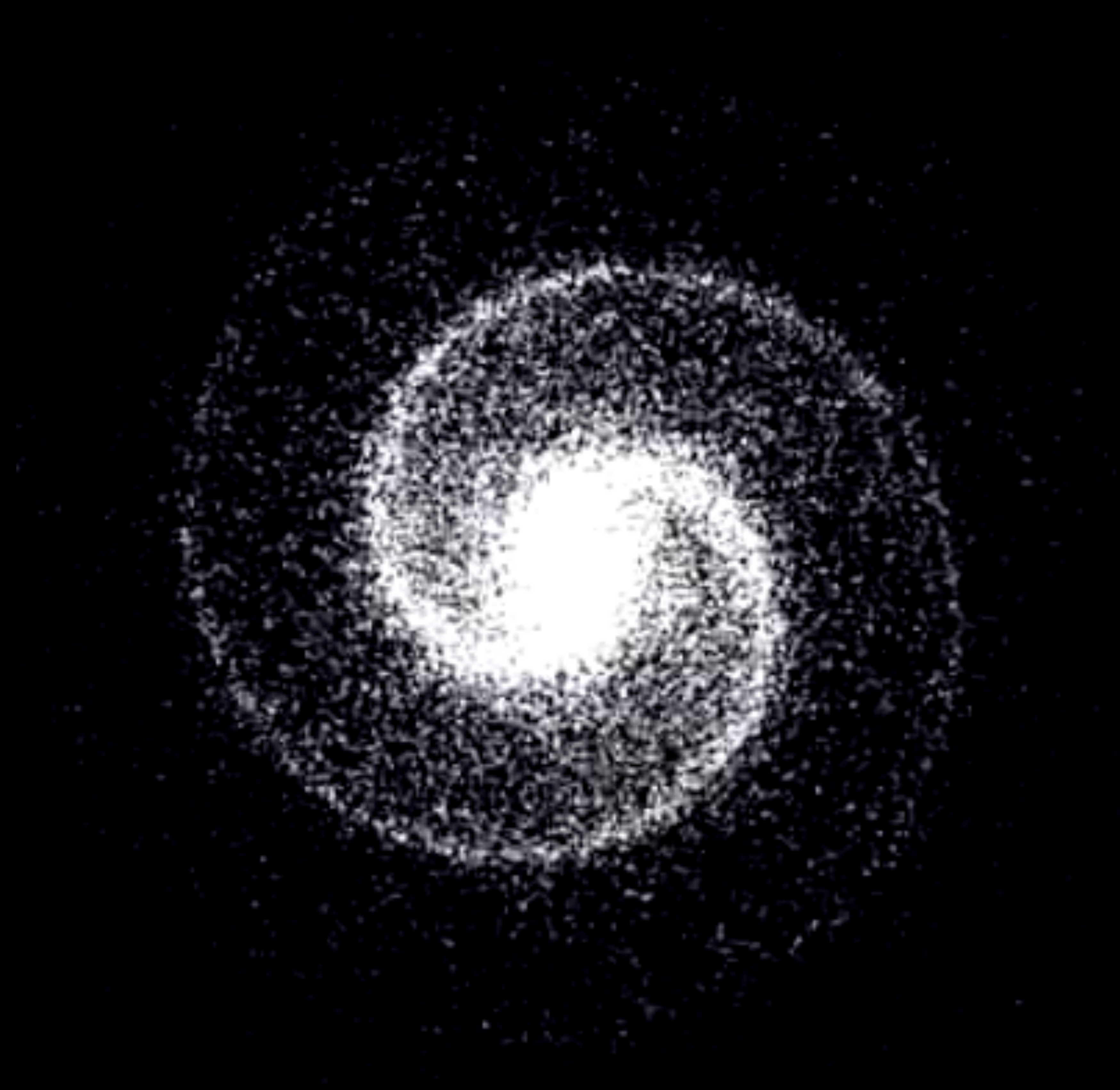
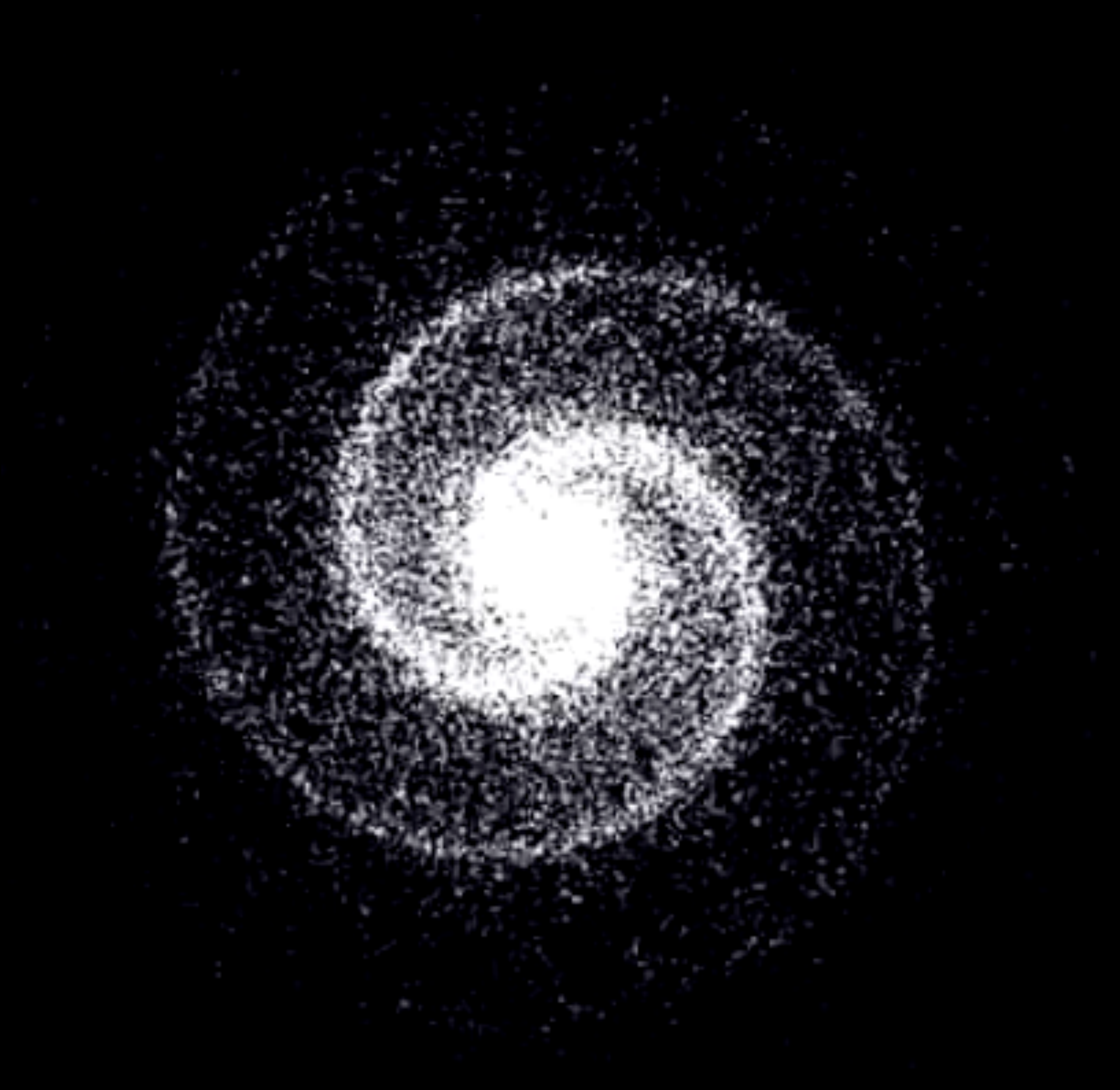
solid body

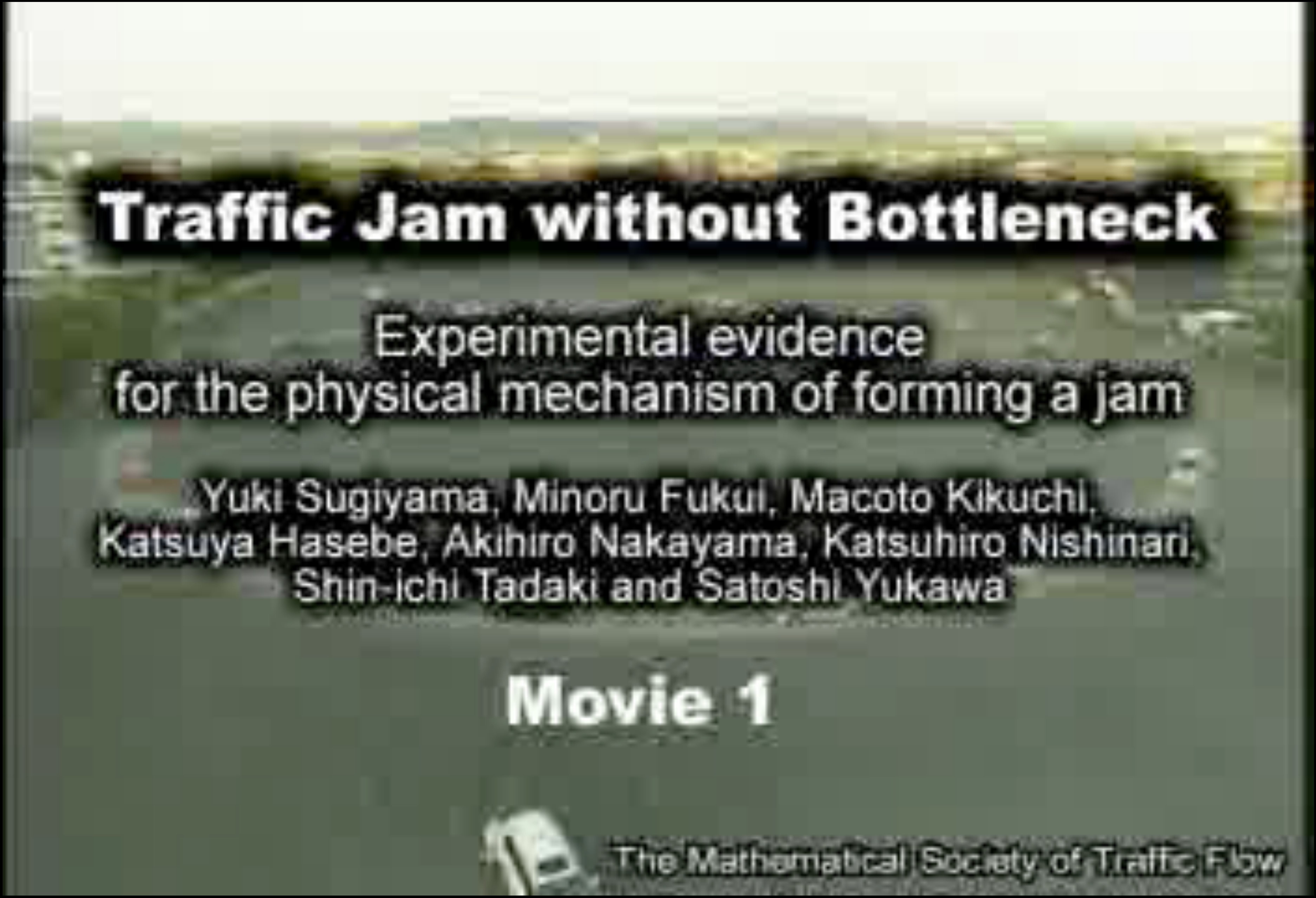


angular speed = constant
linear speed increases with radius

wind up



angular speed increases with radius
linear speed ~ constant


Traffic Jam without Bottleneck
Experimental evidence
for the physical mechanism of forming a jam
Yuki Sugiyama, Minoru Fukui, Macoto Kikuchi,
Katsuya Hasebe, Akihiro Nakayama, Katsuhiro Nishinari,
Shin-ichi Tadaki and Satoshi Yukawa
Movie 1
The Mathematical Society of Traffic Flow

density wave

What happens when a star encounters the density wave?

- As it nears the wave, it speeds up towards the density wave. *Why?*
- After it passes through the wave, it slows down and leaves very slowly. *Why?*
- So the star spends more time around the density wave than it otherwise would. We see this as an enhanced density of stars -- a spiral arm!

How does this help us with the winding problem?

angular PATTERN speed ~ constant
linear speed ~ constant

Why is there so much more star formation in spiral arms?

density wave

angular PATTERN speed ~ constant
linear speed ~ constant

density wave

Why is there so much more star formation in spiral arms?

One idea: as gas clouds move into the density wave, the local mass density increases. Since the criteria for cloud collapse (Jeans mass) depends on density, a higher density makes it more likely for clouds to collapse and form stars.

Another idea: as clouds get swept up by the spiral arms, they collide with one another and drive shock waves through the gas, which in turn causes the gas to collapse and form stars.

angular PATTERN speed ~ constant
linear speed ~ constant

Something has to "seed" this perturbation. Once it is seeded, the self-gravity of the disk will amplify the perturbation and make it grow.

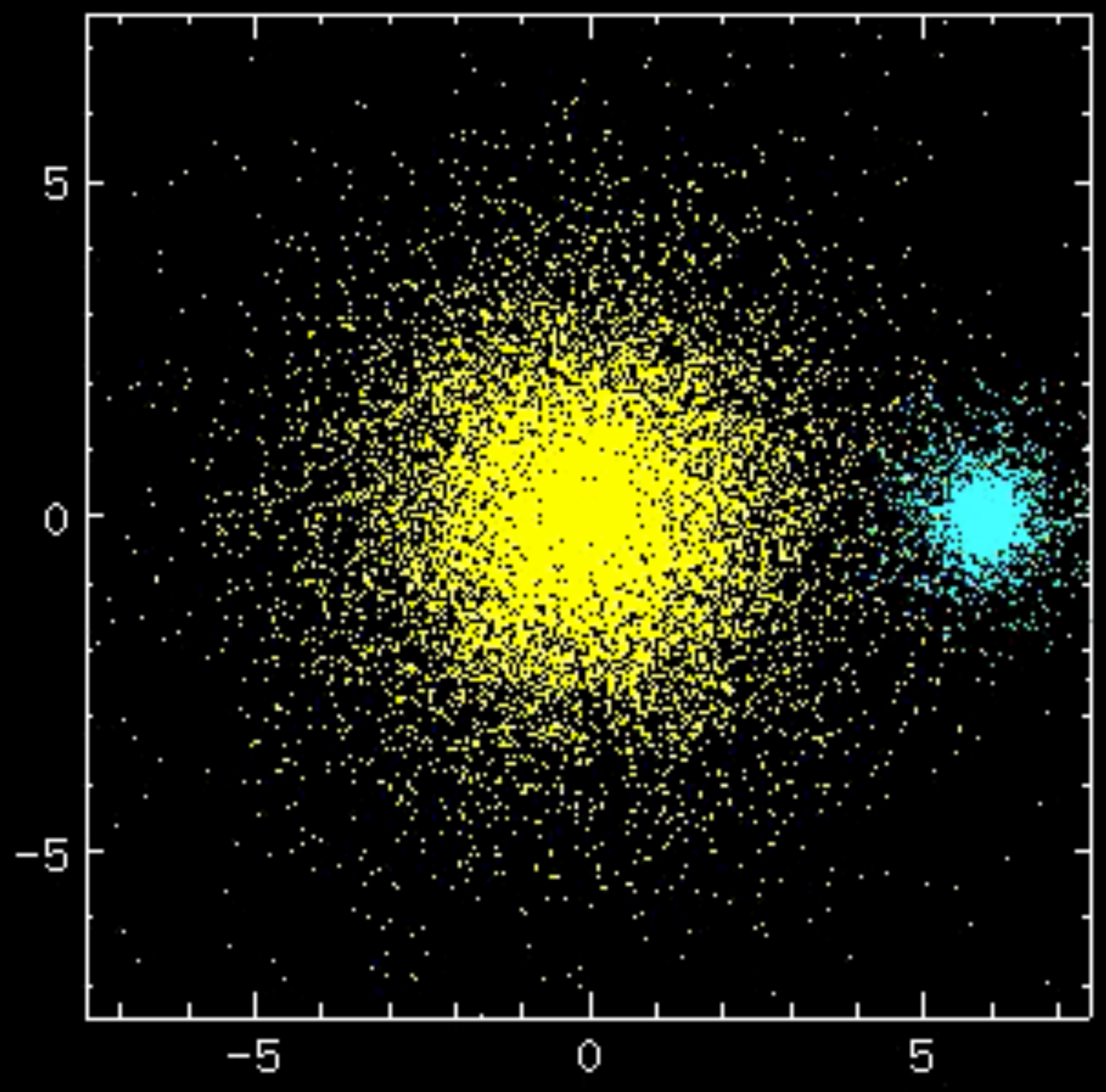
Ideas:

Initial non-axisymmetry in the disk and/or halo (ie galaxy formation processes)

Galaxy encounters (environmental processes)

Here's an example of how an encounter between a big galaxy and a small satellite companion can drive spiral structure —>

The answer is that we don't really know for sure though: we can produce spiral arms many different ways!



Many ellipticals have surface brightness profiles that follow

$$\log I \sim r^{1/4}$$

Characterized by effective radius (radius that contains 50% of light)

$$r_e$$

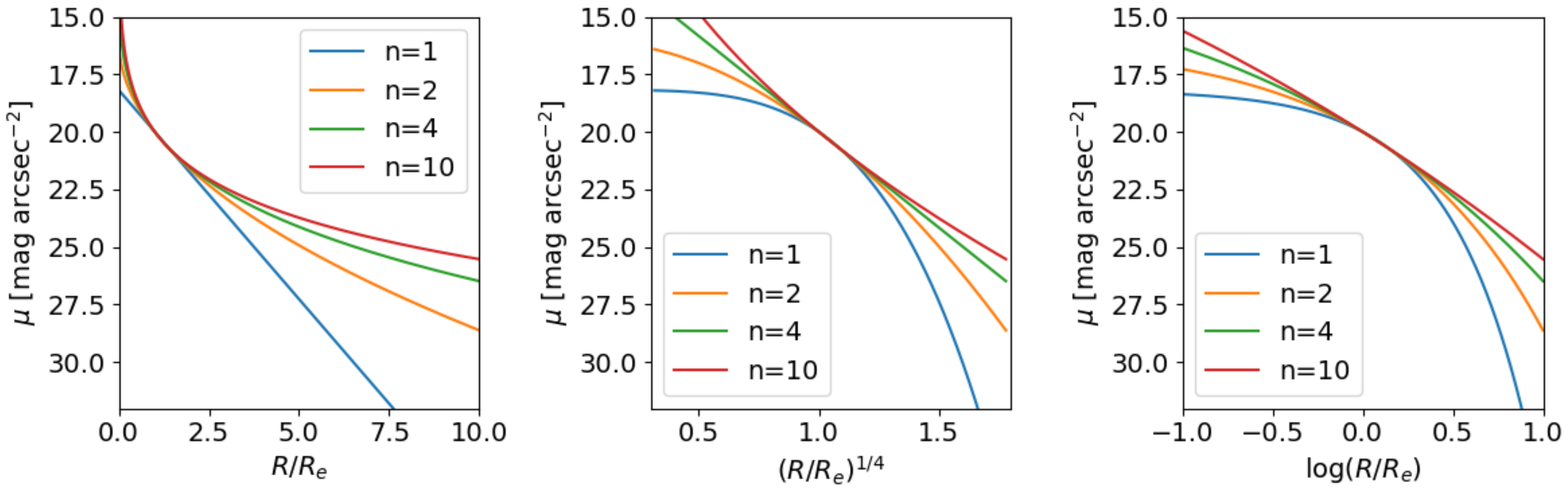
and mean surface brightness (inside effective radius)

$$\langle I_e \rangle \text{ or } \langle \mu_e \rangle$$

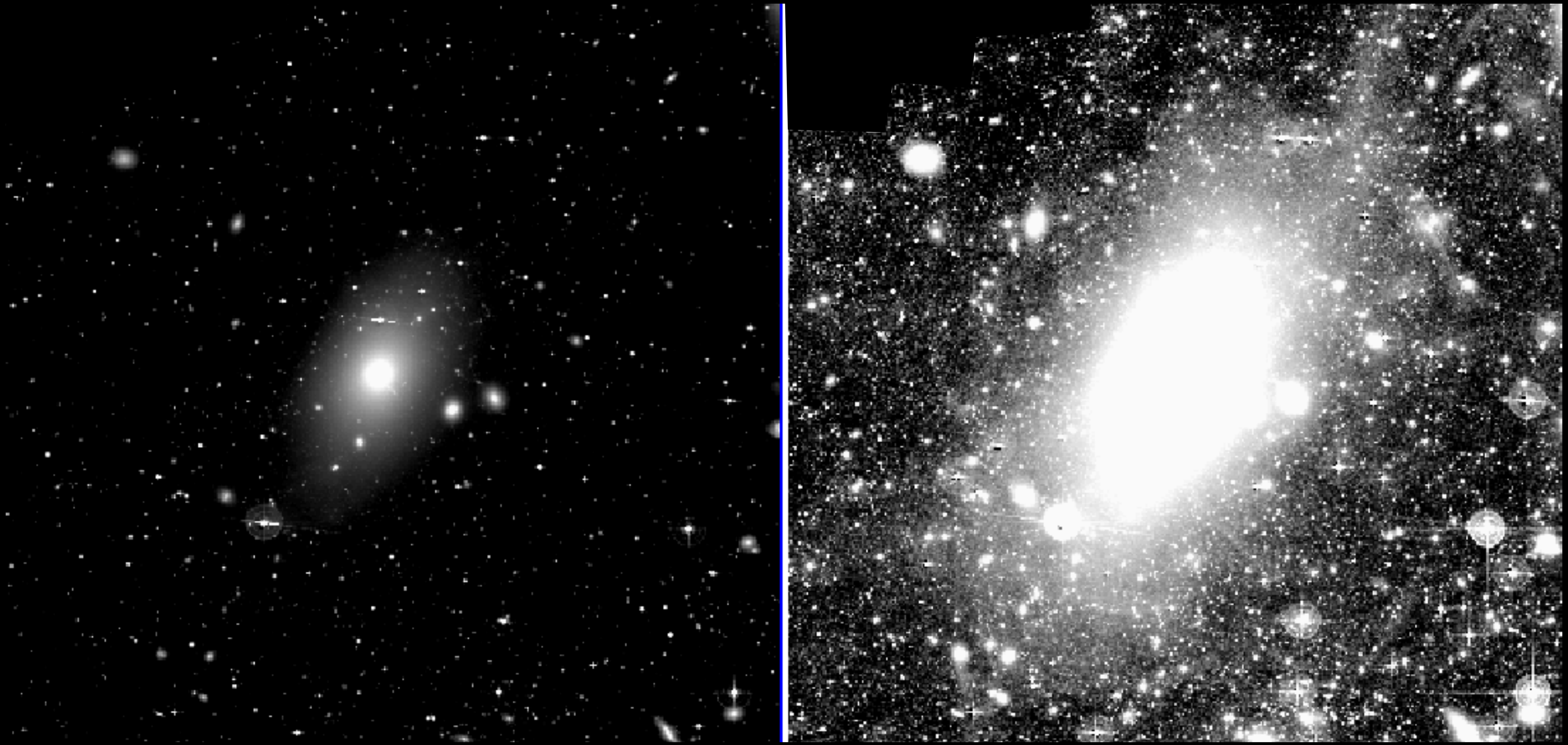
Most ellipticals do not exactly follow an r¼ law, and can instead be fit by the generalized "Sersic profile"

$$\log I \sim r^{1/n}$$

where *n* is the Sersic index

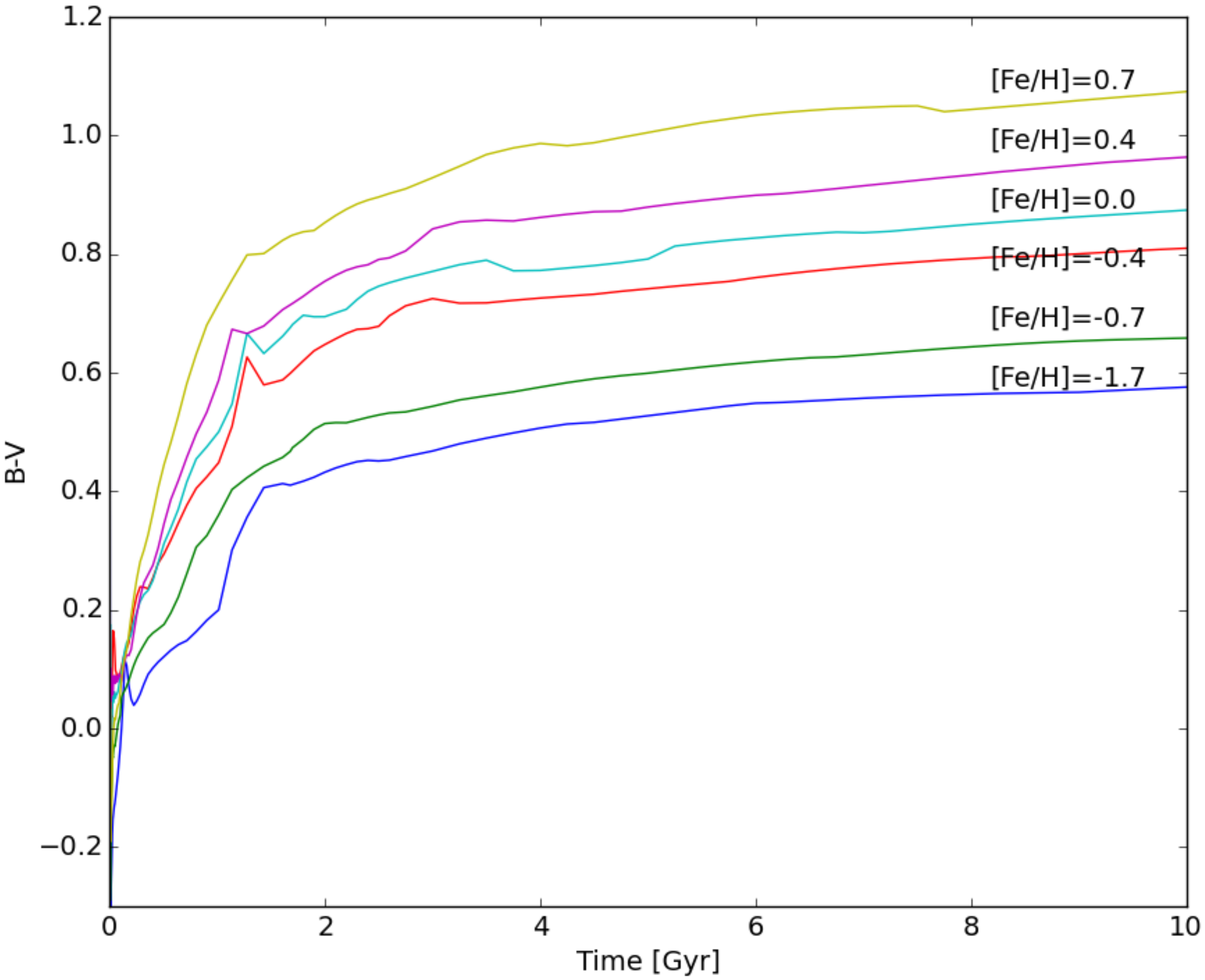


M87 has n ~ 10-11



Stellar population synthesis tracks: B-V color vs age, for an evolving "single burst" population of stars with different metallicities:

So two things make a stellar population red: old age, and high metallicity. The colors of a galaxy cannot distinguish between the two without already knowing age.



Elliptical galaxies (like spirals) show a color-luminosity relationship: brighter, more massive galaxies are redder. In elliptical galaxies, this is well-established to be a *metallicity effect, not age*. So brighter galaxies are more metal-rich.

The differences between elliptical galaxies and star forming spirals can be seen in plots of color versus luminosity or stellar mass: they form a distinct "red sequence" which is offset from the "blue cloud" of star forming galaxies: