What powers quasars and active galactic nuclei?

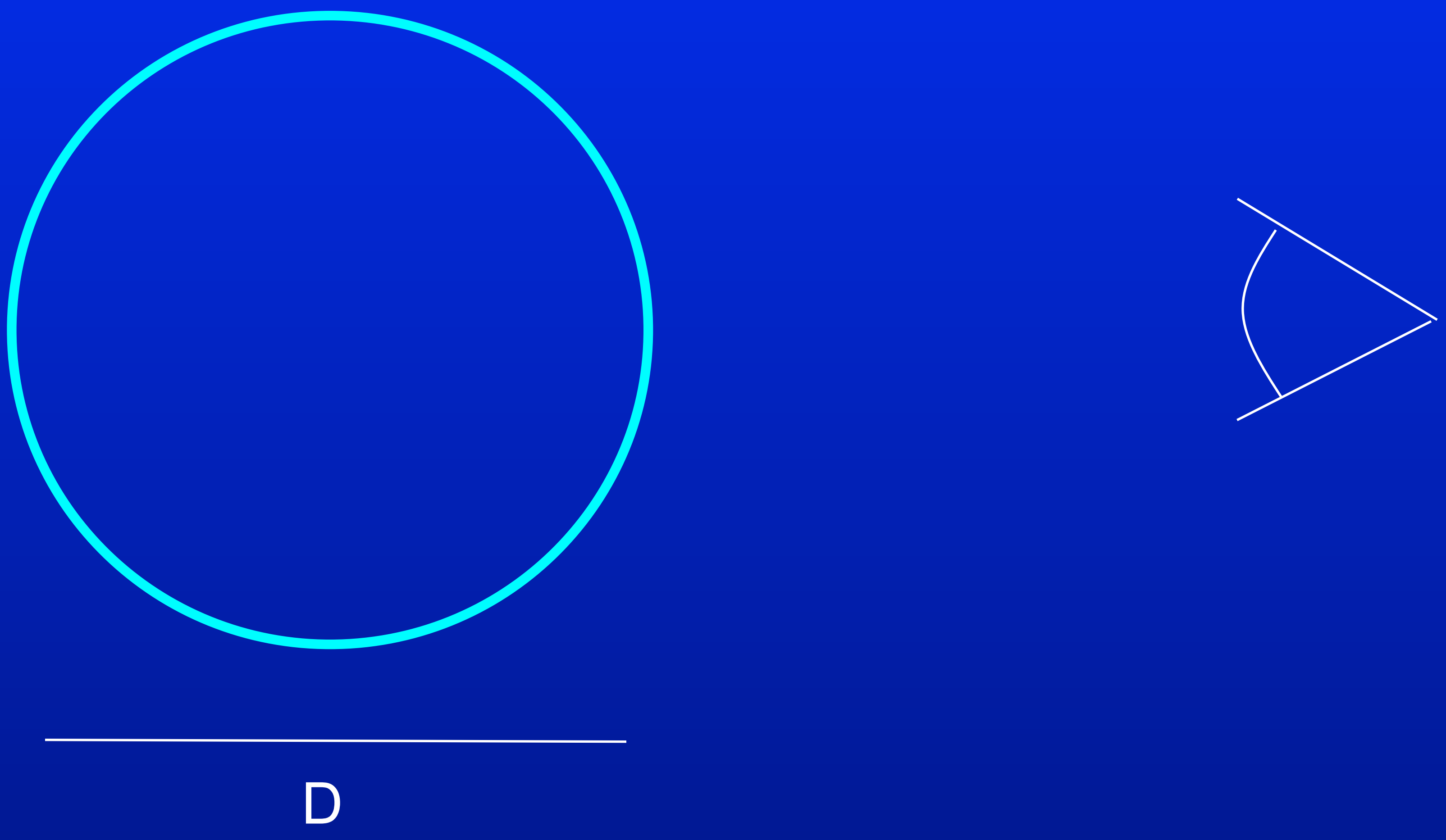
Powerful:

- Luminosities of Billions to 100 Trillion suns
- Emit from Radio to optical to Gamma rays
- Very broad emission lines.

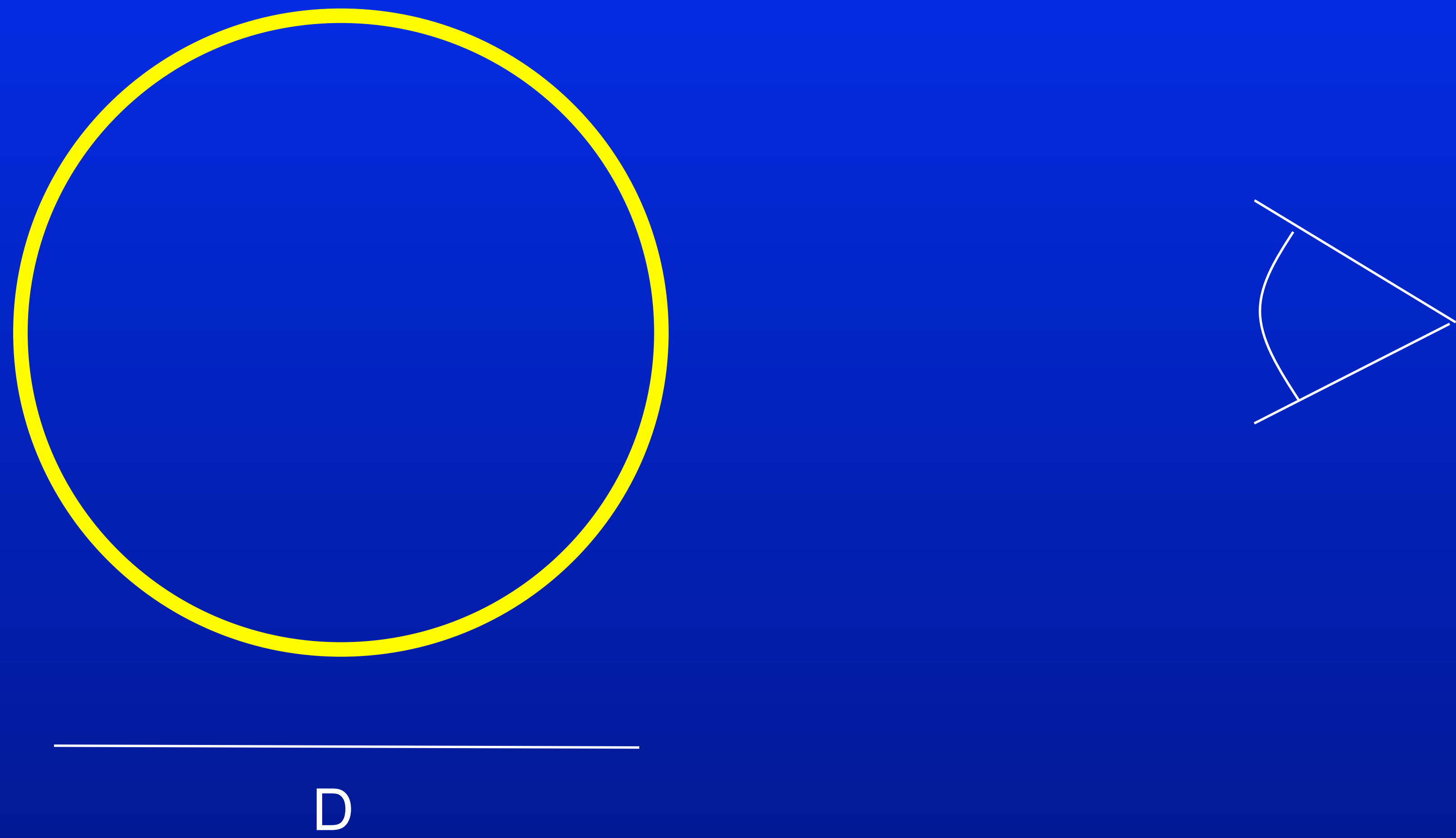
Compact:

- Optical light varies on day timescales
- X-rays can vary on a few hour timescales!

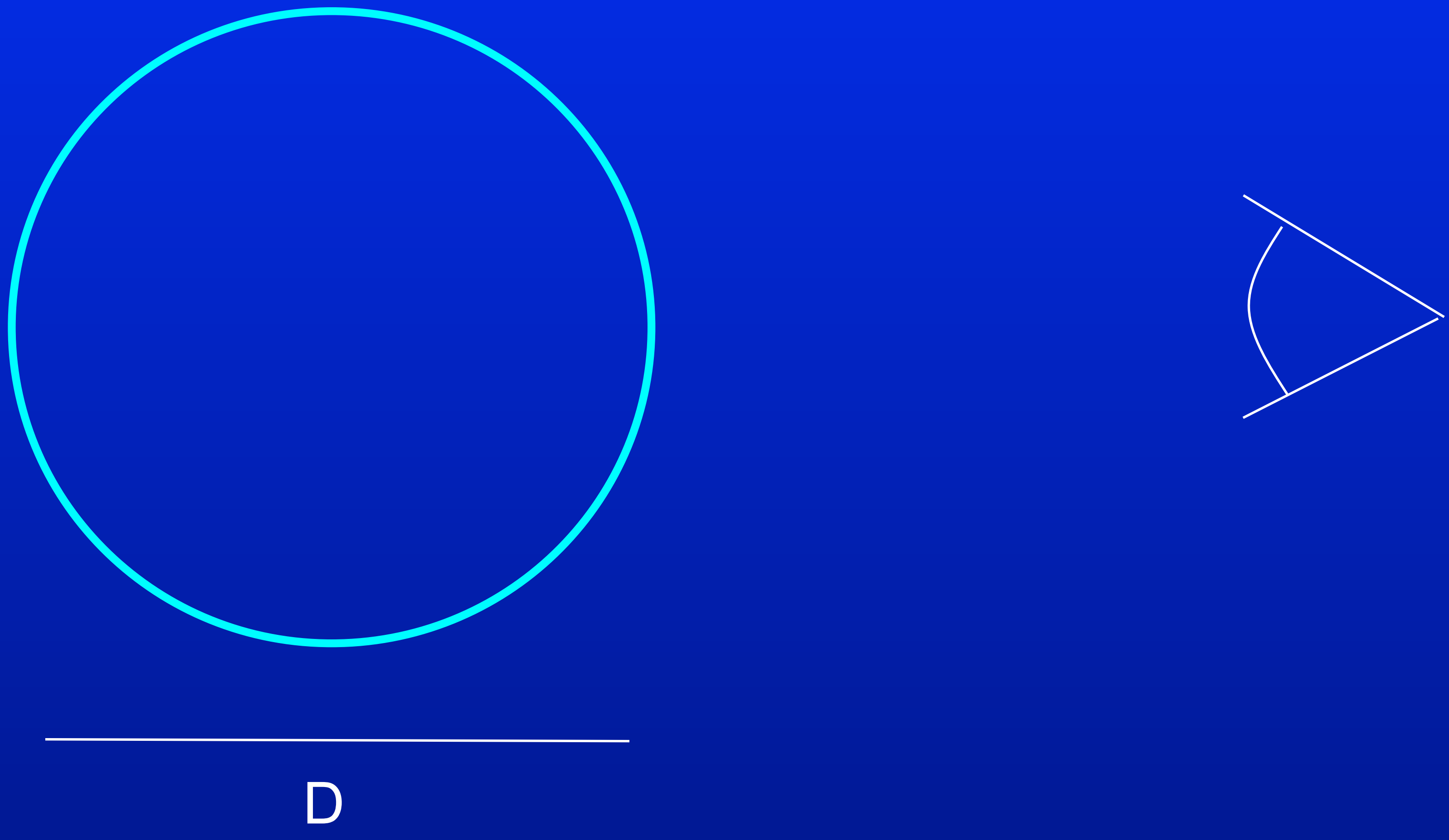
Imagine a semi-transparent shell with diameter D. It is some very large distance away.



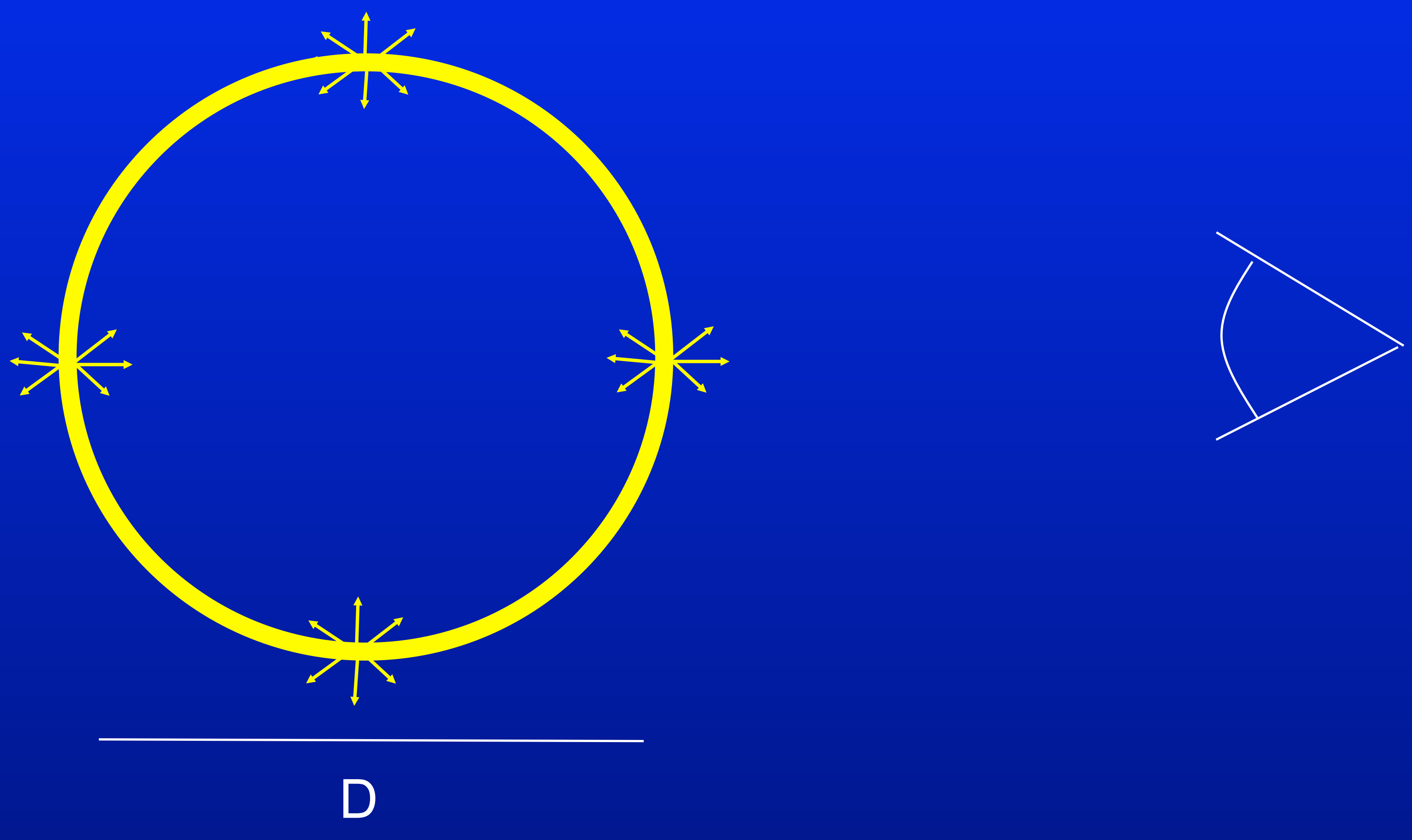
It brightens instantaneously for some very short amount of time.



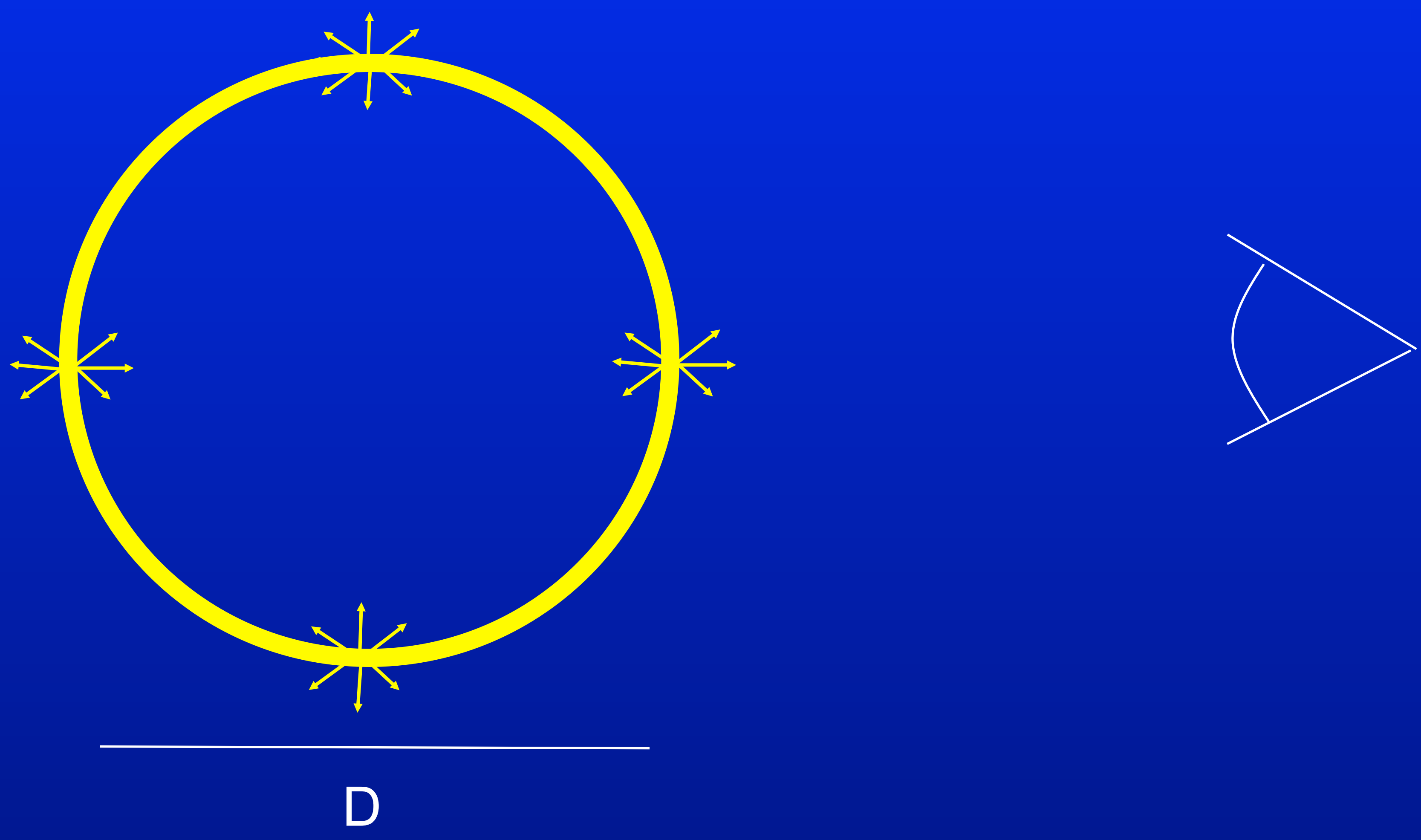
Then, it turns off. What do you see?



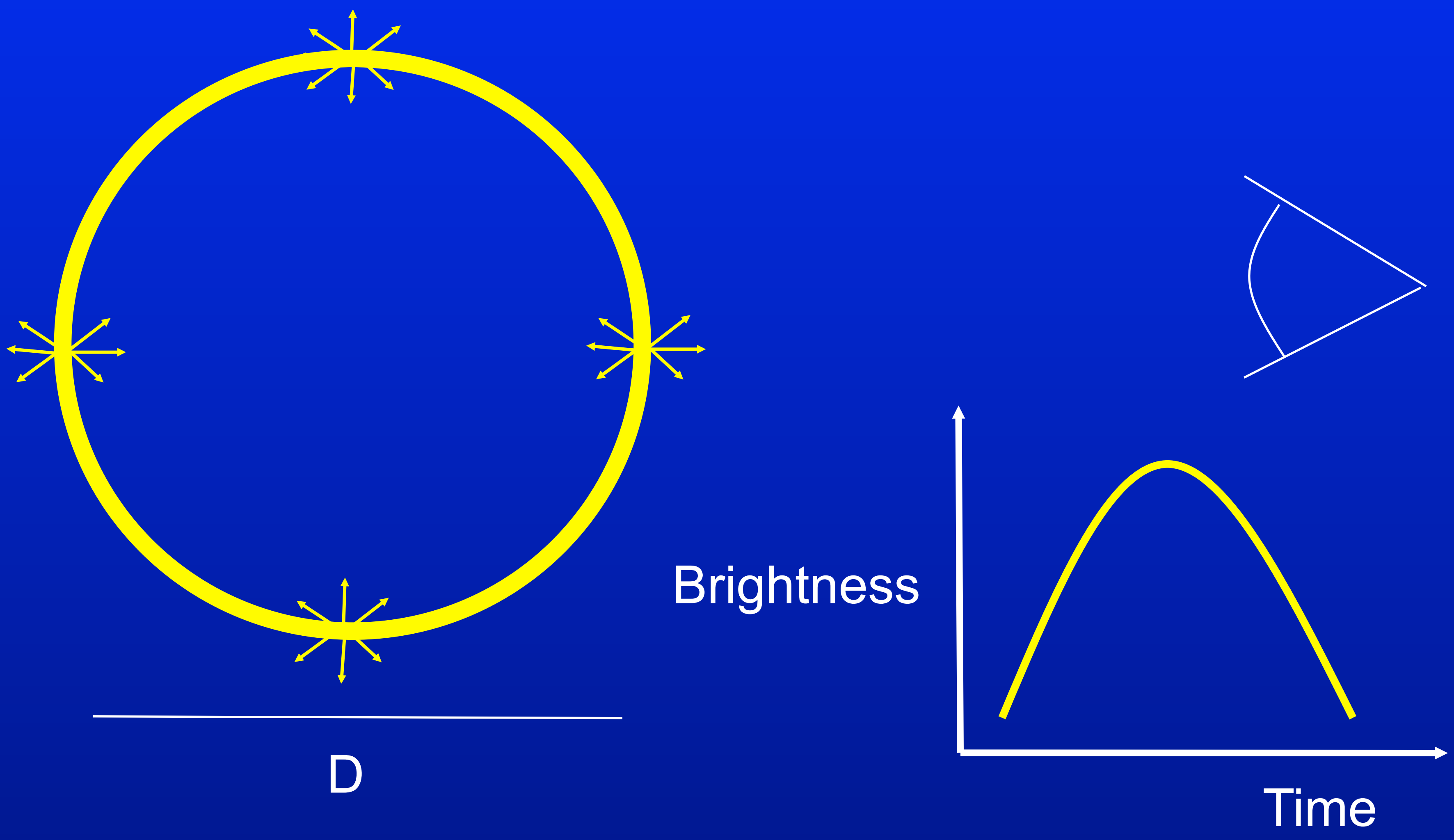
For the moment that the shell is bright, all parts on it are emitting into space in all directions.



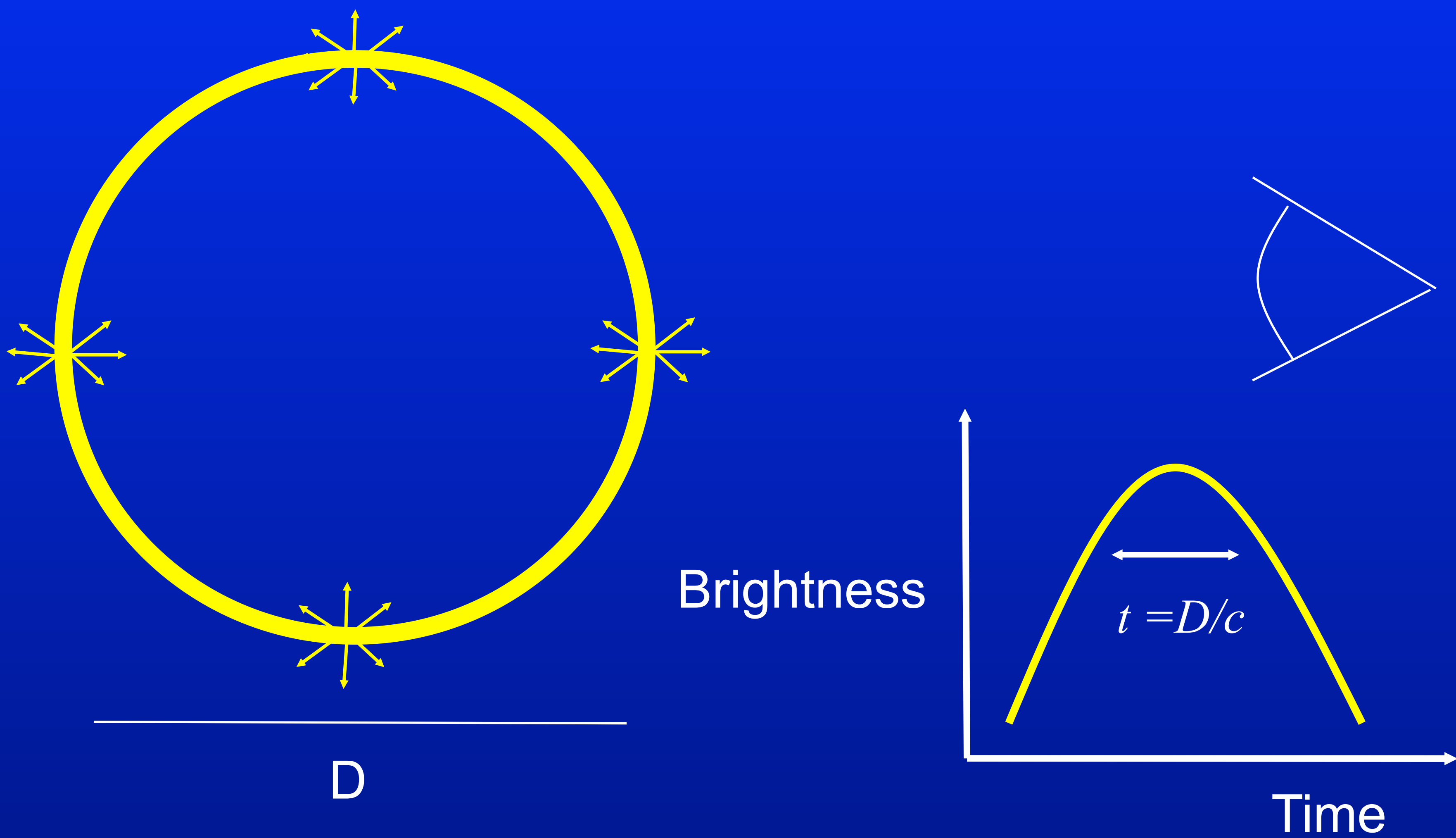
The photons emitted from the part of the shell closest to you reach you first.
The photons emitted from the back of the shell take more time to reach you. How much more? *time to vary = D/c*



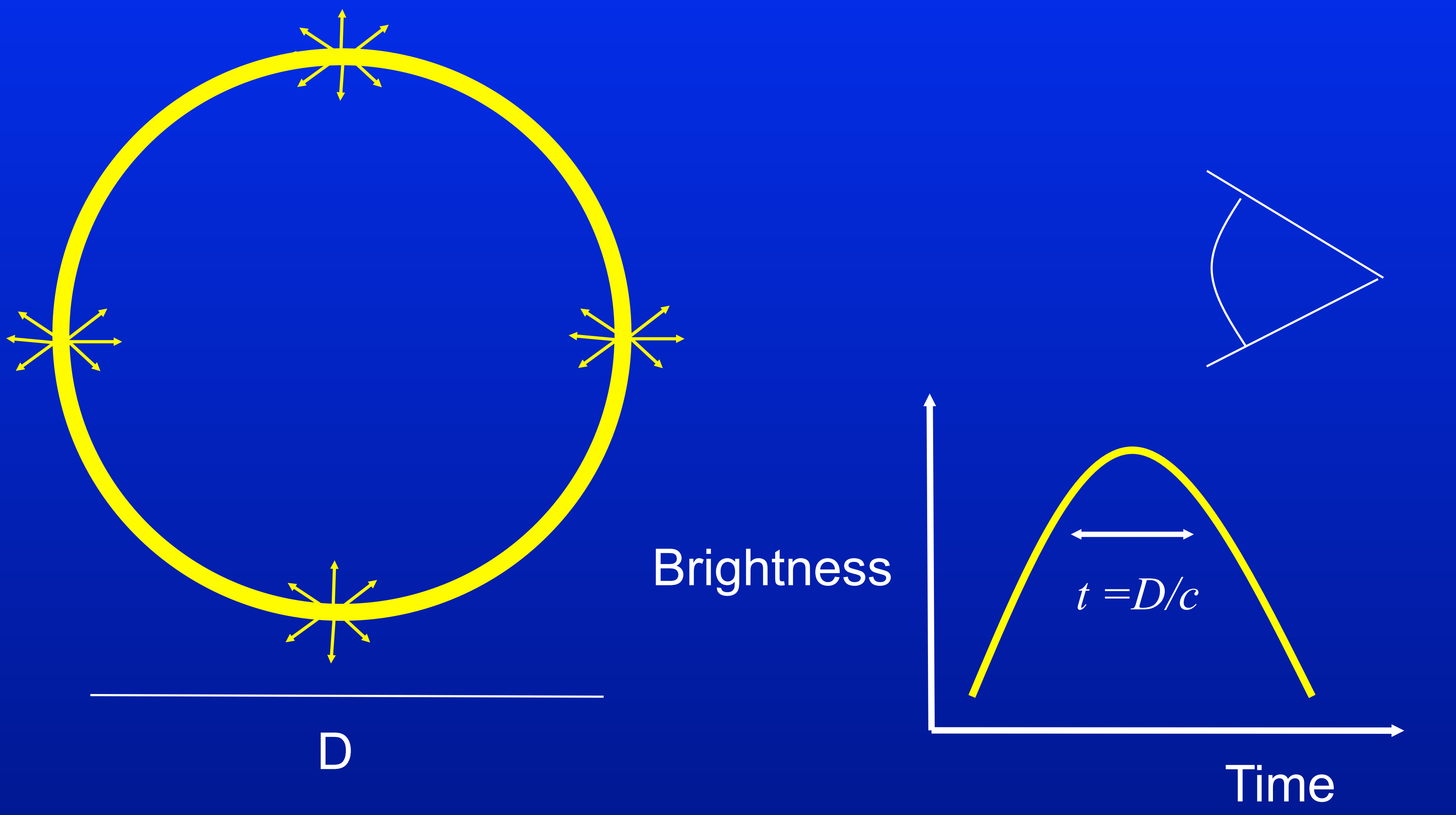
So, the pulse of light is spread out in time by an amount
time to vary = D/c   What do you see in your telescope?



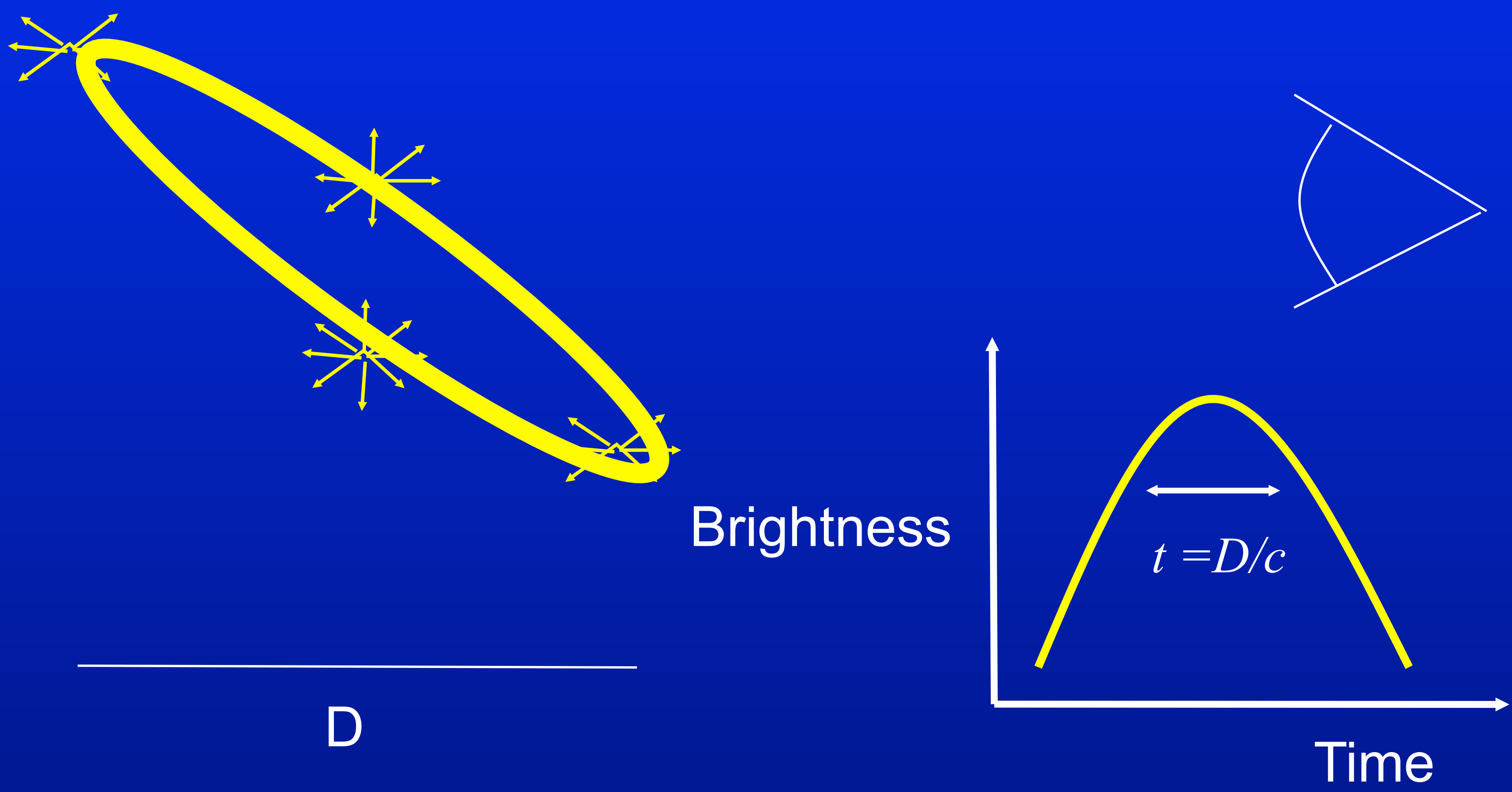
So, the pulse of light is spread out in time by an amount *time to vary = D/c* What do you see in your telescope?



Even for an **instantaneous** change in the brightness, you see the change smeared out over the light-travel time across the shell.



Although this example is for a sphere, applies to virtually any geometry. Imagine a disk/torus:



Why is this important?

Suppose you see a source (like a bright galactic nucleus!) in the sky vary in brightness on a 1 day timescale.

Well, the distance light can travel in one day is about 150 AU.

Because nothing travels faster than c, and because even an instantaneous flash would get smeared in time over 1 day, the object that is varying **must be smaller** than 150 AU.

To see why this is true, imagine that the object is actually larger than 150 AU, say 1500 AU, 10x bigger.

Even if the flash it made were instantaneous, the pulse of light you see would be spread out by 10 days, not 1 day.

Example #1

An average Cepheid varies in brightness on a timescale of 1 day.

Thus, it must be smaller than 150 AU.

This isn't very interesting because we already know that stars are smaller than 150 AU.

Besides, a Cepheid is only 1000 x the luminosity of the Sun.

Example #2

A bright quasar with a luminosity of 10^{14} L_{sun} varies on a timescale of 1 day.

Thus, it must be smaller than 150 AU. You have to pack this luminosity into a small region.

This is **very interesting** because the Schwarzschild radius for a 10^{9} M_{sun} black hole is 20 AU!

Also, because you can't pack 10^{14} Suns into 150 AU, **it can't** be stars.

Besides, how would you get them all to vary at the same time?. It must be a black hole! We do not know of anything else that can power bright AGN.