Le principe n° 0 de la physique théorique

Jean-Marc Lévy-Leblond

Université de Nice

Avertissement.
Les pages suivantes ne proposent que le squelette de l'exposé, qui a été détaillé en *live* au tableau noir.

Le principe n° 0
de la physique théorique :

Ne jamais faire de calcul
avant d'en connaître le résultat

Autrement dit :

Avant de se lancer dans des calculs théoriques compliqués, se convaincre que le choix des arguments théoriques et des valeurs numériques utilisés est raisonnable et conduira à des résultats plausibles

John A. Wheeler

Le principe n° 0
de la physique théorique :

« Never make a calculation until you know the answer. Make an estimate before every calculation, try a simple physical argument (symmetry! invariance! conservation!) before every derivation, guess the answer to every paradox and puzzle. (…) A right guess reinforces your intuition. A wrong guess brings the refreshment of surprise. »

John A. Wheeler

John Archibald Wheeler
(1911-2008)

— physique nucléaire
(+ projet Manhattan)
— gravitation et relativité générale
— fondations de la théorie quantique

Une brève histoire de l'*art* de la physique qualitative

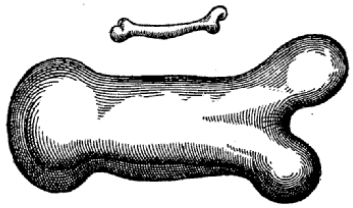
— XVIIè siècle : préliminaires
(Galilée)
— XVIIIè siècle : latence
(???)
— XIXè siècle : développement
(Maxwell, Rayleigh, Kelvin,…)
— XXè siècle : déploiement
(Fermi, Weisskopf, Wheeler, Feynman…)

Une brève histoire de l'*art* de la physique qualitative

DISCORSI
E
DIMOSTRAZIONI
MATEMATICHE,
intorno à due nuoue ſcienze
Attenenti alla
MECANICA & I MOVIMENTI LOCALI,
del Signor
GALILEO GALILEI LINCEO,
Filoſofo e Matematico primario del Sereniſſimo
Grand Duca di Toſcana.
Con vna Appendice del centro di grauità d'alcuni Solidi.

IN LEIDA,
Appreſſo gli Elſevirii. M. D. C. XXXVIII.

E per vn breue eſempio di queſto che dico diſegnai già la figura di vn' oſſo allungato ſolamente tre volte, & ingroſſato con tal proporzione, che poteſſe nel ſuo animale grande far l'uffizio proporzio-



nato à quel dell' oſſo minore nell' animal più piccolo, e le figure ſon queſte: doue vedete ſproporzionata figura, che diuiene quella dell' oſſo ingrandito. Dal che è manifeſto, che chi voleſſe mantener in vn vaſtiſſimo Gigante le proporzioni, che hanno le membra in vn huomo ordinario, biſognerebbe ò trouar materia molto più dura, e reſiſtente per formarne l'oſſa, ò vero ammettere, che la robuſtezza ſua fuſſe à proporzione aſſai più fiacca, che ne gli huomini di ſtatura mediocre; altrimente creſcendogli à ſmiſurata altezza ſi vedrebbono dal proprio peſo opprimere, e cadere. Doue che all' incontro ſi vede nel diminuire i corpi non ſi diminuir con la medeſima proporzione le forze, anzi ne i minori creſcer la gagliardia con proporzion maggiore. Onde io credo che vn piccolo cane porterebbe addoſſo due, ò trè cani eguali à ſe, mà non penſo già che vn cauallo portaſſe ne anco vn ſolo cauallo à ſe ſteſſo eguale.

Simp. *Mà ſe così è, grand' occaſione mi danno da dubitare le moli immenſe, che vediamo ne i peſci, che tal Balena, per quanto intendo, ſarà grande per dieci Elefanti, e pur ſi ſoſtengono.*

Salu. *Il voſtro dubbio S. Sim. mi fà accorgere d'una condizione da me non auuertita prima, potente eſſa ancora à far che Giganti,*

Une brève histoire de l'*art* de la physique qualitative

LES ÉPOQUES
DE
LA NATURE,
PAR MONSIEUR
LE COMTE DE BUFFON,
Intendant du Jardin & du Cabinet du Roi, de l'Académie Françoiſe, de celle des Sciences, &c.

TOME PREMIER.

A PARIS,
DE L'IMPRIMERIE ROYALE.

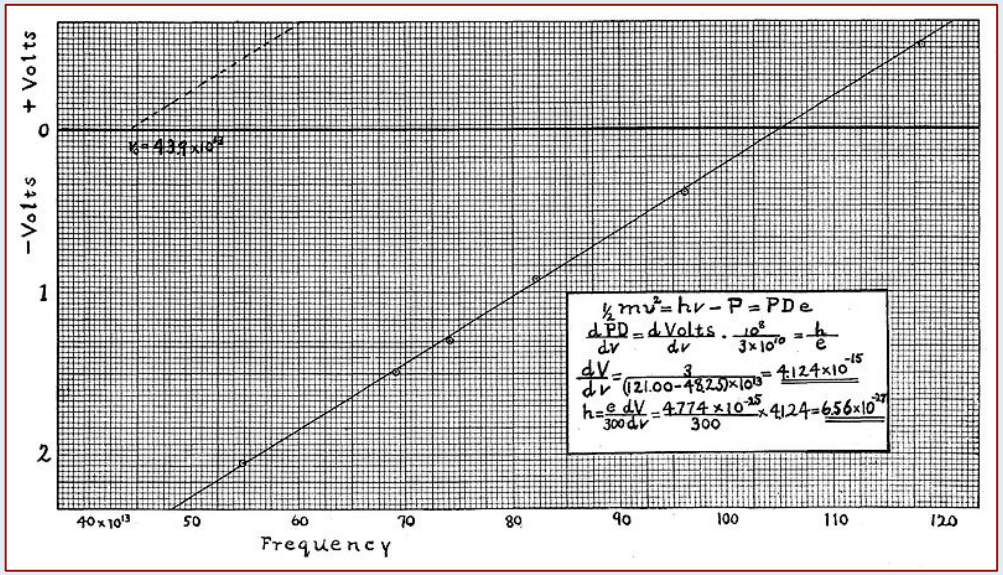
M. DCC. LXXX.

COMMENCEMENT, FIN & DURÉE *de l'exiſtence de la* NATURE ORGANISÉE *dans chaque* PLANÈTE.

	COMMENCEMENT.	FIN.	DURÉE abſolue.	DURÉE à dater de ce jour.
	de la format.	de la format.	ans.	ans.
V.Satel. de Sat.	5161 des Plan.	47558 des Plan.	42389...	6 . . .
LA LUNE.	7890 . . .	72514 . . .	64624...	0 . . .
MARS.	. .13685 . . .	60326 . . .	56641...	0 . . .
IV.Satel. de Sat.	18399 . . .	76525 . . .	58126...	1693 . . .
IV.Satel. de Jup.	23730 . . .	98696 . . .	74966...	23864 . . .
MERCURE...	26053 . . .	187765 . . .	161712...	112933 . . .
LA TERRE.	35985 . . .	168123 . . .	132140...	93291 . . .
III.Satel. de Sat.	37672 . . .	156658 . . .	118986...	81826 . . .
II.Satel. de Sat.	40373 . . .	167928 . . .	127655...	93096 . . .
I.Satel. de Sat.	42021 . . .	174784 . . .	132763...	99952 . . .
VÉNUS.	. .44067 . . .	228540 . . .	184473...	153708 . . .
An. de Sat....	56396 . . .	177568 . . .	121172...	102736 . . .
III.Satel. de Jup.	59483 . . .	247401 . . .	187918 . .	172569 . . .
SATURNE.	. .62926 . . .	262020 . . .	199114...	187188 . . .
II.Satel. de Jup.	64496 . . .	271098 . . .	206602...	196266 . . .
I.Satel. de Jup.	74724 . . .	311973 . . .	237249...	237141 . . .
JUPITER....	115623 . . .	483121 . . .	367498...	

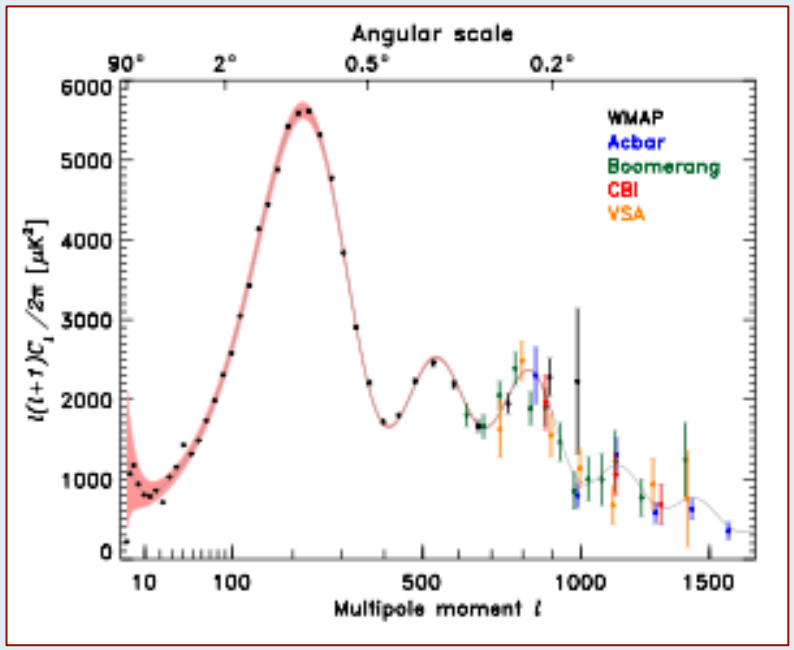
Pascal Richet

Histoire de l'*art* de la physique qualitative

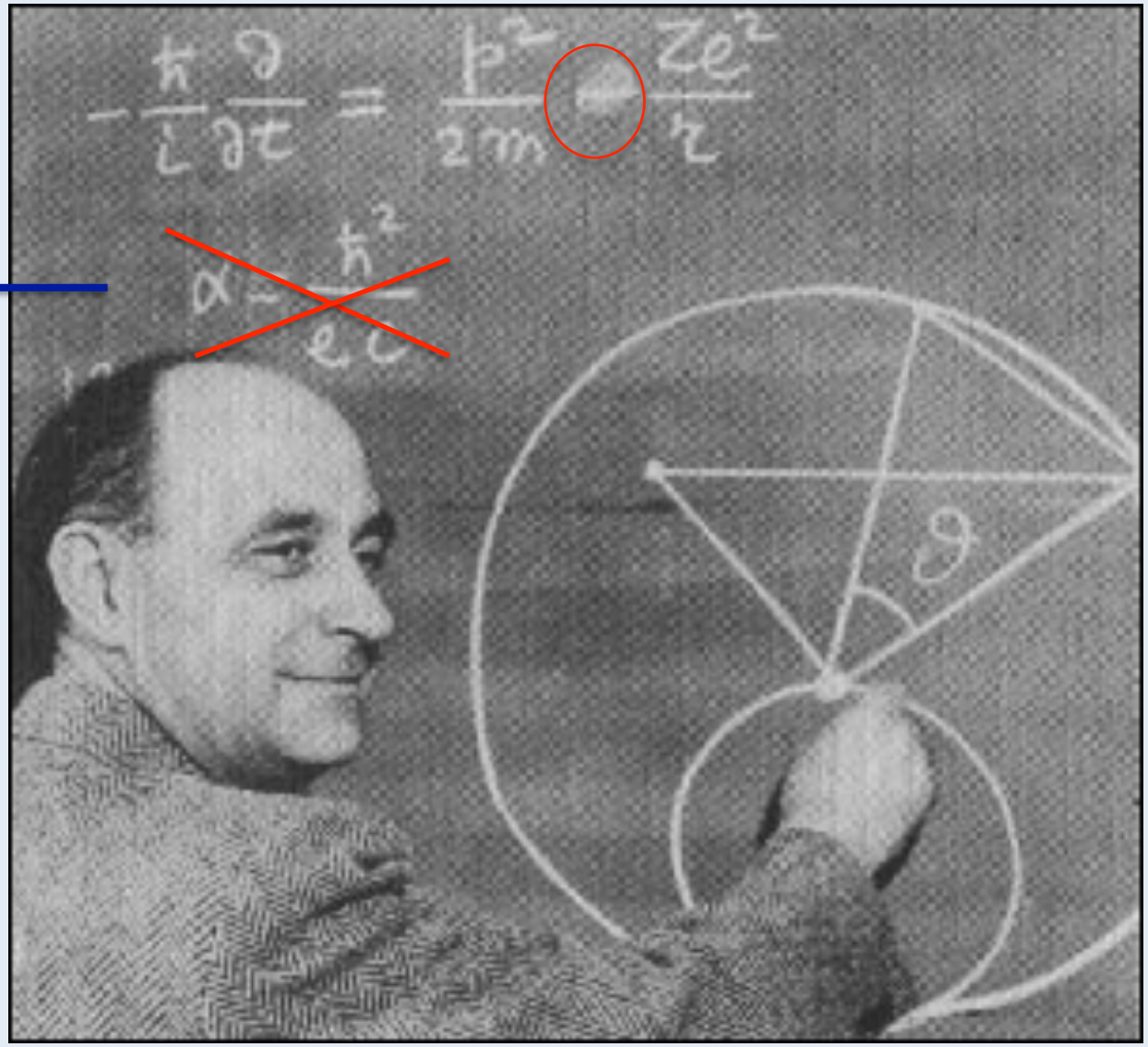


Effet photoélectrique
Millikan, 1906

Spectre de puissance du
rayonnement cosmique
en fonction de l'échelle angulaire,
2004-2006



$$\alpha = \frac{e^2}{\hbar c}$$



Enrico Fermi
1901-1954

Une brève histoire de l'*art* de la physique qualitative

Plus la physique théorique est devenue
quantitativement précise,
plus il lui a fallu devenir
qualitativement compréhensible.

Méthodes qualitatives, (heuristiques, approximatives, …)

— Ordres de grandeur
— Symétries
— Échelles et analyse dimensionnelle
— Étude des cas limites
— Approximations brutales

Méthodes qualitatives, (heuristiques, approximatives, …)

— Ordres de grandeur

L'expérience de Franklin (1763) et la taille des atomes

"At length at Clapham where there is, on the common, a large pond, which I observed to be one day very rough with the wind, I fetched out a cruet of oil, and dropped a little of it on the water. I saw it spread itself with surprising swiftness upon the surface. The oil, though not more than a teaspoonful, produced an instant calm over a space several yards square, which spread amazingly and extended itself gradually until it reached the leeside, making all that quarter of the pond, perhaps half an acre, as smooth as a looking glass.", Franklin, 1773

Expérience refaite par C. H. Giles, *Chem. Ind.*, 1969, 1616

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No. ... of ... Copies, Series ...

My Observations During the Explosion at Trinity on July 16, 1945 — E. Fermi

On the morning of the 16th of July, I was stationed at the Base Camp at Trinity in a position about ten miles from the site of the explosion.

The explosion took place at about 5:30 A.M. I had my face protected by a large board in which a piece of dark welding glass had been inserted. My first impression of the explosion was the very intense flash of light, and a sensation of heat on the parts of my body that were exposed. Although I did not look directly towards the object, I had the impression that suddenly the countryside became brighter than in full daylight. I subsequently looked in the direction of the explosion through the dark glass and could see something that looked like a conglomeration of flames that promptly started rising. After a few seconds the rising flames lost their brightness and appeared as a huge pillar of smoke with an expanded head like a gigantic mushroom that rose rapidly beyond the clouds probably to a height of the order of 30,000 feet. After reaching its full height, the smoke stayed stationary for a while before the wind started dispersing it.

About 40 seconds after the explosion the air blast reached me. I tried to estimate its strength by dropping from about six feet small pieces of paper before, during and after the passage of the blast wave. Since, at the time, there was no wind I could observe very distinctly and actually measure the displacement of the pieces of paper that were in the process of falling while the blast was passing. The shift was about 2½ meters, which, at the time, I estimated to correspond to the blast that would be produced by ten thousand tons of T.N.T.

CLASSIFICATION CANCELLED OR CHANGED TO Unclassified
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BY B. Wise DATE 1-27-65

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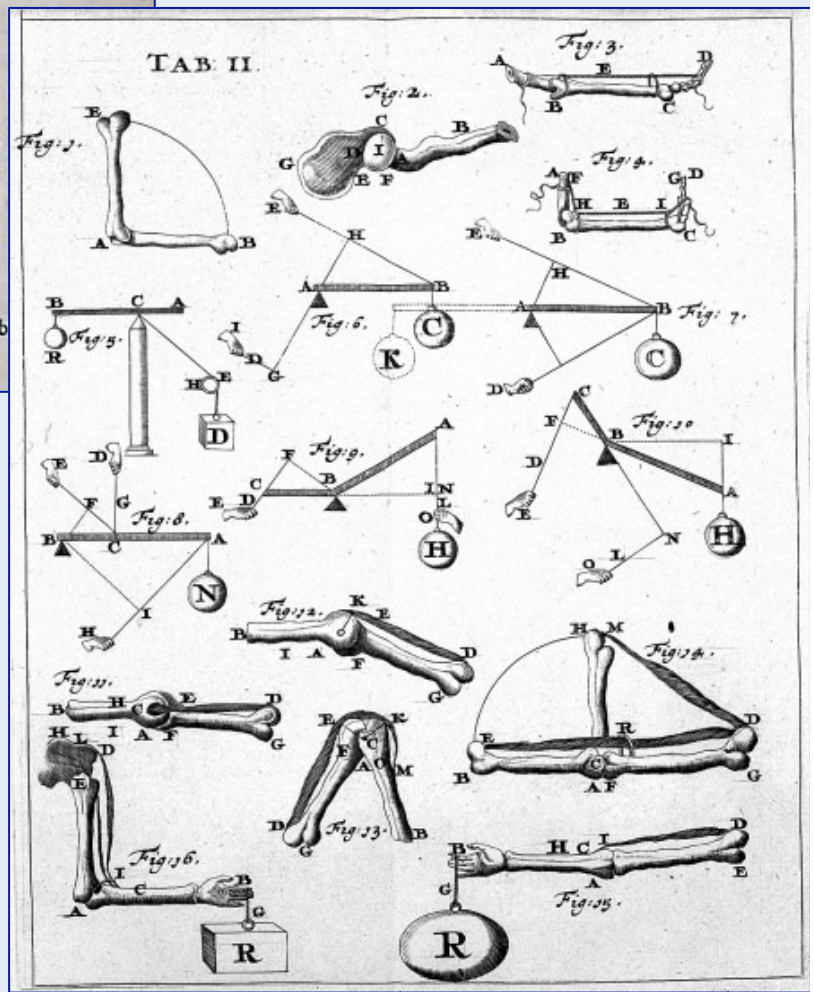
Méthodes qualitatives, (heuristiques, approximatives, …)

— Symétries

Méthodes qualitatives, (heuristiques, approximatives, …)

— Échelles et analyse dimensionnelle



Giovanni Alfondo Borelli (1608-1679)

“Dimension” des grandeurs physiques

En géométrie physique :

longueurs

surfaces = (longueurs)^2

volumes = (longueurs)^3

En cinématique :

vitesse = longueur/temps

accélération = vitesse/temps = longueur/(temps)^2

Plus généralement, la nature d’une grandeur physique s’exprime en termes d’un nombre restreint de grandeurs choisies (conventionnellement) comme fondamentales

Dans le système SI, grandeurs fondamentales :

longueurs $\mathcal{L}$

temps $\mathcal{T}$

masses $\mathcal{M}$

“Dimension” des grandeurs physiques

[longueur] = $\mathcal{L}$

[temps] = $\mathcal{T}$

[masse] = $\mathcal{M}$

[surface] = $\mathcal{L}^2$

[volume] = $\mathcal{L}^3$

[vitesse] = $\mathcal{L}\mathcal{T}^{-1}$

[accélération] = $\mathcal{L}\mathcal{T}^{-2}$

[force] = $\mathcal{M}\mathcal{L}\mathcal{T}^{-2}$

[pression] = $\mathcal{M}\mathcal{L}^{-1}\mathcal{T}^{-2}$

[énergie] = $\mathcal{M}\mathcal{L}^2\mathcal{T}^{-2}$

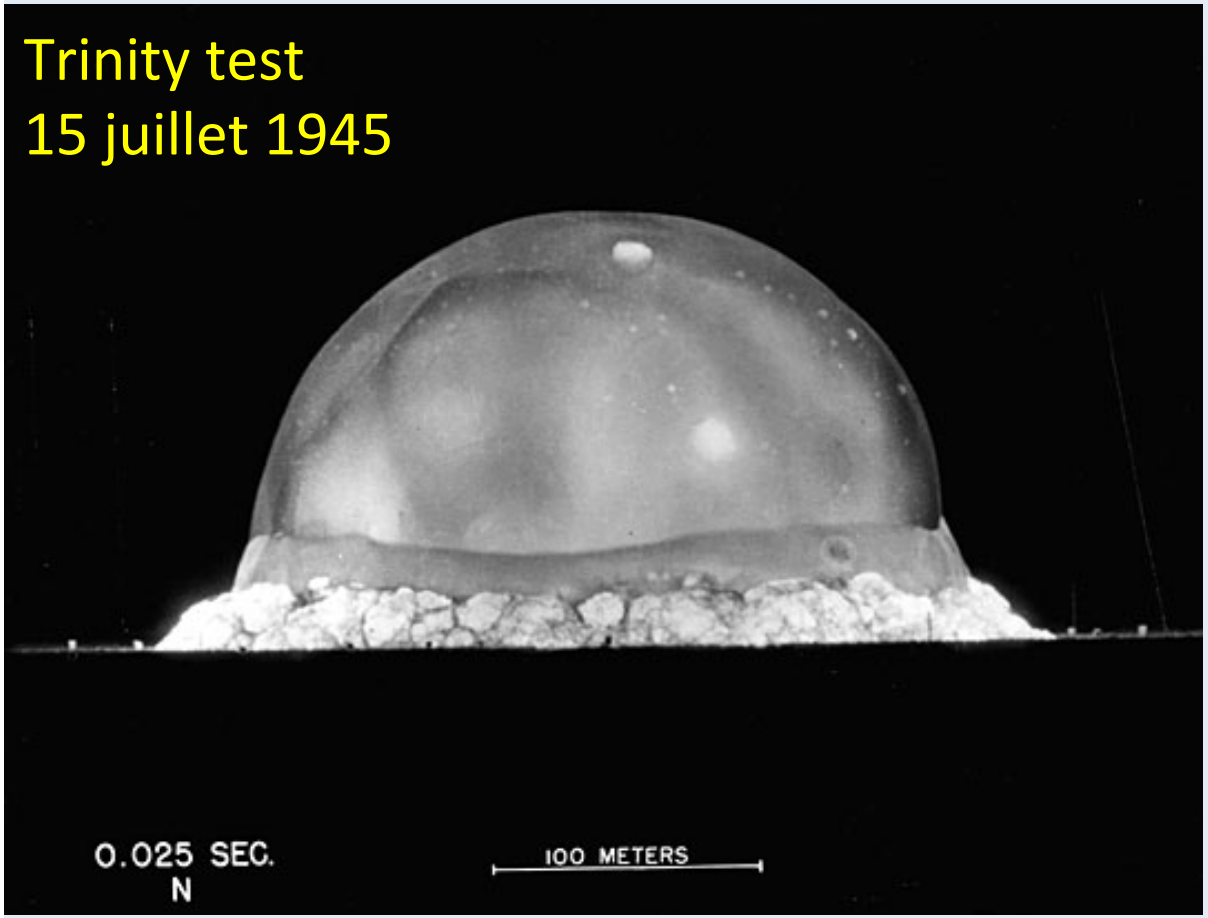
Dogme fondamental
de l'analyse dimensionnelle

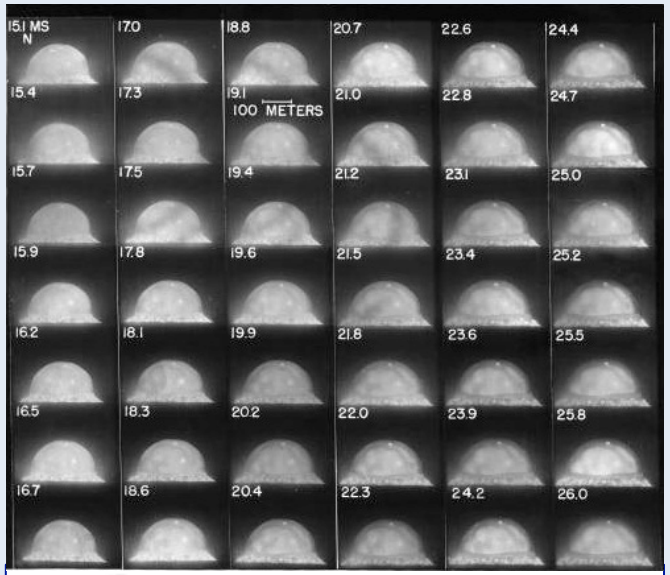
En analyse dimensionnelle, toute constante sans dimension est de l'ordre de l'unité

…si les grandeurs caractérisent bien le phénomène

…sauf exceptions

Encore la bombe A…





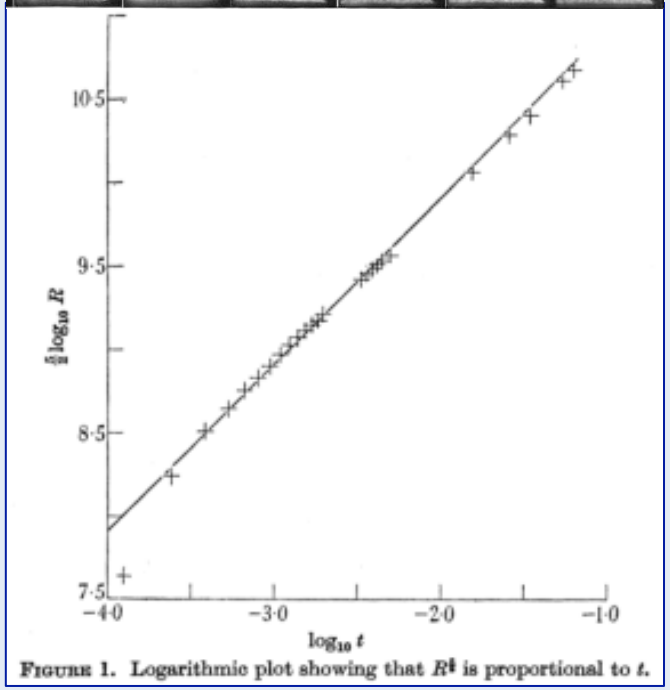


FIGURE 1. Logarithmic plot showing that $R^{\frac{5}{2}}$ is proportional to t.

Geoffrey I. Taylor, « The formation of a blast wave by a very intense explosion » *Proceedings of the Royal Society of London. Series A, Mathematical and Physical Sciences* 201.1065 (1950): 159-186.

de la physique qui se dit
à la physique qui se fait…