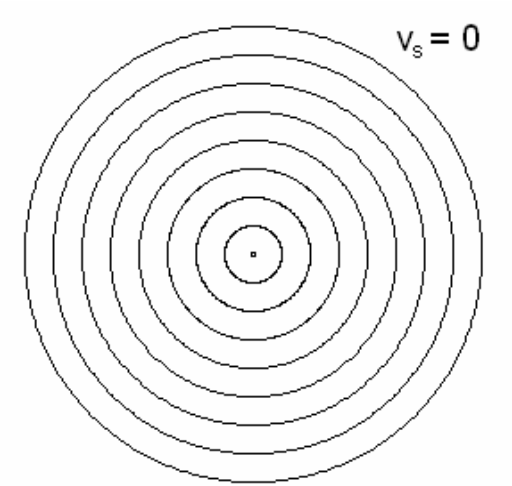
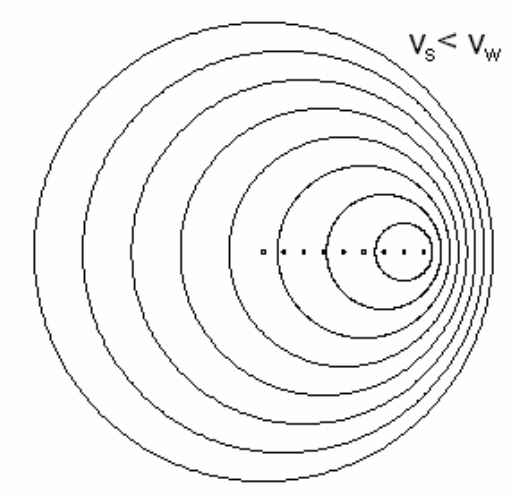
# Doppler-effekten




Källa (s)
Observatör (obs)

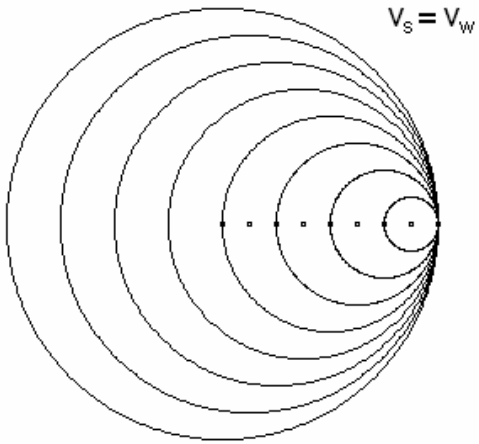
$$\lambda f = v_{ljud}$$




$$f_{obs} = \frac{v_{ljud} \pm v_{obs}}{v_{ljud} \pm v_s} f$$

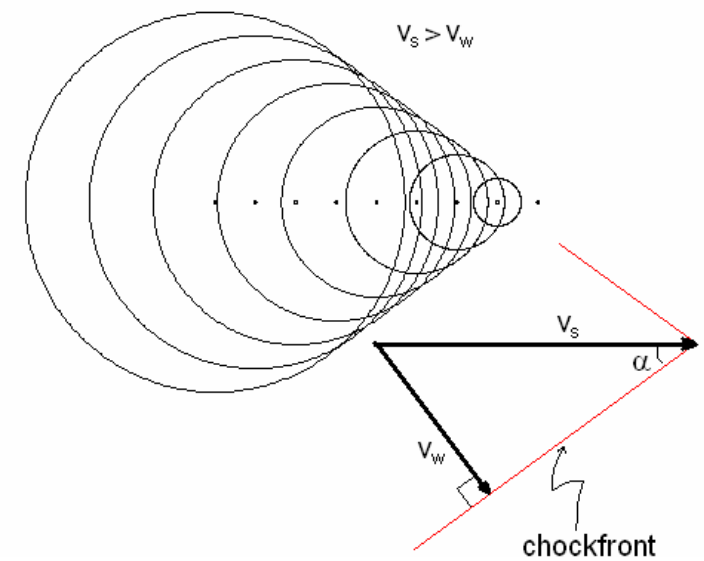
Tänk på tecknen...

# Mach-tal




$$v_s \rightarrow v_{ljud}$$

$$f \rightarrow \infty$$

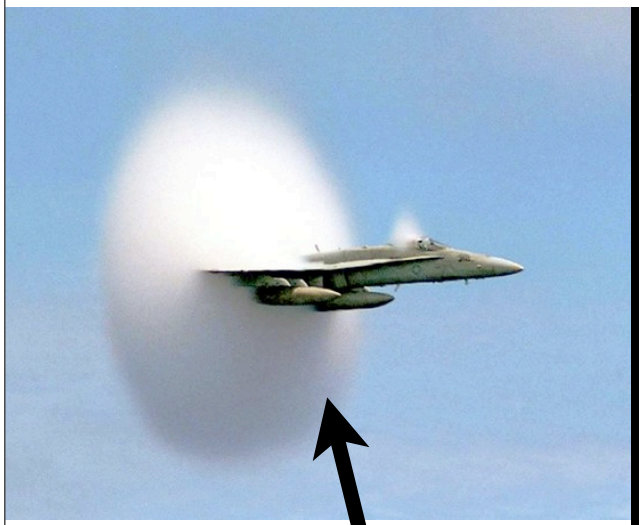


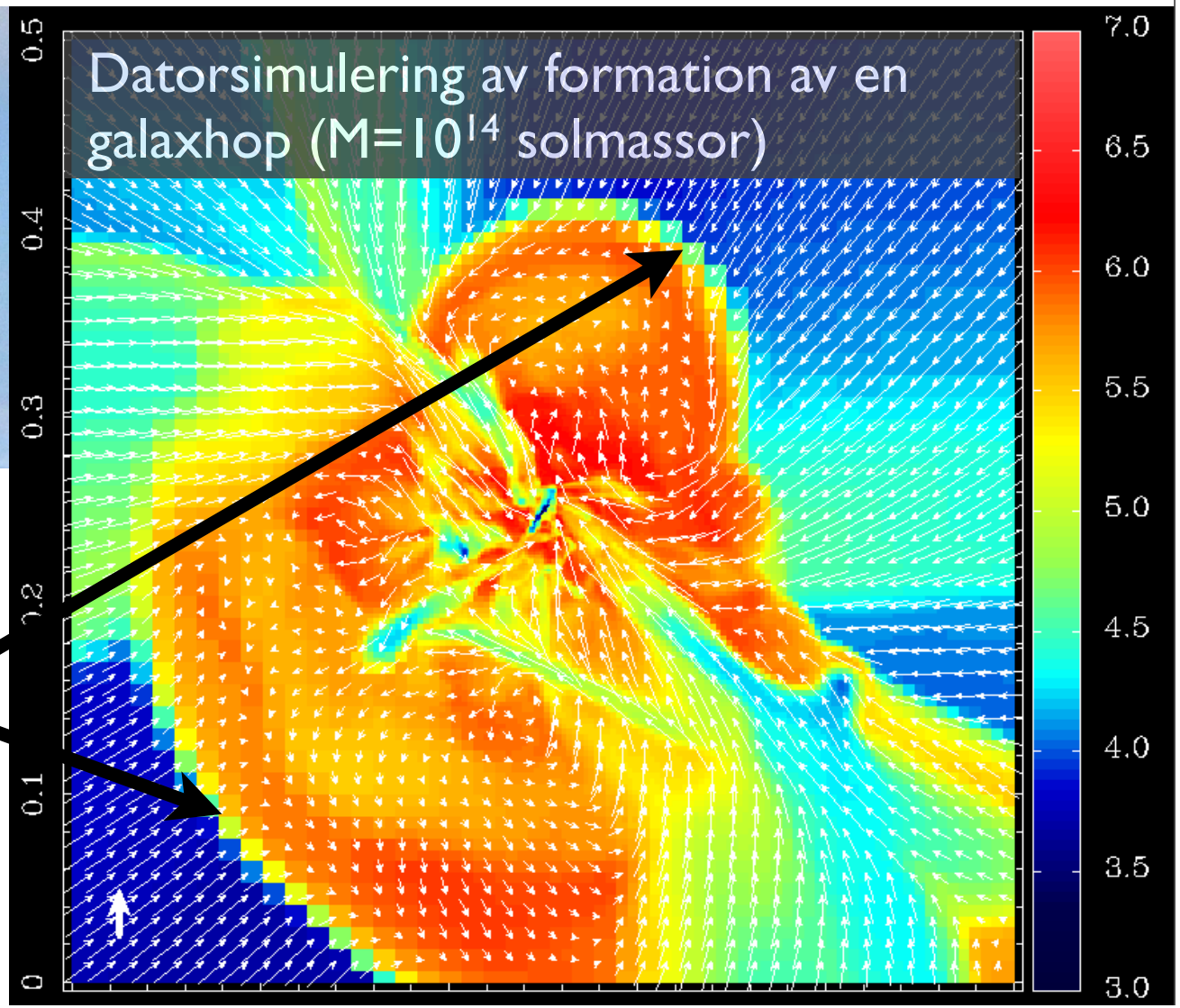

Chock-konens öppningsvinkel:

$$sin\alpha = \frac{v_{ljud}}{v_s}$$

$$\text{Mach-tal} = \frac{v_s}{v_{ljud}}$$

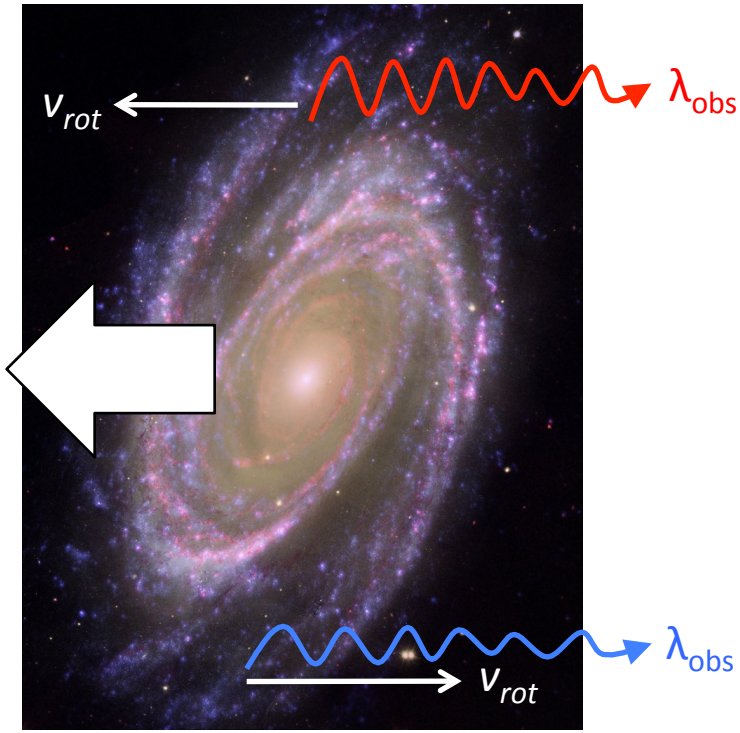
# Chockvågor

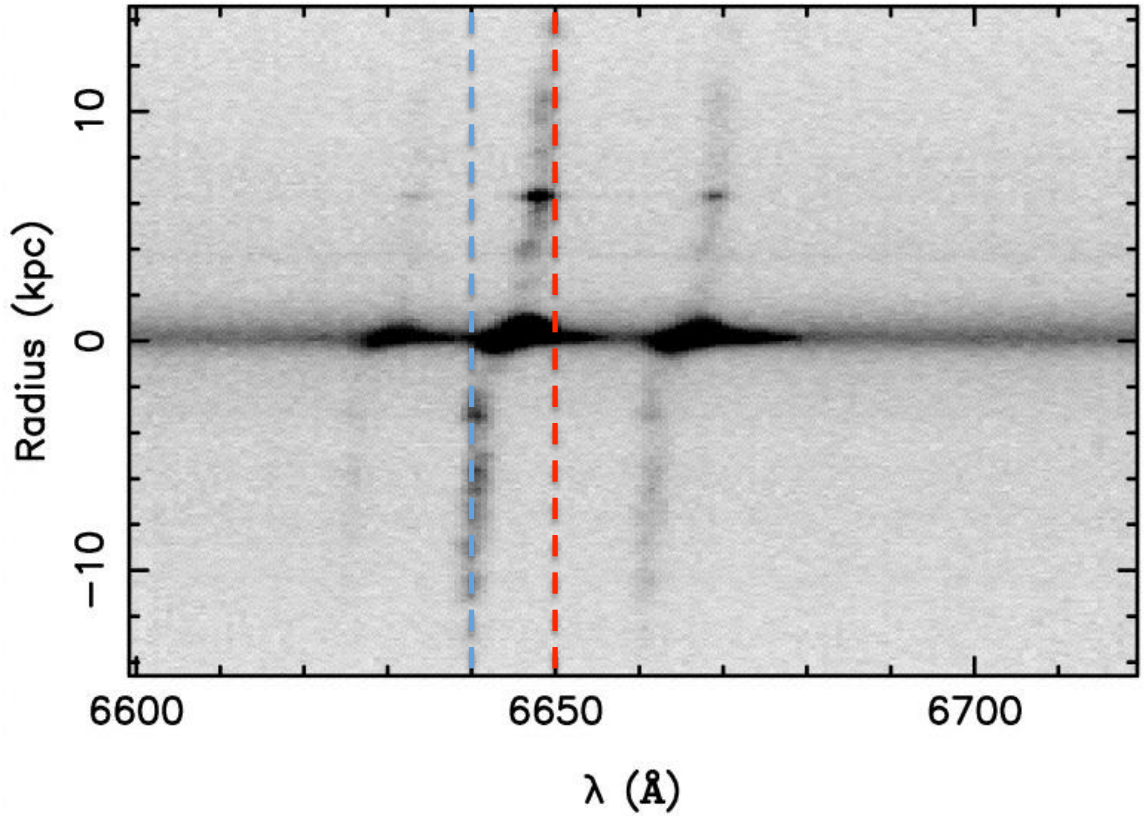





Chock-
front

# Doppler-förskjutning av spektrallinjer

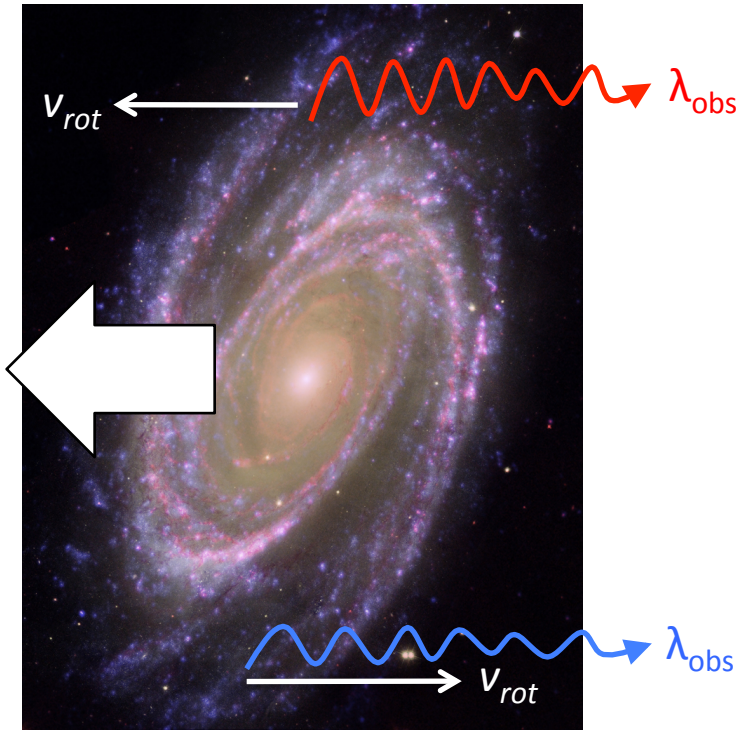


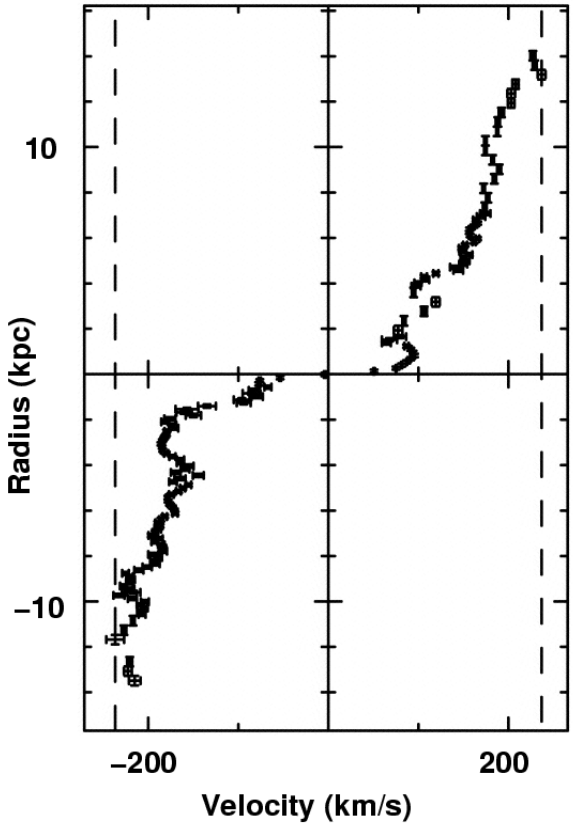




$$\frac{\lambda_{obs}}{\lambda_{ref}} = \frac{c \pm v_{rot}}{c \pm \underbrace{v_{obs}}_{=0}} = 1 \pm \frac{v_{rot}}{c}$$

$$v_{rot} = \left(\frac{6650\,\text{Å}}{6645\,\text{Å}} - 1\right) \cdot c \approx 225\ km/s$$

# Doppler-förskjutning av spektrallinjer



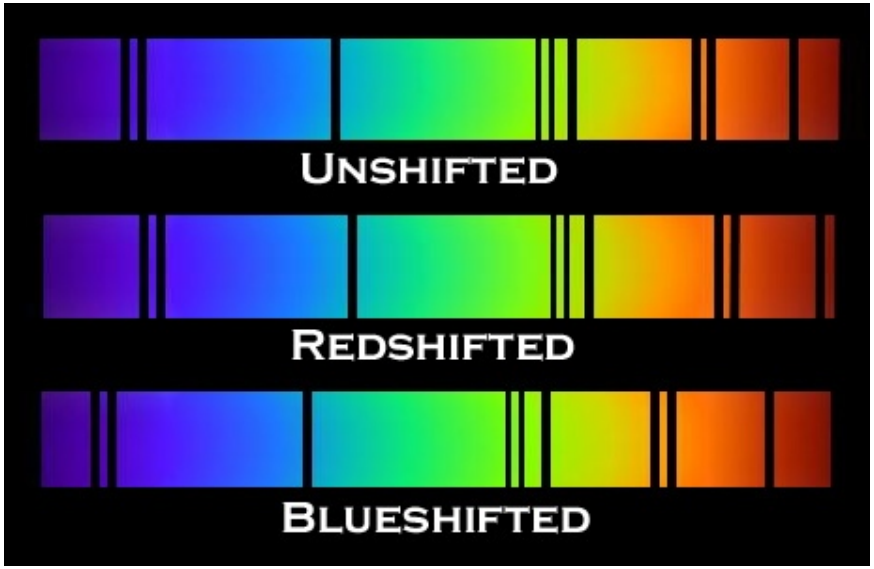

$$v_{circ} = \sqrt{\frac{GM}{r}}$$

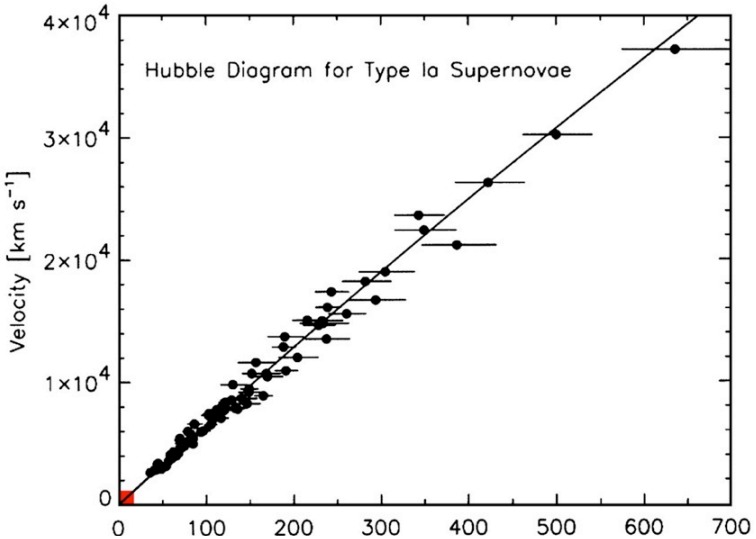
(➔ mass-uppskattning…)

$$\frac{\lambda_{obs}}{\lambda_{ref}} = \frac{c \pm v_{rot}}{c \pm \underbrace{v_{obs}}_{=0}} = 1 \pm \frac{v_{rot}}{c}$$

$$v_{rot} = \left(\frac{6650\,\text{Å}}{6645\,\text{Å}} - 1\right) \cdot c \approx 225\ km/s$$

# Blå-/rödförskjutning

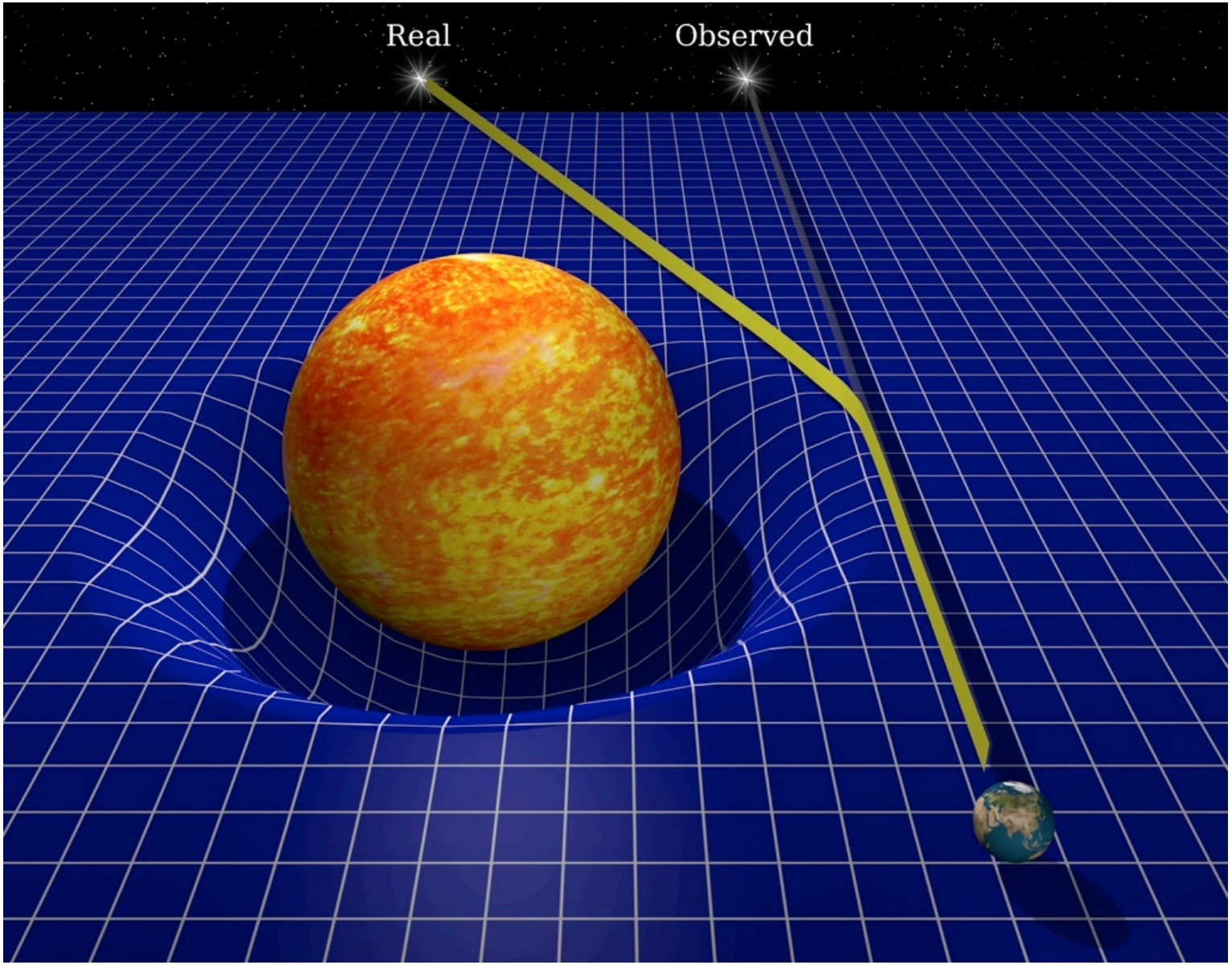


Orsaker:

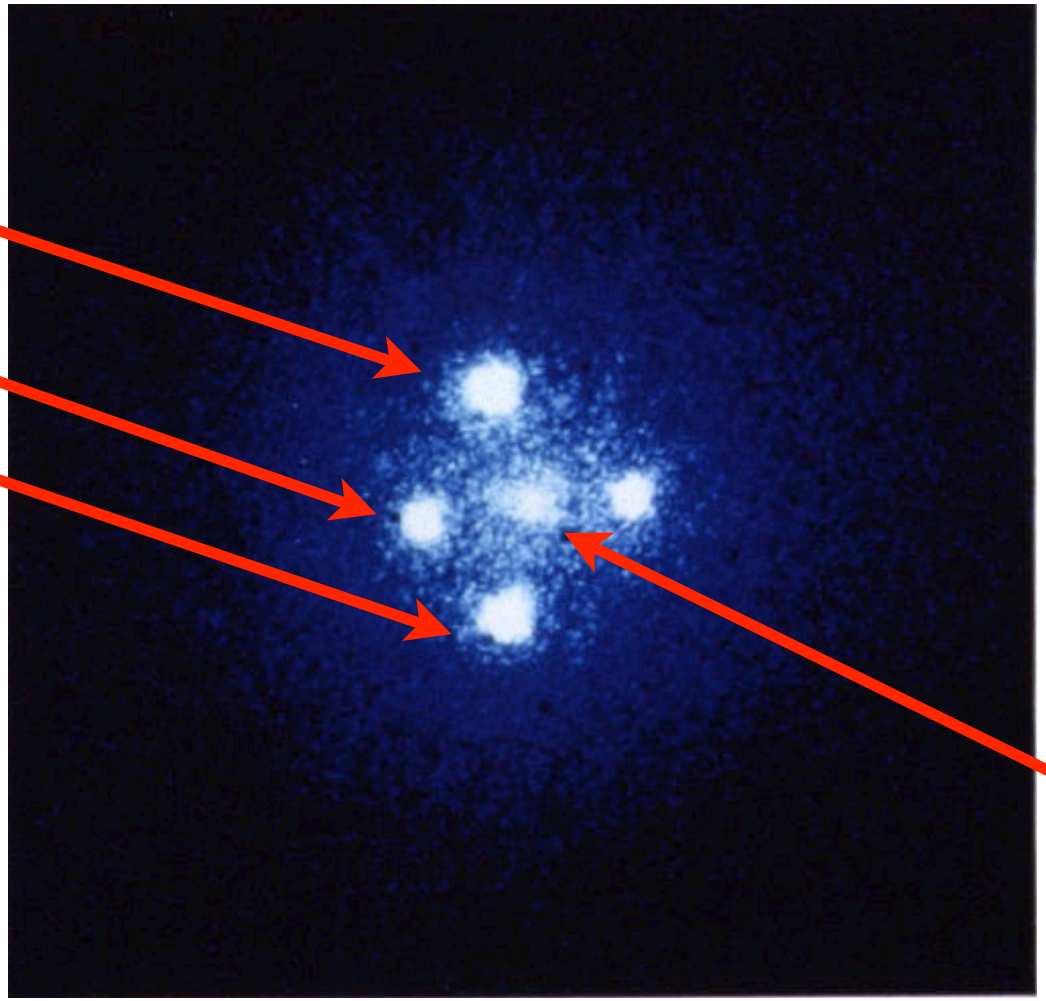
- rummets expansion
- källan rör sig (=Doppler)

# (Relativitets-teori...): Ljus känner av gravitation



# Gravitationslinsning

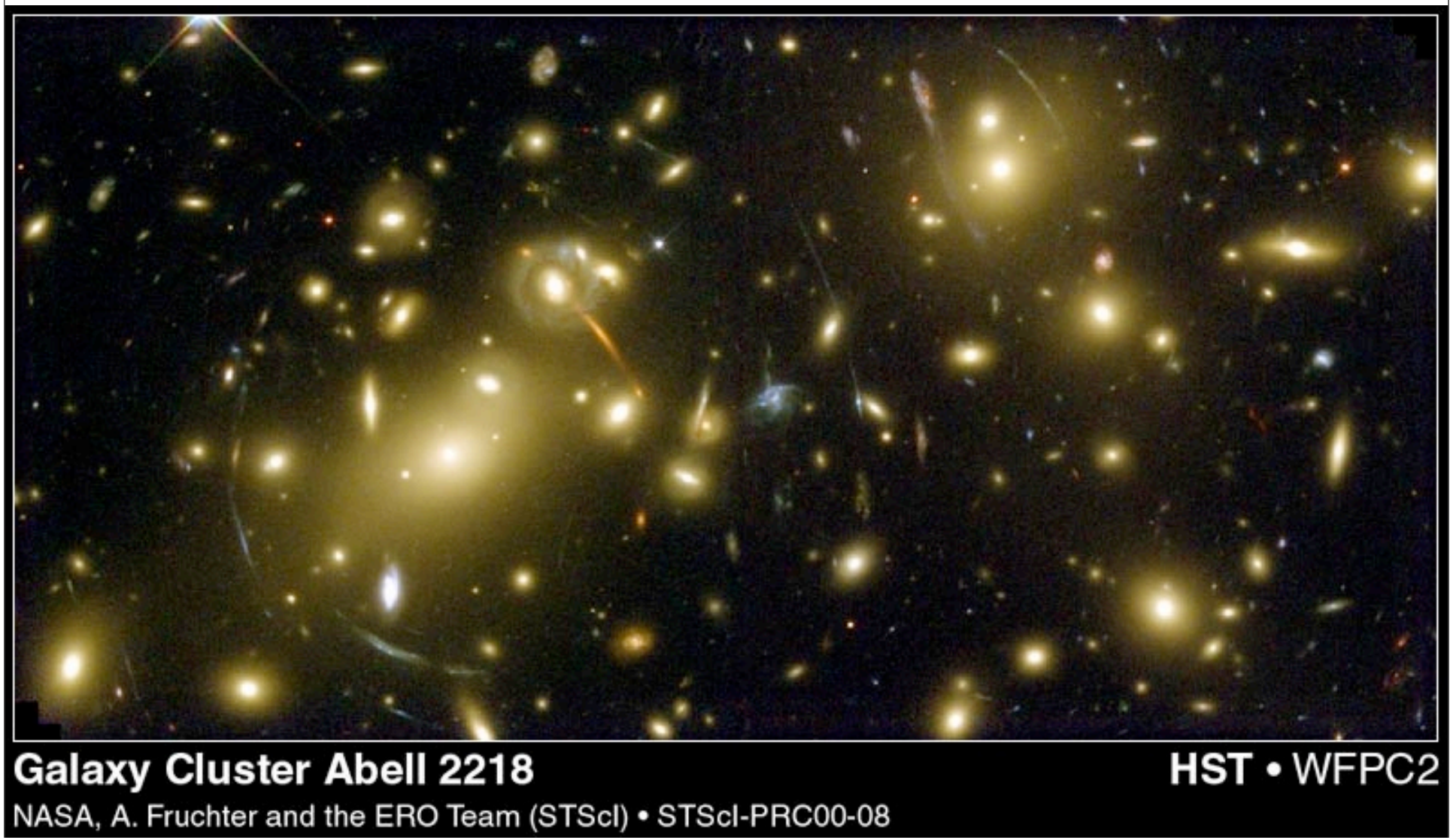
4 bilder:
Bakgrunds-
galax
(kvasar)



Lins:
Förgrunds-
galax

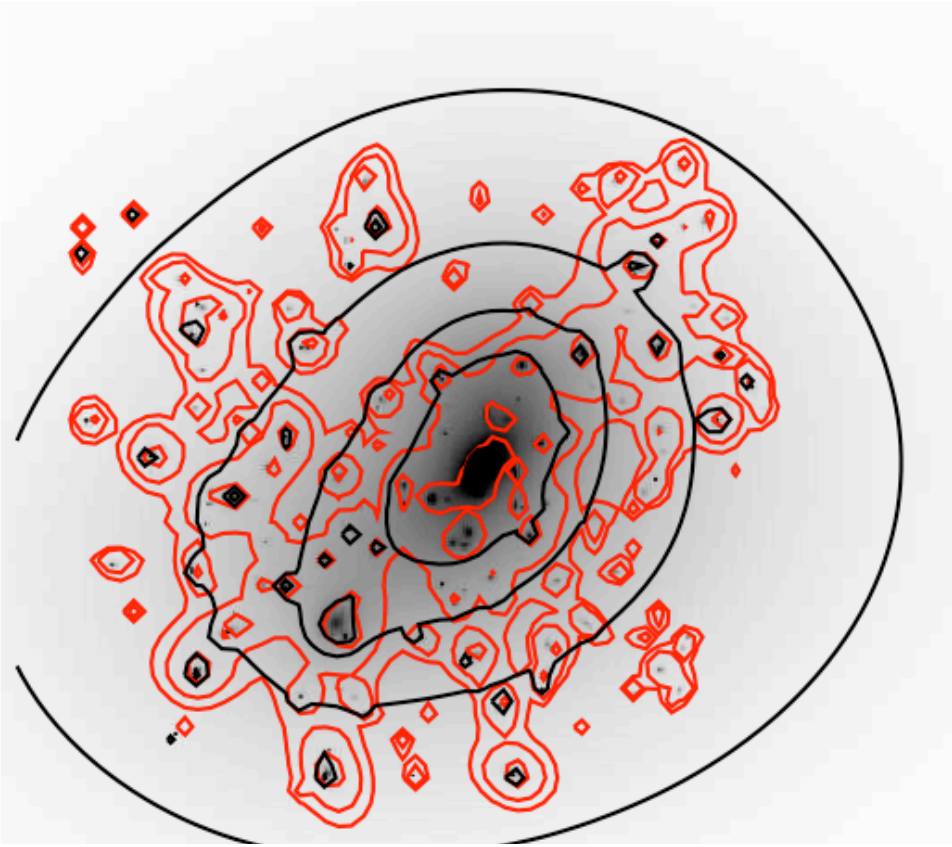
("Einstein cross")

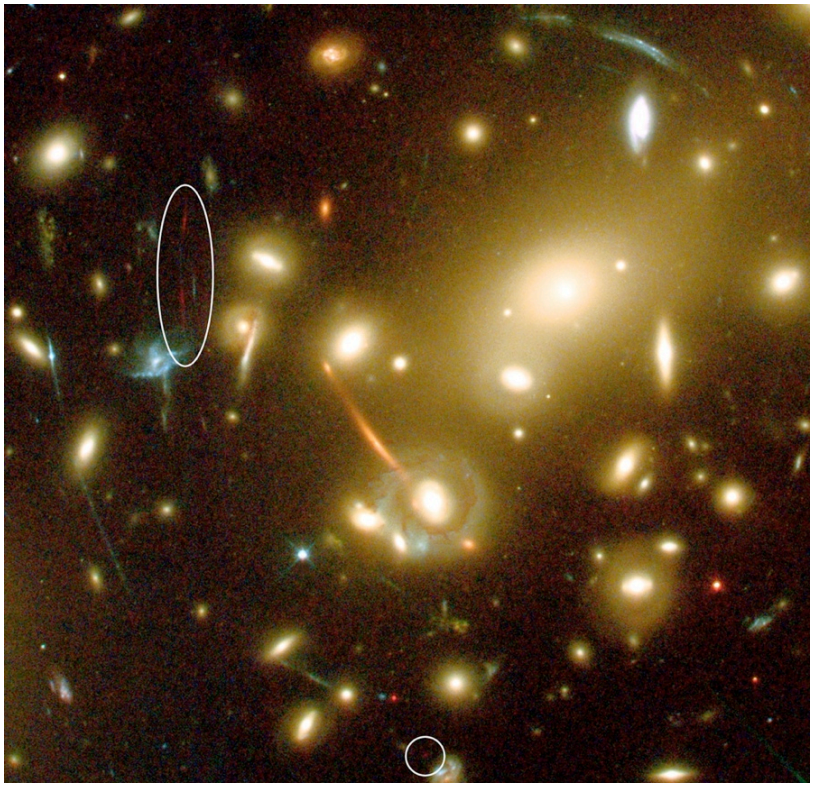
# Gravitationslinsning



# Gravitationslinsning

- Rekonstruera ”linsens” (galaxhopens) massa
- Naturliga teleskop!





# Nåt om brytningsindex

Brytningsindex

$$n = \frac{c}{v}$$

Vad saktar ner ljuset?

Ljushastigheten (i vakuum)

$$c = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$$

- What's waving?!
- Inget magiskt med siffrorna..

# Nåt om brytningsindex

## Ljus = elektromagnetisk våg → växelverkar med fält!

Taking $\alpha$ from Eq. (32.6), Eq (32.25) would give us

$$n^2 = 1 + \frac{Nq_e^2}{m\epsilon_0}\frac{1}{-\omega^2 + i\gamma\omega + \omega_0^2}. \tag{32.27}$$

First, we have the new term in $i\gamma\omega$, because we are including the dissipation of the oscillators. Second, the left-hand side is $n$ instead of $n^2$, and there is an extra factor of 1/2. But notice that if $N$ is small enough so that $n$ is close to one (as it is for a gas), then Eq. (32.27) says that $n^2$ is one plus a small number: $n^2 = 1 + \epsilon$. We can then write $n = \sqrt{1 + \epsilon} \approx 1 + \epsilon/2$, and the two expressions are equivalent. Thus our new method gives for a gas the same result we found earlier.

Now you might think that Eq. (32.27) should give the index of refraction for dense materials also. It needs to be modified, however, for several reasons. First, the derivation of this equation assumes that the polarizing field on each atom is the field $E_x$. That assumption is *not* right, however, because in dense materials there is also the field produced by other atoms in the vicinity, which may be comparable to $E_x$. We considered a similar problem when we studied the static fields in dielectrics. (See Chapter 11.) You will remember that we estimated the field at a single atom by imagining that it sat in a spherical hole in the surrounding dielectric. The field in such a hole—which we called the *local* field—is increased



*(Feynman lectures in Physics)*