Vorming en Evolutie van Sterrenstelsels in het Jonge Heelal

Jesse van de Sande

Sterrewacht Leiden



Leidse Weer- en Sterrekundige Kring

De Melkweg



De Melkweg







Kernvragen

-Is de melkweg uniek?

-Hoe is melkweg gevormd?

-Is de melkweg het eindproduct?

Overzicht

-Gereedschap: afstanden, kleur, massa, grootte

-Sterrenstelsels “dichtbij”

-Vorming van sterrenstelsels

-Uitdaging voor de huidige theorie

Hoe bepaal je de afstand tot een sterrenstelsel?

GEREEDSCHAP

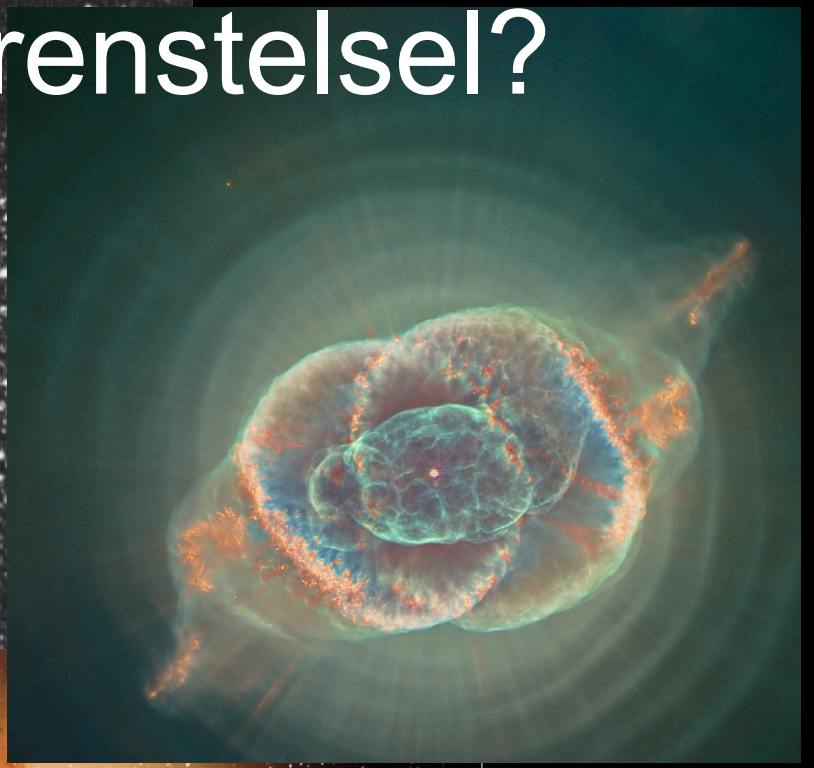
Andromeda:
Nevel of Sterrenstelsel?

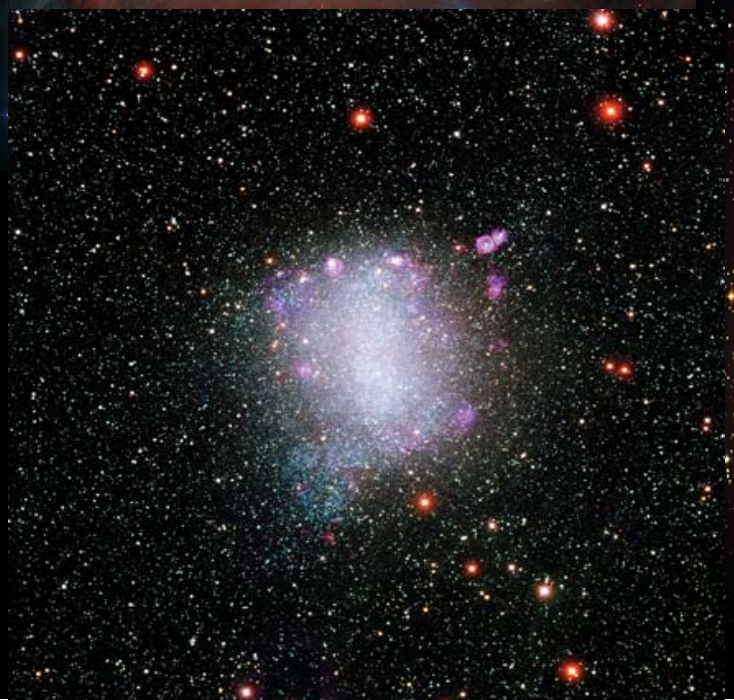


Waarom een sterrenstelsel?



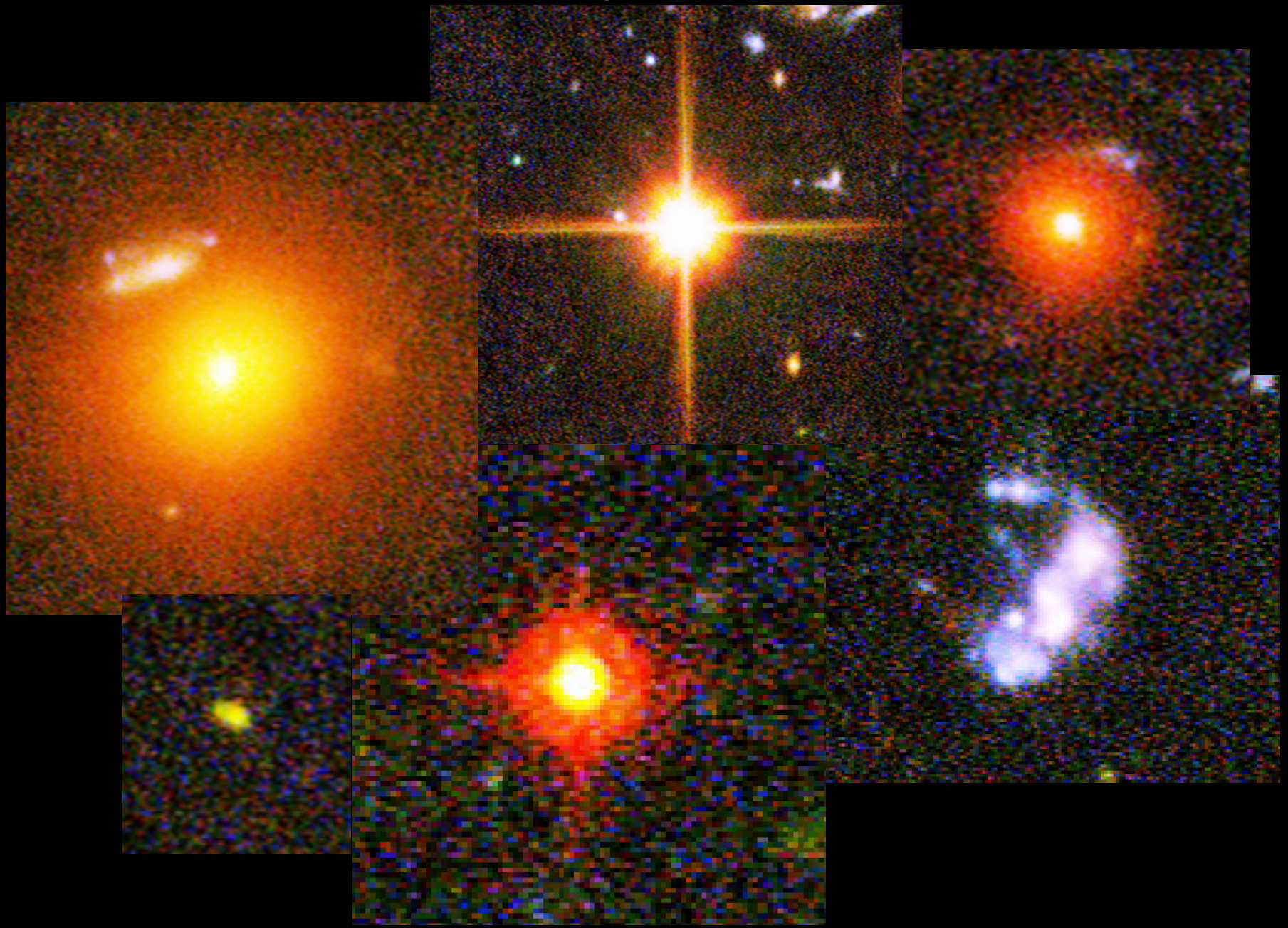








lets moeilijker misschien?




Andromeda Sterrenstelsel

OCT 20 1913
CAMBRIDGE, MASS.

The Observatory of

LOWELL OBSERVATORY

BULLETIN No. 58

VOL. II No. 8

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THE RADIAL VELOCITY OF THE ANDROMEDA NEBULA

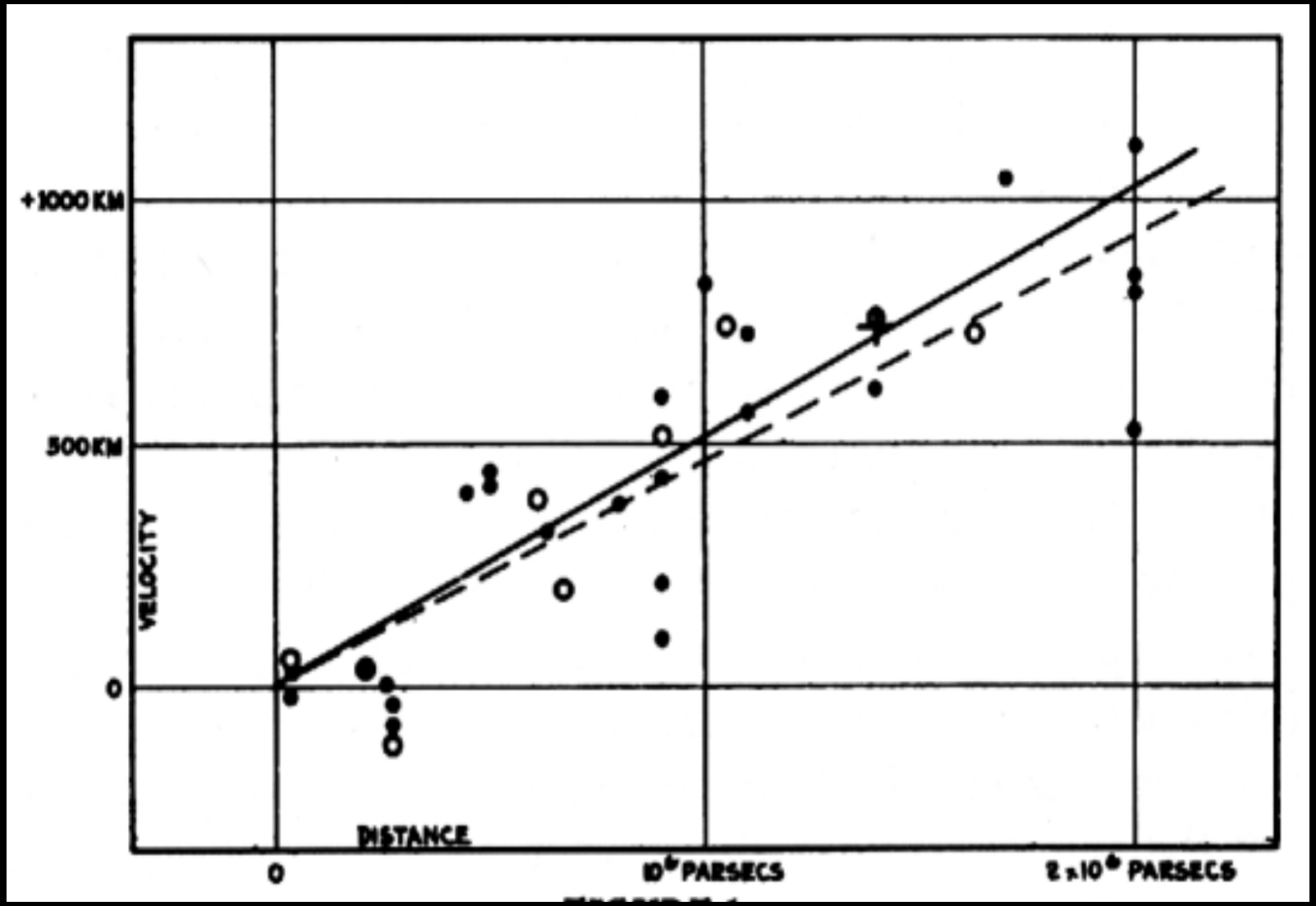
Keeler, by his splendid researches on the nebulæ, showed, among other things, that the nebulæ are generally spiral in form, and that such nebulæ exist in far vaster numbers than had been supposed. These facts seem to suggest that the spiral nebula is one of the important products of the forces of nature. The spectra of these objects, it was recognized, should convey valuable information, and they have been studied, photographically, first by Huggins and Scheiner, and recently more extensively by Fath and Wolf; but no attempt has to my knowledge been made to determine their radial velocity, although the value of such observations has doubtless occurred to many investigators.

The one obstacle in the way of the success of this undertaking is the faintness of these nebulæ. The extreme feebleness of their dispersed light is difficult to realize by one not experienced in such observing, and it no doubt appears strange that the magnificent Andromeda Spiral, which under a transparent sky is so evident to the naked eye, should be so faint spectrographically. The contest is with the low intrinsic brightness of the nebular surface, a condition which no choice of telescope can relieve, However, the proper choice of parts in the spectrograph will make the best of this difficulty. The collimator must of course fit the telescope, but the dispersion-piece and the camera may and should be carefully selected for ters. When making this exposure the brightness of the nebula on the slit-plate compared with that of the clusters indicated that one night's exposure should suffice for the single-prism, and suggested that, by extending the exposure through several nights, one could employ the battery of three dense flint prisms whose dispersion would make it possible to observe the velocity of the nebula. The success of the plate bore out this suggestion. Indeed, upon subsequent examination of this plate it was seen that the nebular lines were perceptibly displaced with reference to the comparison lines. The next plate secured showed the same displacement. Still other single-prism plates were obtained during the autumn and early winter, but the observing program with the 24-inch telescope did not allow an opportunity to carry out the original plan to make the longer exposure spectrogram with the prism-train.

These spectrograms were measured with the Hartmann spectrocomparator, using a magnification of fifteen diameters. A similar plate of Saturn was employed as a standard. The observations were as follows:

1912,	September 17,	Velocity,	—284 km.
	November 15–16,	"	296
	December 3–4,	"	308
	December 29–30–31,	"	—301
		Mean velocity,	—300 km.

Hubble's Uitdijende Heelal



Snelheid

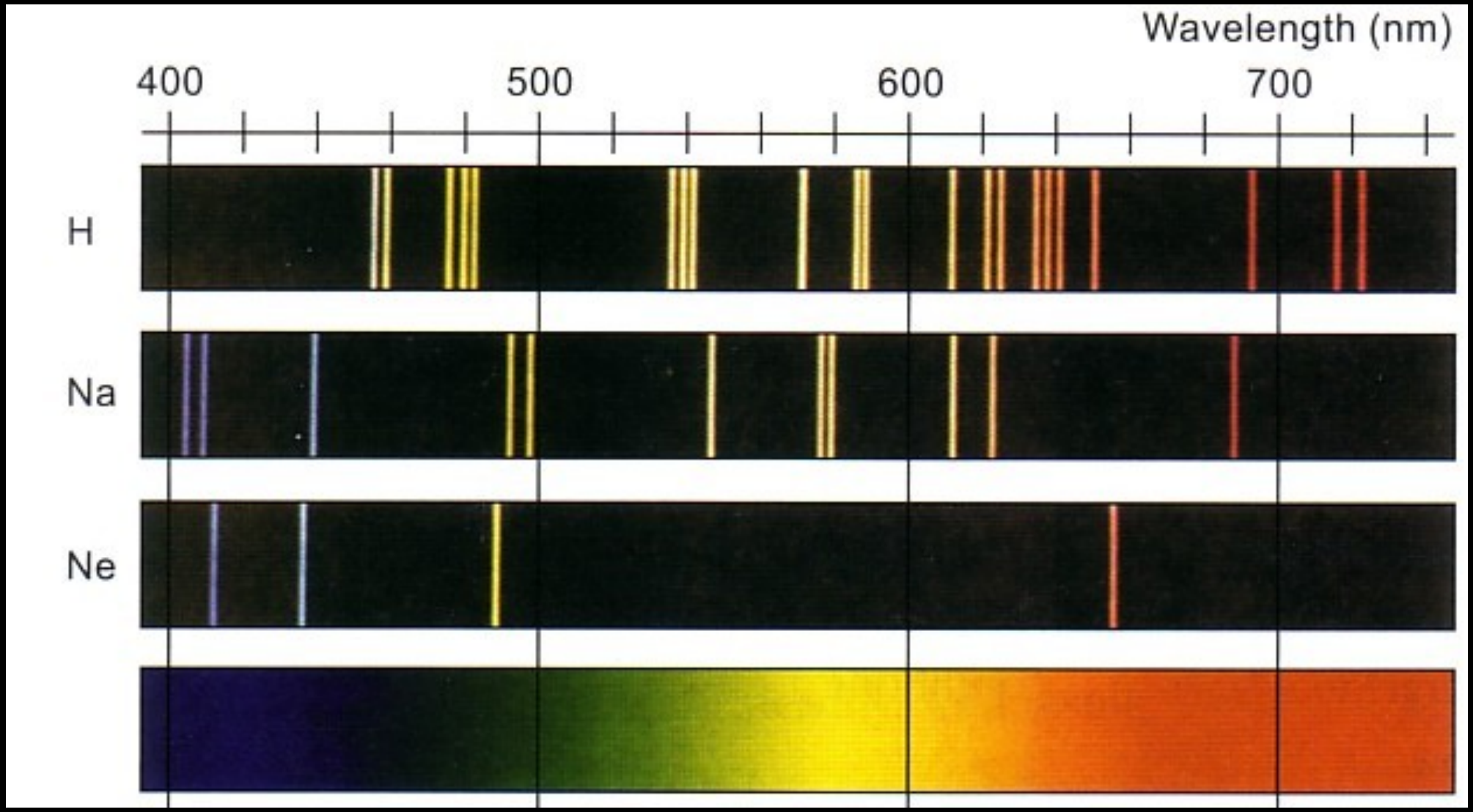
Afstand

Wet van Hubble

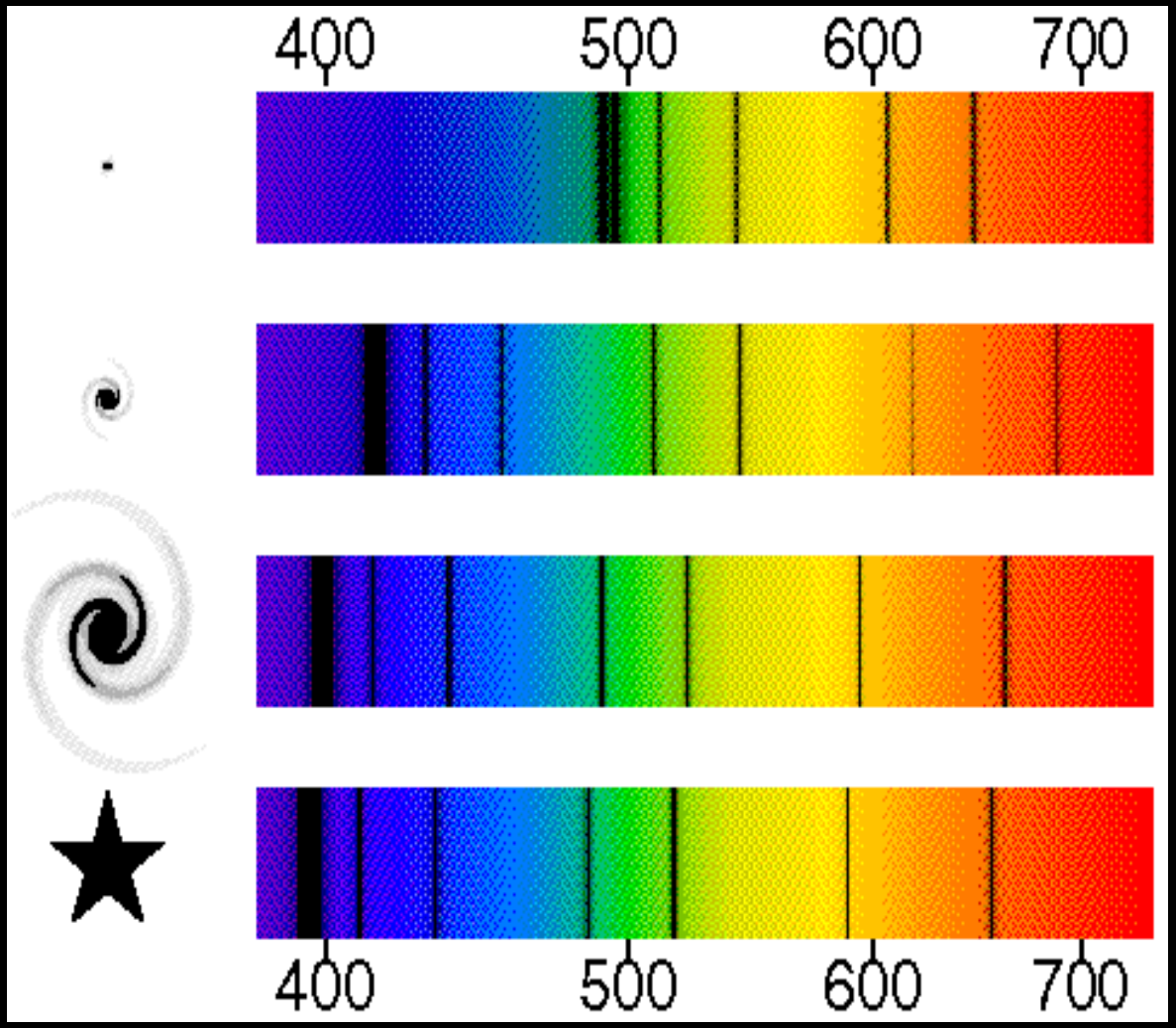
$$v = H_0 D$$

*snelheid = constante * afstand*

Spectrum



Doppler Effect voor licht



Extreem hoge snelheid

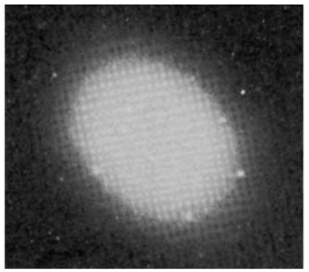
Hoge snelheid

Matige snelheid

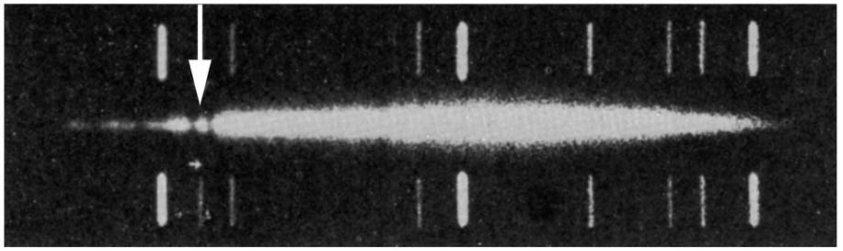
Stilstaand

Sterrenstelsel in **Roodverschuiving**

K en H lijnen van calsium

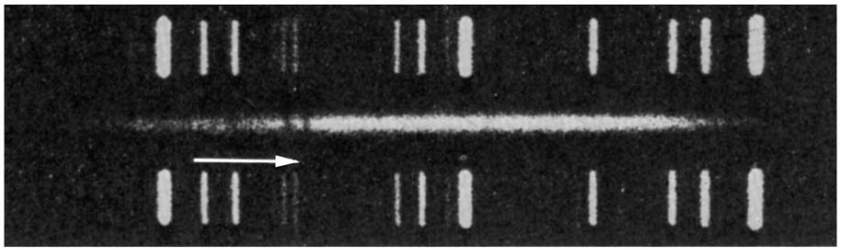


Virgo



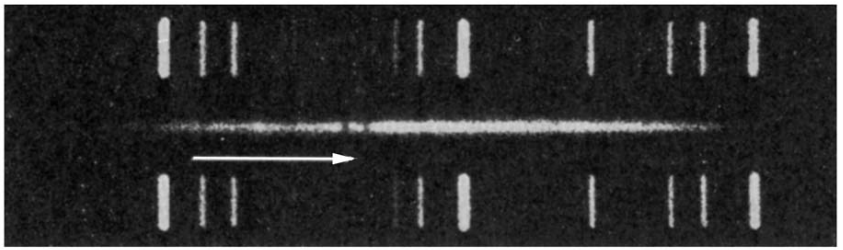


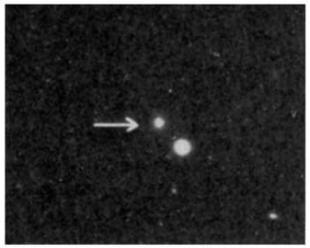
Ursa Major



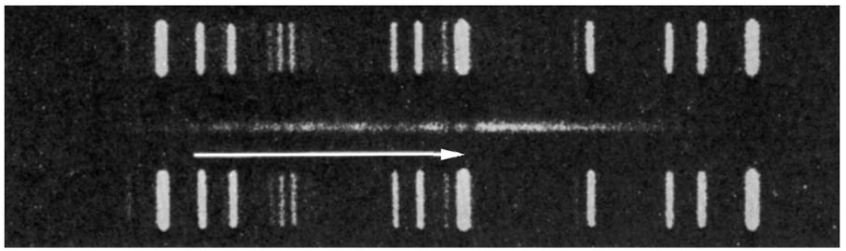


Corona Borealis

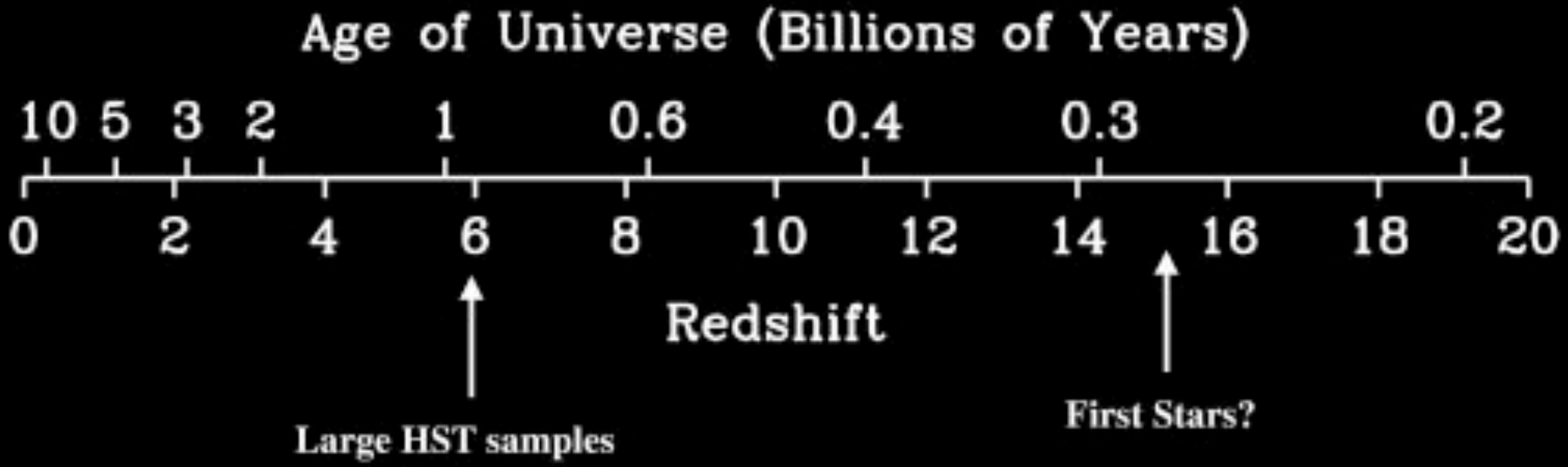




Boötes



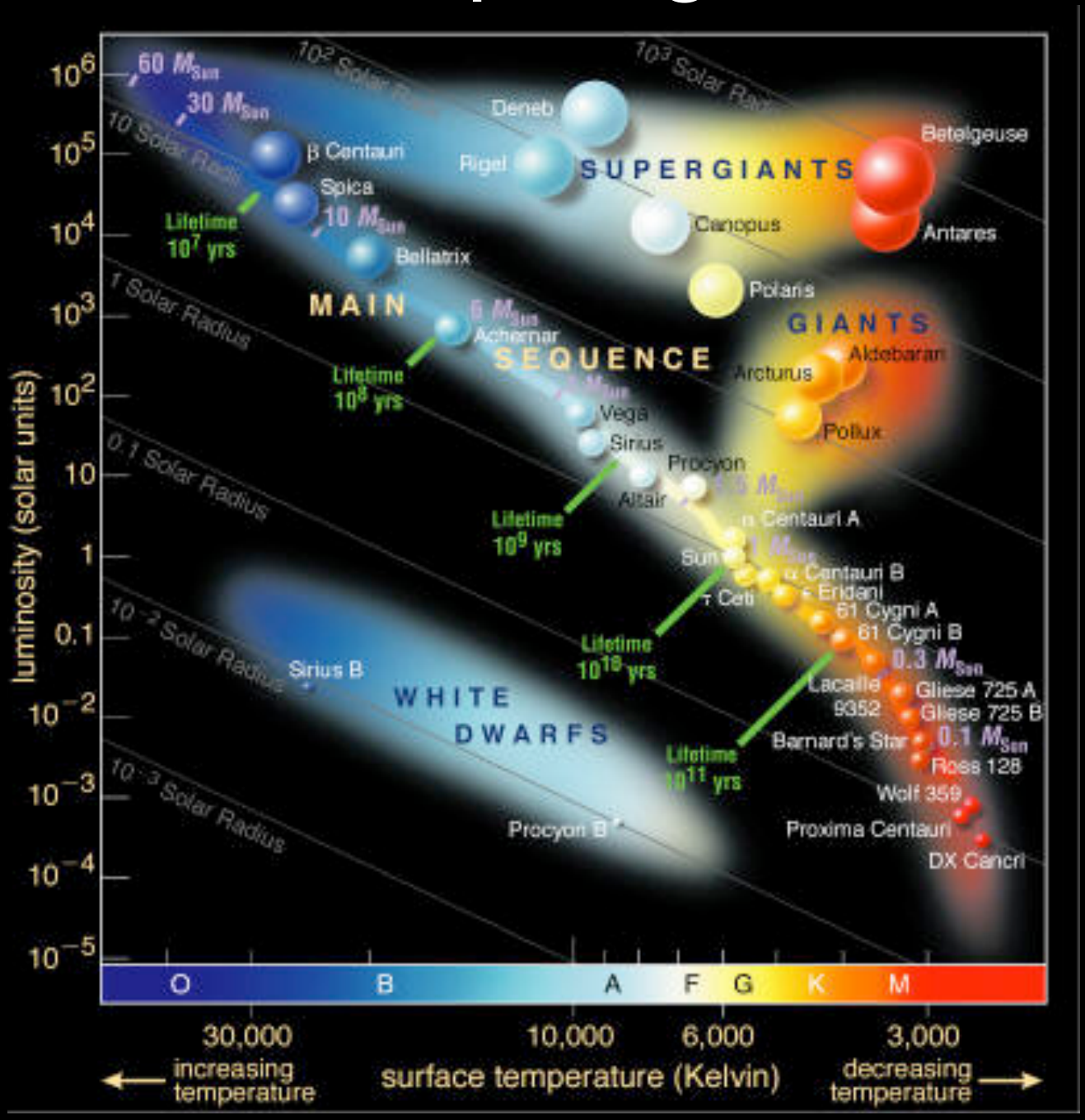
Roodverschuiving: z



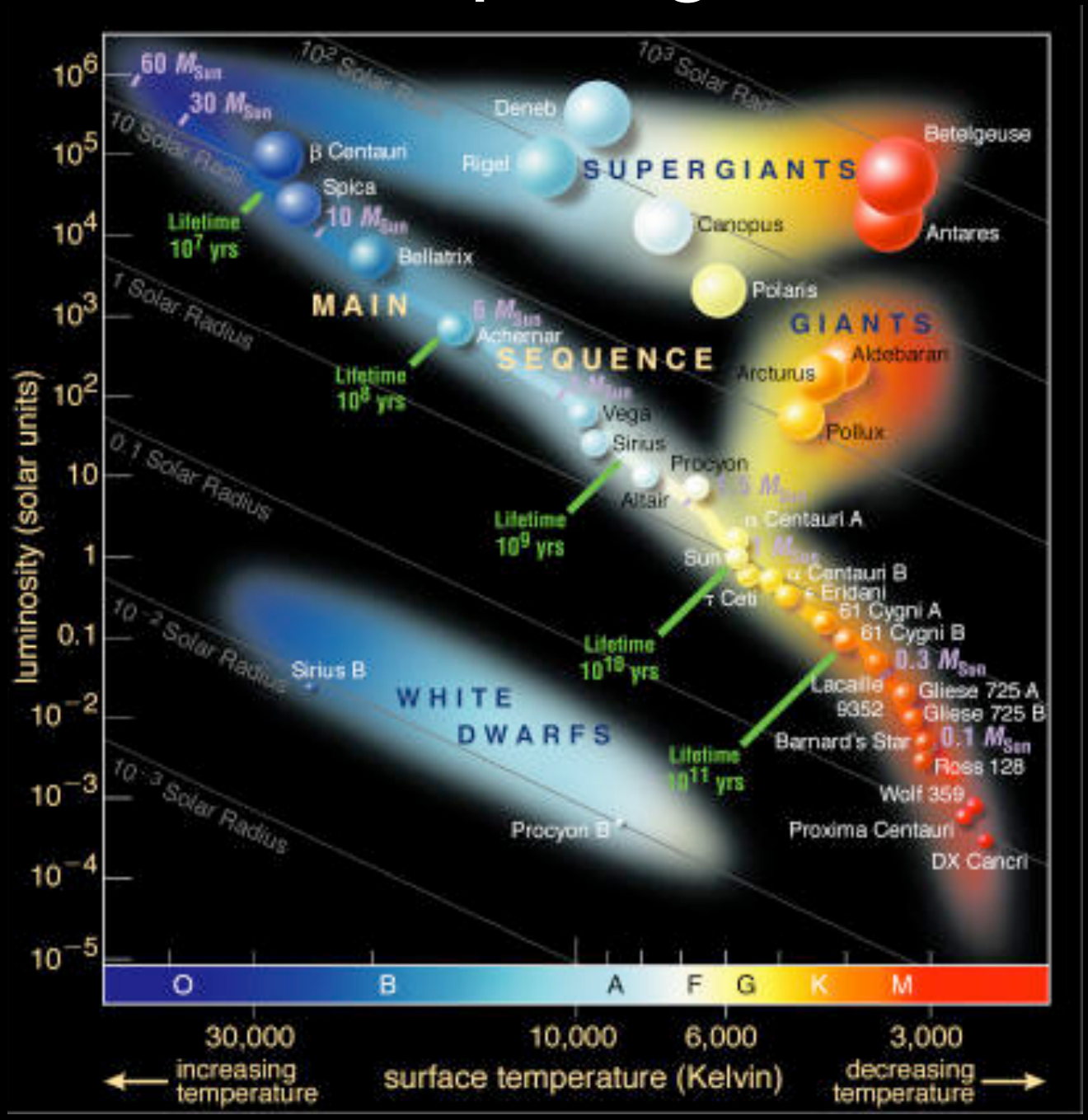
Kleur als lakmoesproef voor sterrenstelsels?

GEREEDSCHAP

Hertzsprung-Russell diagram



Hertzsprung-Russell diagram



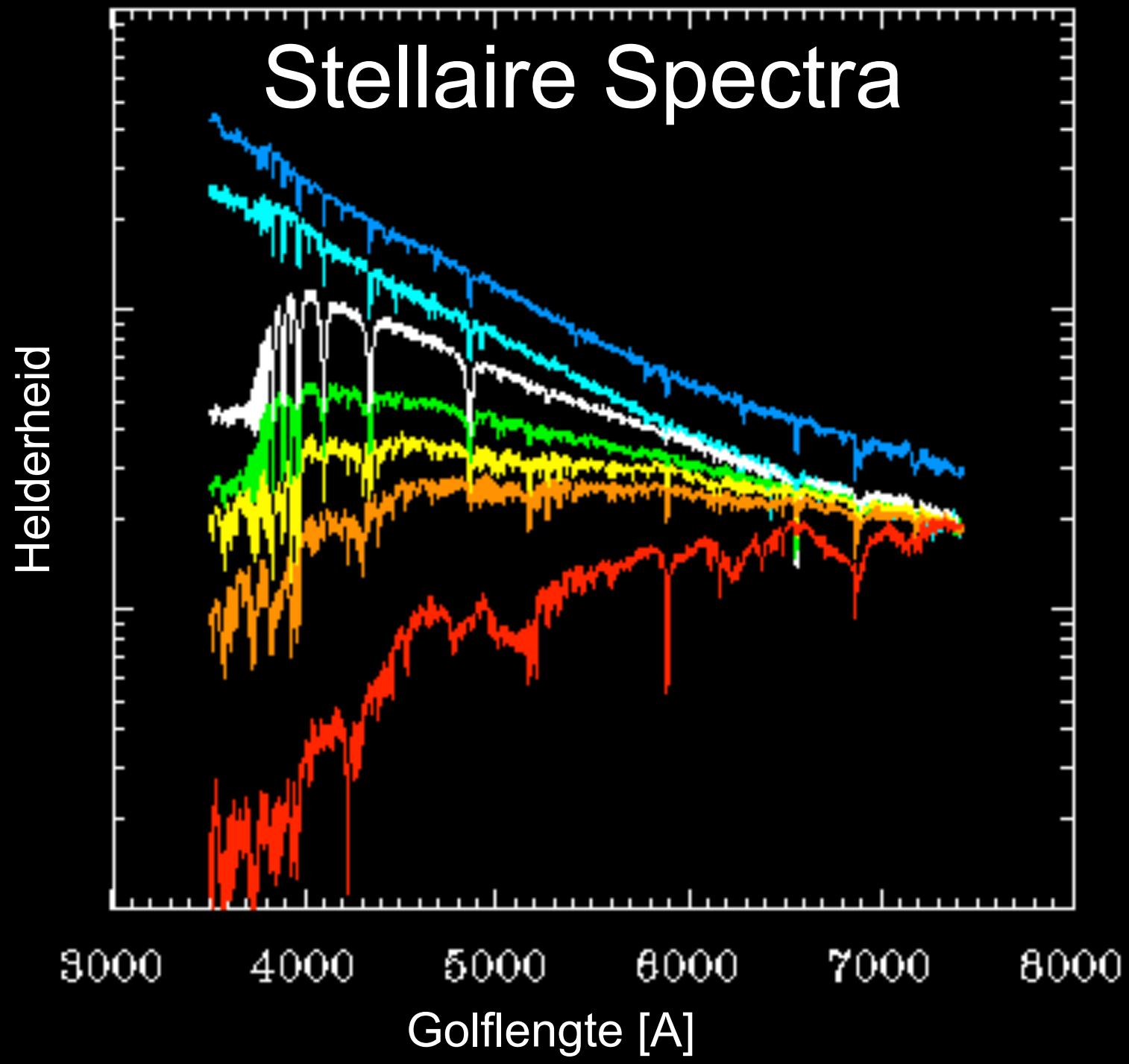
Kleur = leeftijd

Blauw=jong
Rood = oud

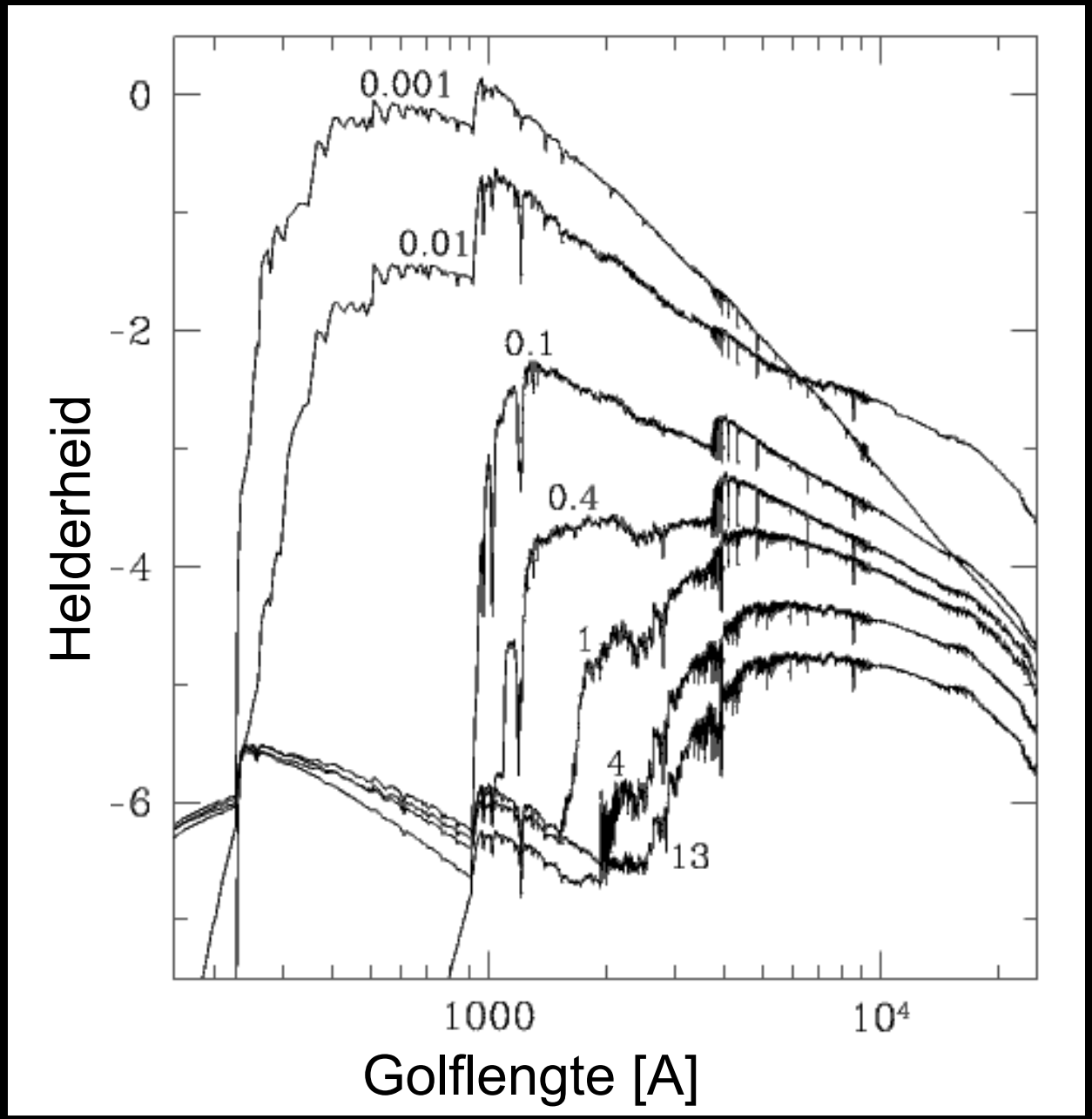
Kleur = Massa

Blauw = Zwaar
rood = licht

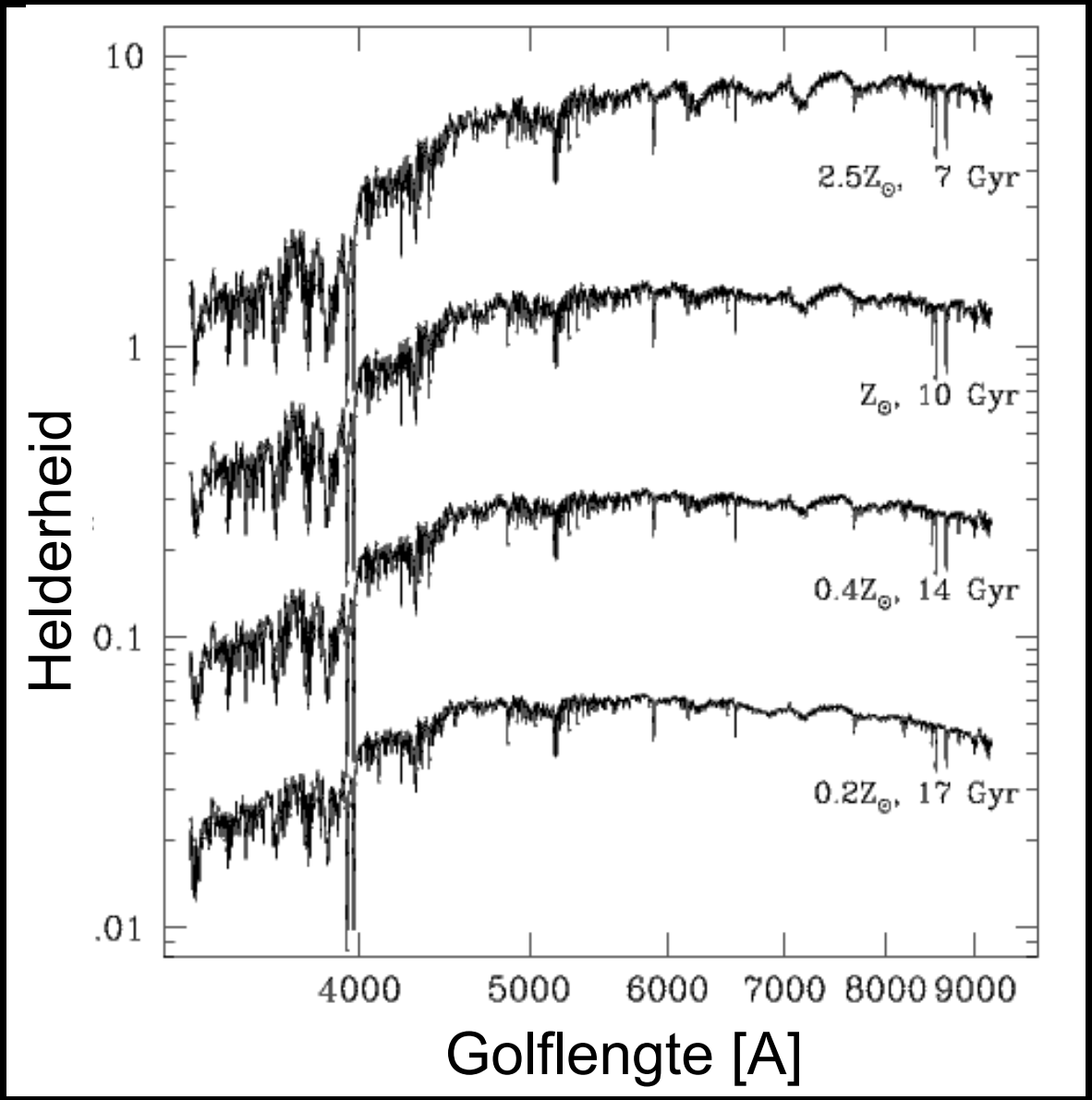

Kleur = massa
Rood = oud en licht
Blauw = jong en zwaar
Kleur = leeftijd


Stellaire Spectra
Helderheid
3000
4000
5000
6000
7000
8000
Golflengte [A]

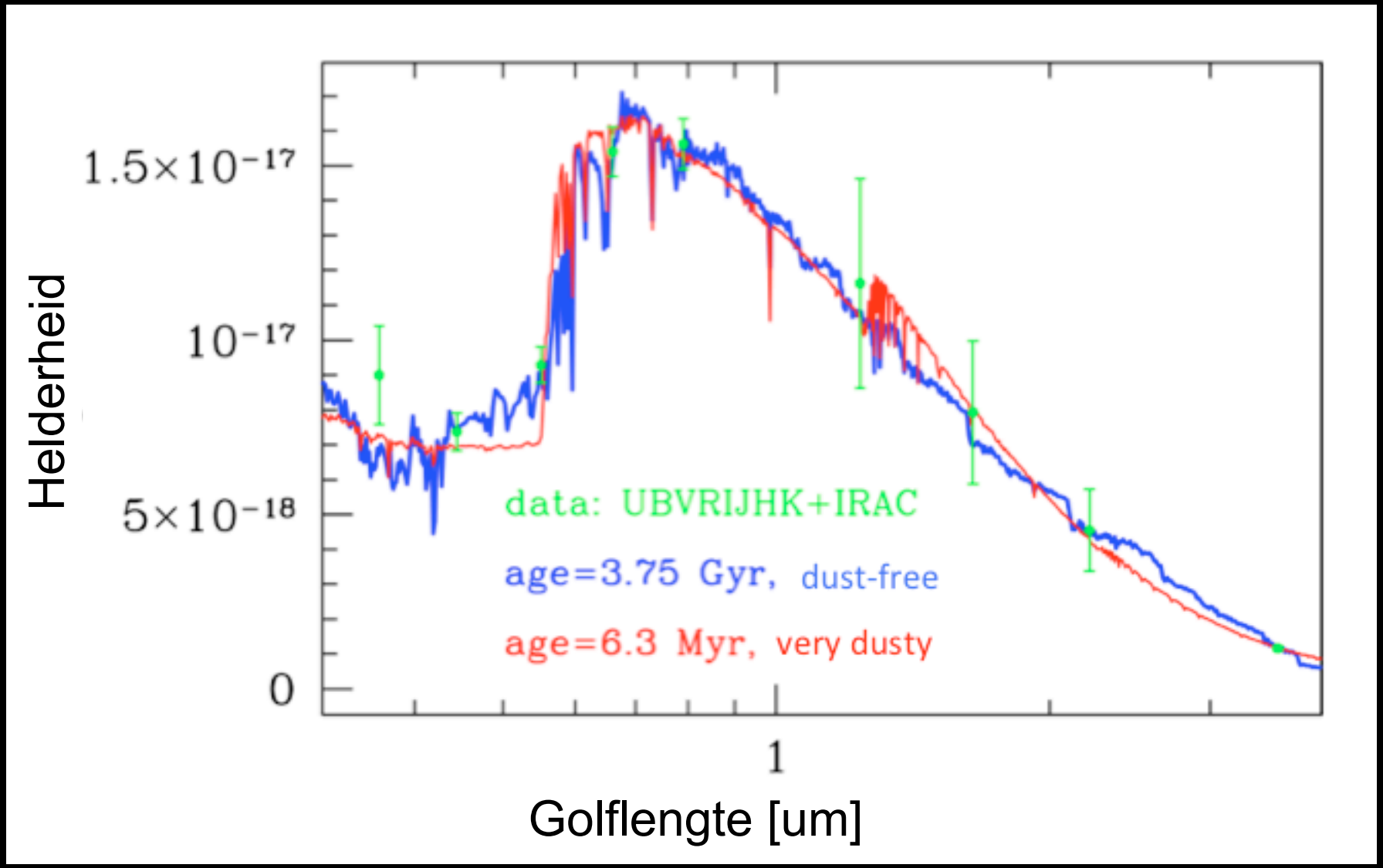
Spectra Sterrenstelsels



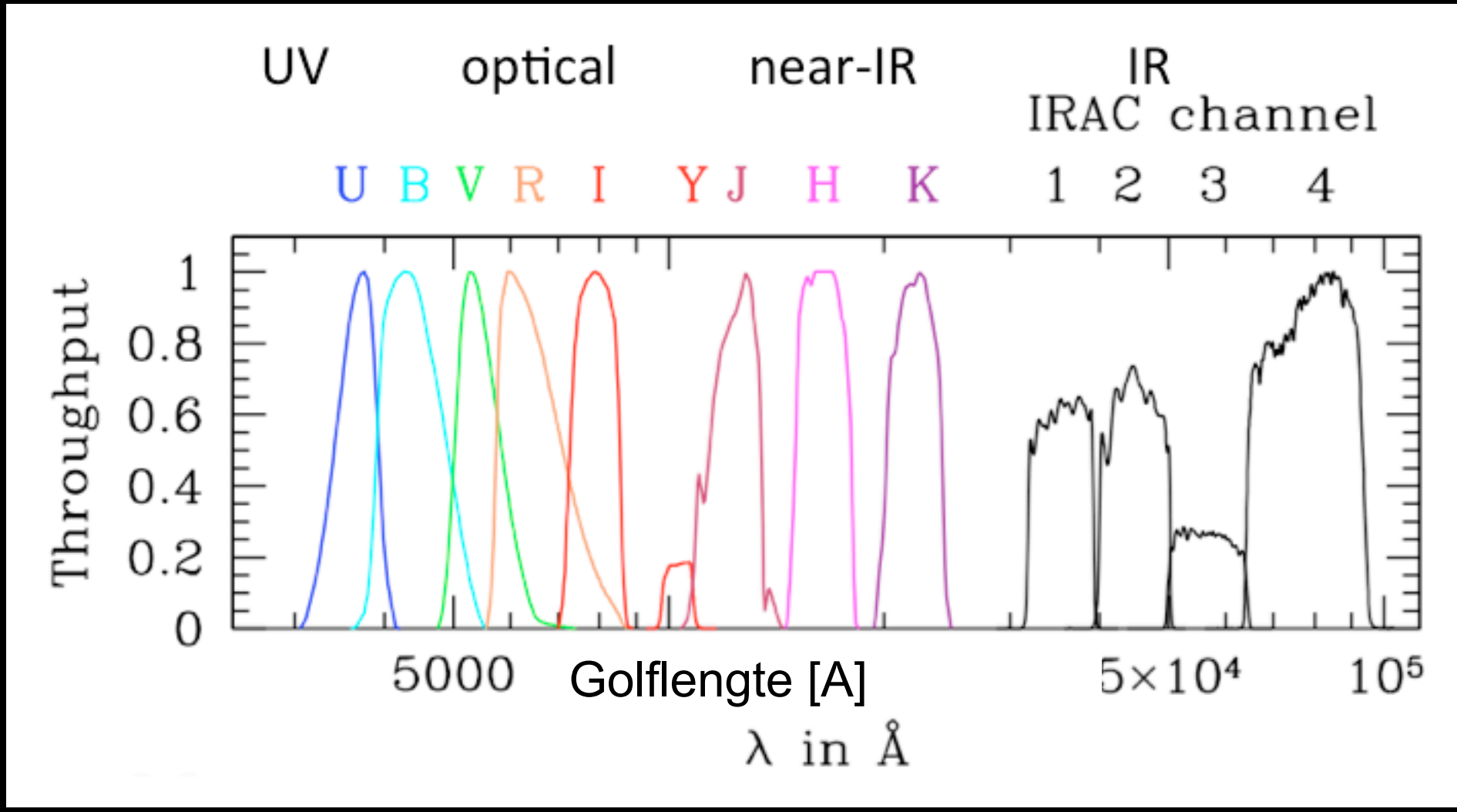
Effect van metalen en leeftijd moeilijk te onderscheiden



Effect van stof en leeftijd moeilijk te onderscheiden

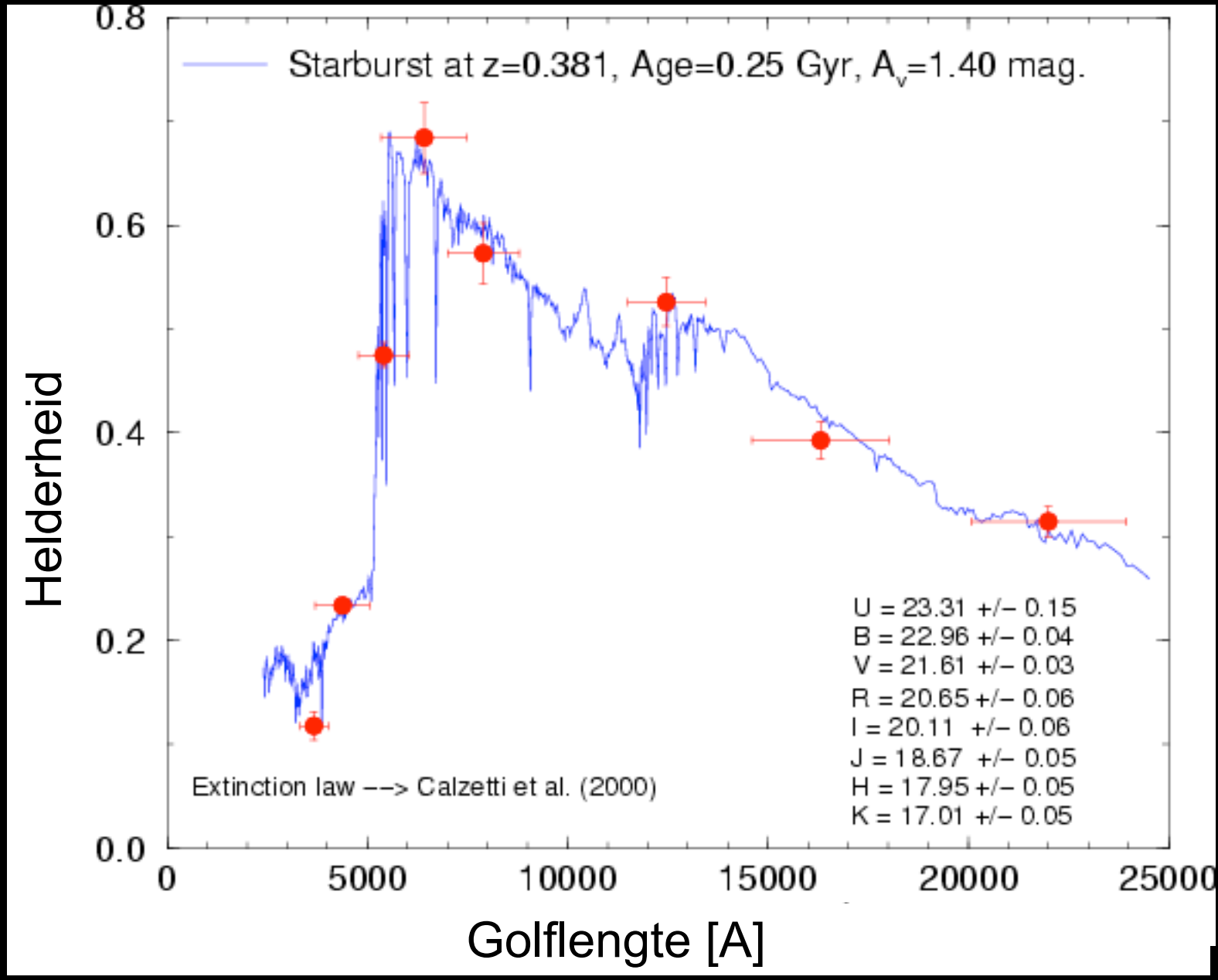


Filters versus Spectra



Waarom filters?



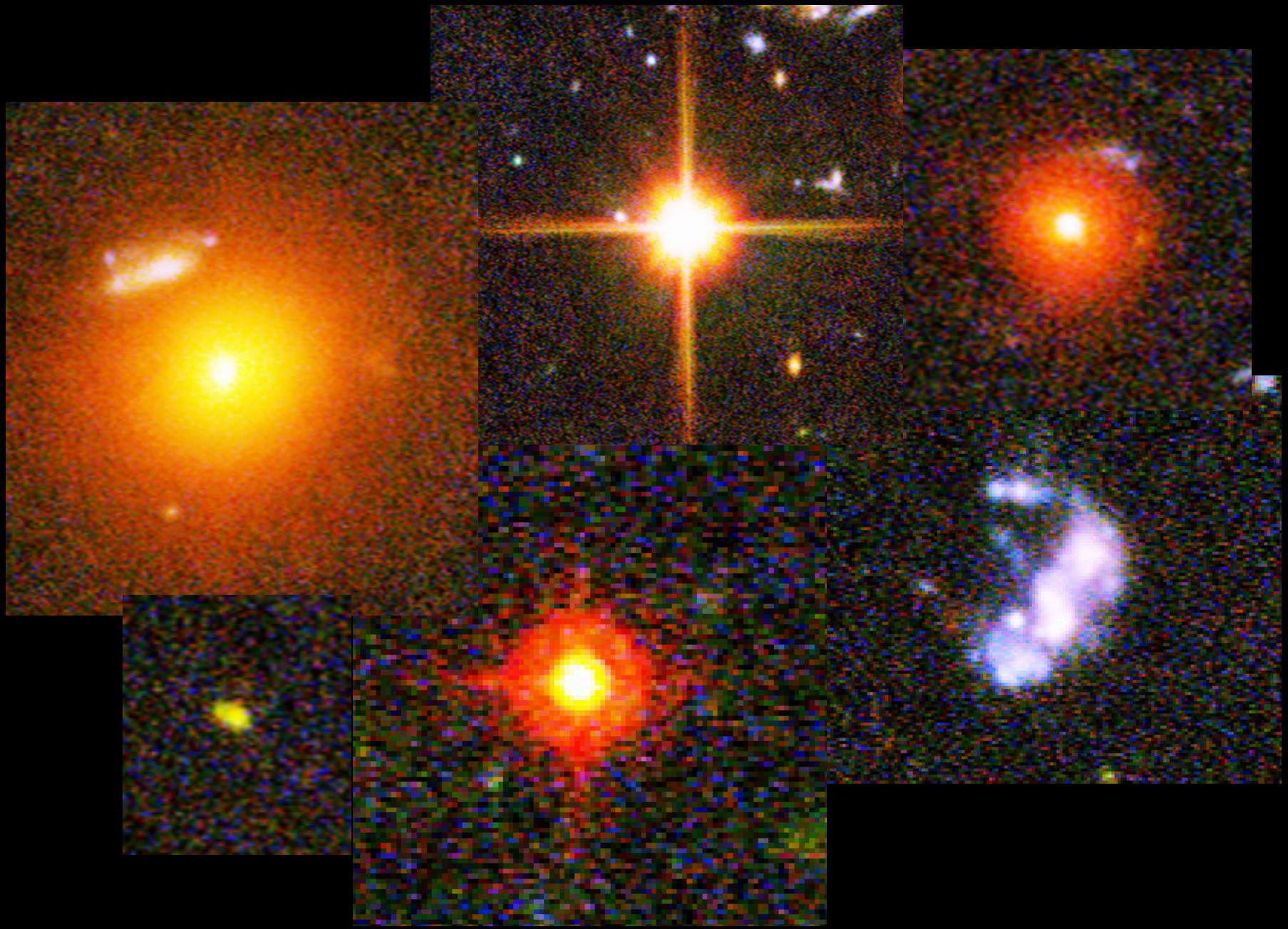

Starburst at z=0.381, Age=0.25 Gyr, A$_v$=1.40 mag.
U = 23.31 +/– 0.15
B = 22.96 +/– 0.04
V = 21.61 +/– 0.03
R = 20.65 +/– 0.06
I = 20.11 +/– 0.06
J = 18.67 +/– 0.05
H = 17.95 +/– 0.05
K = 17.01 +/– 0.05
Extinction law –> Calzetti et al. (2000)
Helderheid
Golflengte [A]
0.0
0.2
0.4
0.6
0.8
0
5000
10000
15000
20000
25000

Hoe zwaar zijn sterrenstelsels?

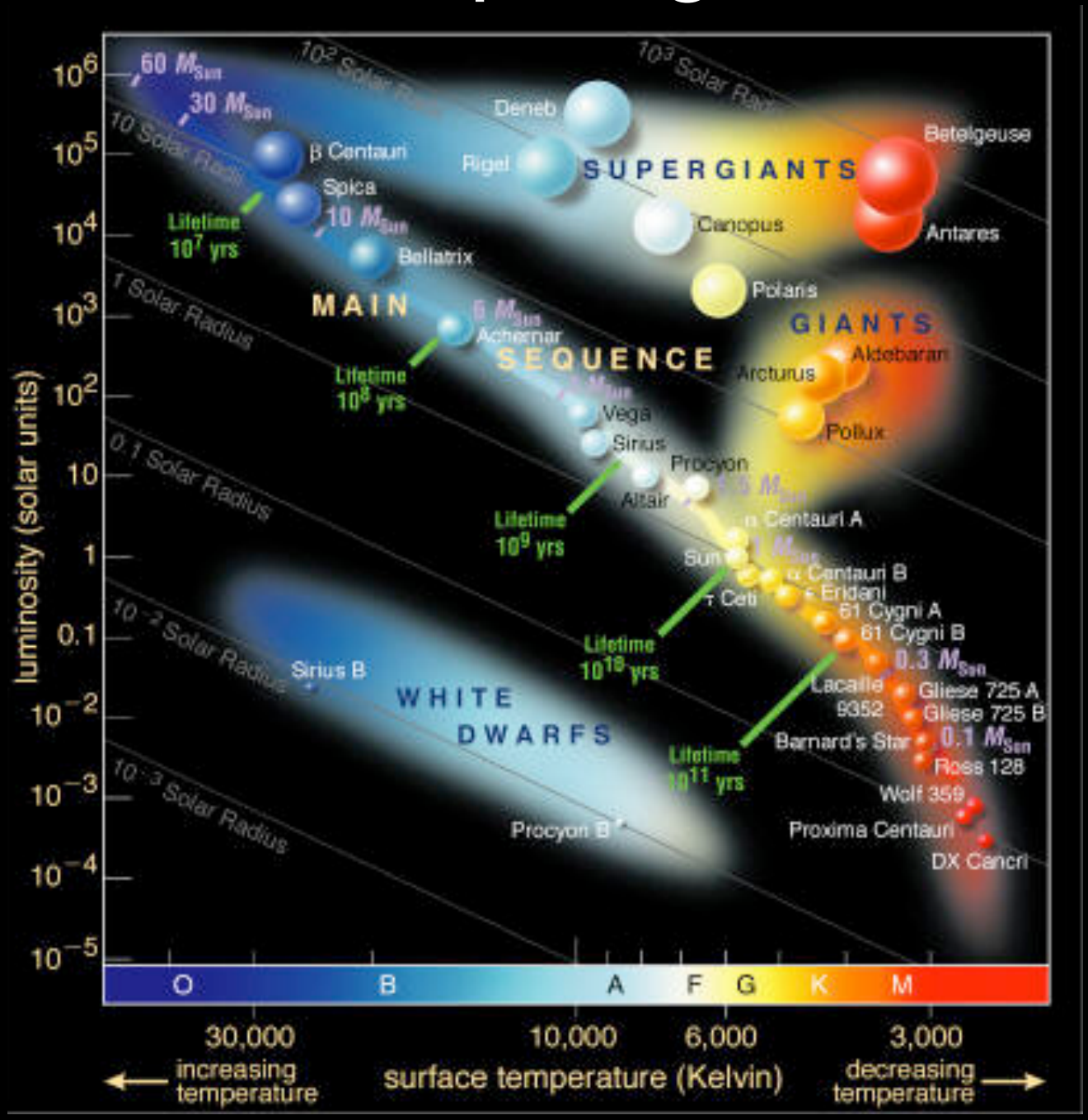
GEREEDSCHAP


Sterren tellen
Rood = oud en licht
Blauw = jong en zwaar

Sterren tellen?



Hertzsprung-Russell diagram

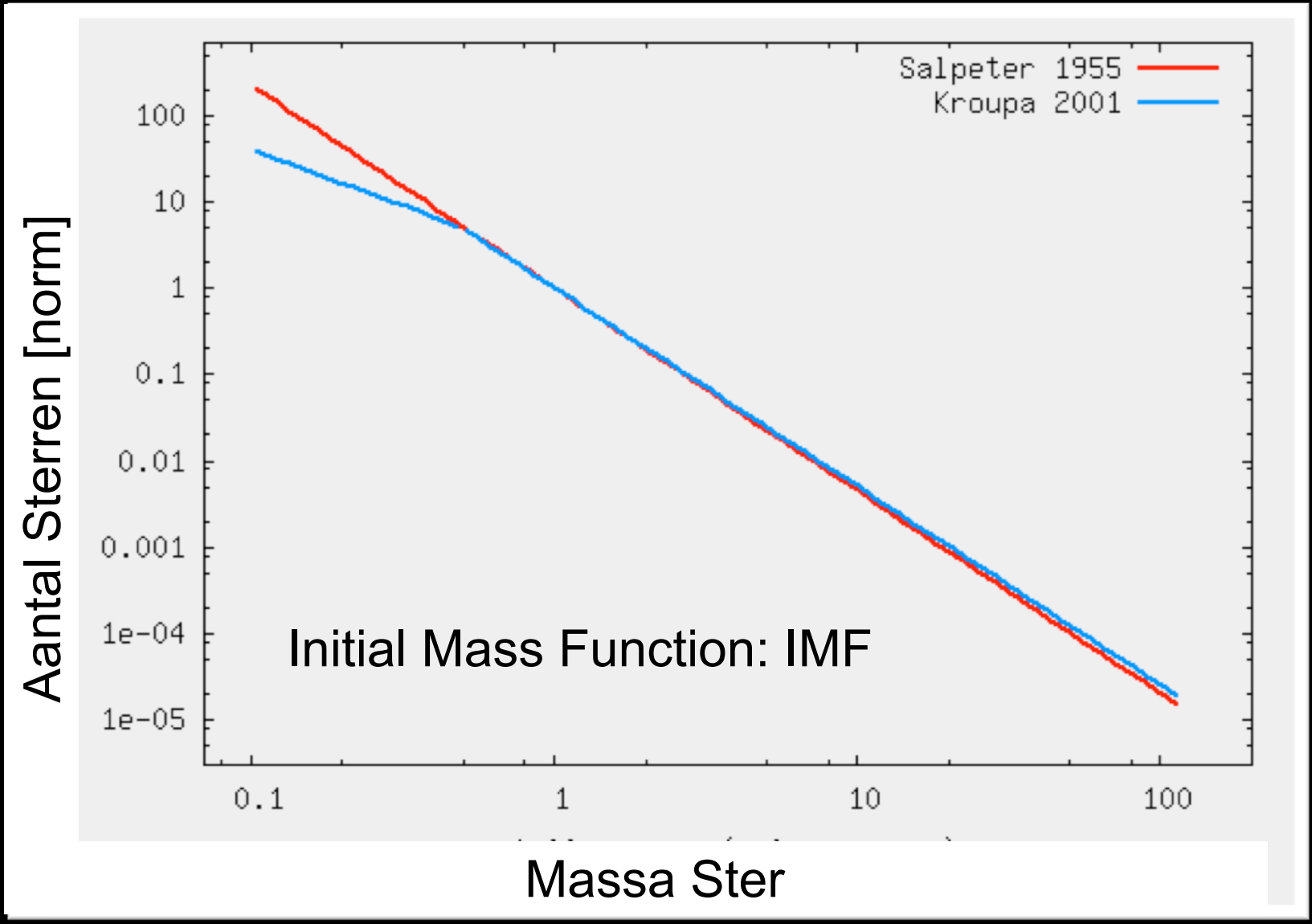


Blauwe zware sterren

overschijnen

Rode lichte sterren

Veel meer lichte rode sterren dan zware blauwe sterren

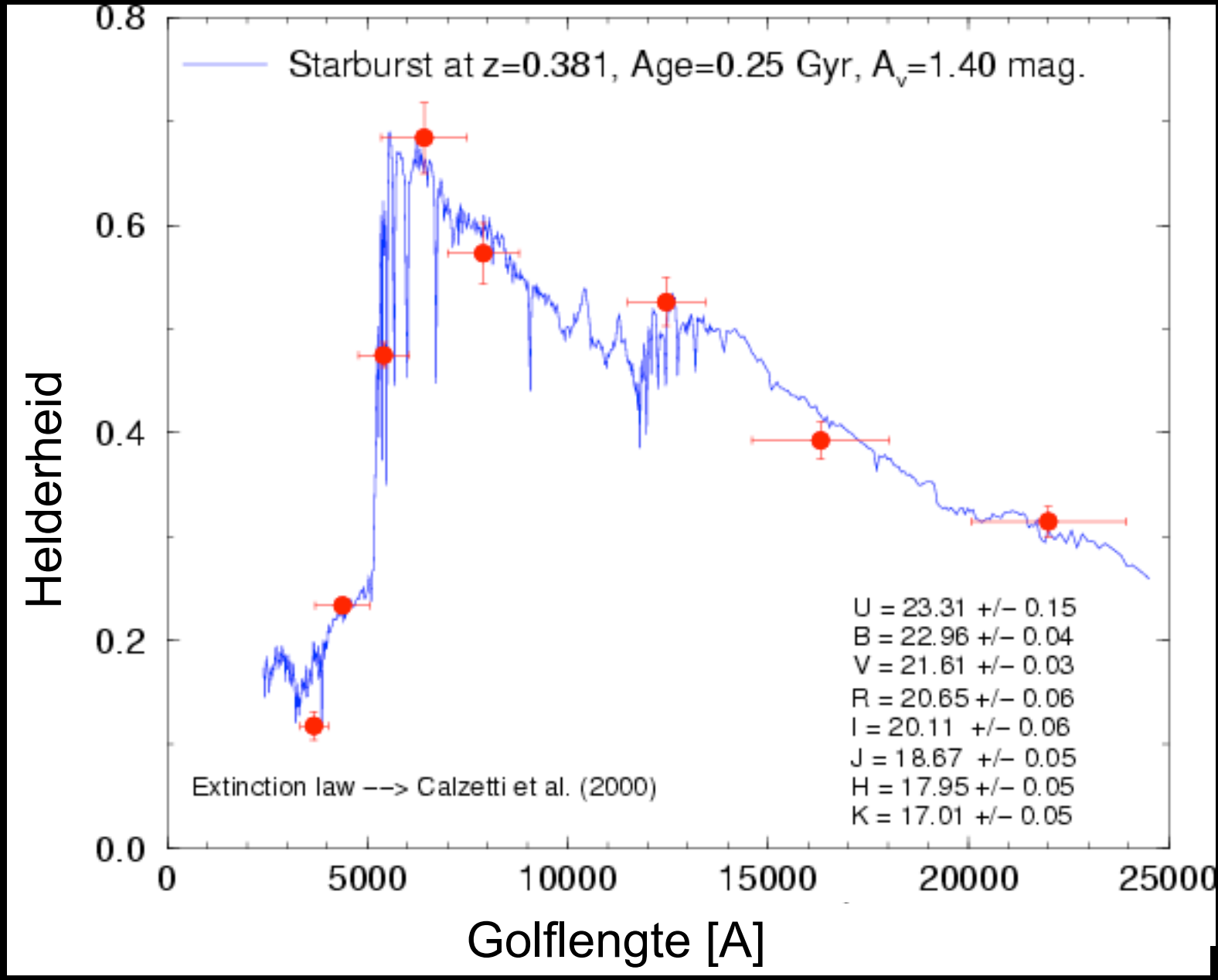


Massa van sterrenstelsels



Meet hoeveelheid licht met filters

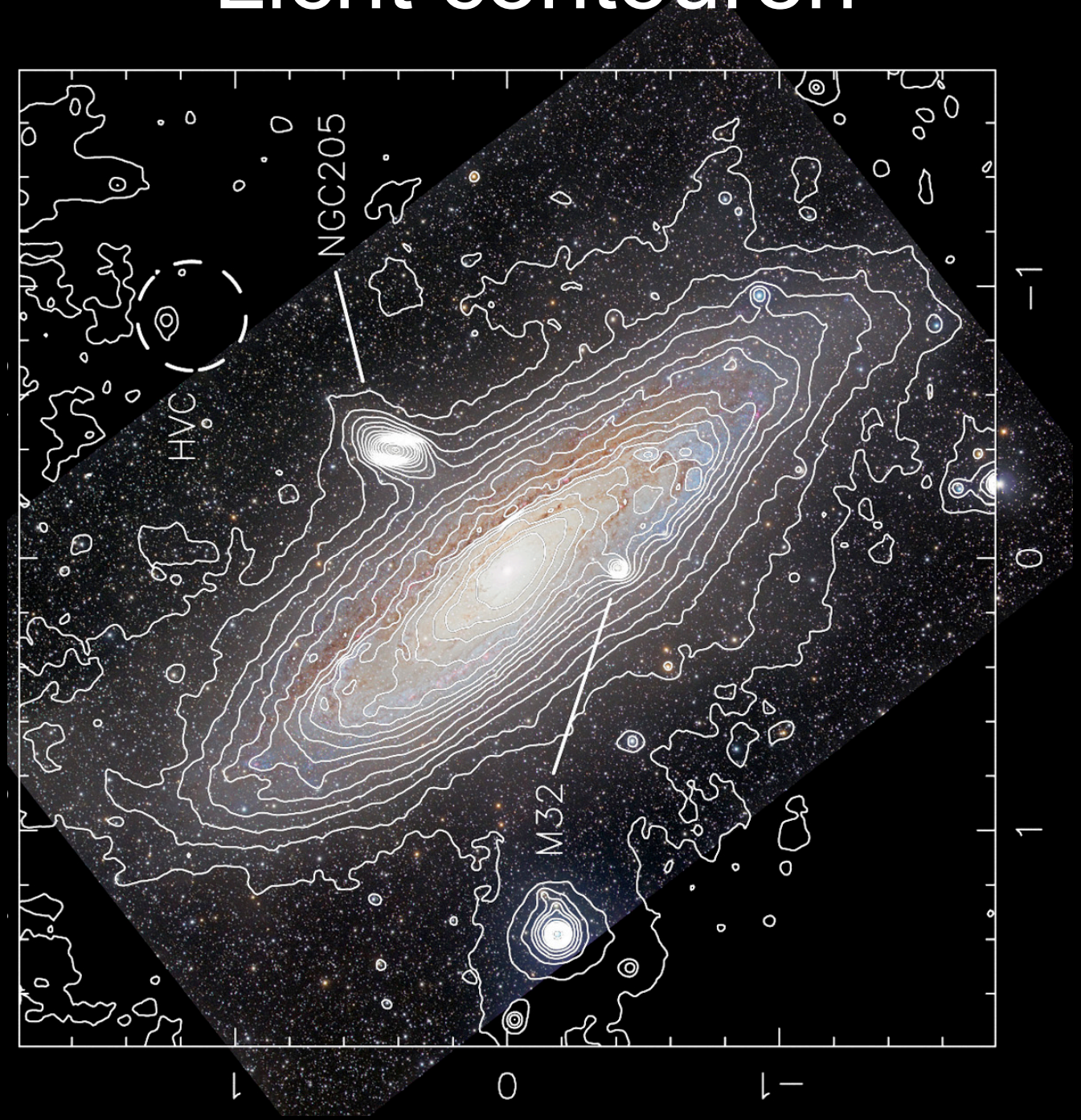
Weeg licht met IMF


Starburst at z=0.381, Age=0.25 Gyr, A$_v$=1.40 mag.
U = 23.31 +/– 0.15
B = 22.96 +/– 0.04
V = 21.61 +/– 0.03
R = 20.65 +/– 0.06
I = 20.11 +/– 0.06
J = 18.67 +/– 0.05
H = 17.95 +/– 0.05
K = 17.01 +/– 0.05
Extinction law –> Calzetti et al. (2000)
Helderheid
Golflengte [A]
0.0
0.2
0.4
0.6
0.8
0
5000
10000
15000
20000
25000

Hoe groot zijn sterrenstelsels?

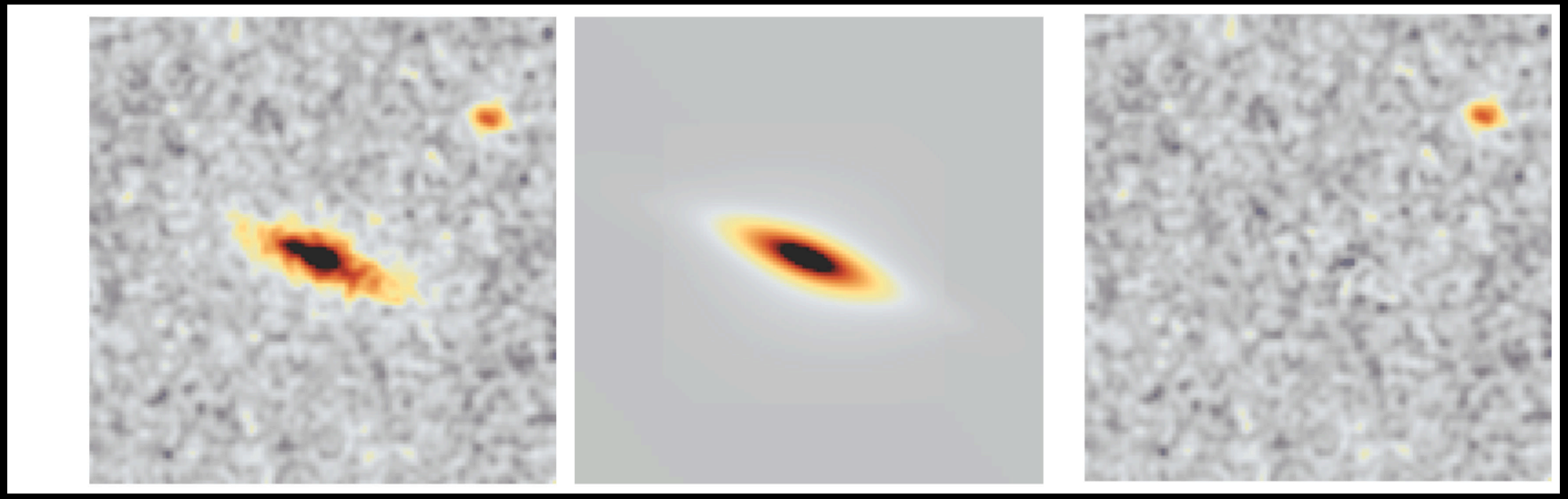
GEREEDSCHAP

Licht contouren



Sersic Licht Model

Sterrenstelsels - model = verschil

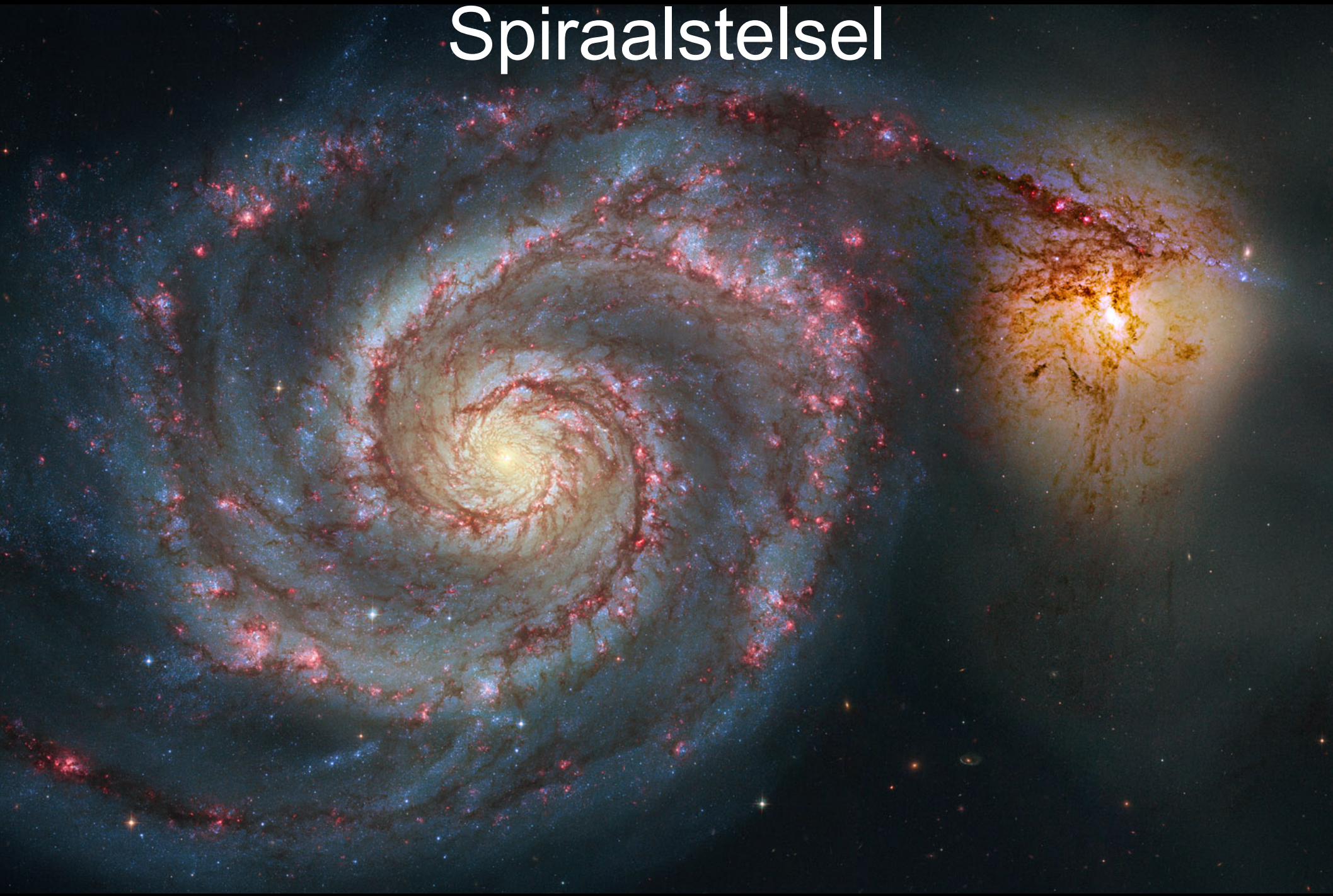


Model geeft: grootte, ellipticiteit, helderheid, …

Is onze melkweg uniek?

STERRENSTELSELS DICHTBIJ

Spiraalstelsel



Balkstelsel



Elliptisch Stelsel



Onregelmatige Stelsels



Hubble's Stemvork: Evolutie?

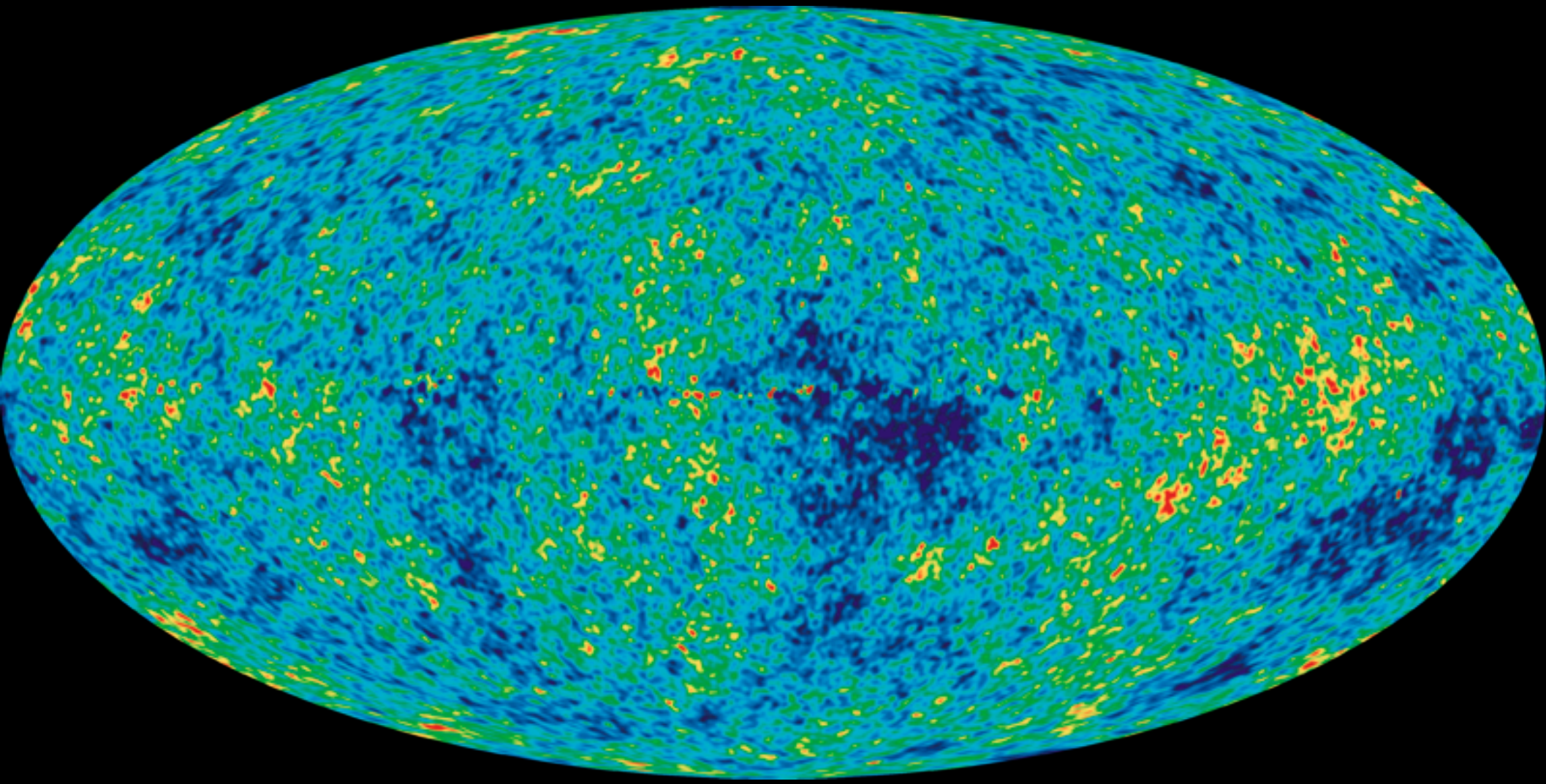


Hoe is de melkweg ontstaan?

VORMING VAN STERRENSTELSELS

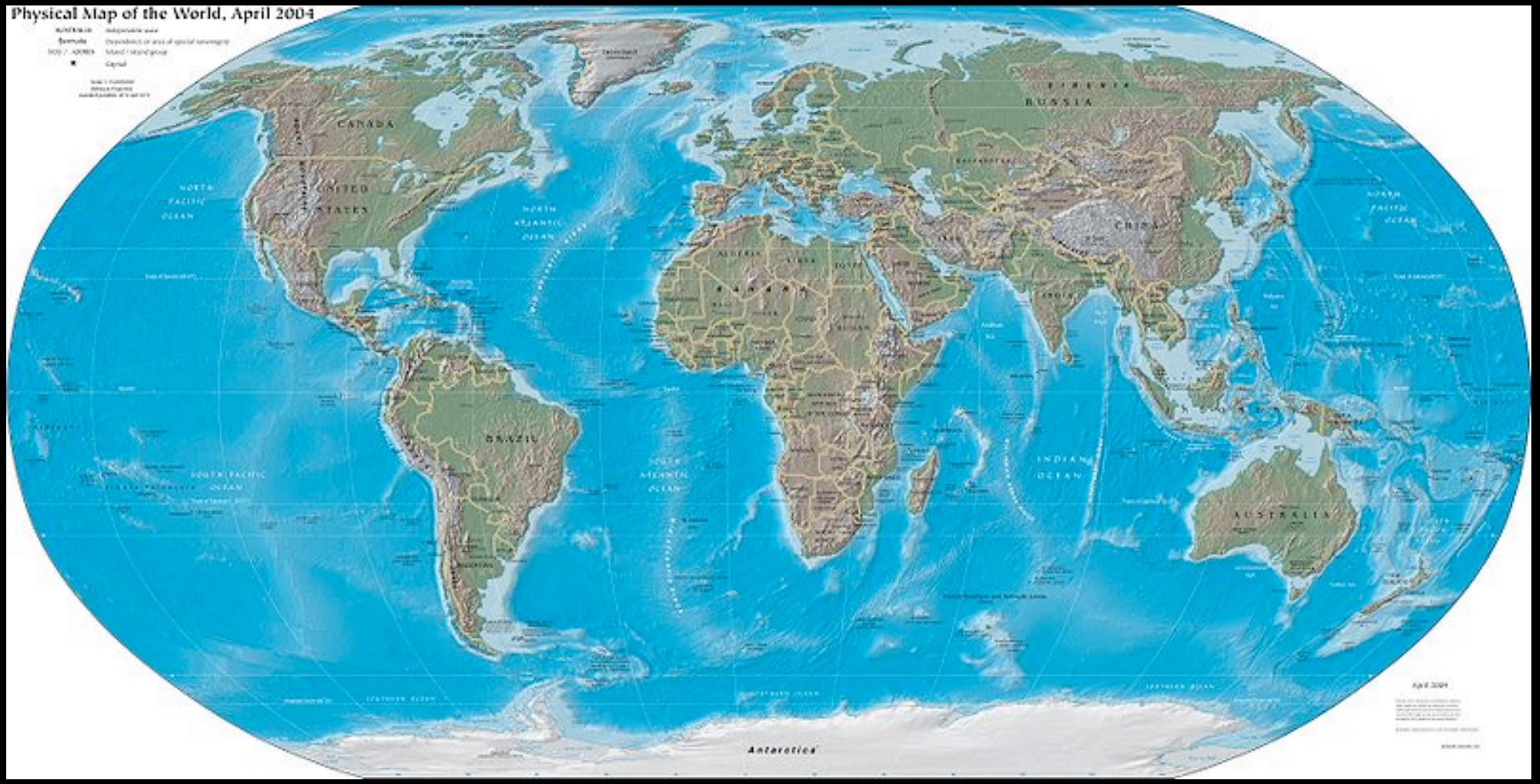
Oerknal

Kaart van het Heelal



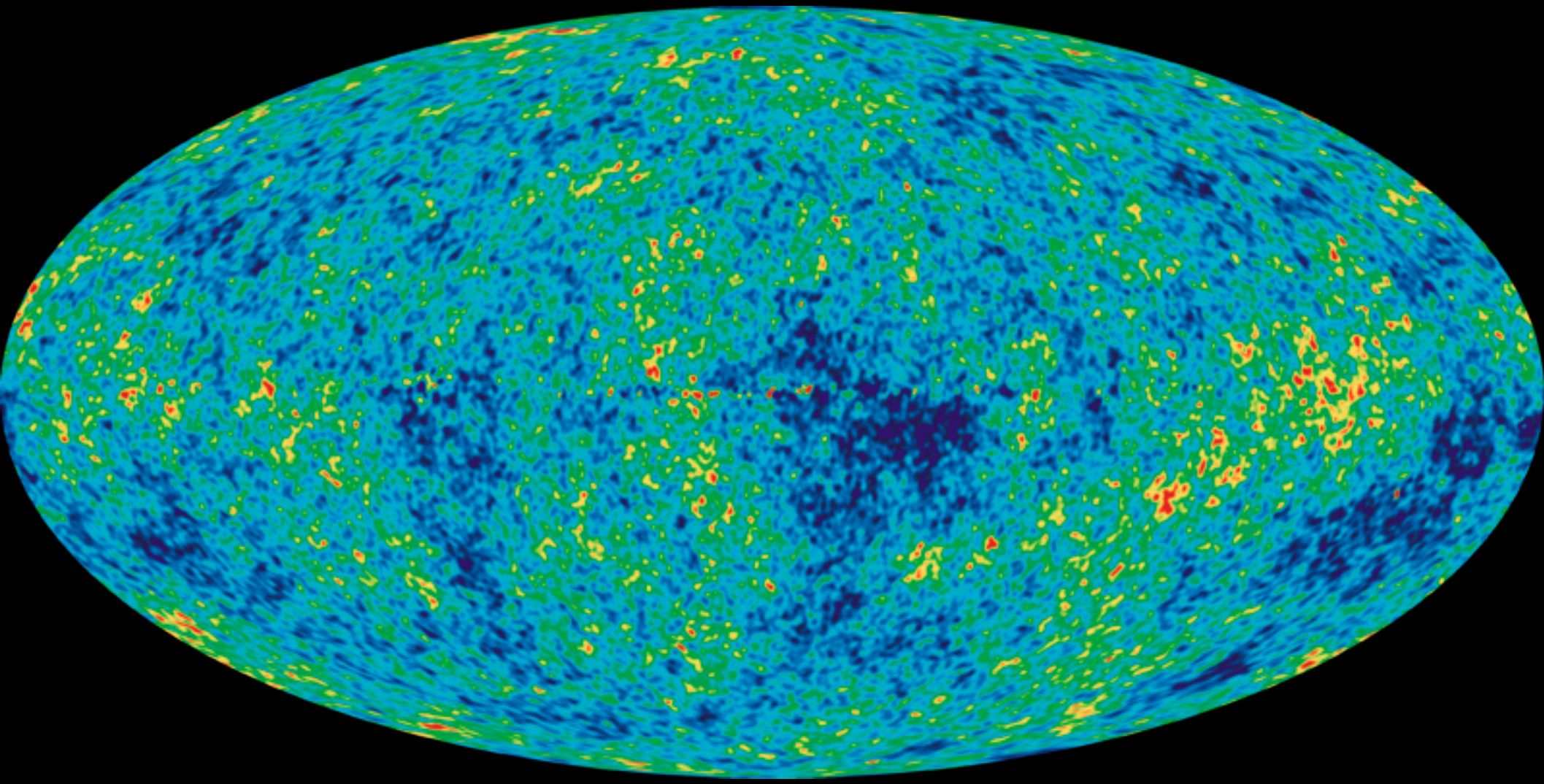
kosmische achtergrond straling

Kaart van het Heelal



Allereerste licht

300 000 jaar na de oerknal

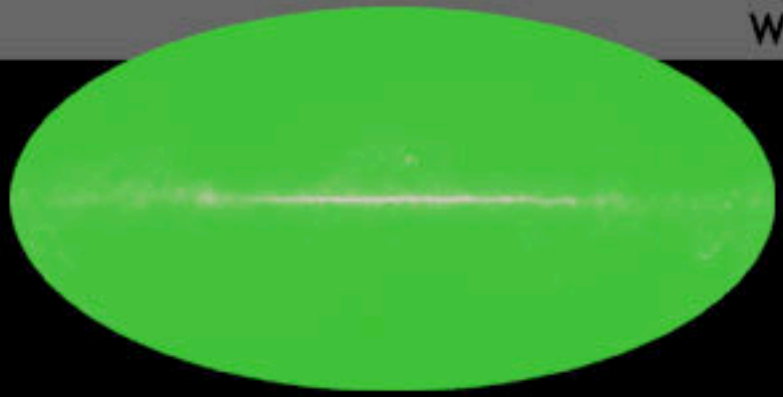


kosmische achtergrond straling

1965

Penzias and Wilson

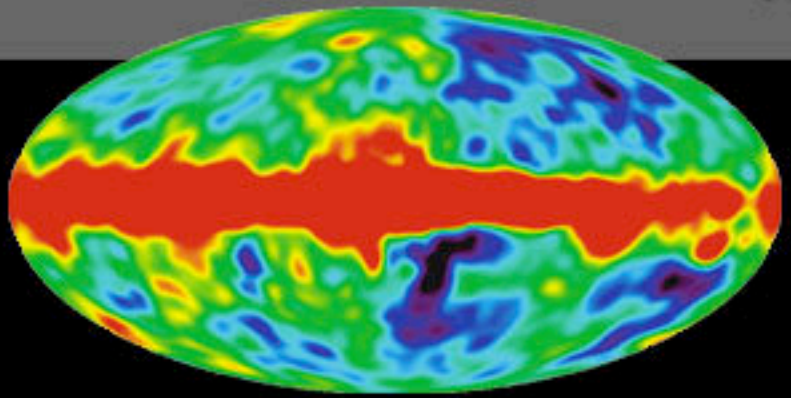




1992

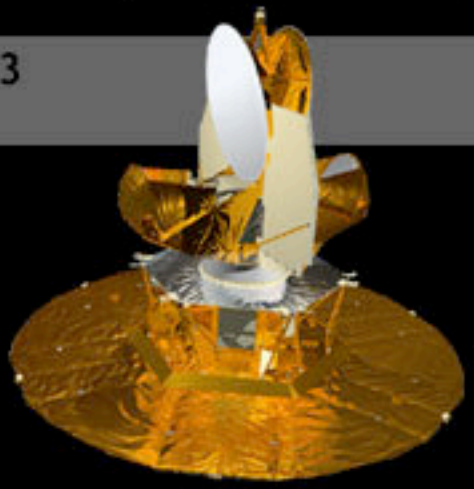
COBE

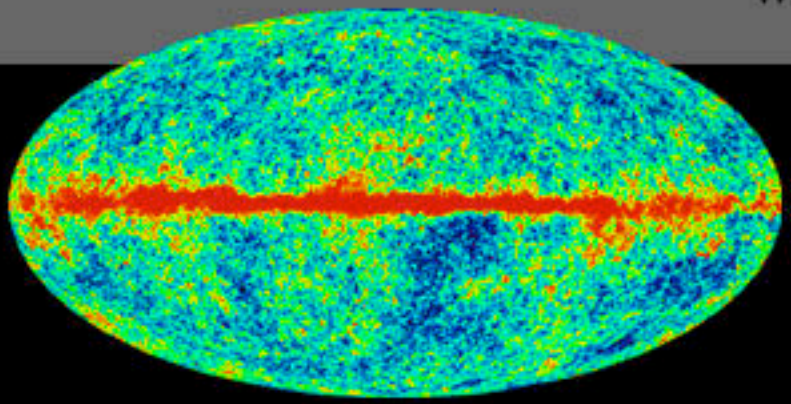




2003

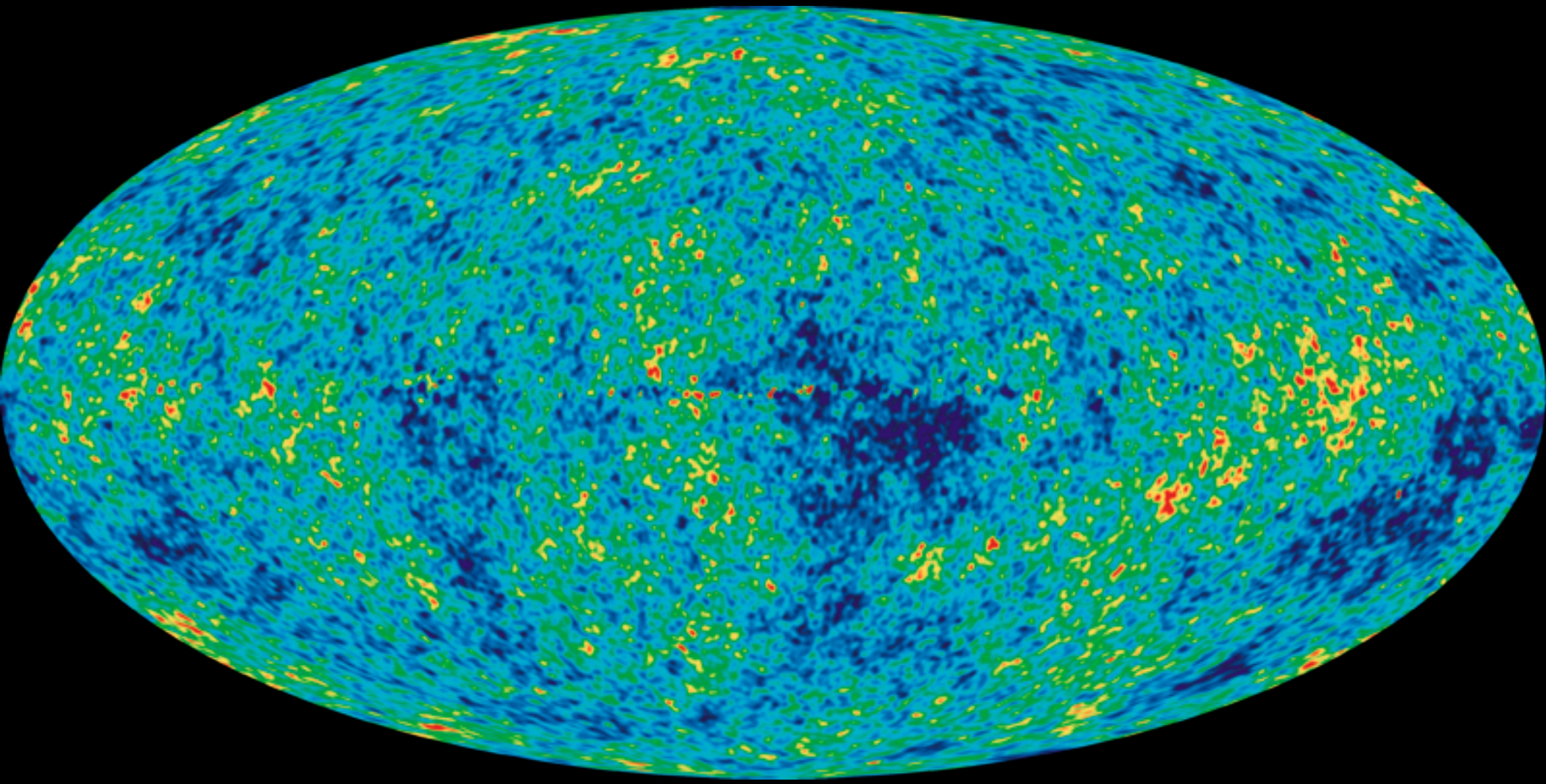
WMAP

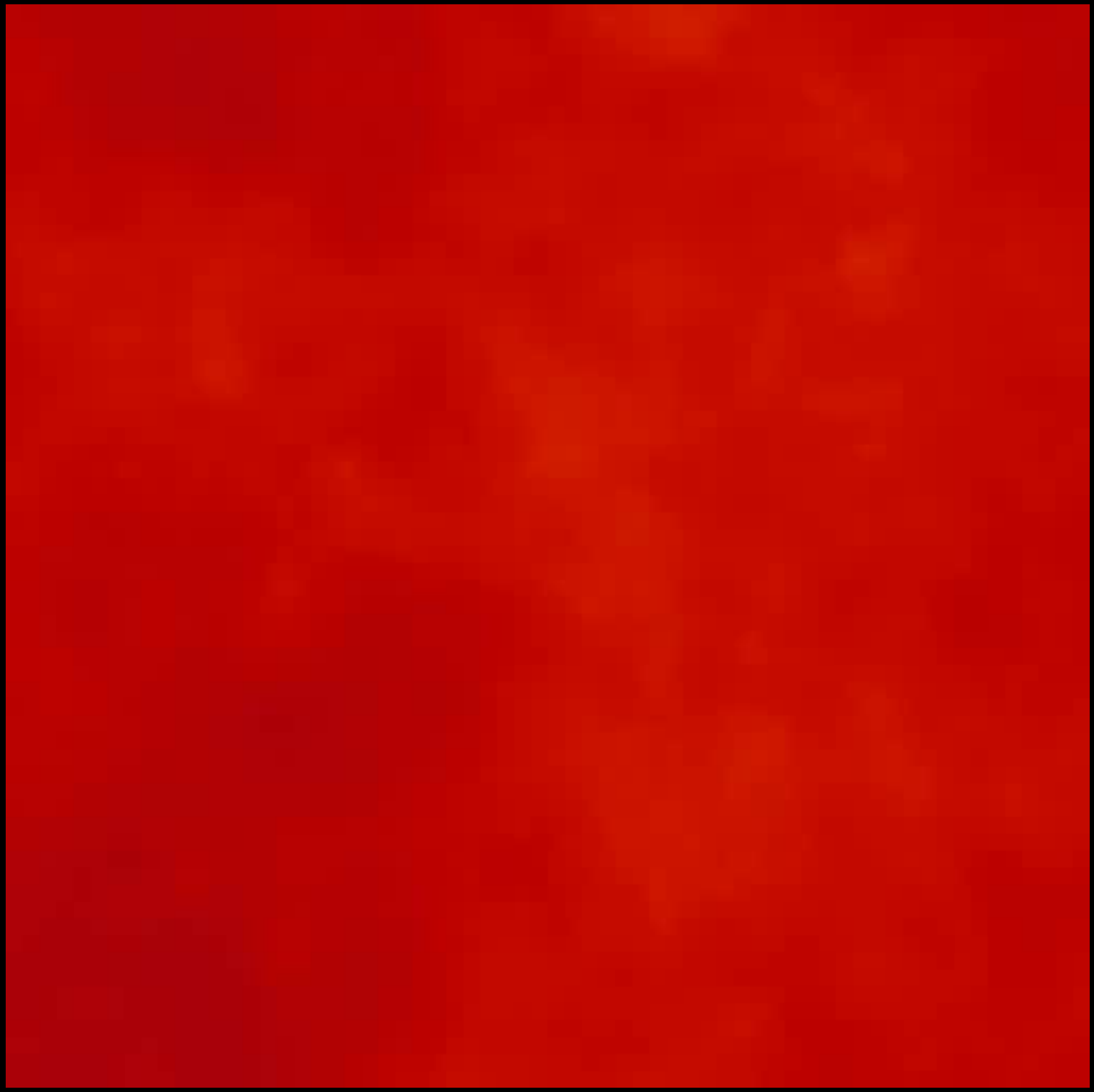




Dichtheid fluctuaties

groeien uit tot sterrenstelsels

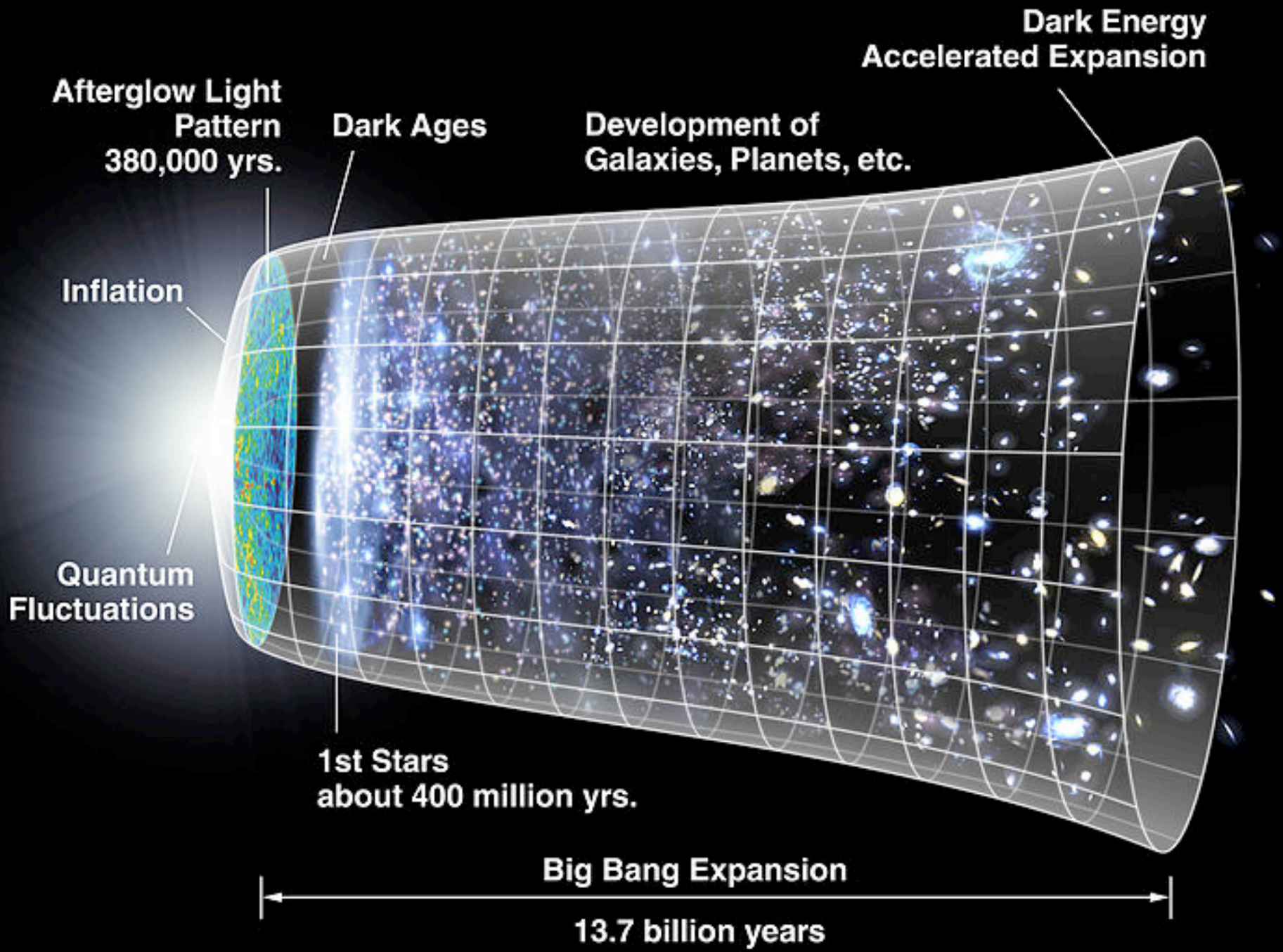




Simulatie van het Heelal

Dichtheid fluctuaties groeien uit tot sterrenstelsels

Tijdlijn


Dark Energy
Accelerated Expansion
Afterglow Light
Pattern
380,000 yrs.
Dark Ages
Development of
Galaxies, Planets, etc.
Inflation
Quantum
Fluctuations
1st Stars
about 400 million yrs.
Big Bang Expansion
13.7 billion years

Is er bewijs voor deze theorie?

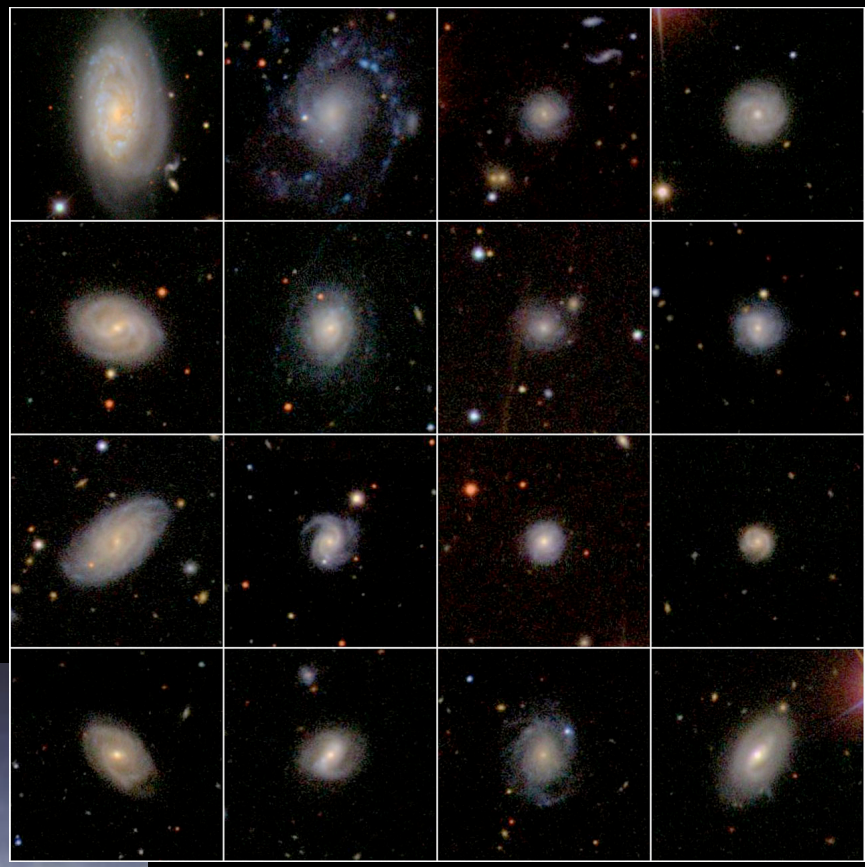
HET ECHTE HEELAL

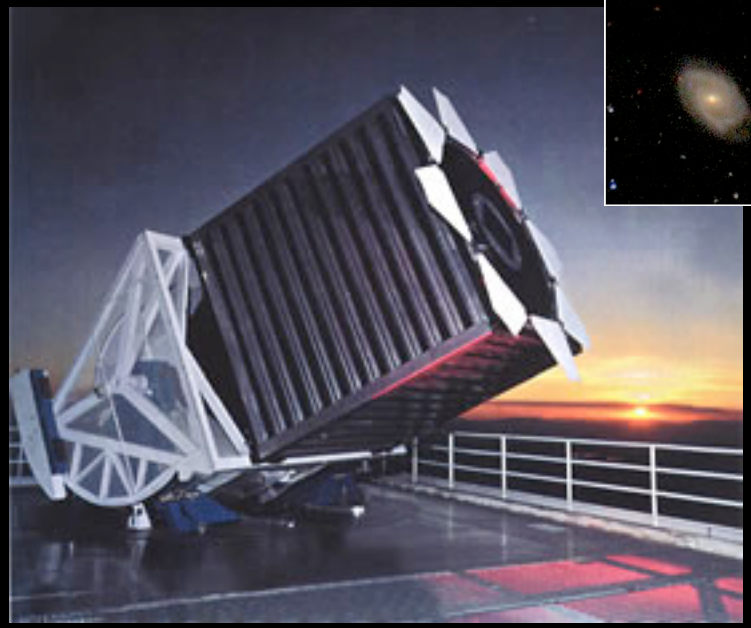
Sloan Digital Sky survey

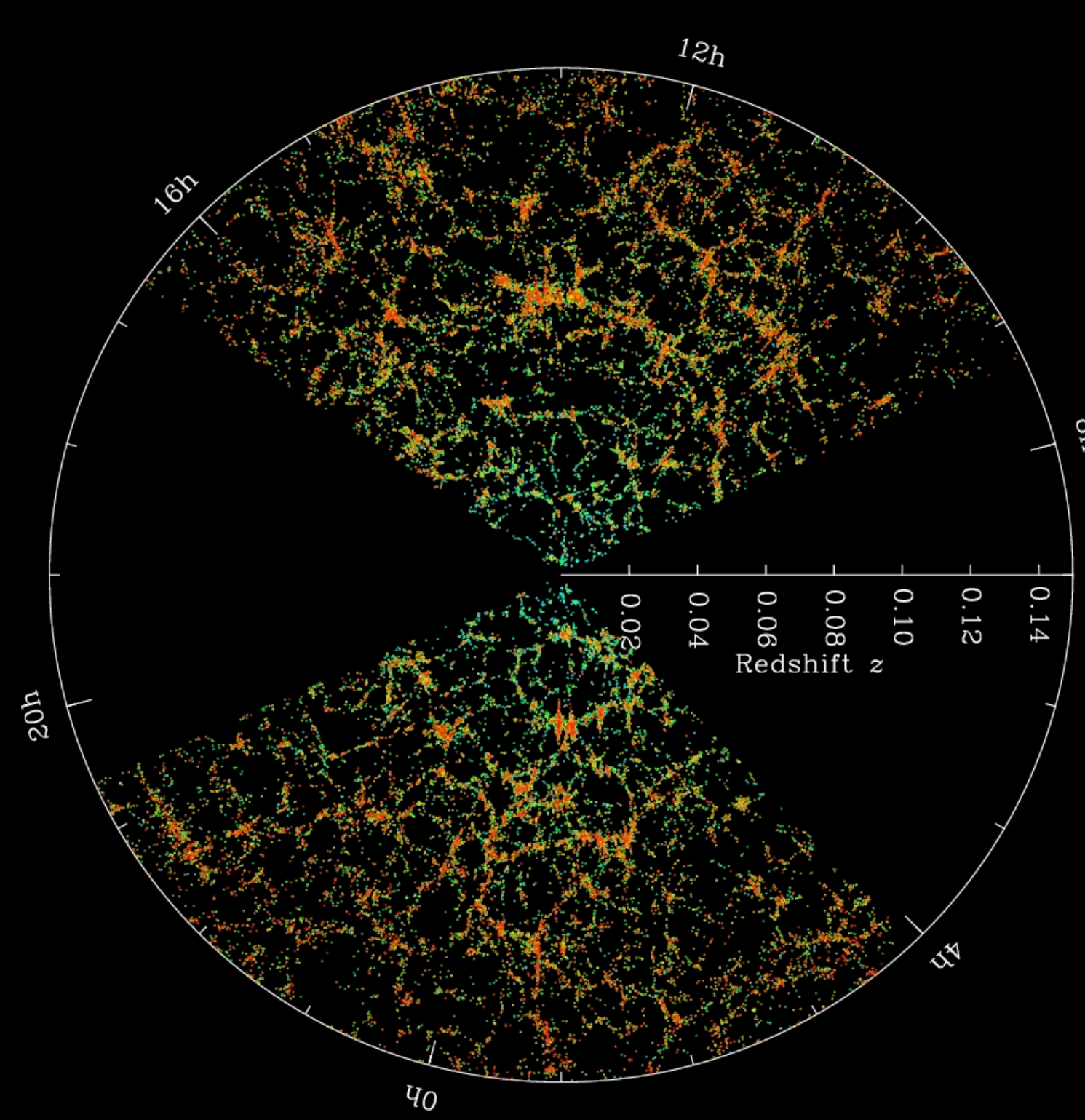
35% van de nachthemel geobserveerd

225,000 sterren

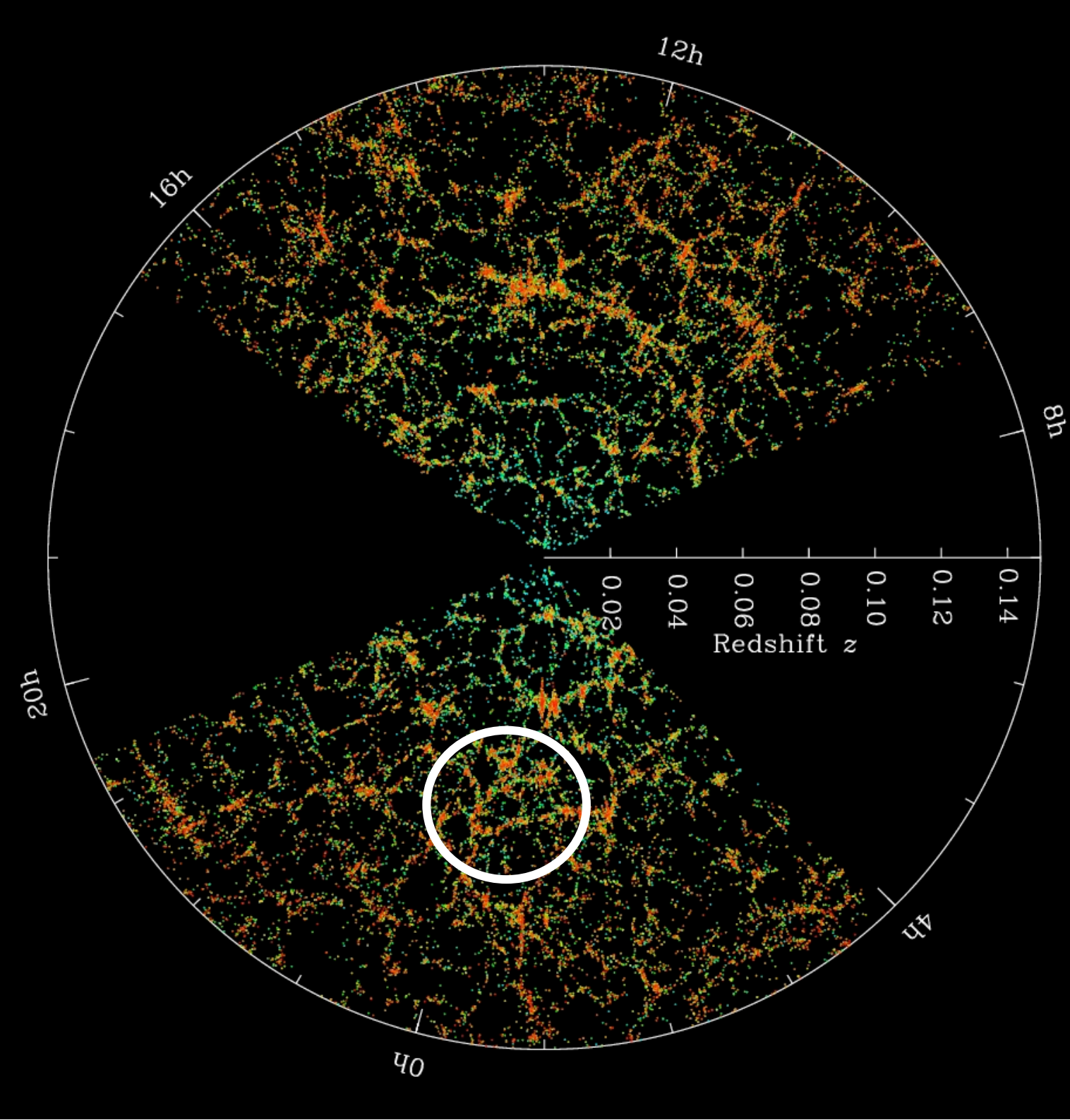
930,000 sterrenstelsels







Dichtheid fluctuaties

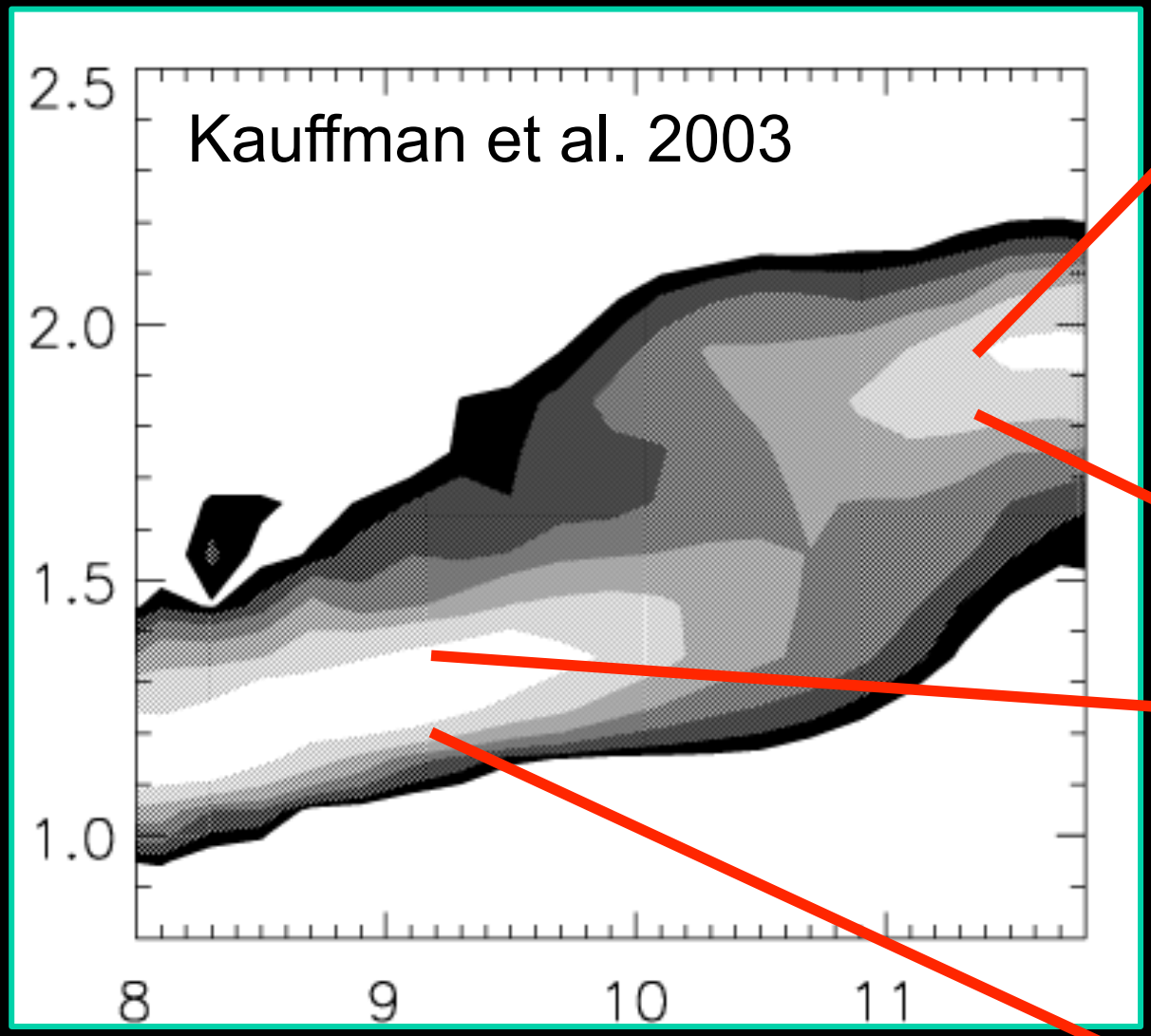


Dichtheid fluctuaties

Cluster van Sterrenstelsels



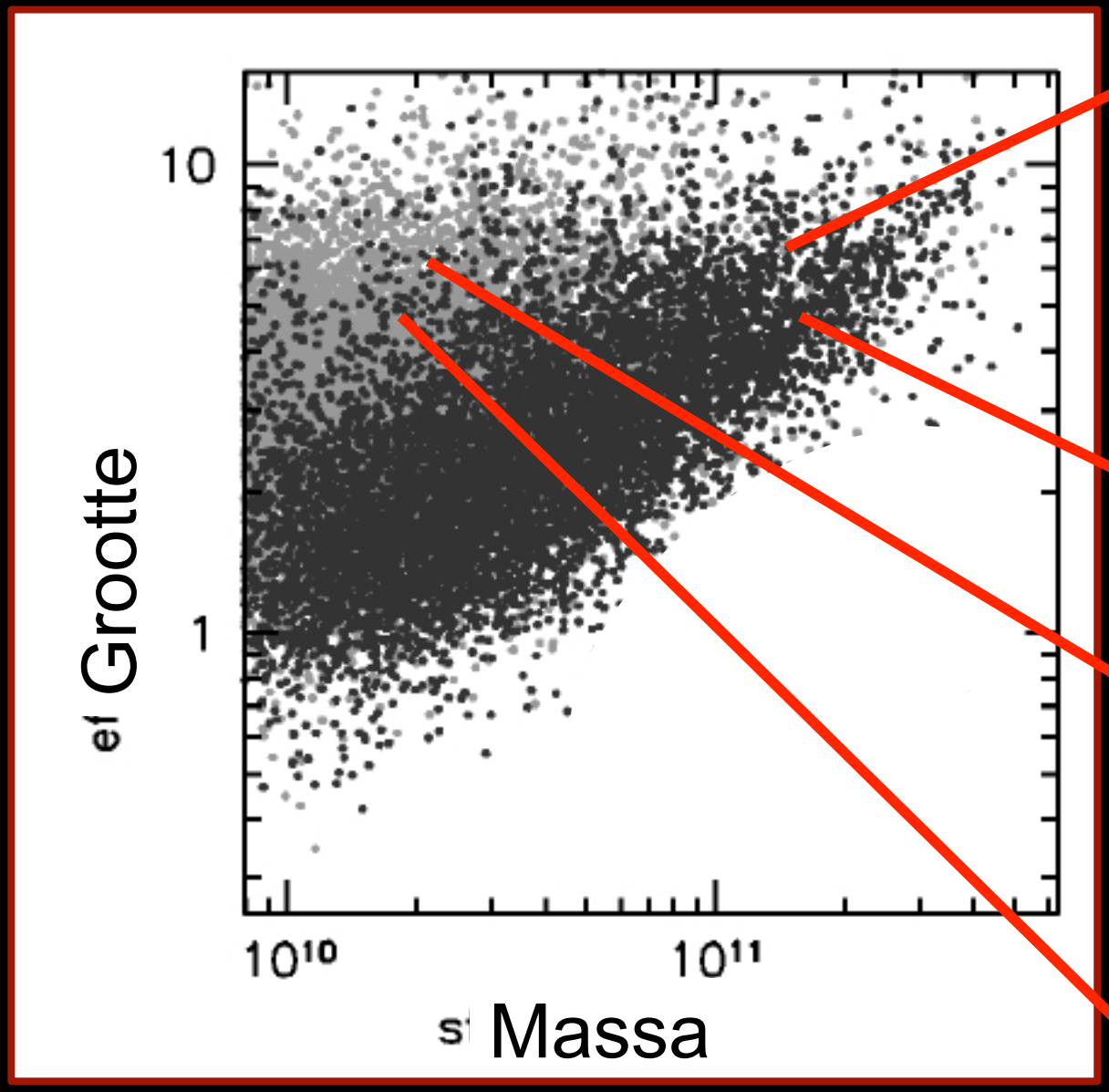
Eigenschappen van sterrenstelsels







Eigenschappen van sterrenstelsels









Elliptische Sterrenstelsels:

Massief en groot
Oude Sterren
(Rood en Dood)

Spiraal Sterrenstelsels:

Veel sterformatie uit gas
Jonge sterren in schijf
Oude sterren in kern



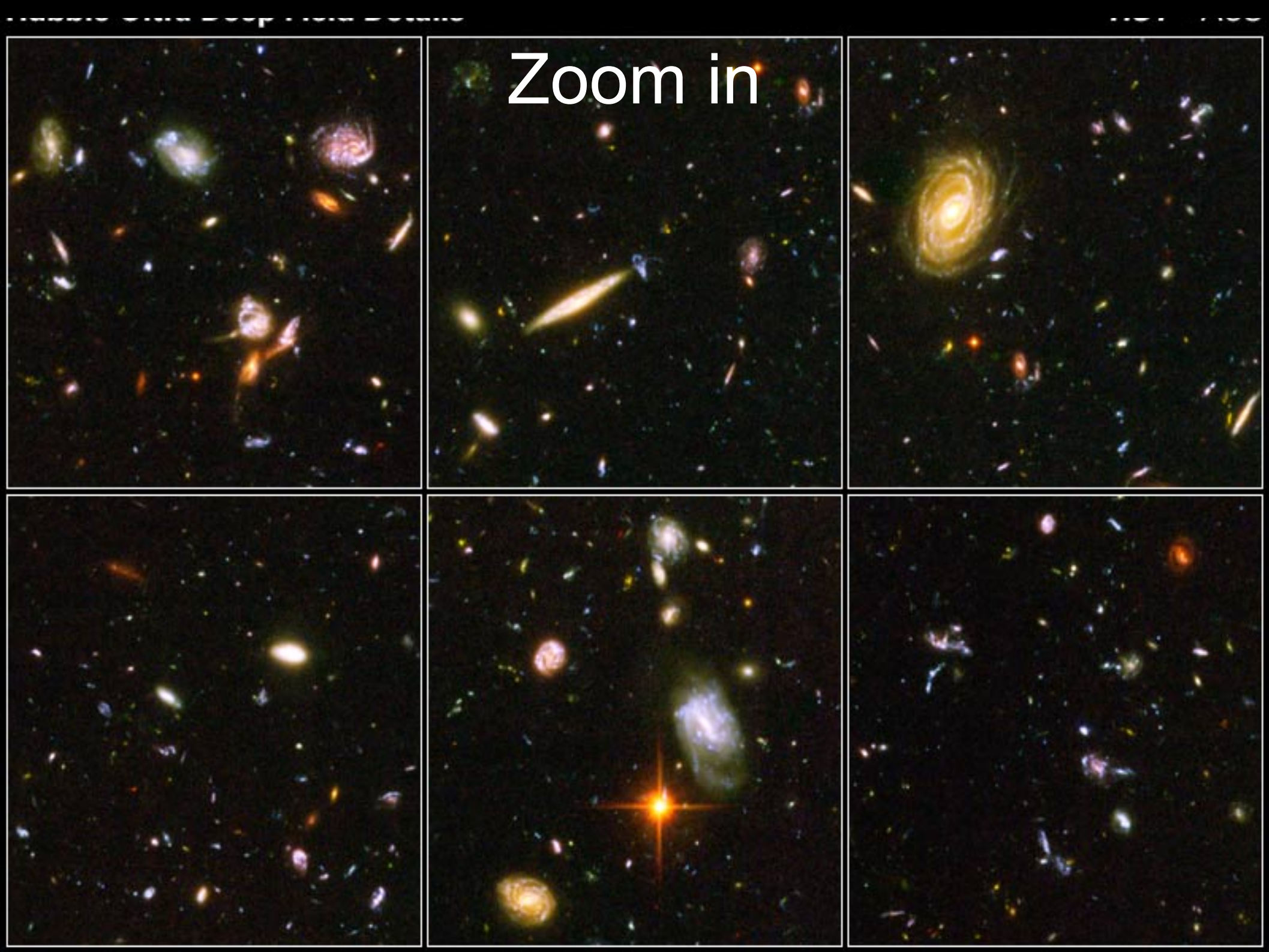
Hubble Space Telescope



The Hubble Ultra Deep field

- Diepste waarneming ooit!
- Miljoen seconden belichting (11.4 dagen)
- 10.000 sterrenstelsels

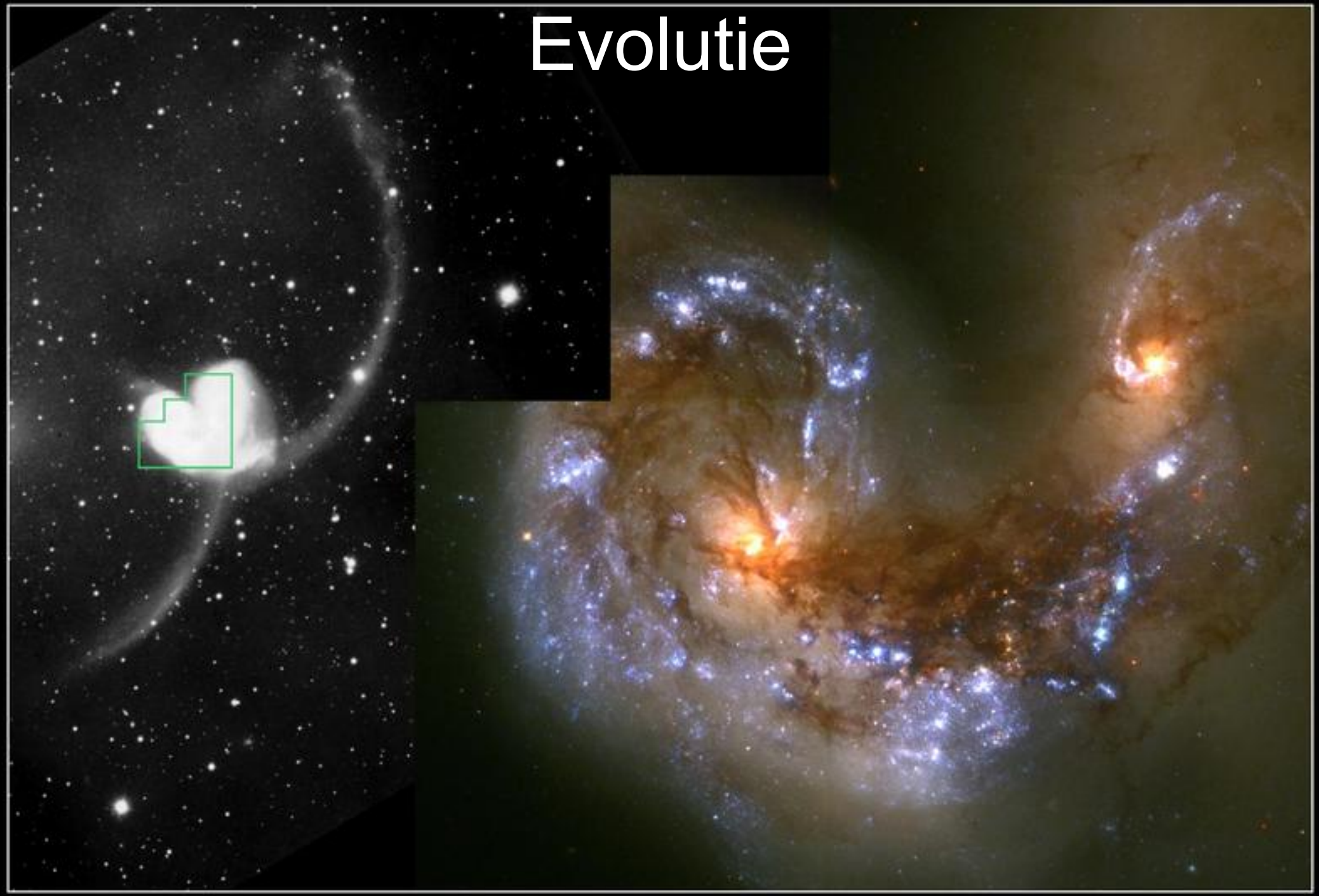

The Hubble Ultra Deep field


Zoom in

Hubble's Stemvork: Evolutie?

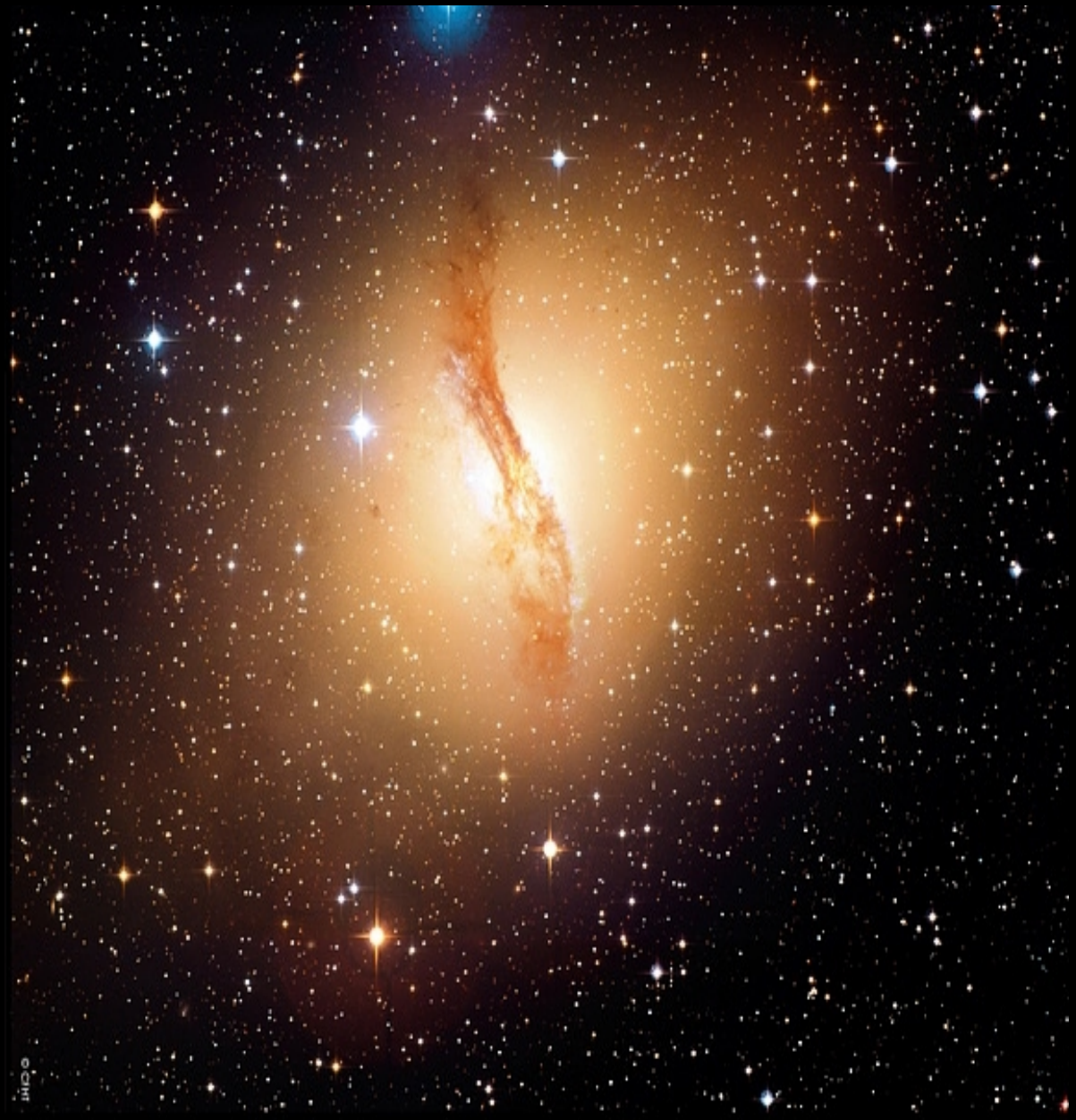


Evolutie



Botsende Sterrenstelsels

Restant





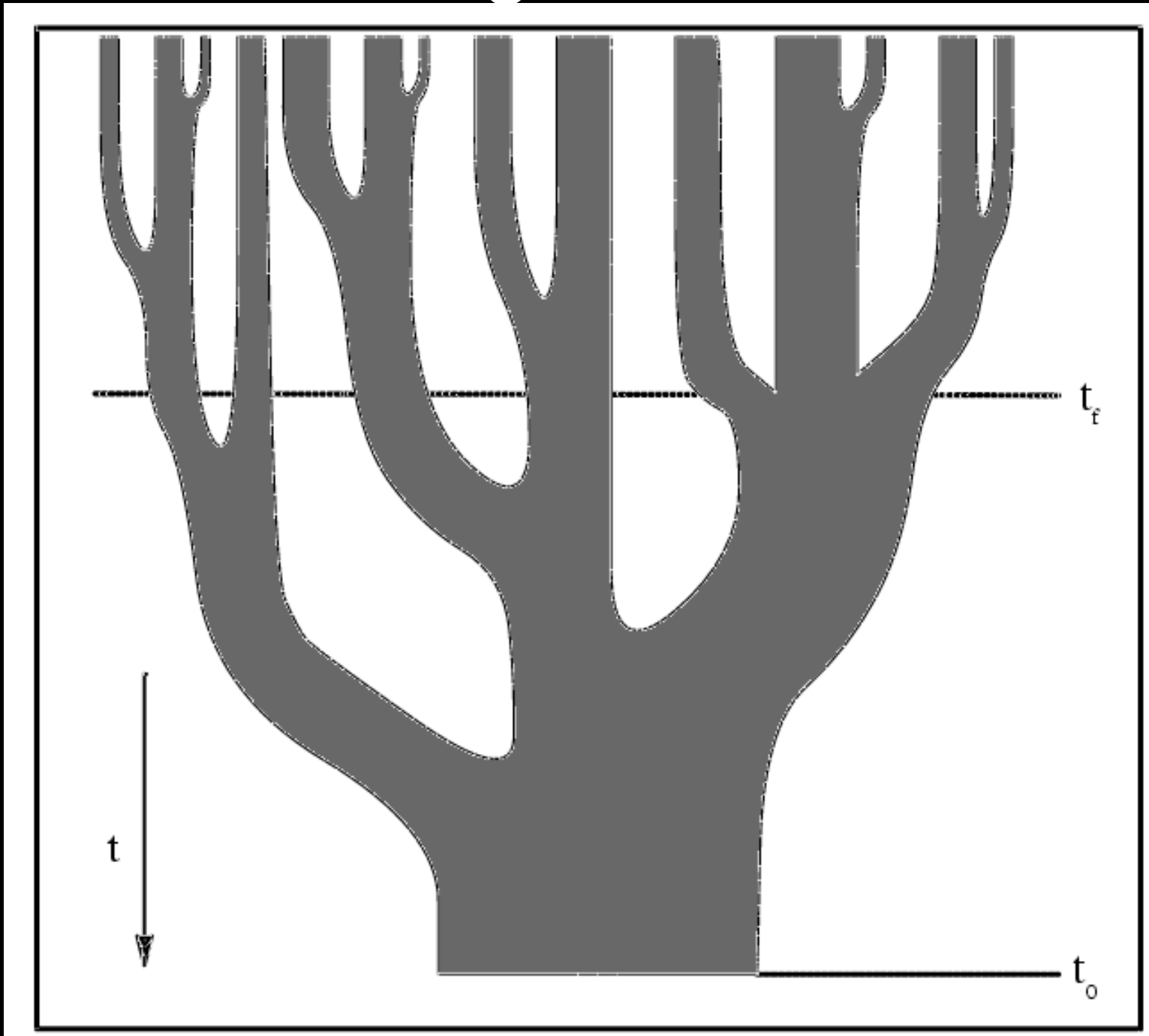
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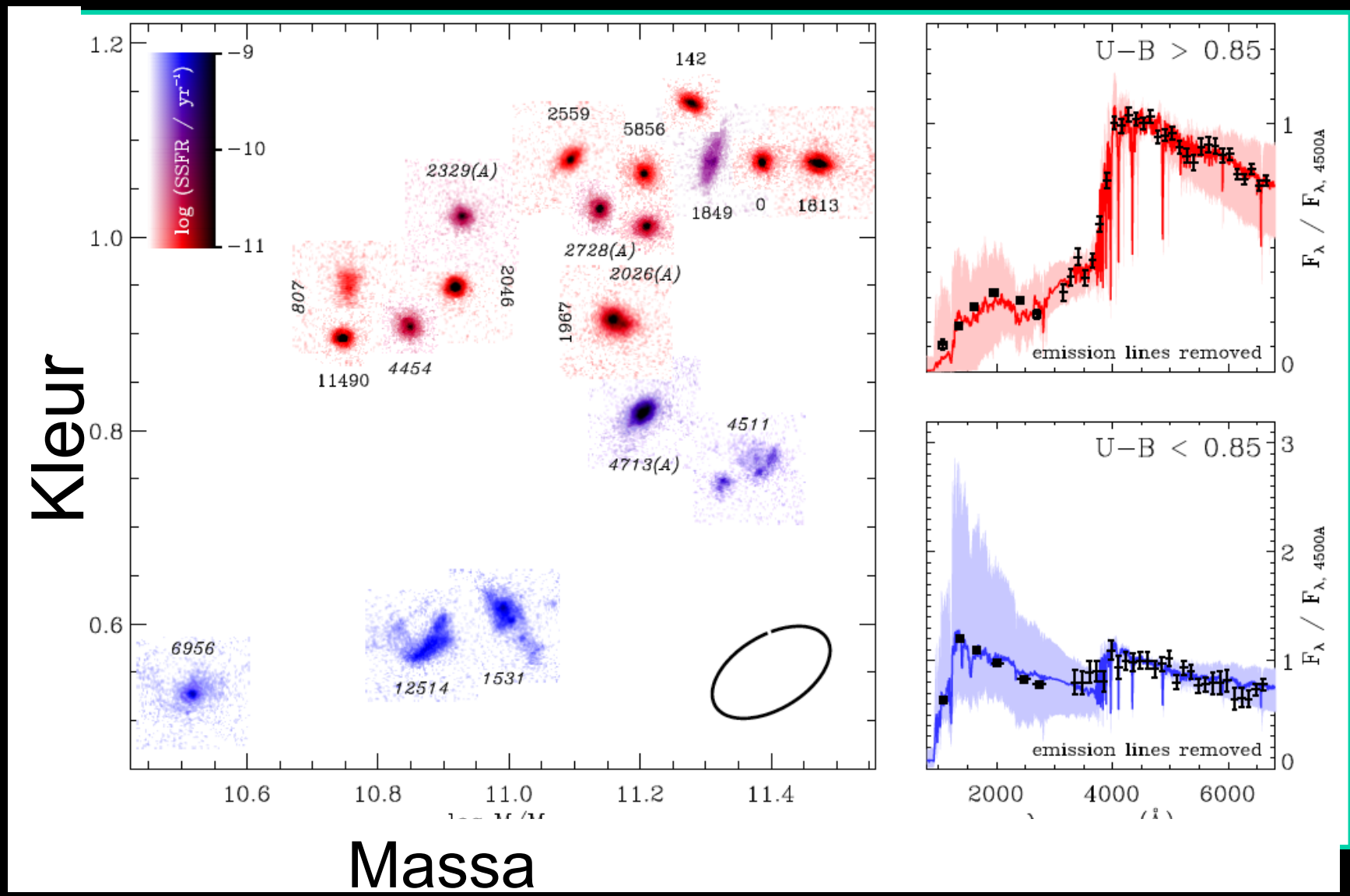
Merger Tree



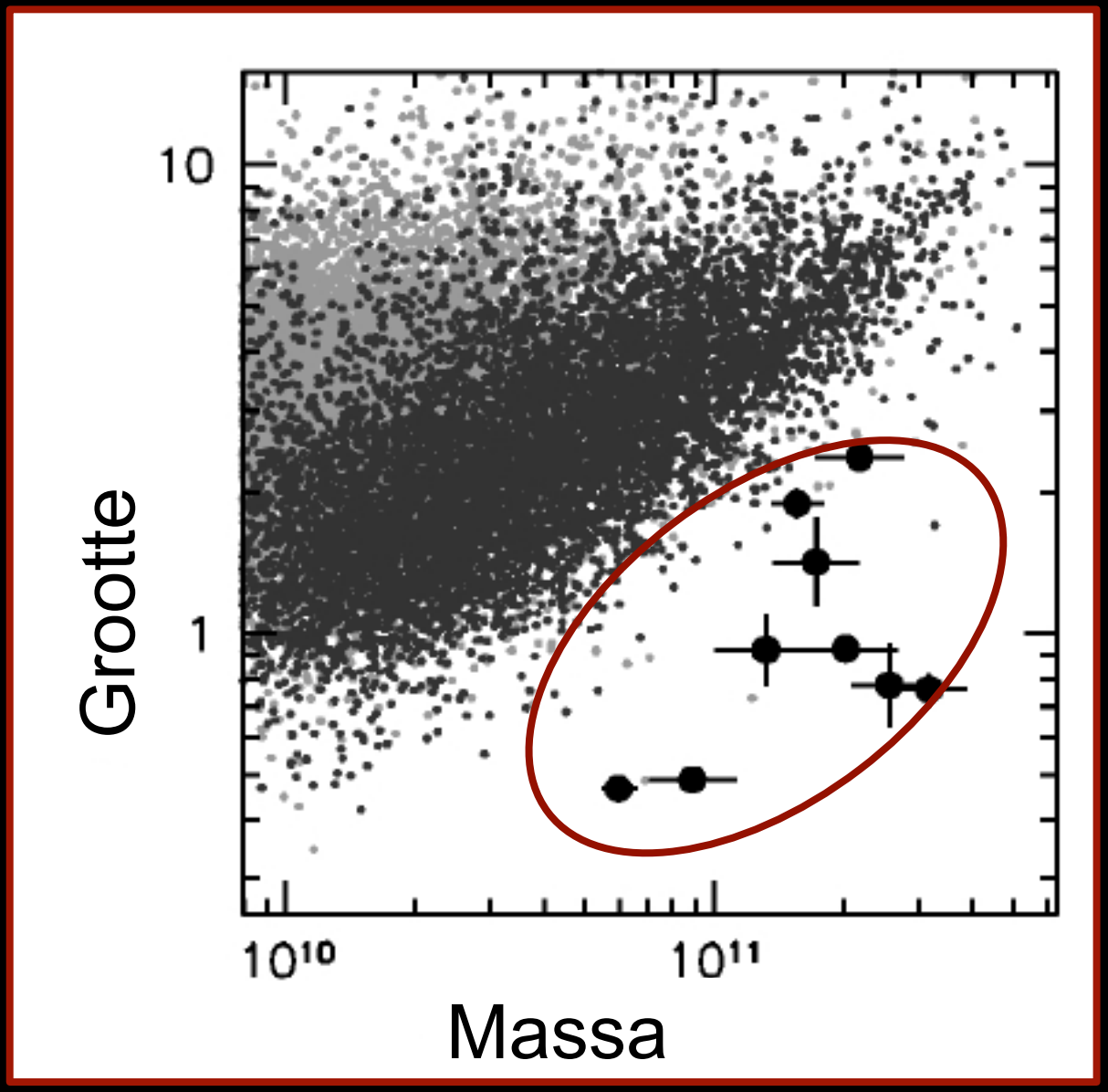
Speurtocht naar Elliptische Sterrenstelsels in het Jonge Heelal



Rood en Dood:
3 miljard jaar na de oerknal



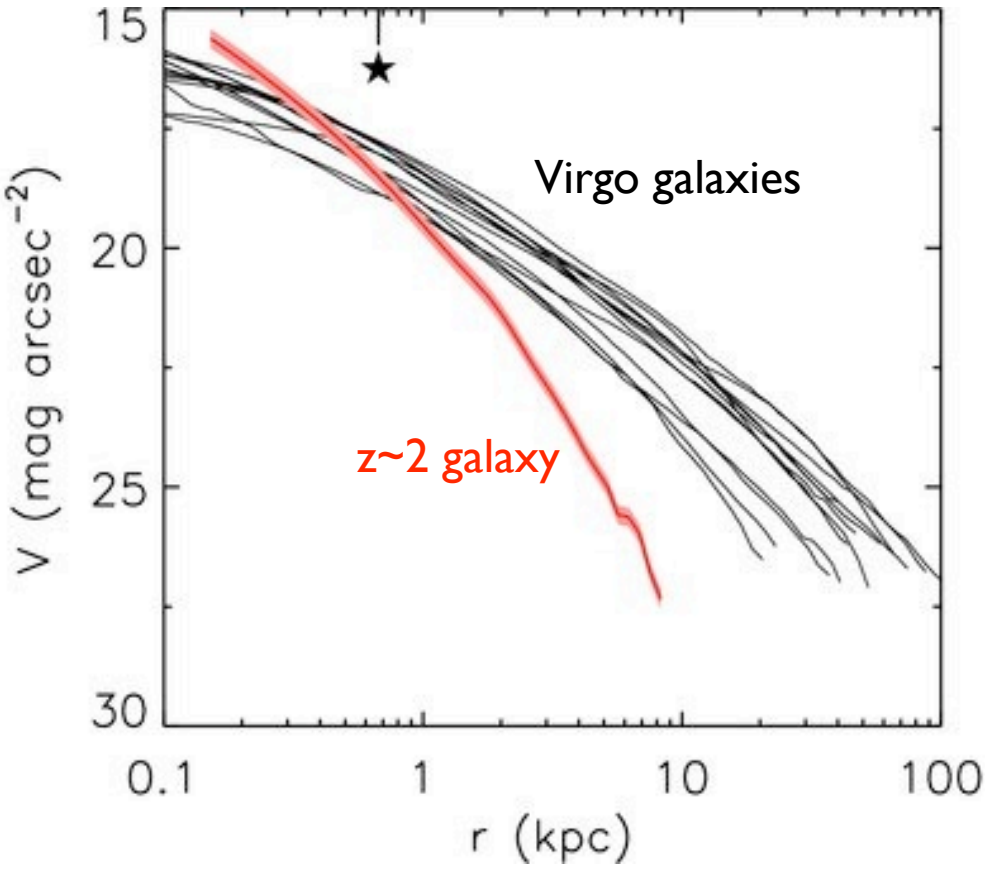
Eigenschappen van sterrenstelsels

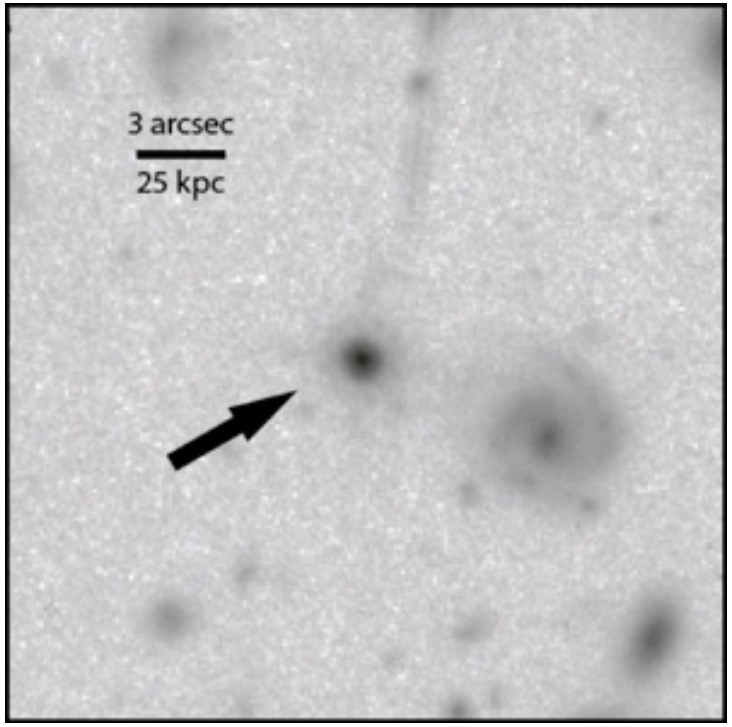


Rode dode stelsels in het jonge heelal veel kleiner dan gedacht

Groot probleem voor Huidige theorie!

Stelsels zijn echt klein!





Zijn de massa's correct?

Onzeker door :

Gebruik van alleen maar filters
Aannames over IMF
Massa berekening

Mijn onderzoek:
Meet dynamische massa

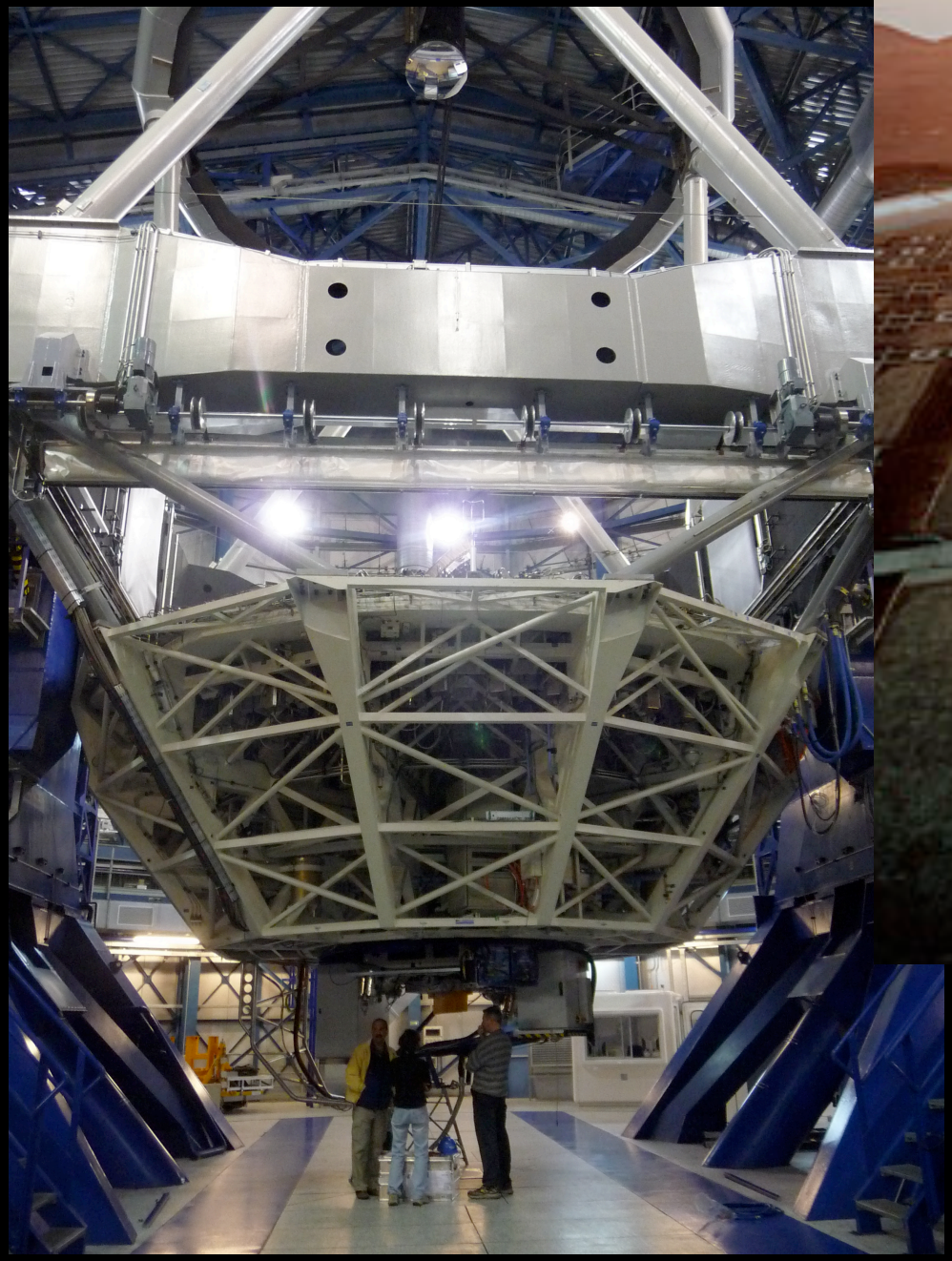
Dynamische Massa

Beweging van sterren in elliptische sterrenstelsels verbreden absorptie lijnen (dispersie)

$$M_{dyn} = K(n) \cdot r_e \cdot \sigma^2$$

Massa = constante * grootte * dispersie^2

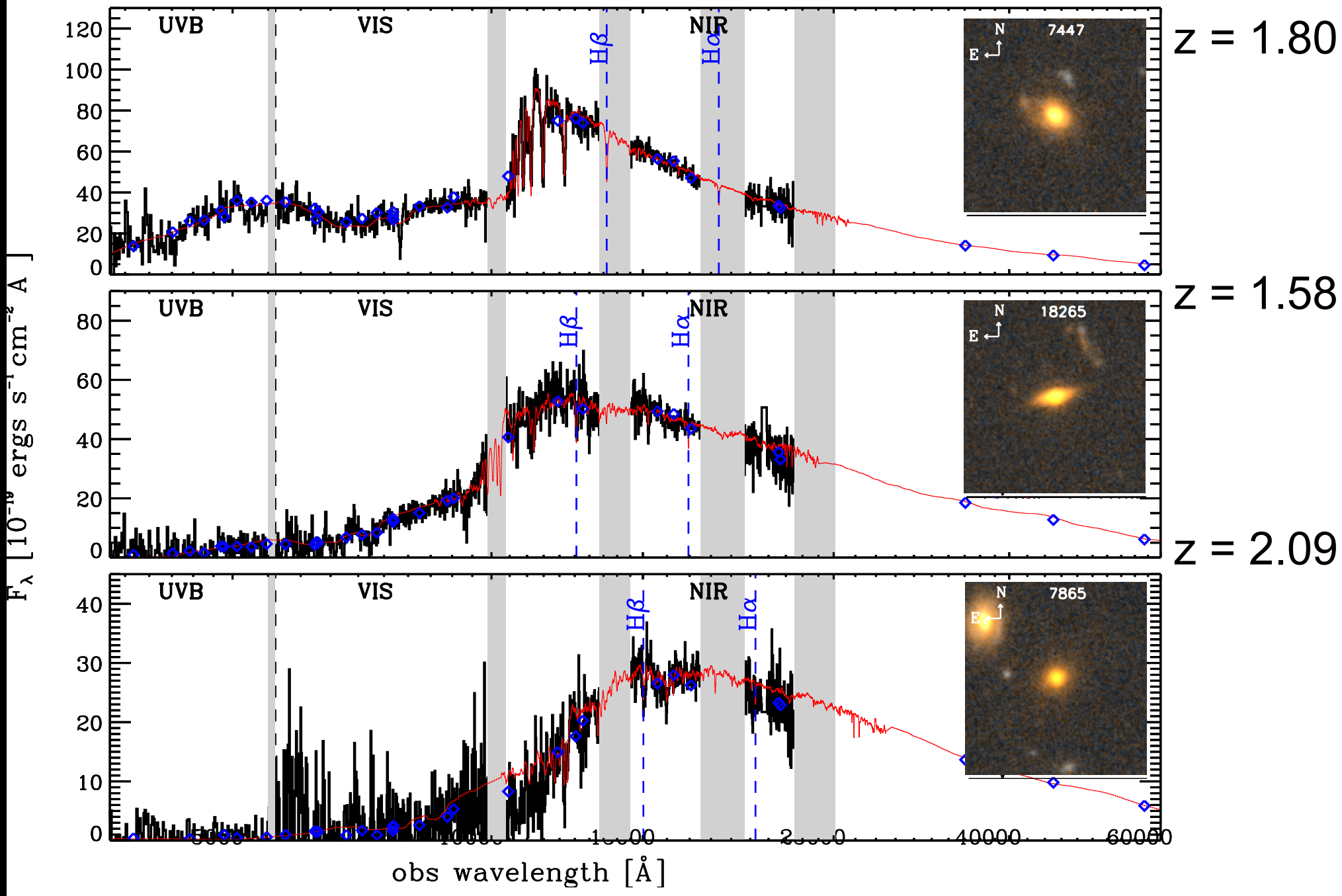
Very Large Telescope



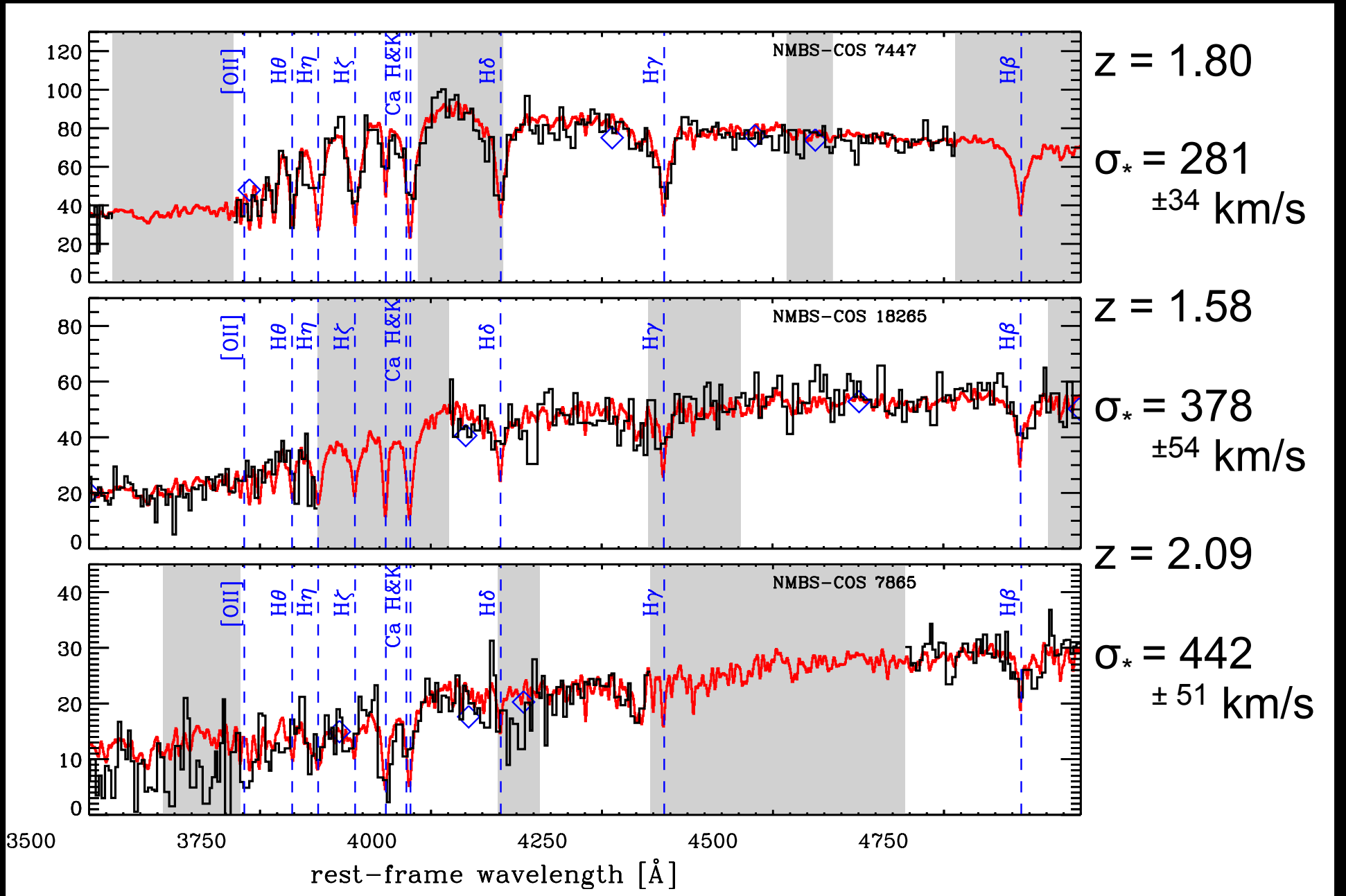


X-Shooter

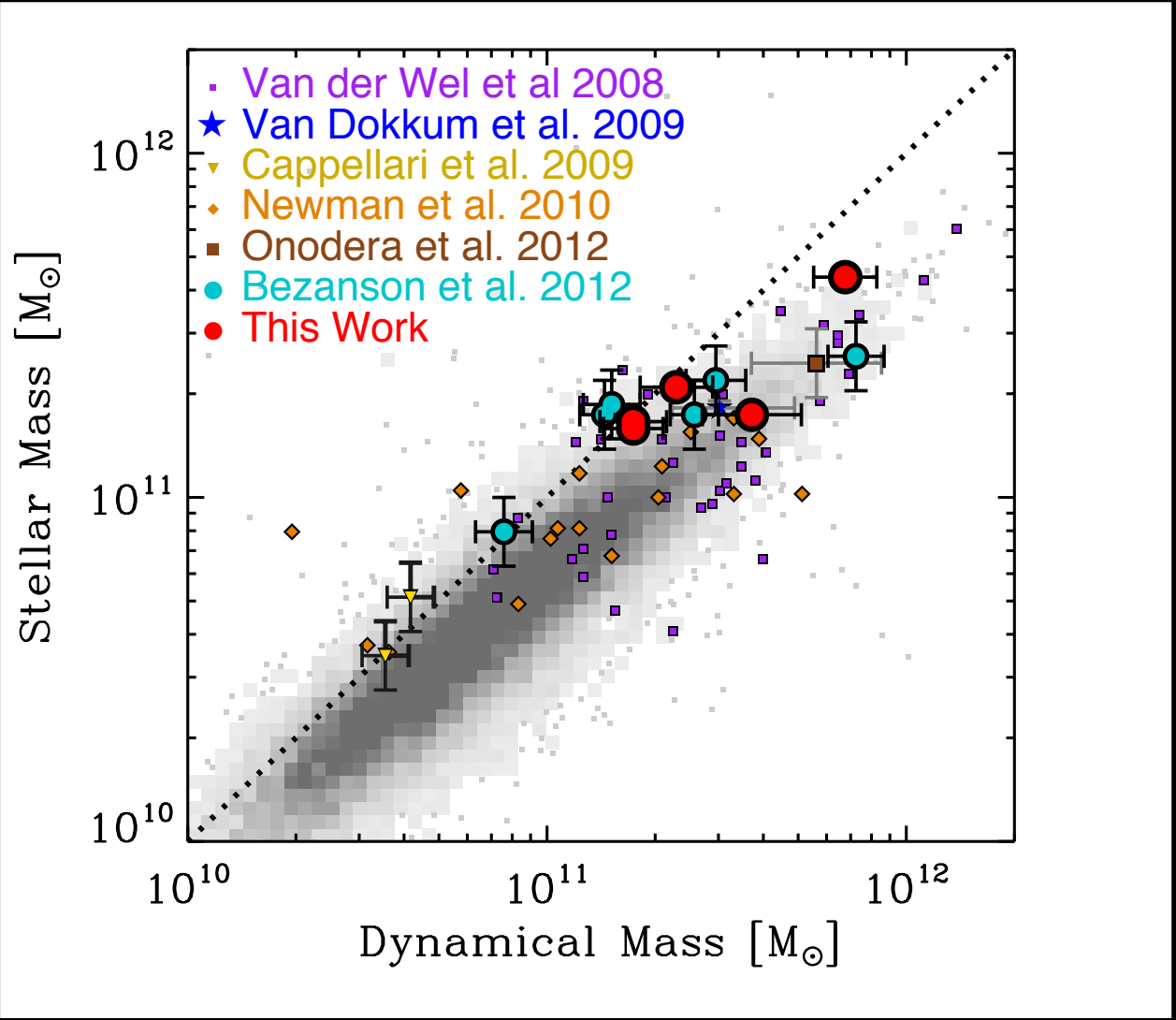
X-Shooter Spectra



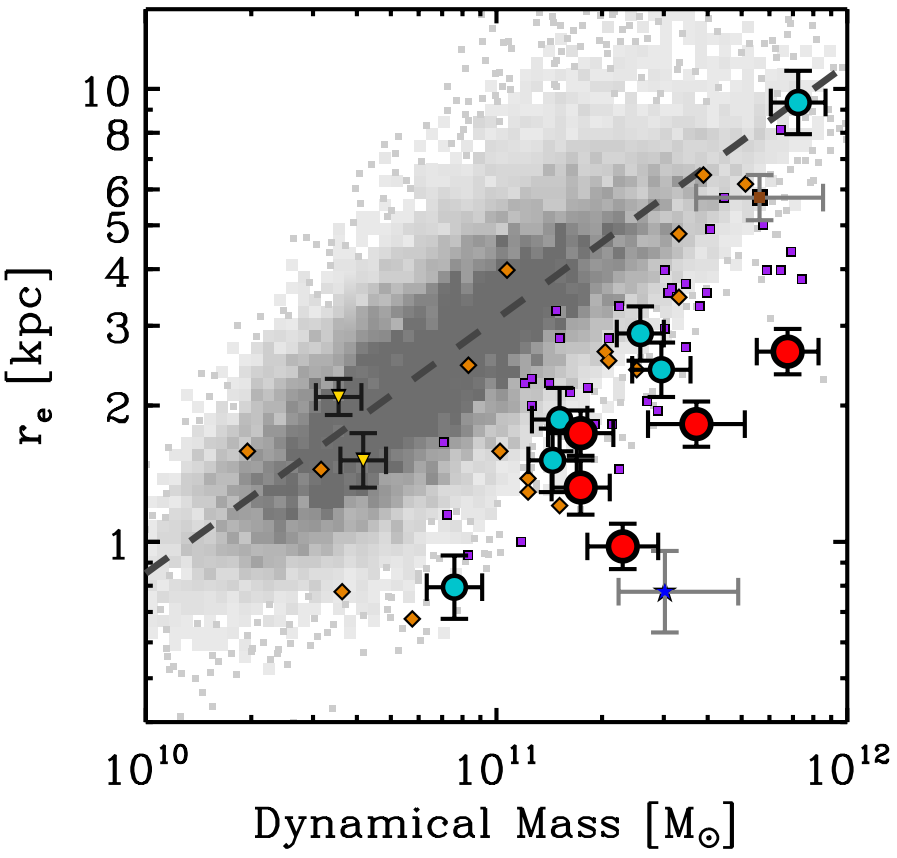
X-Shooter Spectra

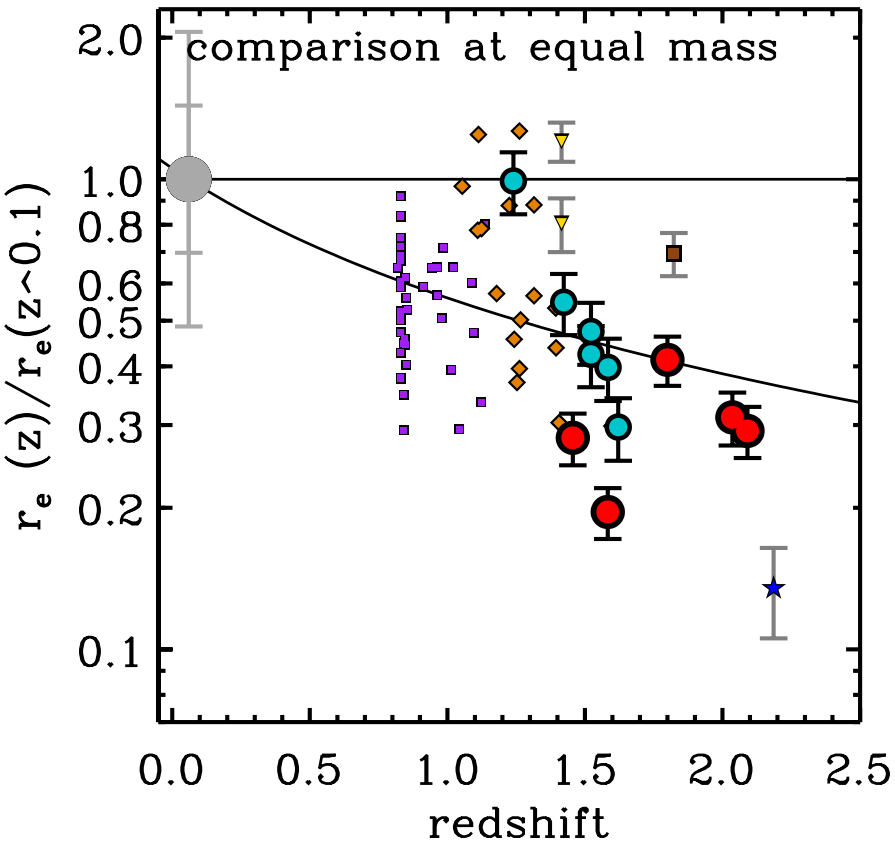


Verschillende massa bepalingen komen overeen



Rode dode stelsels ziin het jonge heelal zijn echt kleiner

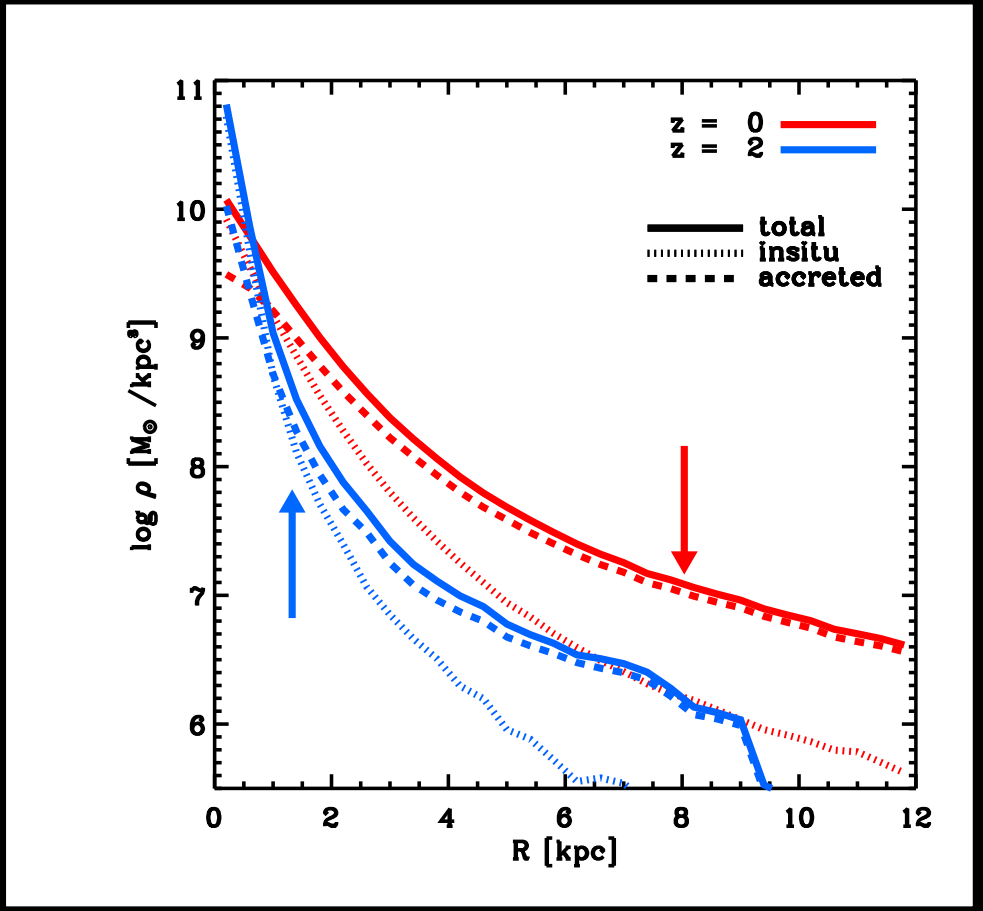




Probleem voor theorie?

Rode dode stelsels in het jongen heelal zijn de kernen van huidige elliptische stelsels

Deze stelsels groeien door botsingen met kleine stelsels



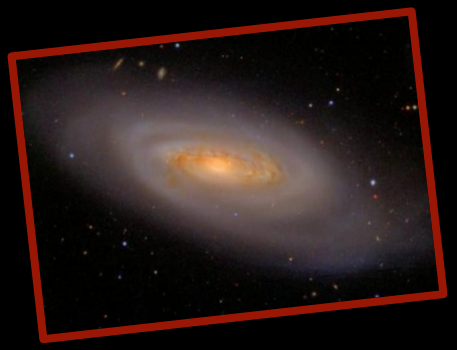
Om mee naar huis te nemen

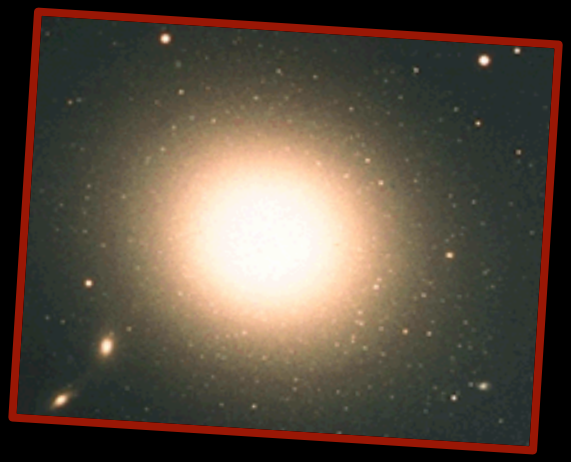
Sterrenstelsels ontstaan uit dichtheids fluctuaties

Rode dode sterrenstelsels bestaan al na 3 miljard jaar

Veel kleiner dan verwacht, en groeien door botsingen

Spiraal Sterrenstelsels: veel sterformatie en jonge sterren, oude kern





Elliptische Sterrenstelsels: massief, groot met oude Sterren (Rood en Dood)