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Ticket N 3

1. Search for dark matter particles (cont)

Direct DM searches:

- Relict massive neutrinos. Non-relitivistic particles with $m \sim eV$ ($\sim 10eV$) and $\lambda \sim \frac{1}{mv} \Rightarrow$ microspic size and coherent scattering $\Rightarrow$ (spin-independant) interaction lead to observable effect of oscillization of matter. $\Rightarrow$ possible only for dirac neutrinos.
- Cosmic axions. In magnetic field it decays into photons γ with specific polarization. So when a enters underground radiofrequency cavity we see light coming through the walls. Not dominant form of DM (CDM due to non-relitivistic)
- WIMPs.

Weakly interacting massive particles freeze-out in early Universe and they could be candidates to CDM.

Searched by WIMP-nucleus interaction. 2 types of inter.: (Dirac fermions) scalare and (Majorana fermions) spin-spin. Annual modulation; DAMA expeziment.

- SIMPs. DM may consist of strongly interacting massive particles, that could be braked down by ordinary matter, so they become insensitive for underground detectors $\Rightarrow$ Rocket experiment XQC. $\Rightarrow$ observation of X-rays during a rocket flight (100s)

Indirect DM searches:

- Condensation of DM in Galaxy. Collisionless gas motion in nonstationary field of barionic matter provides effective dissipation and contracting of the gas $\Rightarrow$ colisionless DM condenses in Galaxy, but it is distributed more steeply $\Rightarrow$ explains the difference in distribution of barionic and dark matter.

- Annihilation and decays of DM as a source of CR
Stable DM particles can annihilate:
Charged – $X\bar{X} \to e^+e^- + \ldots$; decay of neutral DM part.: $X \to e^+e^- + \ldots$
If particles are double charged, we have $X^{++} \to l^+l^+$
- Neutrinos from DM capture and annihilation in Sun and Earth. Accumulation due to particles being captured ⇒ process of annihilation ⇒ a flux of neutrinos is produced.
- WIMP capture ~~dff~~ by the Solar System → gravitational scattering of the planets and interaction with matter of the sun and planets
- Gravitational lensing. Possible distribution of DM, doesn't depend on ~~f~~ frequency of photons. Macro- and Micro lensing
$\theta_E \sim 1''$ $\theta_E^* = 0{,}001''$
MACHO results on dark baryon abundance.
↳ dissipating DM
↳ ≤20% of DM in Galaxy.
Compact non-baryonic (DM) objects mirror worlds, axionic clumps

2. Primordial black holes (PBH)
Superheavy metastable particles in early universe could have ~~constructed~~ formed Black holes, if constracted within its gravitational radius:

$$r \leq r_g = \frac{2GM}{c^2}$$

It naturally happens ~~does~~ due to evolution of massive stars and dense star clusters.
BH could be formed if expansion can stop within cosmological horizon → it corresponds to strong non-homogeneity in early universe:

$$\delta \equiv \frac{\delta\rho}{\rho} \sim 1$$

In homogeneous and isotopic Universe, while $\delta \ll 1$ with equation of state $p = k\varepsilon$ probability of strong non-homogeneity $\delta \sim 1$ is exponentially suppressed.

At $k=0$ suppression is absent. The minimal estimation is determed by direct production of BHs:

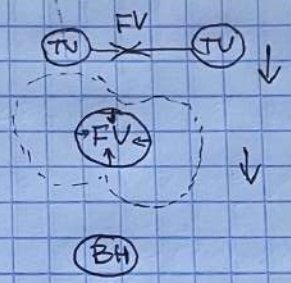
$$A(\delta, \delta_0) \geq \left(\frac{\delta_0}{\delta}\right)^5 \left(\frac{\delta_0}{\delta}\right)^{3/2} = \left(\frac{\delta_0}{\delta}\right)^{13/2}$$

~~inhomogeneity~~ isotropy, homogiwity

BHs could be formed either direcly from collapse of symm. and homogen. configurations, or in result of evolution of grav.-ly bound systems by:

- Superheavy particles with m, $\tau = \frac{h}{mg}$ at $T \leq m$
- coherent oscillations of massive scalar field.

Also, PBH could be formed in processes of first order phase transitions:



Bubbles with true vacuum collide (expand) → formation of false vacuum bag, which contract and collapse in BH

PBHs evaporate due to creation of pairs by its nonstationary grav. field. Products have spectrum with

$$T_{PBH} \propto \frac{1}{r_g} \qquad T_{PBH} \approx 10^{13}\,\text{GeV}\left(\frac{g}{M}\right)$$

timescale is $t \approx 10^{27}\,s$

Any particle with $m \leq T_{PBH}$ is created by universal source PBHs behave like a specific form of dark matter, they should have small masses (less then the mass of stars), and PBHs with $M < 10^{15}\,g$ evaporate.