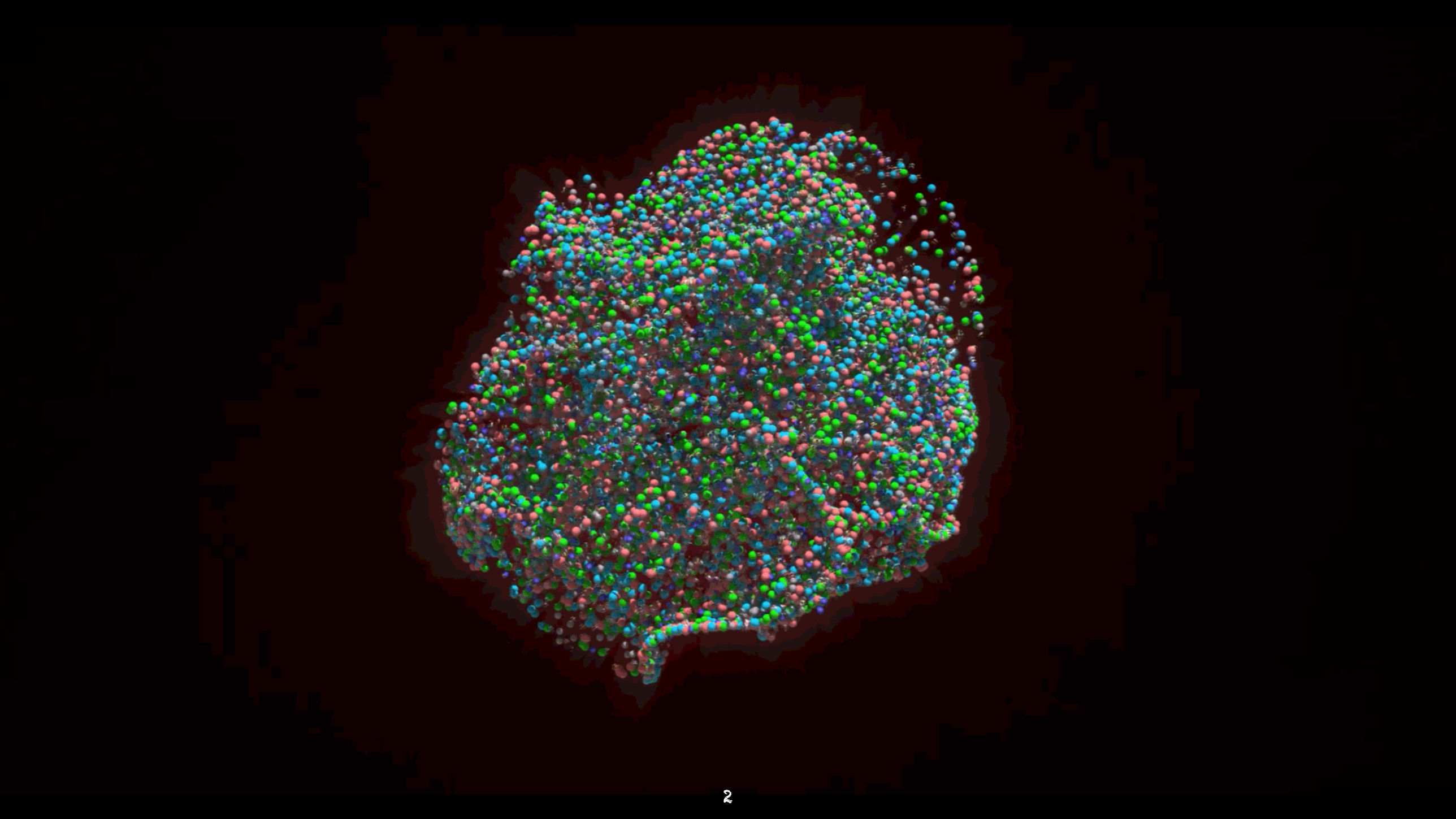
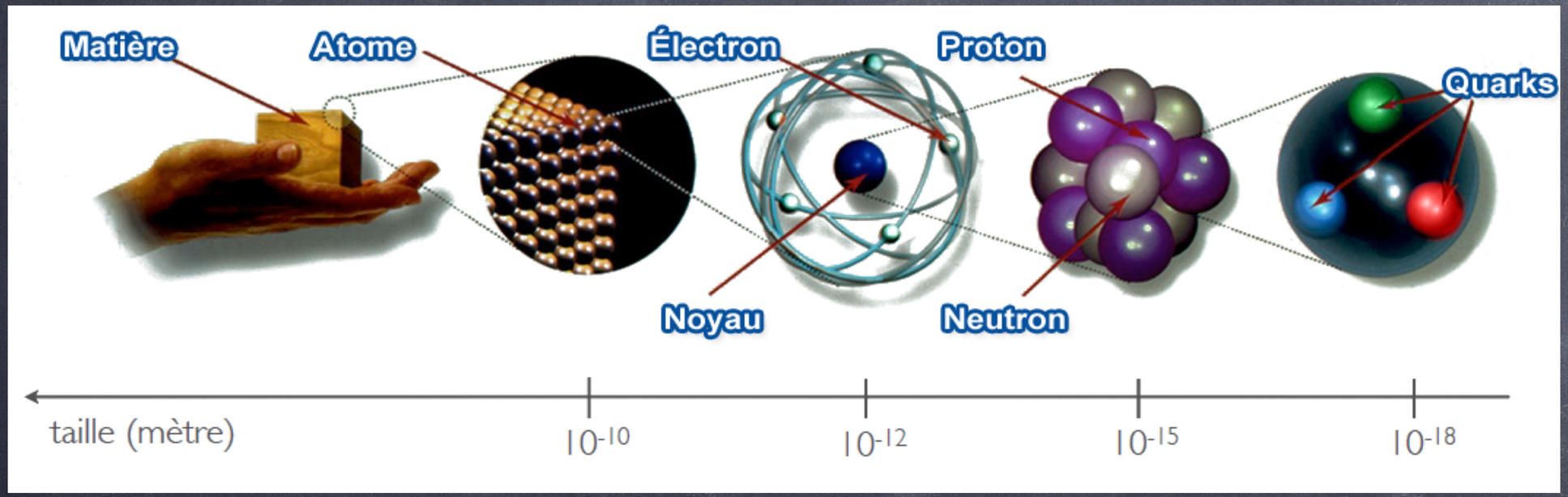
Hearing sound in quark-gluon plasma

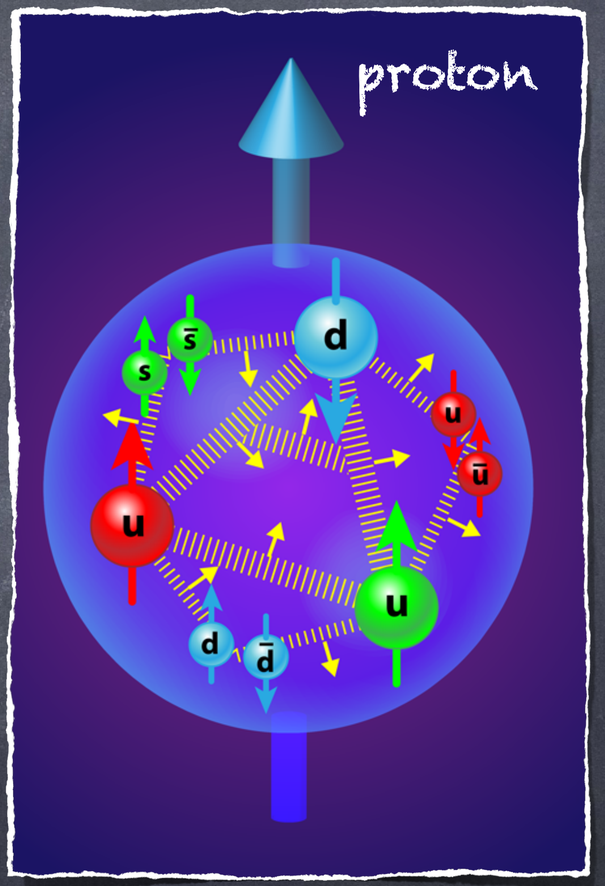
Quel bruit fait un plasma quark-gluon ?

AnimaSciences - March 7th 2024

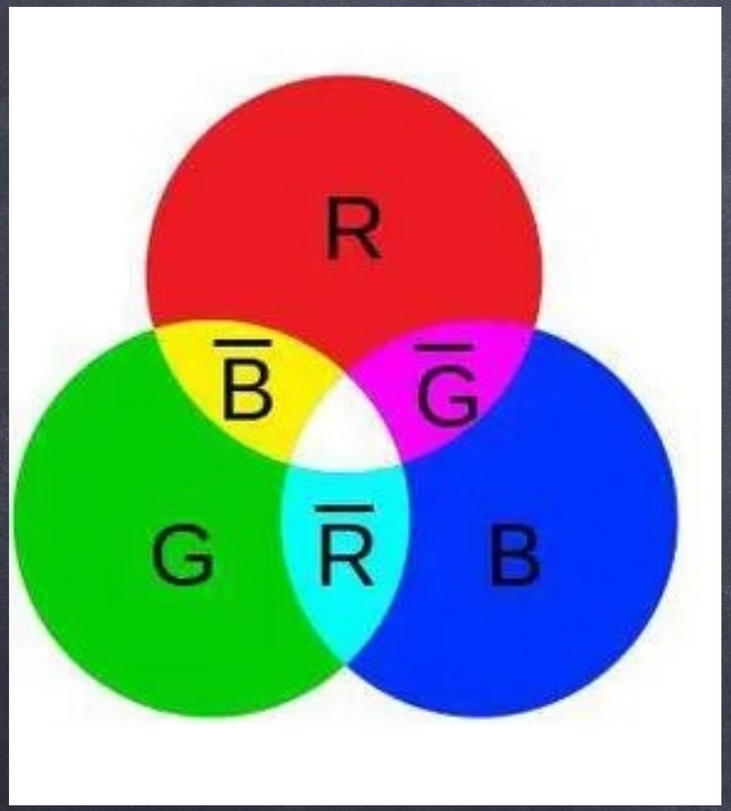


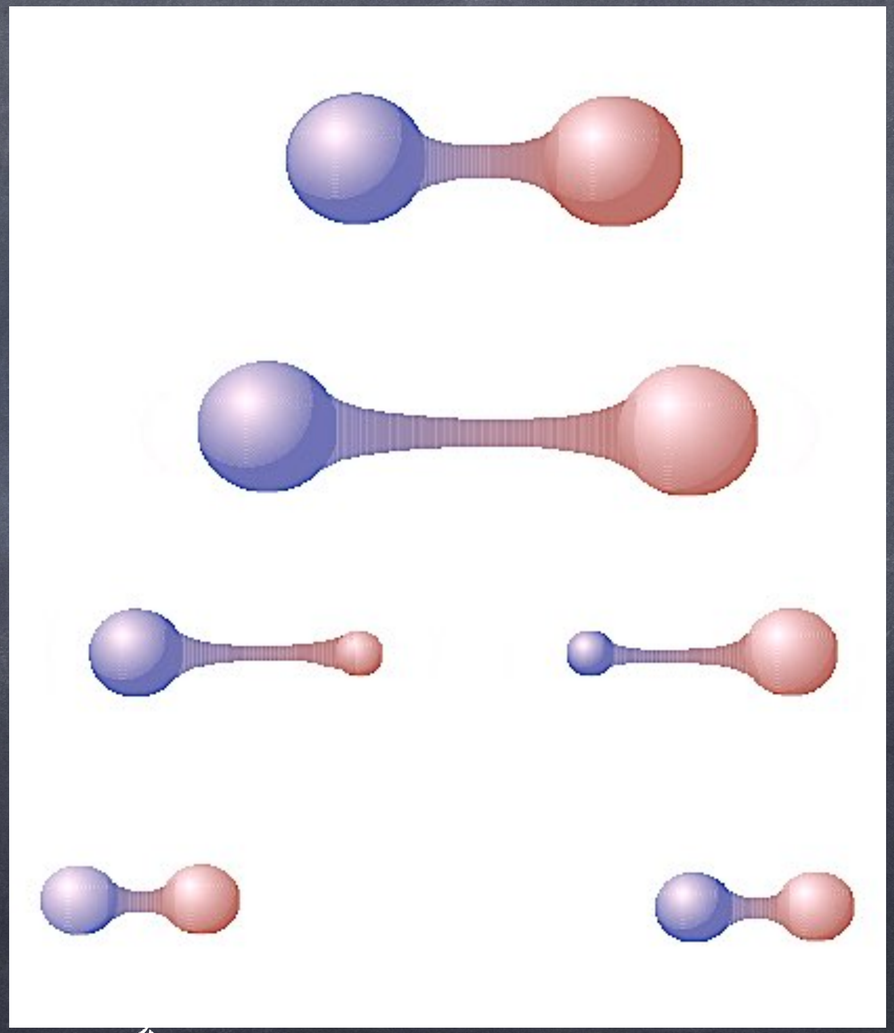
What are quarks and gluons ?





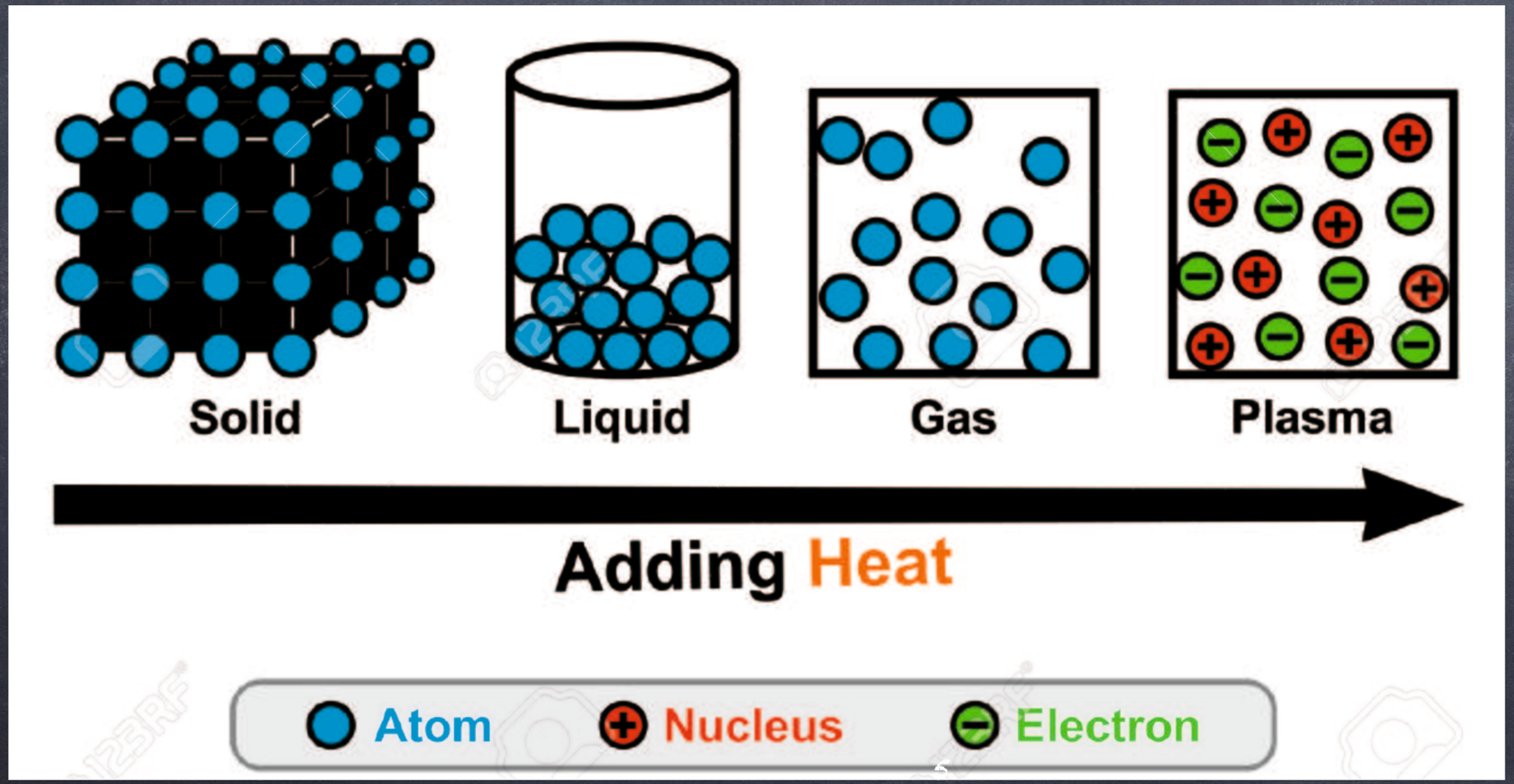
Confinement of quarks



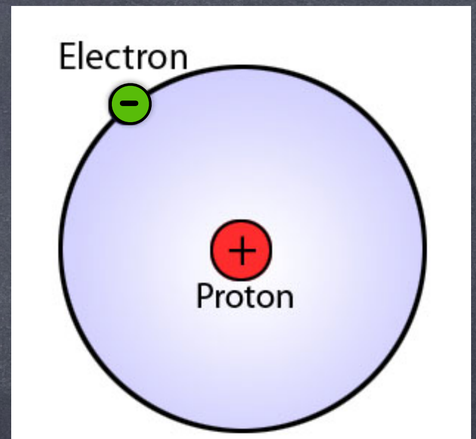


What is a Plasma ?

- The 4th state of matter !

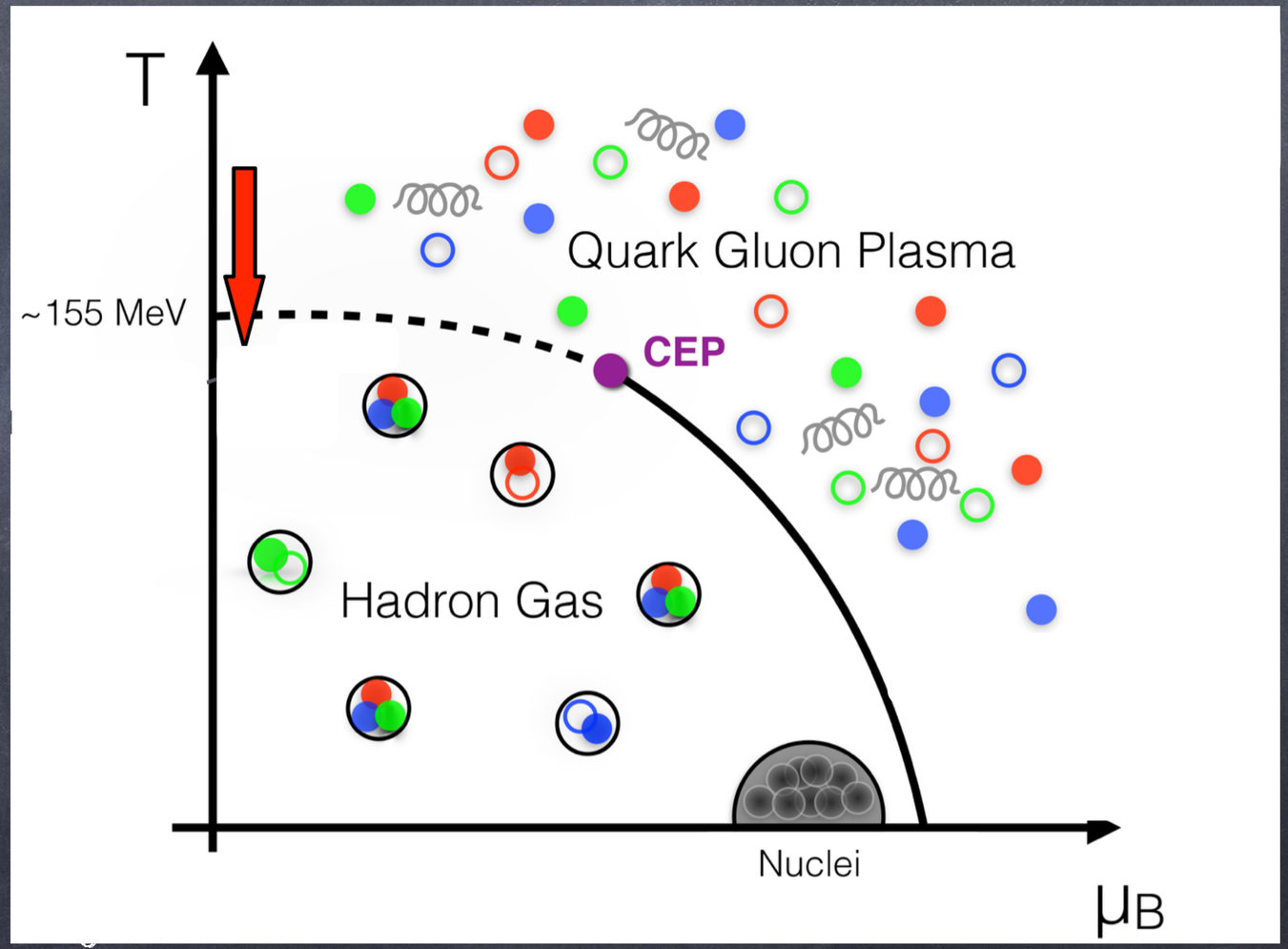


Hydrogène



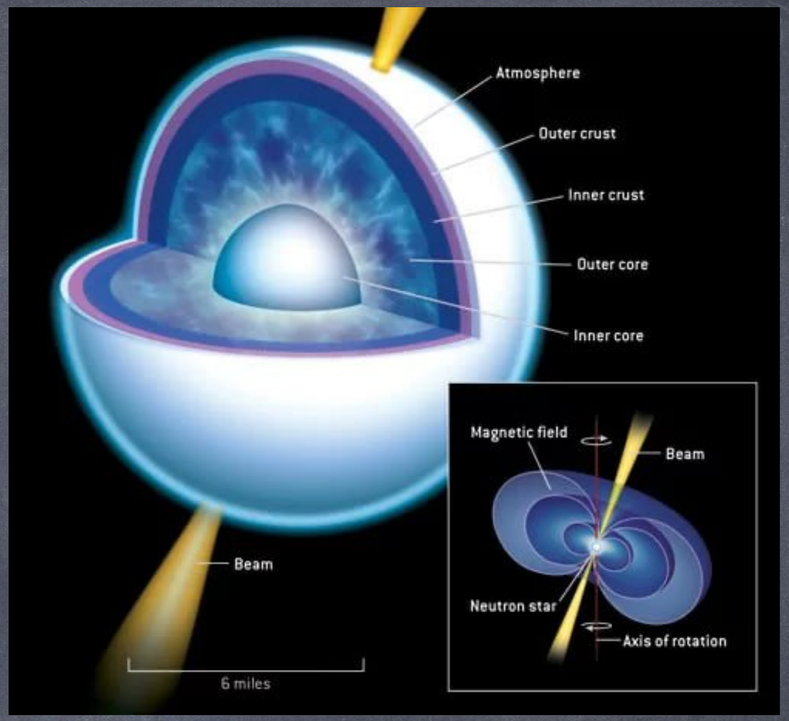
Higher temperature and density: quark-gluon plasma (QGP)

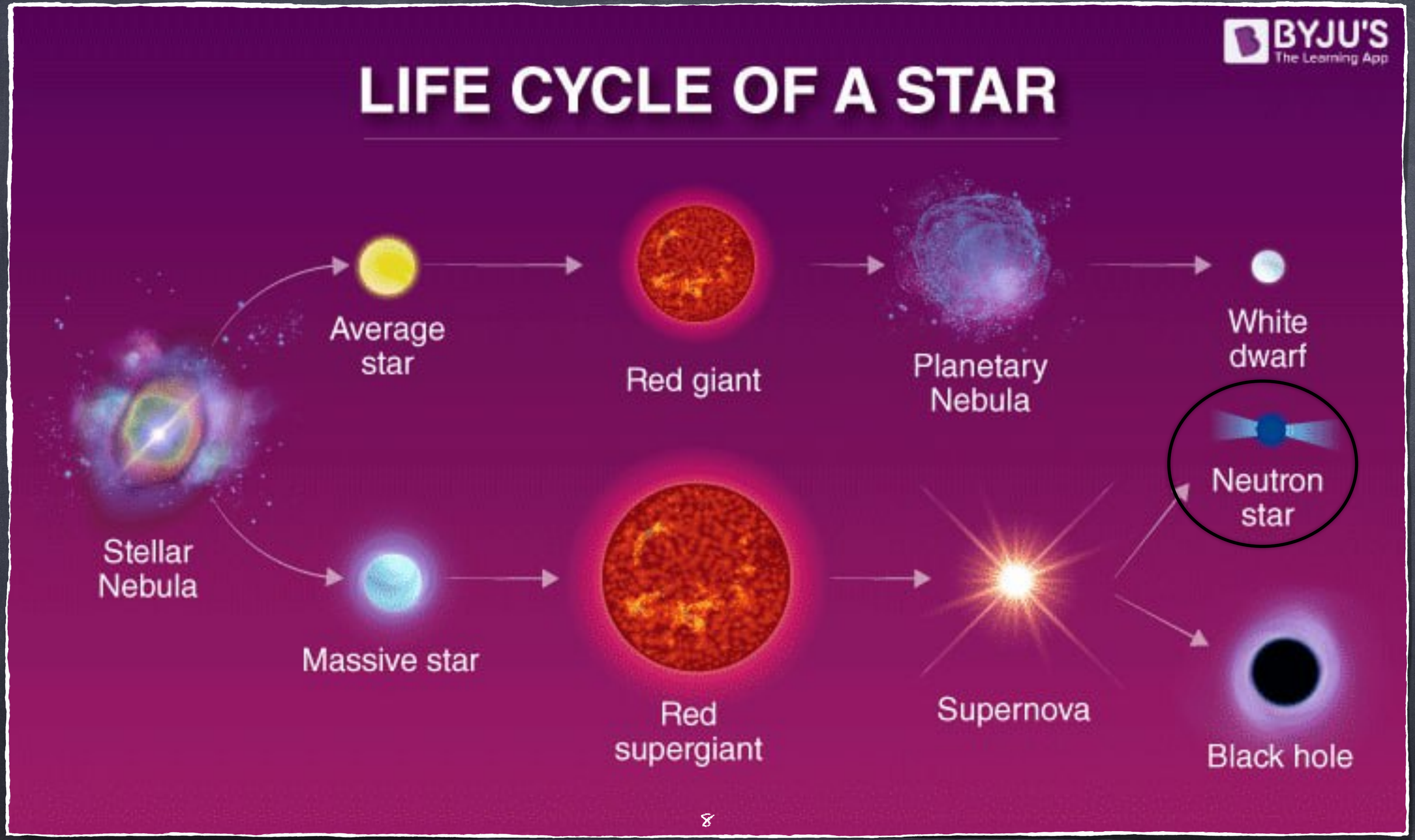
- Starting for temperatures around 1 trillion degrees ! (1e12 degrees)
  - 100 000 times the temperature in Sun center
- Depends also on density



Where do we find QGP ?

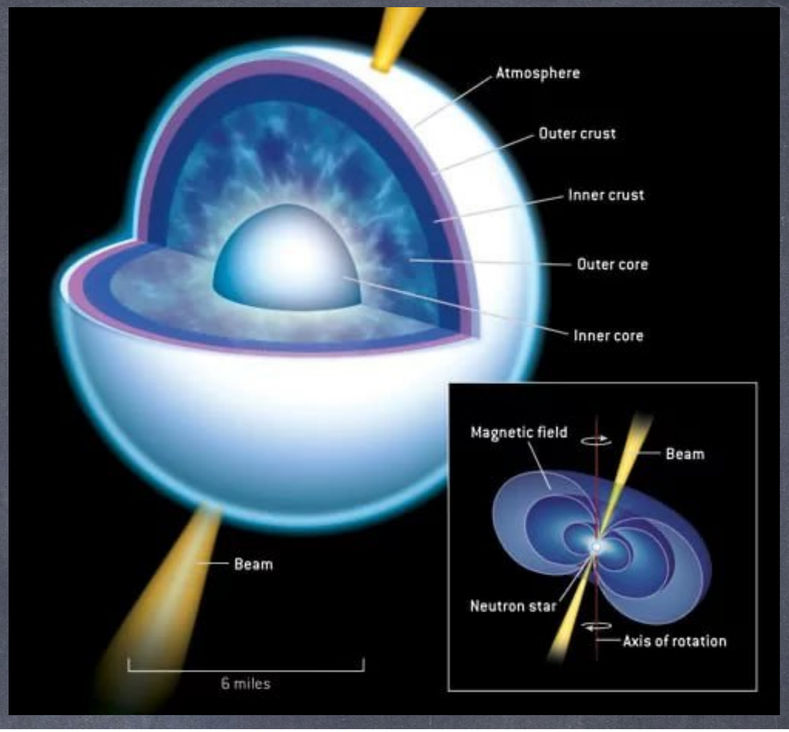
- Core of Neutron stars

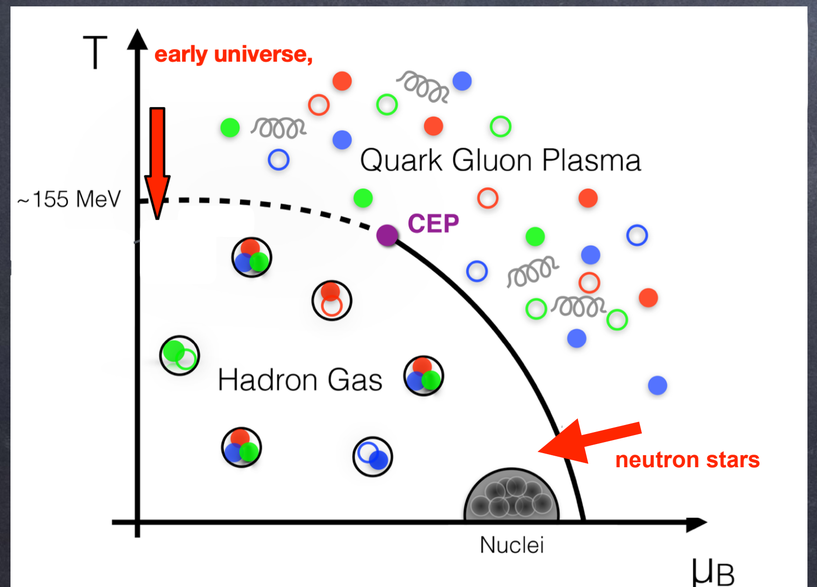


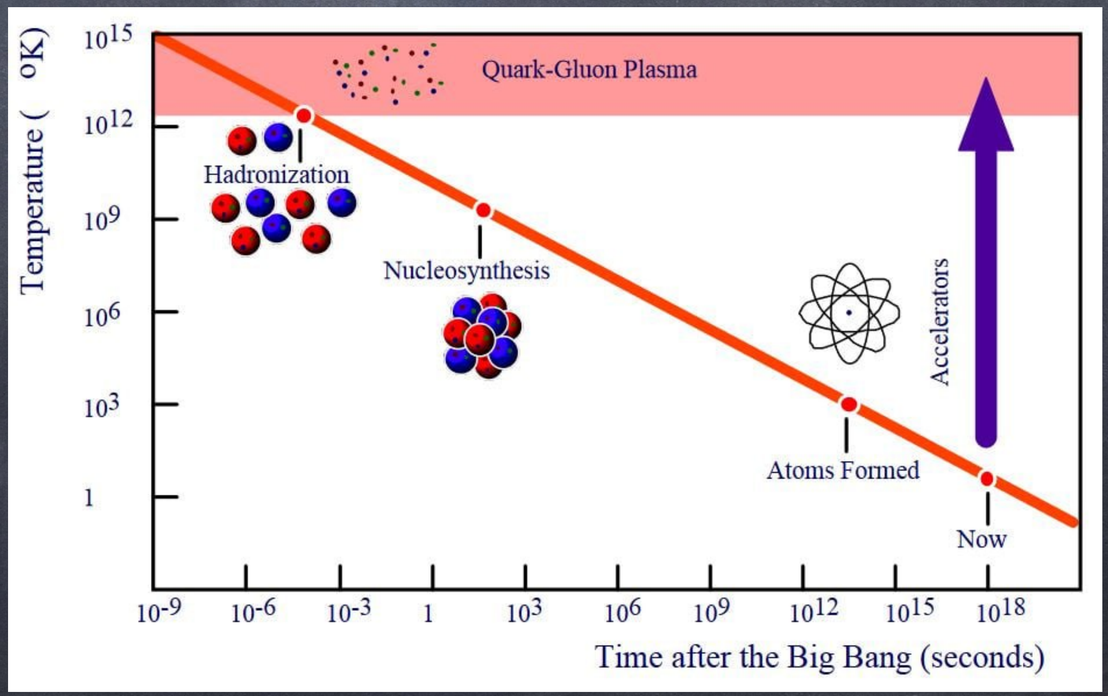

BYJU'S
The Learning App
LIFE CYCLE OF A STAR
Stellar Nebula
Average star
Red giant
Planetary Nebula
White dwarf
Neutron star
Massive star
Red supergiant
Supernova
Black hole

Where do we find QGP ?

- Core of Neutron stars
- Primordial universe (a few µs after Big-Bang)

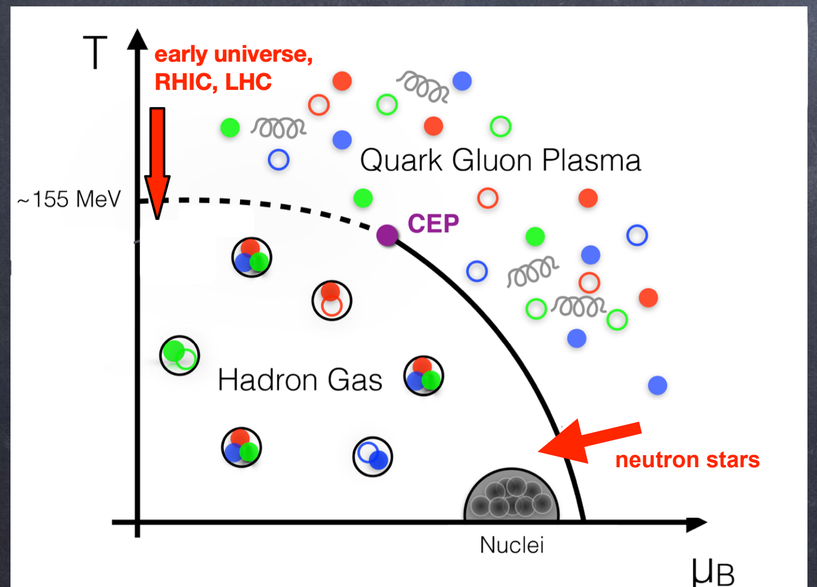


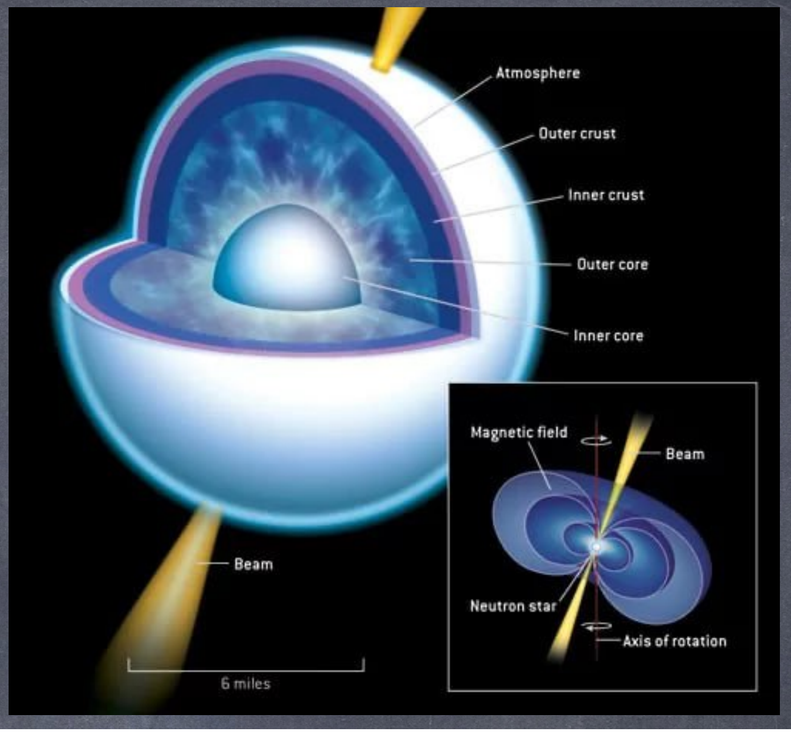


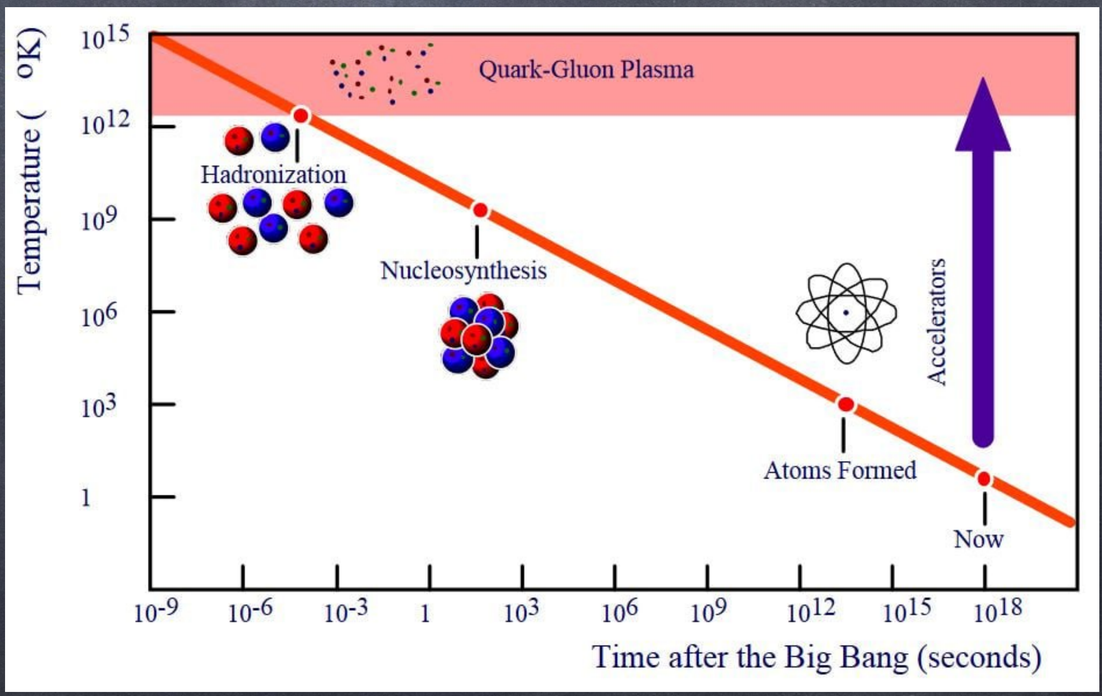


Where do we find QGP ?

- Core of Neutron stars
- Primordial universe (a few µs after Big-Bang)
- Heavy-ions collisions at LHC !

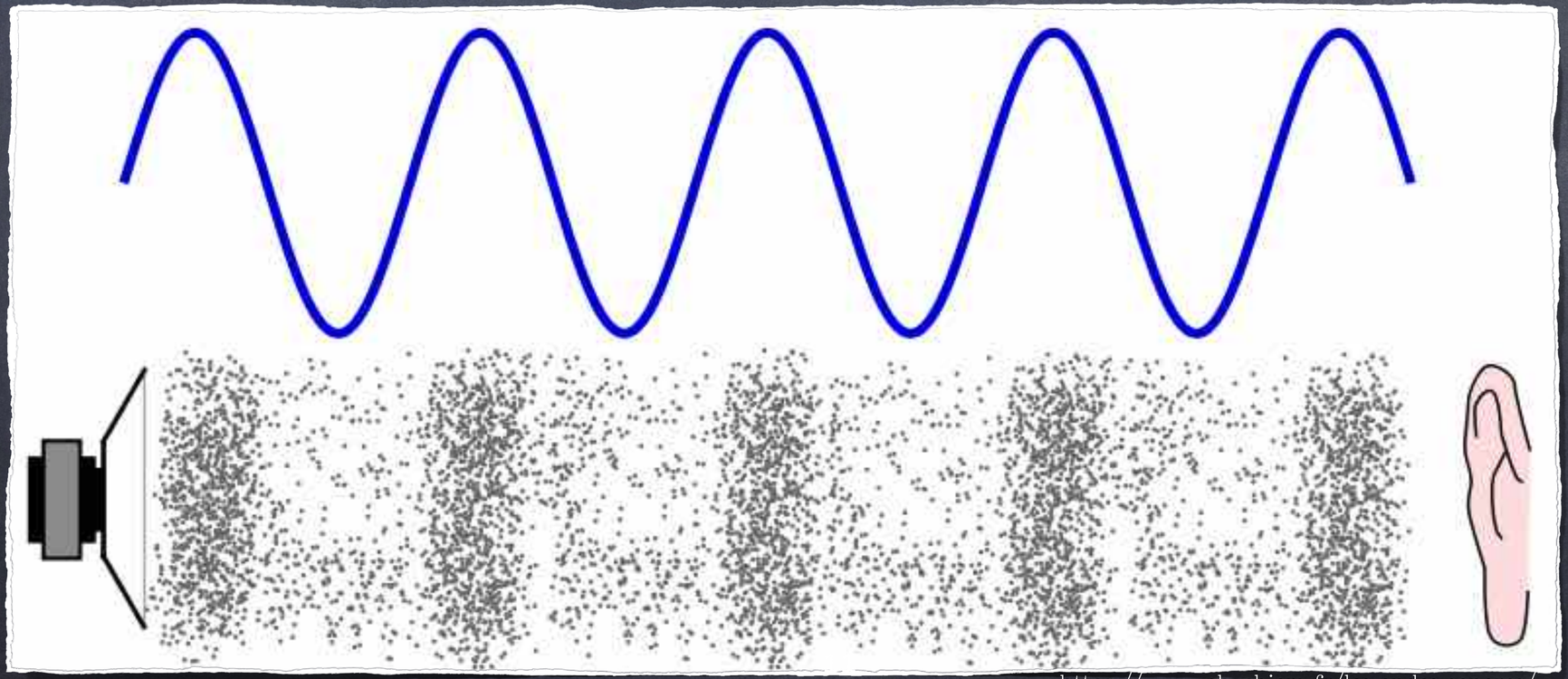






Hearing a sound

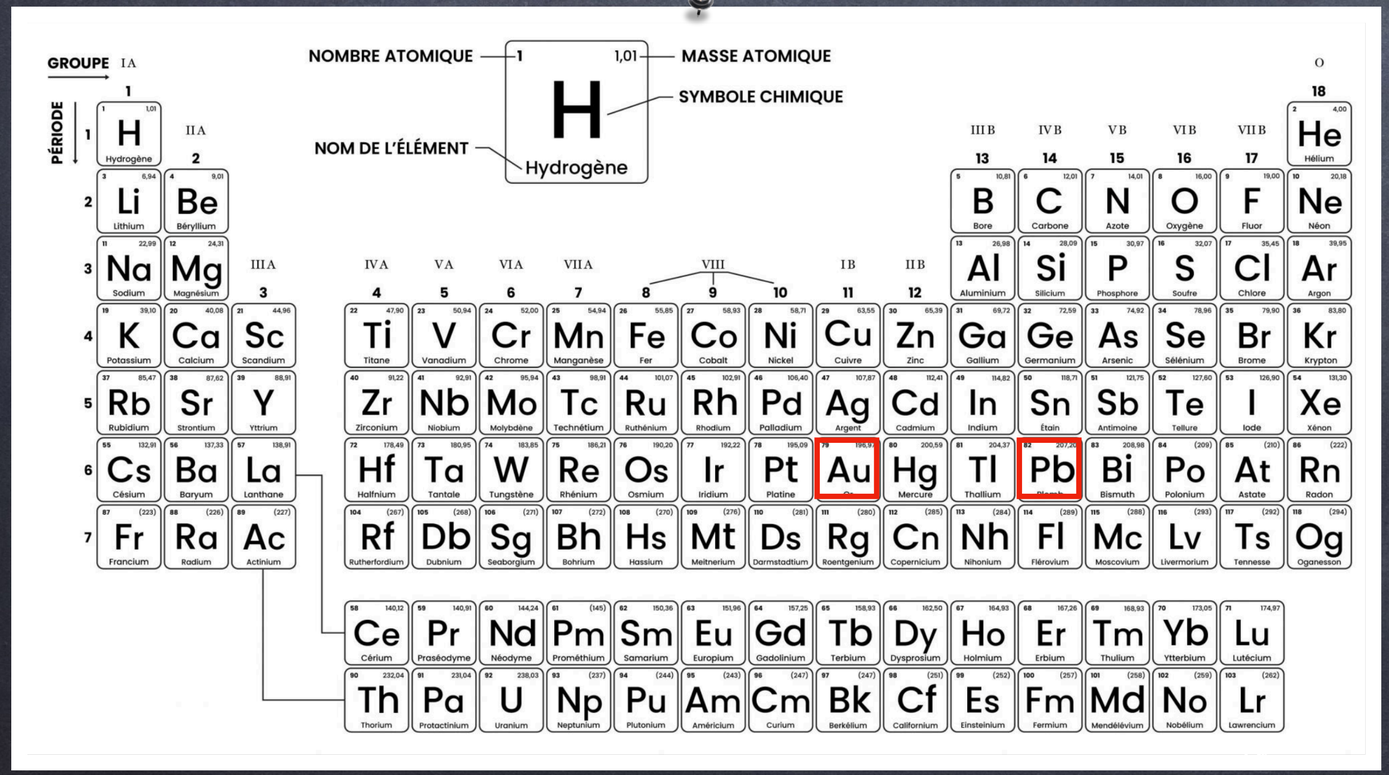
- Sound = mechanical wave that propagate in a physical medium.
- Succession of compression / dilation without displacement of matter
- Sound speed tells a lot about matter properties !

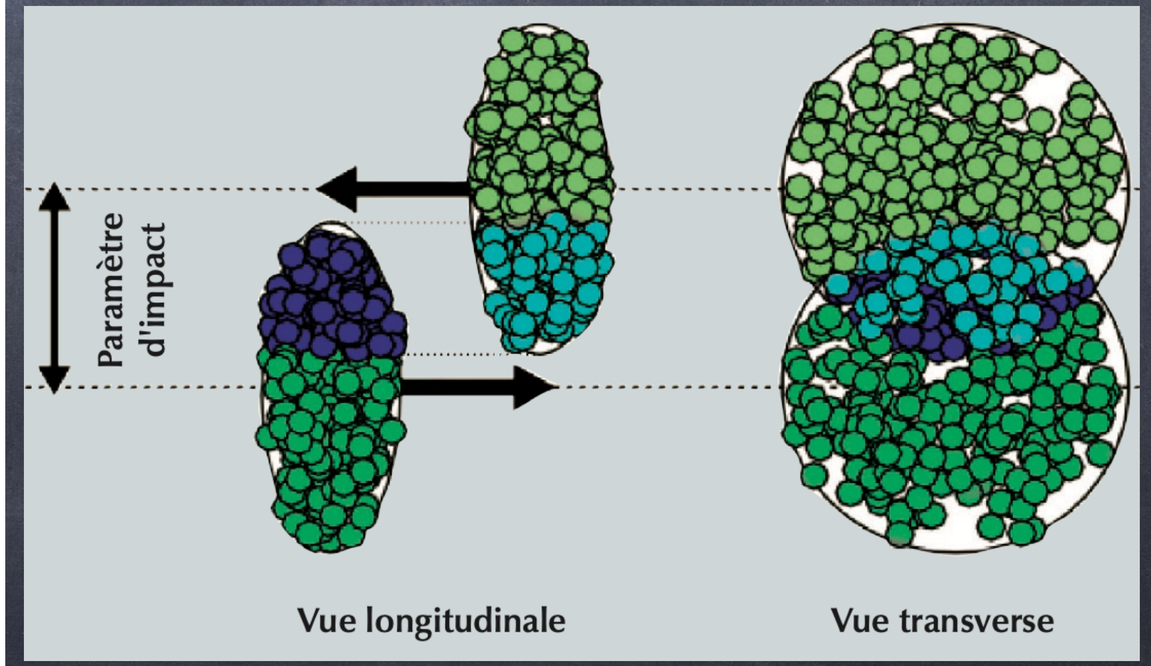


https://www.phychiers.fr/les-ondes-sonores/

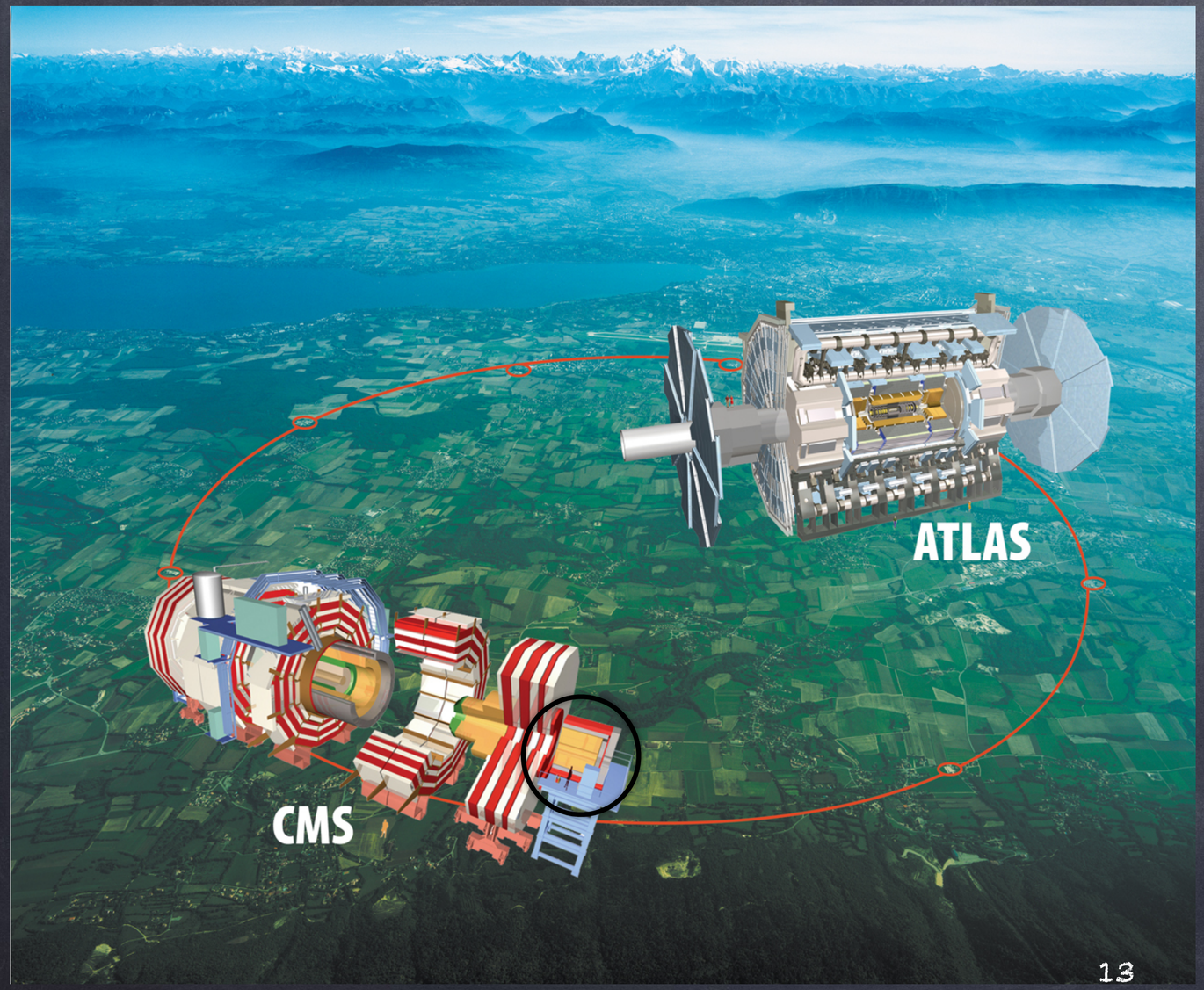
Heavy-ions collisions at LHC

- Usually Pb-Pb (82) or Au-Au (79)
- Very high density and high temperature/energy -> QGP





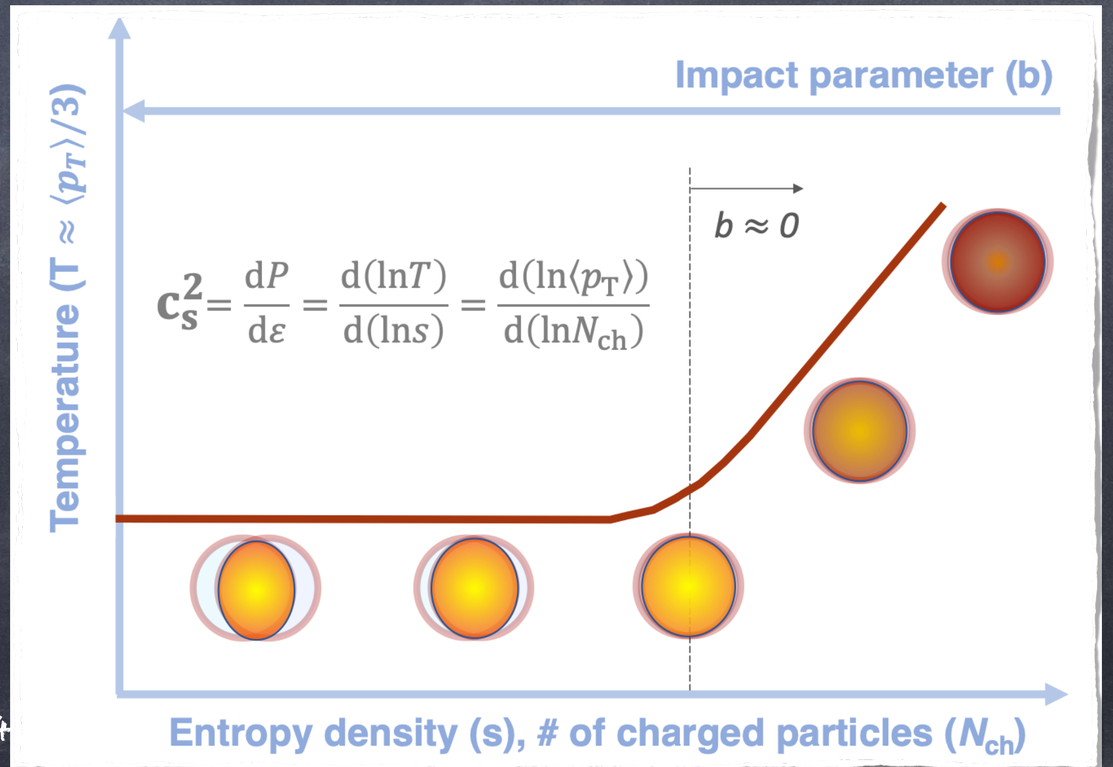
Detection with CMS detector



- Data taken in 2018, energy in the collision of ~5TeV
- Pb-Pb collisions
- Use of forward calorimeters to detect particules formed after cooling of PQG

Speed of sound

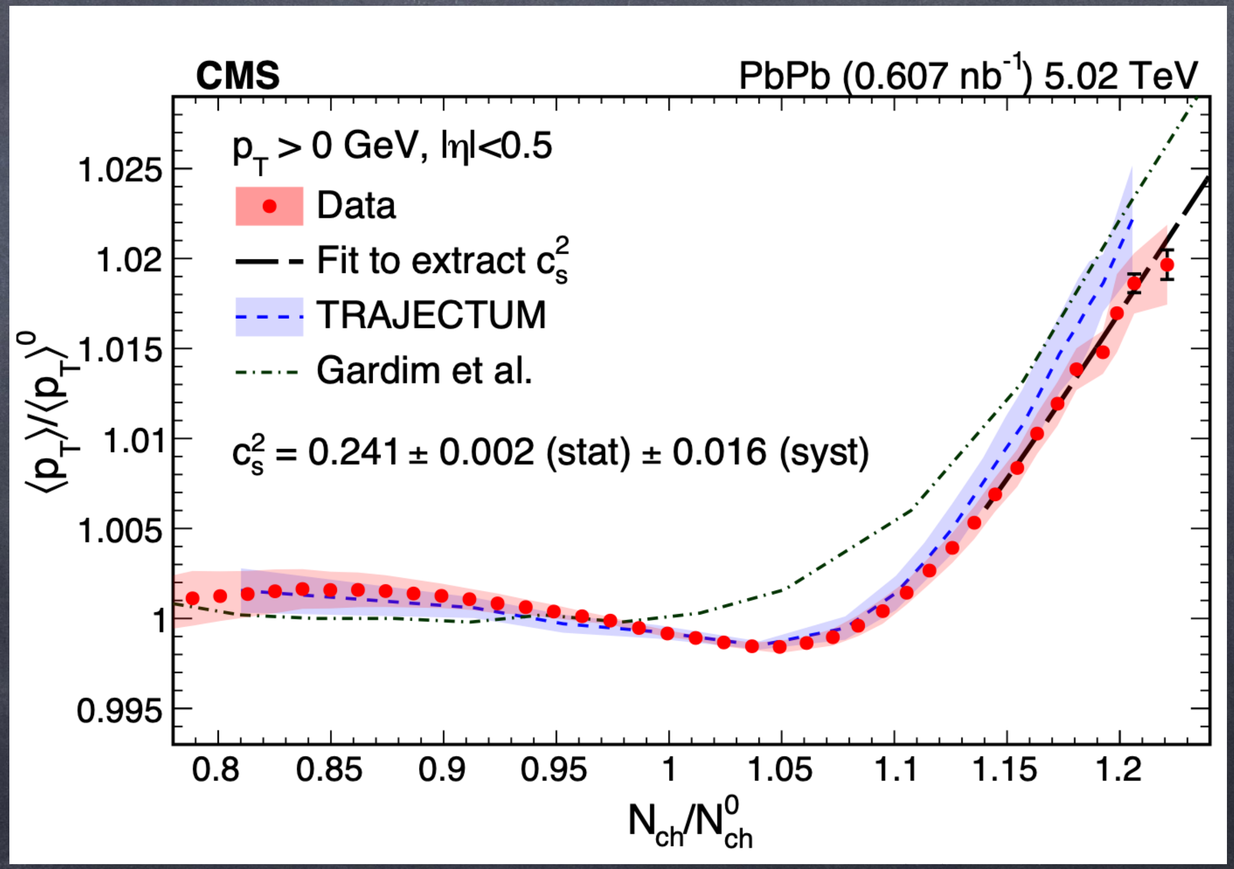
- Already measured in the past by other experiment (ALICE), but large uncertainties
- This time: innovative technic: use of ultra-central collision (very small impact parameter) -> determined by the total transverse energy deposit in both HF calorimeters
- Squared speed of sound (c_s^2) proportional to:
  - pression over energy density variations
  - particule transverse momentum and number of particules emitted



Result

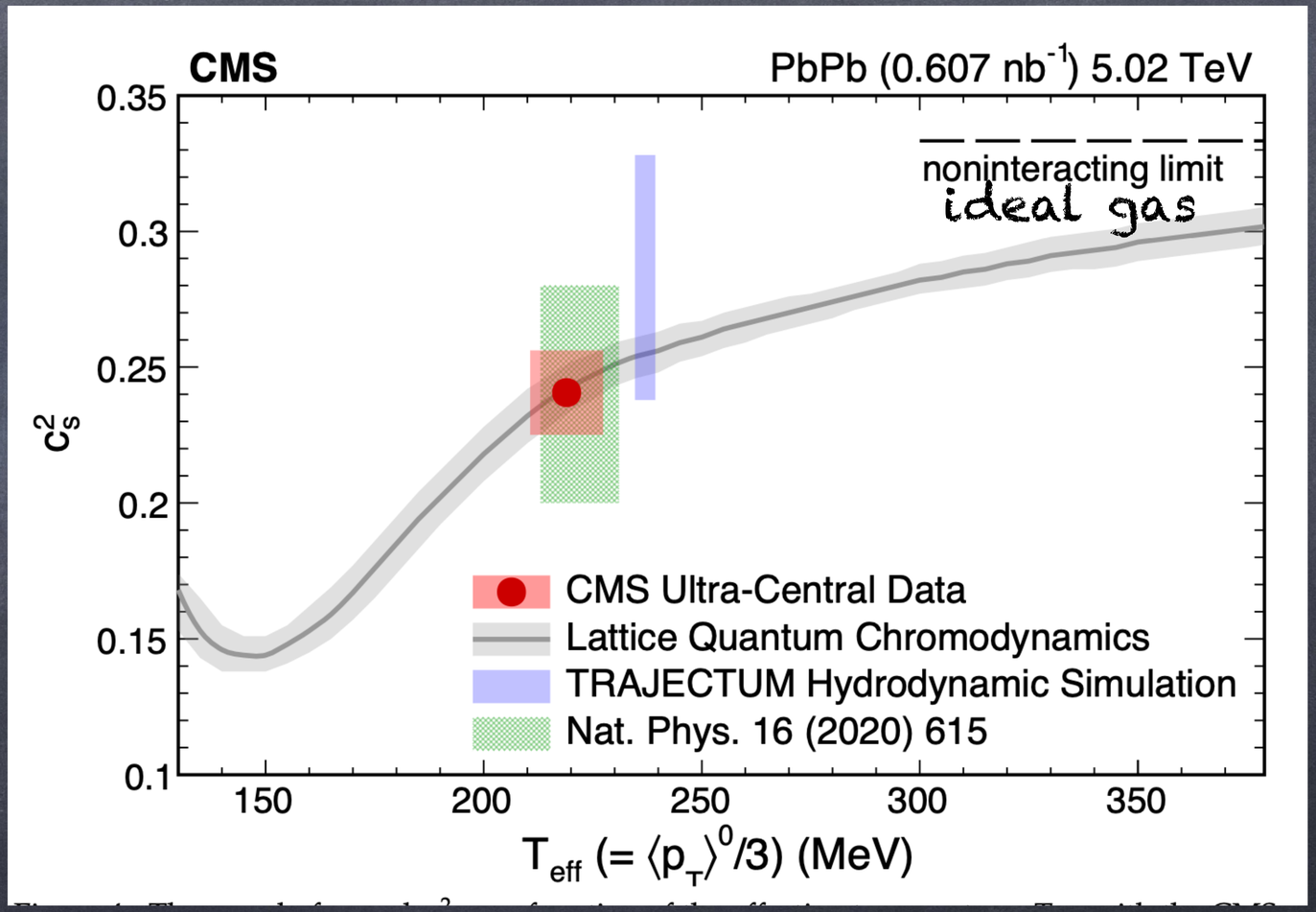
- c_s^2 =0.241 ± 0.002 (stat) ± 0.016 (syst) x c (c is light speed)
- c_s ~150 000 km/s !
  - in comparison 12000 m/s in diamond
- Value theoretically possible only for QGP

$$\langle p_{\mathrm{T}} \rangle^{\mathrm{norm}} = \left(\frac{N_{\mathrm{ch}}^{\mathrm{norm}}}{\langle \overline{N_{\mathrm{ch}}^{\mathrm{knee}}} | N_{\mathrm{ch}}^{\mathrm{norm}} \rangle} \right)^{c_s^2}$$



Result

- Most precise value to date
- In excellent agreement with theory (lattice QCD)
- One more evidence of deconfined quarks/gluons state



References

- https://arxiv.org/abs/2401.06896
- https://home.cern/fr/news/news/physics/hearing-sound-quark-gluon-plasma