

Het onzichtbare heelal

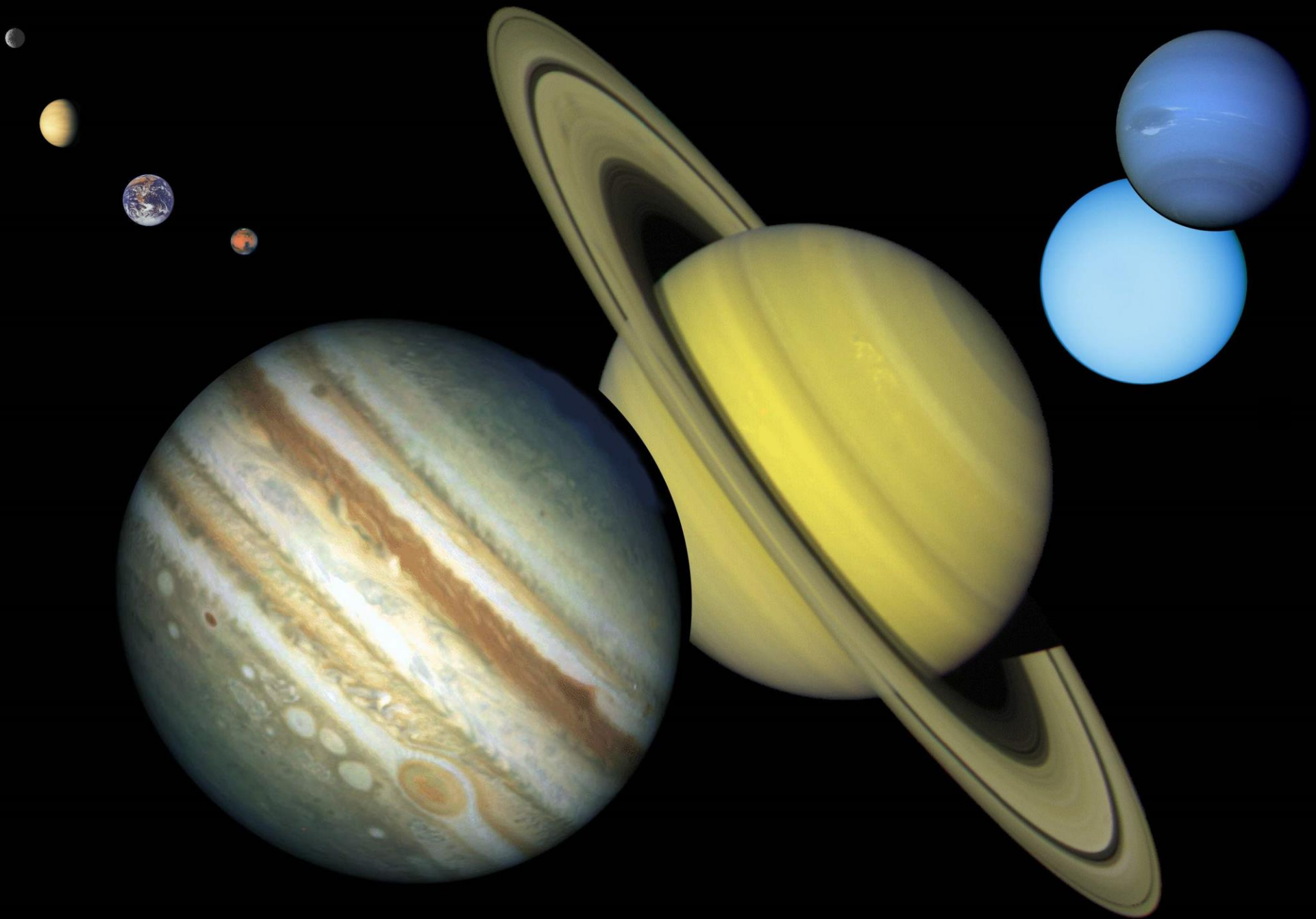
DONKERE MATERIE, DONKERE ENERGIE
EN DE SAMENSTELLING VAN ONS HEELAL

Govert Schilling
allesoversterrenkunde.nl

The background is a high-resolution image of a star field, likely from a deep space survey. It features numerous stars of varying brightness and colors, including blue, white, and yellow. A prominent, faint, and diffuse nebula is visible in the lower central region, showing a mix of blue and white hues. The overall texture is grainy, typical of astronomical imagery.

vijfentachtig procent van
alle materie in het heelal
is onzichtbaar en bestaat
uit mysterieuze deeltjes









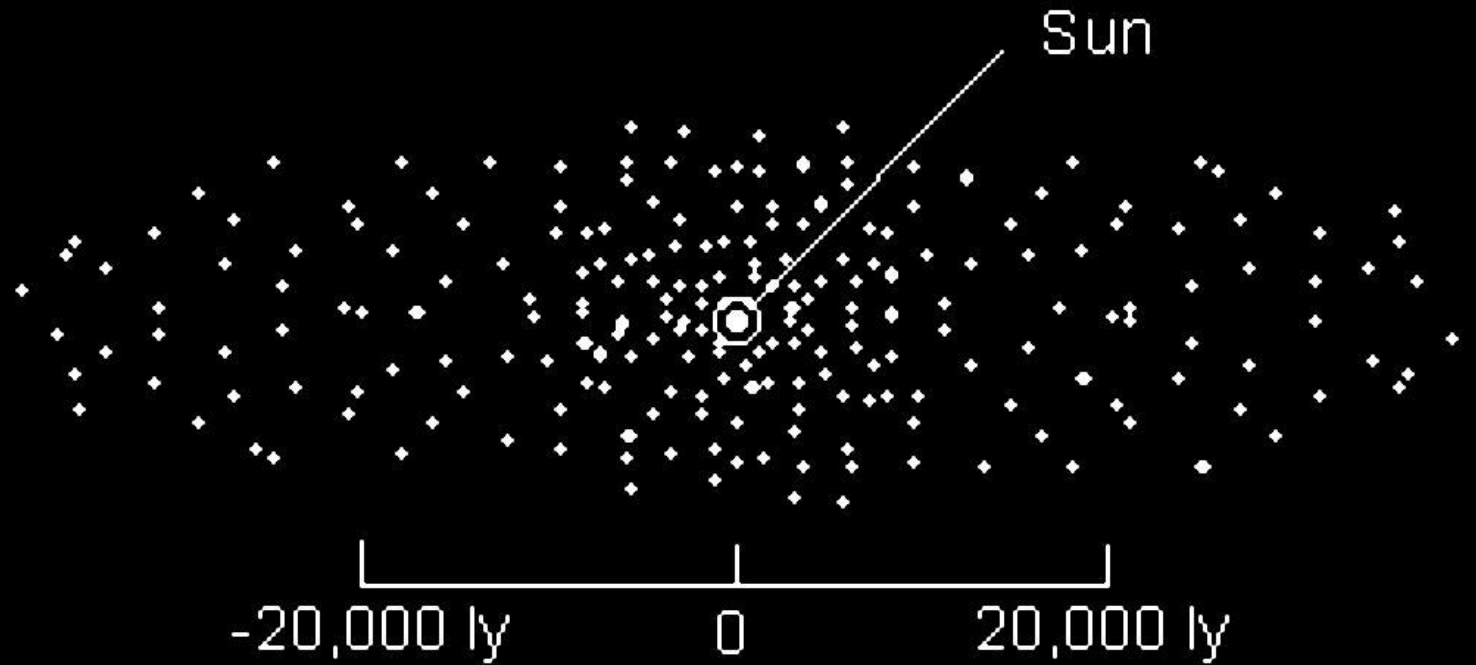




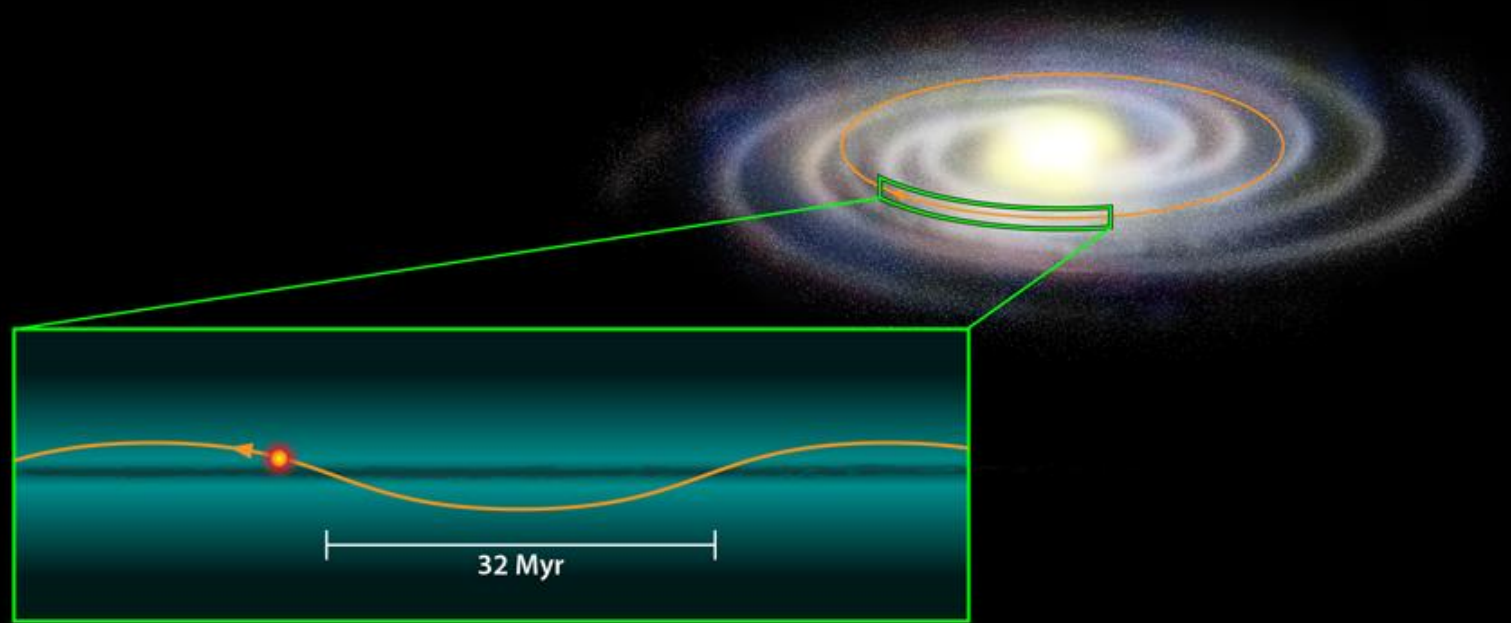
$$v_c = \sqrt{\frac{GM}{r}}$$







Jacobus Kapteyn (1851-1922)



Jan Oort (1900–1992)



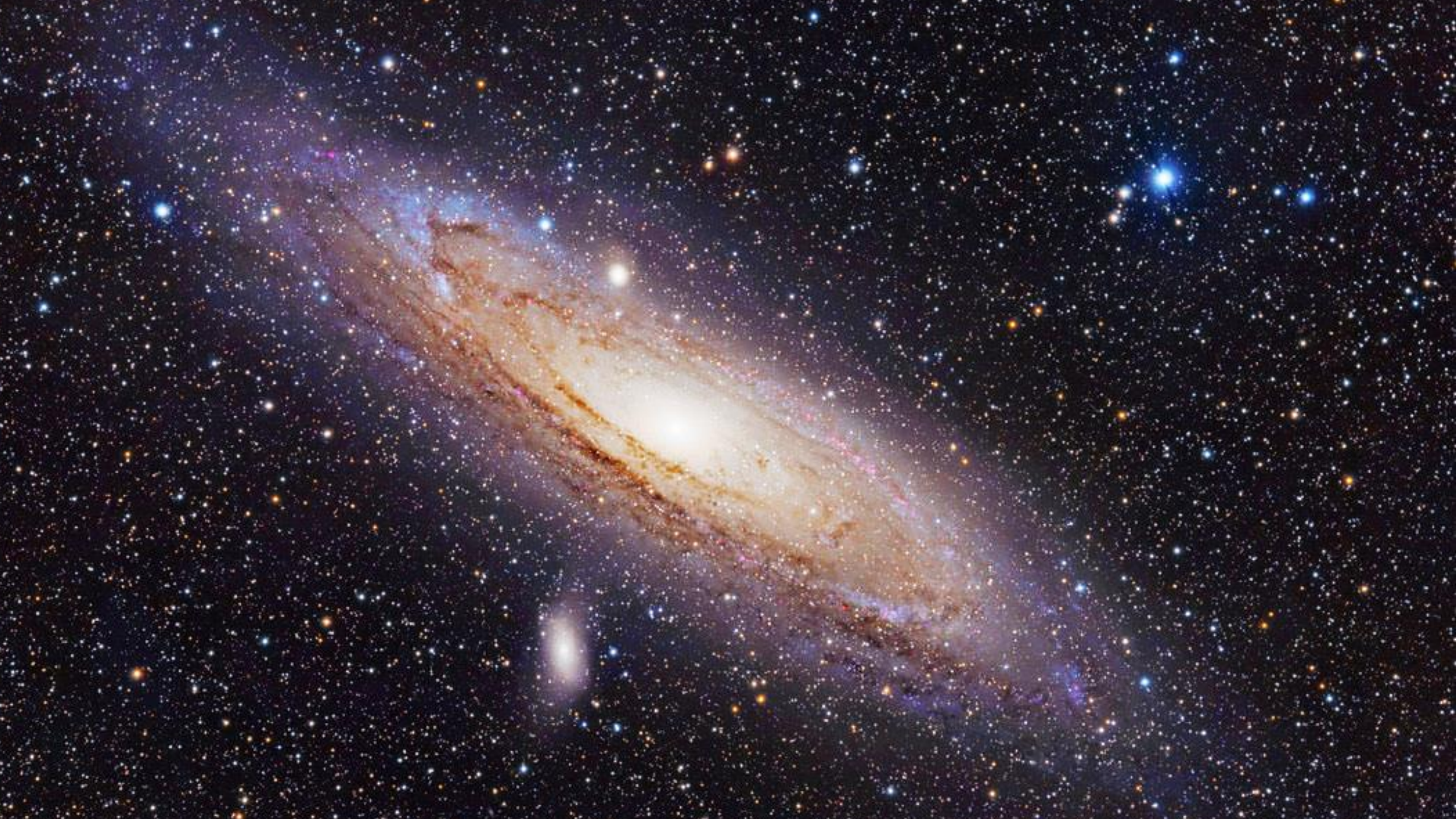
Fritz Zwicky (1898–1974)

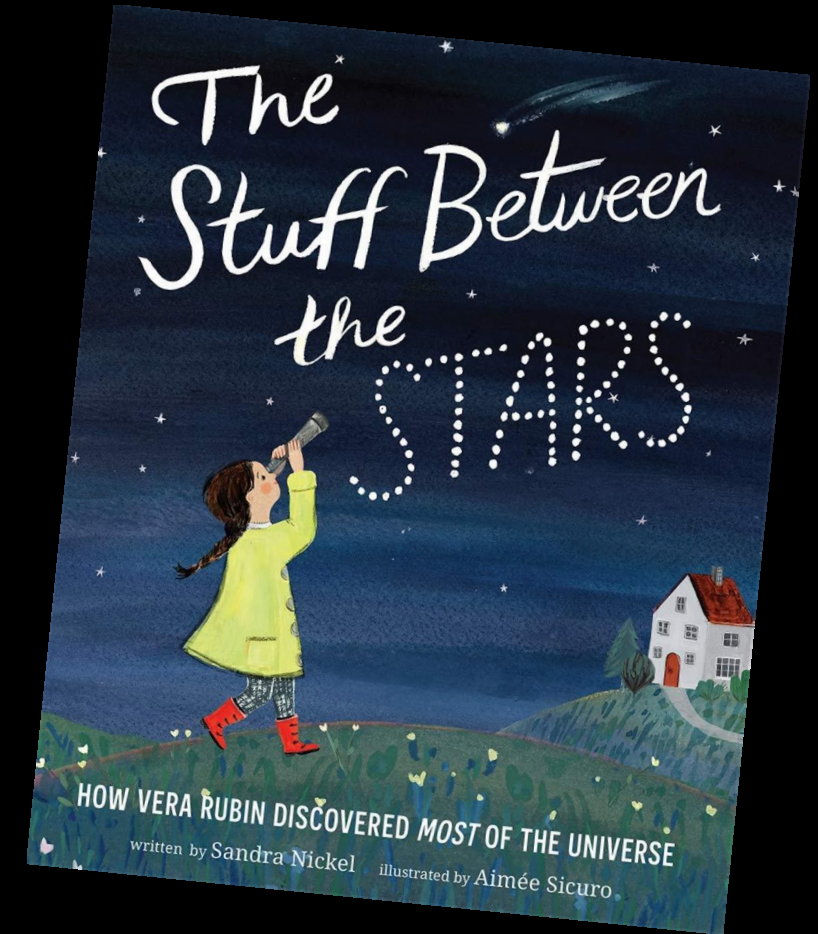


Lichtbron in rust





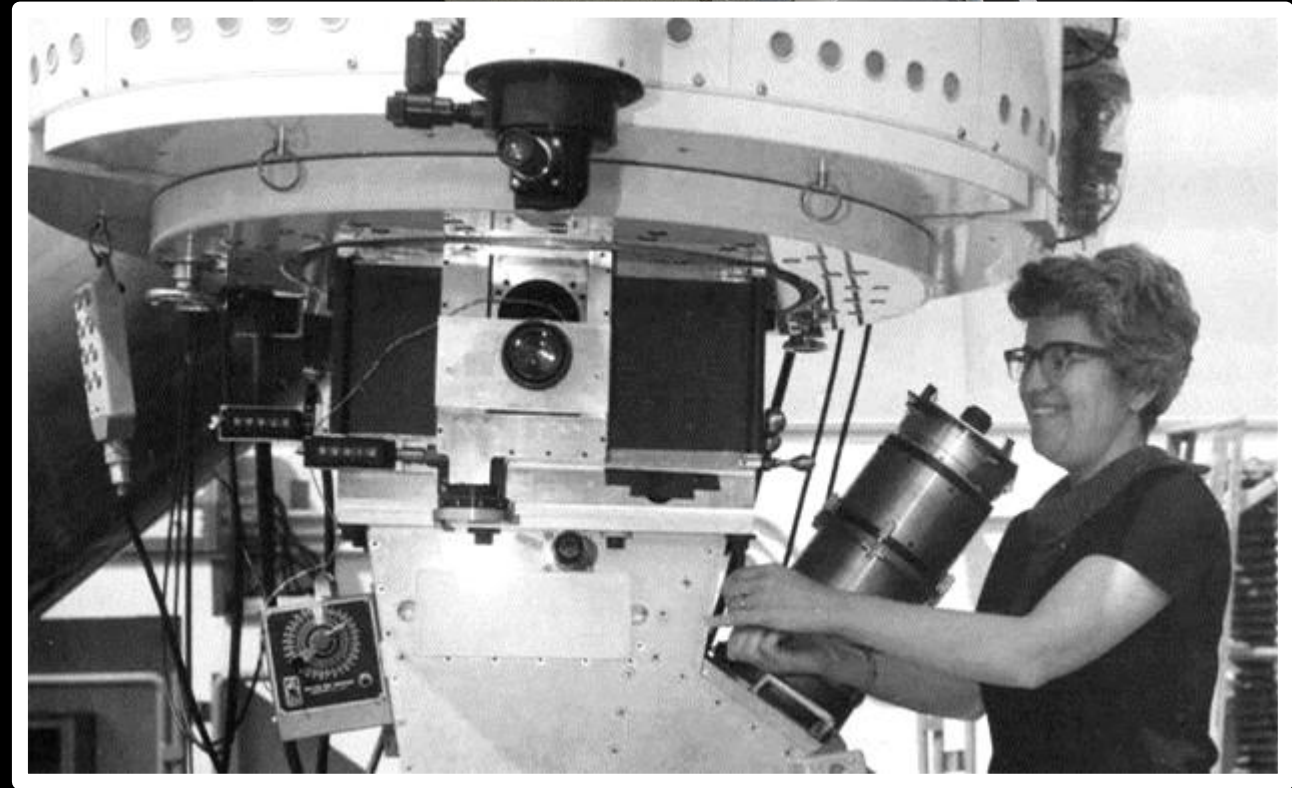
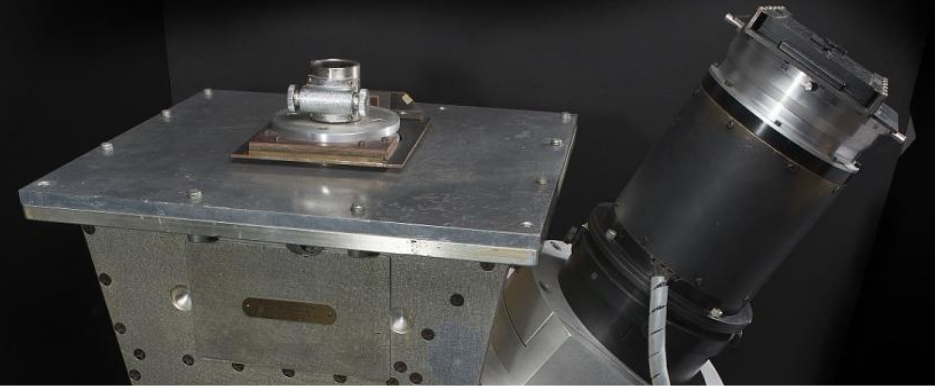


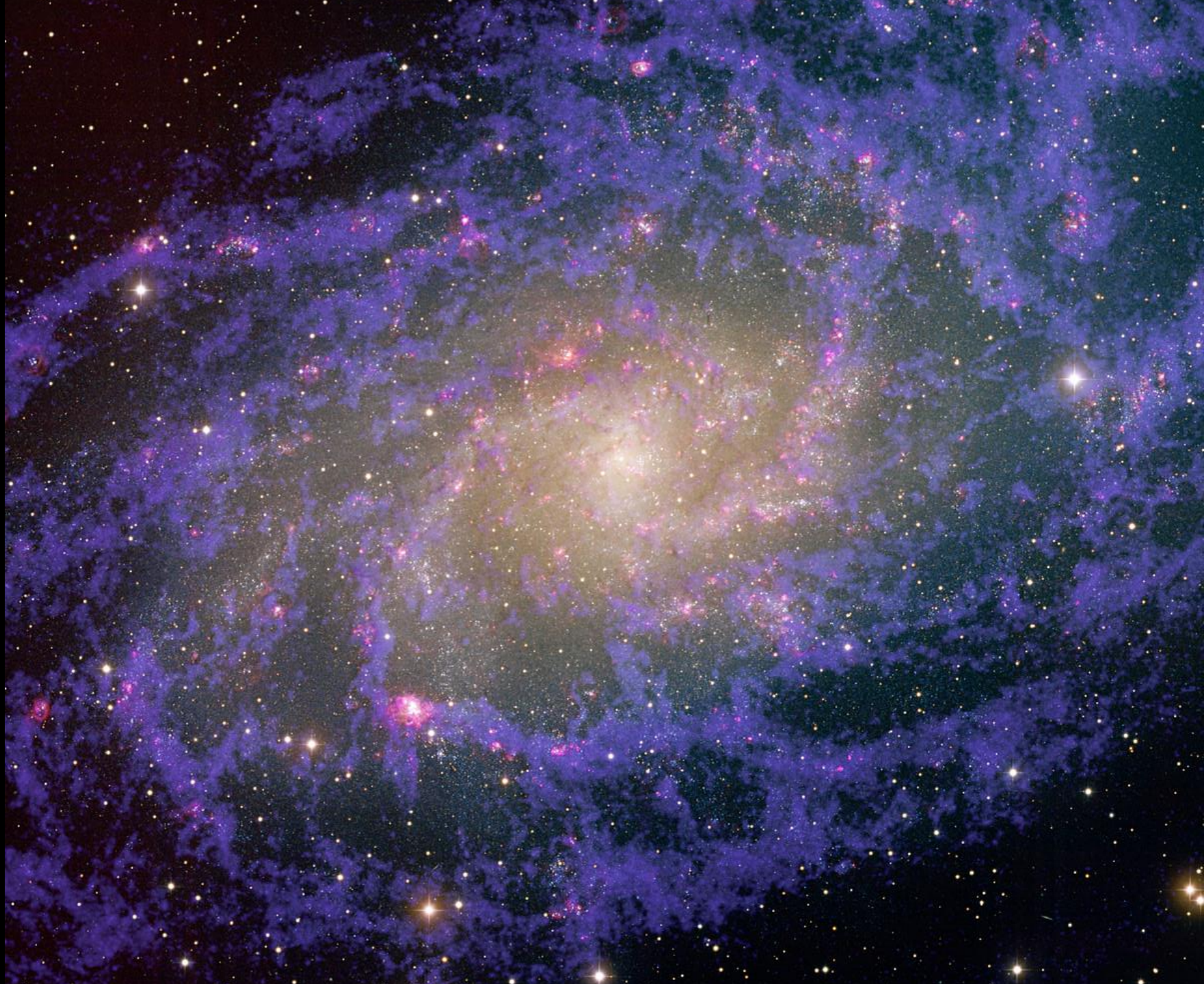


Vera Rubin (1928–2016)

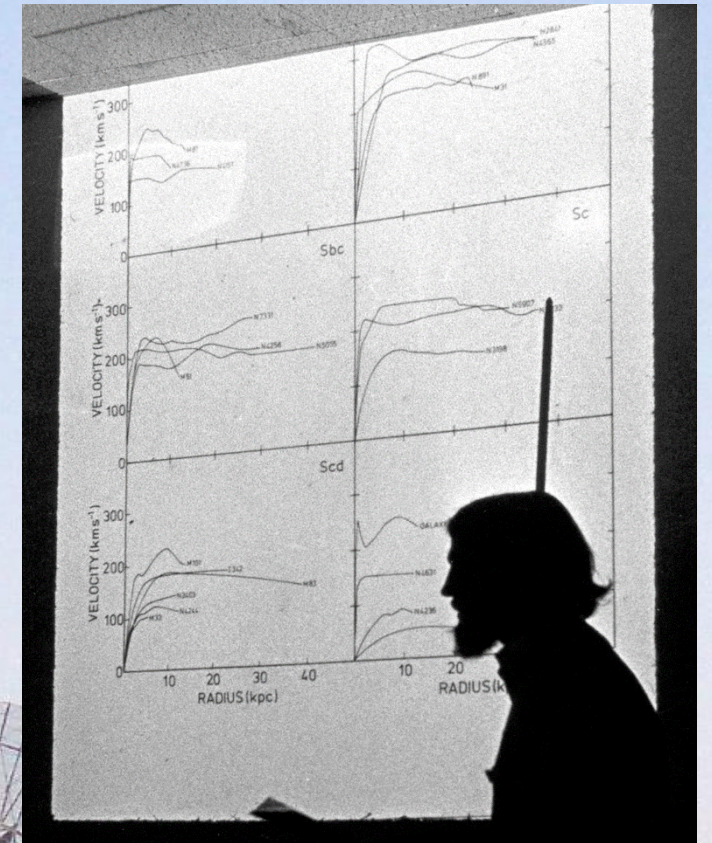
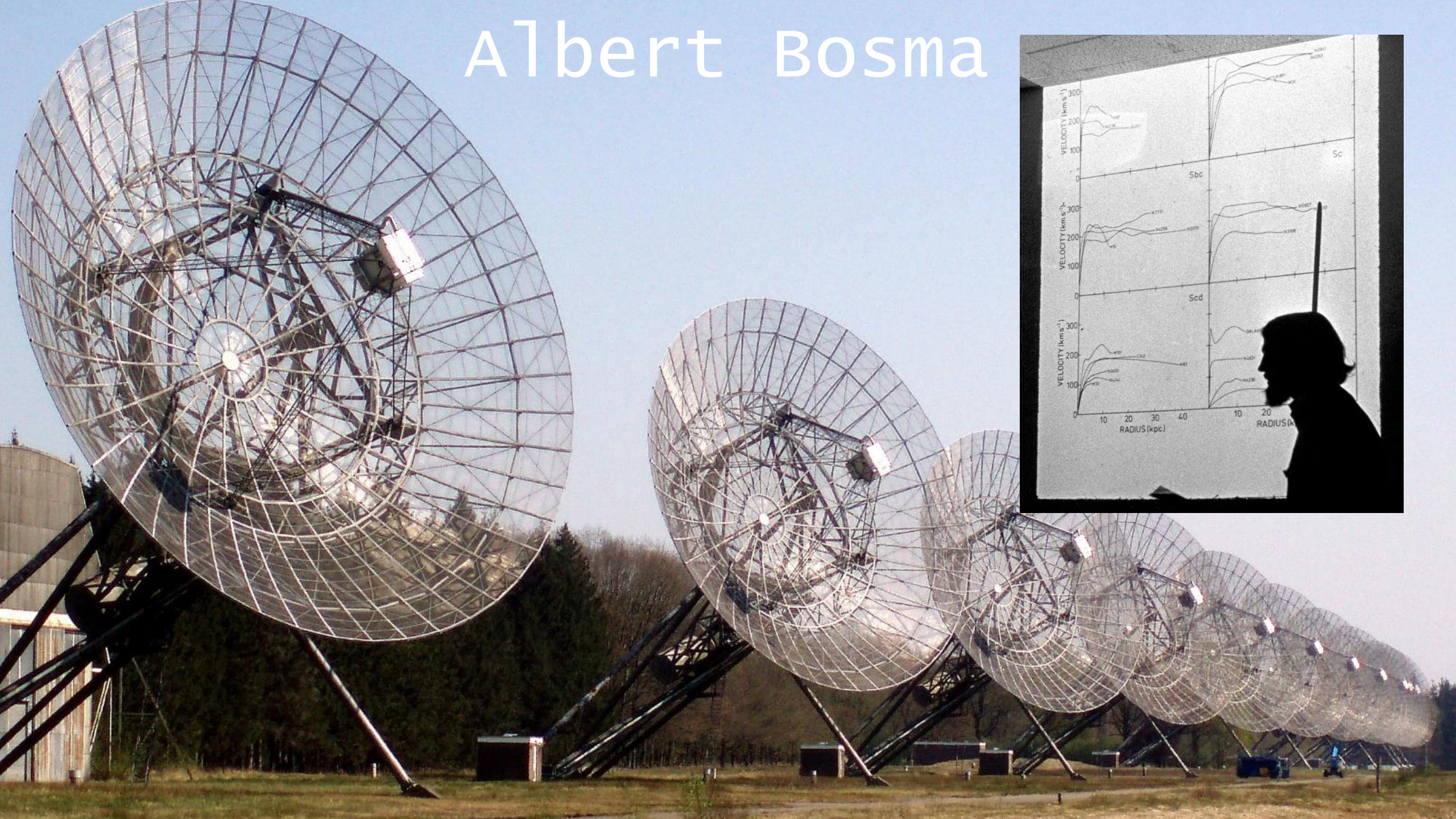


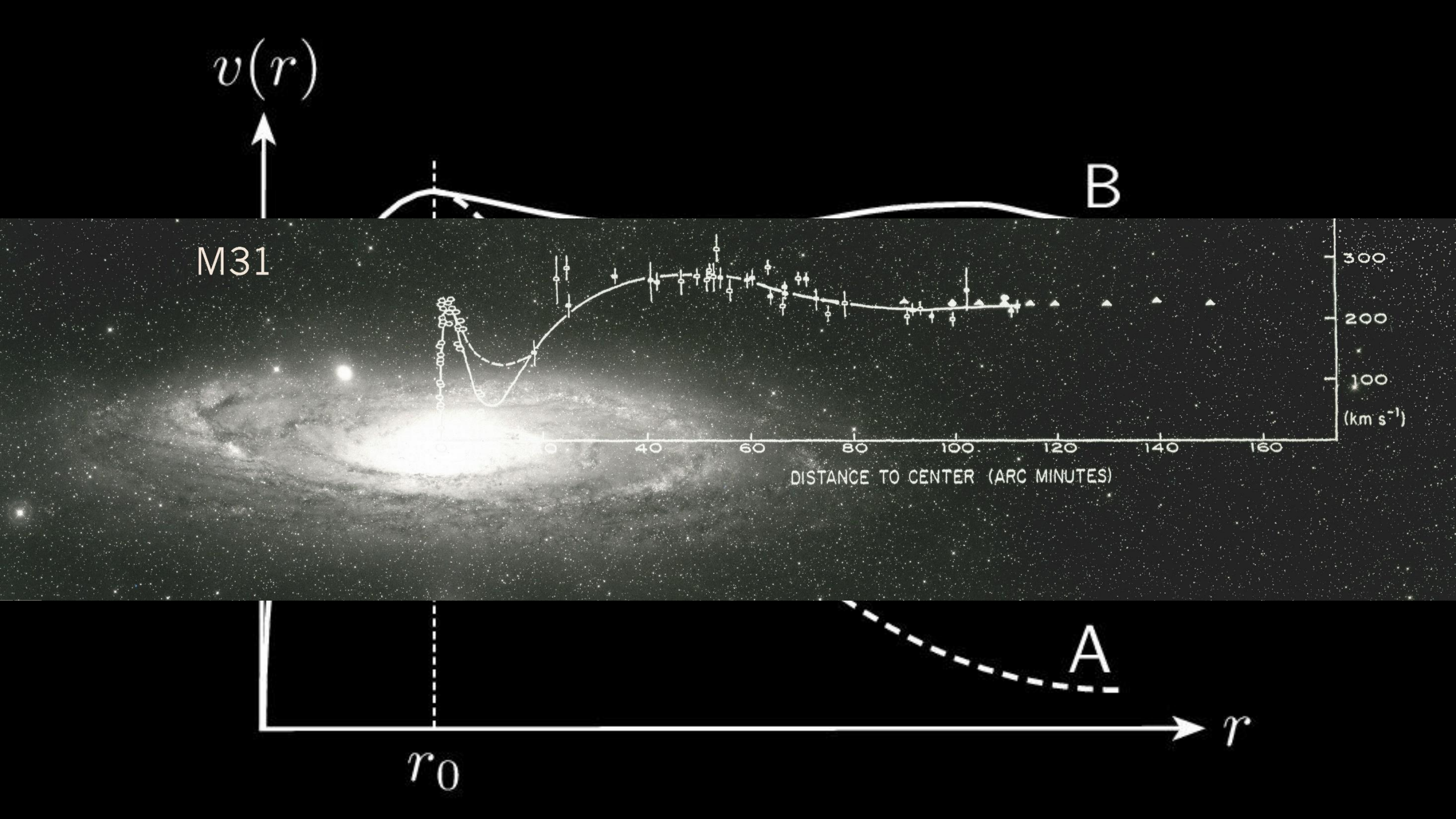
Kent Ford





Albert Bosma



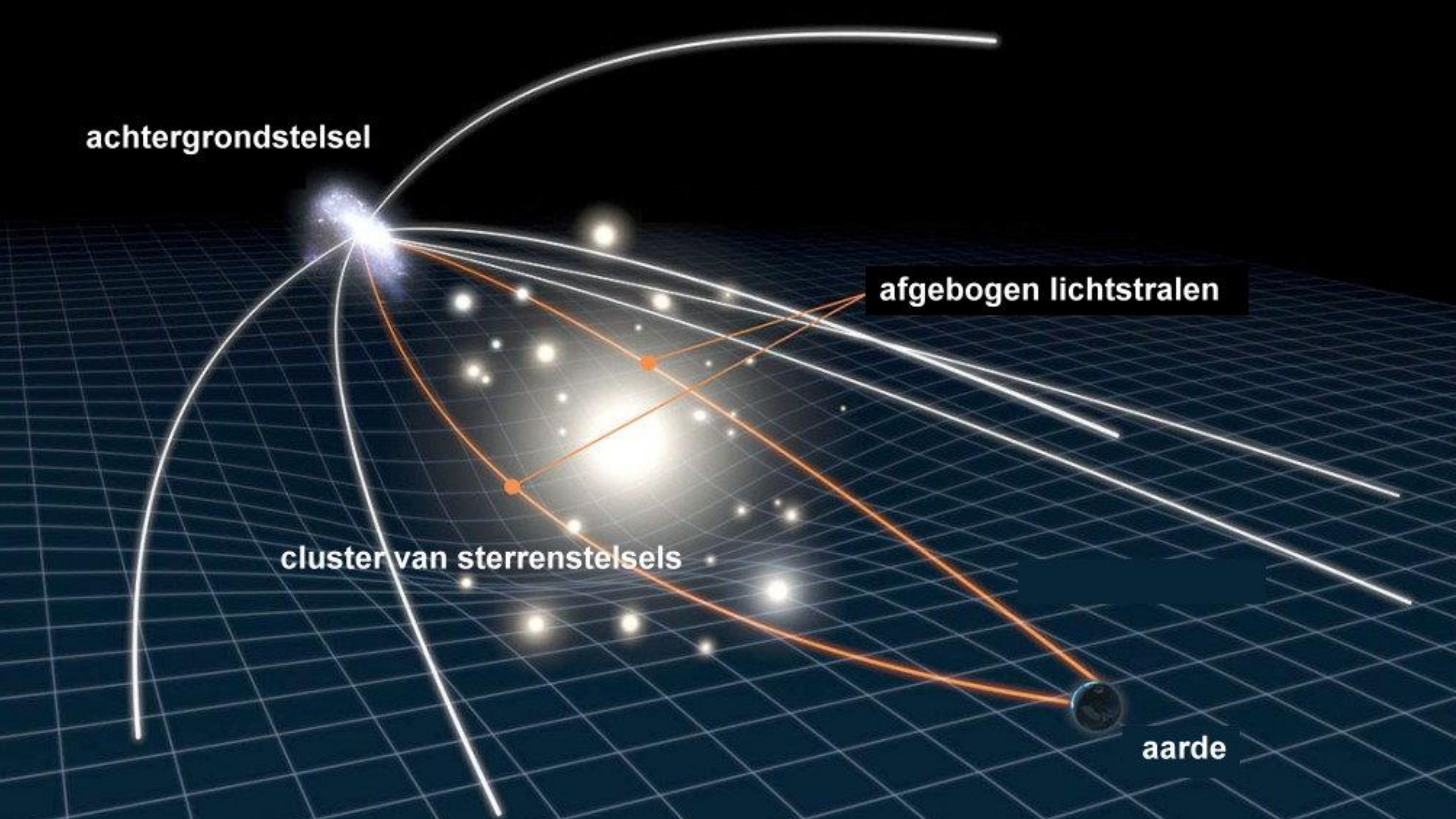


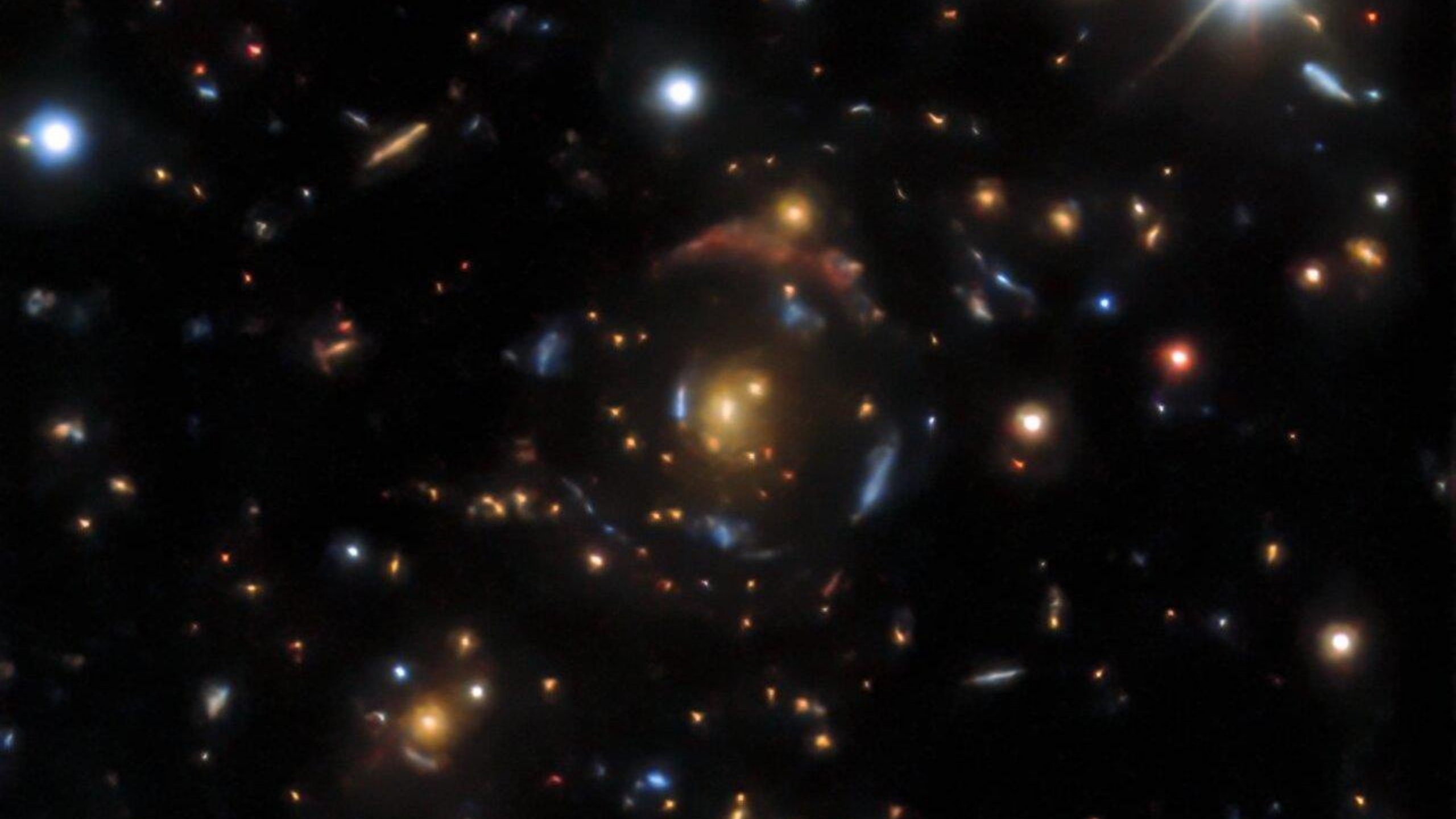
achtergrondstelsel

afgebogen lichtstralen

cluster van sterrenstelsels

aarde

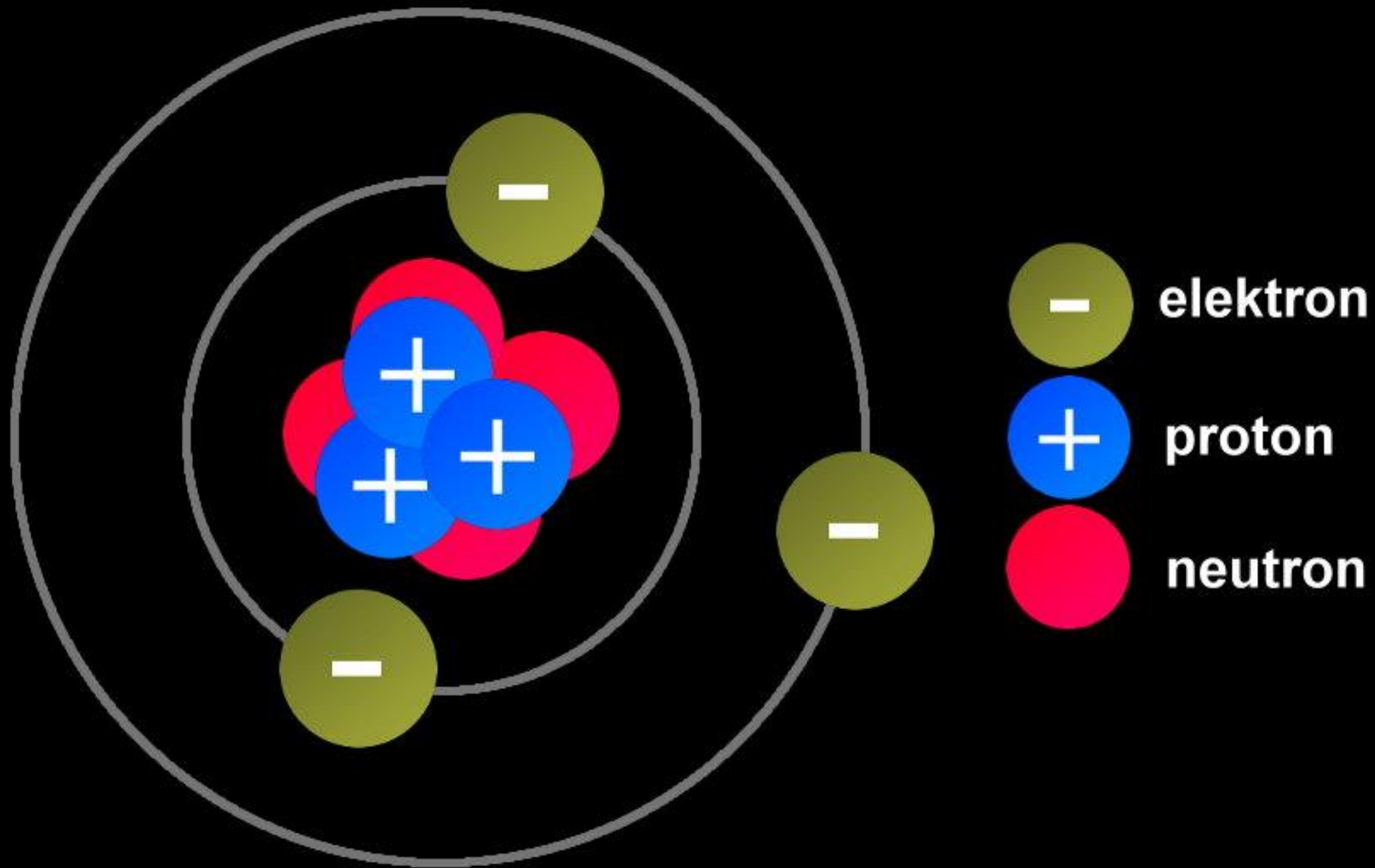




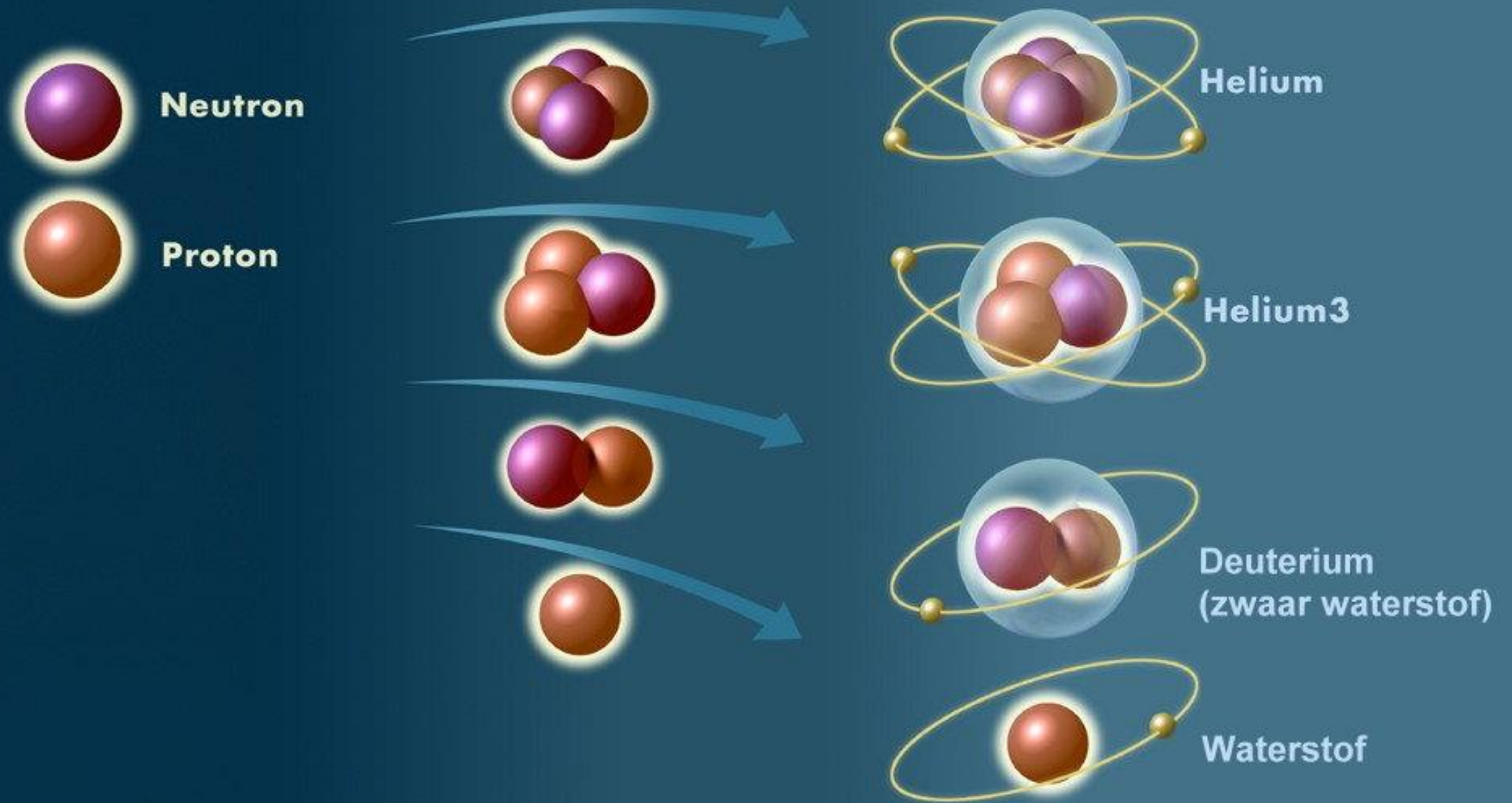


Donkere materie kan niet
bestaan uit de gewone
atomen en moleculen waaruit
de zichtbare wereld om ons
heen is opgebouwd











Copernicus



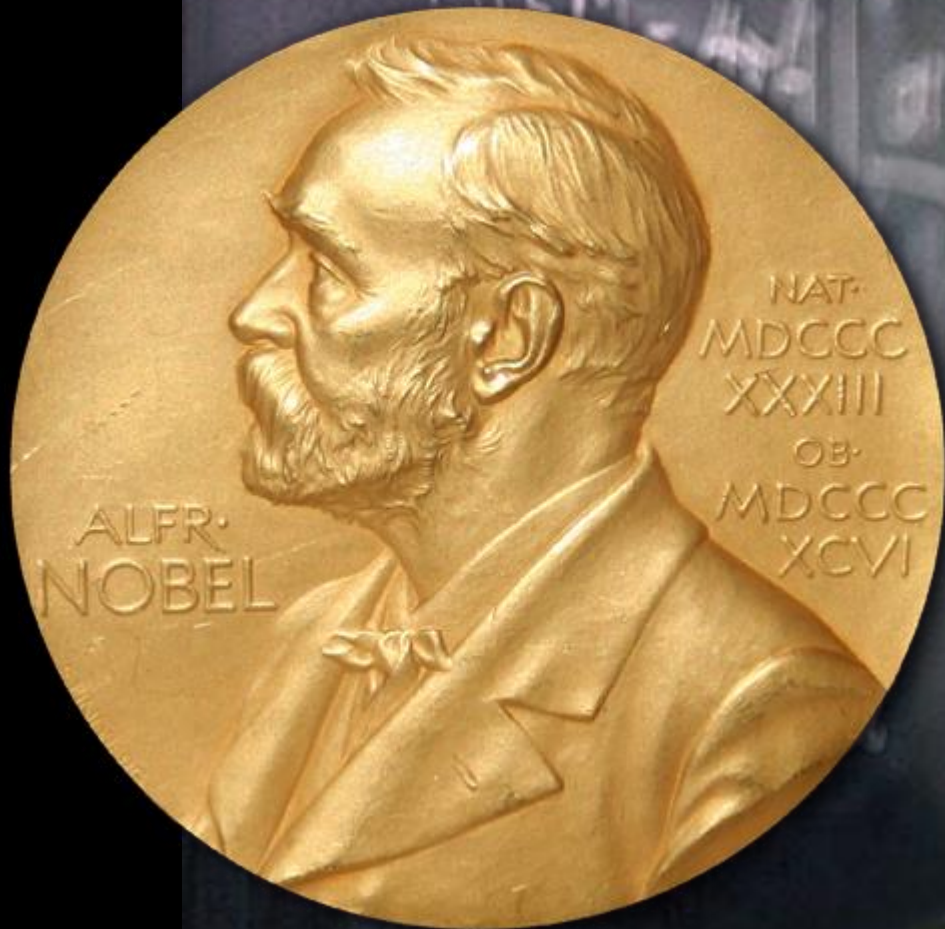


baryonische
materie

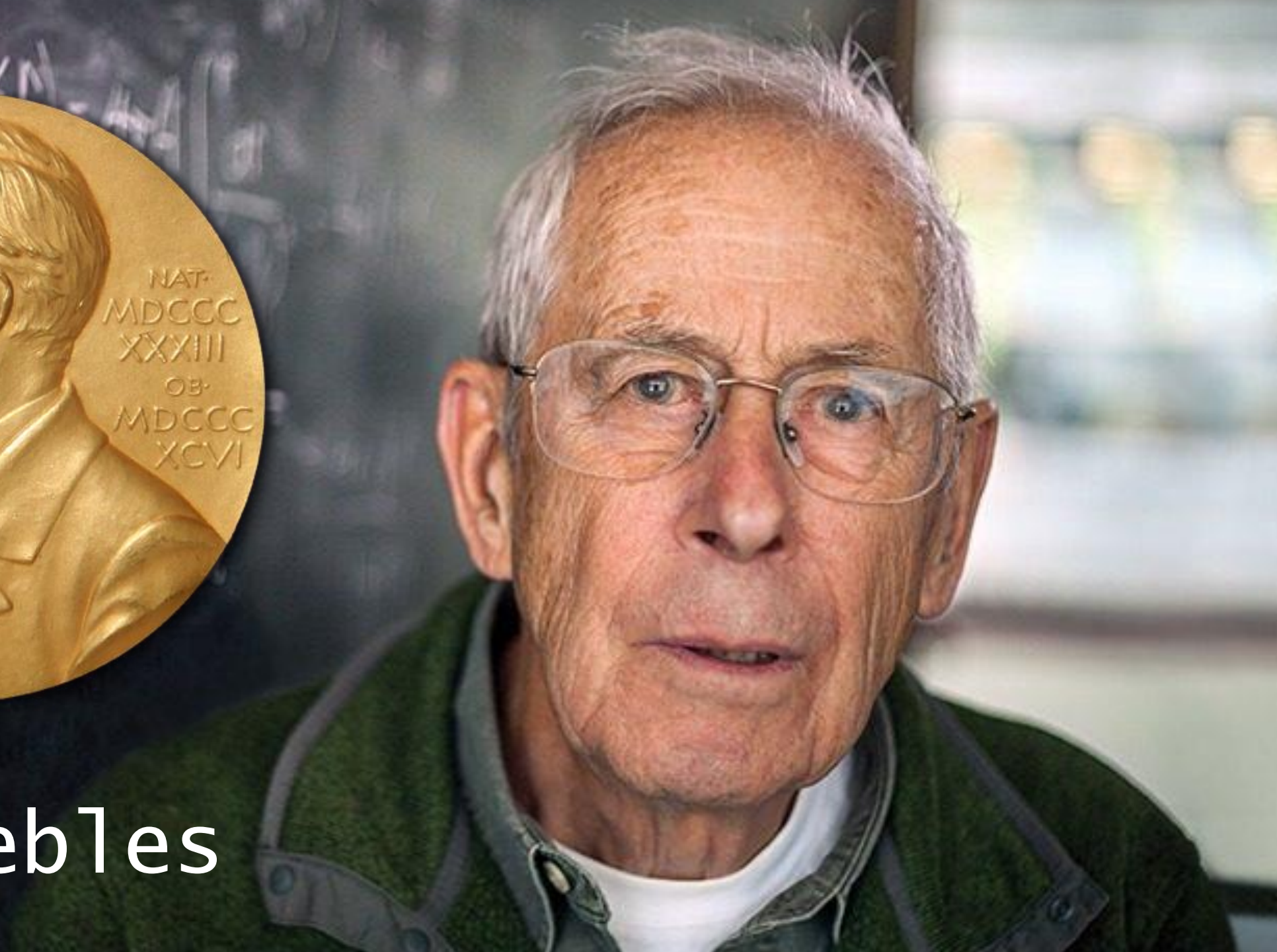


baryonische
materie

niet-baryonische materie

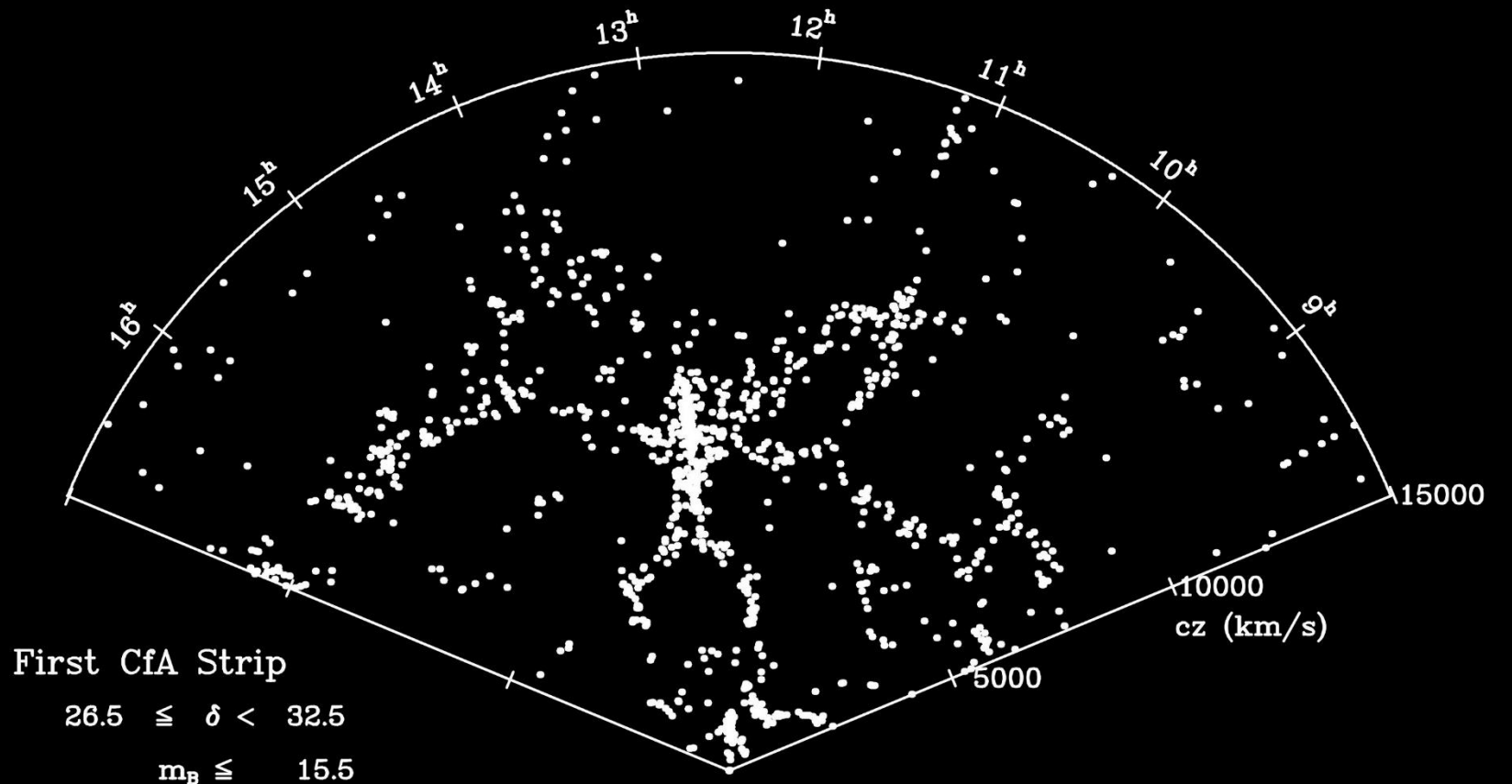


Jim Peebles



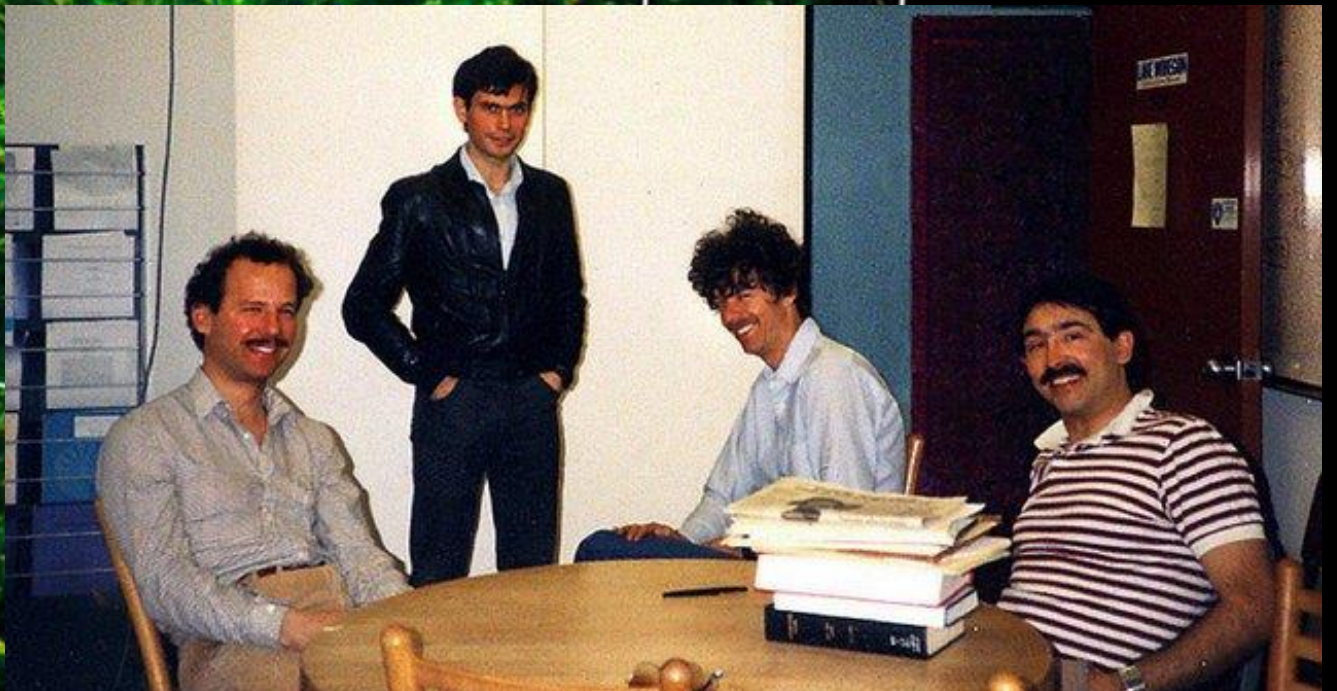


Arno Penzias en Robert Wilson

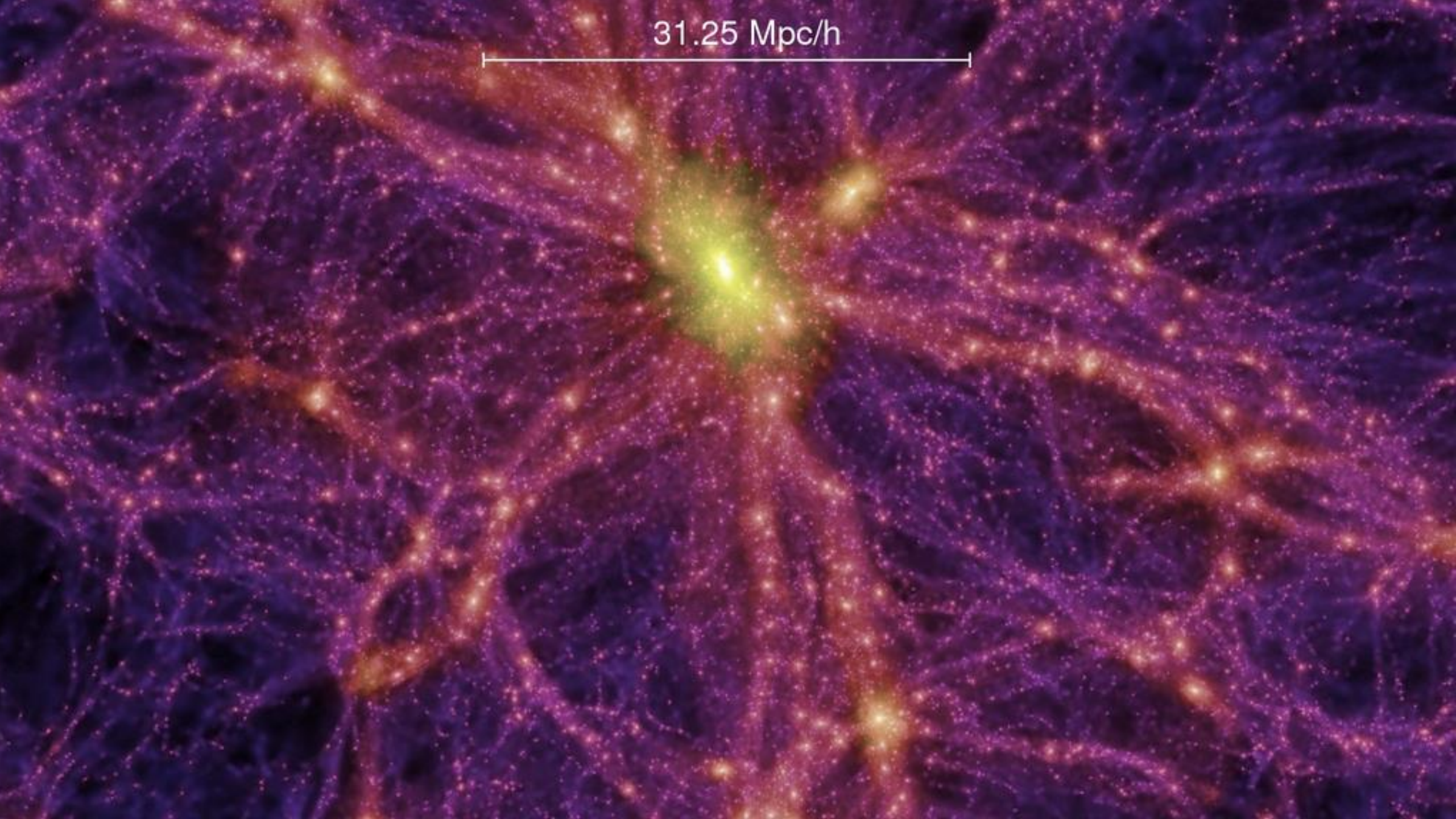


Bende van Vier:

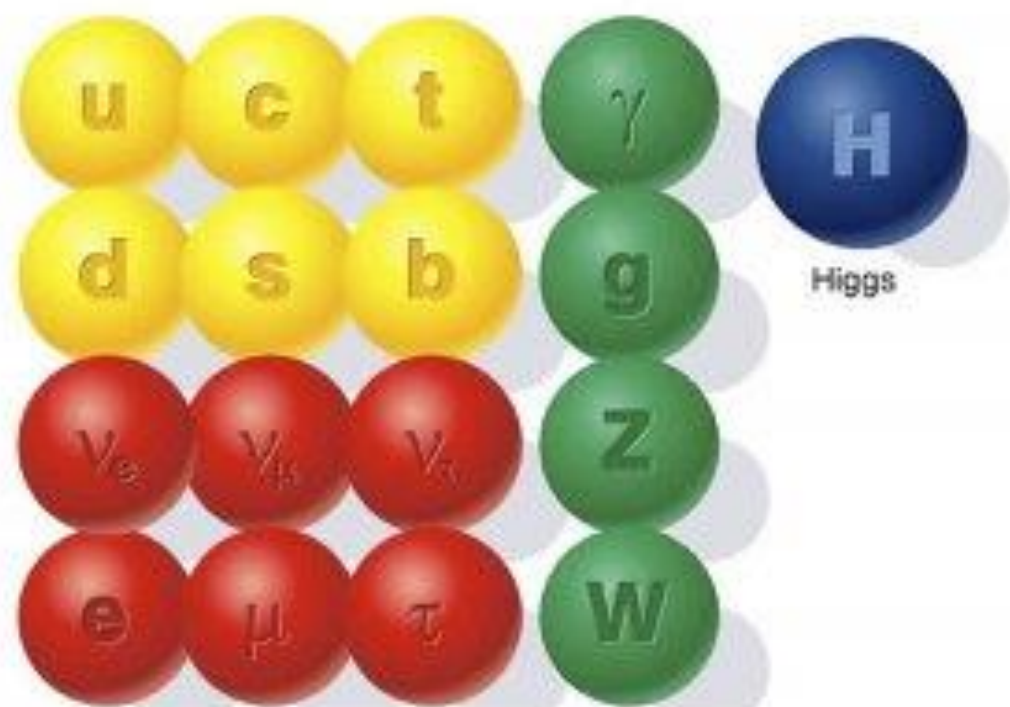
Marc Davis
George Efsthathiou
Simon White
Carlos Frenk



31.25 Mpc/h



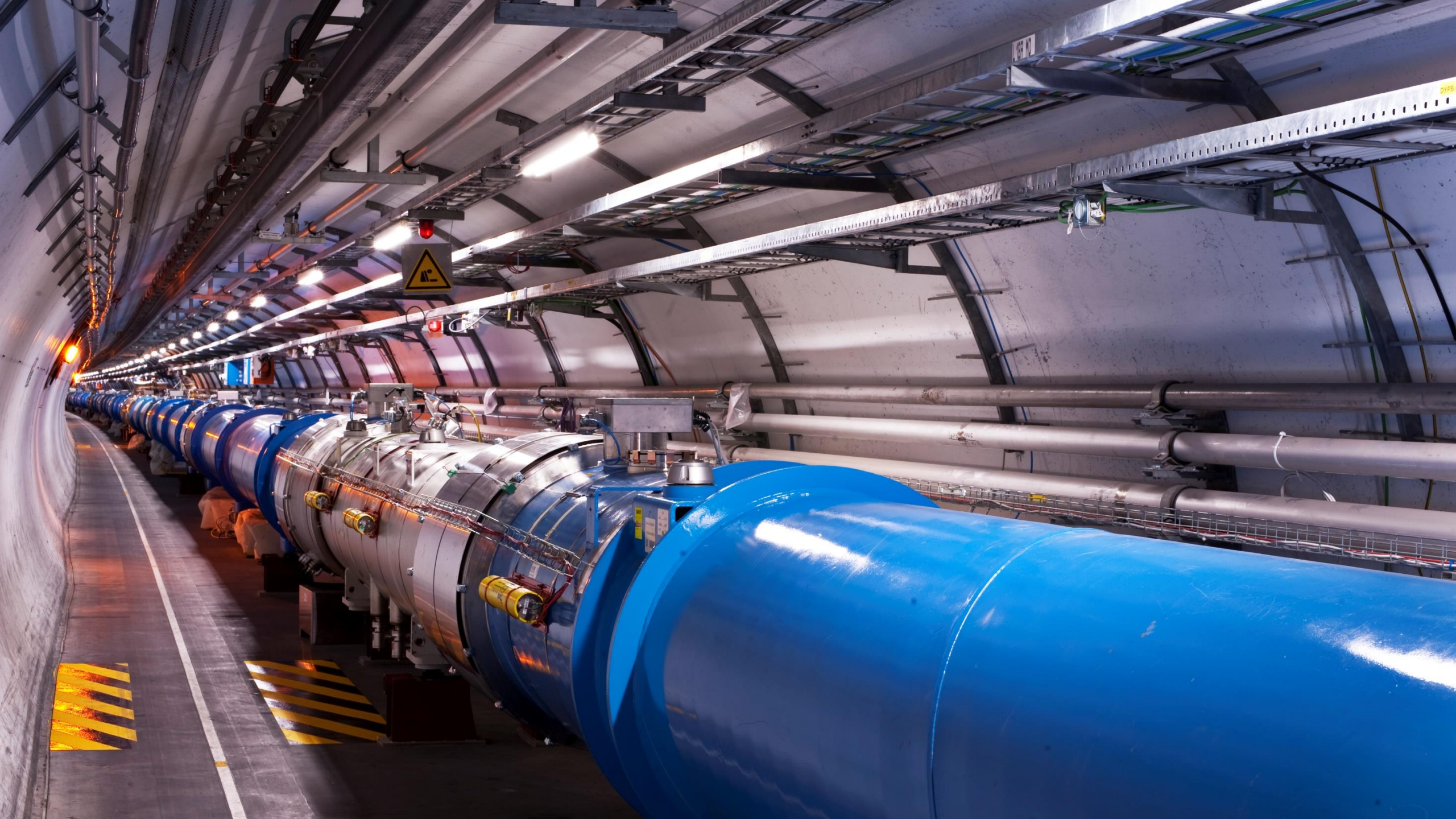
Standaardmodel

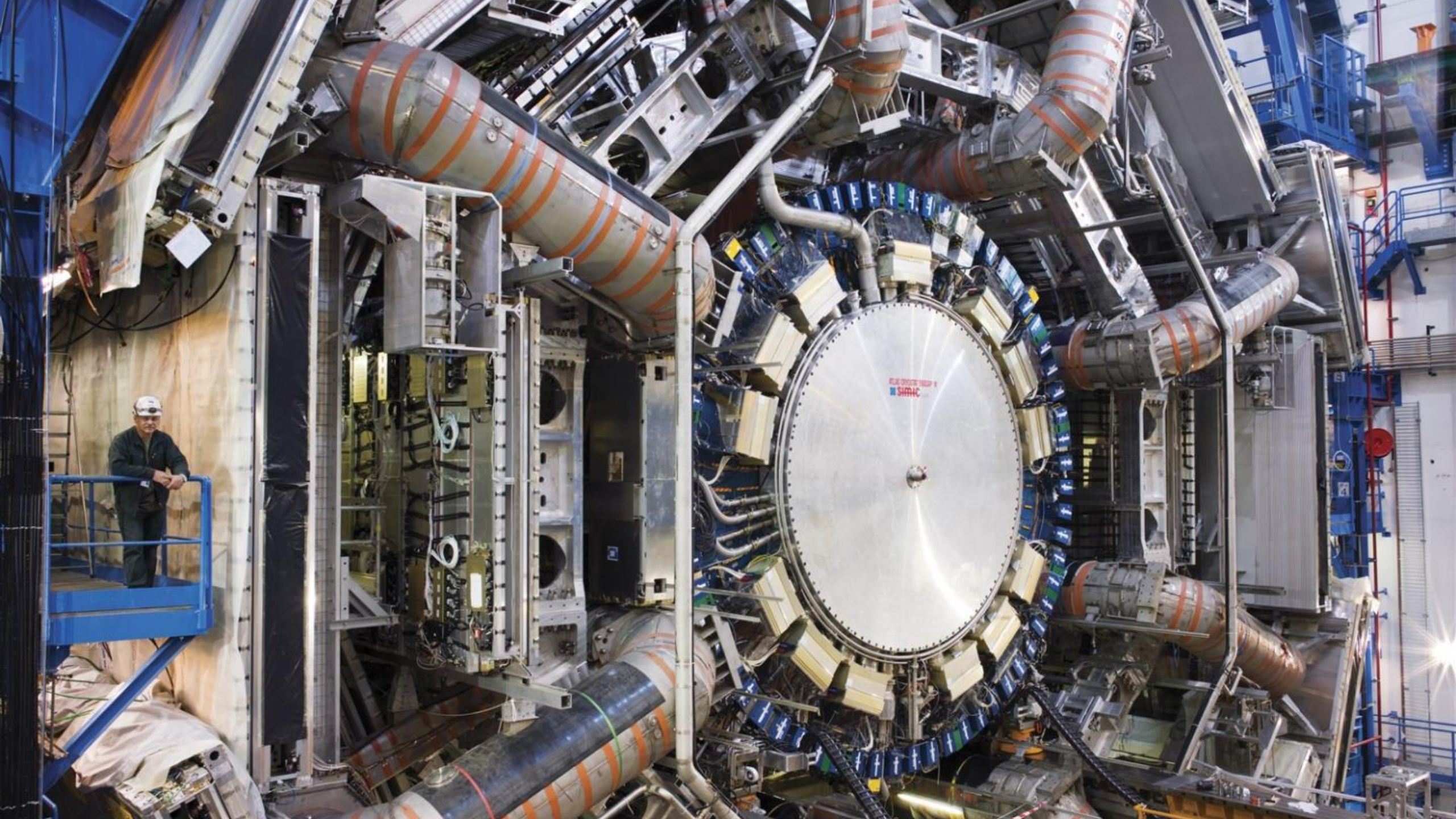


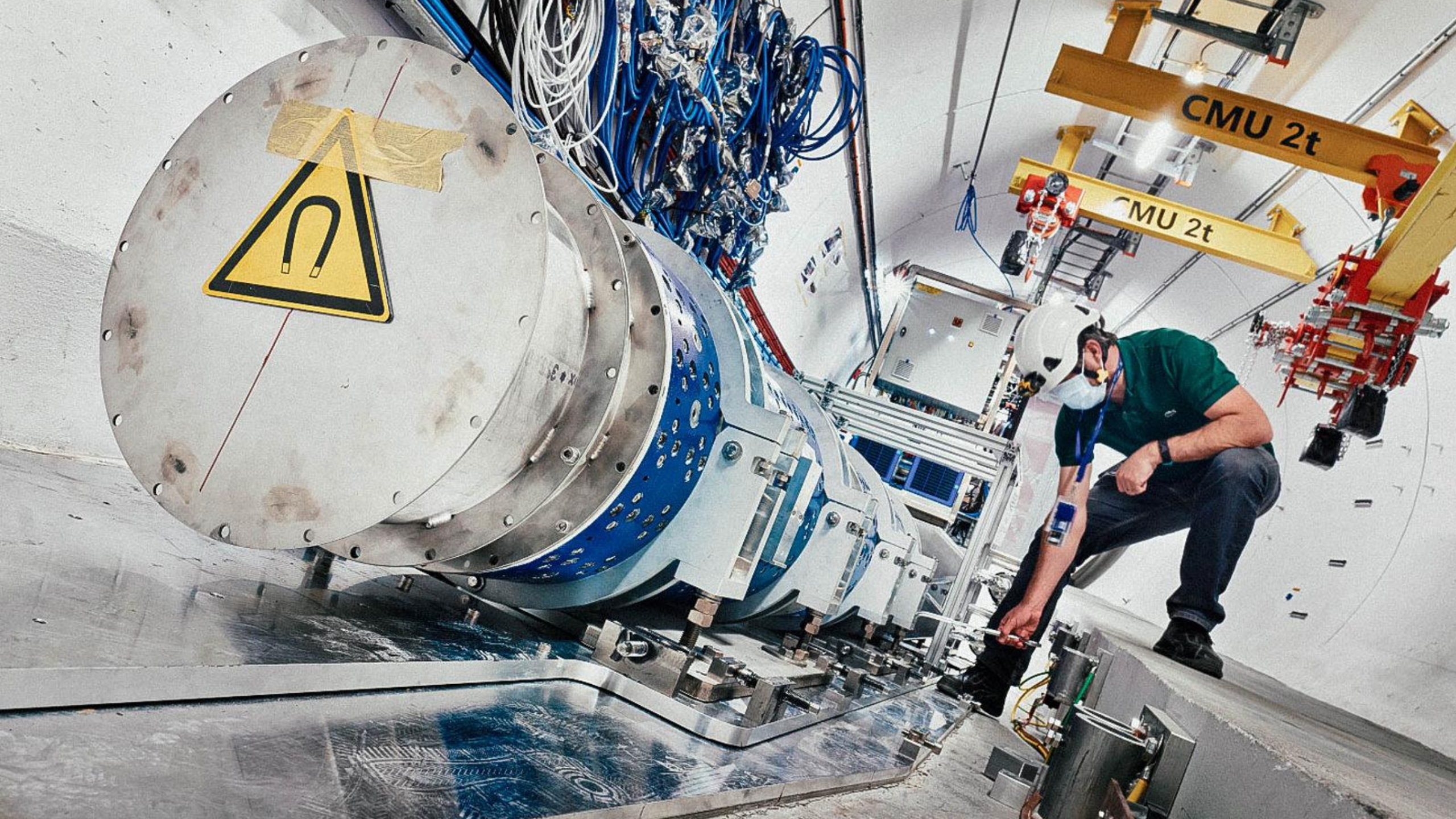
- quarks
- leptonen
- krachtdragende deeltjes



WIMP:
weakly
Interacting
Massive
Particle





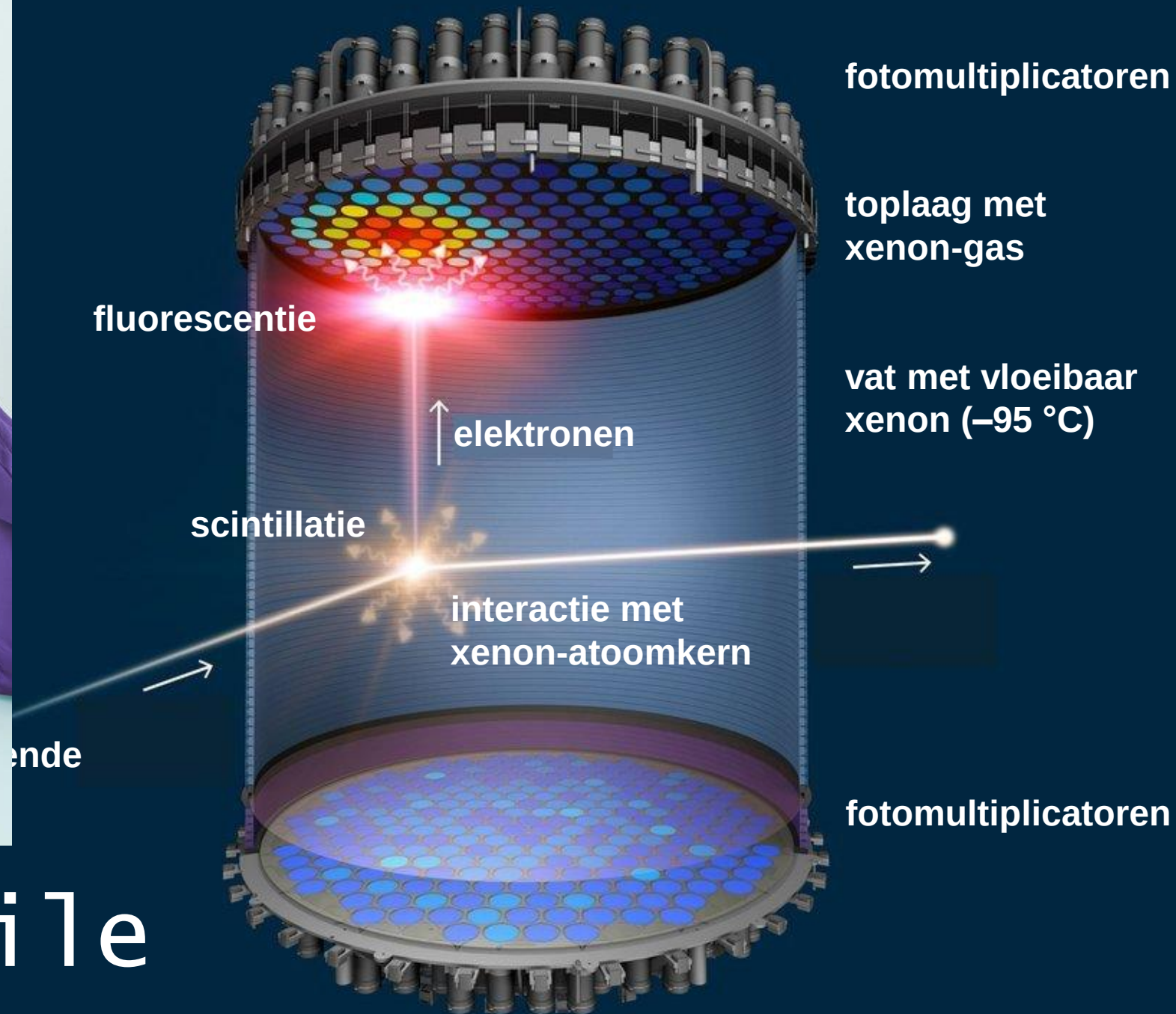


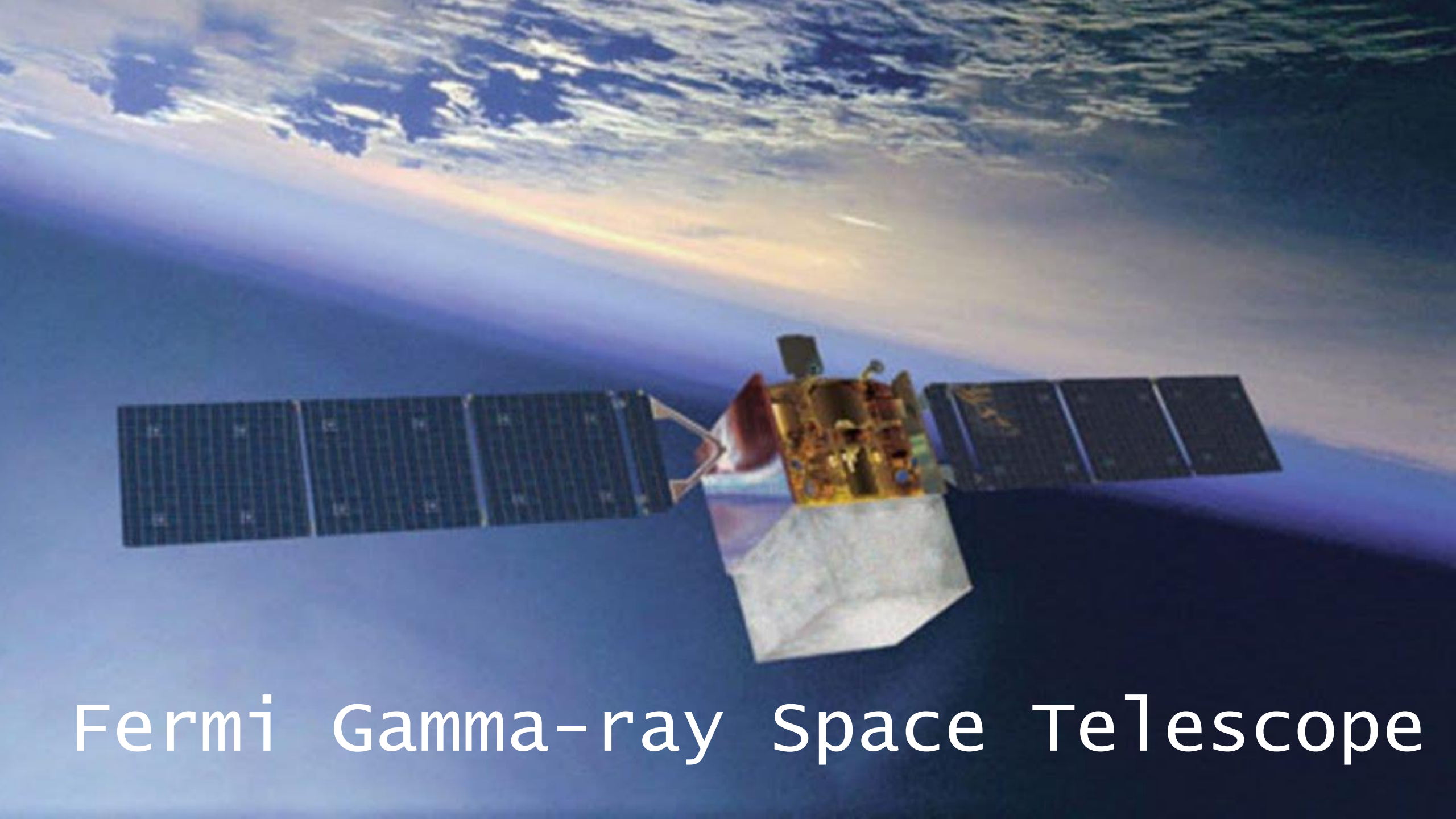






Elena Aprile



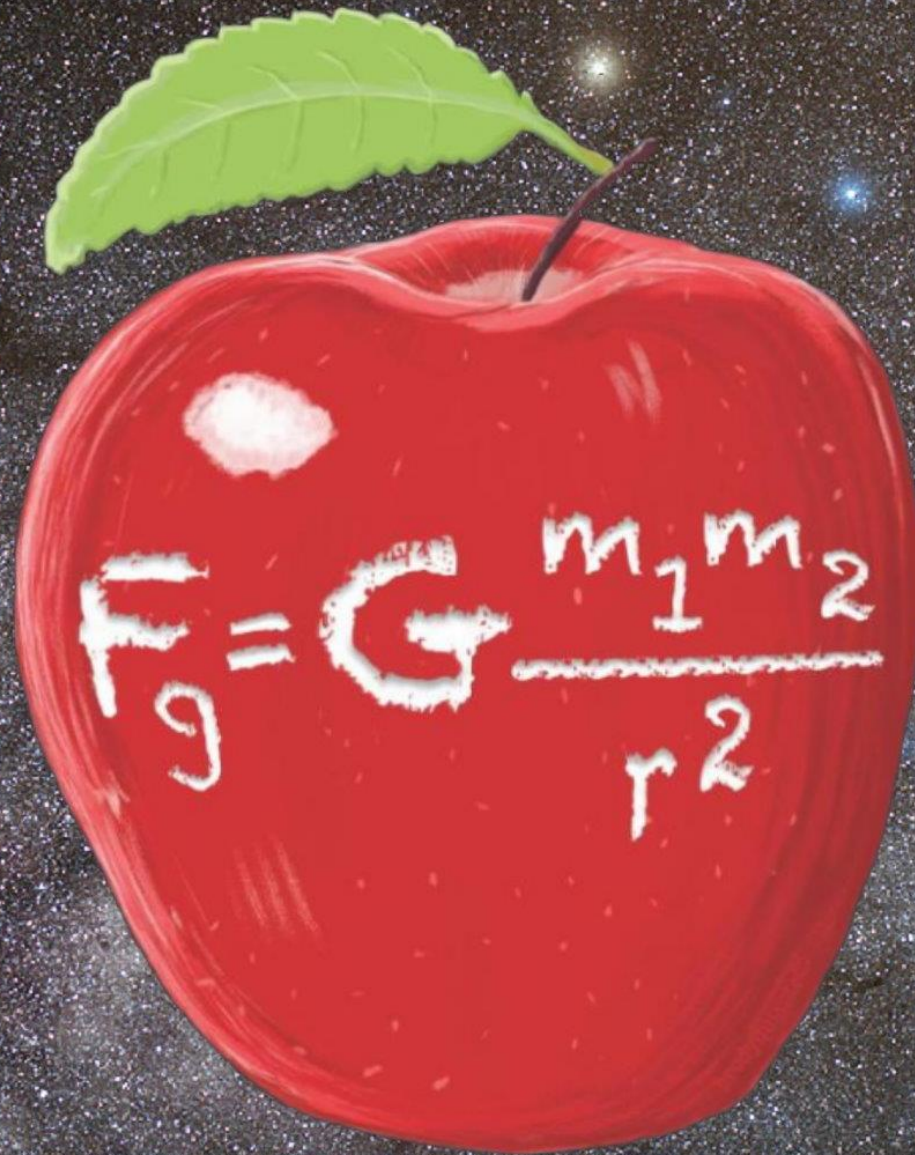


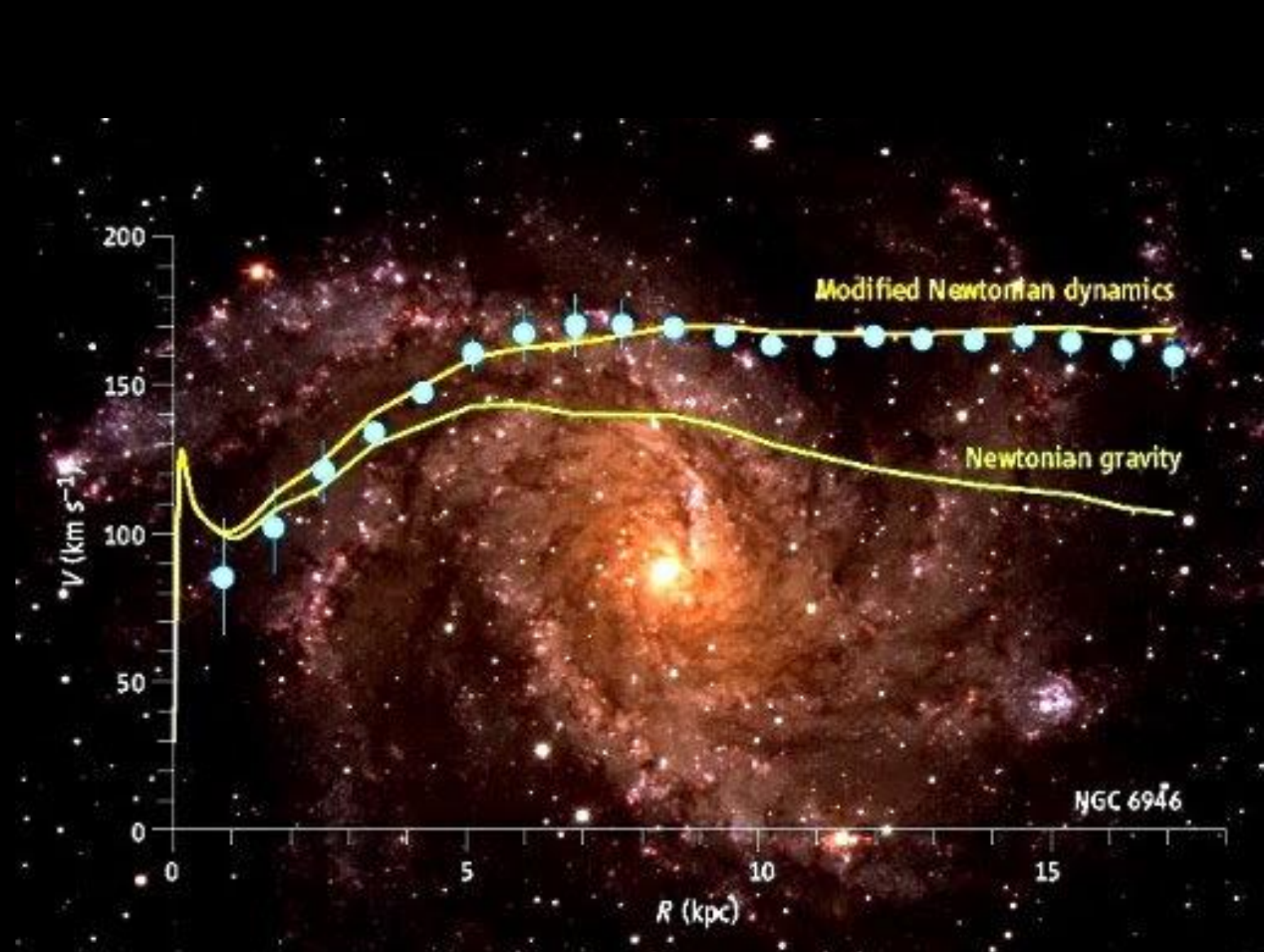
Fermi Gamma-ray Space Telescope



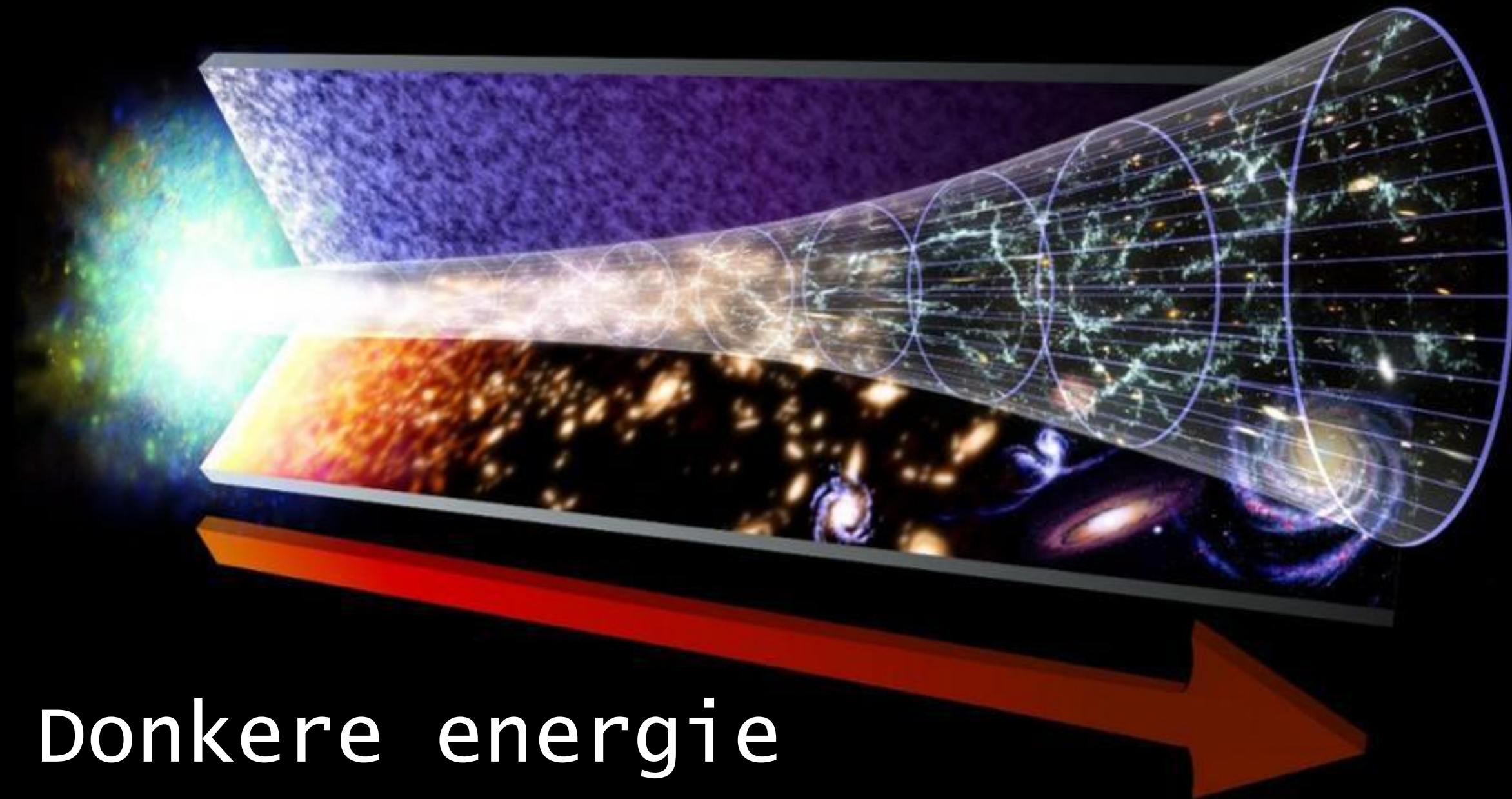


MOND:
Modified
Newtonian
Dynamics





Mordehai Milgrom



Donkere energie

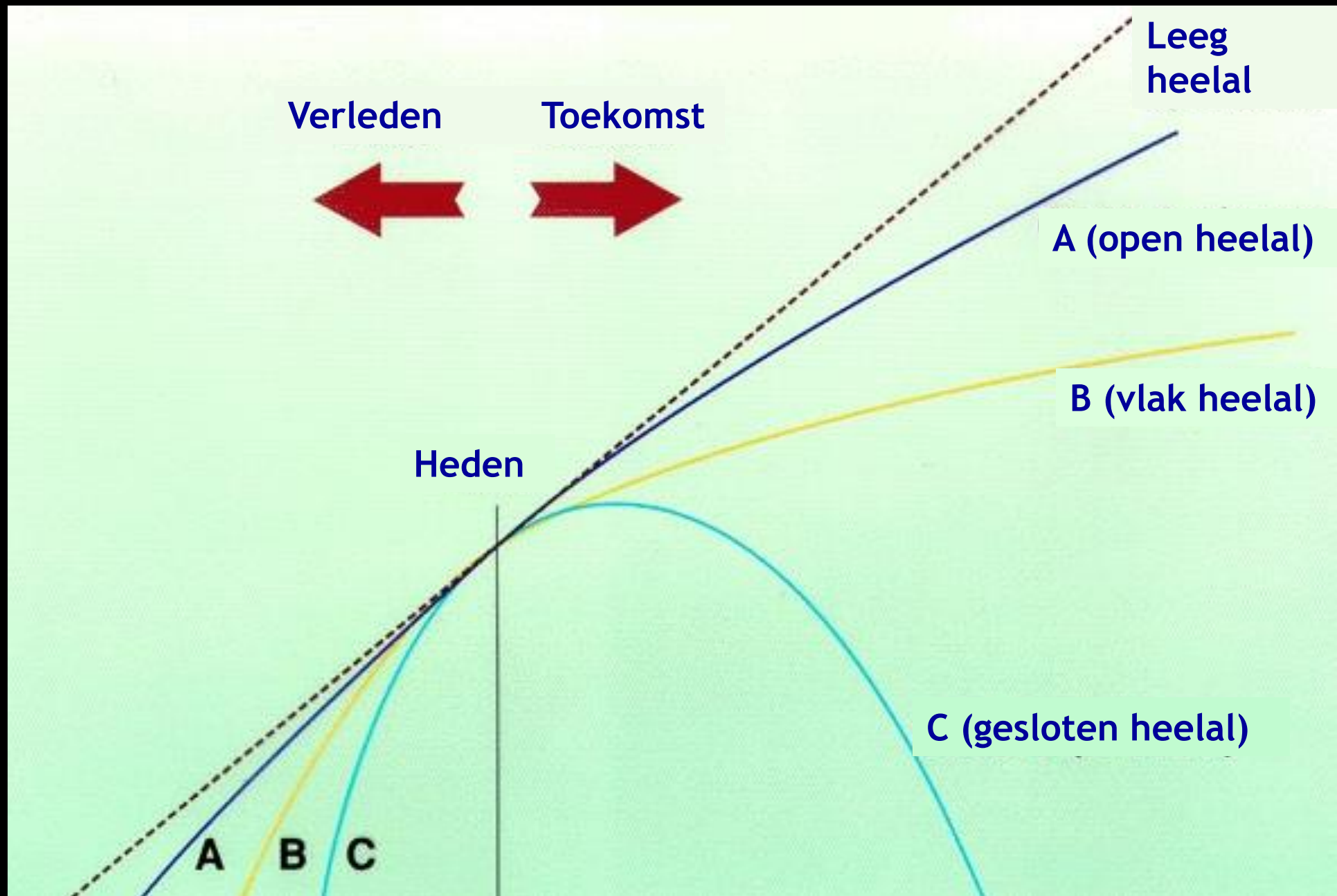
De toekomst van het heelal

Zwaartekracht remt uitdijning af

Veel materie: uitdijning keert om in
inkrimping (*big crunch*)

Weining materie: uitdijning gaat eeuwig
door; snelheid is uiteindelijk constant

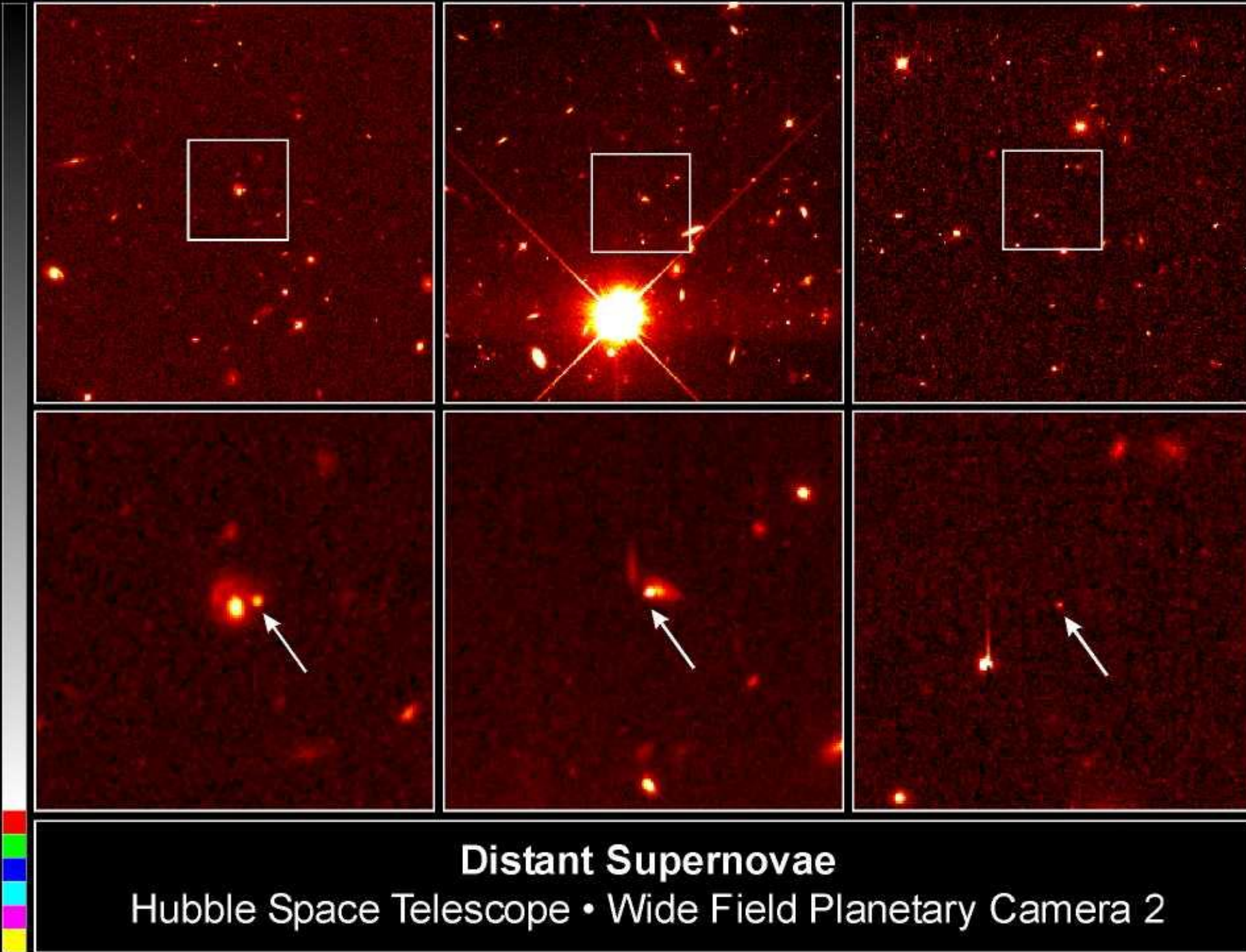
Grensgeval (kritische dichtheid): uitdijning
komt nooit echt tot stilstand, maar
snelheid nadert naar nul

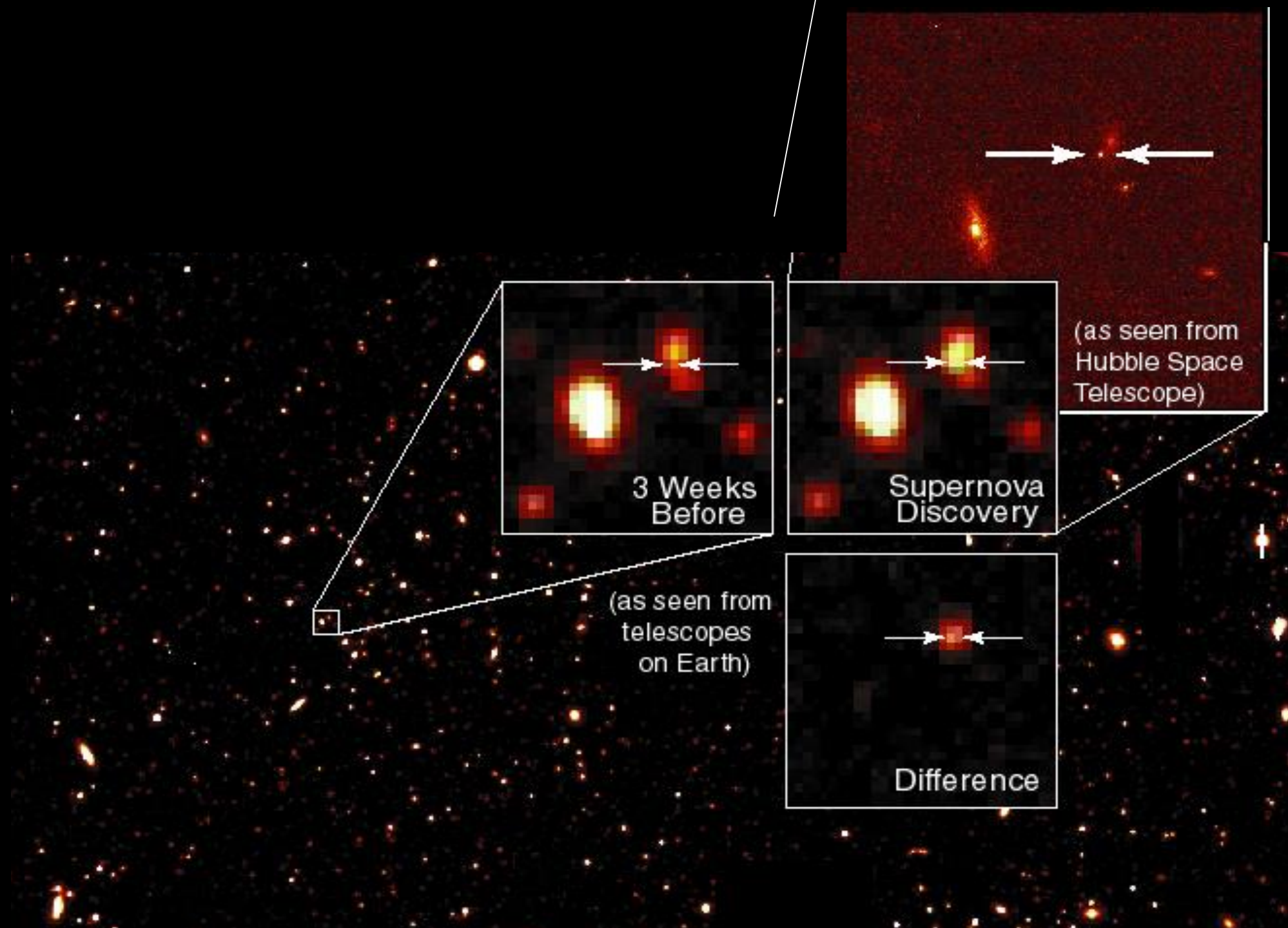


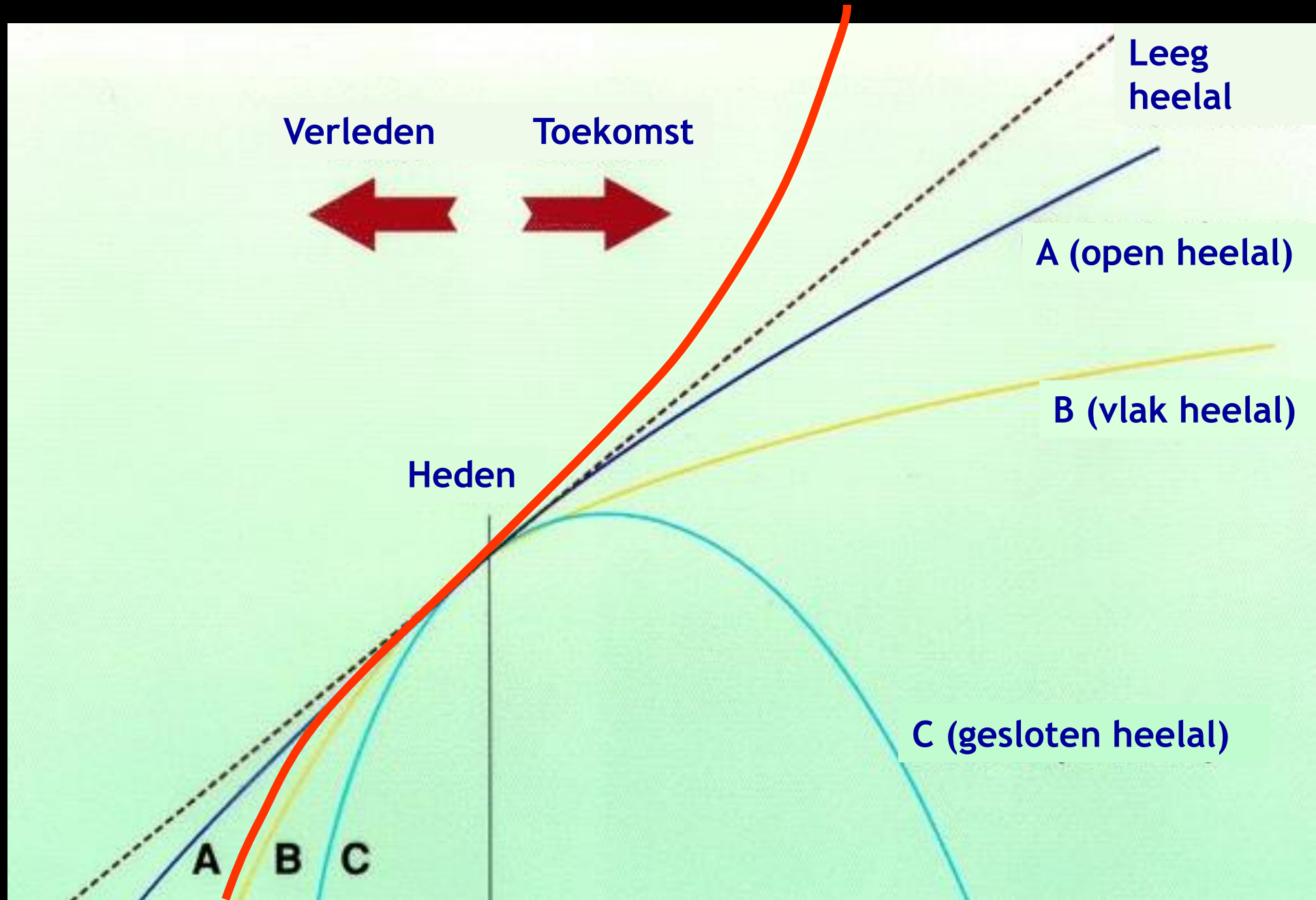






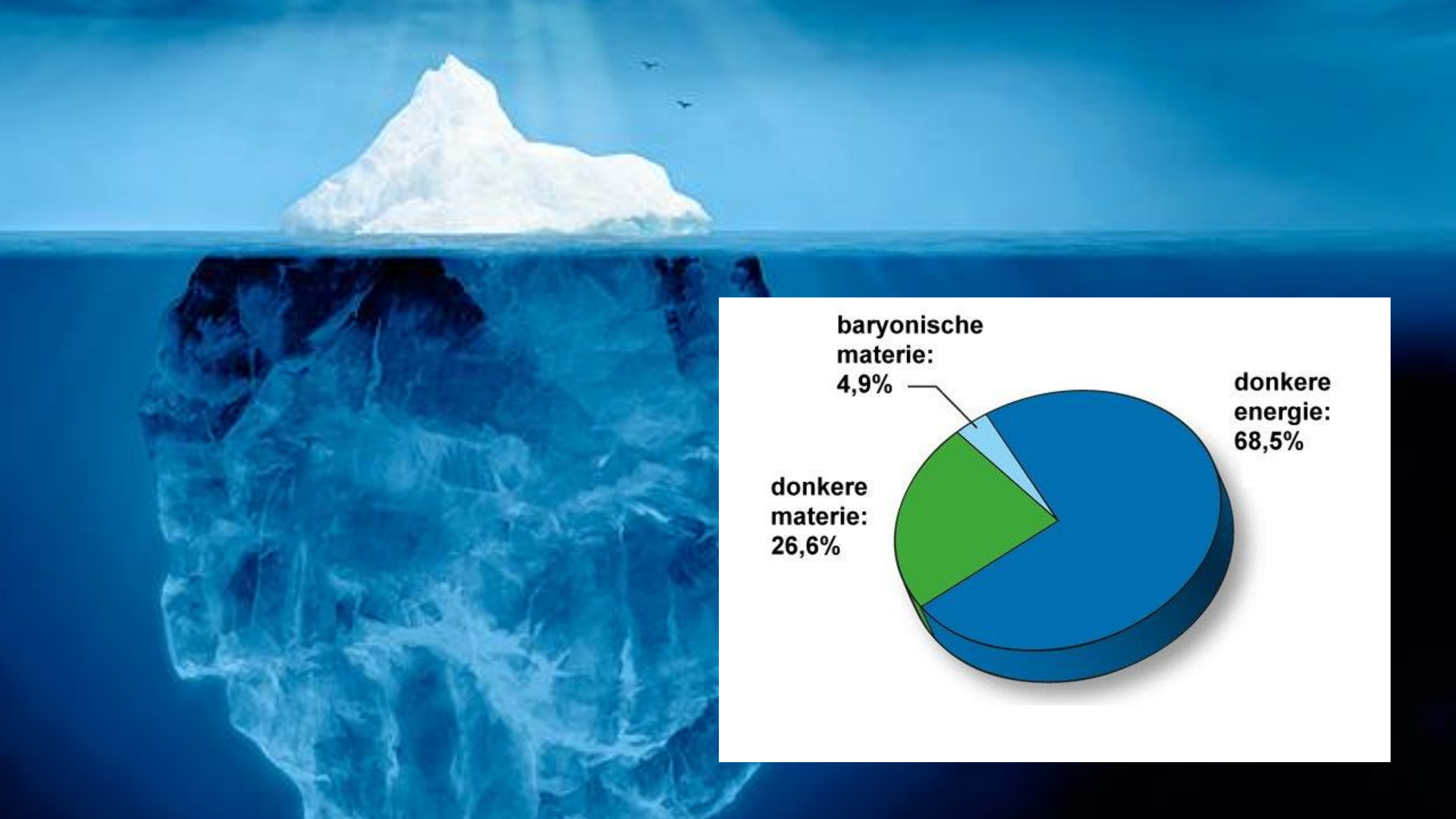








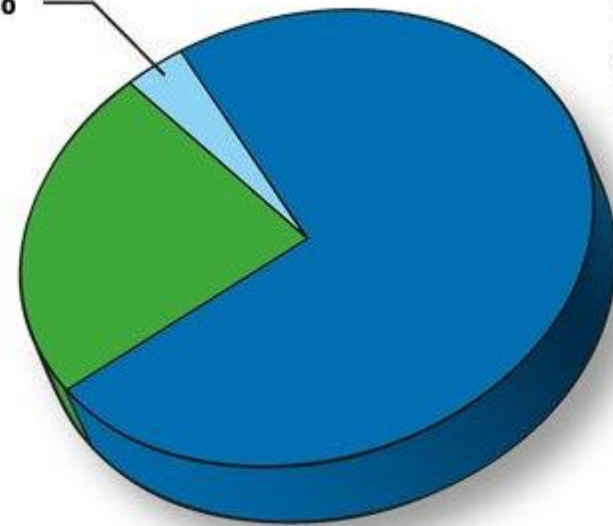
Precisi kosmologie



**baryonische
materie:**
4,9%

**donkere
materie:**
26,6%

**donkere
energie:**
68,5%

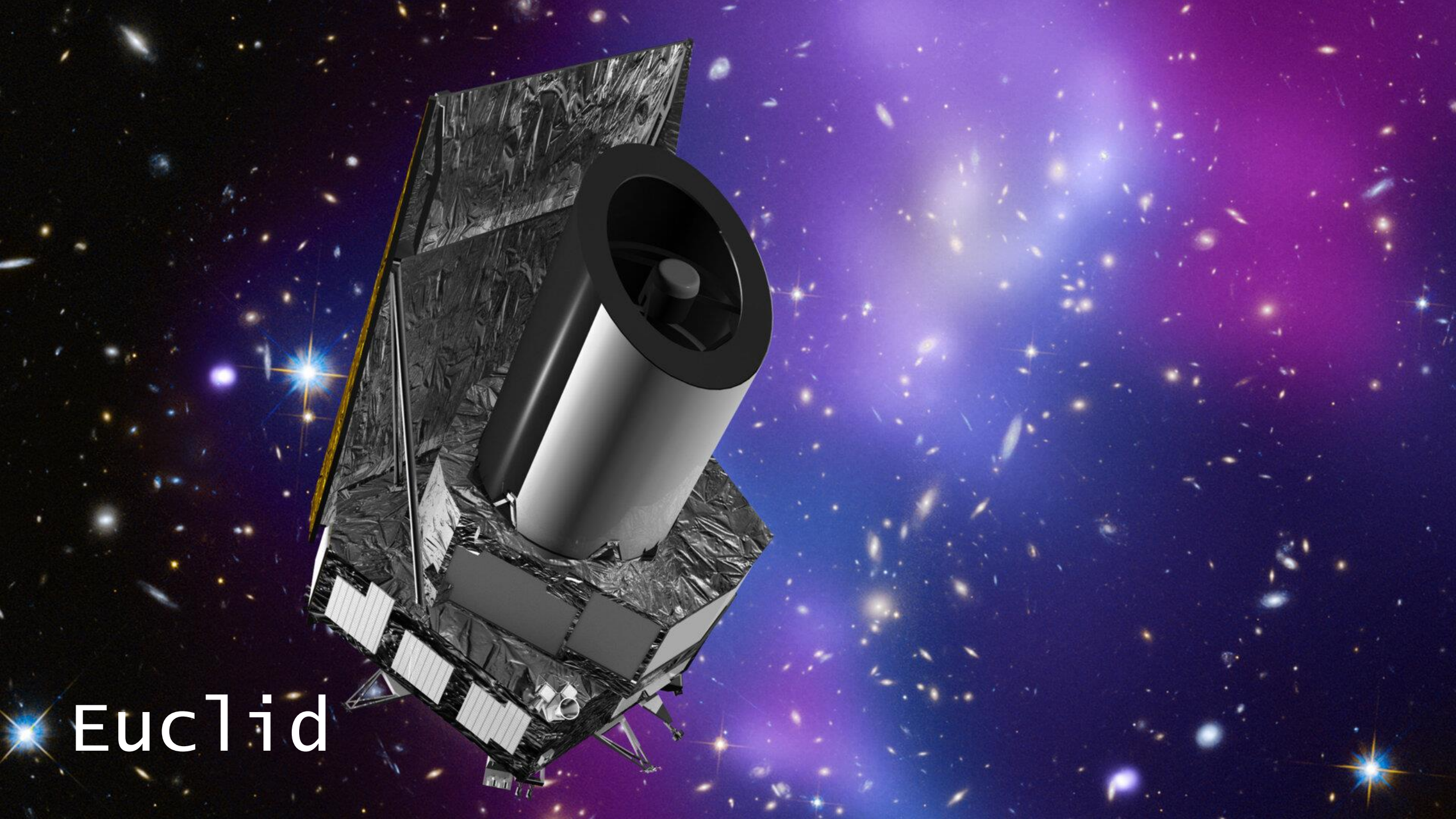




James Webb Space Telescope



Vera C. Rubin Observatory



Euclid



