

Les Trous Noirs et la fin du temps en Relativité Générale

**CPPM
07-12-2013**

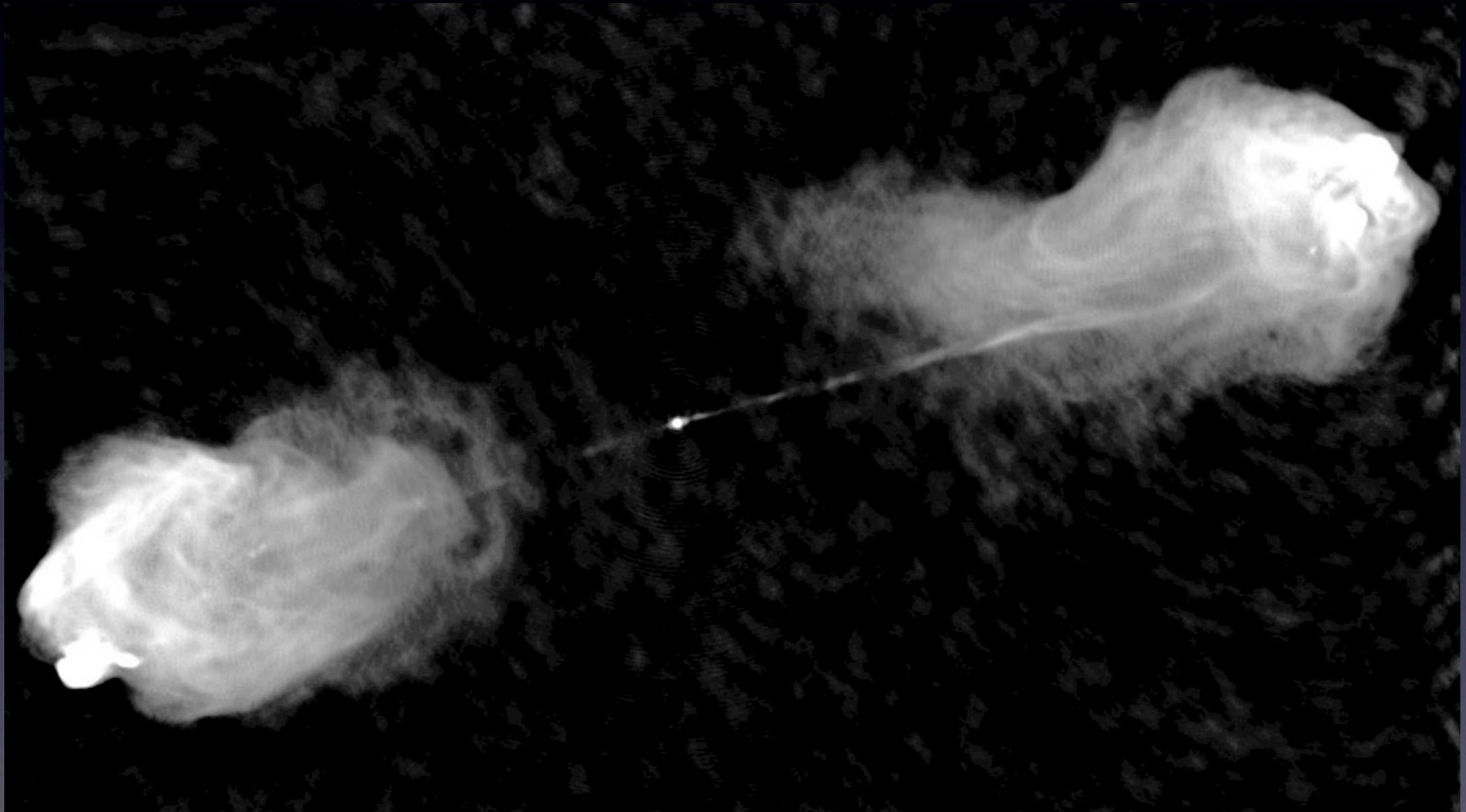
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Centre de Physique Théorique,
Marseille, France.**



Evidence Observationnelle

Evidence Observationnelle:

Production de phénomènes très énergétiques dans les jeunes galaxies (ici Cygnus A).

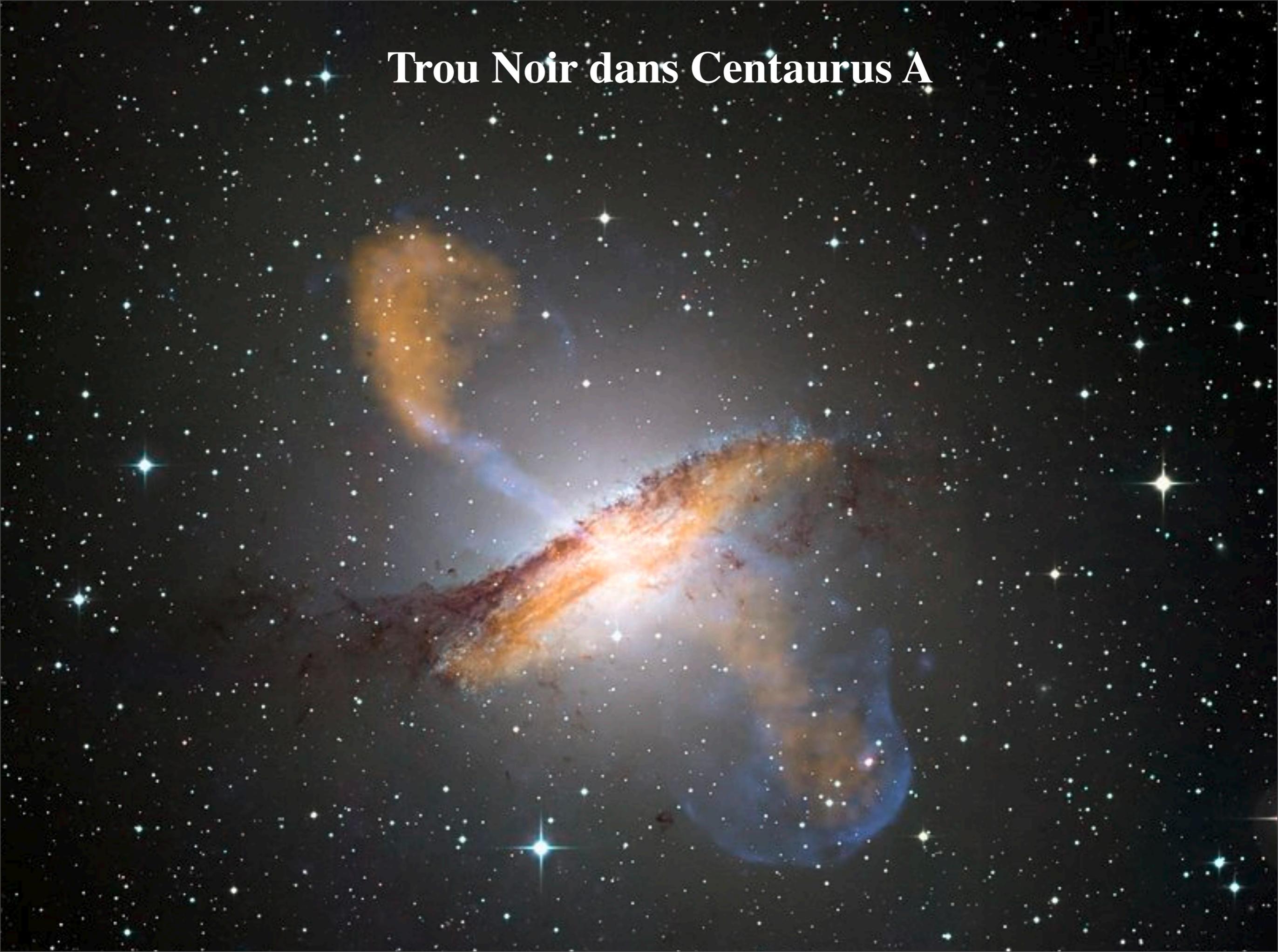


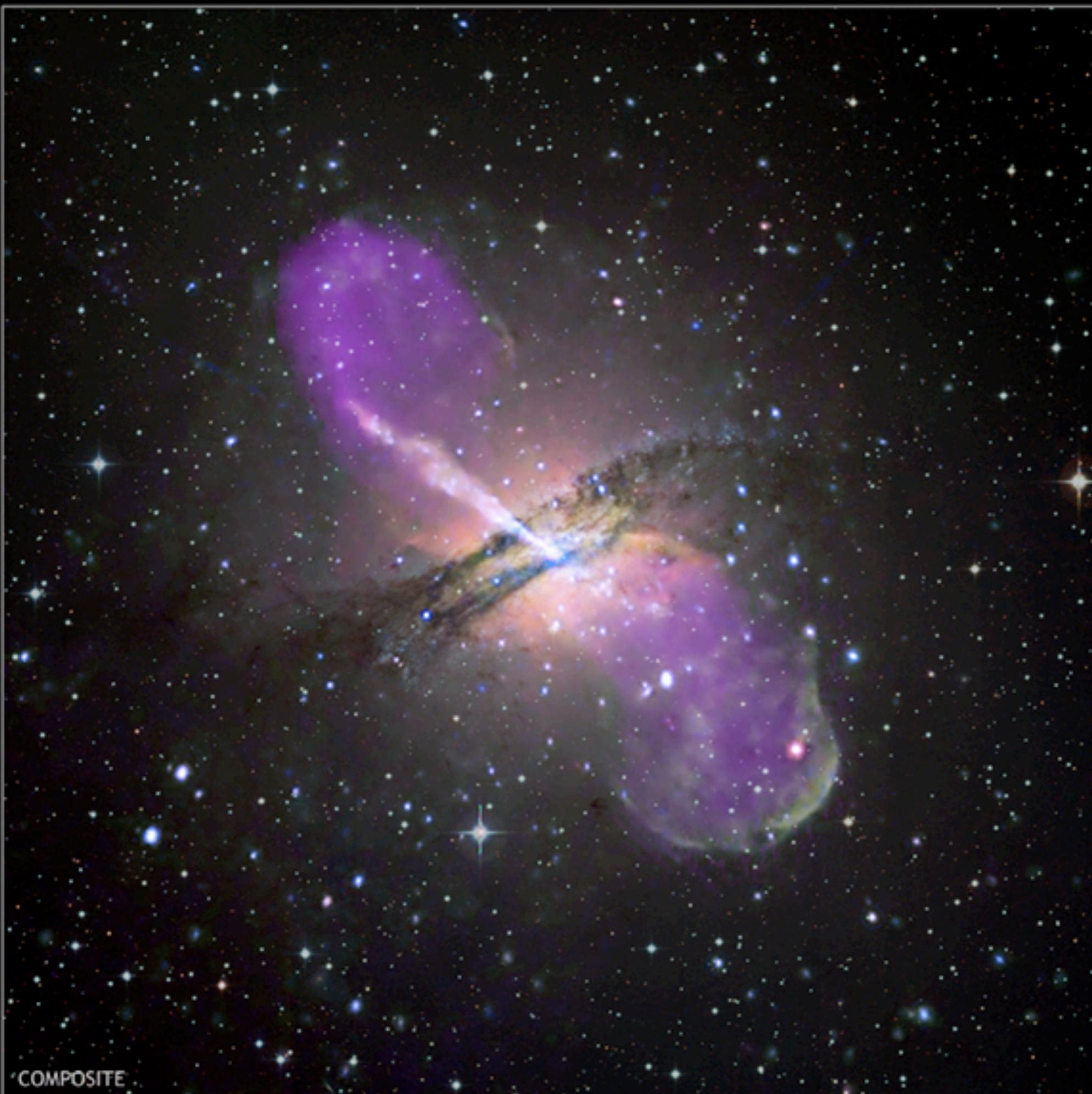
$$\Delta E = 10^7 M_{\odot} c^2$$

Trou noir binaire dans 3C 75



Trou Noir dans Centaurus A

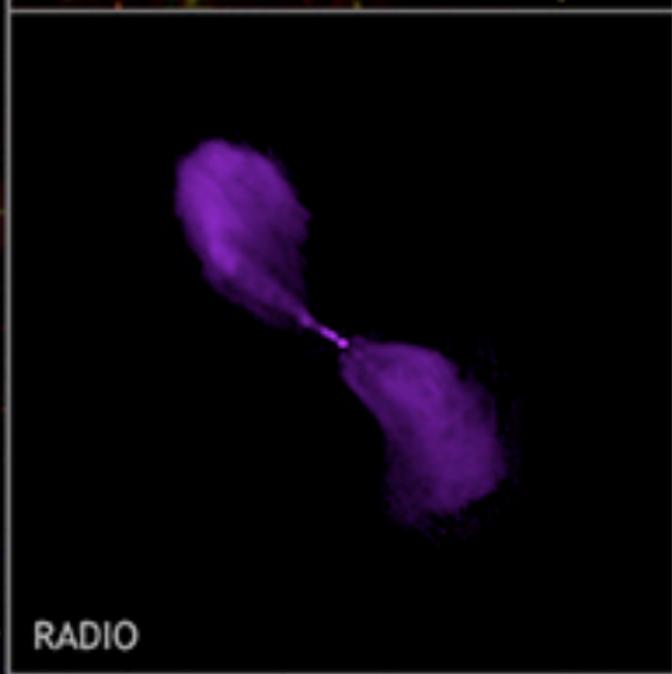




COMPOSITE



X-RAY



RADIO



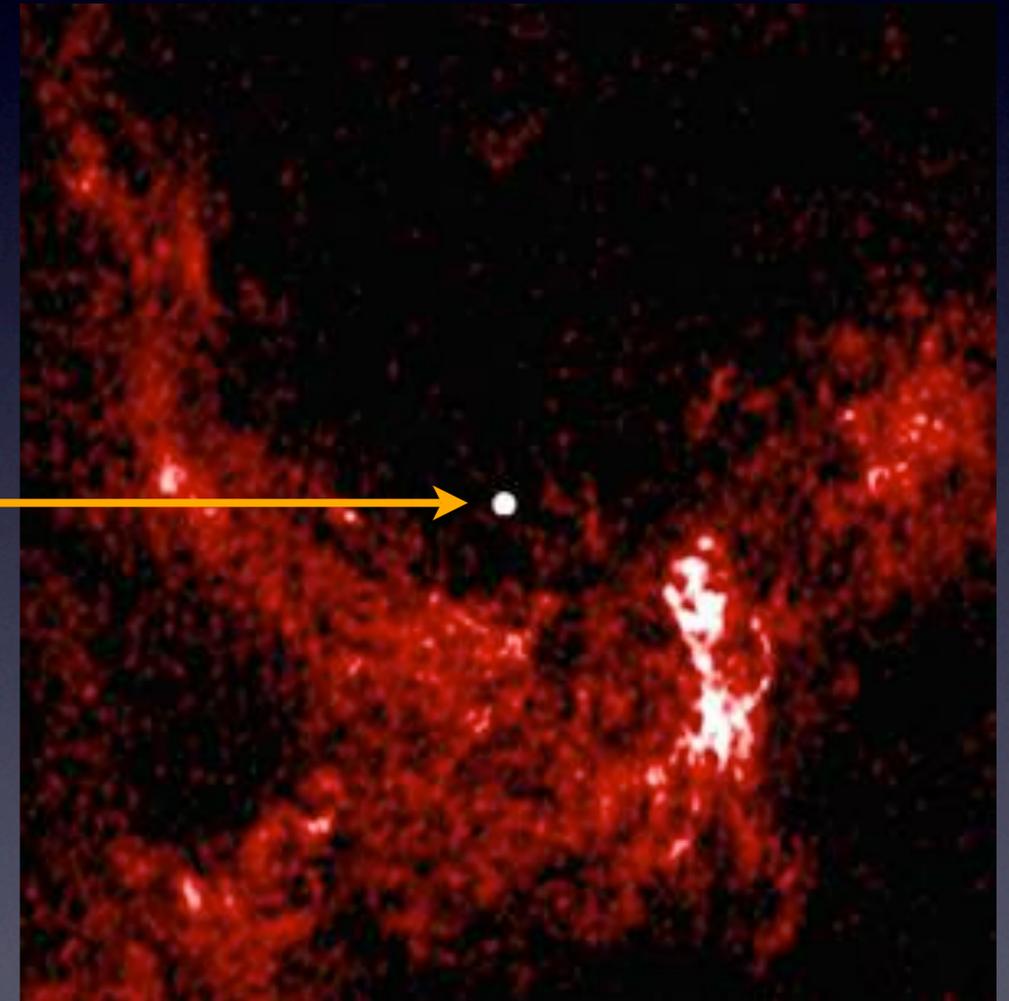
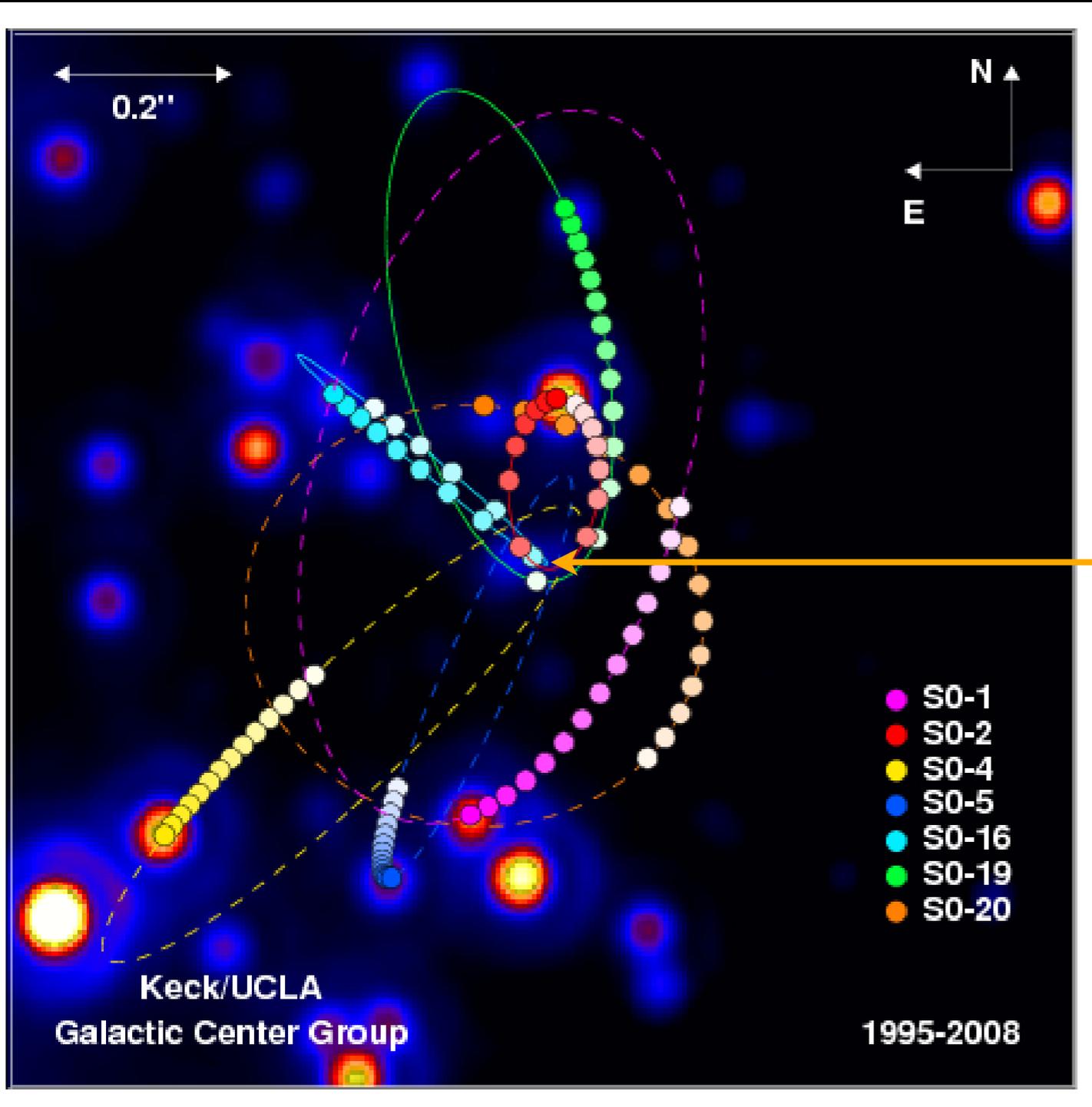
OPTICAL



$d \approx 27000al$

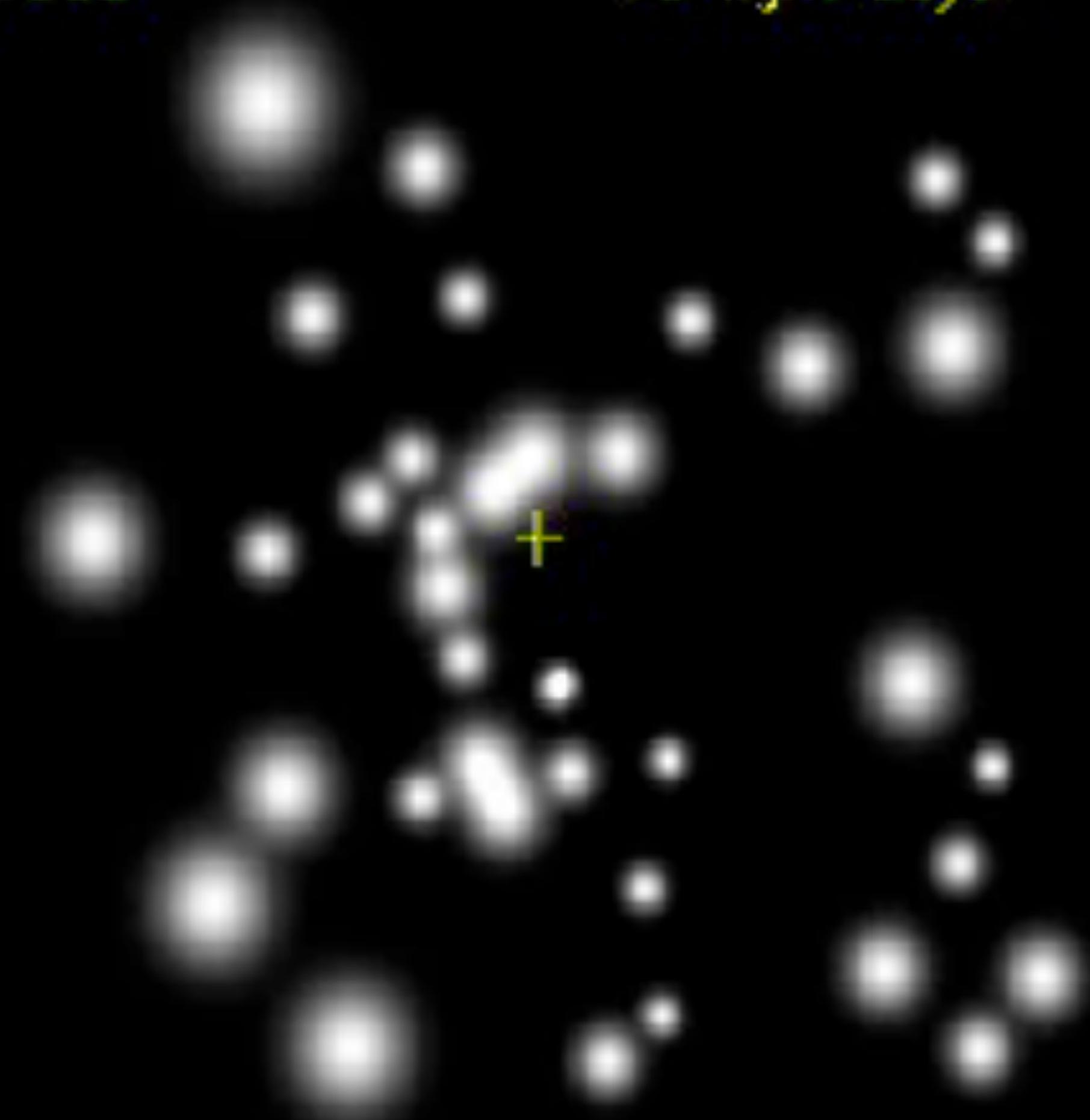
Evidence Observationnelle:

Observation directe des ses manifestations gravitationnelles.



1992

10 light days



Cignus X1 vue par Chandra



$$M \approx 10 M_{\odot}$$

$$d \approx 6000 \text{al}$$

Le plus grand, PKS 0745-19

$$M = 4 \times 10^{10} M_{\odot}$$

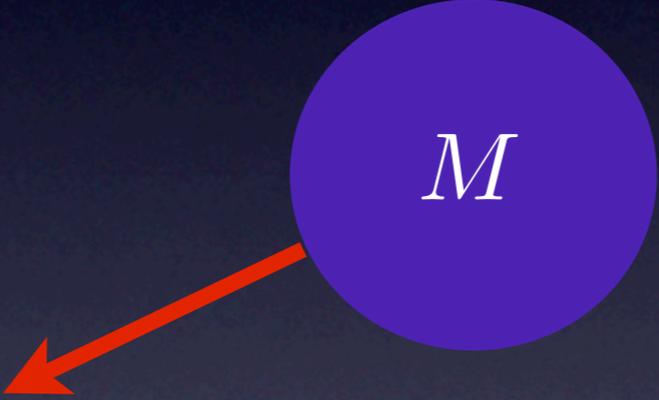


Qu'est-ce qu'un **Trou
Noir?**



Intuition Newtonienne

gravitation toujours attractive+vitesse de tout corps matériel inférieure a la vitesse de la lumière

$$v_L = \sqrt{\frac{2MG}{r}}$$


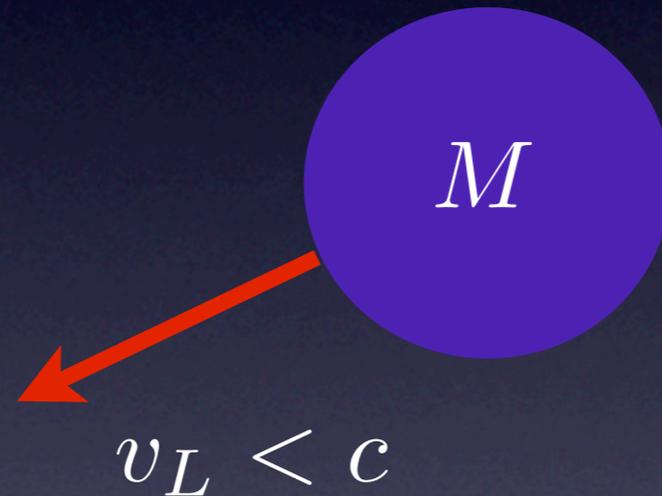
$v_L < c$

En augmentant M on peut rendre la vitesse de libération v_L proche de c

Intuition Newtonienne

gravitation toujours attractive+vitesse de tout corps matériel inférieure a la vitesse de la lumière

$$v_L = \sqrt{\frac{2MG}{r}}$$



$$v_{Lune} = 2.4 \text{ km/s}$$

$$v_{Terre} = 11 \text{ km/s}$$

$$v_{Soleil} = 600 \text{ km/s}$$

En augmentant M on peut rendre la vitesse de liberation v_L proche de c

A person's silhouette is visible in the lower right foreground, looking up at a vast night sky filled with stars and the Milky Way galaxy. The text is centered in the upper half of the image.

Qu'est-ce qu'un **Trou
Noir en Relativité
Générale ?**

A photograph of a person's silhouette standing on a dark horizon, looking up at a vast night sky filled with stars. The Milky Way galaxy is visible as a bright, hazy band of light stretching across the sky. The person is positioned in the lower right foreground, their dark form contrasting with the bright, star-filled background. The sky is a deep, dark blue, and the stars are numerous and bright, creating a sense of depth and wonder. The overall mood is contemplative and awe-inspiring.

Résultat final de l'effondrement gravitationnel

A person's silhouette is visible in the lower right foreground, looking up at a vast night sky filled with stars and the Milky Way galaxy. The text is centered in the upper half of the image.

Qu'est-ce qu'un **Trou
Noir en Relativité
Générale ?**

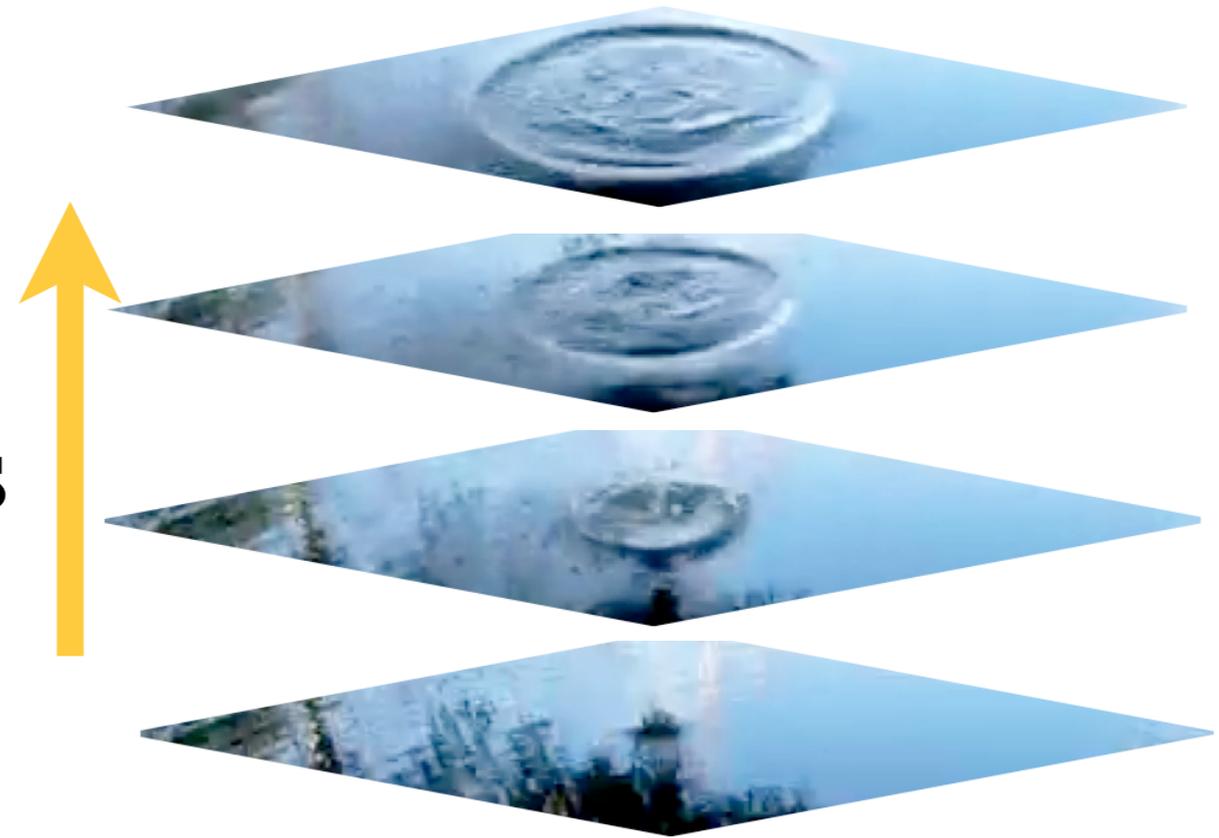
La relativité générale: une théorie de l'espace et du temps



Diagrammes d'espace-temps



Temps



Diagrammes d'espace-temps

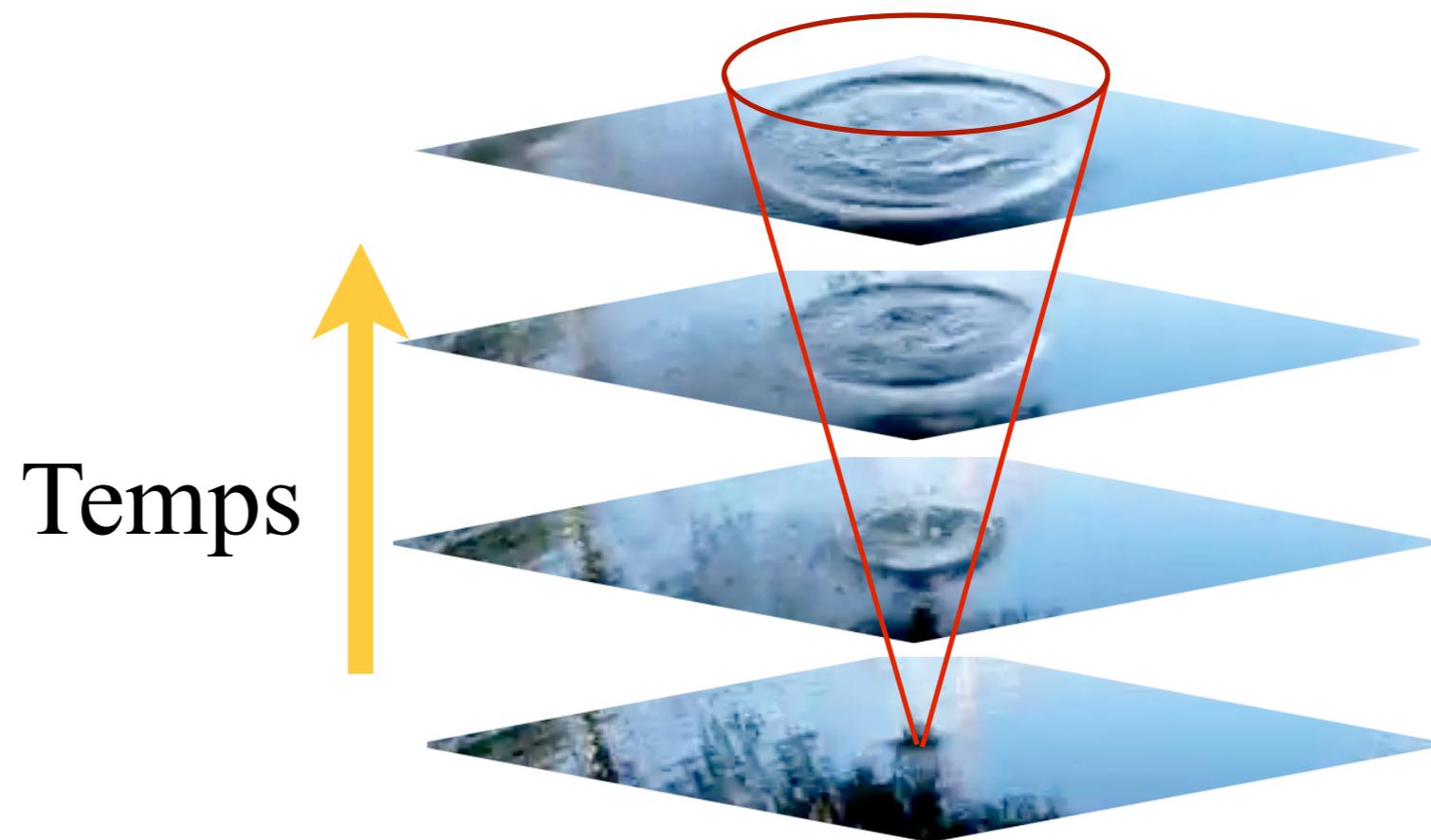


Diagramme d'espace-temps d'une étoile.

Temps

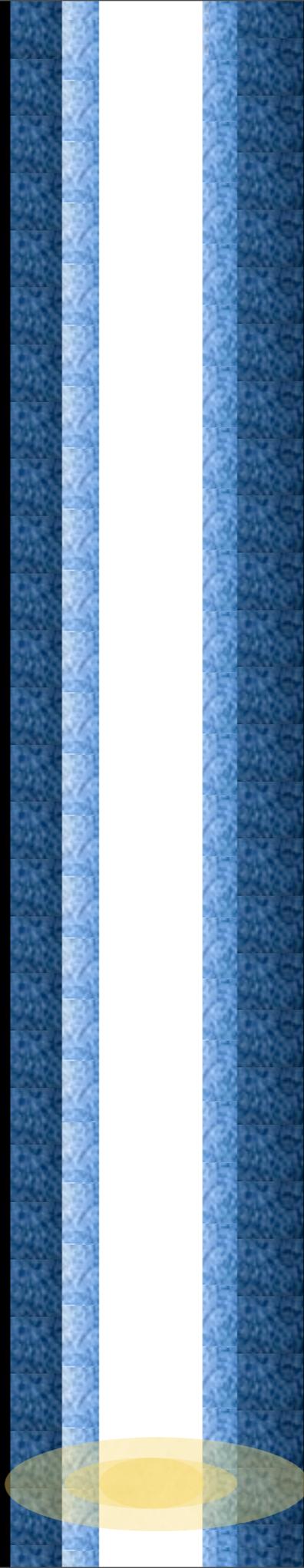


Image instantanée

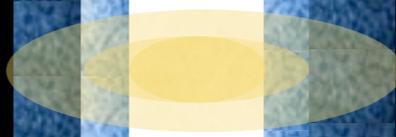
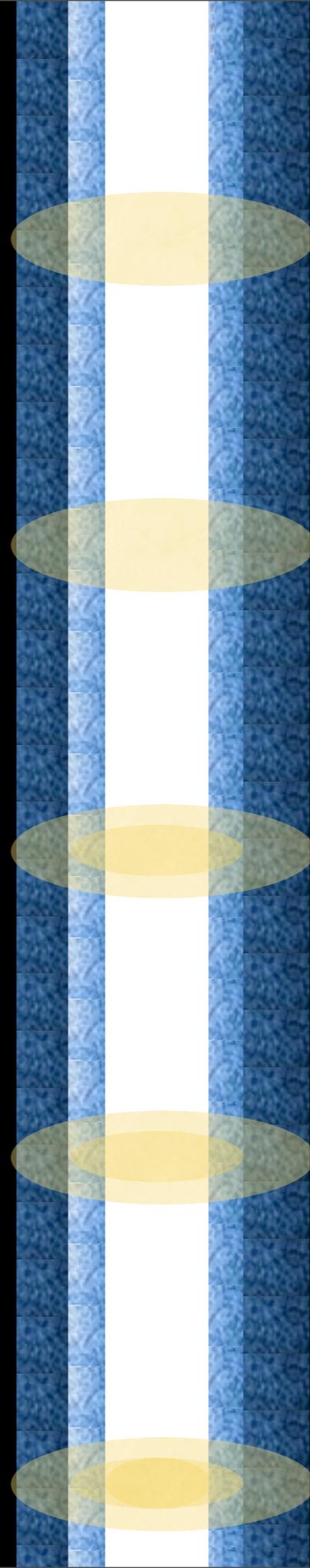


Diagramme d'espace-temps d'une étoile.

Temps



Orbite d'une planète

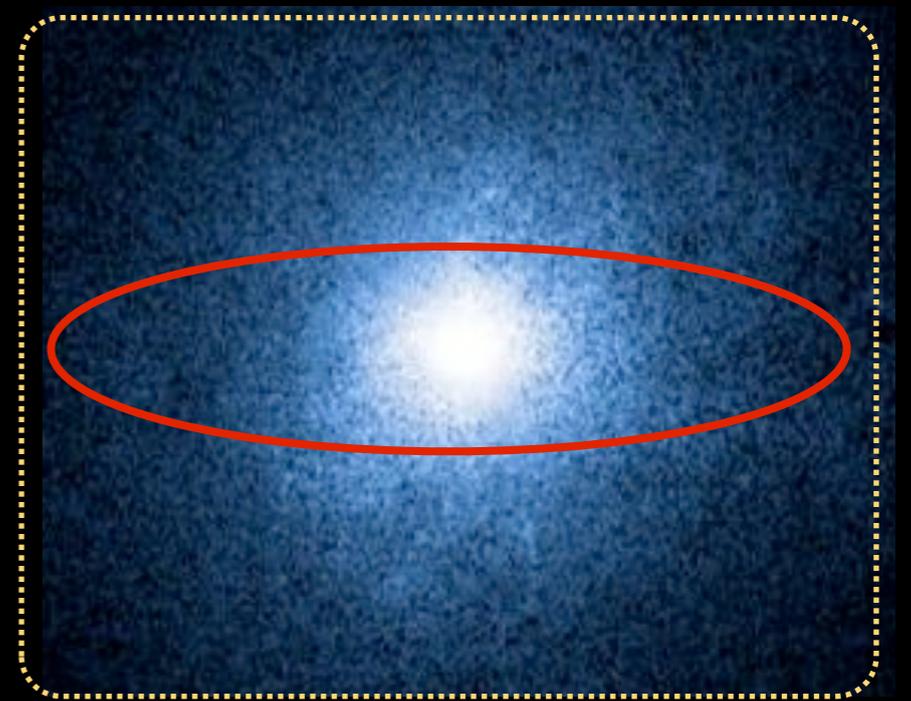
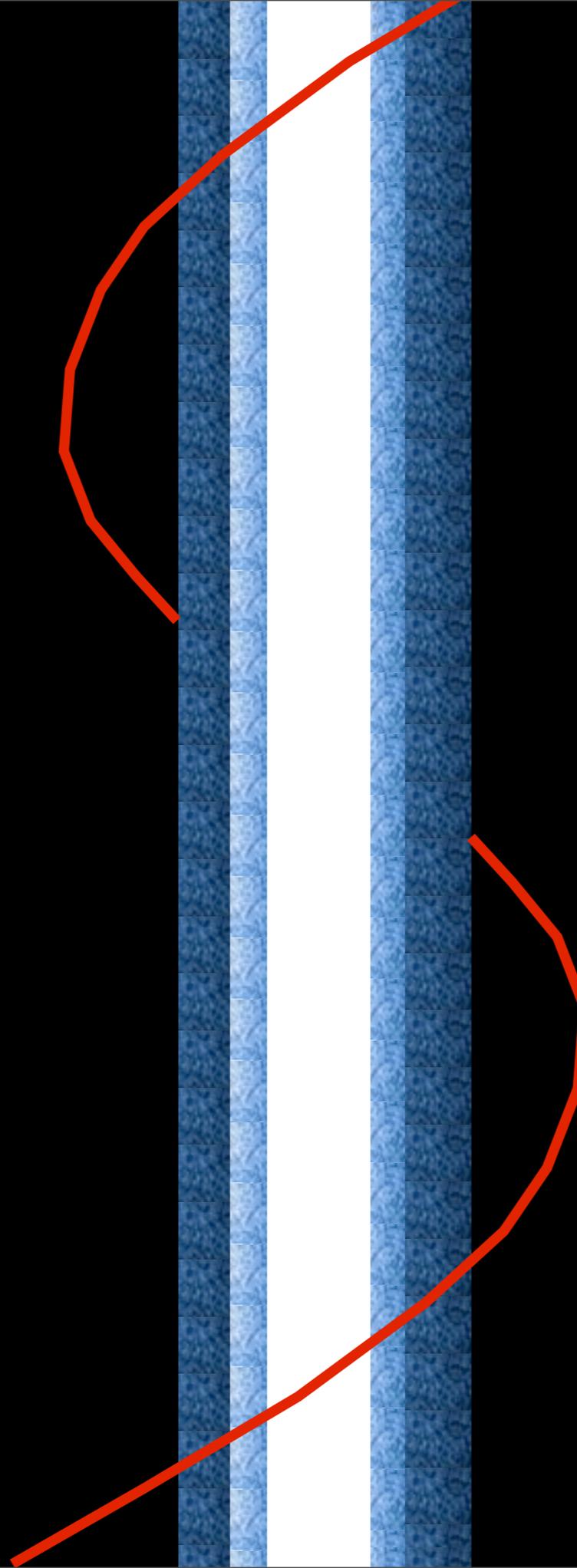


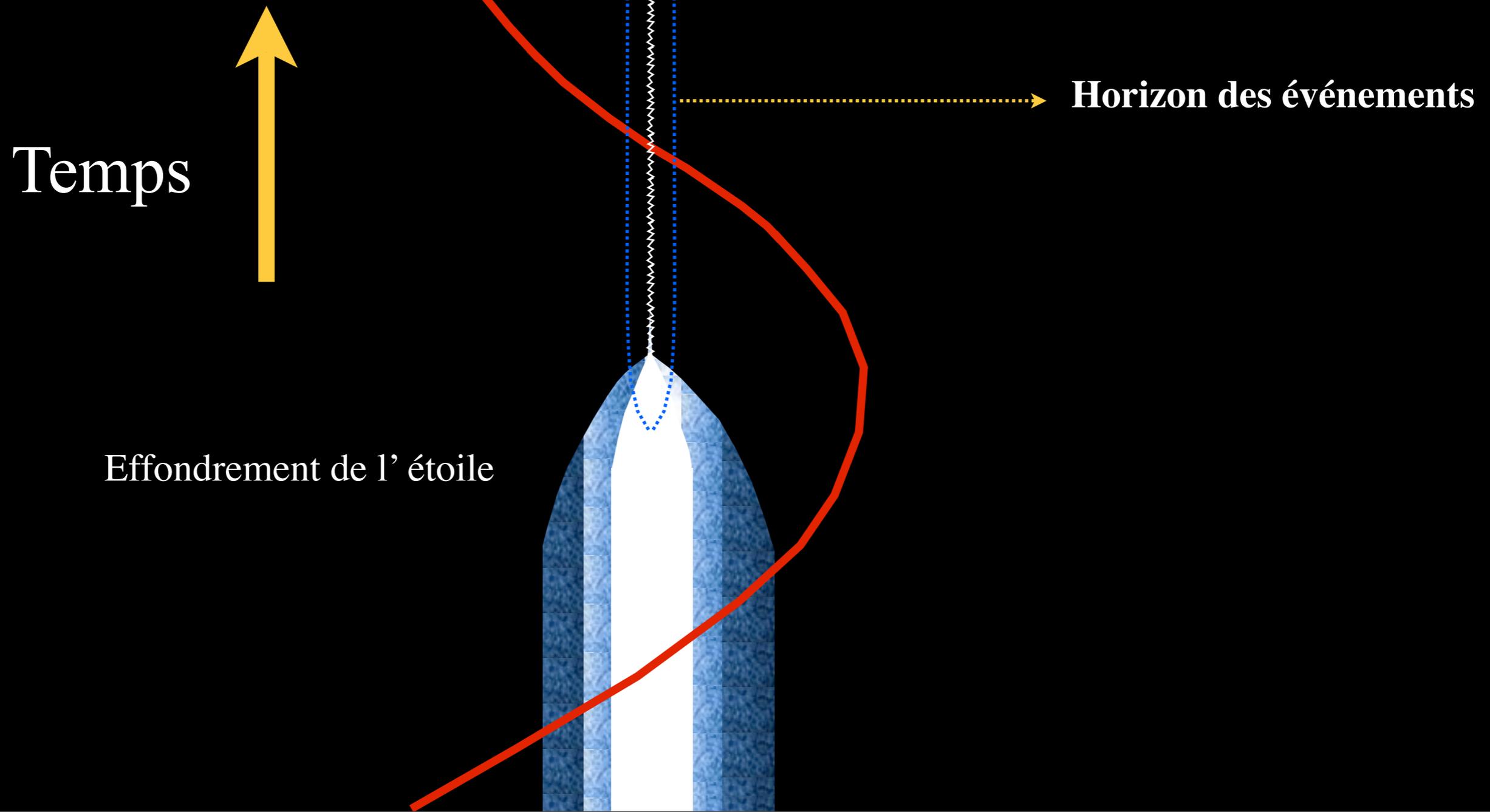
Diagramme d'espace-temps d'une étoile.

Temps

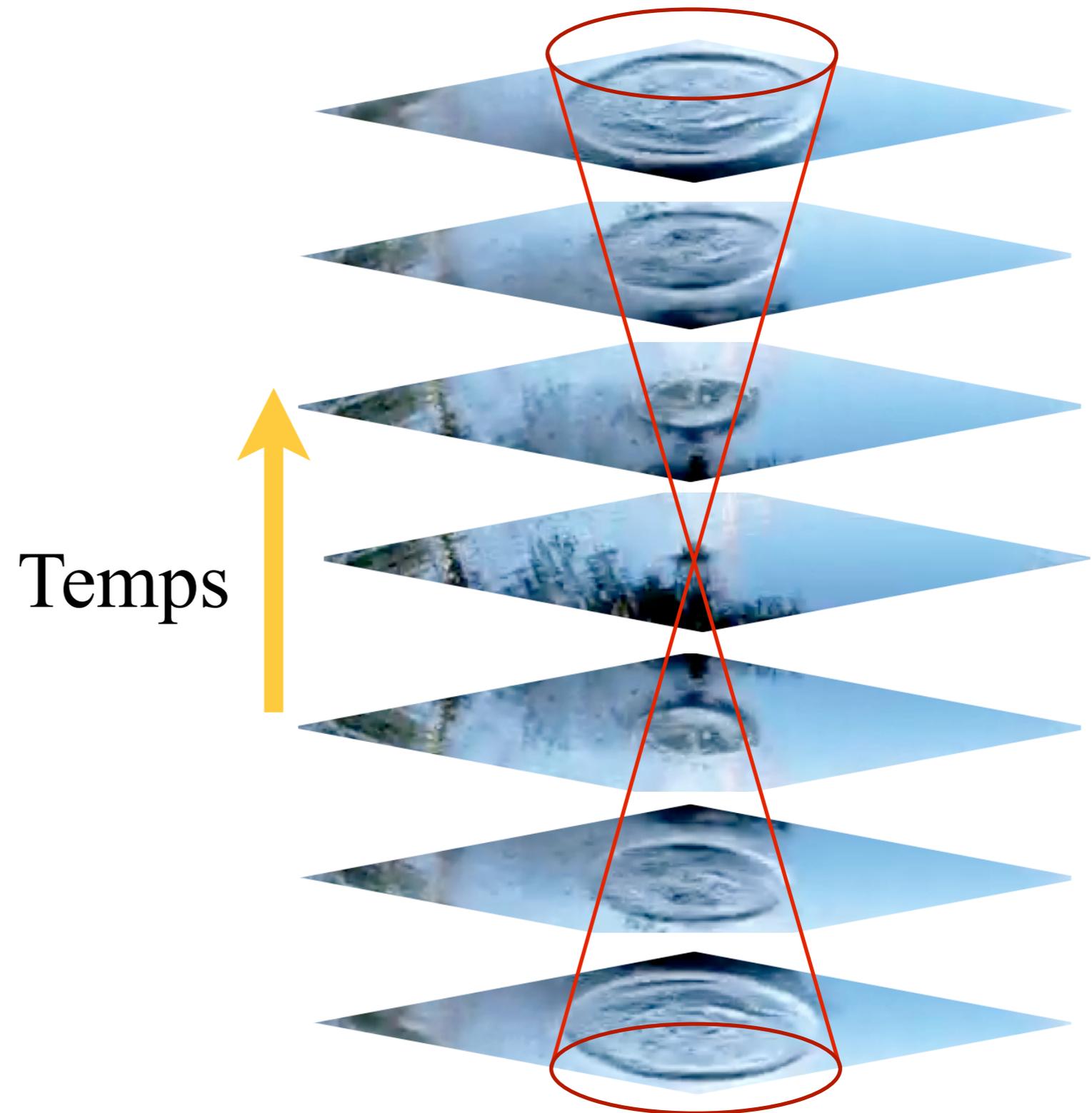


Planète en orbite

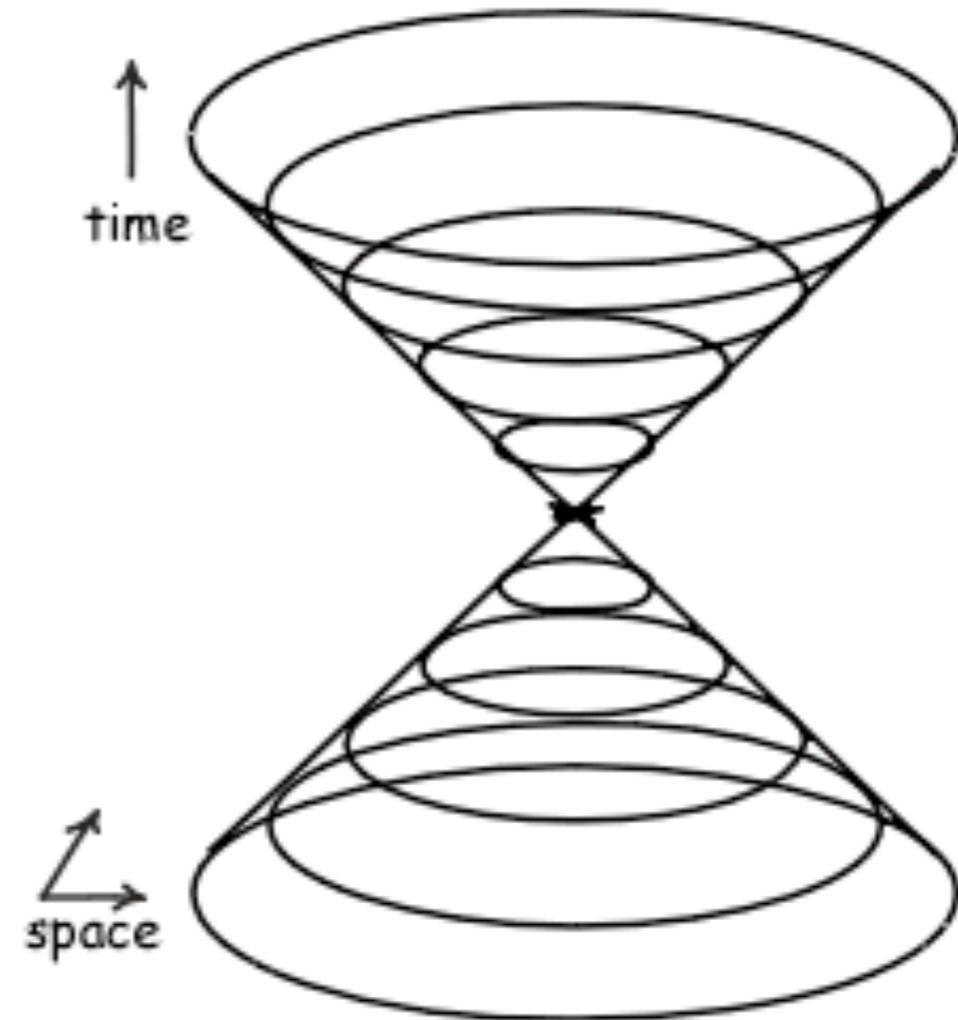
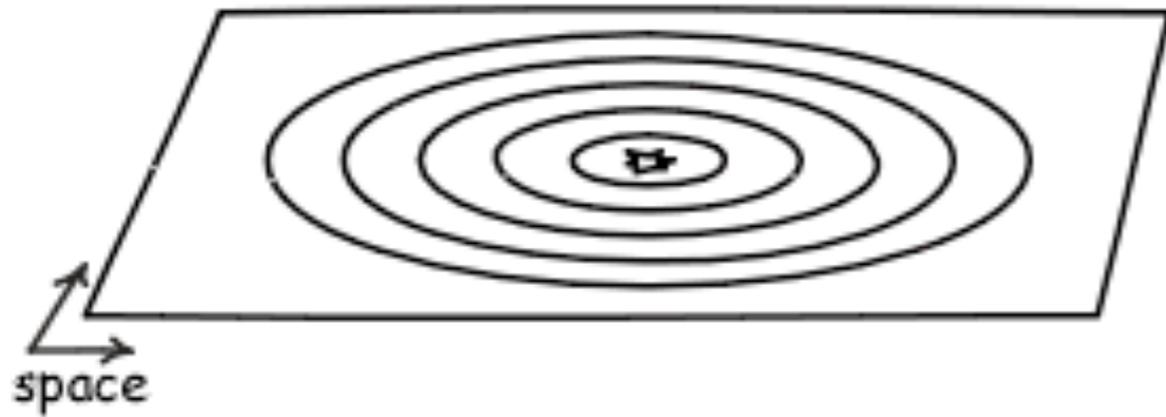
Diagramme d'espace-temps d'une étoile.



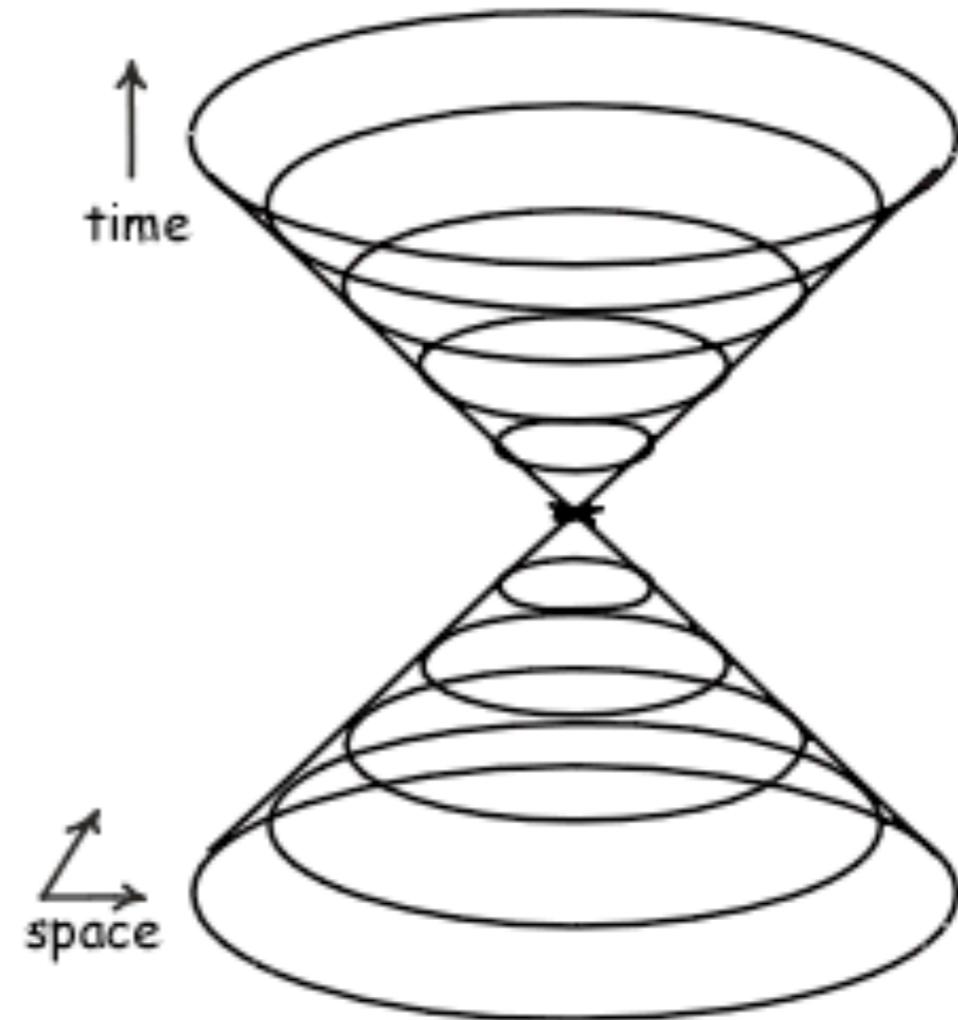
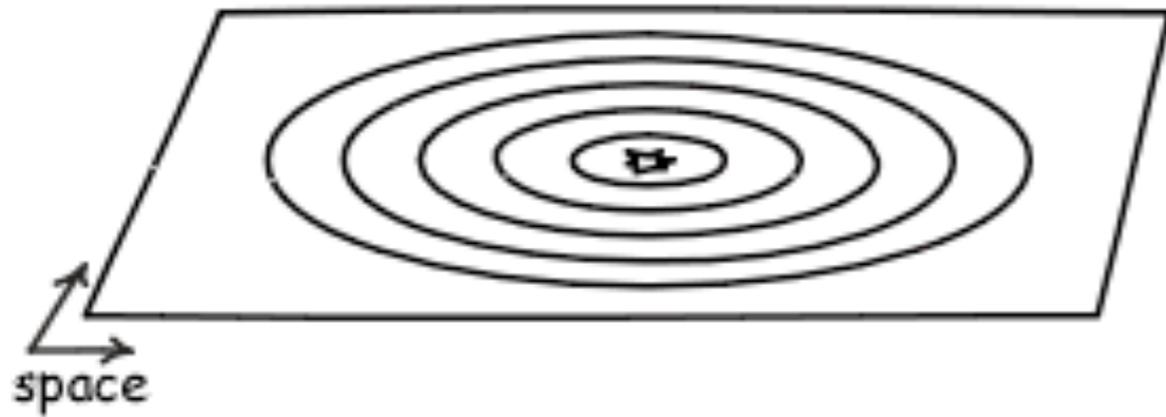
Diagrammes d'espace-temps: le cône de lumière



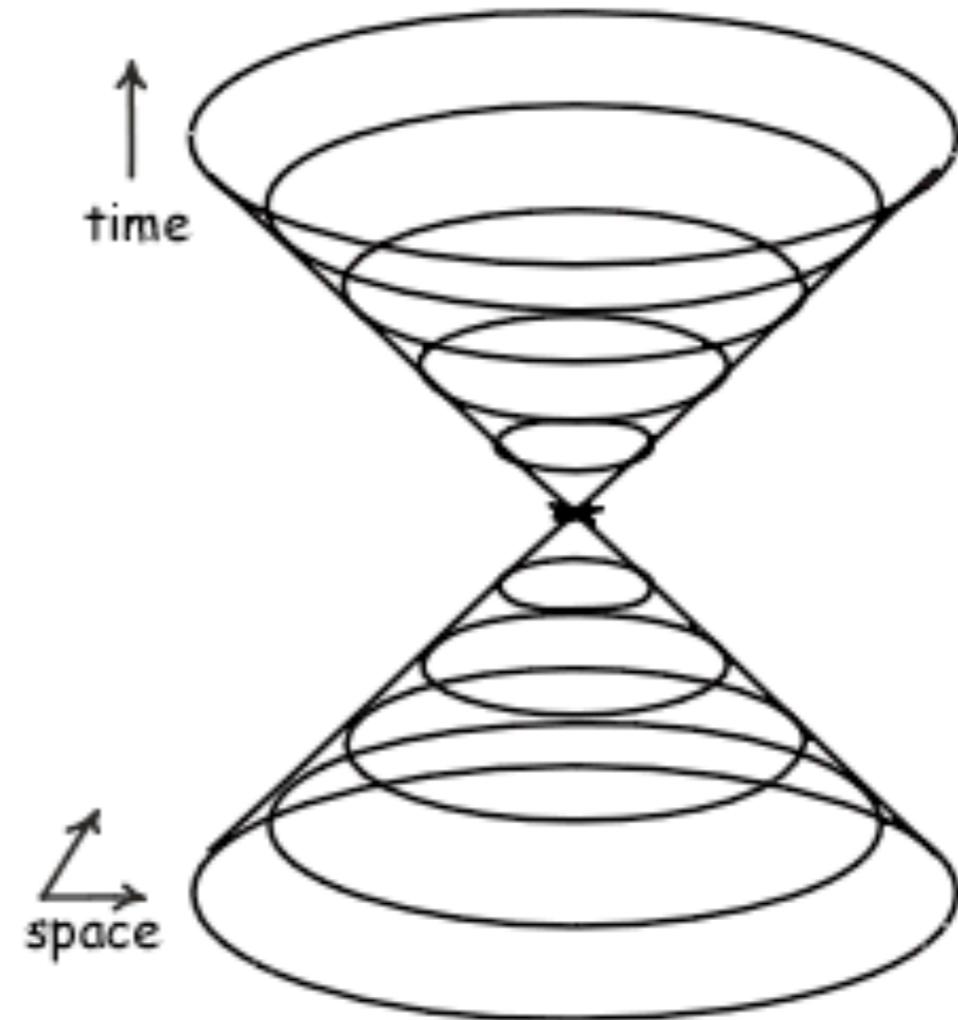
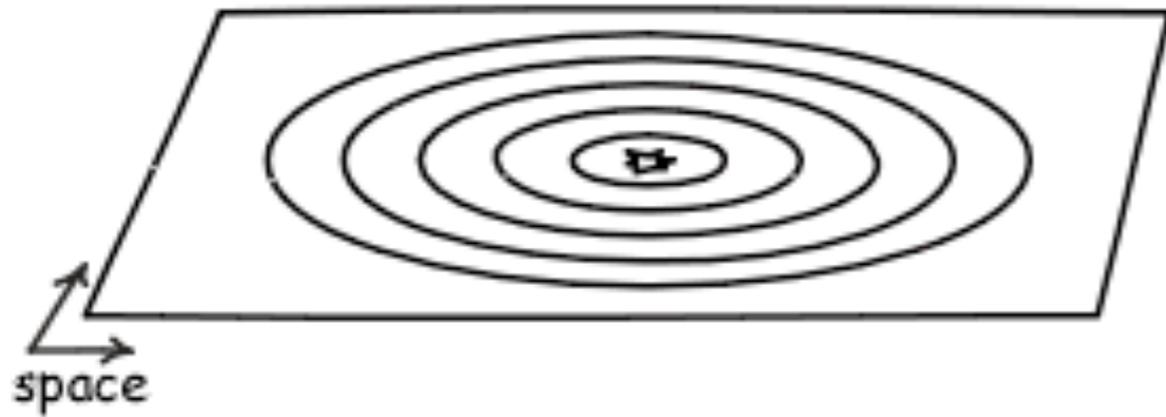
Diagrammes d'espace-temps: le cône de lumière

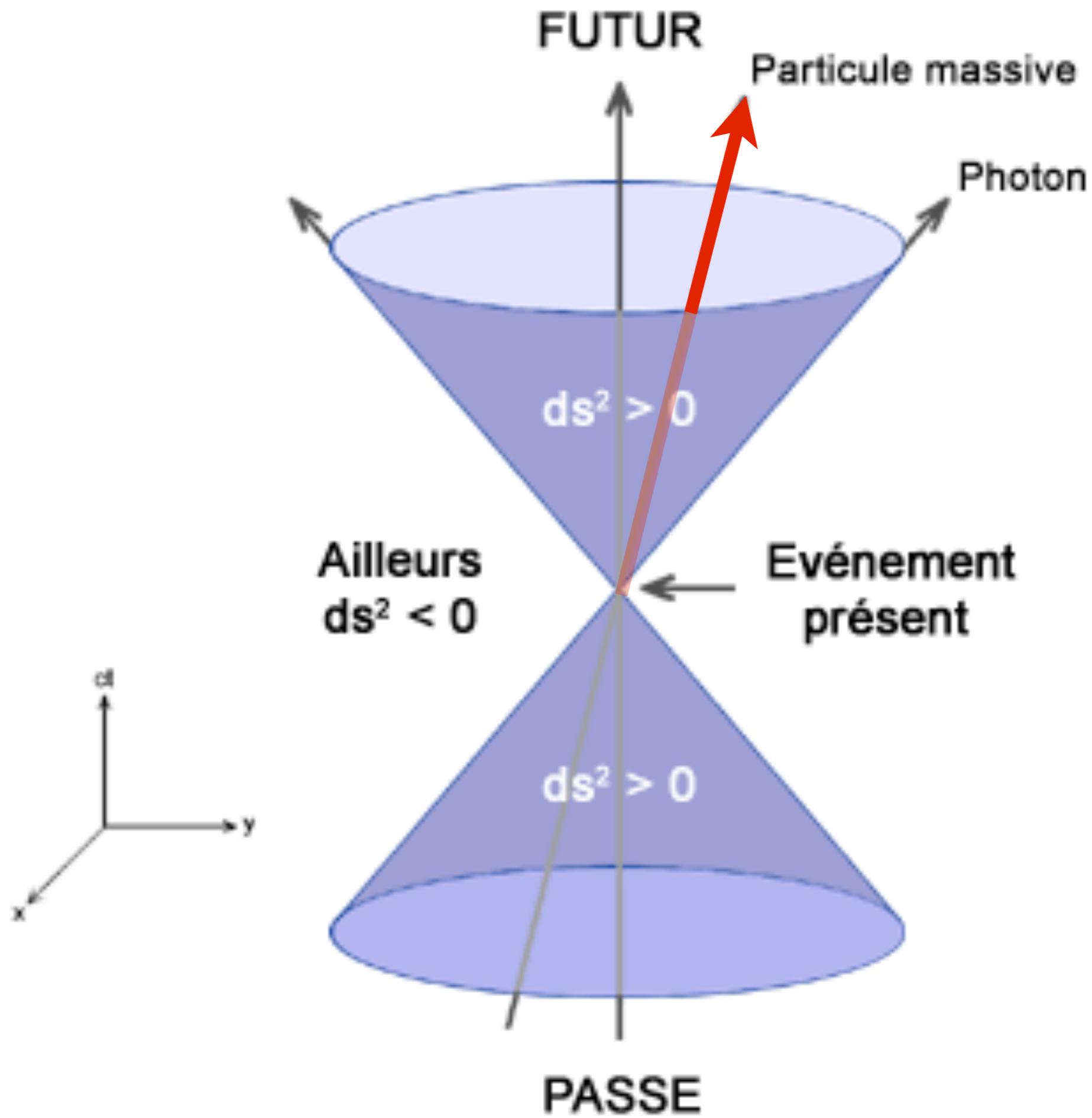


Diagrammes d'espace-temps: le cône de lumière

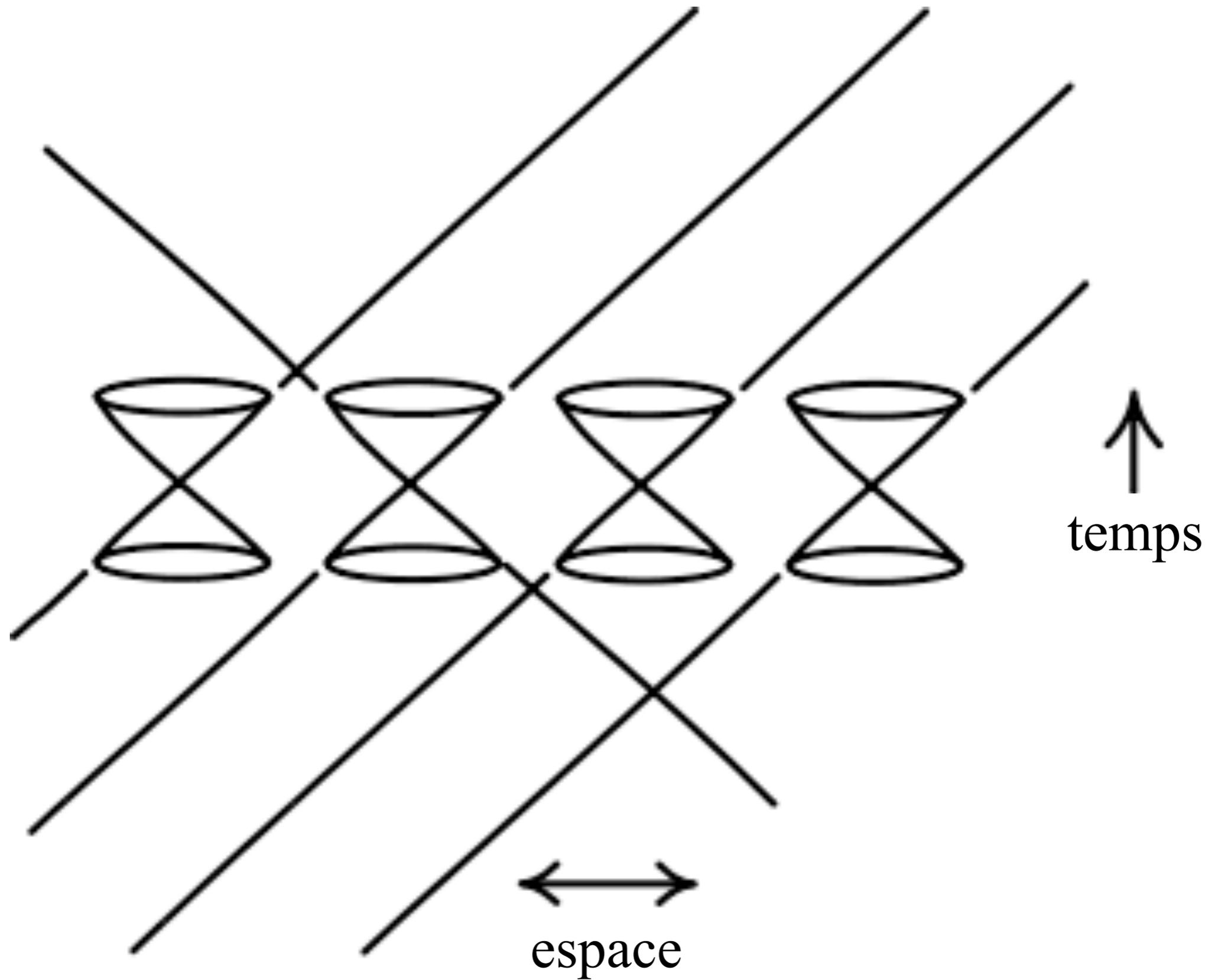


Diagrammes d'espace-temps: le cône de lumière





Cônes de lumière dans un espace-temps plat

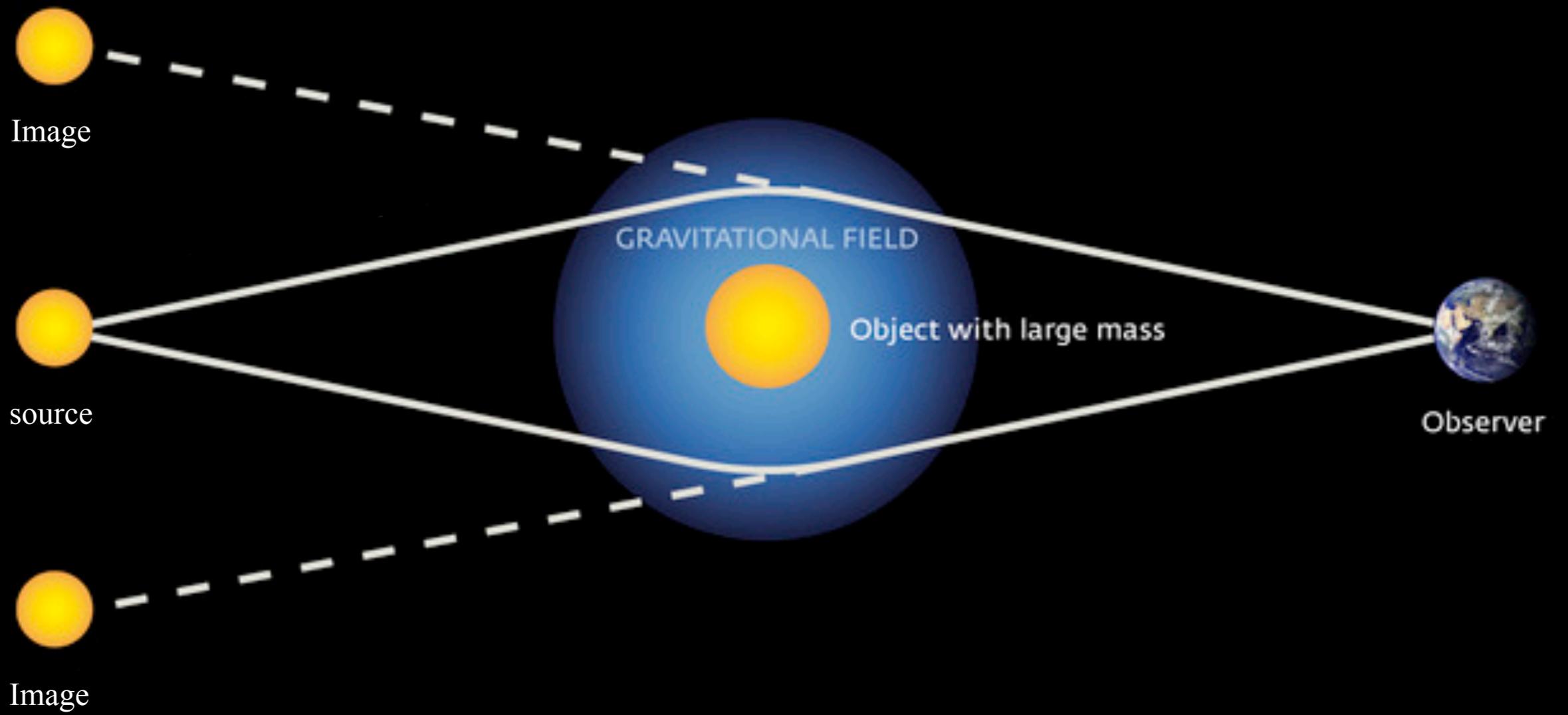


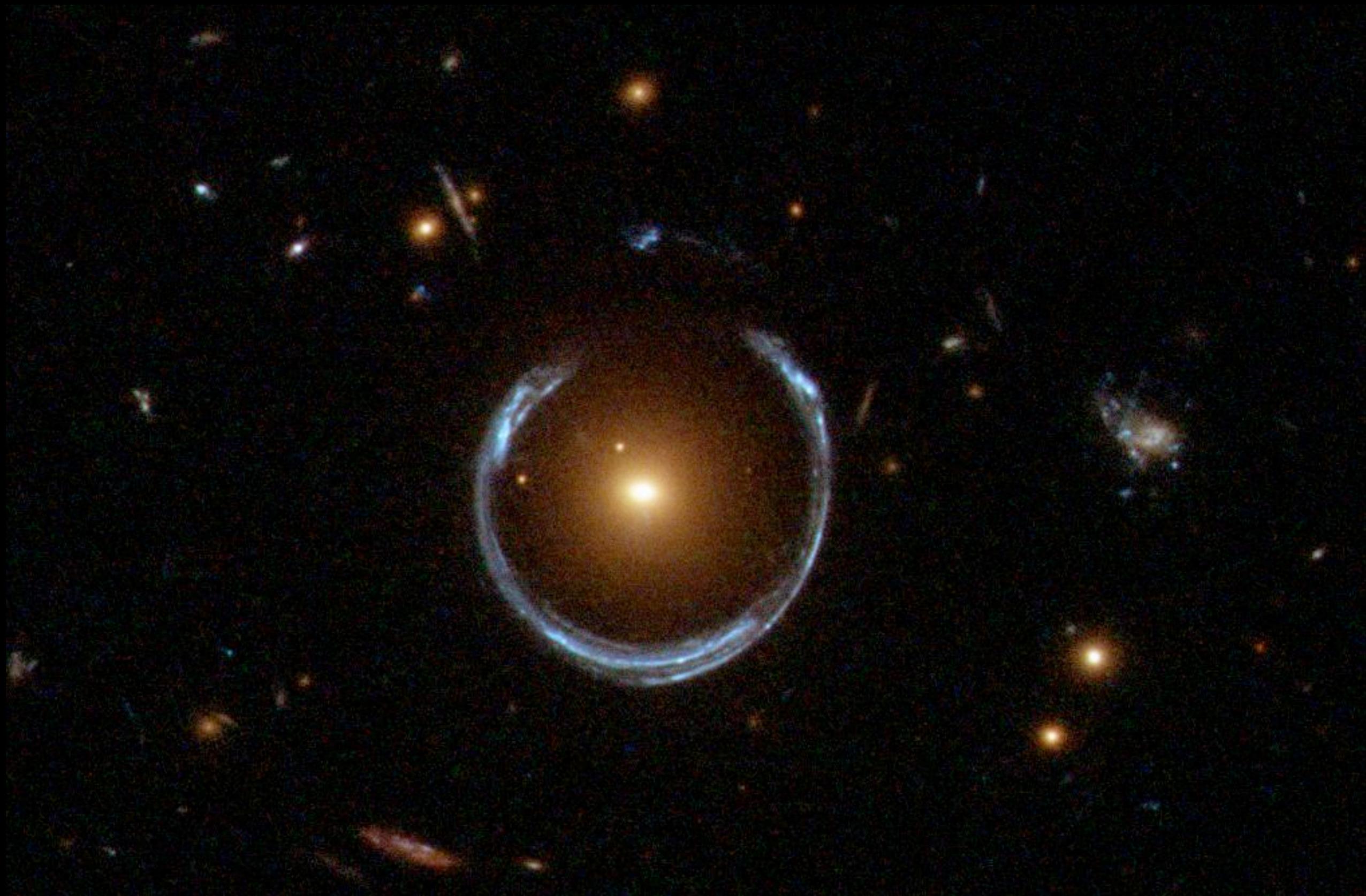
Cônes de lumière dans un espace-temps plat

temps

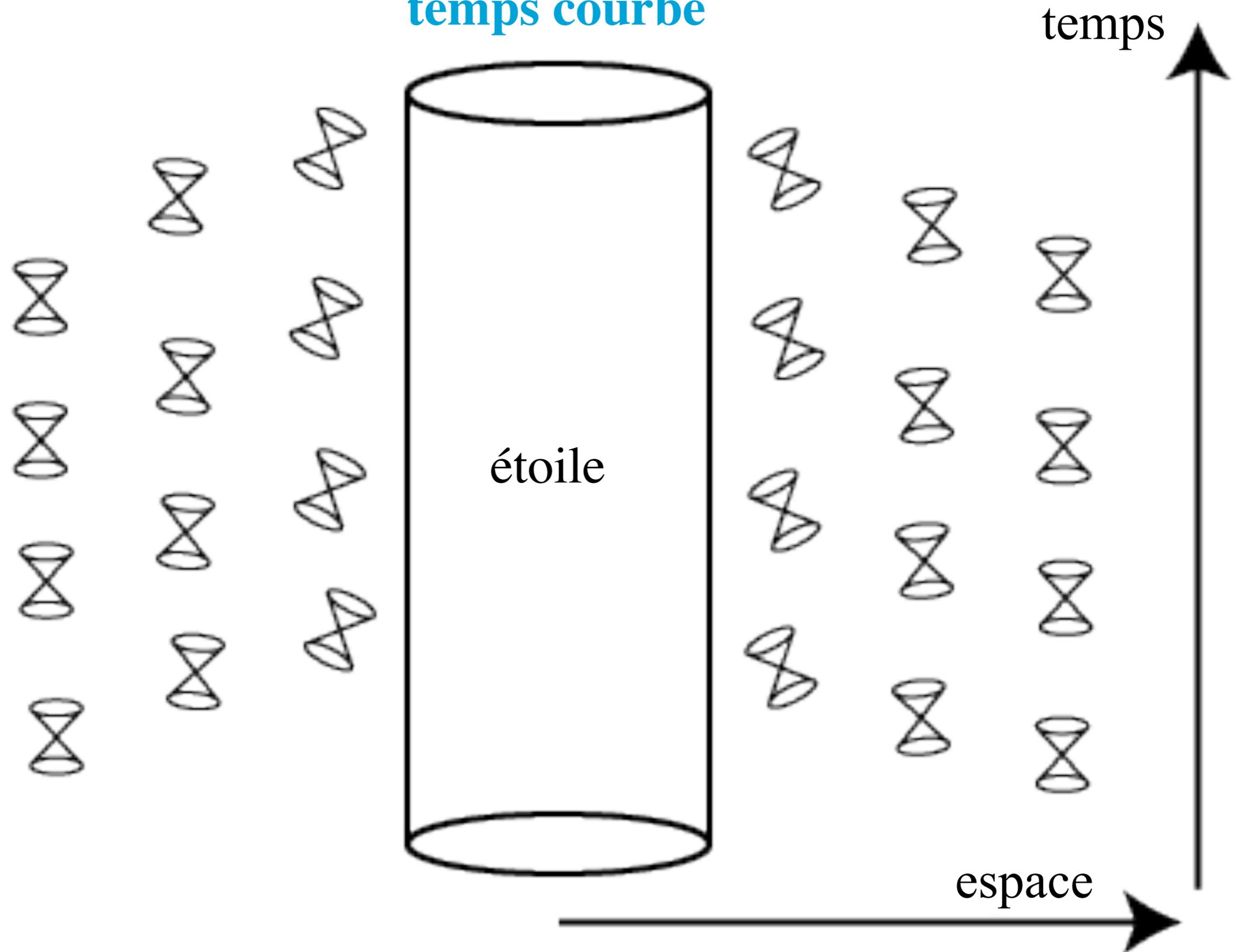


espace

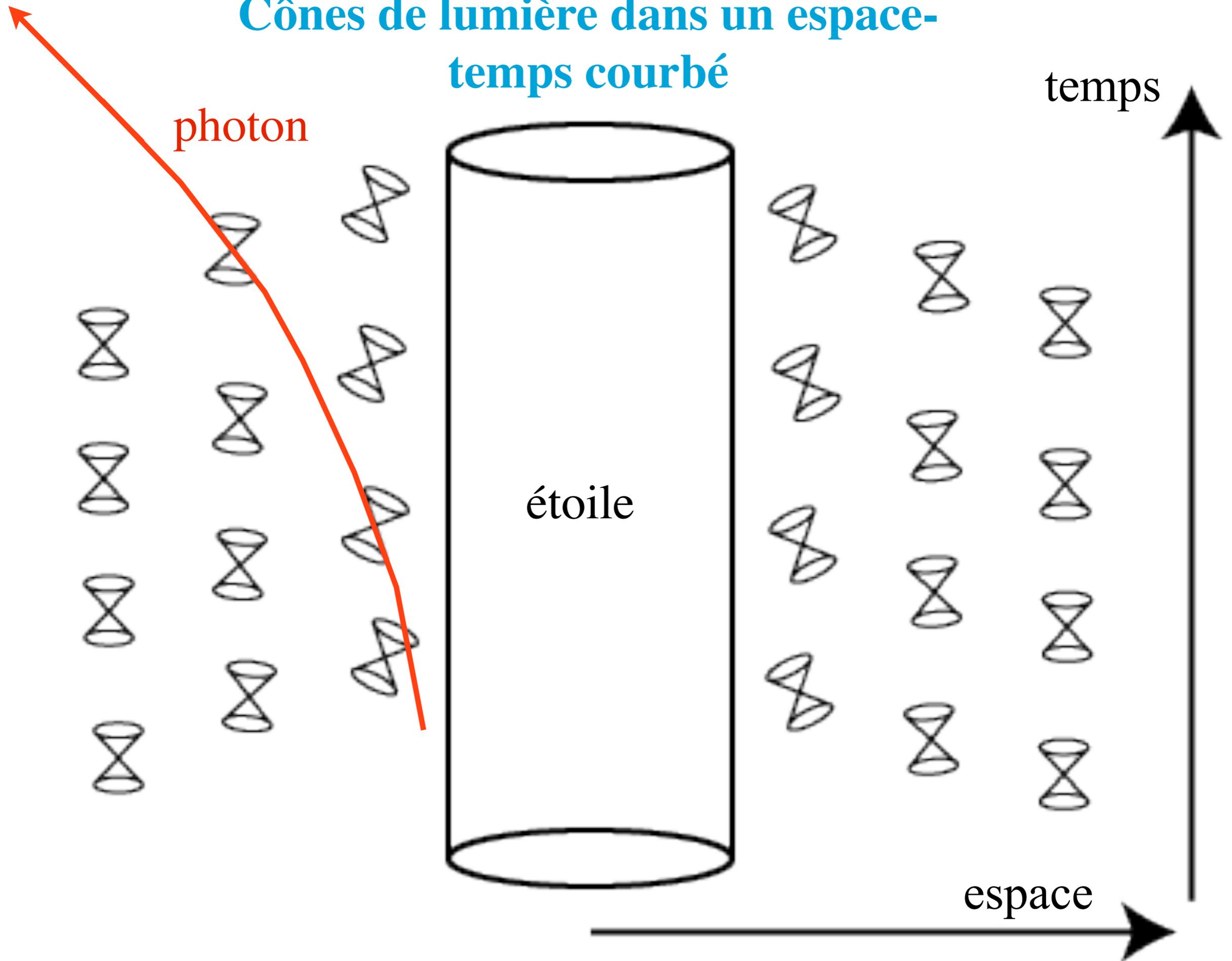




Cônes de lumière dans un espace-temps courbe



Cônes de lumière dans un espace-temps courbé

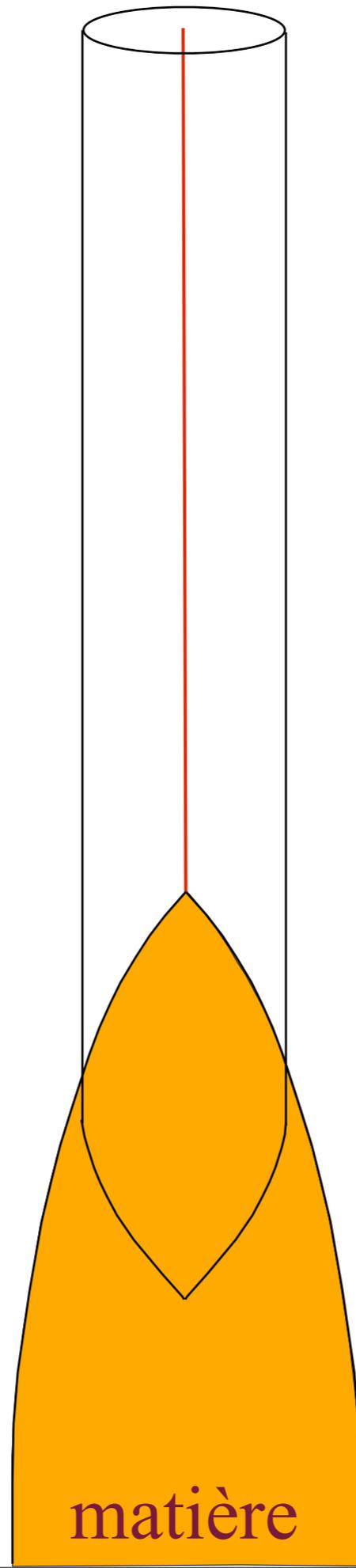


photon

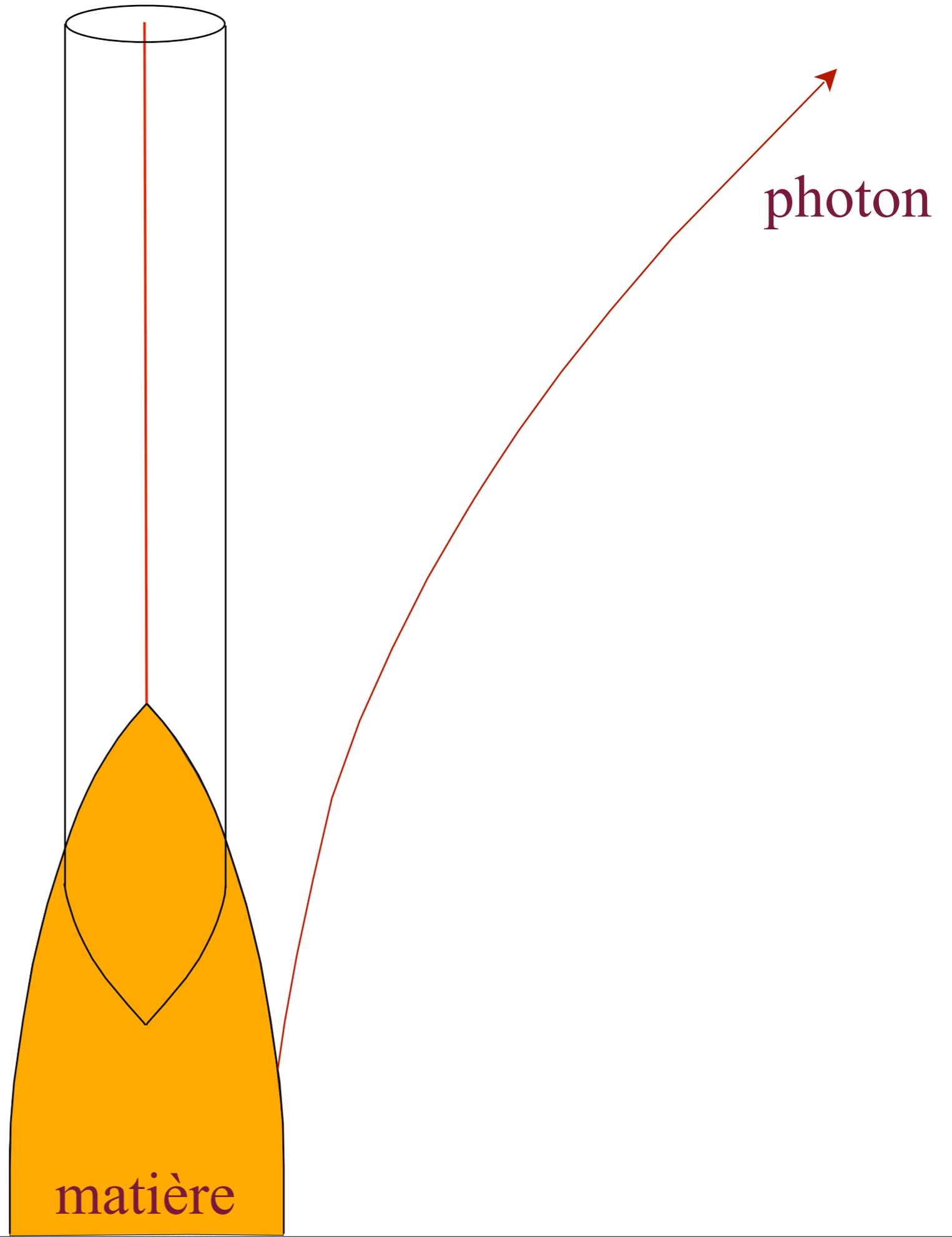
étoile

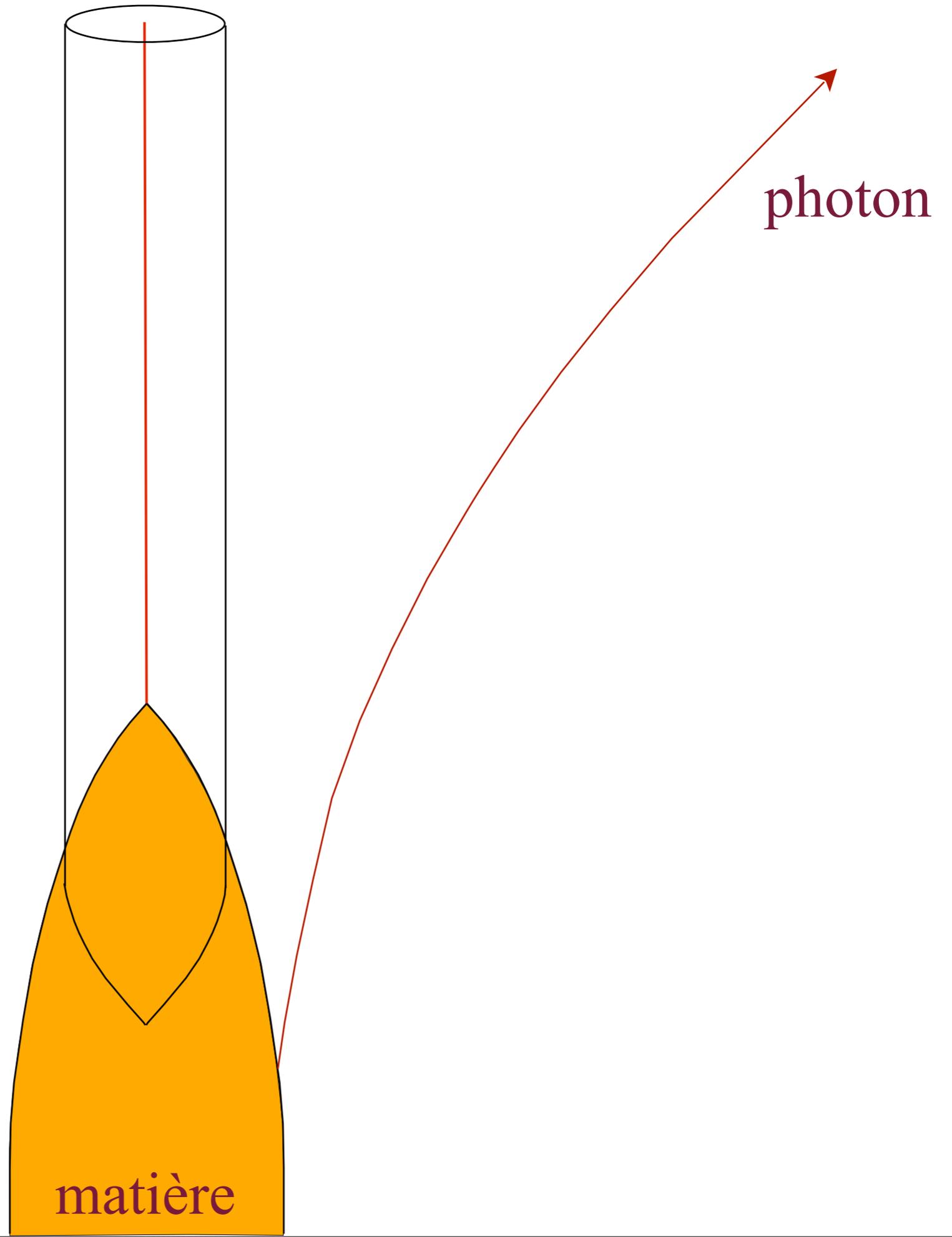
temps

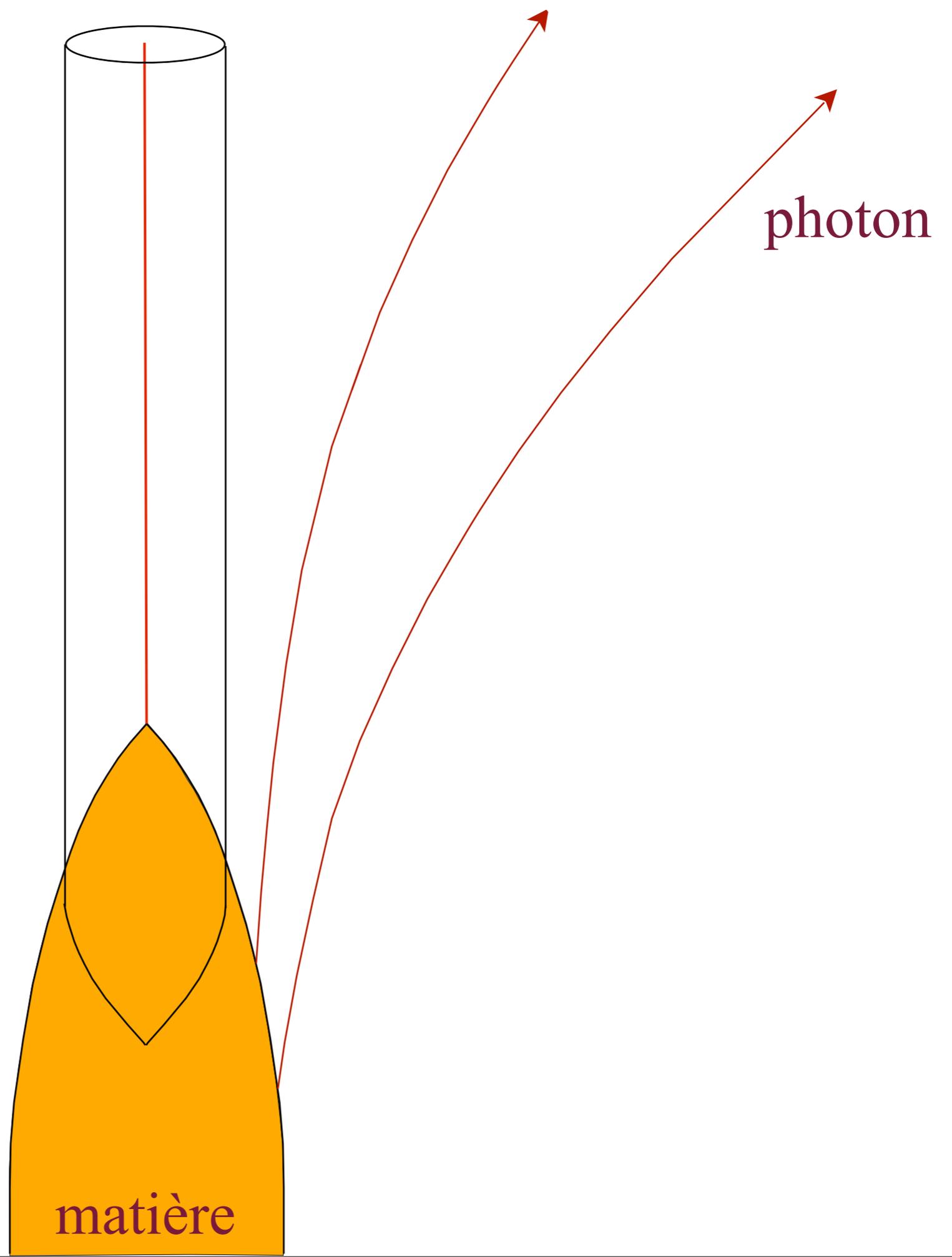
espace

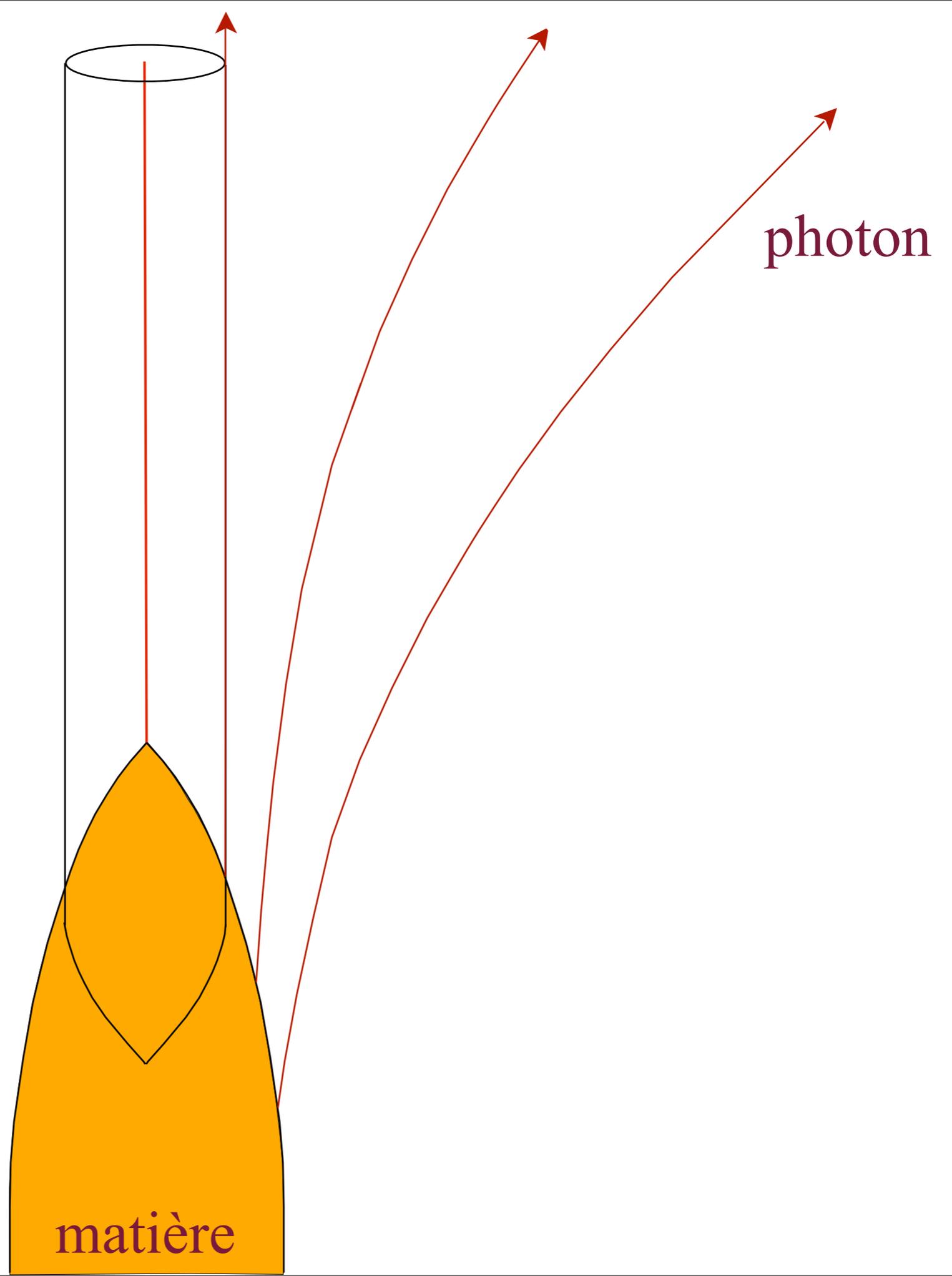


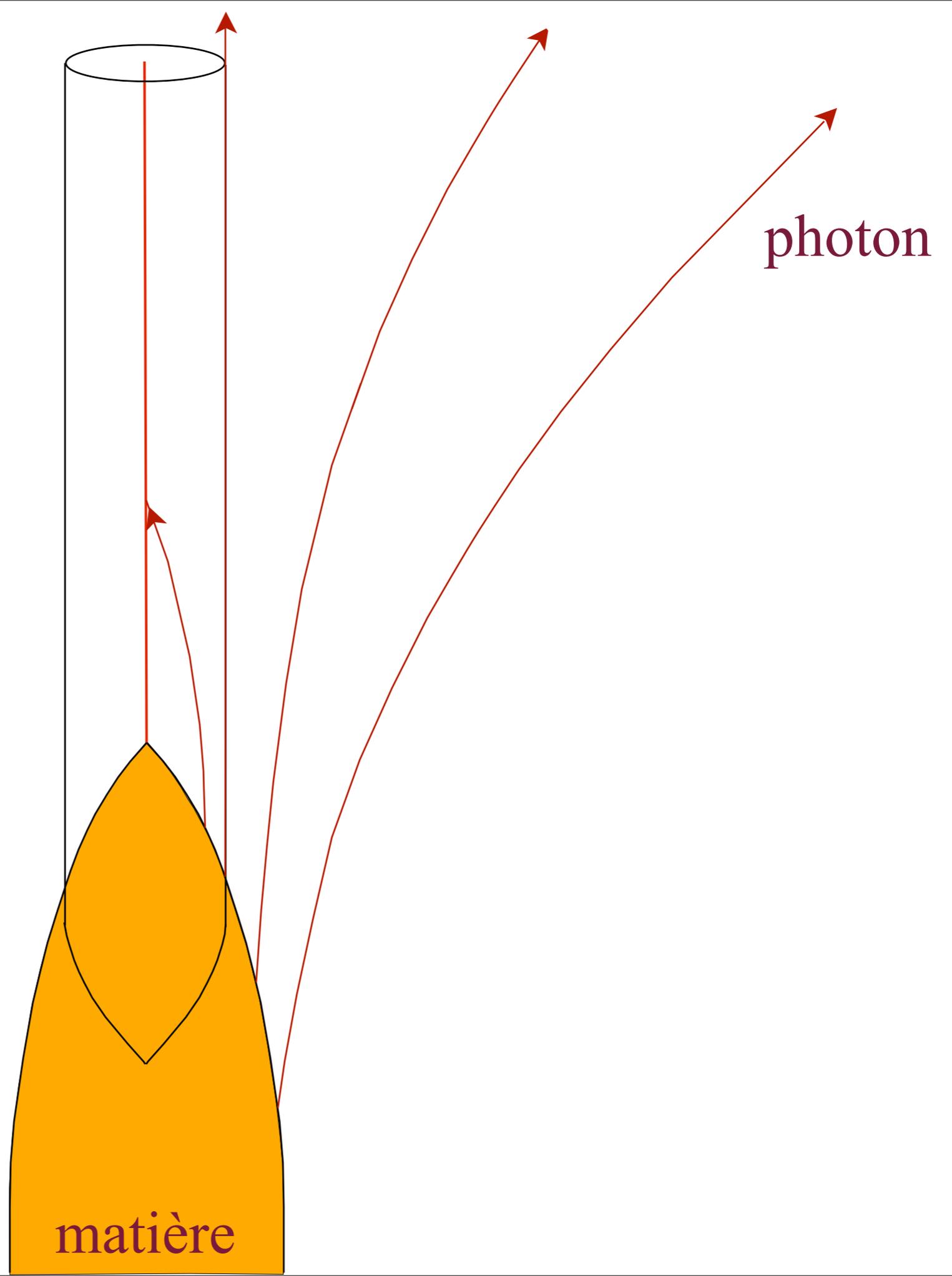
matière

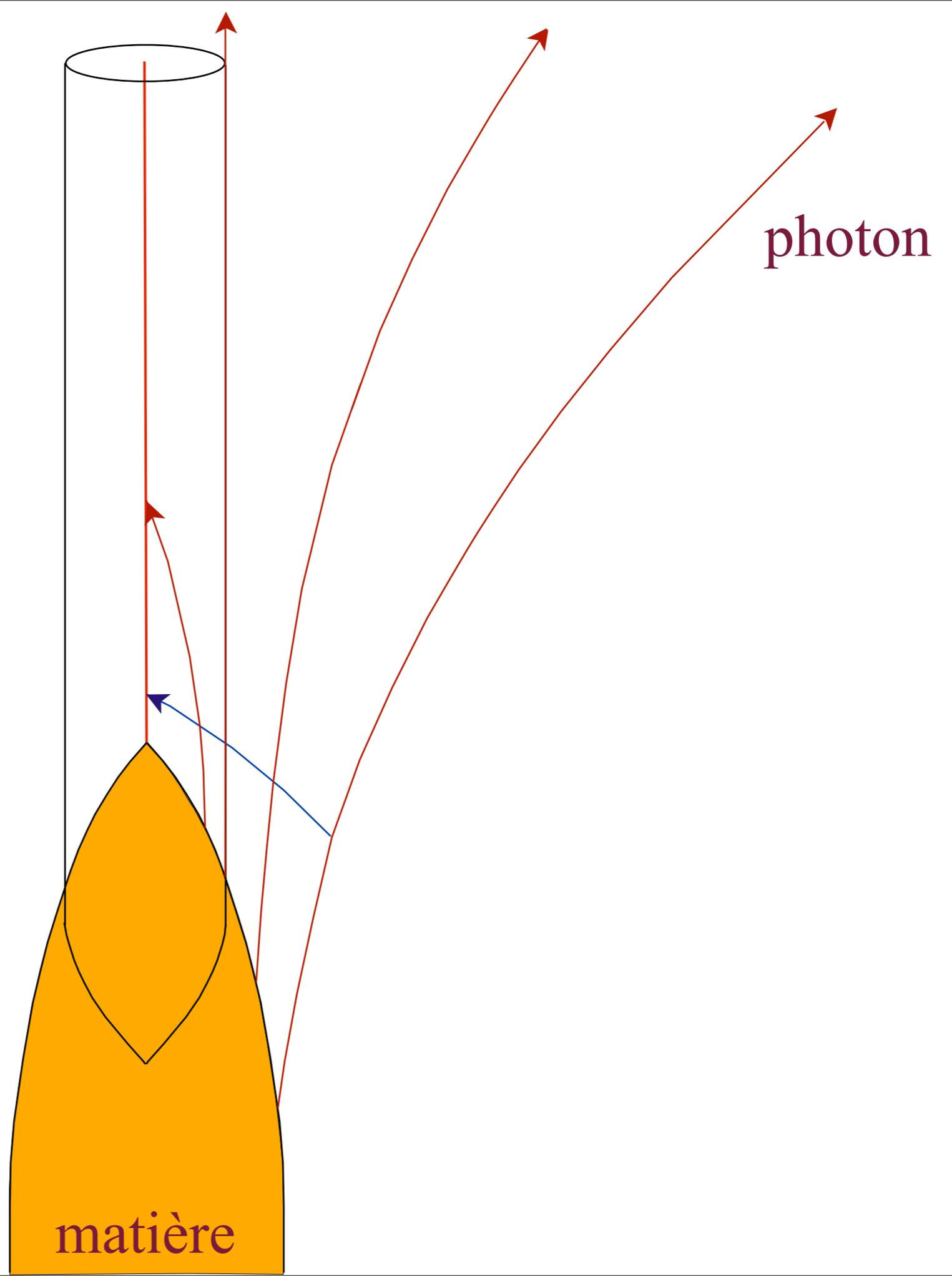


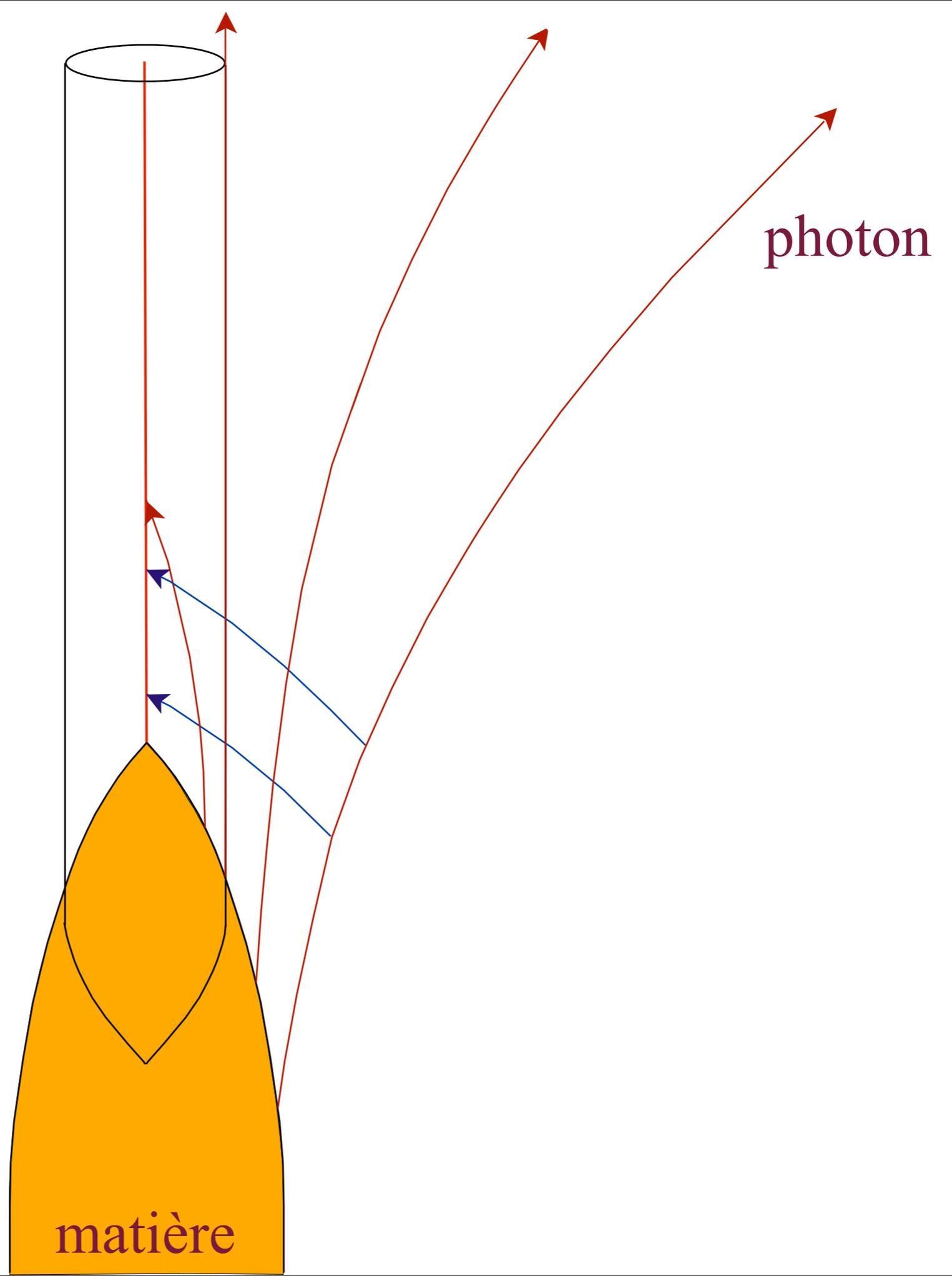


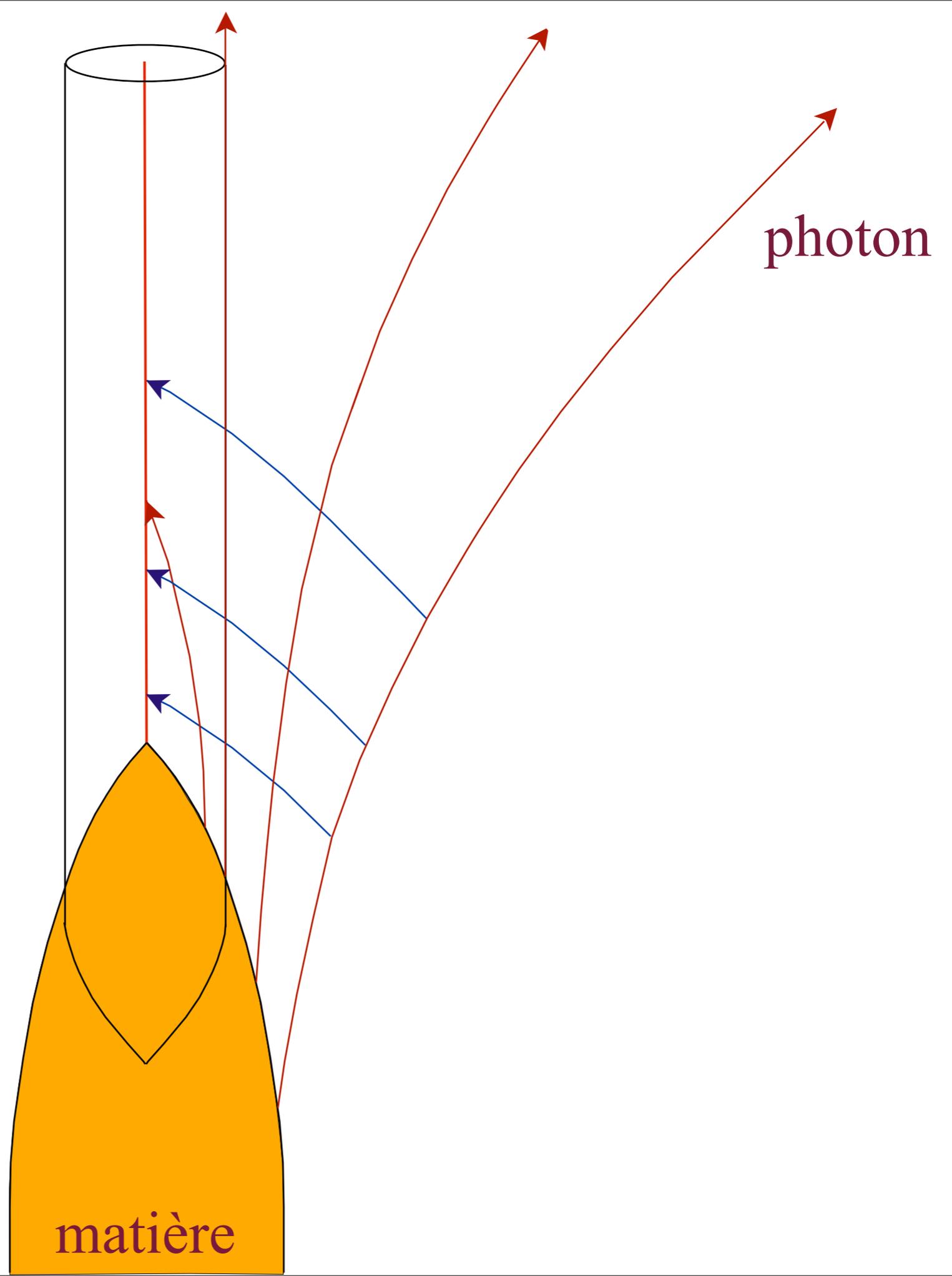


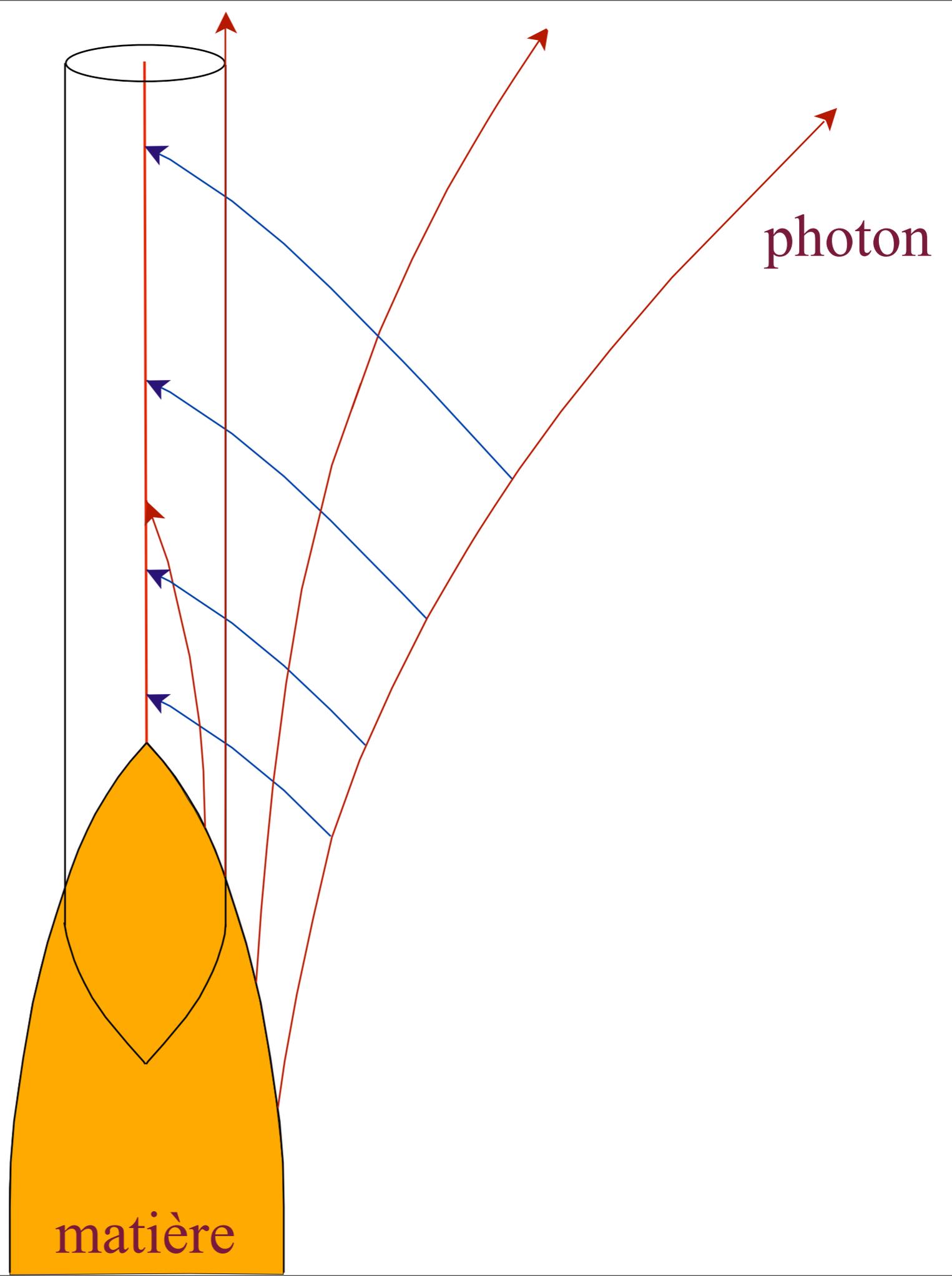


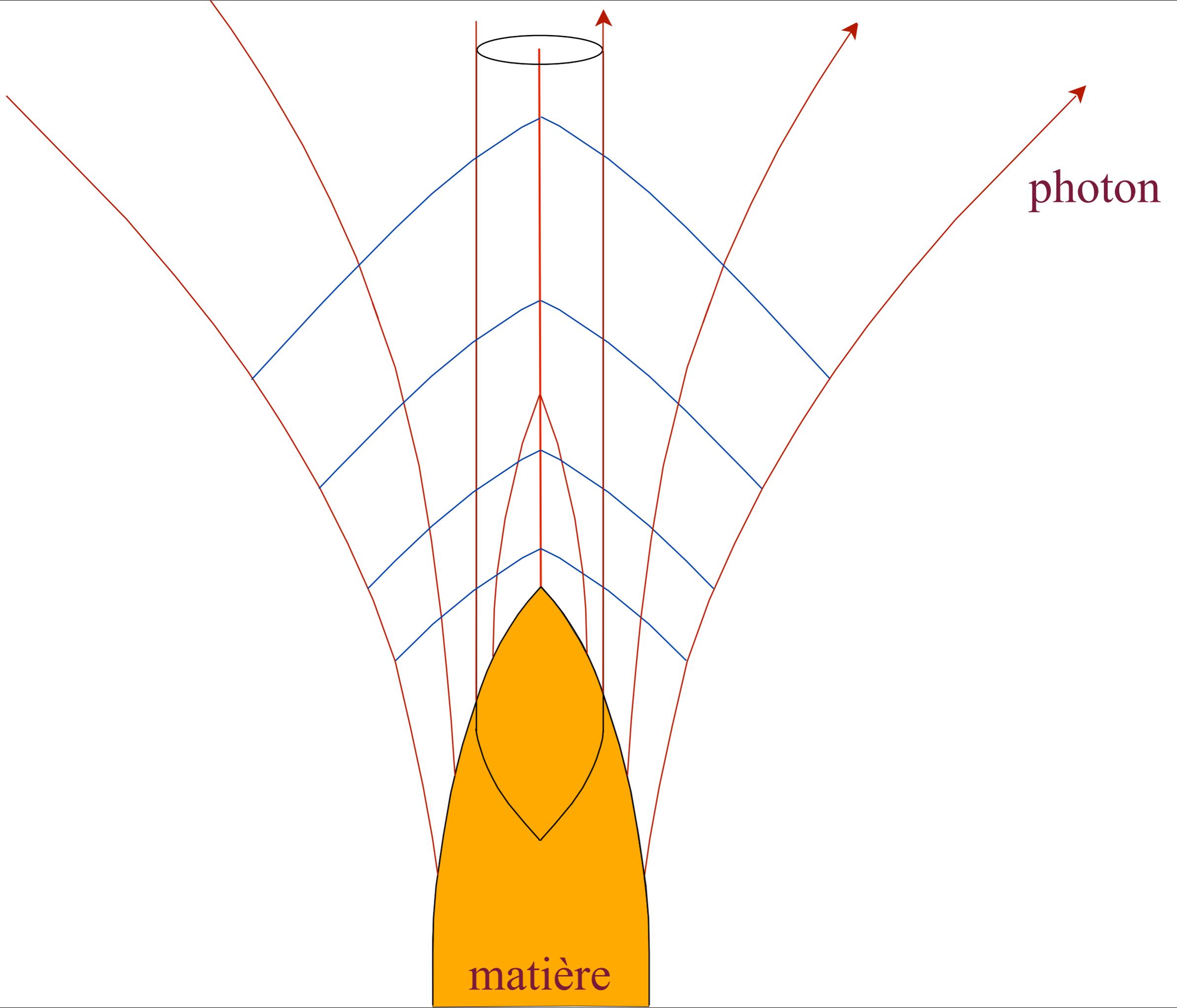


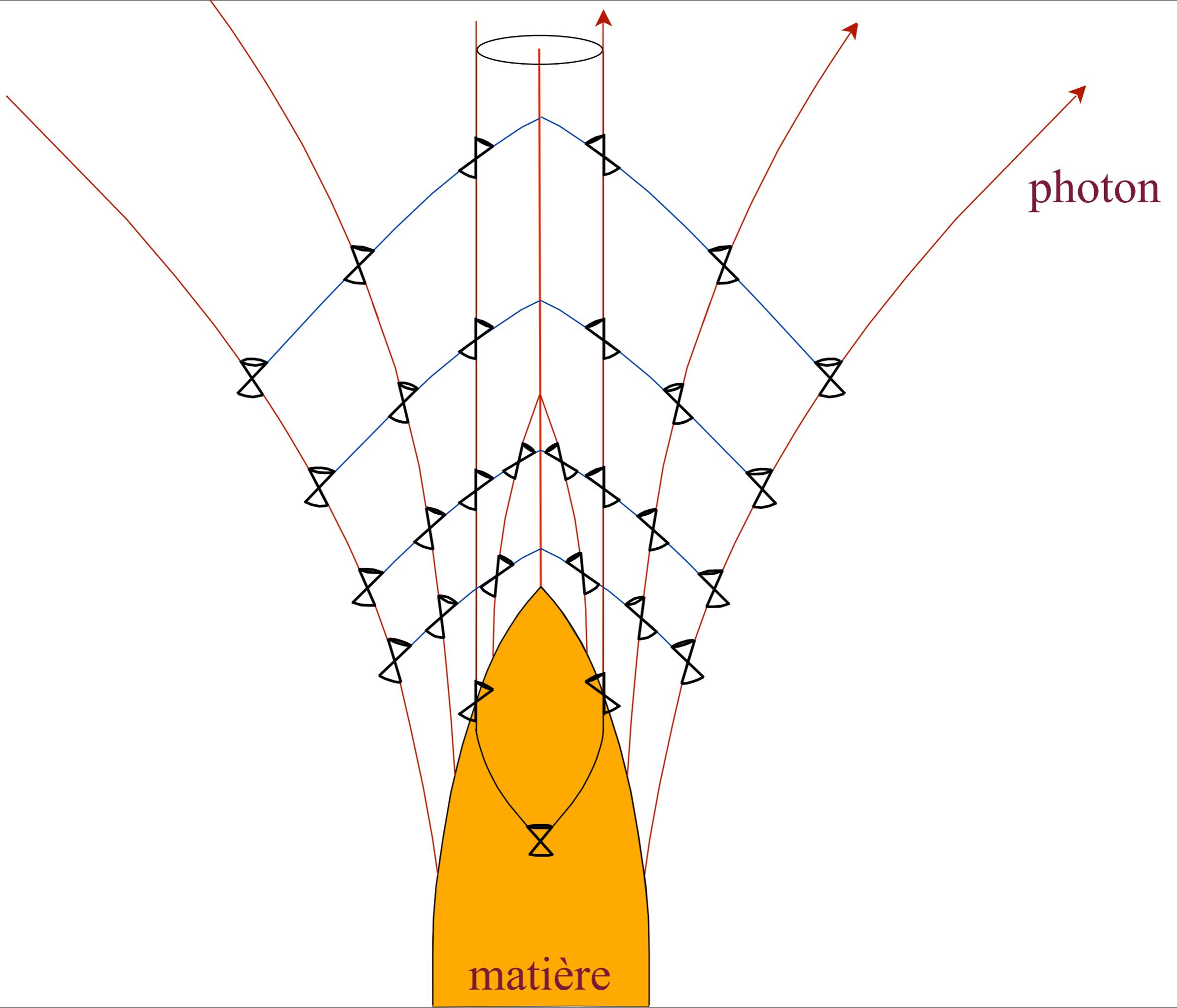


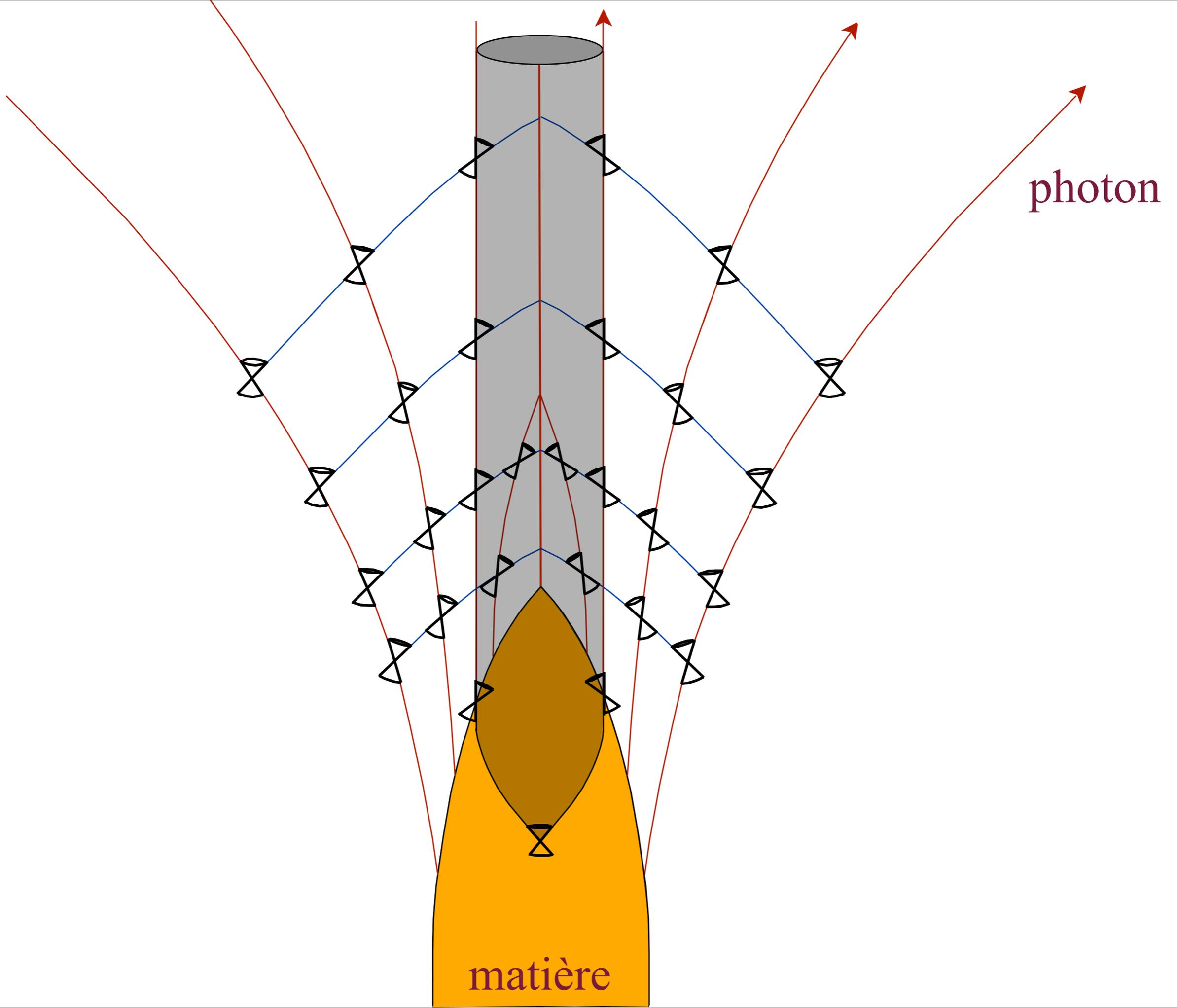


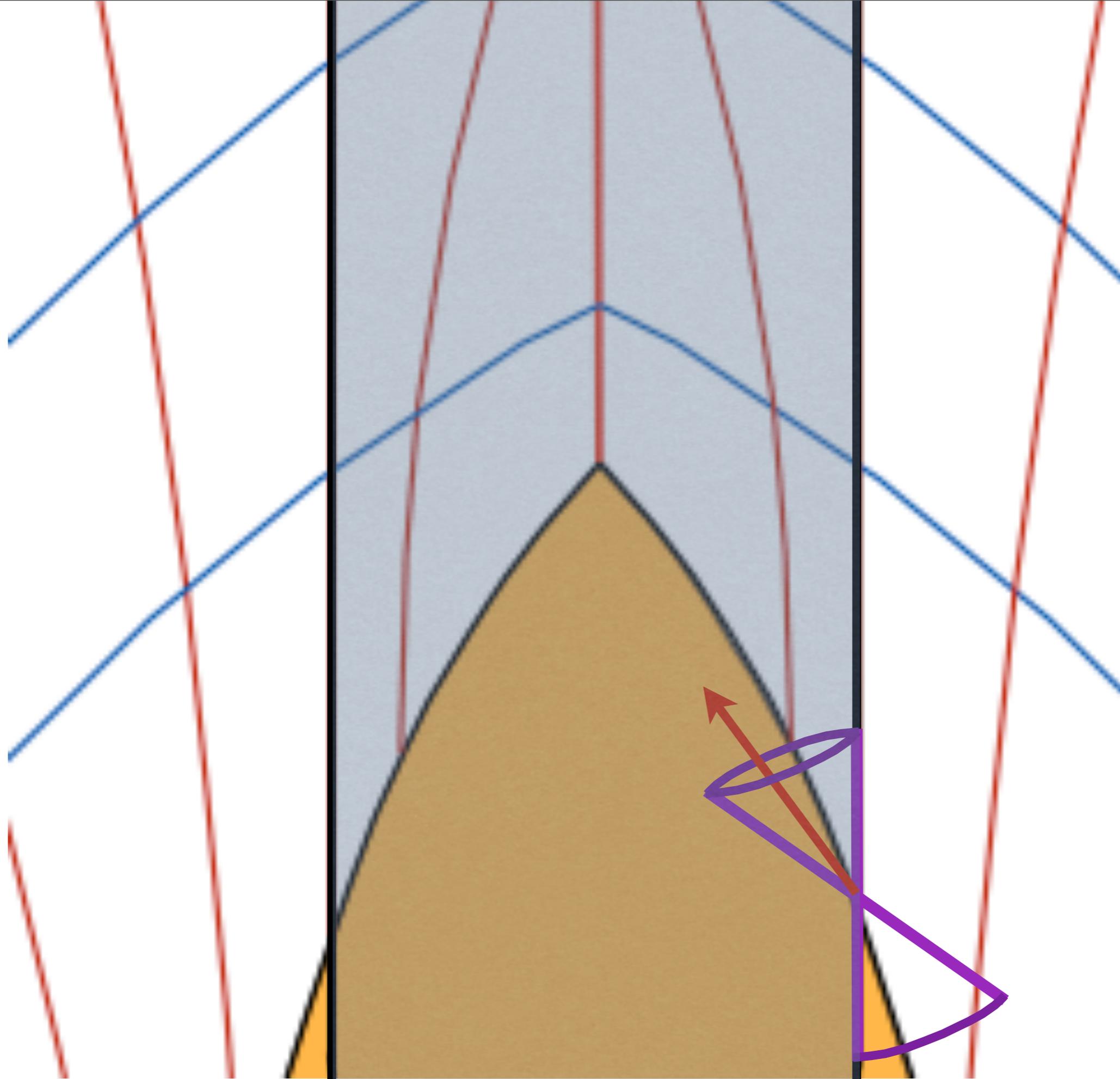


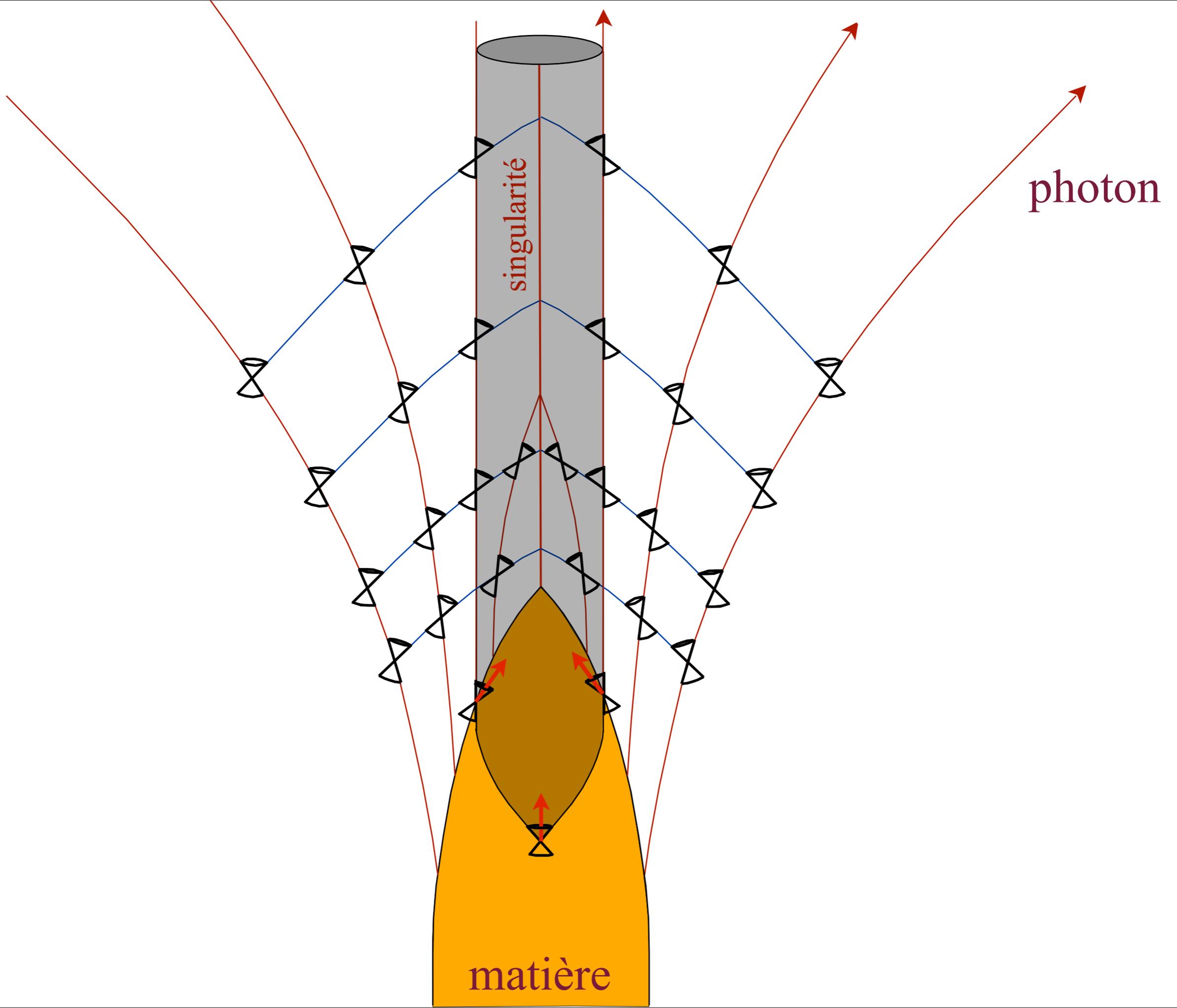




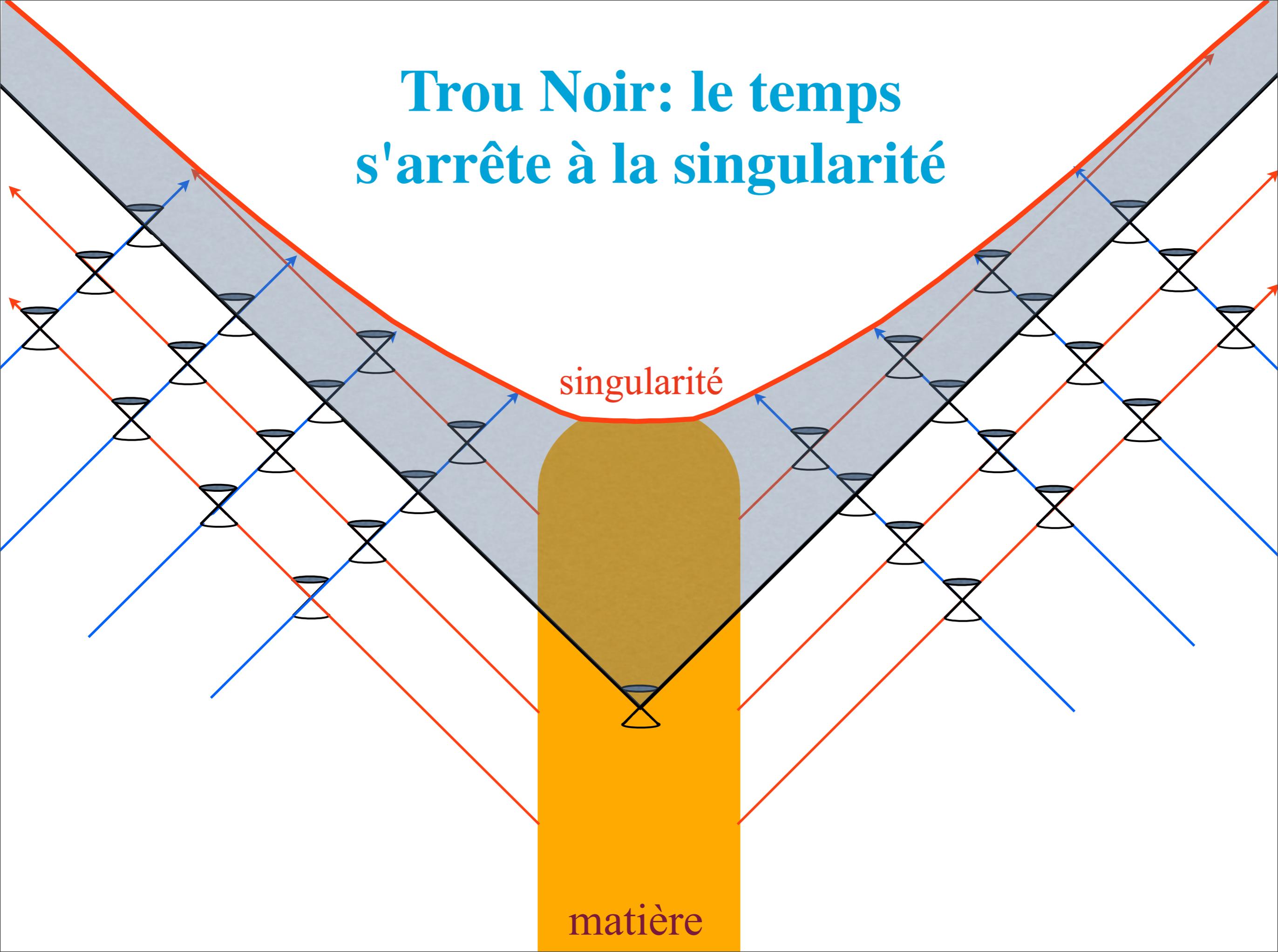








Trou Noir: le temps s'arrête à la singularité

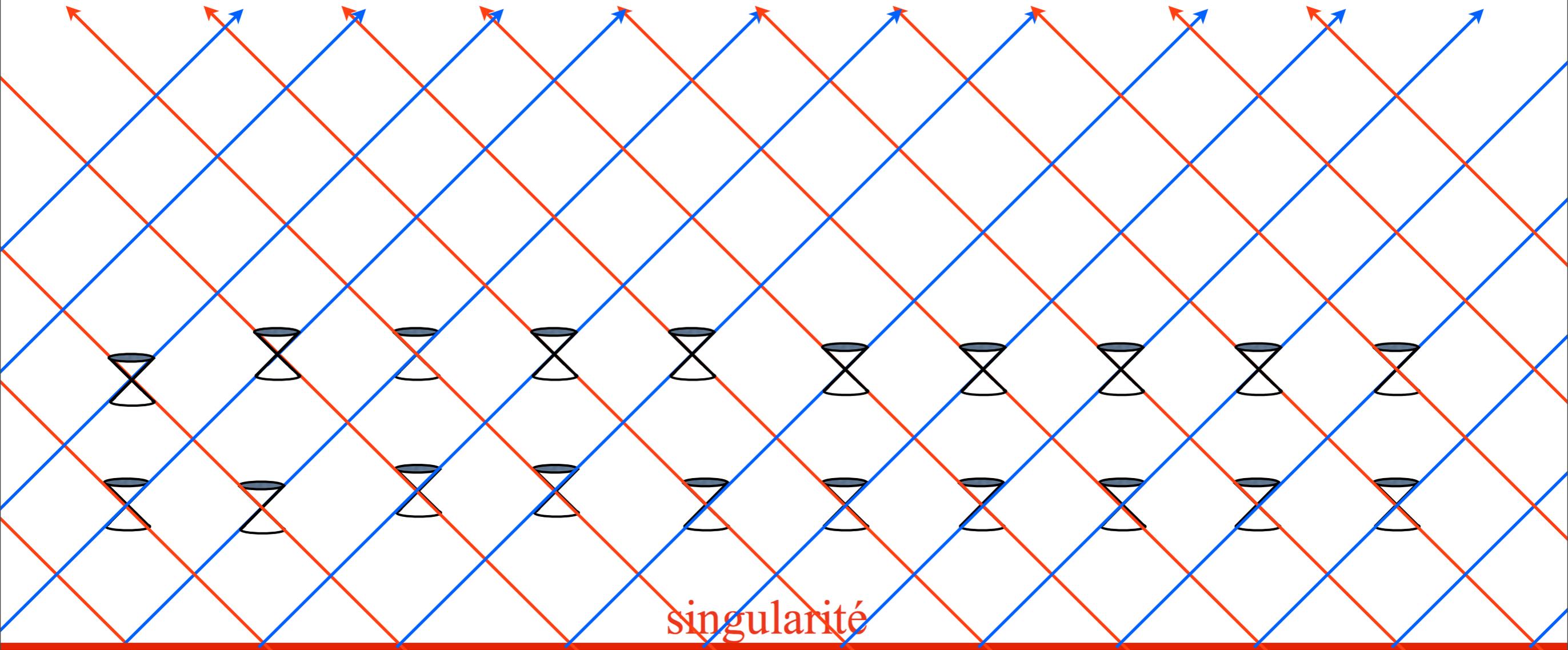


singularité

matière

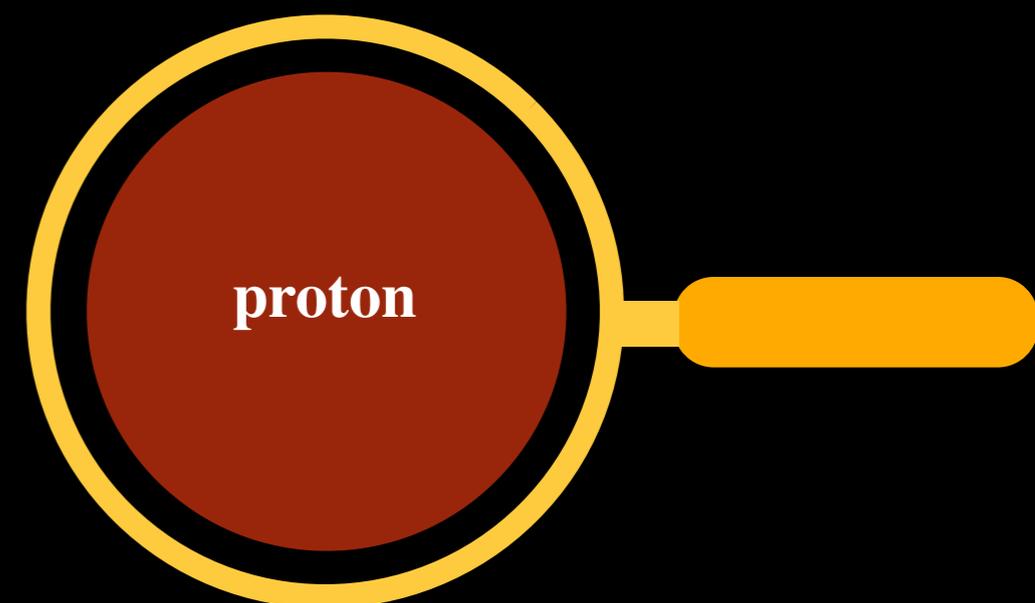
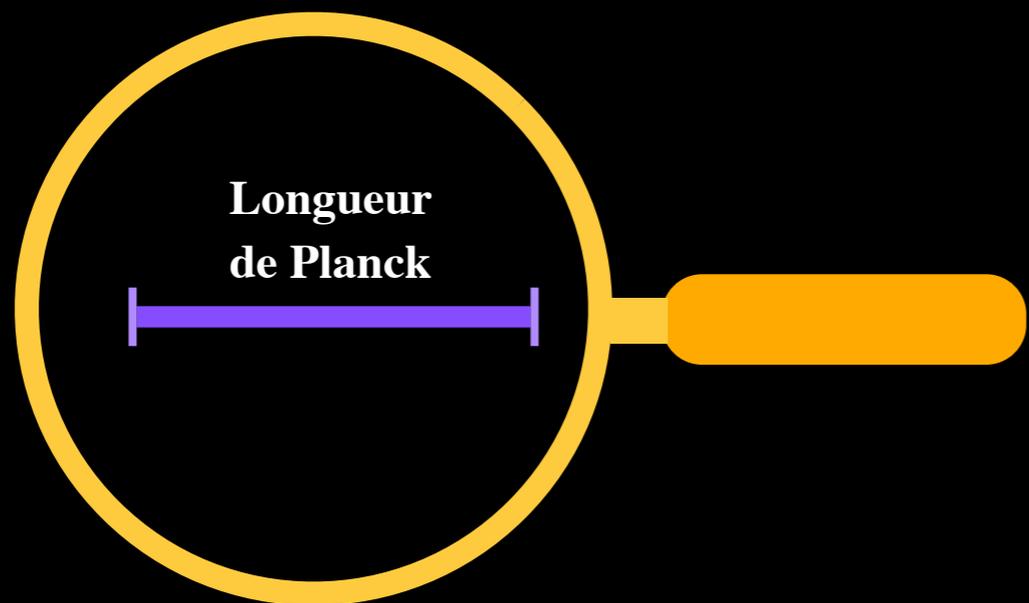
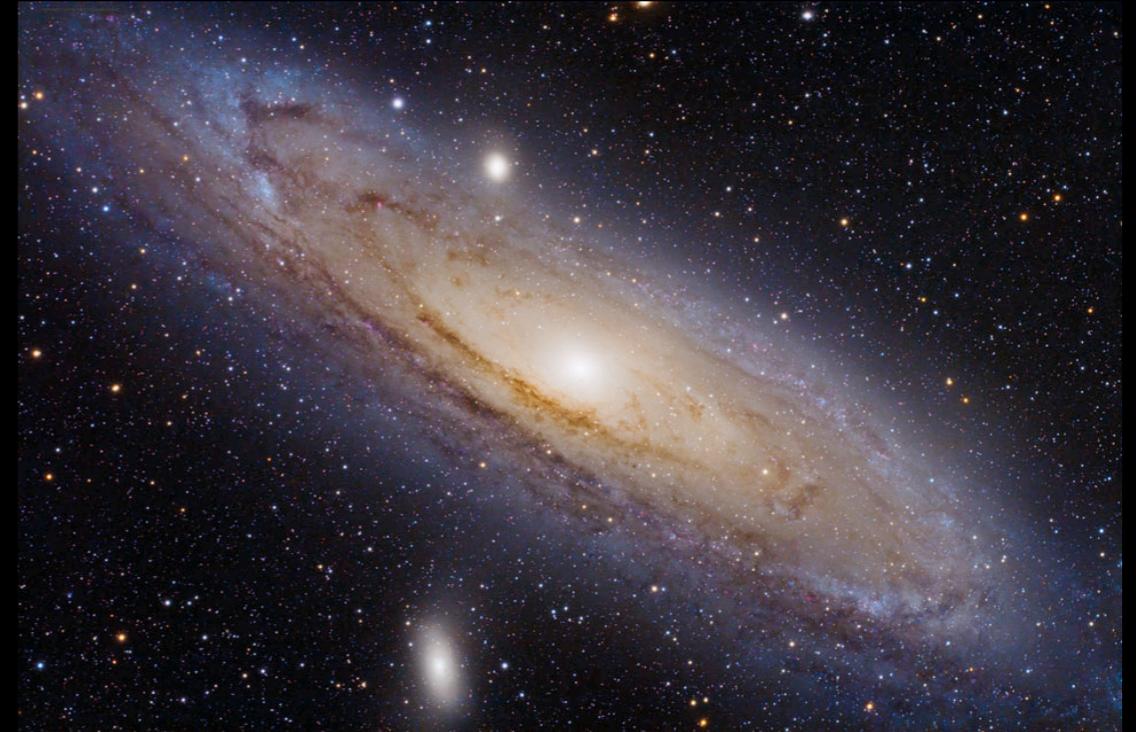
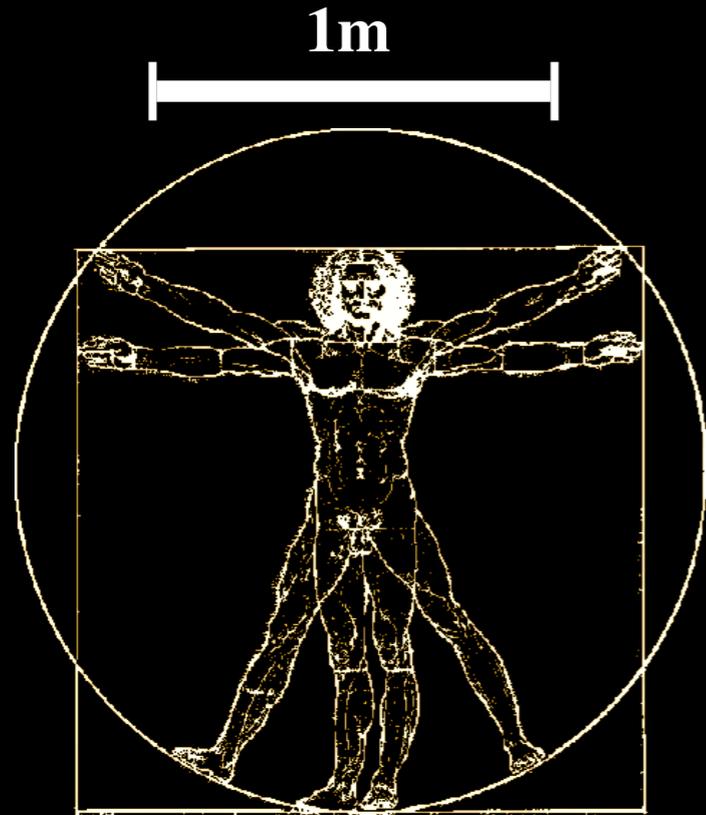
Cosmologie: le temps commence à la singularité

NOUS



Big Bang

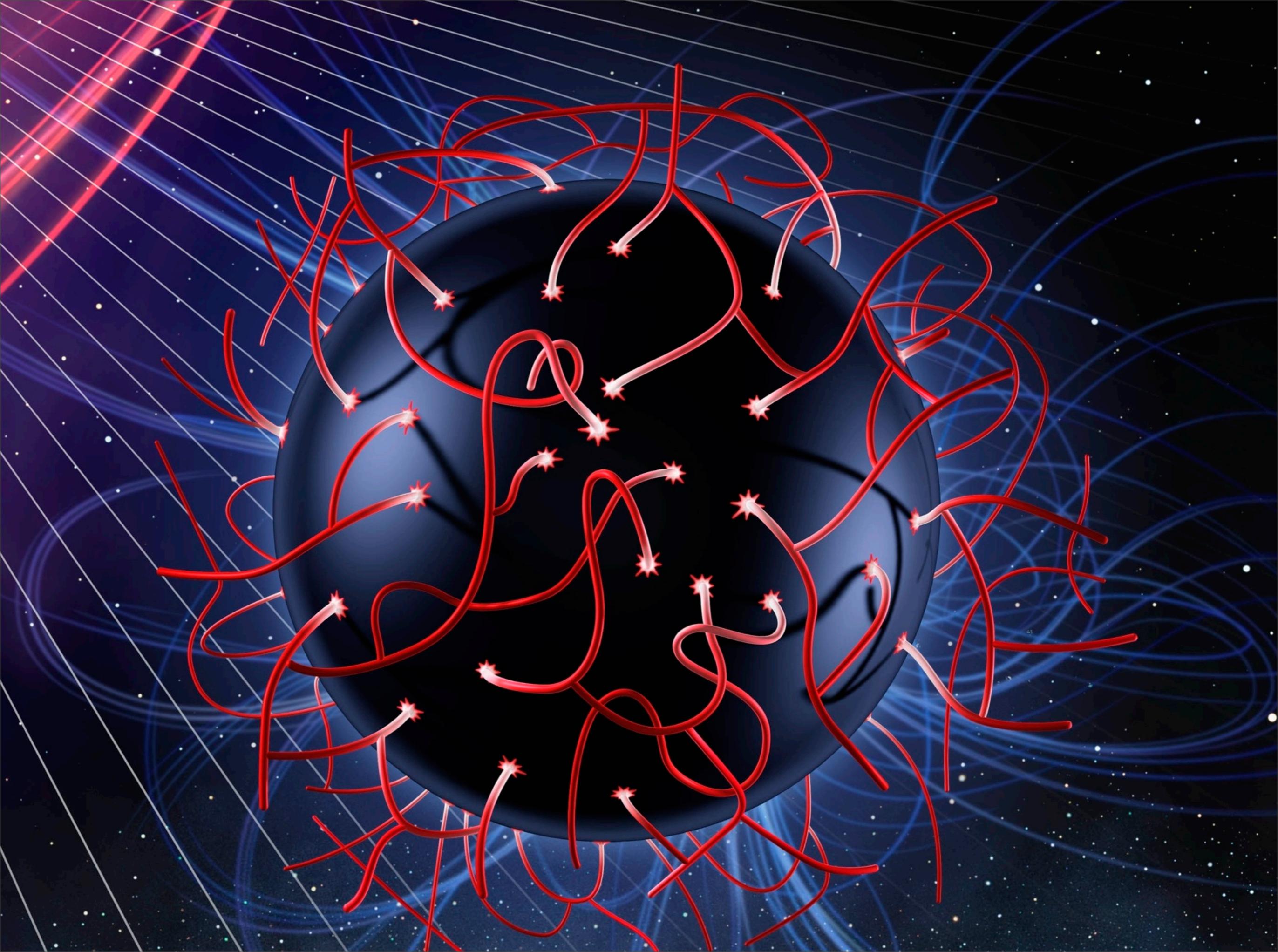
Gravitation Quantique: nouvelle physique à l'échelle de Planck







2,500,000*al*



Merci Beaucoup!



