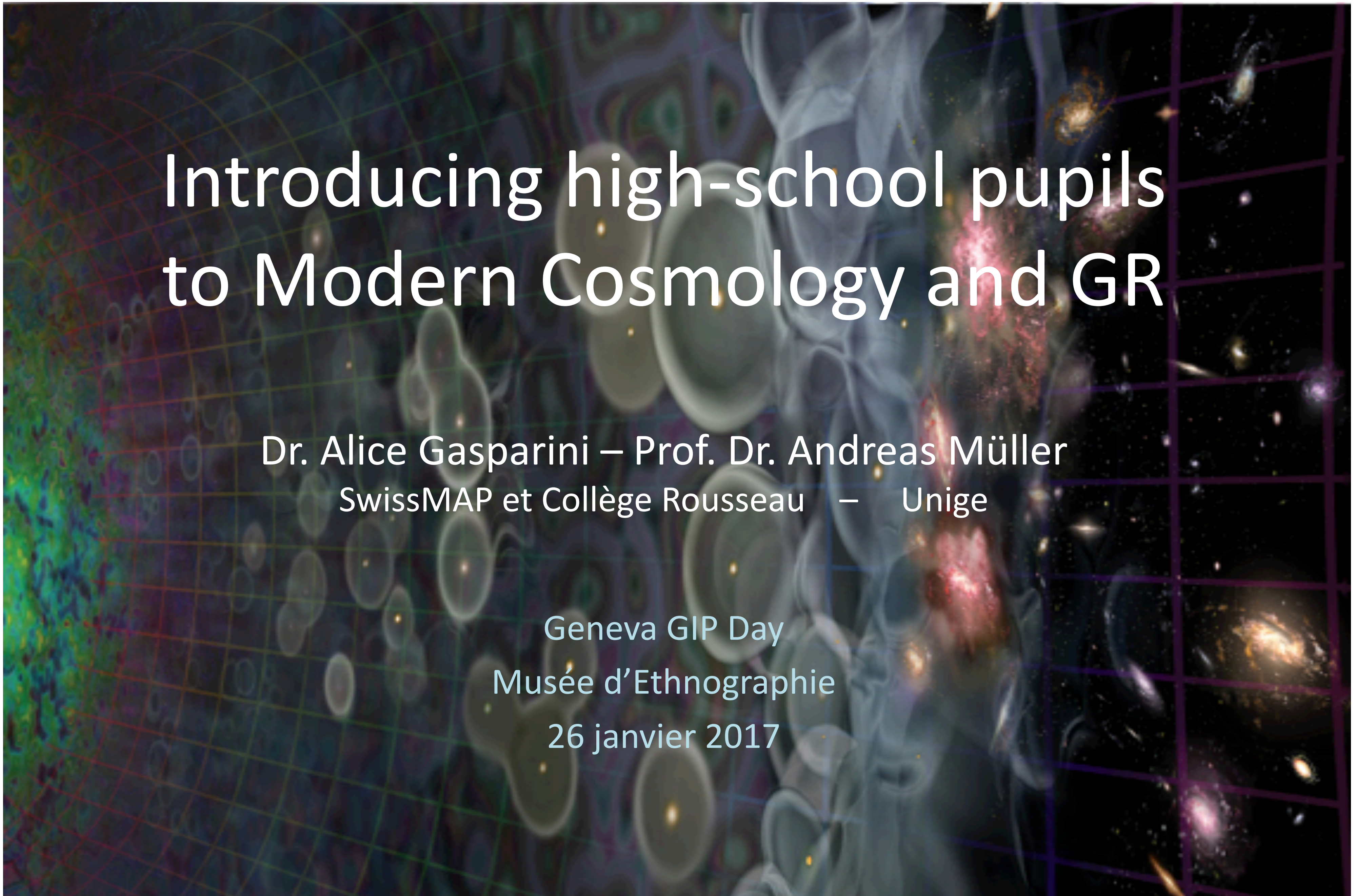


Introducing high-school pupils to Modern Cosmology and GR

Dr. Alice Gasparini – Prof. Dr. Andreas Müller

SwissMAP et Collège Rousseau – Unige

Geneva GIP Day

Musée d'Ethnographie

26 janvier 2017

SwissMAP

The Mathematics of Physics

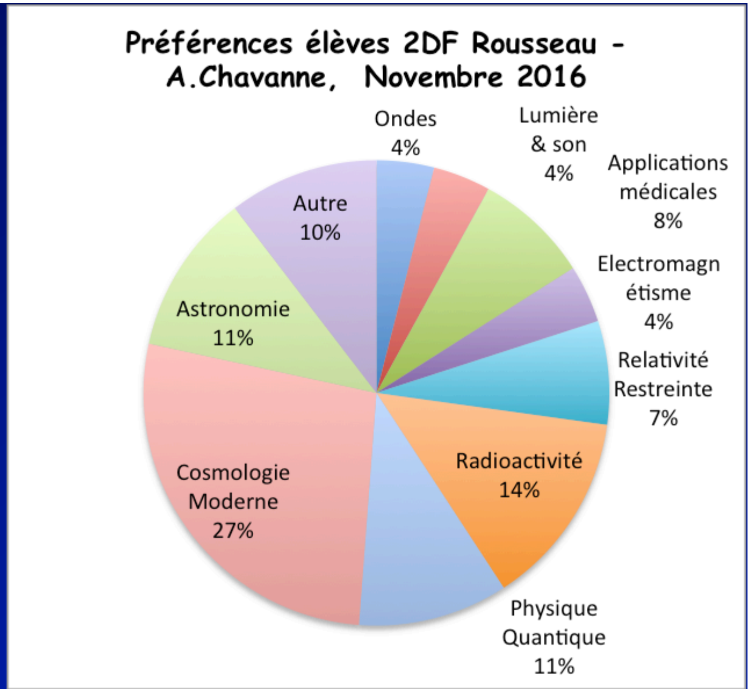
National Centre of Competence in Research

UNIVERSITÉ DE GENÈVE

Didactique de la physique

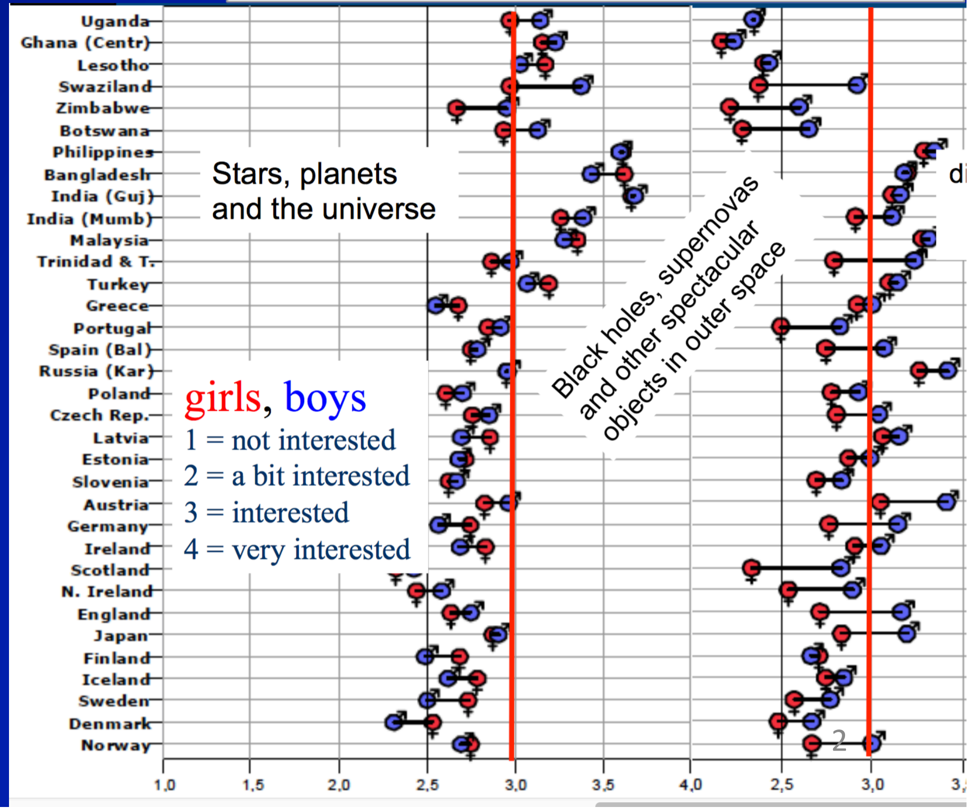
Motivation & Purposes

1. Boost the pupils' level in maths and in « classical » taught physics by <u>attractive</u> subjects : <u>not replace but complete</u> the "classical" curriculum



+ Research ROSE (Relevance of Science Education)

- Similar results across many countries
- Averages for « ordinary » science subjects are about 2



Motivation & Purposes

2. Improve the links between high school and actual research:

   pupils who learn physics up to the 19^{th} century have a distorted idea about the main issues of modern physics

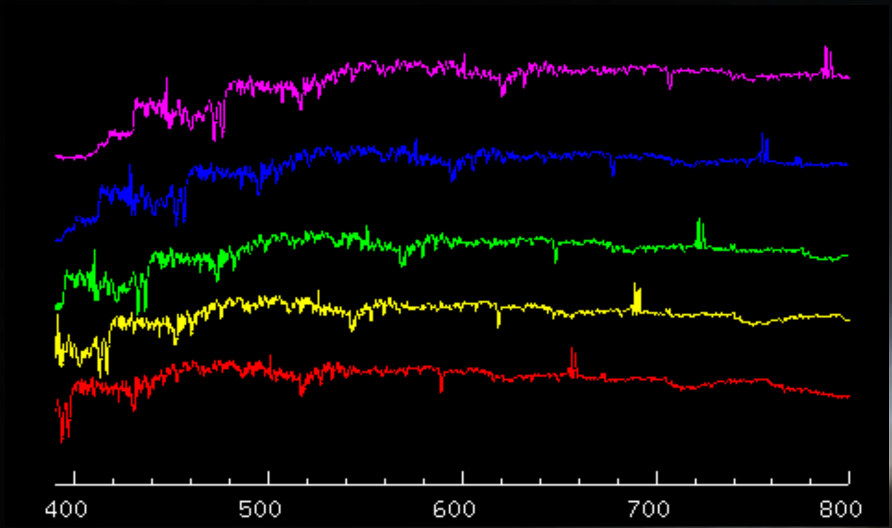
3. Medium level of elementarisation:

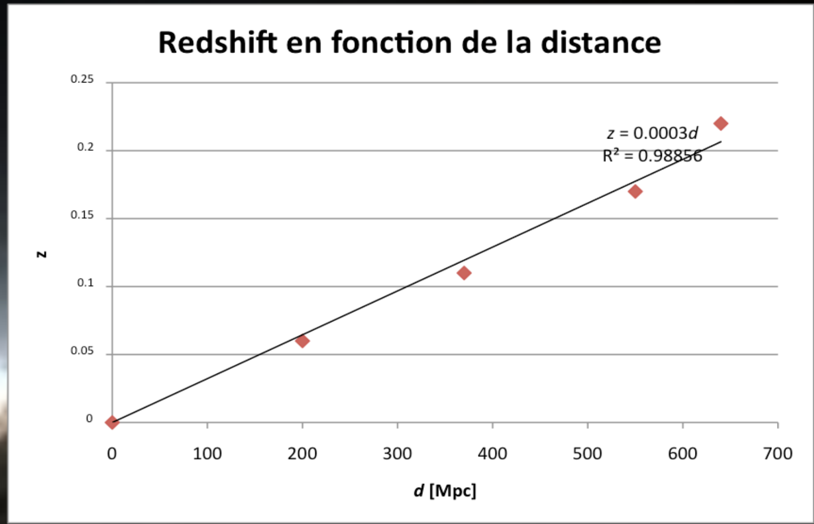
   activities based on high school skills on maths and "classical" taught physics;

   => not for a wide public (zero equations), not academic level.

Examples of tested activities: Cosmological distances

- Finding Hubble's law by comparing some nearby galaxies spectra





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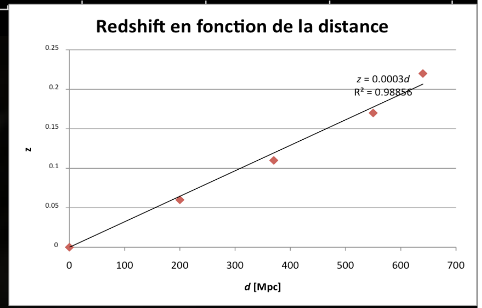

- **Comparing the OOM of the expansion speed at different scales:**

H_0 = 70 km/s /Mpc = … /mm = … /km = … /Gpc

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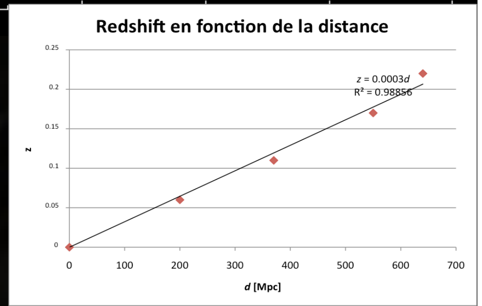
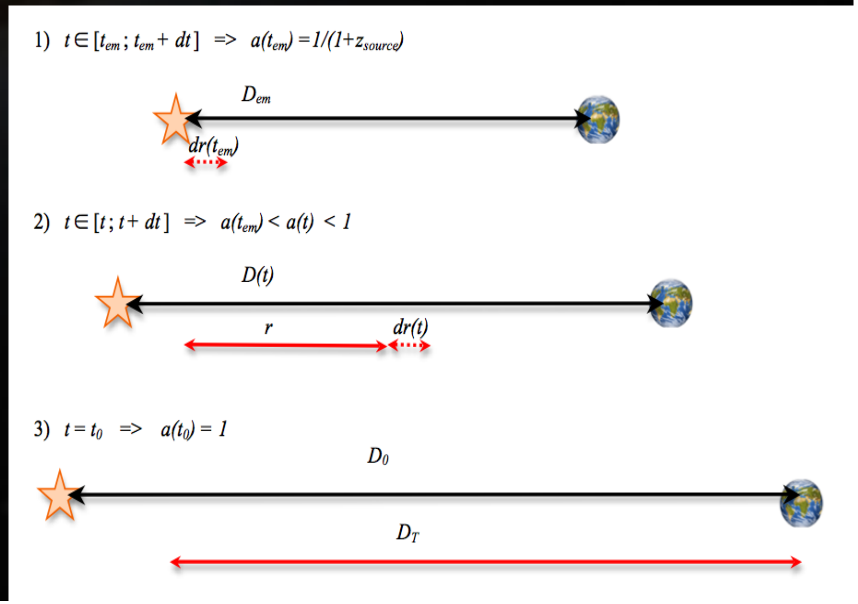


- **Finite value of *c* + expansion = the notion of distance split into Proper/Comoving/Time-travel/Angular/Luminosity distances**

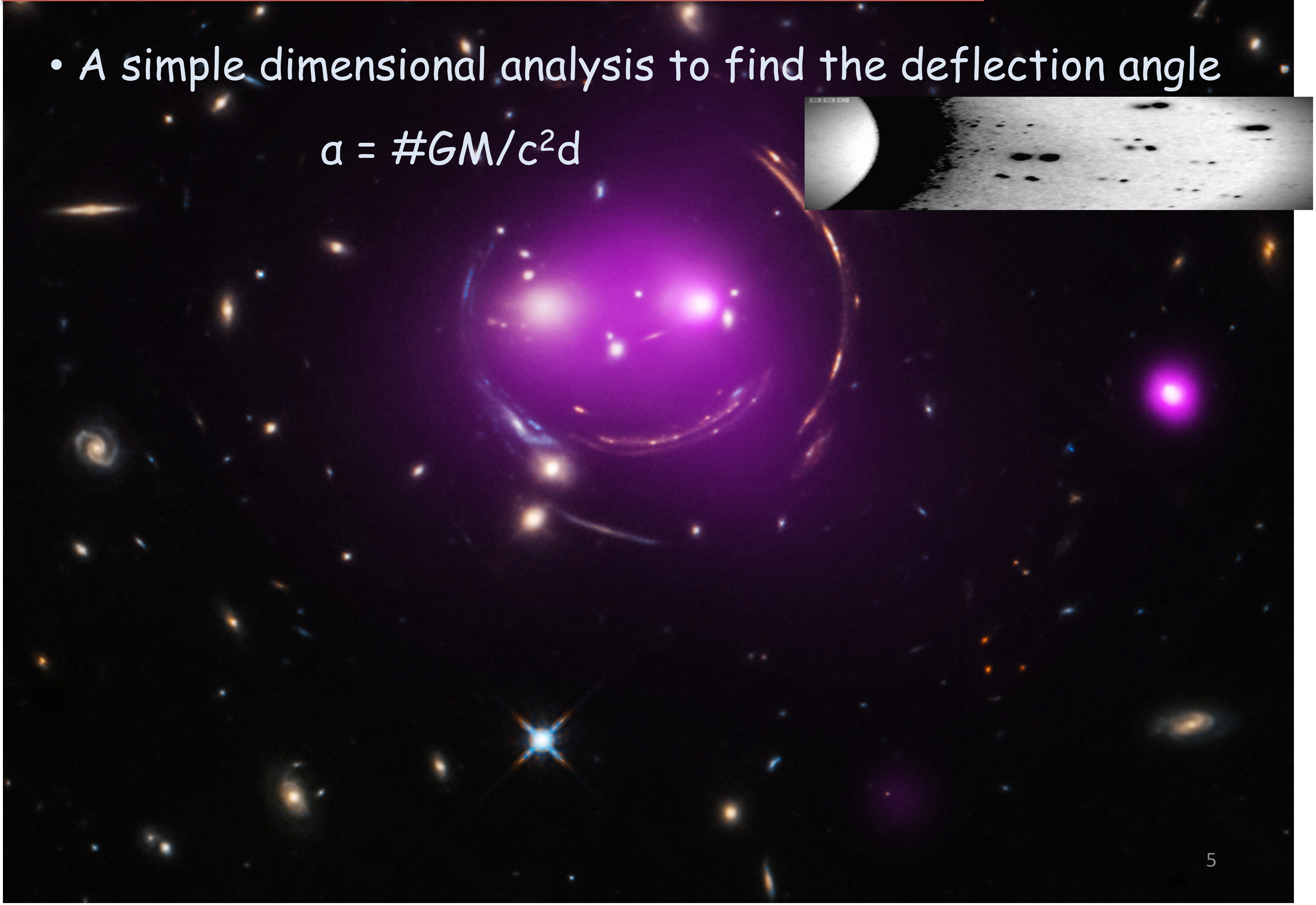
  - Deriving the integral formula for each one as a function of z, Ω_m and Ω_Λ
  - Studying limit cases
  - Numerical integration + comparing with the Supernova Cosmology Project data



Examples of tested activities: Strong Lensing

- A simple dimensional analysis to find the deflection angle

$$\alpha = \#GM/c^2d$$



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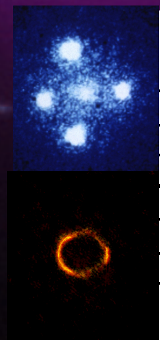
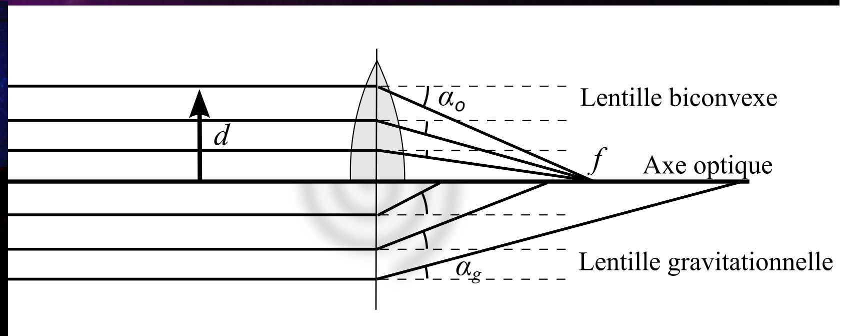
- A simple dimensional analysis to find the deflection angle

$$a = \# GM/c^2 d$$

- How the bottom of wineglass can simulate the strong lensing effect?

  - ➢ Solving a differential equation (simple integration) to find the profile of the optical lens: a curve of kind $y(x) = y_0 \ln(x)$
  - ➢ + Manip. Einstein's ring/cross





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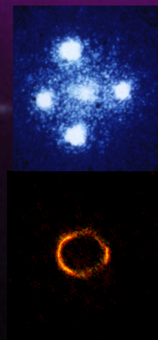

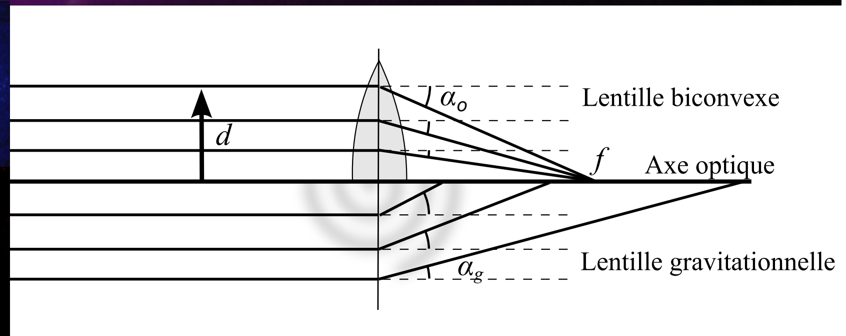

- Trigonometry + algebra to find M as a function of the Einstein's radius θ_{Einst} and the distances observer - lens - source.

$$\theta_{Einst.} = \sqrt{\frac{4GM\,D_{SL}}{c^2 D_{LO} D_{SO}}}$$

Examples of tested activities: Nature of gravity

- **Compare gravitational interaction and electromagnetic interaction;**

  - For the system e^-/p^+ in the H atom, and for the system Moon/Earth (if we could get all the electrons out of them): $F_{em}/F_g \approx 10^{39}$

  - For $F_{em} \approx F_g$ between 2 identical particles, we need their $m/q \approx 10^{10}$ kg/C. Replacing $q = e$, we get $m \approx 10^{27}$eV (unification energy)

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  - Schwarzschild Radius => when $v_l = c$

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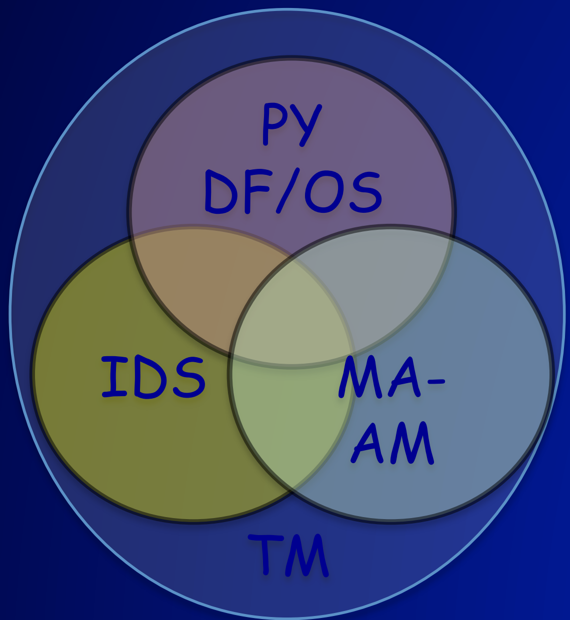
- **BH: Use Wien's law to get its temperature + Estimate the time of evaporation using Stefan-Boltzmann law**

CM & GR: introduction pour élèves du secondaire II

Dr. A. Gasparini (SwissMAP) – Prof. Dr. A. Müller (Dida de la Physique), UniGE

- ➔ 9 chapters : theory + activities
- ➔ Ideal for a PY OC course (2h/week) planned on 2 semesters
- ➔ Toolbox for many others teaching contexts (punctual activities):



Cosmologie Moderne et Relativité Generale

Activités pour les élèves du Secondaire II

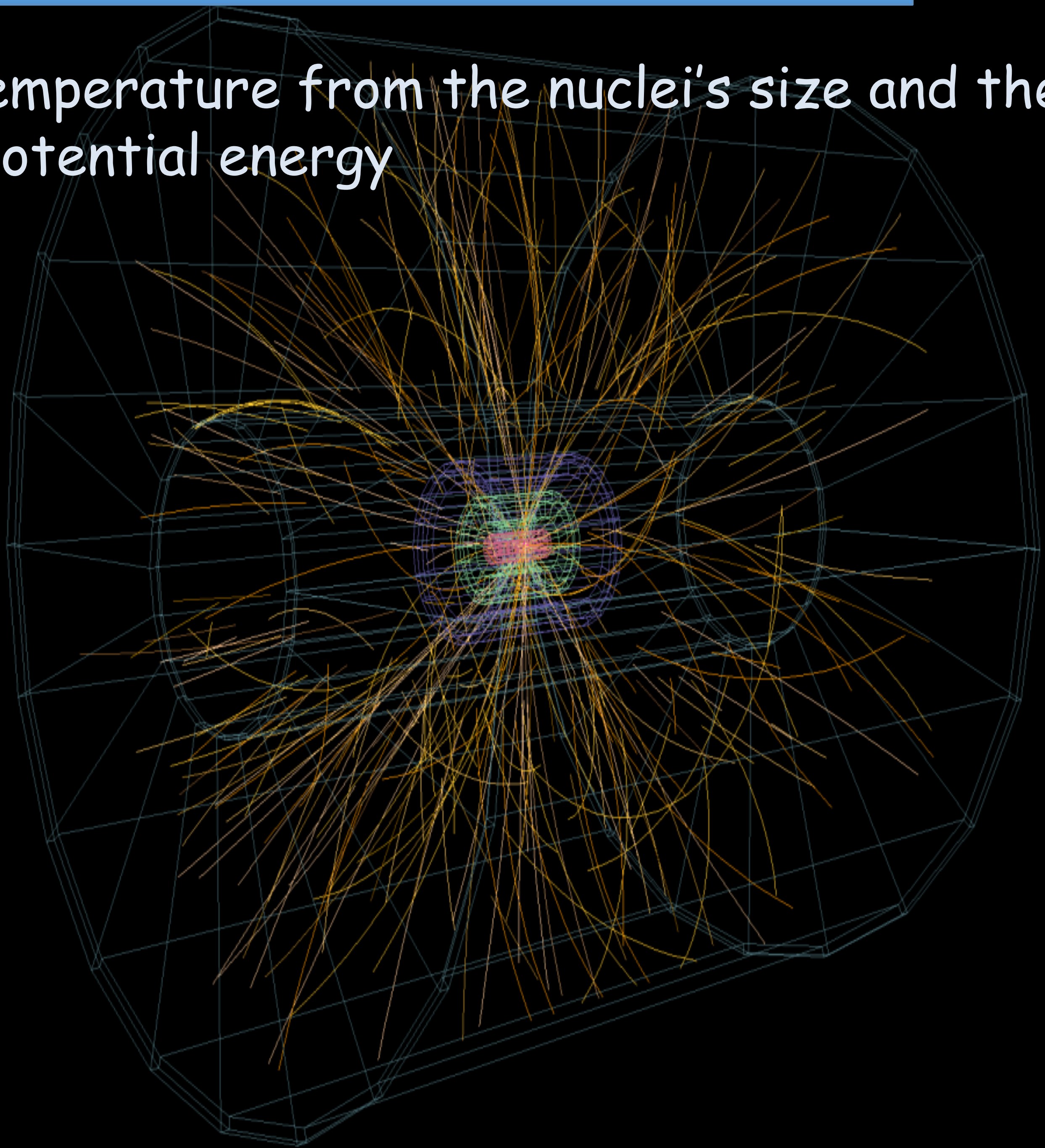
Alice Gasparini, Andreas Müller

- Série 1 : Grandeurs
- Série 2 : Expansion
- Série 3 : Principe d'équivalence
- Série 4 : Courbure
- Série 5 : Lentille gravitationnelle
- Série 6 : Trous noirs
- Série 7 : Equations cosmologiques
- Série 8 : Chronologie du Big Bang
- Série 9 : Ondes Gravitationnelles

- Activité expérimentale 1 : L'effet Doppler cosmologique
- Activité expérimentale 2 : La courbure du cône

Outlook: exemples of activities to be tested

- Fusion temperature from the nuclei's size and the Coulomb potential energy



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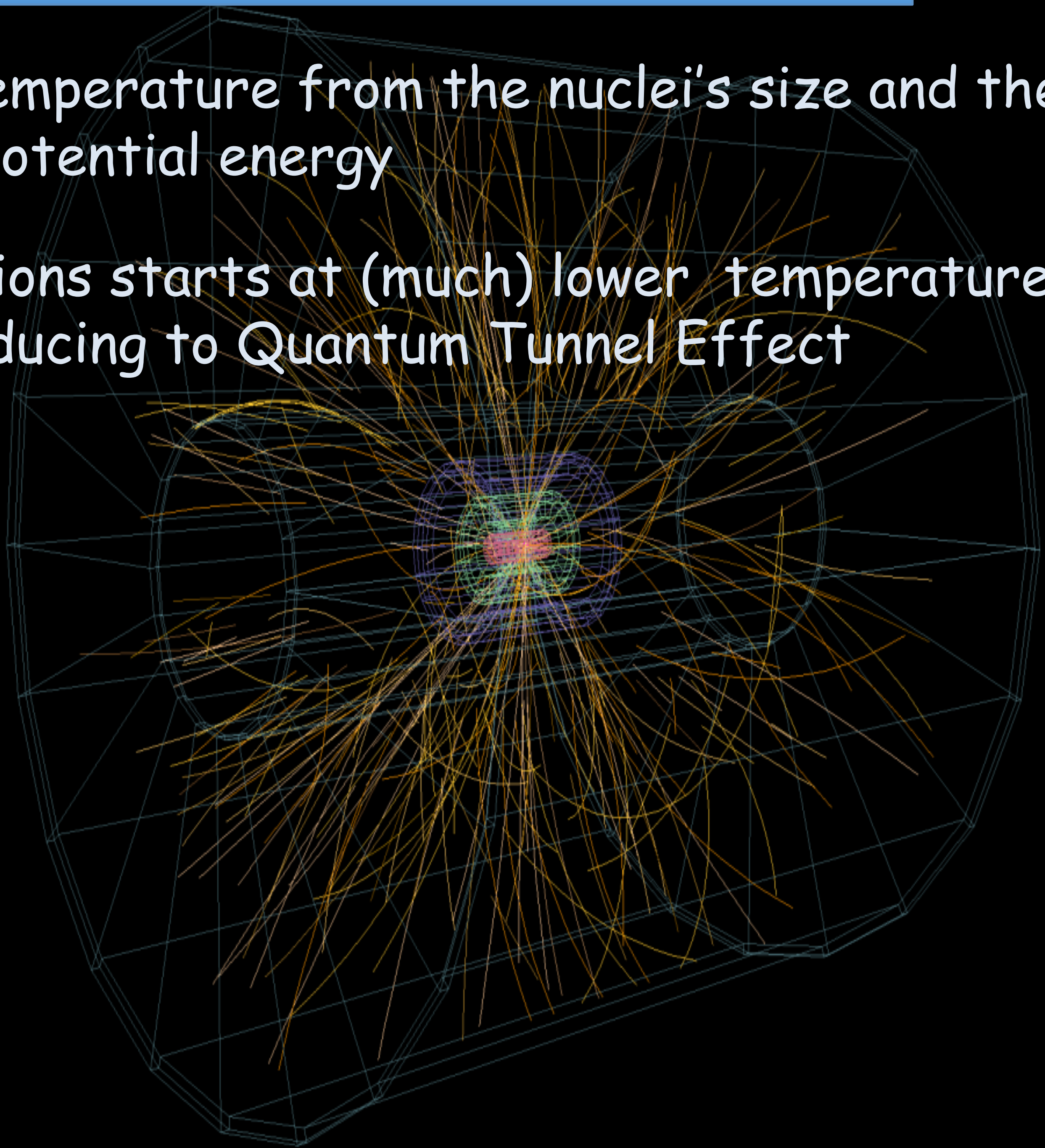
- Why fusions starts at (much) lower temperature?
  => Introducing to Quantum Tunnel Effect



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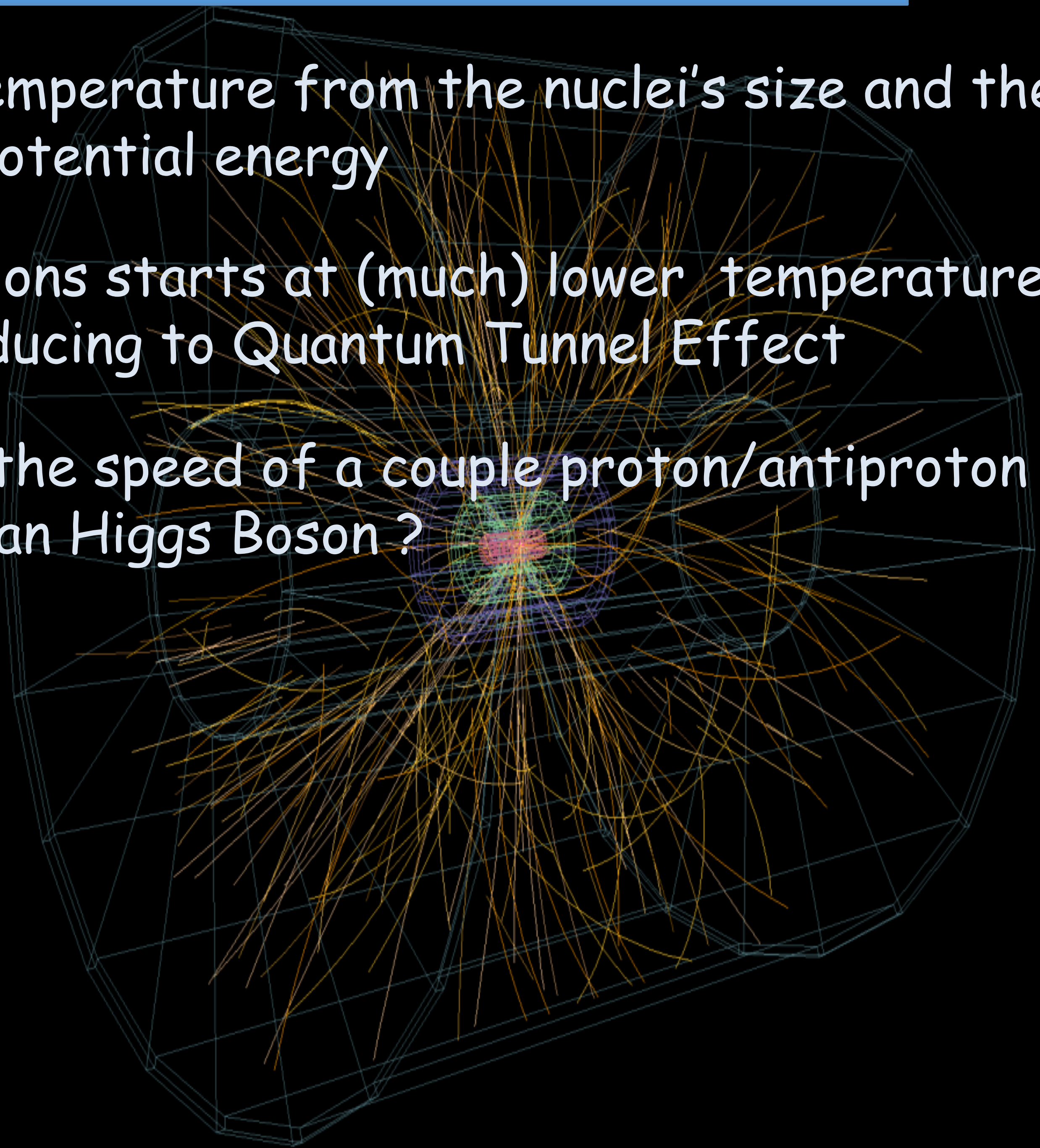

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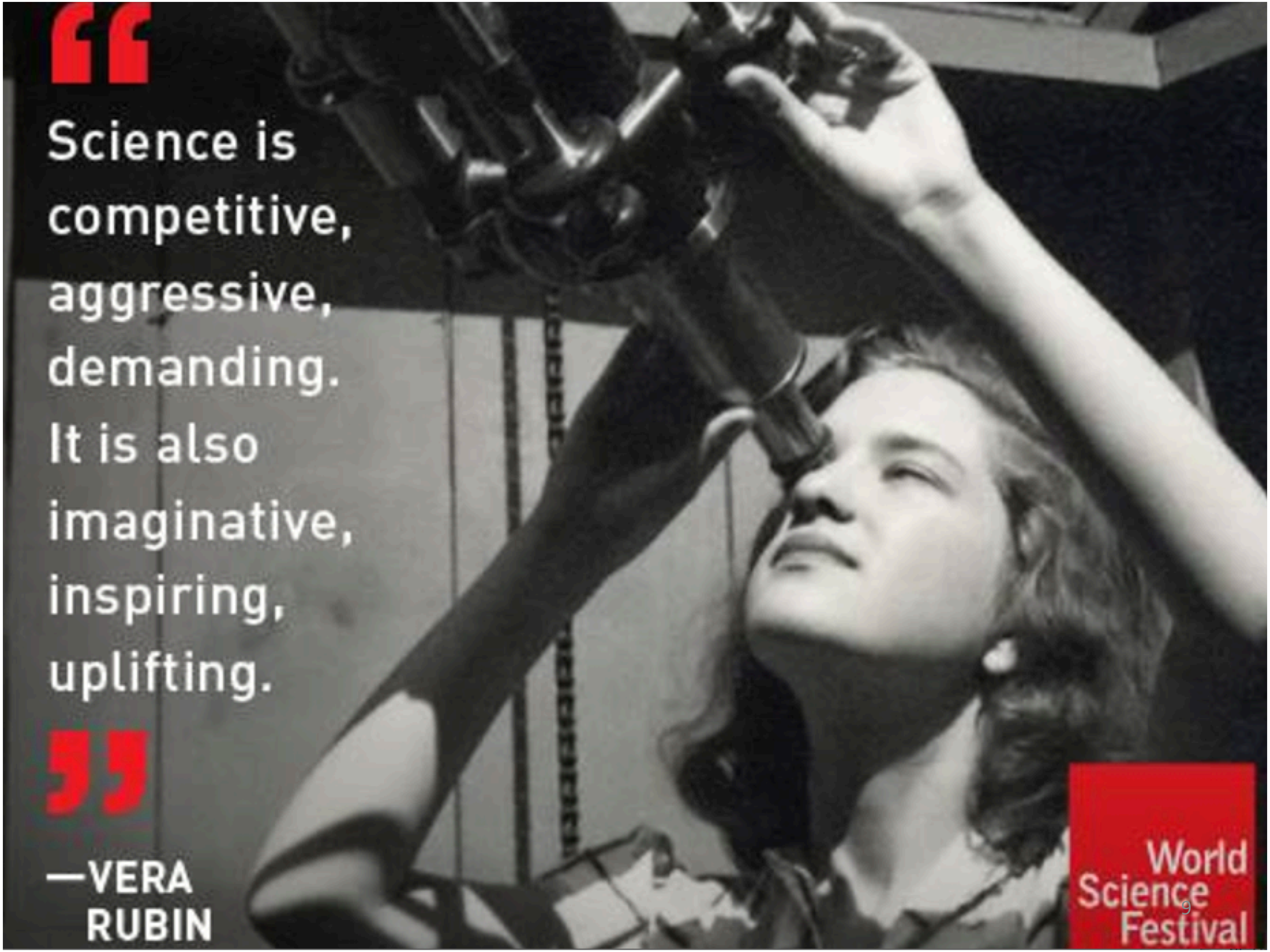
- Quadrupole formula for the amplitude of a GW:

  - ➢ Comparing quadrupole (GW) vs dipole (EMW) emission
  - ➢ Why only astrophysical masses can produce such a wave?
  - ➢ Why do we need "relativistic sources"? (BH or NS)
  - ➢ Why are these waves so important in the nowadays physics?
  - ➢ Relation M_{source}/ frequency/ detector's size
  - ➢ + all the exercises you can do with waves (DF & OS curriculum)


Science is competitive, aggressive, demanding. It is also imaginative, inspiring, uplifting.
—VERA RUBIN
World Science Festival