  BDM conglomerates are condensed quark-less QCD matter which can be originated in ultra-high energy events like Big Bang, Supernova explosions or be thrown out with relativistic jets from Super Massive Black Holes.

Heavy neutral BDM conglomerates have multiple states of discrete masses and can fulfil the following important functions in the Universe.

a) They keep the stock of dark matter provision near the Super Massive Black Holes.

b) BDM states may even make up an interior of SMBHs.

c) BDM conglomerates, which are injected into the space with the relativistic jets from SMBH, give the acceleration to protons and antiprotons during BDM disintegration into lighter states.

d) They are bringing the matter for new stars and galaxies and helping the Universe expand.

e) BDM waves may deliver heat and matter up to Solar system too.

f) The sequence of masses of BDM states corresponds to the masses of hadron generations. It means that BDM states  are progenitors for the generations of hadrons.

As it was analyzed in recent preprint (O.Piskounova, arXiv:2309.14933), Baryonium Dark Matter could as well bring water to Earth, while it is being burned in the oxygen atmosphere.

**!! It should be noticed that super-heavy BDM conglomerates can also bringing disasters to Earth:  the dinosaur catastrophe on Yucatan peninsula (66 millions of years ago) and world flood ( near 10600 year BC).**

The question arises:  how does the baryon-antibaryon asymmetry appear in the framework of this scheme? The baryon-antibaryon Dark Matter dynamics does solve this problem partially: the Universe is mostly symmetrical. The difference between protons and antiprotons may be only in their functional roles: antiprotons participate in the stocking of matter at low energies near SMBH, while high energy protons go far in order to propagate Universe with new stars and galaxies.

# Conclusions II

- At Ultra High Energies, proton-proton collisions give charge-symmetric spectra for particles and antiparticles. As it was expected in Quark-Gluon String approach, the only exchange between colliding UHE protons is Pomeron string (not quarks or diquarks). Since pomeron has vacuum quantum numbers, resulting particle cross sections are similar for baryons and antibaryons. The spectra are able to be calculated for arbitrary high energy in this approach.
- The enhancements on the ends of baryon spectra are caused by three pomeron diffractive contribution and will not disappear at UHE too.
- Since mass distribution of BDM is exponential, they can split into 2 states of smaller mass. The 0.72 of initial mass goes for acceleration of resulting DM particles. So why we observe very long self-accelerating relativistic jets.

**Thank you for attention!**

# Some evidence from cosmological news

The circles of baryonic matter appear from Dark Matter clumps