

Observar el interior de las estrellas

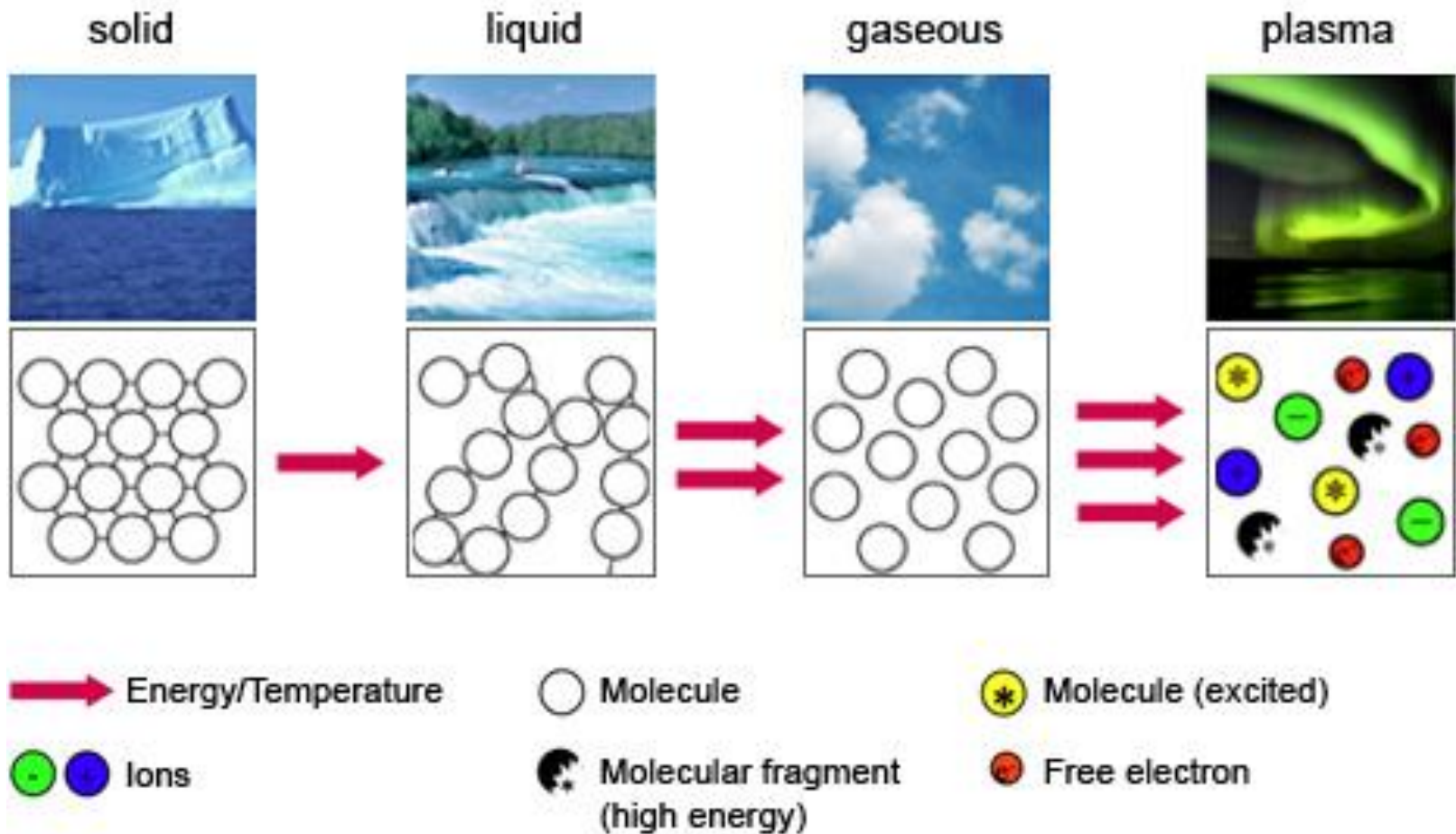
Juan Fabregat

26a Convención de Astronomía

Sabadell, 15 de marzo de 2025



Los estados de la materia

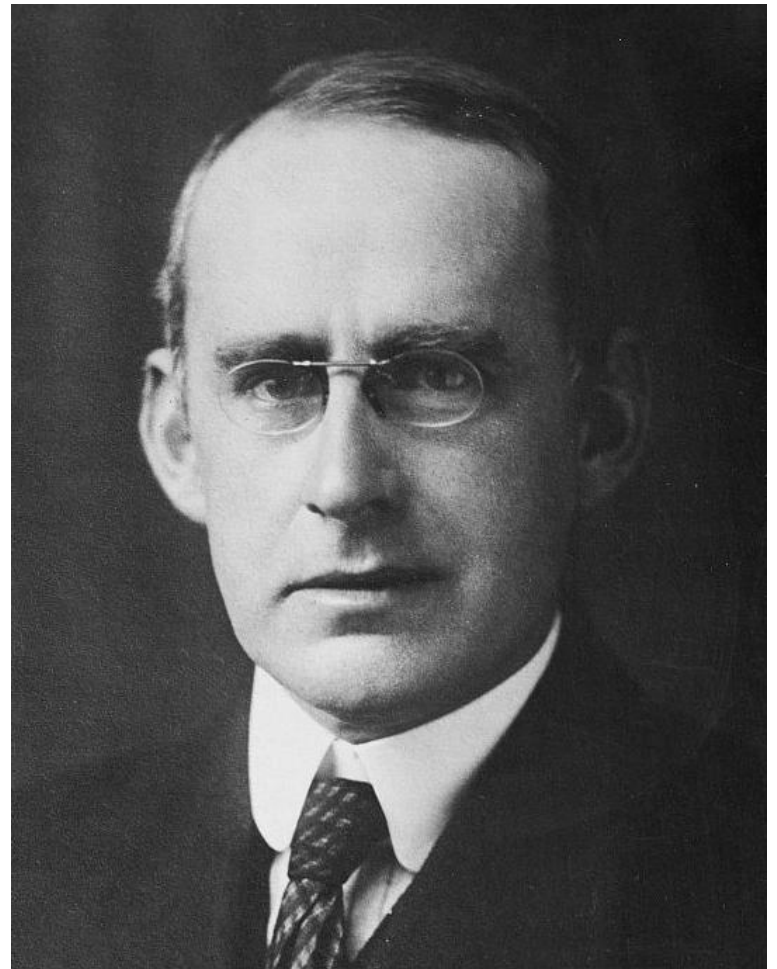


“The internal constitution of the stars”

Arthur Eddington, 1926

Parece que el interior del Sol y de las estrellas es menos accesible a la investigación científica que cualquier otra región del universo.

Nuestros telescopios se adentran cada vez mas en las profundidades del espacio; ¿pero como podremos conocer lo que se oculta tras barreras infranqueables?



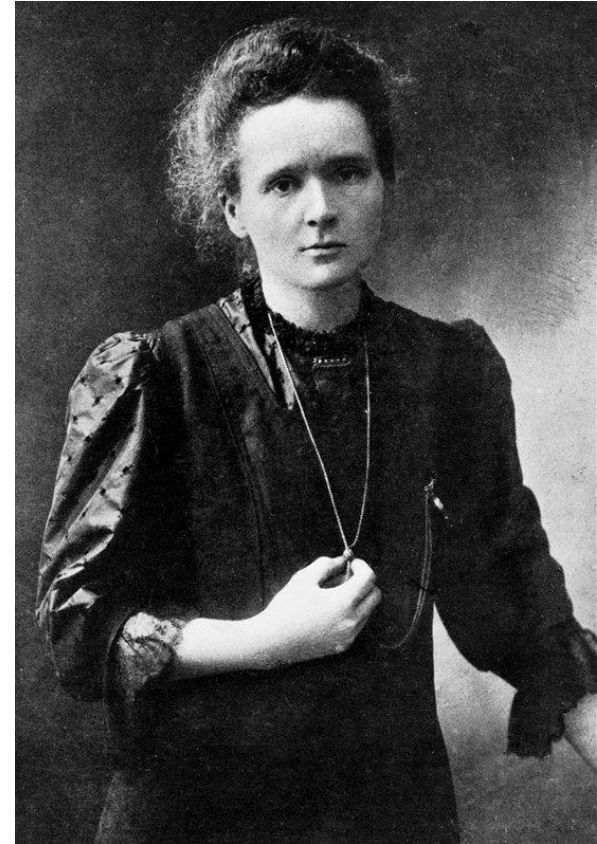
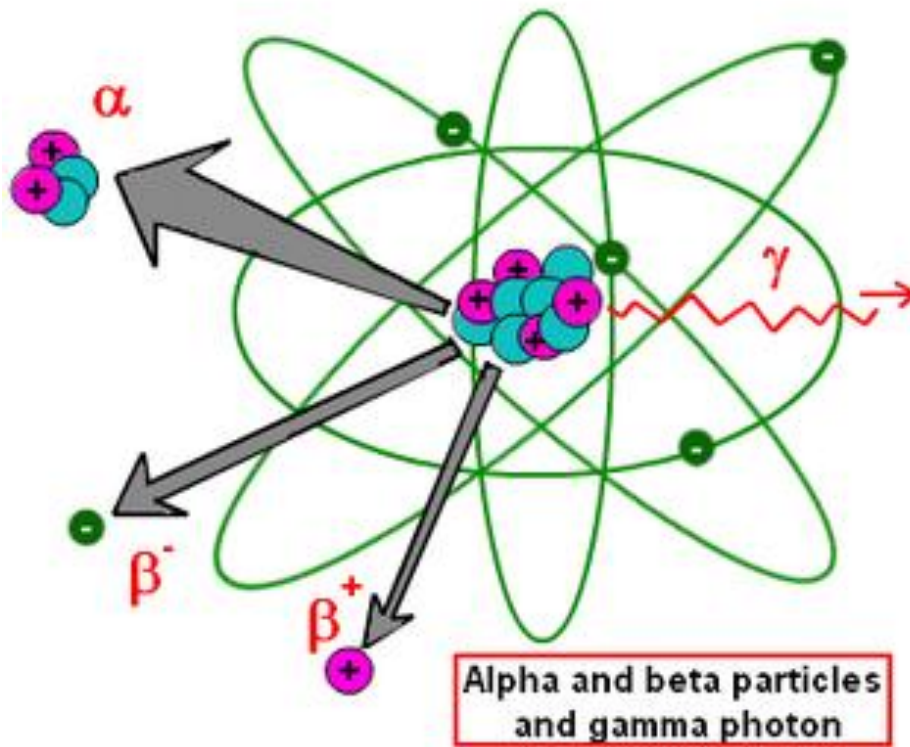
La fuente de energía de las estrellas

I. (a) Ruptura de elementos complejos en elementos más simples (radioactividad)

I. (b) Construcción de elementos complejos a partir de elementos más simples.

II. Cancelación mutua de protones y electrones

Átomos radioactivos



Fusión nuclear

Núcleo de helio: 4 protones + 2 electrones
Masa atómica del helio: 4,000

Núcleo de hidrógeno: 1 protón
Masa atómica del hidrógeno: 1,008

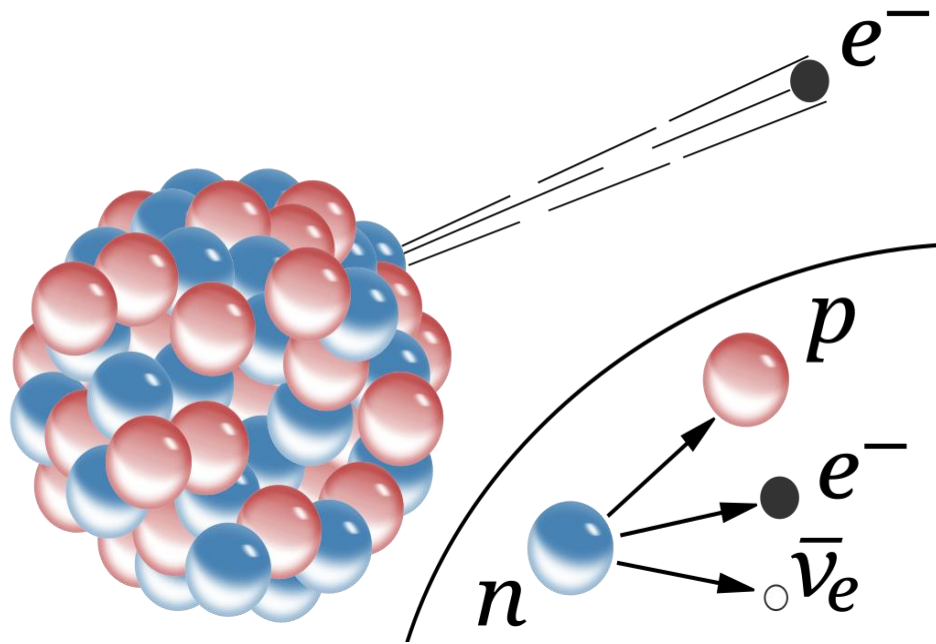
Se pierde el 0,8% de la masa.

Albert Einstein, 1905

$$***E = mc^2***$$



Neutrinos

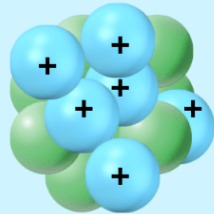


Neutrinos

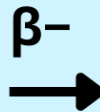
Beta Decay

Beta decay is radioactive decay that either releases an electron (beta minus) or positron (beta plus).

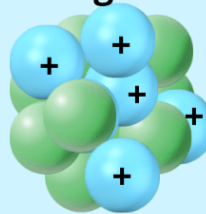
carbon-14



6 protons
8 neutrons



nitrogen-14



7 protons
7 neutrons

+

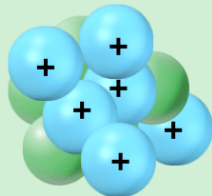


+

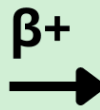
electron



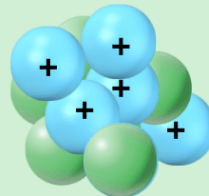
carbon-10



6 protons
4 neutrons



boron-10



5 protons
5 neutrons

+



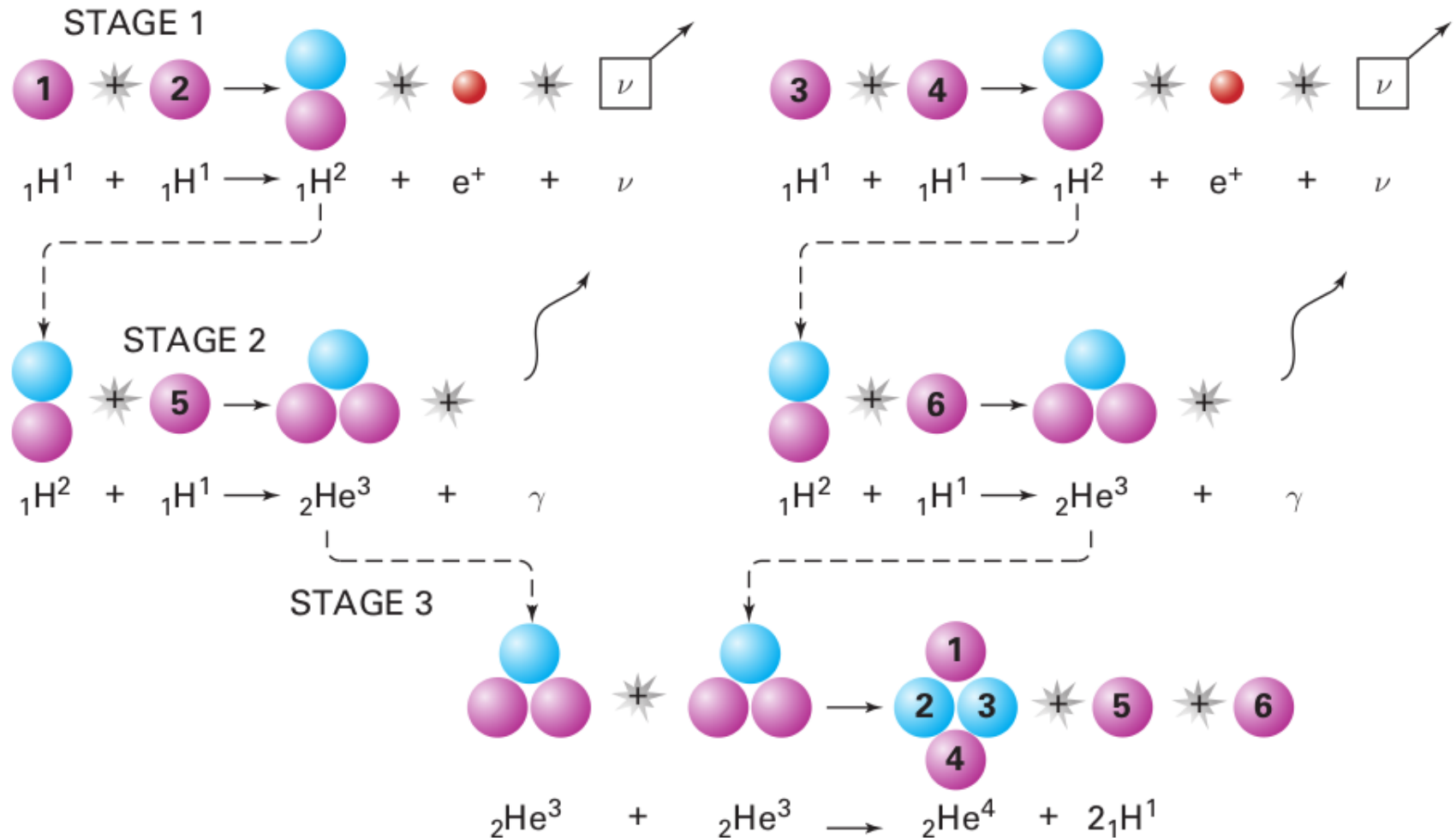
+

neutrino

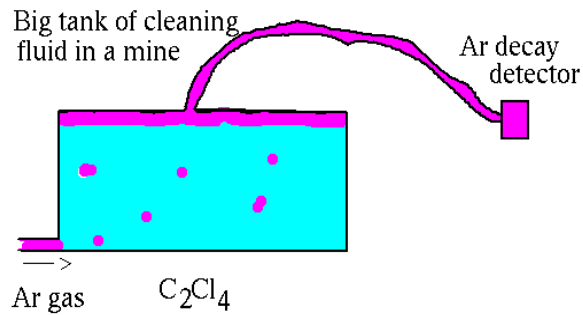
positron



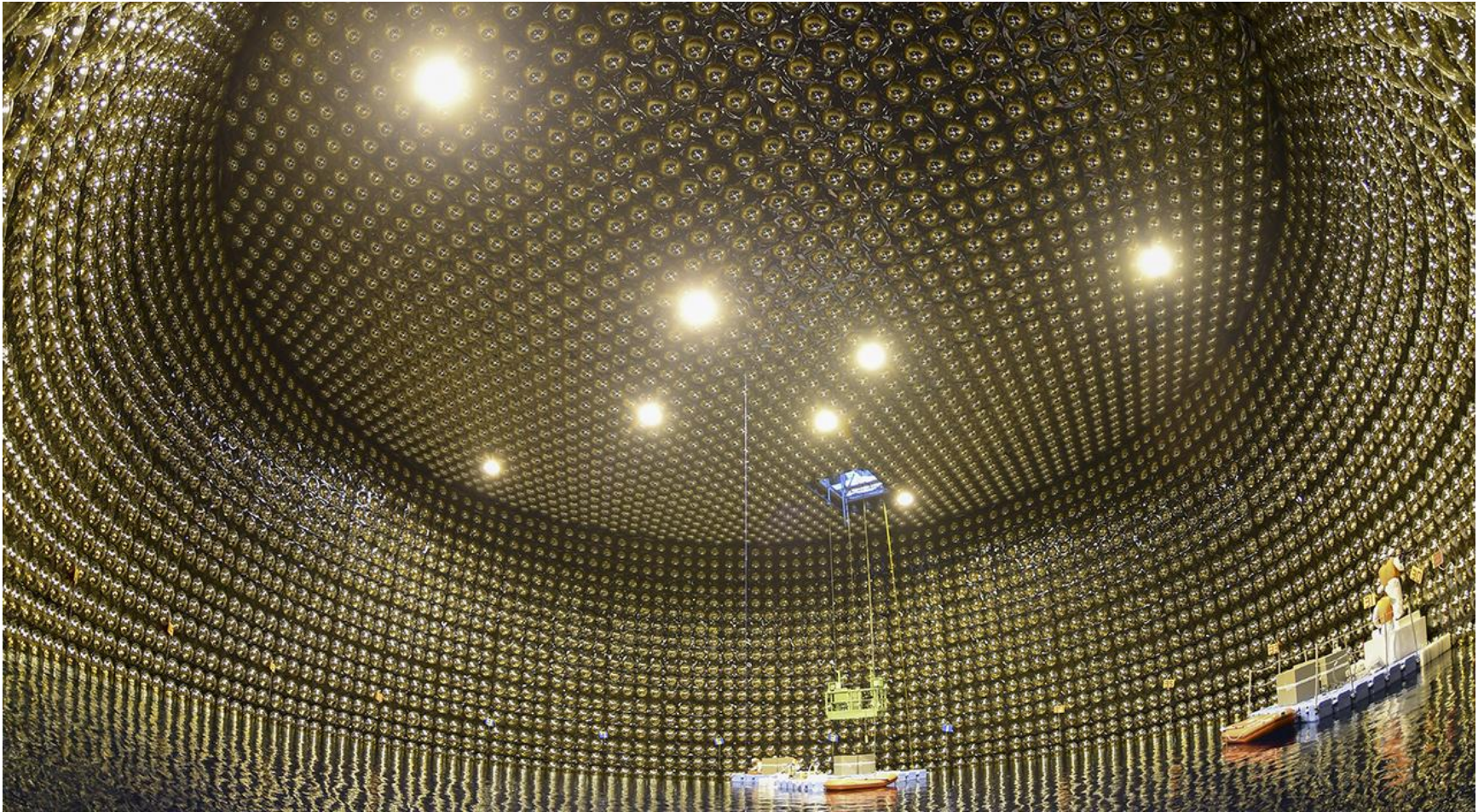
Cadena protón-protón (pp)



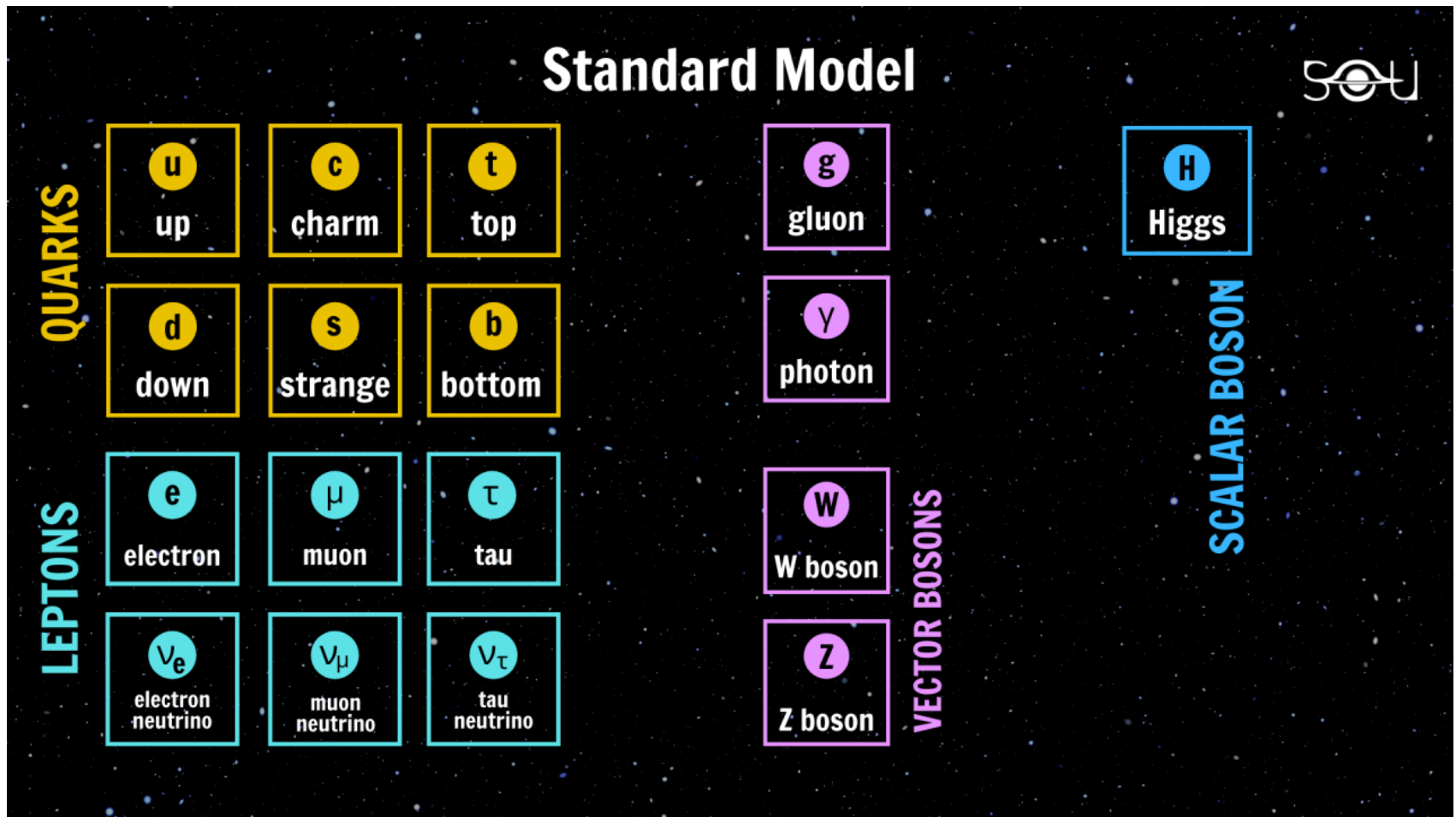
Mina de Homestake (1968)



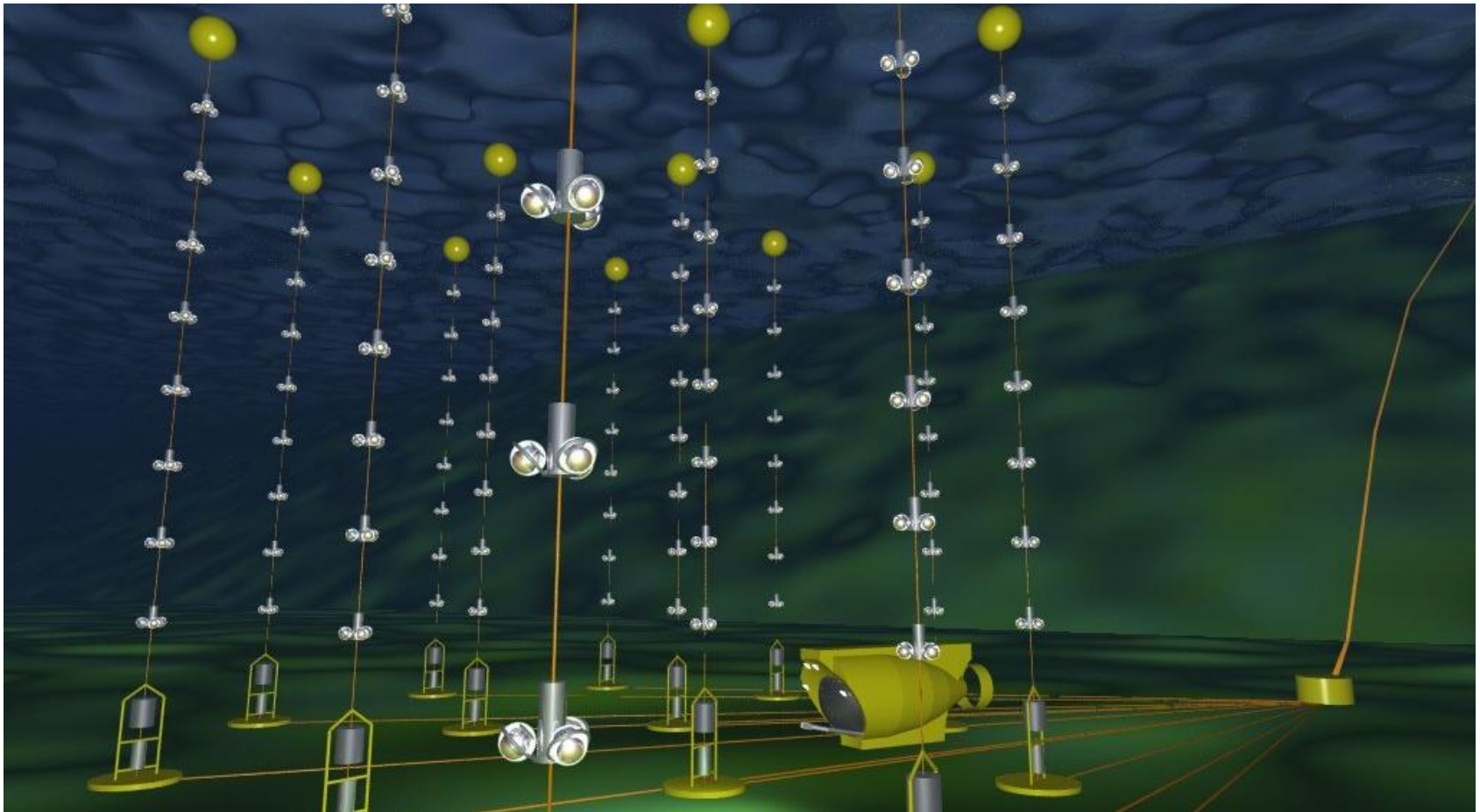
Super-Kamiokande



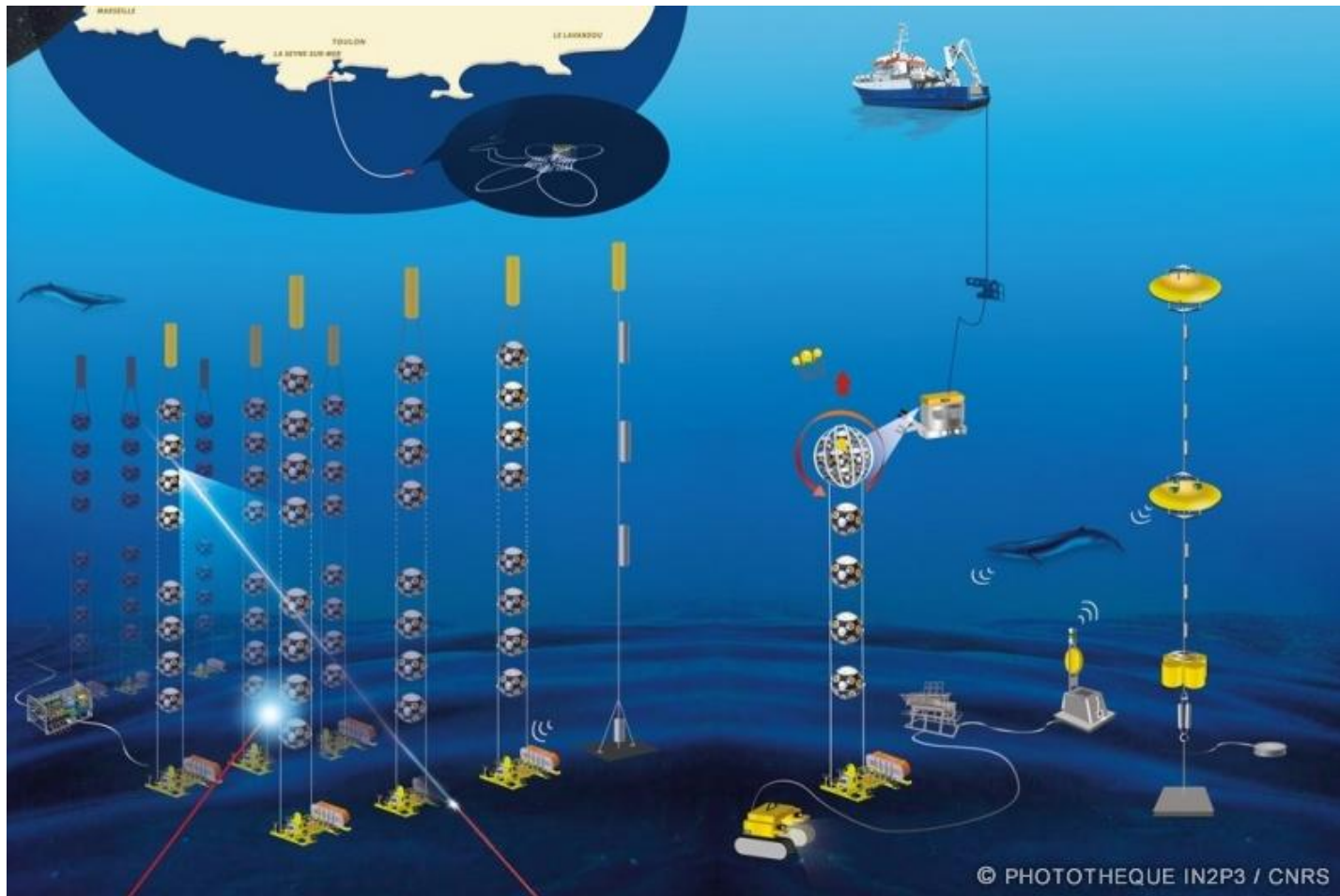
Modelo estándar



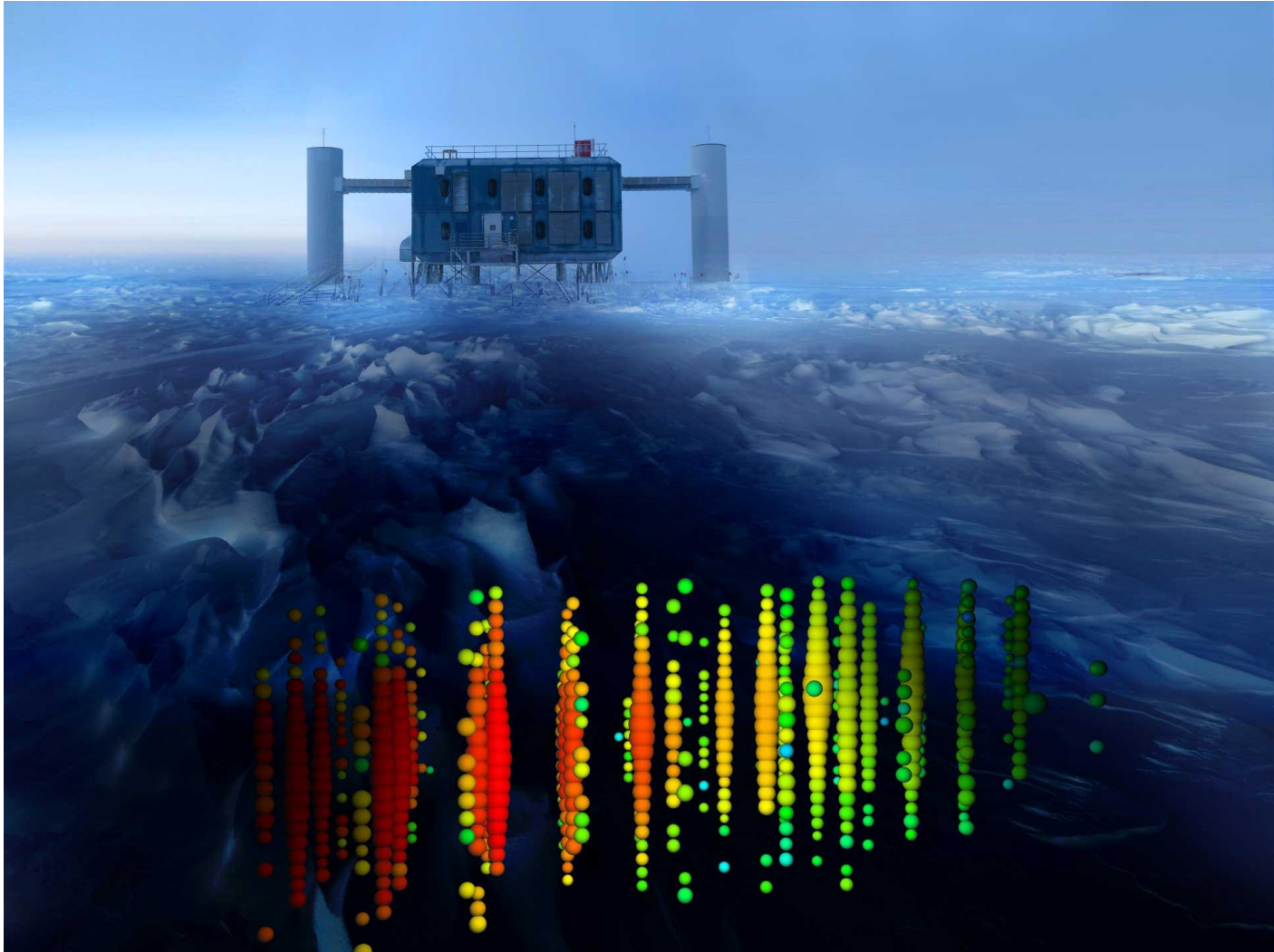
Antares



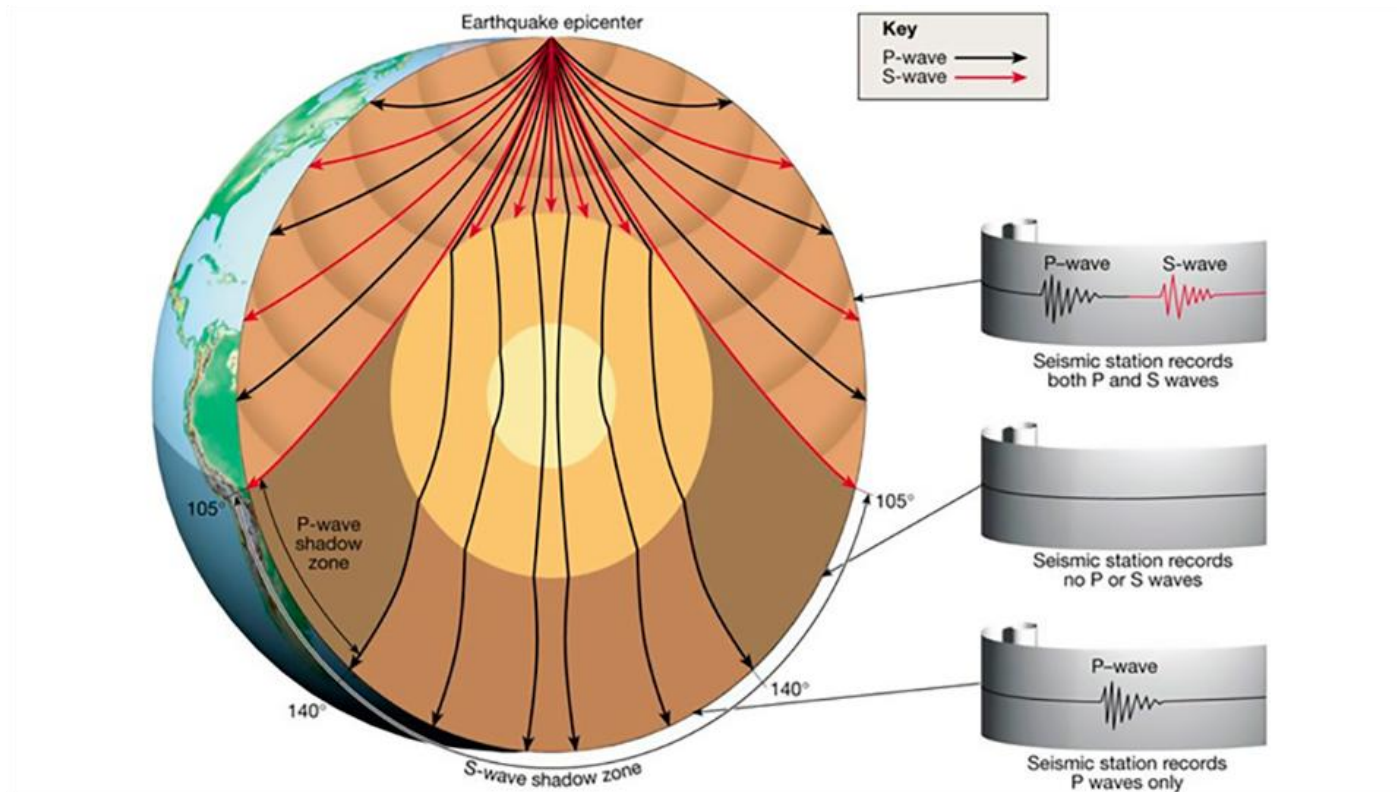
KM3NeT



IceCube

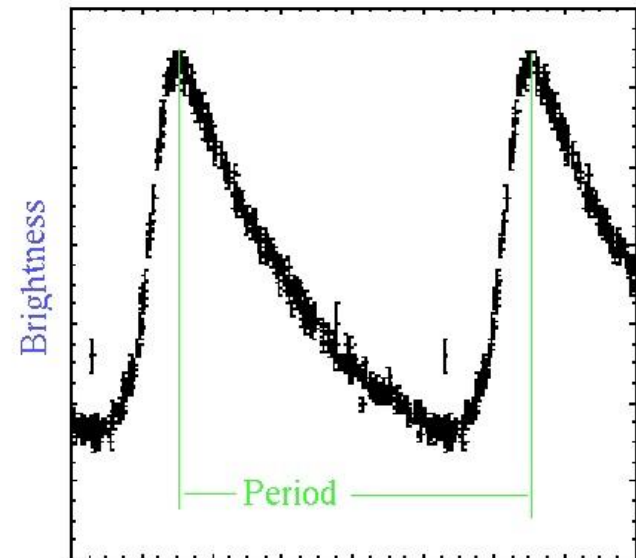
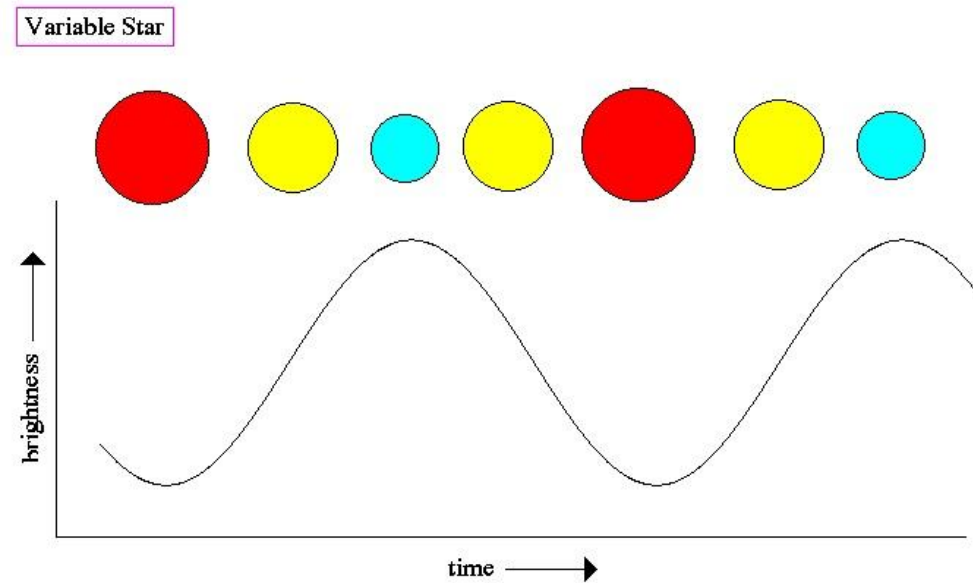


Astrosismología



Cefeidas

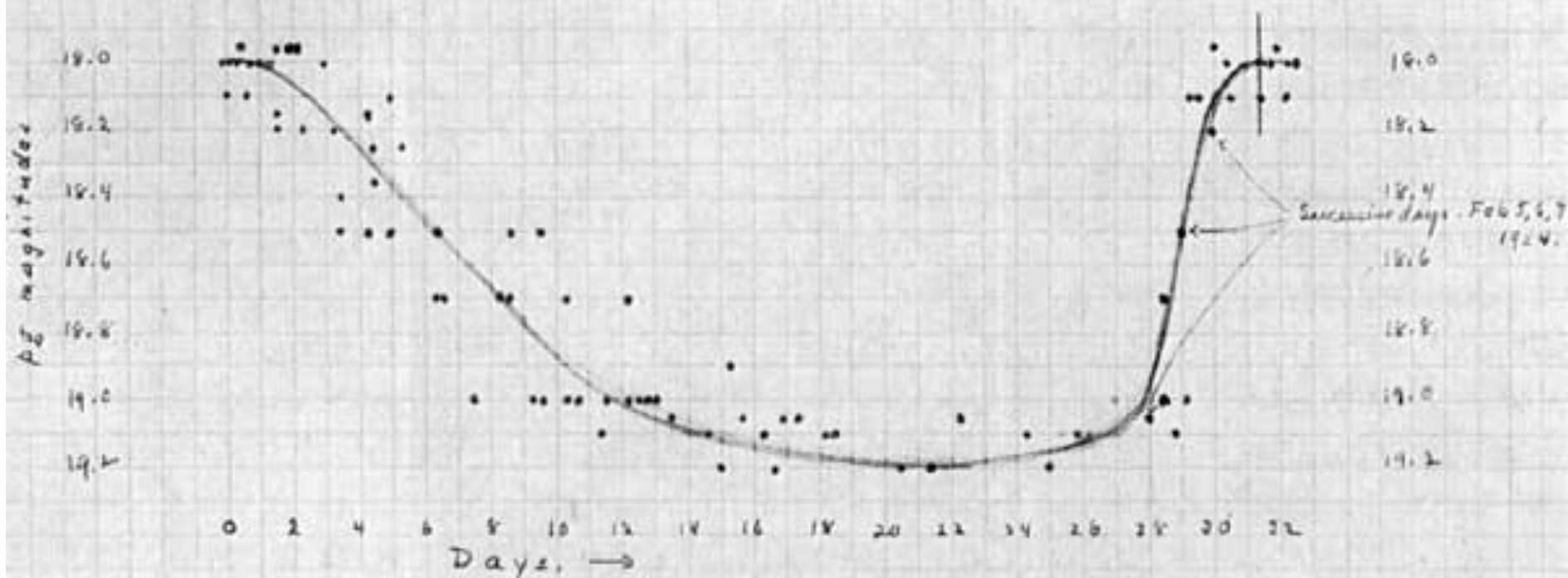
Data from a Well-Measured Cepheid



Time (usually Days)

Variable No 1 in Messier 31.

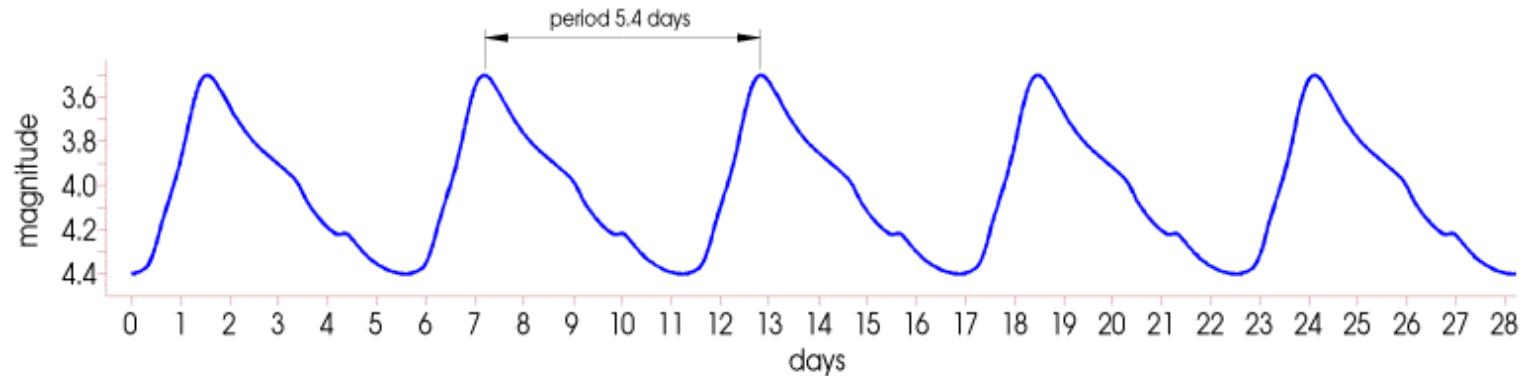
15.80 from nucleus in a direction West by 22½° South.



Period 31.415 days. Range 1.2 $\pm$ pg mag.
Epoch J.D. 2422259.0 median Mag(pg) = 18.6 $\pm$

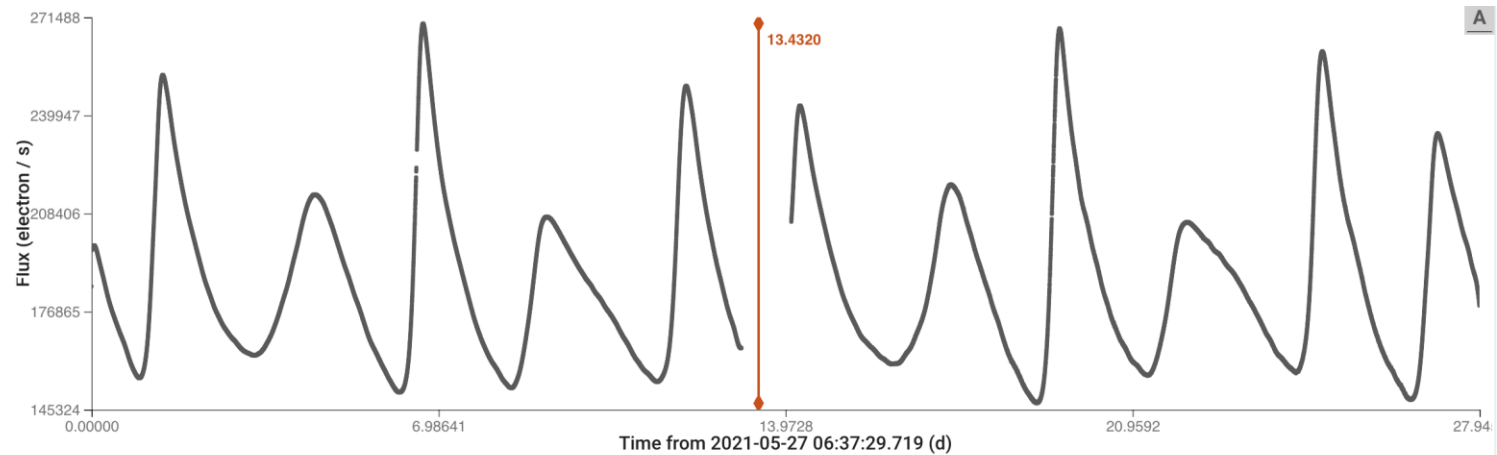
I believe the range and median magnitude are nearer to 1.0 and 18.5 respectively. A reasonable cold index is +0.9. Then,
 $M = -5.0$ (from the period)
distance = 220 000 parsecs (subject to reduction if star is dimmed by intervening nebulosity.)

Cefeidas de periodo doble

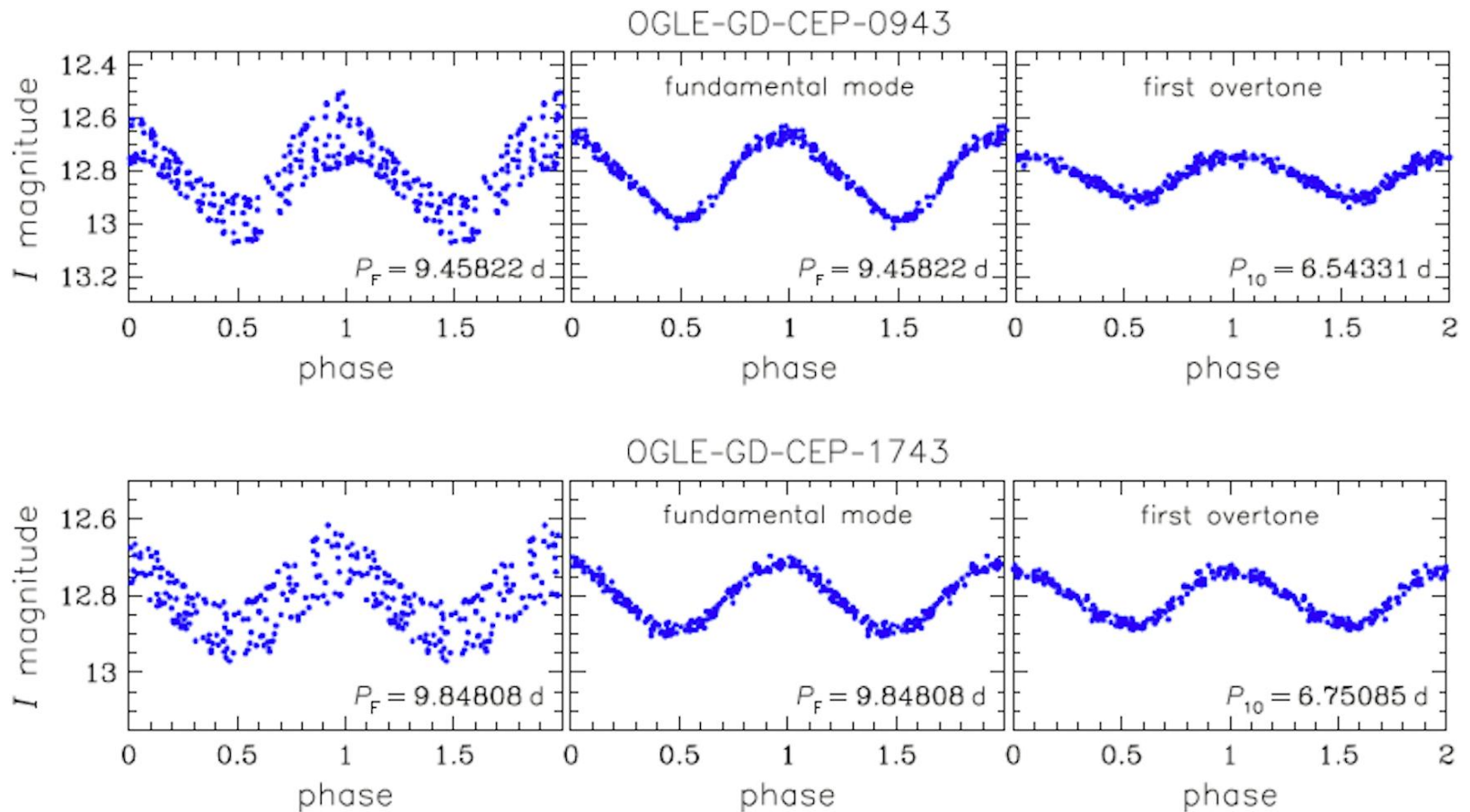


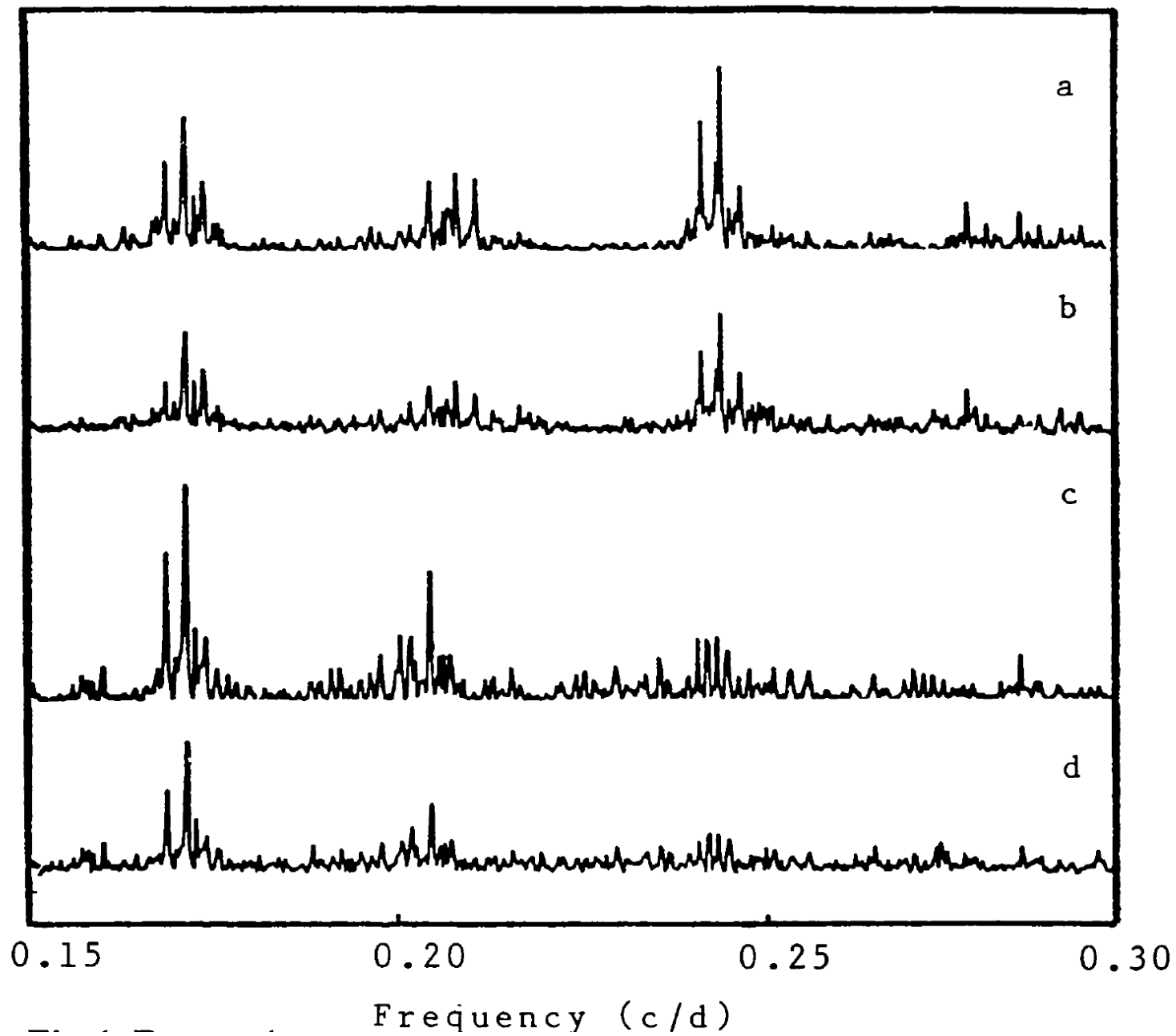
Light curve of Delta Cephei

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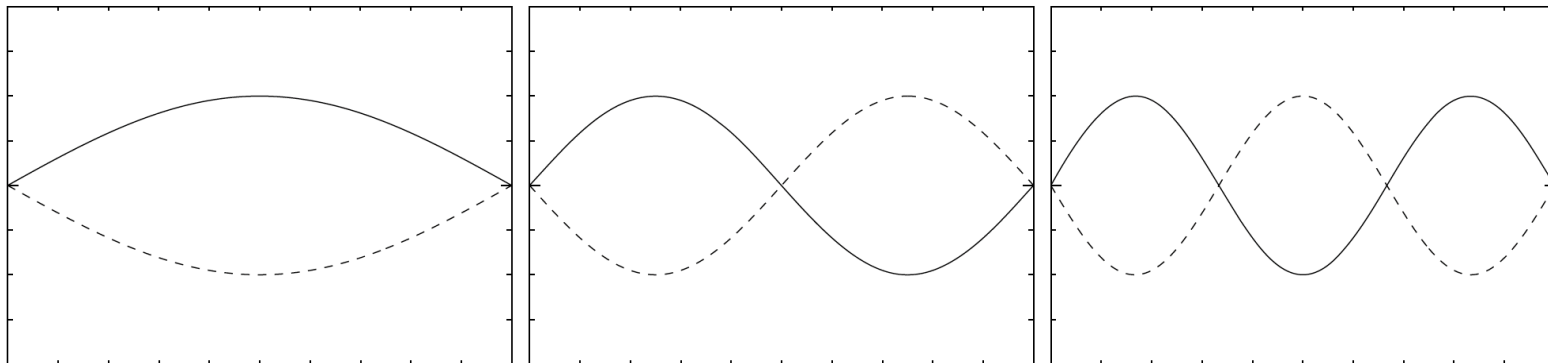


Cefeidas de periodo doble

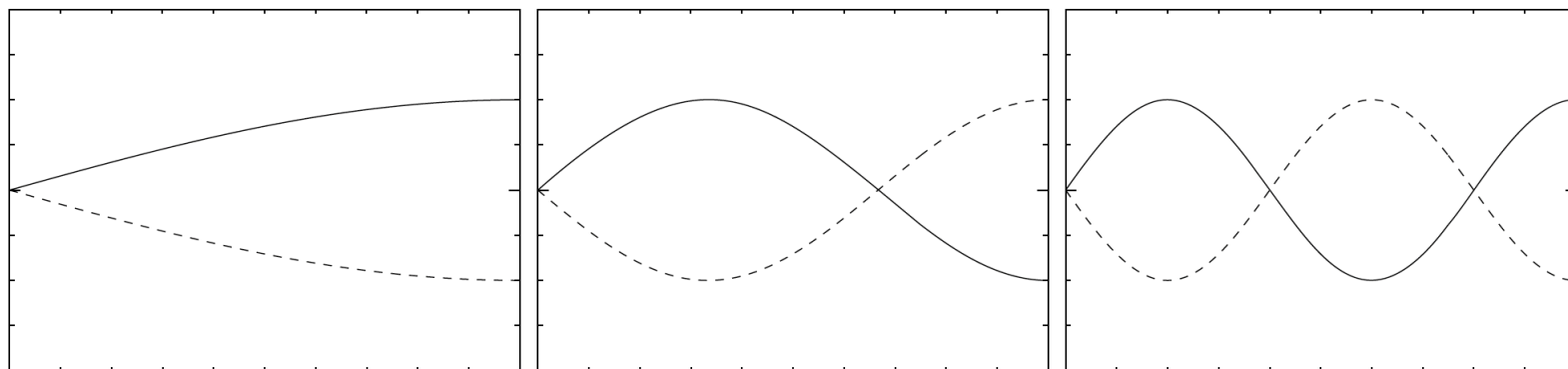




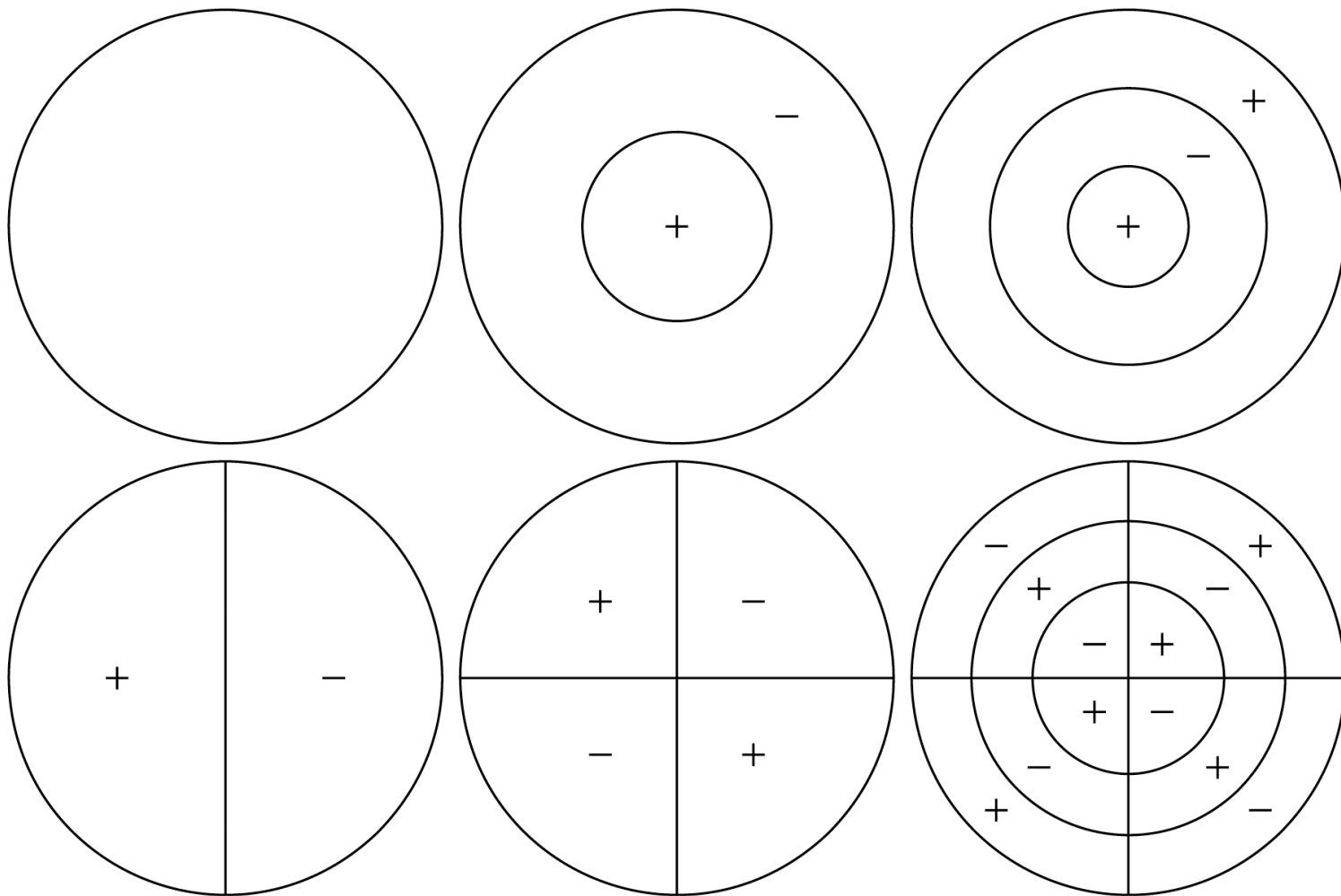
Cuerda vibrante



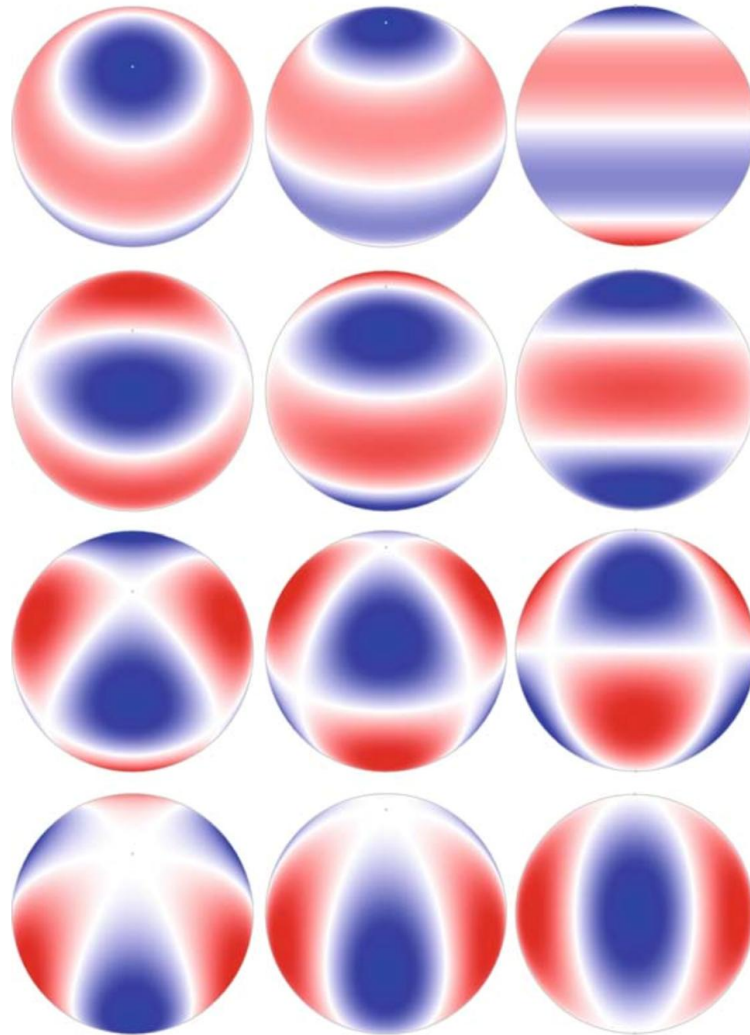
Tubo de órgano



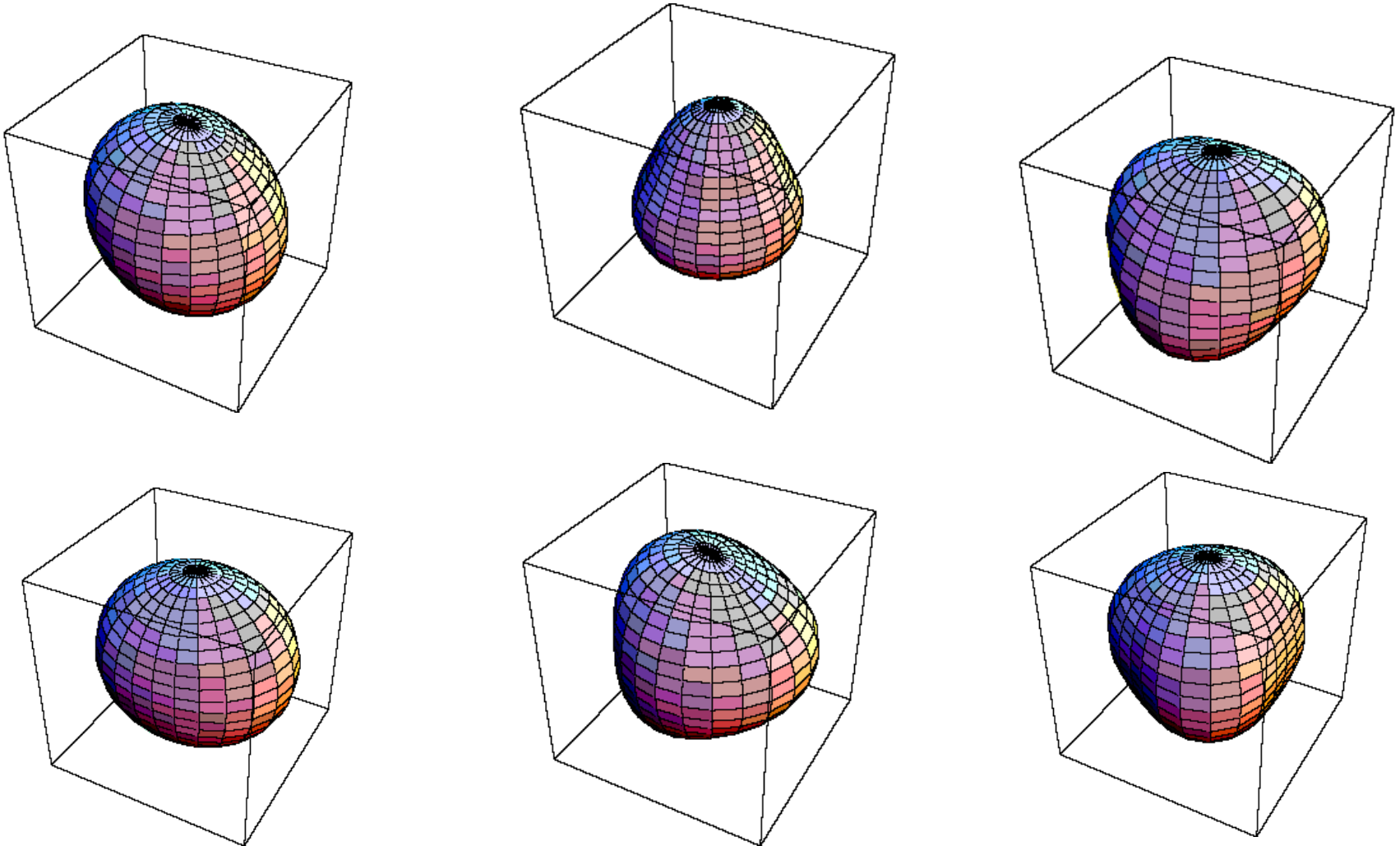
Superficie vibrante

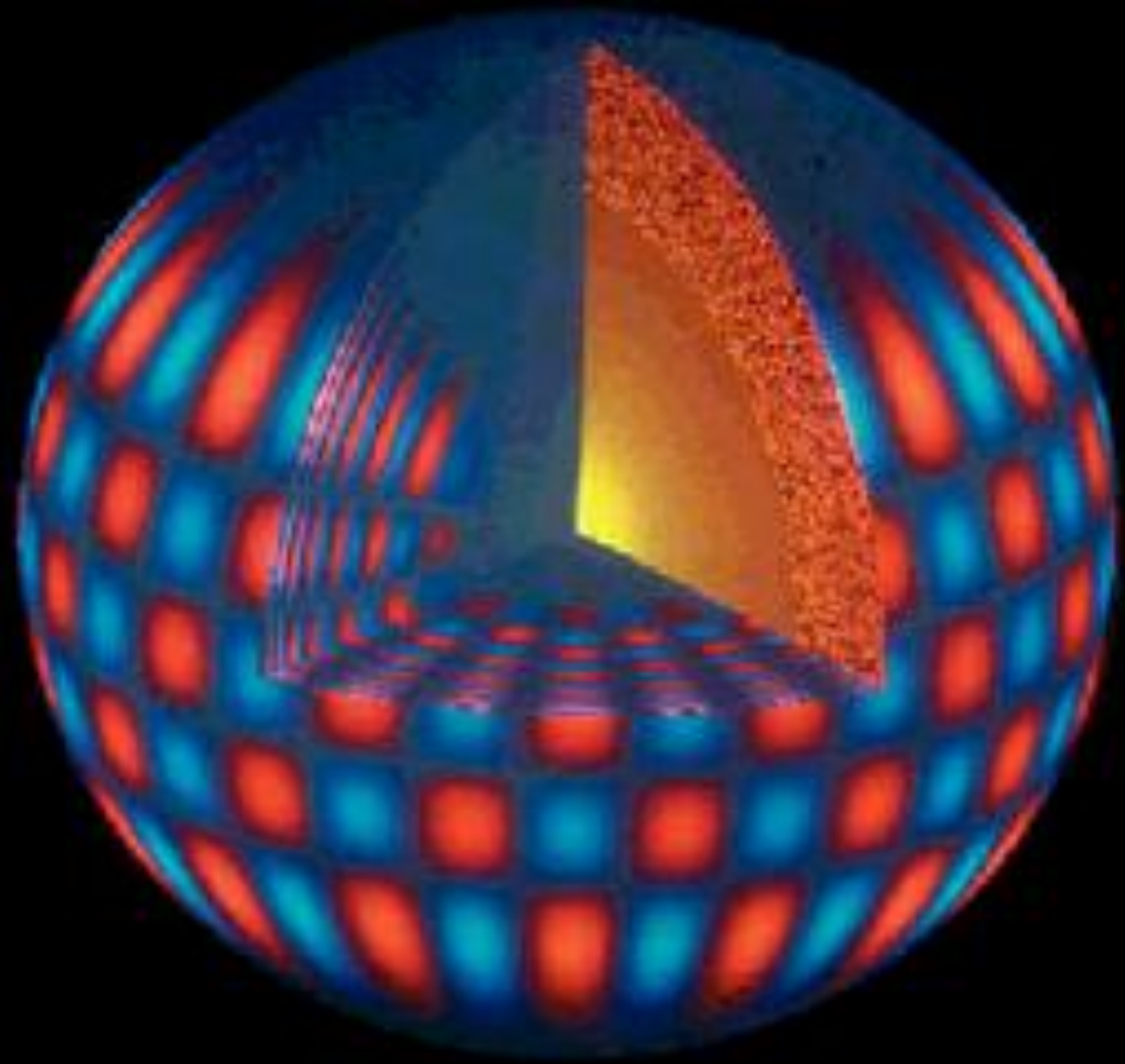


Pulsaciones no radiales

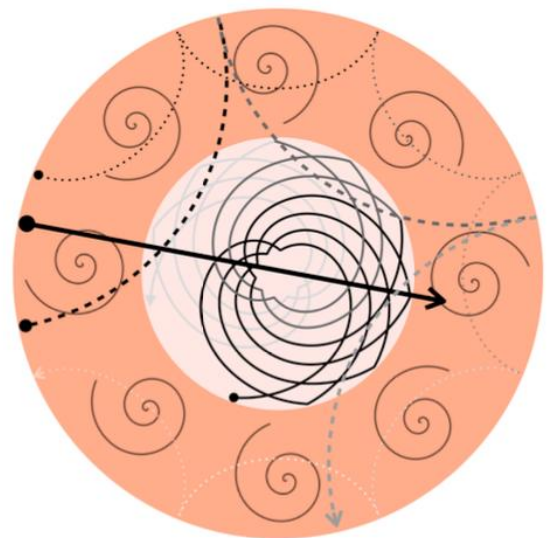
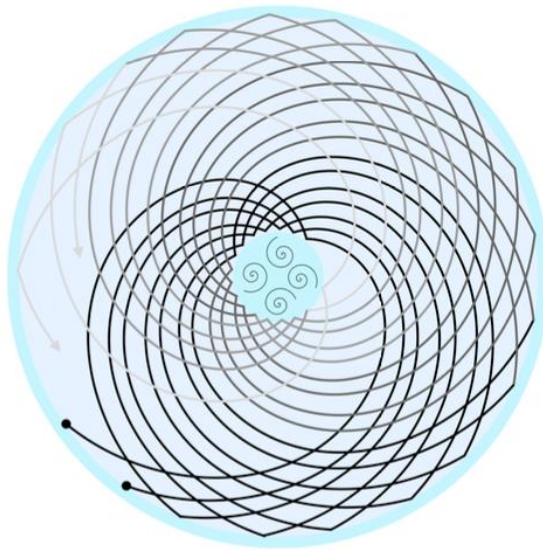
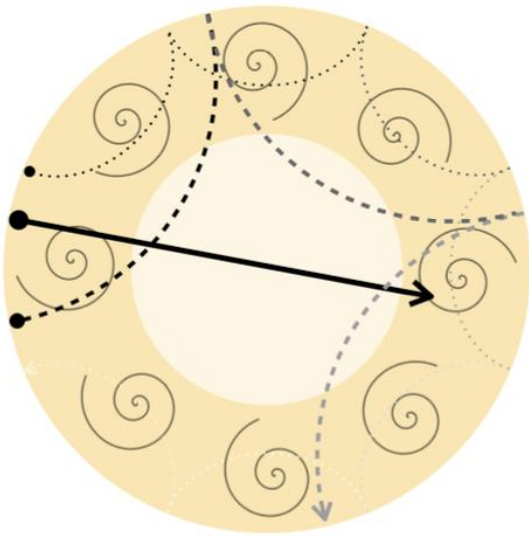


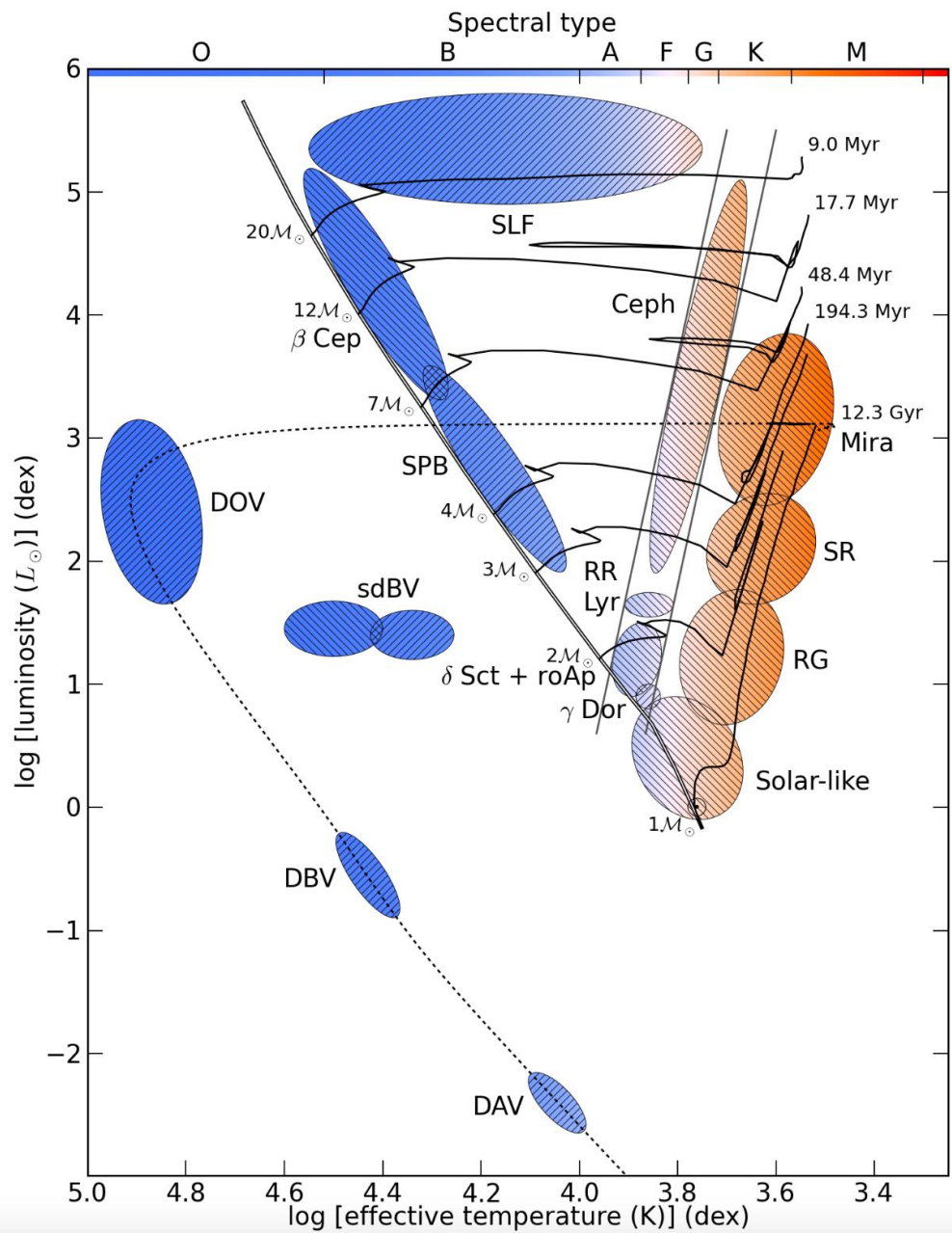
Pulsaciones no radiales





Propagación de las ondas





Pulsantes lentas de tipo B (SPB)

