Einführung in die Astronomie & Astrophysik II

3. Was sind Galaxien?

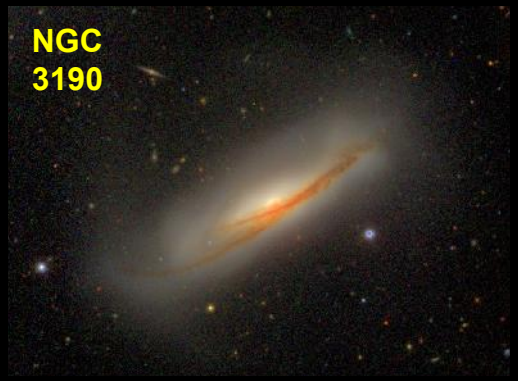
SoSe 2010, Knud Jahnke

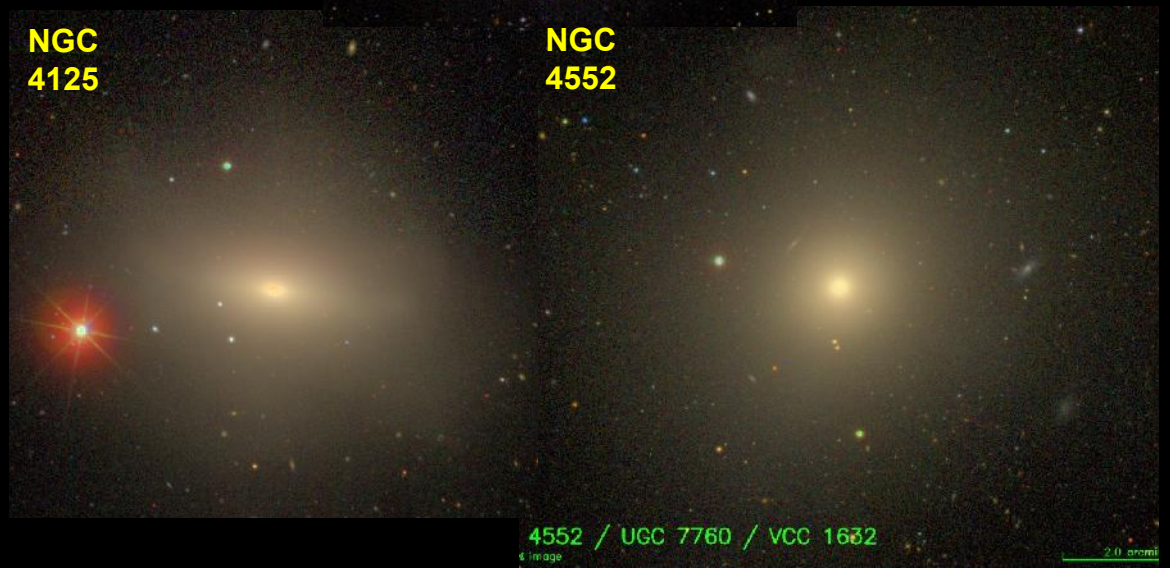
http://mpia.de/coevolution/Lectures/astro210

Geschichtliches

- 10 Jhd., Abd al-Rahman al-Sufi: Andromeda + LMC
- 1750, Thomas Wright: Milchstraße = viele Sterne + Gravitation
- 1755, Immanuel Kant: Nebel = „Welteninseln“
- 26. April 1920: The Great Debate über Nebel
  - Harlow Shapley: Nebel = Teil der Milchstraße (Argument: Abstand Andromeda–MW unvorstellbare 10^8 LJ und Nova in Andromeda heller als Galaxie → Supernova)
  - Heber Curtis: Nebel = „Island Universes“ wie Milchstraße (Argument: mehr Novae in Andromeda beobachtet als in Milchstraße)
- 1922/23: Edwin Hubble, Entfernungsmessungen zu Nebeln → Galaxien!

Bitte sortieren:

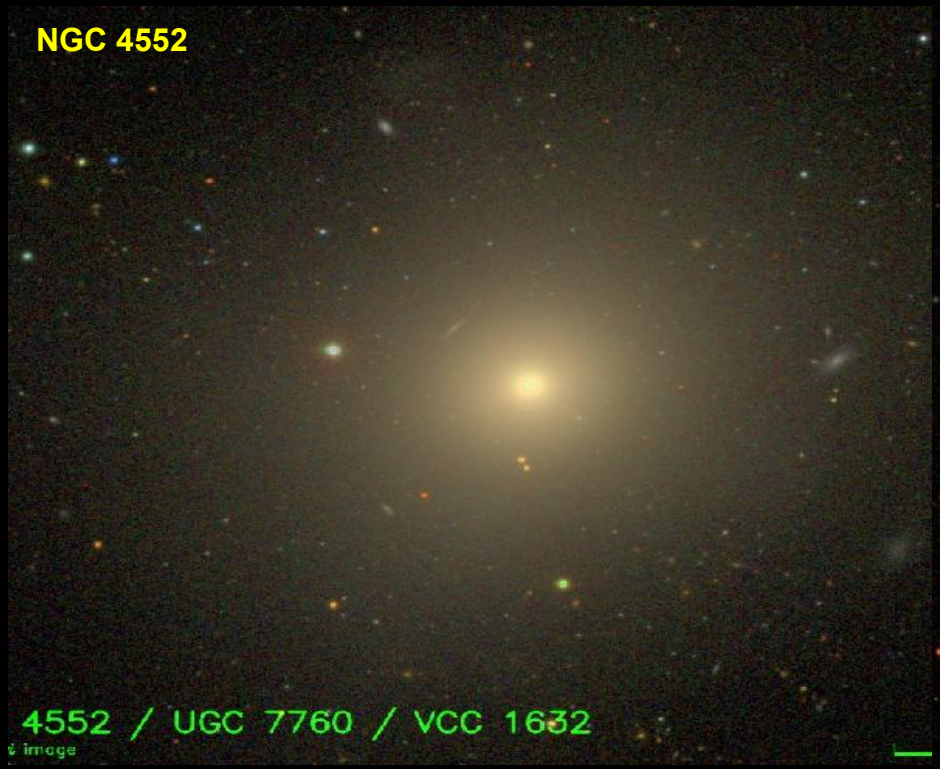




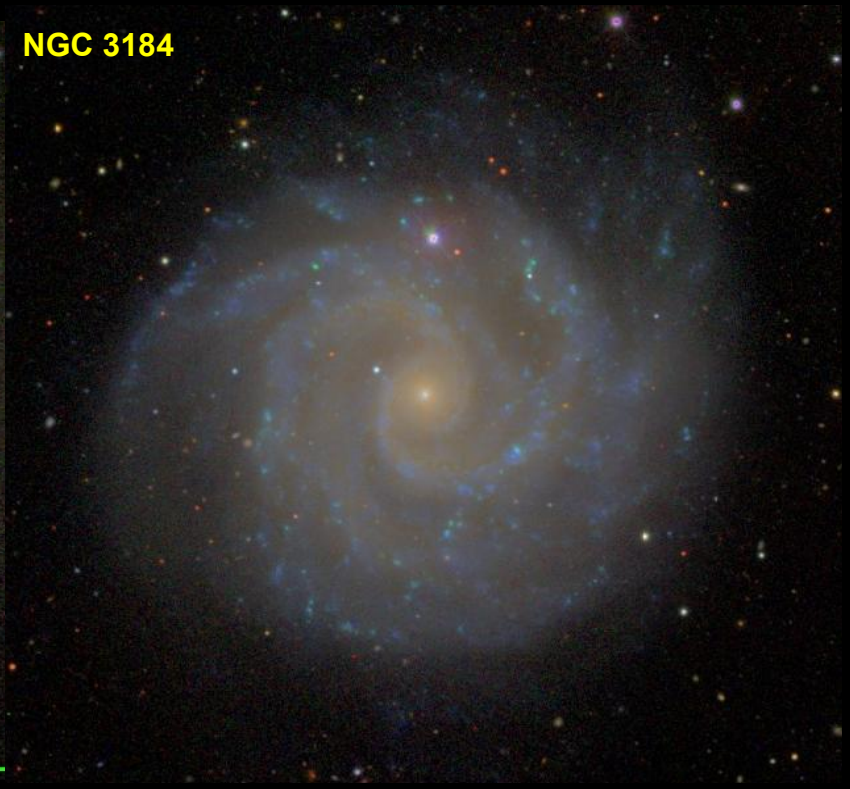
Sortierkriterien

1. Form (Spiralarme)
2. Farbe (blau oder gelblich/rot)
3. Größe
4. Helligkeit
5. Staubspuren?
6. Zentrum: kugelförmig oder elongiert

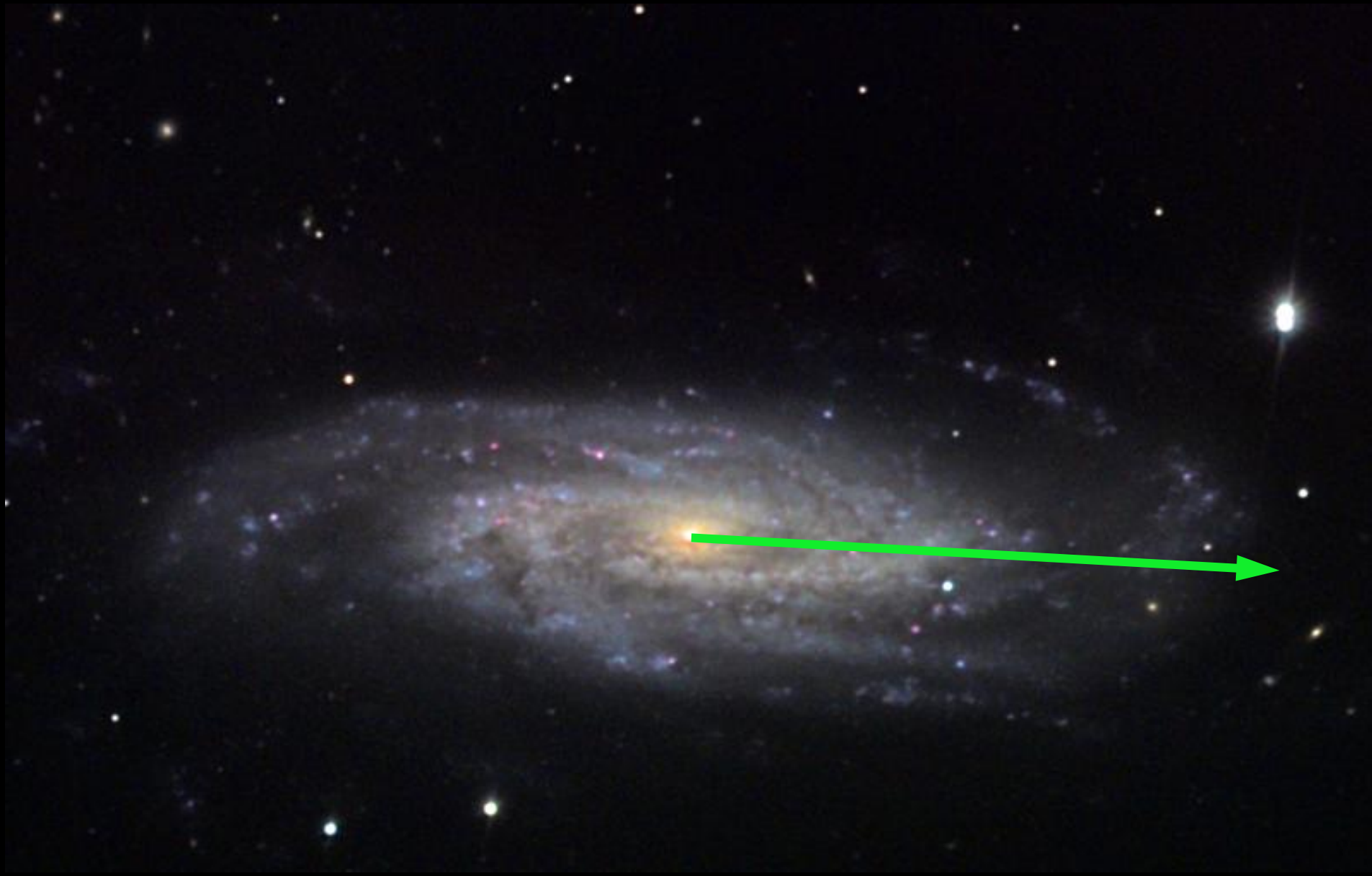
Sterne in Galaxien



Elliptische Galaxie (E)

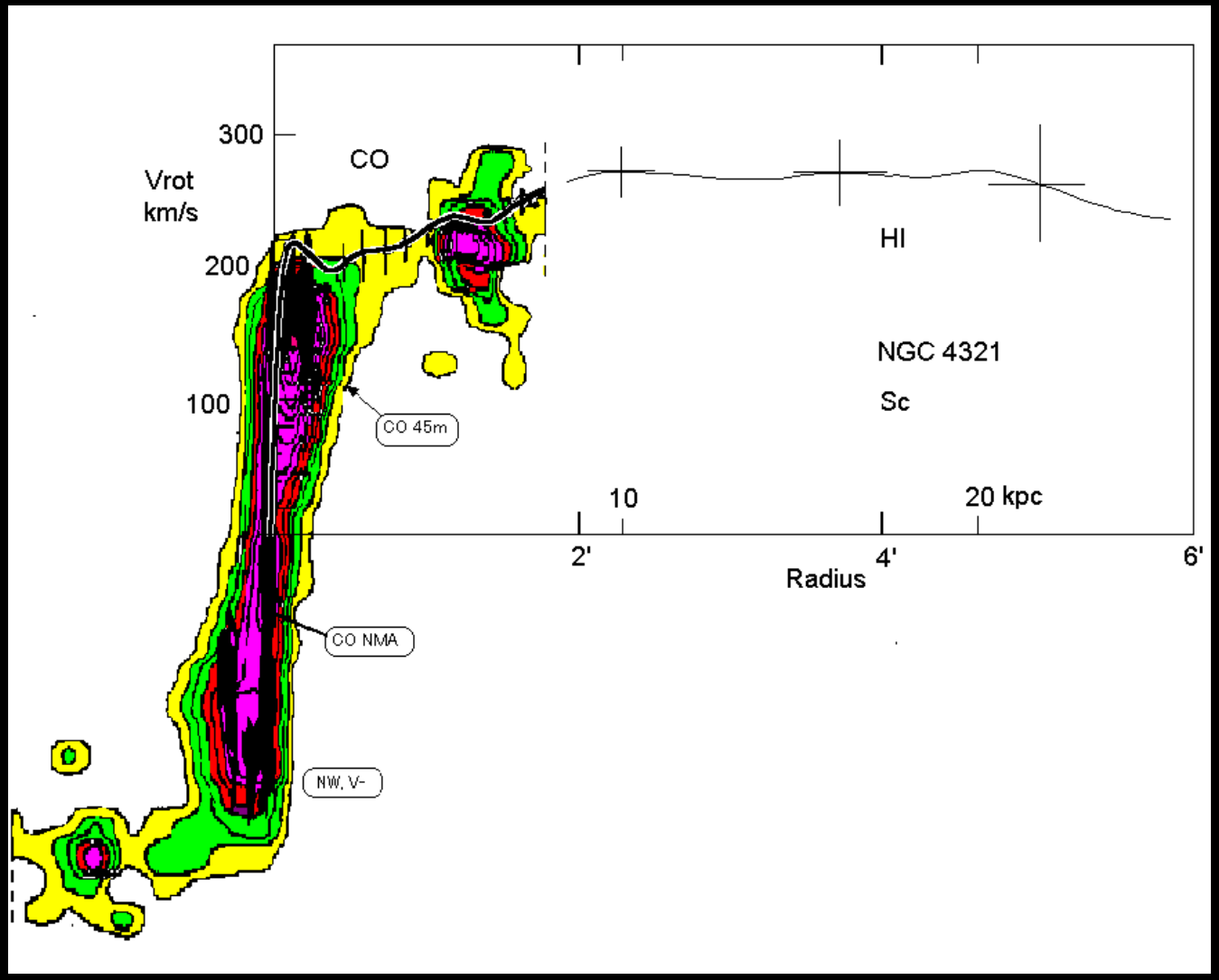


Spiralgalaxie (S…)


NGC 3198

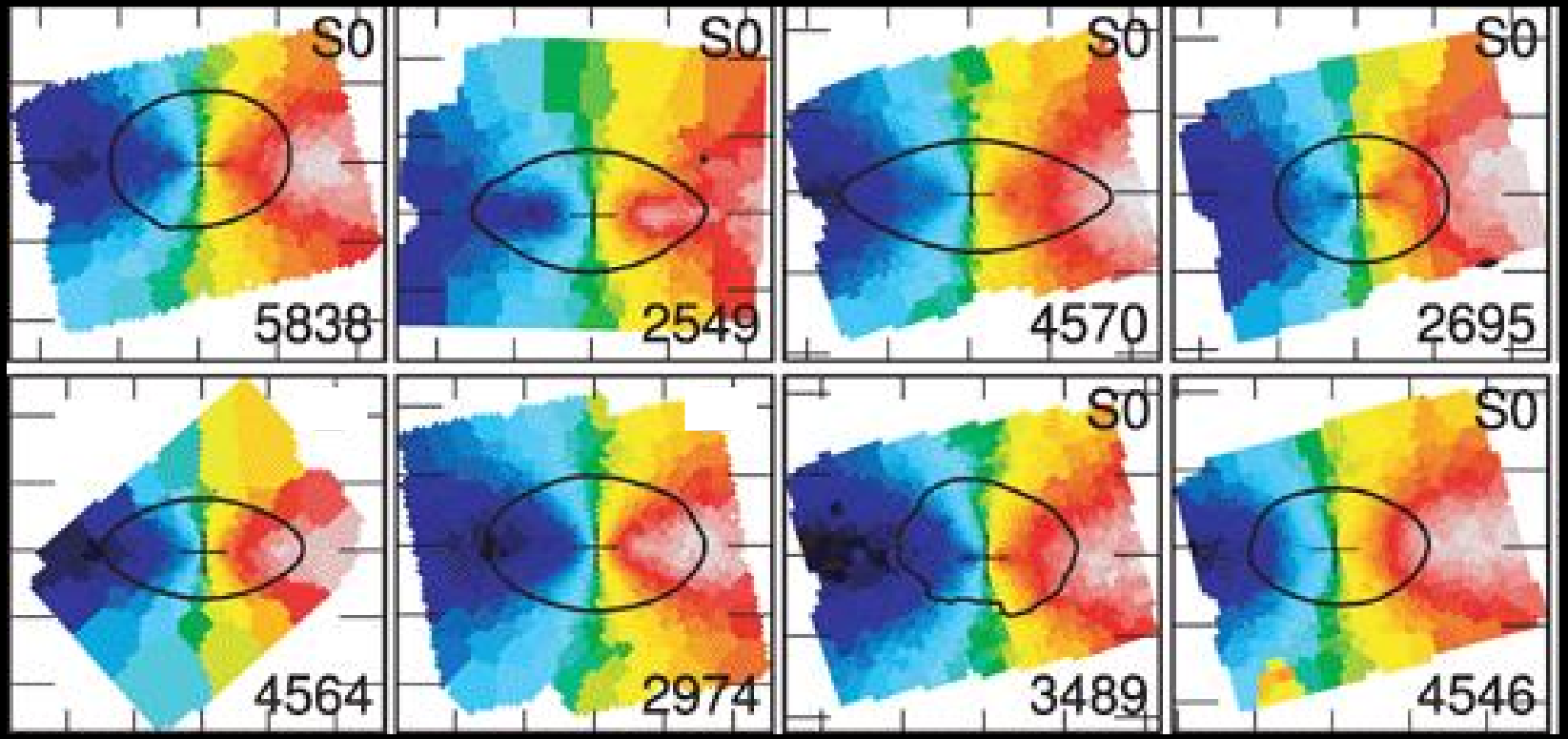
Sterne in Galaxien

Spiralgalaxie: Rotationskurve



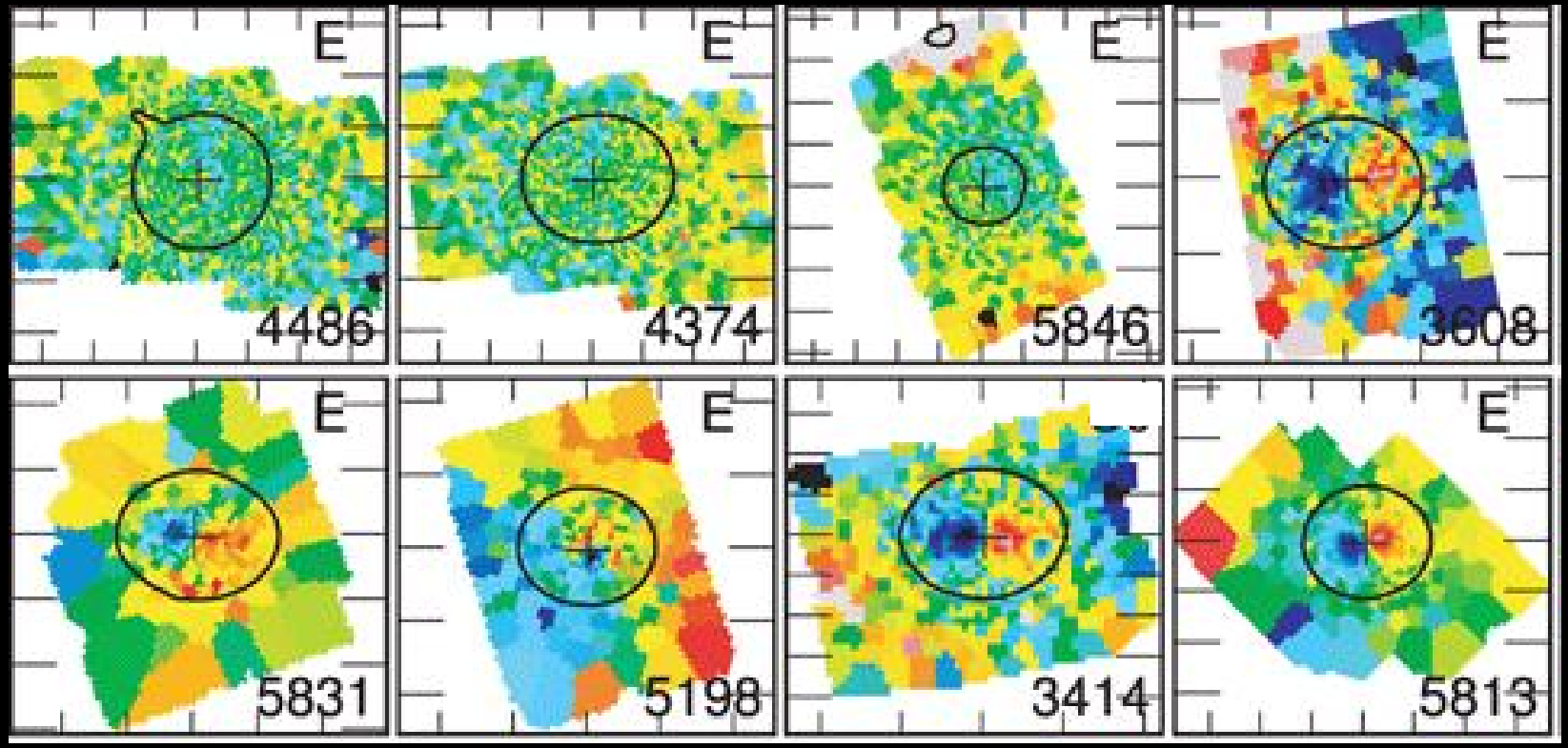
Sterne in Galaxien

Spiralgalaxie: kinematisch „kalt“, koordinierte Rotation, Scheibe



Sterne in Galaxien

Elliptische Galaxie: kinematisch „heiß“, wenig Rotation, Spheroid



Einschub: Rotationskurven

- Newton + zentrifugales Gleichgewicht (sph. Symm.):

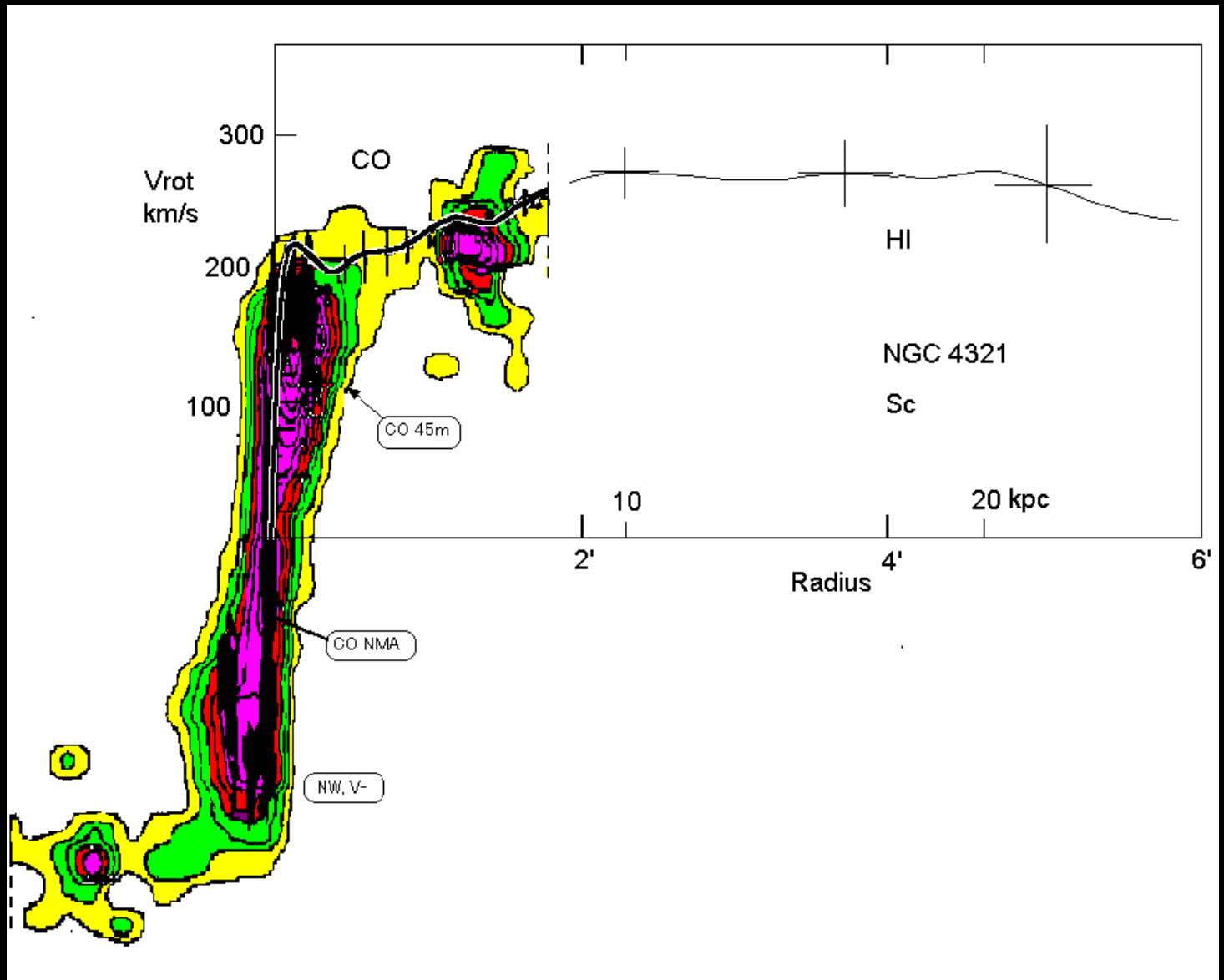
$$\frac{GM(<R)}{R^2} = \frac{v^2(R)}{R} = \omega^2(R)\cdot R$$

- Masse innerhalb Radius R:

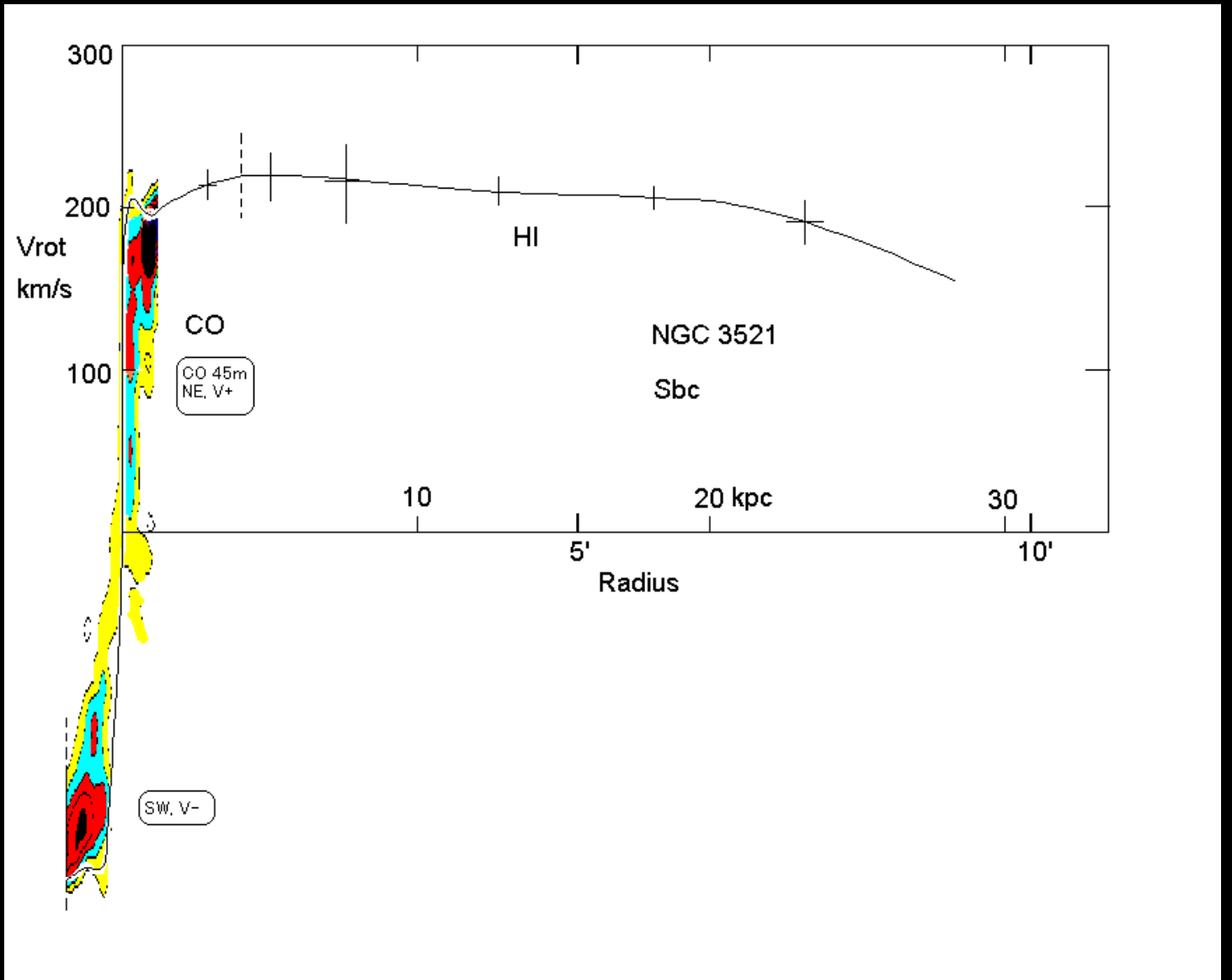
$$M(<R) = \int_0^R dr\, \rho(r) r^2$$

- Beispiele
  - $\rho = \text{const.} \Rightarrow M \propto R^3 \Rightarrow v \propto R,\ \omega = \text{const.}$ (isotherm)
  - $\rho \propto R^{-2} \Rightarrow M \propto R \Rightarrow v = \text{const.}$ (keplersch)
  - Punktmasse $\Rightarrow v \propto \frac{1}{\sqrt{R}}$

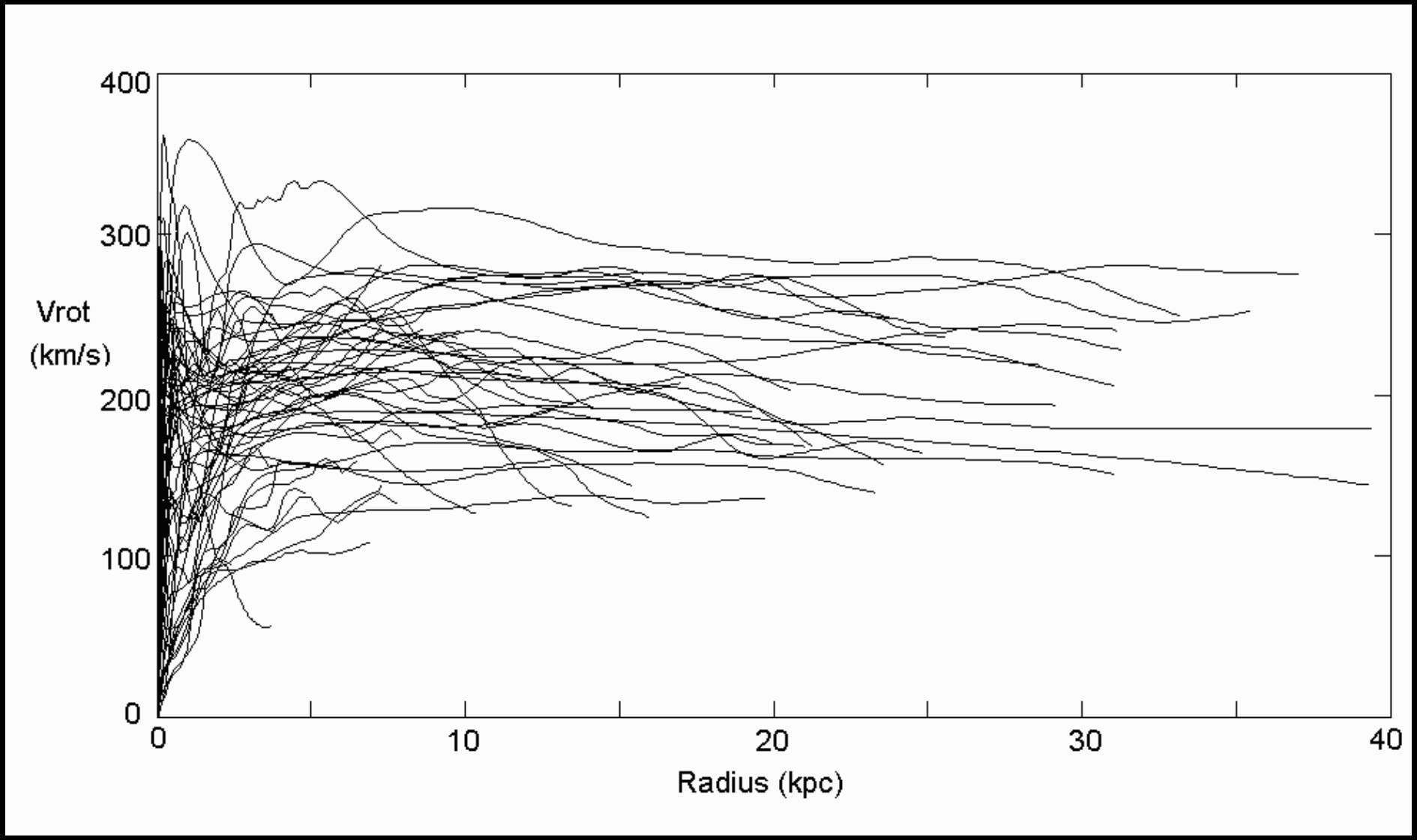
Rotationskurven



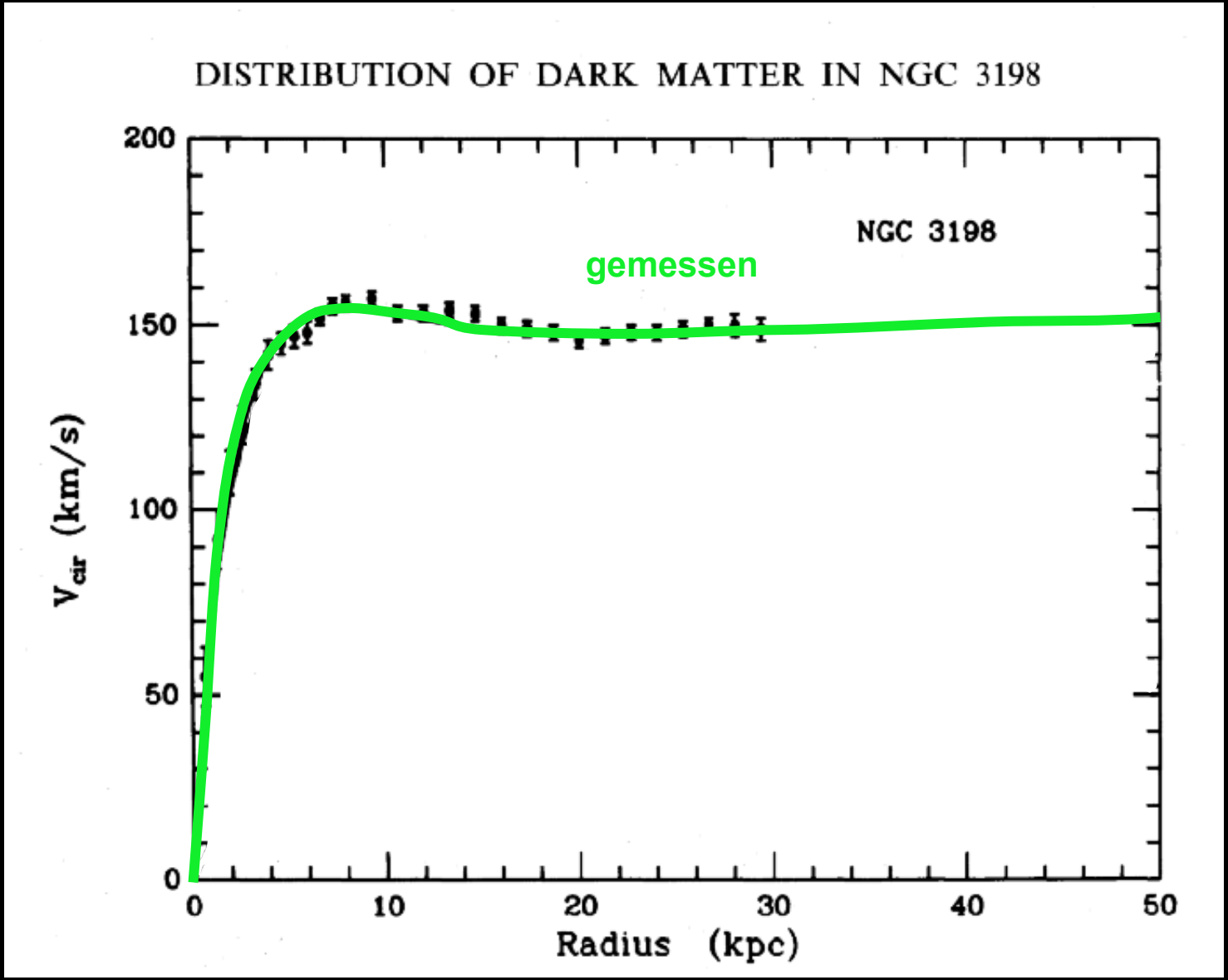
Rotationskurven



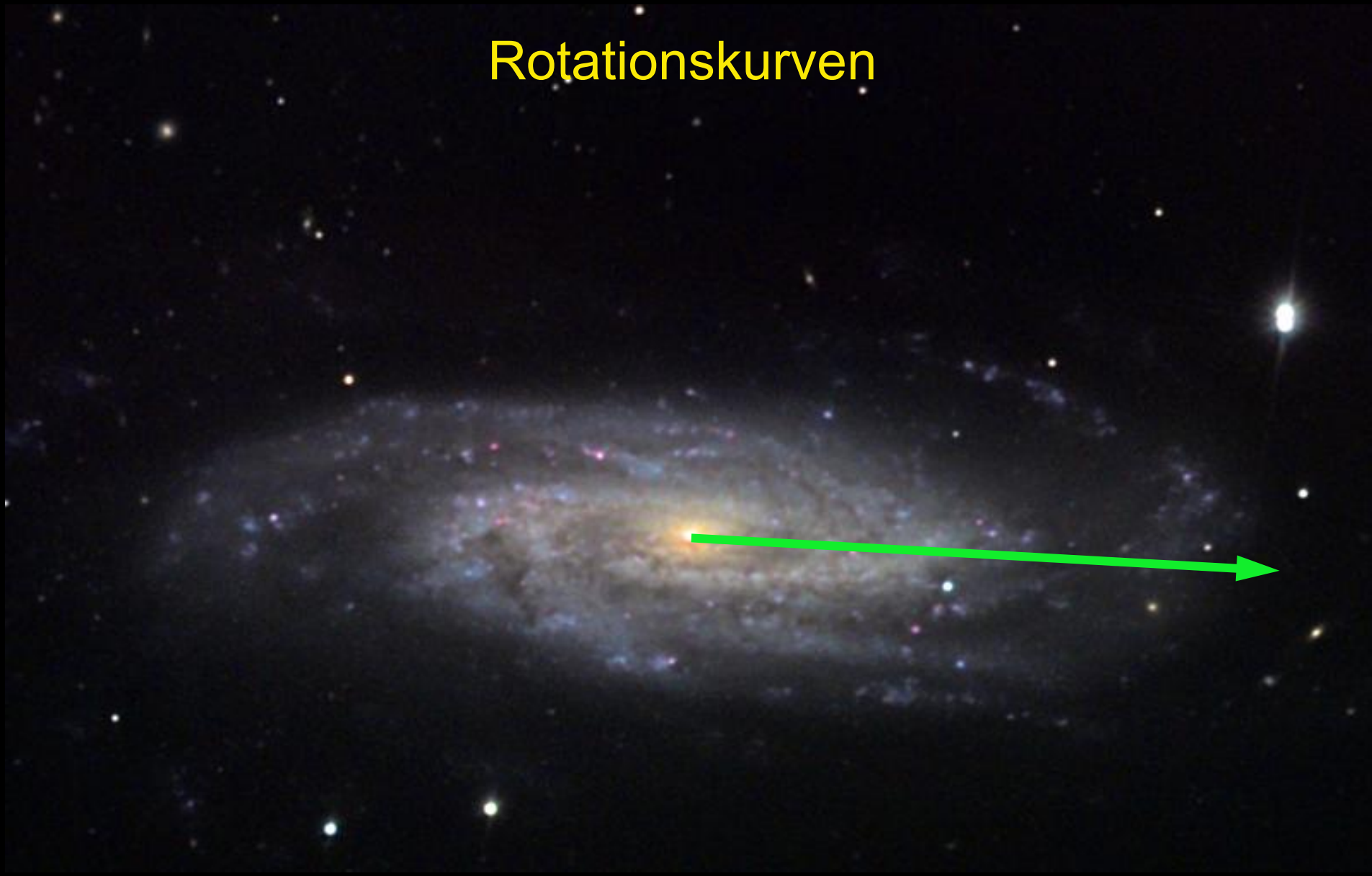
Rotationskurven



Rotationskurven

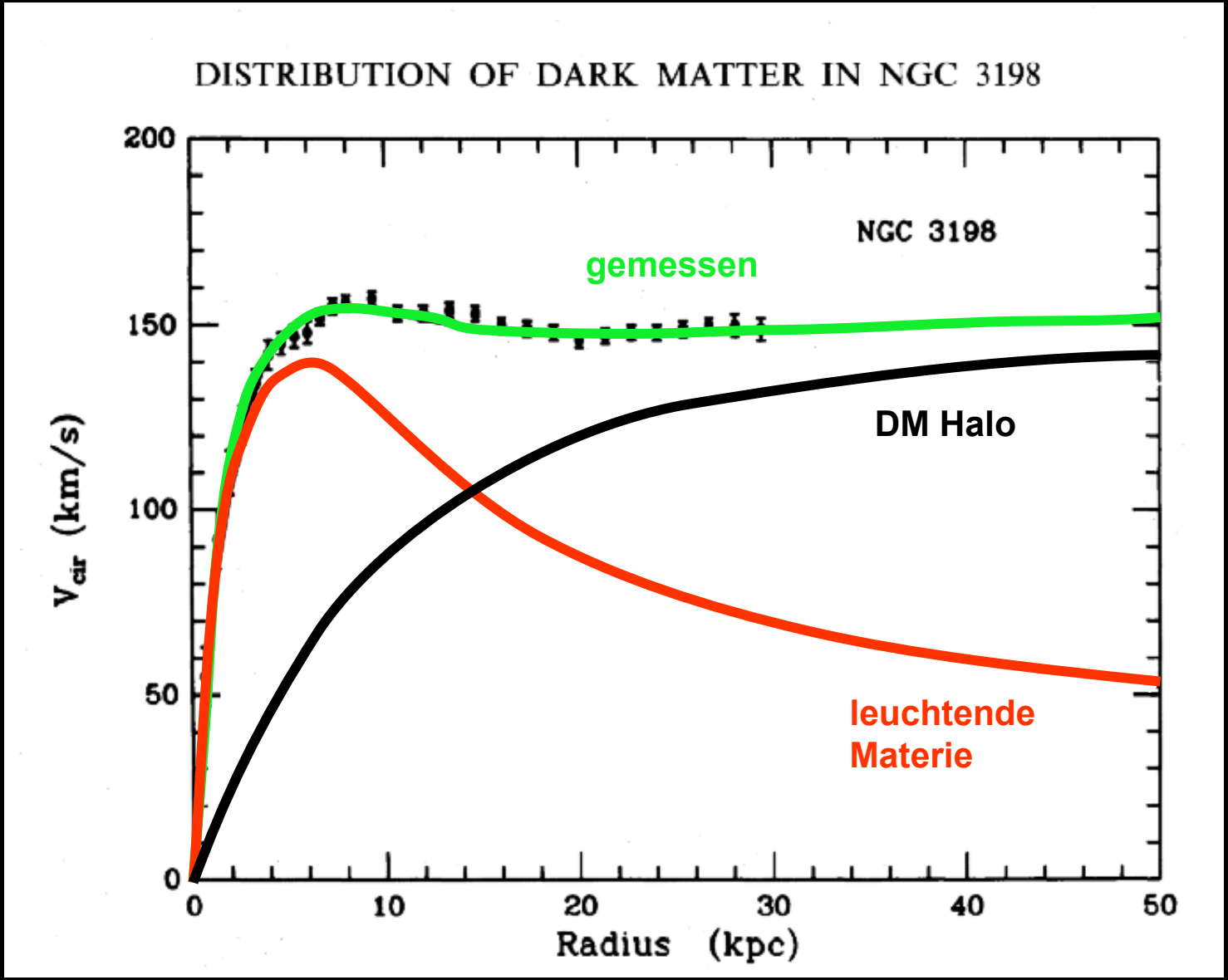


Rotationskurven



NGC 3198

Rotationskurven



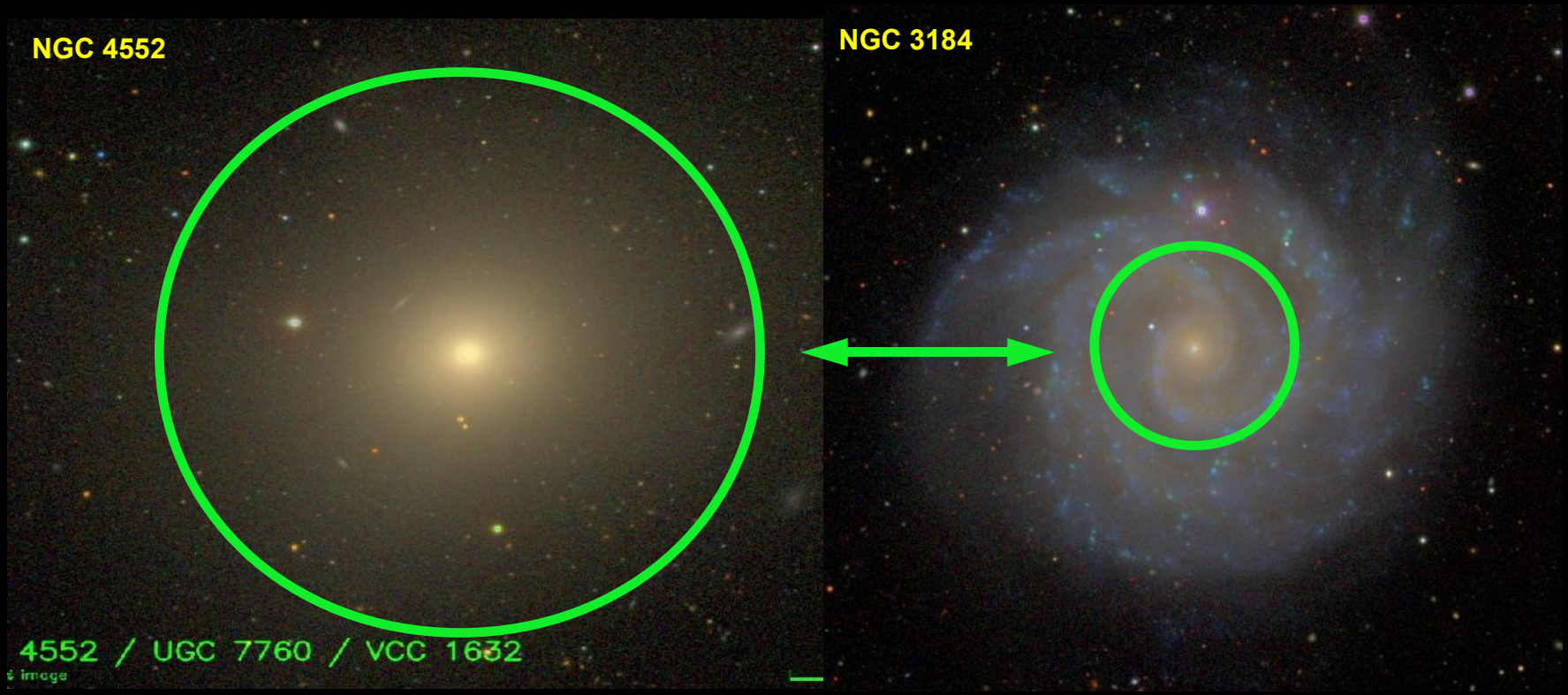
Dunkle Materie

- 25% (!) der globalen Energiedichte (Baryonen ~ 4%)
- nur gravitative WW
- keine el-mag WW
- Was ist es? → Supersymmetrie? → unklar…

→ Nobelpreis 2025?

Sterne in Galaxien

Bulge → Spheroid

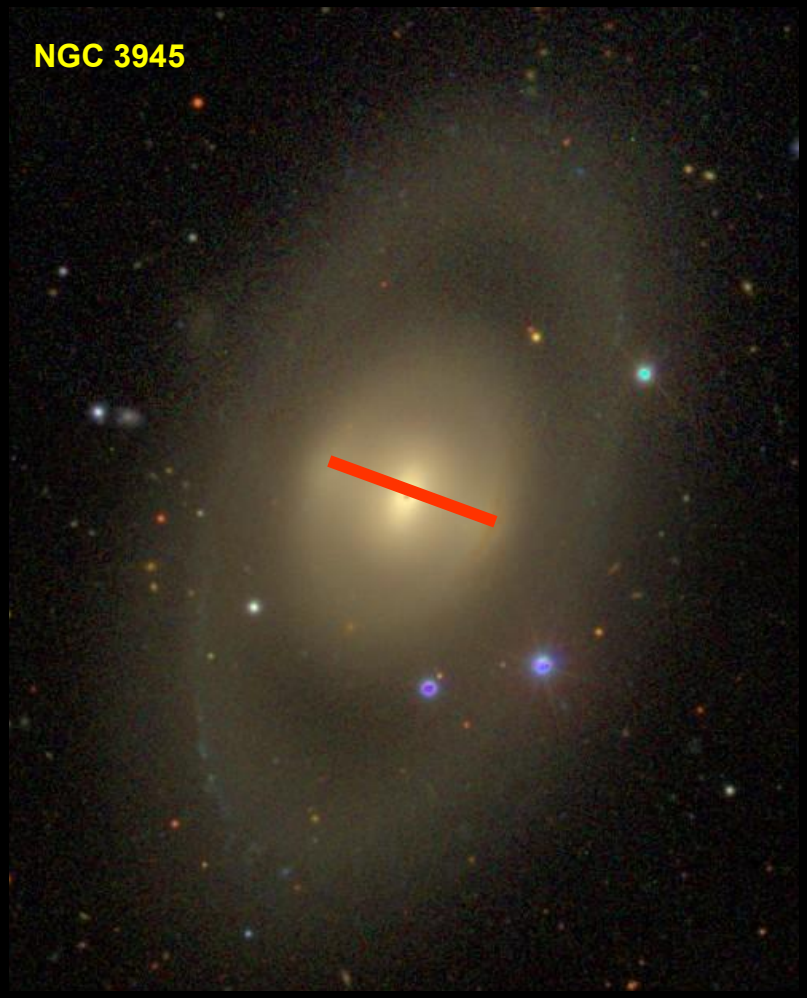


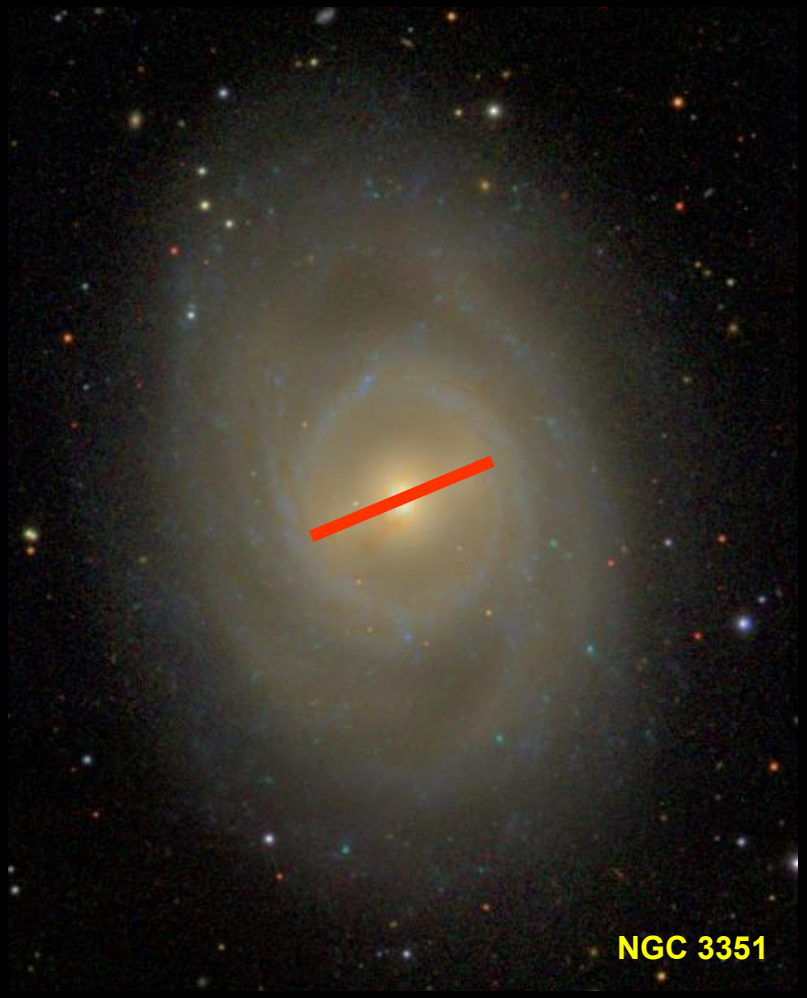
Elliptische Galaxie

Stellarer Bulge
(Zentralverdickung)

Sterne in Galaxien

Balkenspirale (SBa, SBb, SBc, …)





Sterne in Galaxien

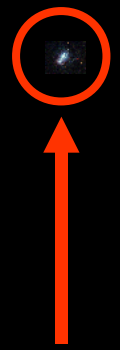
Galaxienzusammenstöße/-verschmelzungen

Sterne in Galaxien

Irreguläre Galaxien

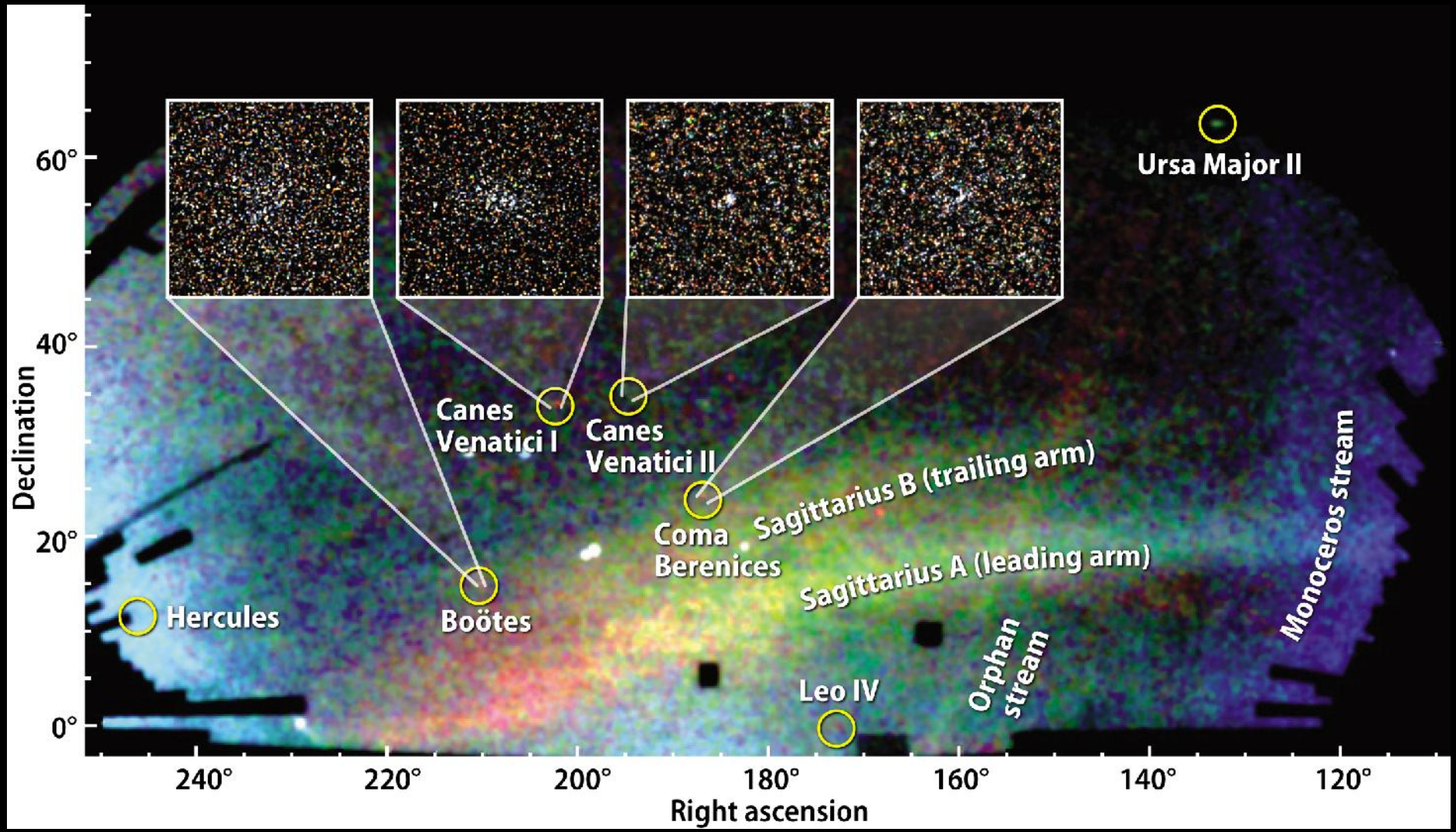
Sterne in Galaxien

Zwerggalaxien



Sterne in Galaxien

MW Zwerggalaxien




THINGS
The HI Nearby Galaxy Survey
NGC 2841
NGC 3621
NGC 7331
NGC 4826 (M64)
NGC 6946
NGC 3184
NGC 925
NGC 3351 (M95)
NGC 3198
NGC 5194 (M51)
NGC 3521
NGC 4214
NGC 2976
DDO 53
NGC 1569
M81dwB
NGC 5236 (M83)
NGC 2366
Our Galaxy HI
Our Galaxy stars
M81dwA
IC 2574
NGC 4449
NGC 3627 (M66)
Holmberg II
NGC 7793
DDO 154
NGC 4736 (M94)
NGC 3077
Holmberg I
NGC 5055
NGC 2903
10 kpc
NGC 628 (M74)
NGC 5457 (M101)
NGC 3031 (M81)
NGC 2403
Data: Walter et al 2008
Milky Way HI map: Dorr et al (1988)
Milky Way art: NASA/JPL, R. Hurt (SSC)

Sterne in Galaxien

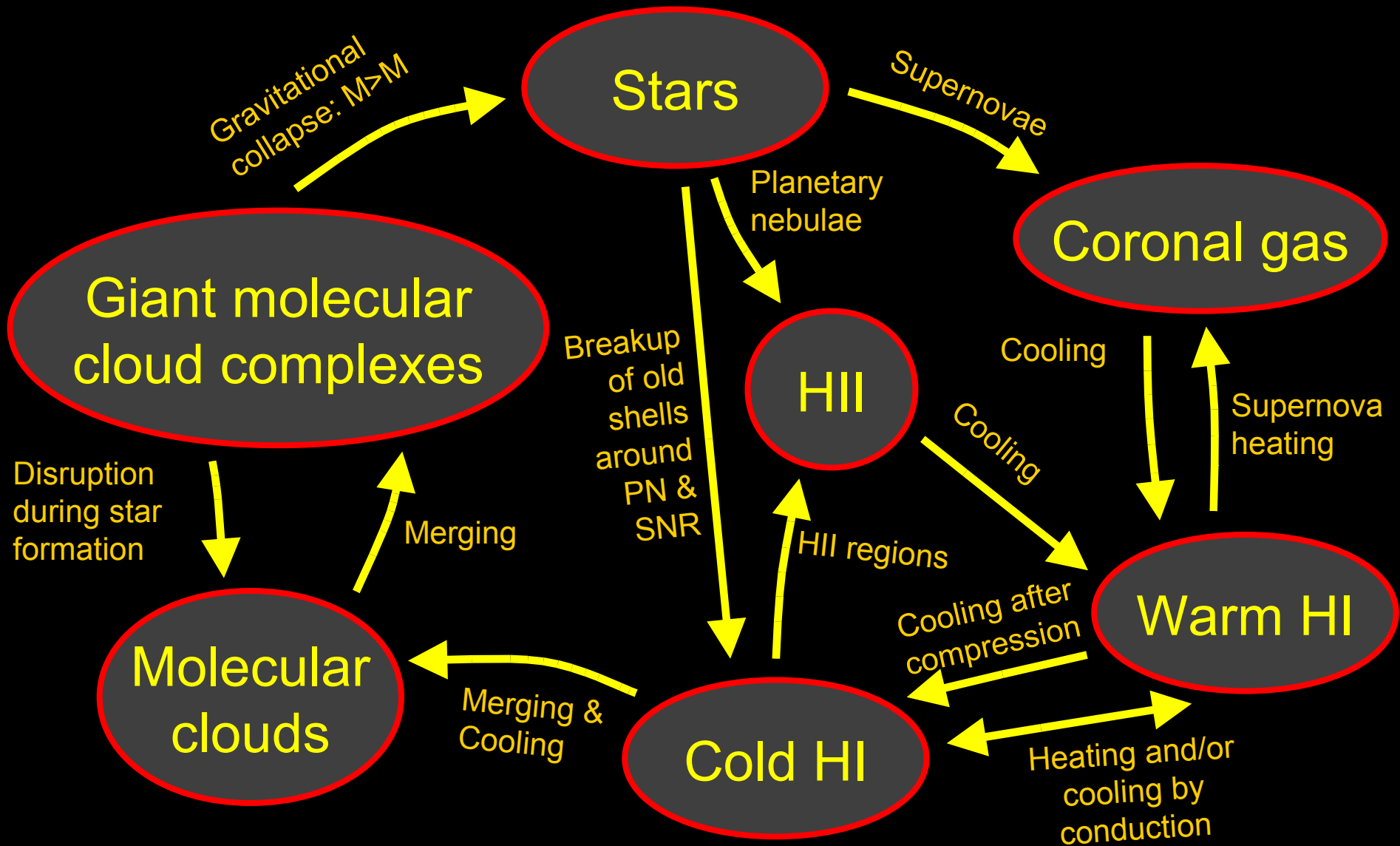
- Stellare Massen:
  - MW: $8 \times 10^{10} M_{sonne}$ (Scheibe 6×10^{10}, Bulge 1×10^{10})
    - MW Halo $5.5 \times 10^{11} M_{sonne}$
  - Andromeda: etwas massereicher
  - Giant Elliptical (M87): $10^{12} M_{sonne}$
  - Zwerggalaxie: 10^{7}–$10^{8} M_{sonne}$
  - MW Zwerggalaxien: $< 10^{7} M_{sonne}$

→ alles „Galaxien“, über 6 Größenordnungen in Masse

Sterne in Galaxien

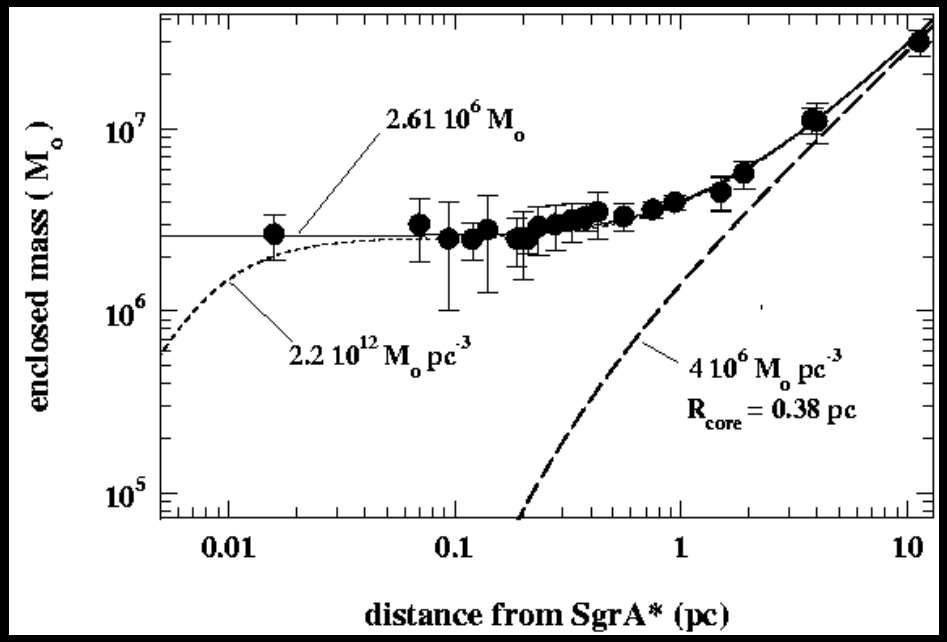
- Parameter:
  - Morphologie (Typ)
  - Dynamik (heiß, kalt)
  - stellare Masse
  - DM Masse
  - Farbe
  - mittleres Alter
  - Stärke Sternentstehung
  - Staubmenge
  - …
- > 8-dimensionaler Parameterraum?

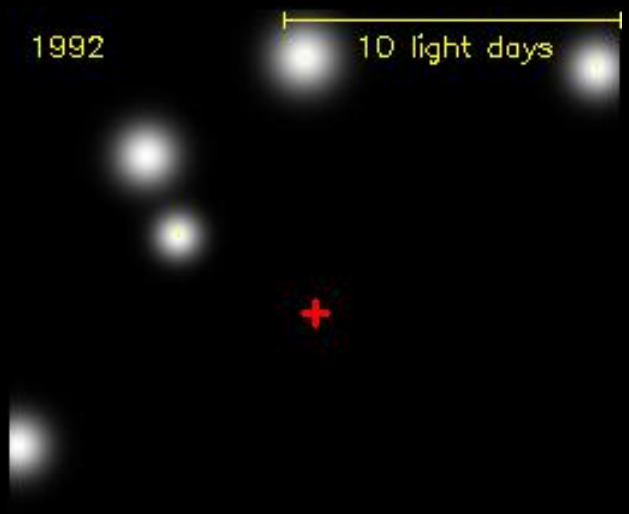
Zyklus der interstellaren Materie



Galaxienkerne

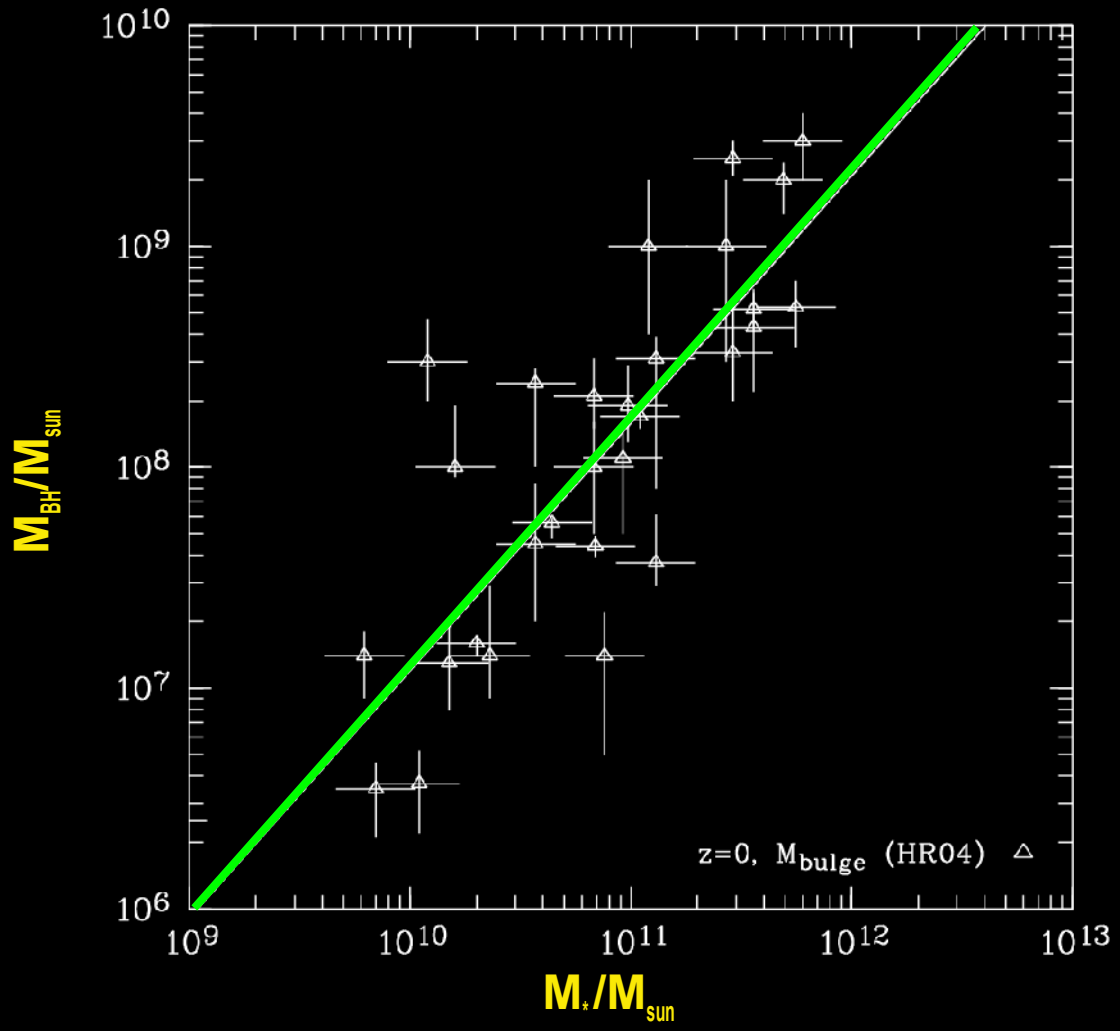
Schwarzes Loch in der Milchstraße: $3 \cdot 10^6 M_{sun}$ $= 6 \cdot 10^{36}$ kg





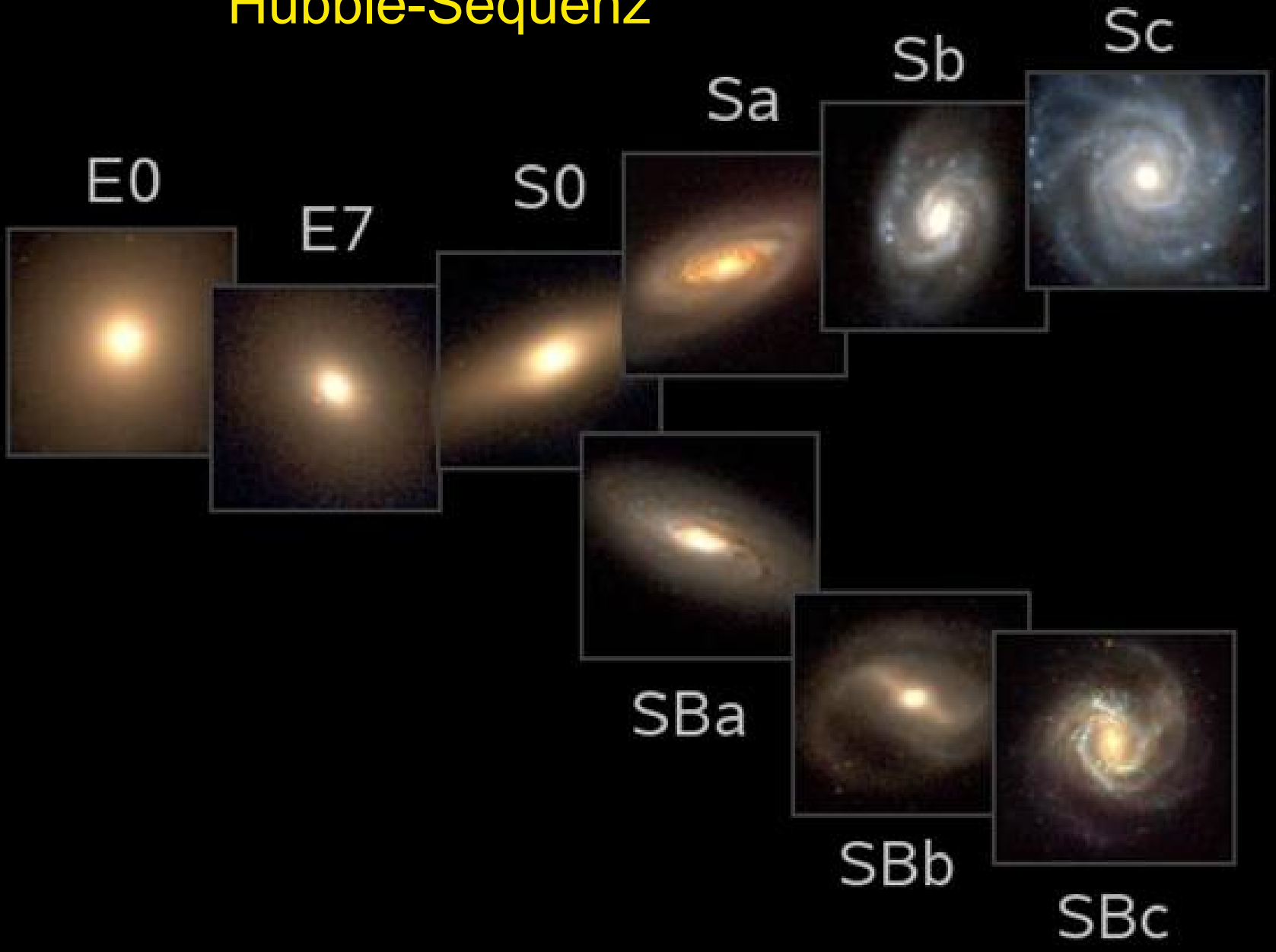
Genzel et al. 1998...2005, und andere

Galaxienkerne

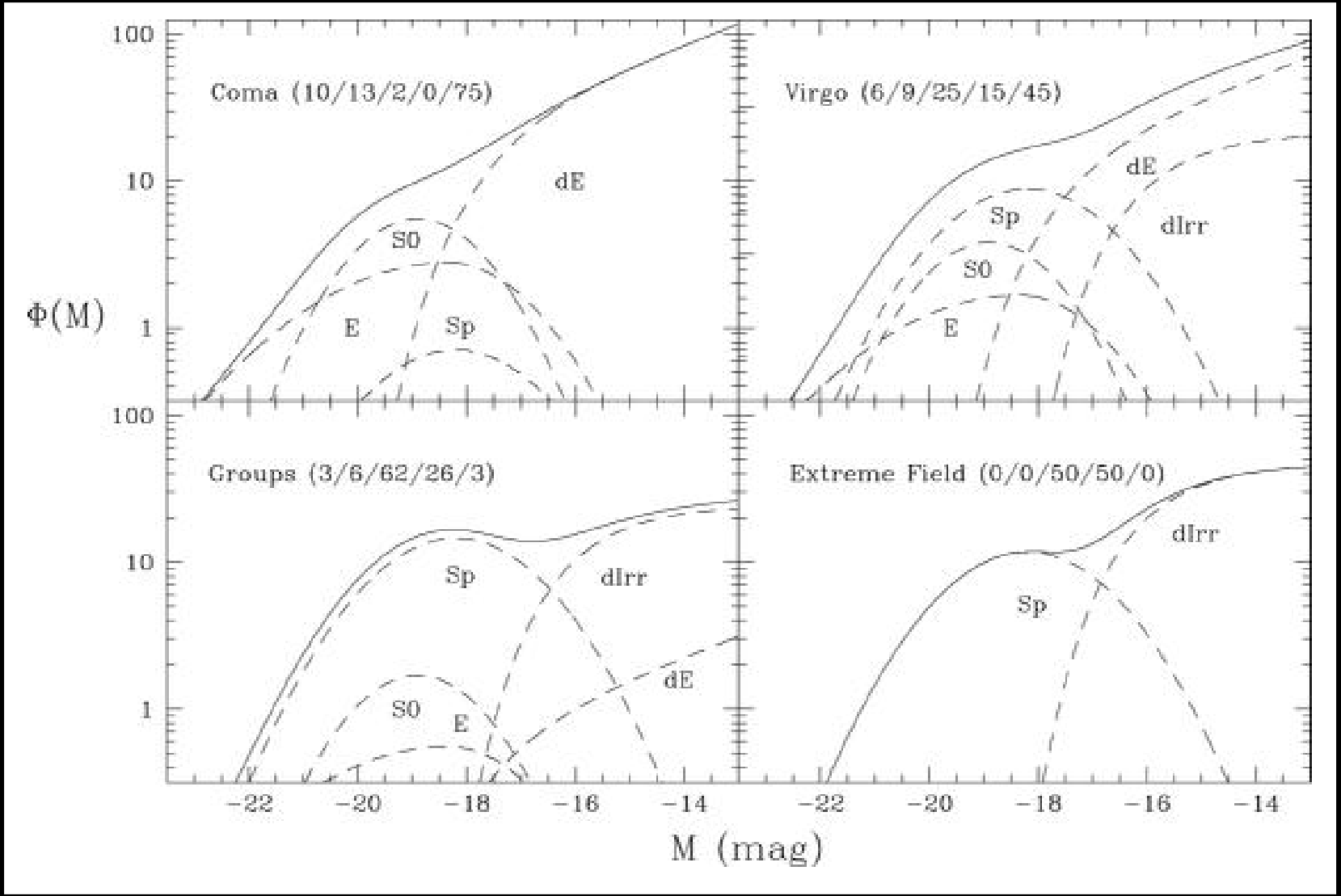


z=0: Häring&Rix 2004

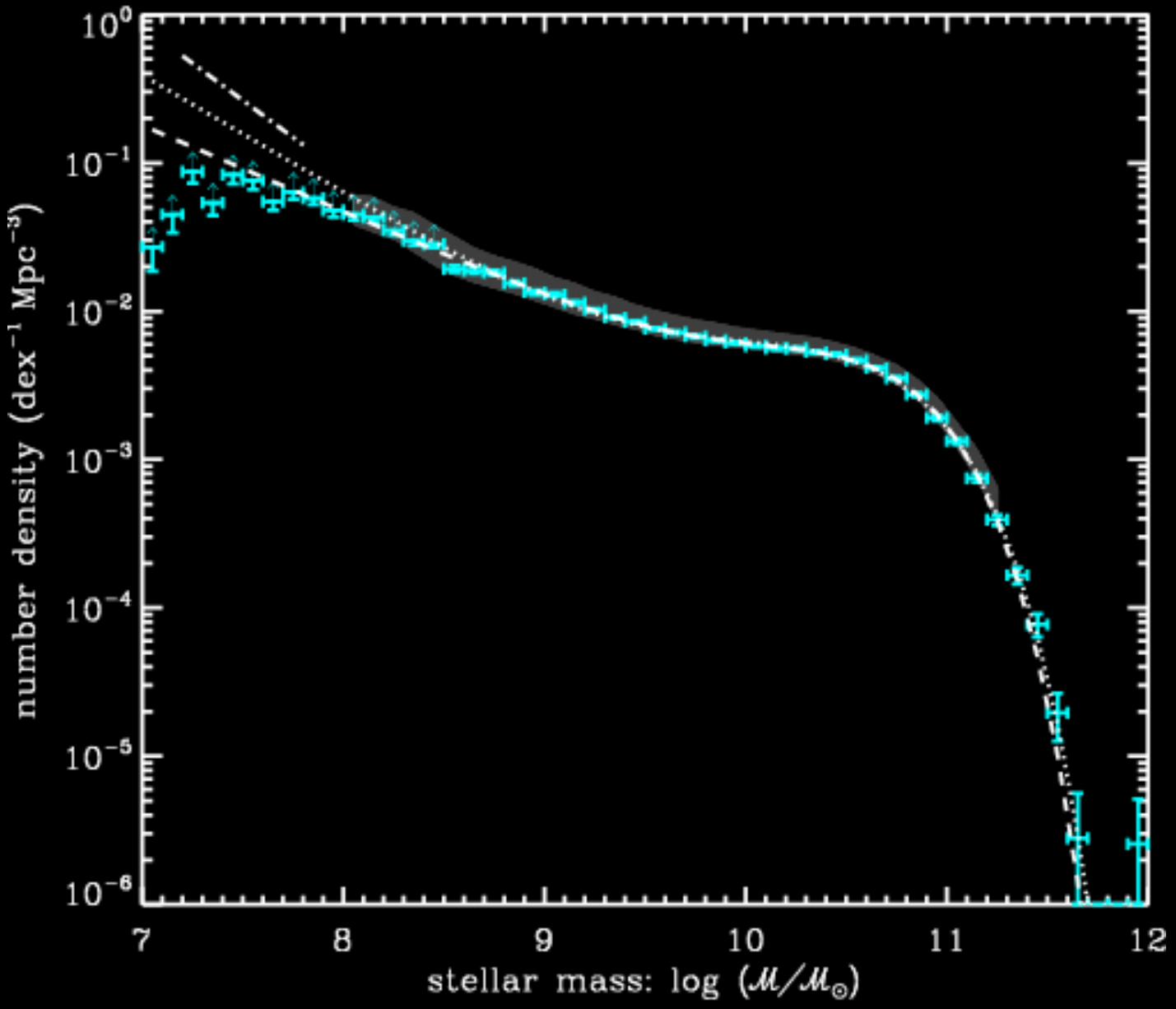
Hubble-Sequenz



Leuchtkraftfunktion

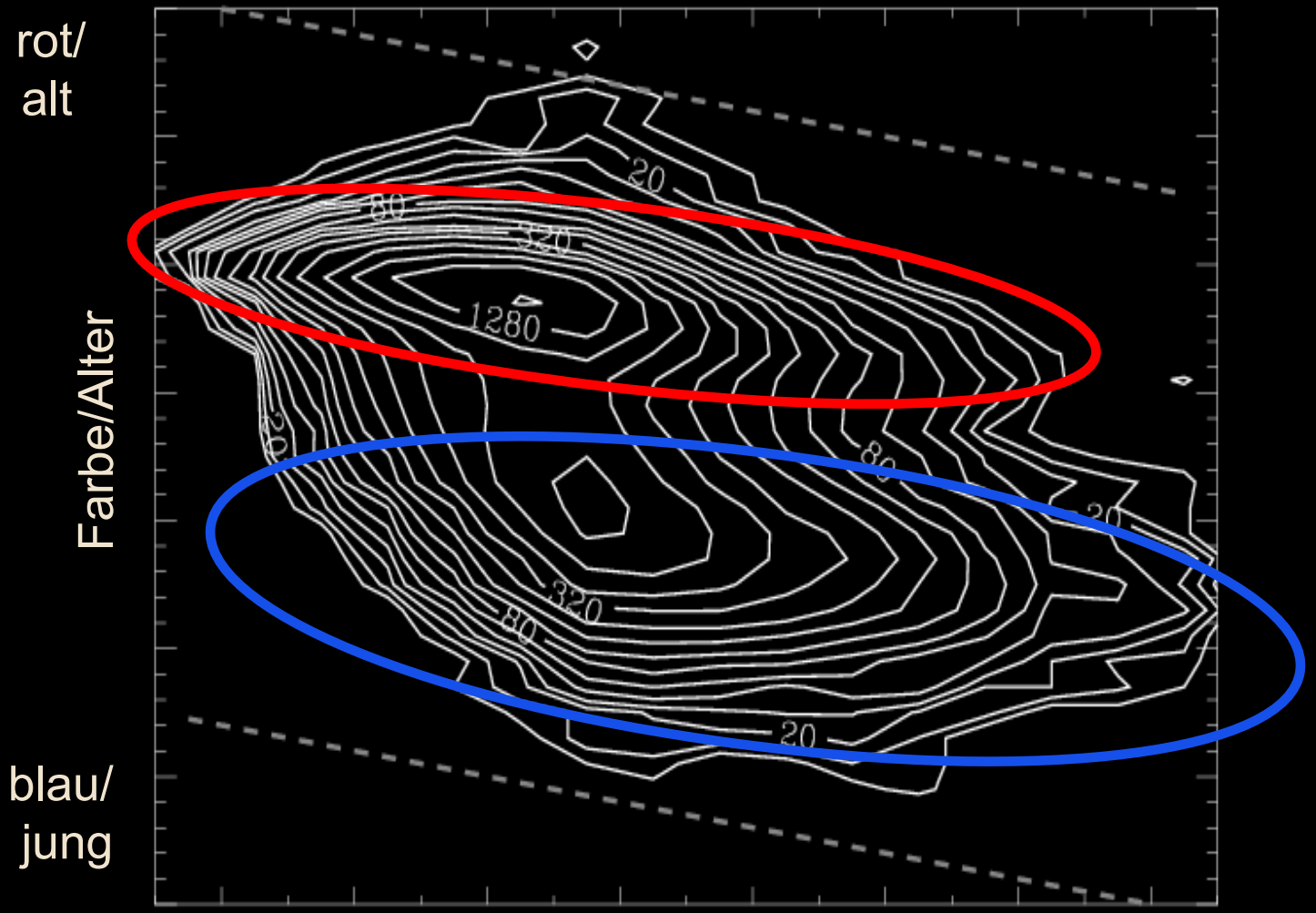


Massenfunktion



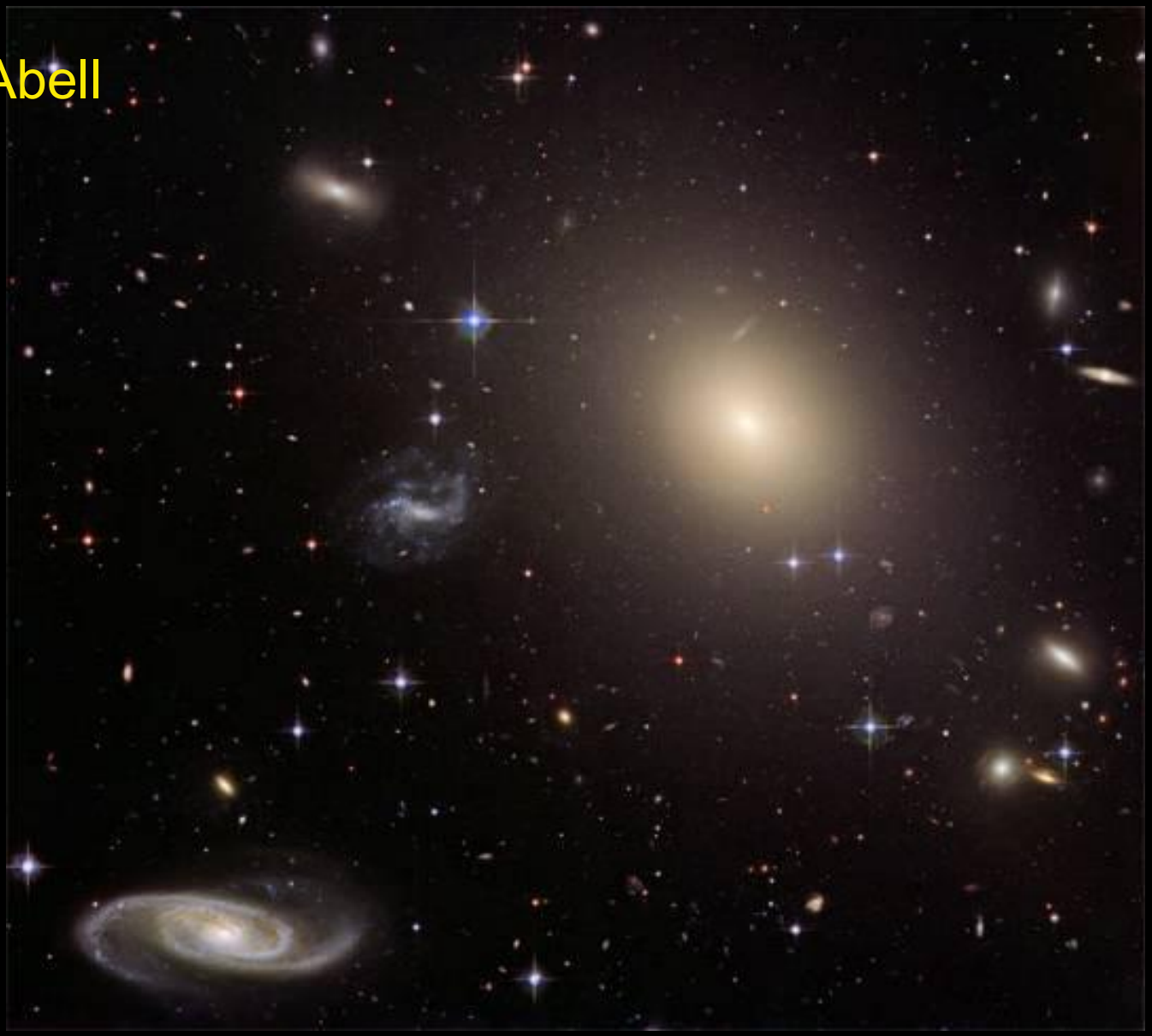
Farb-Helligkeits-Diagramm

20.000 Galaxien



Räumliche Verteilung/„Clustering“

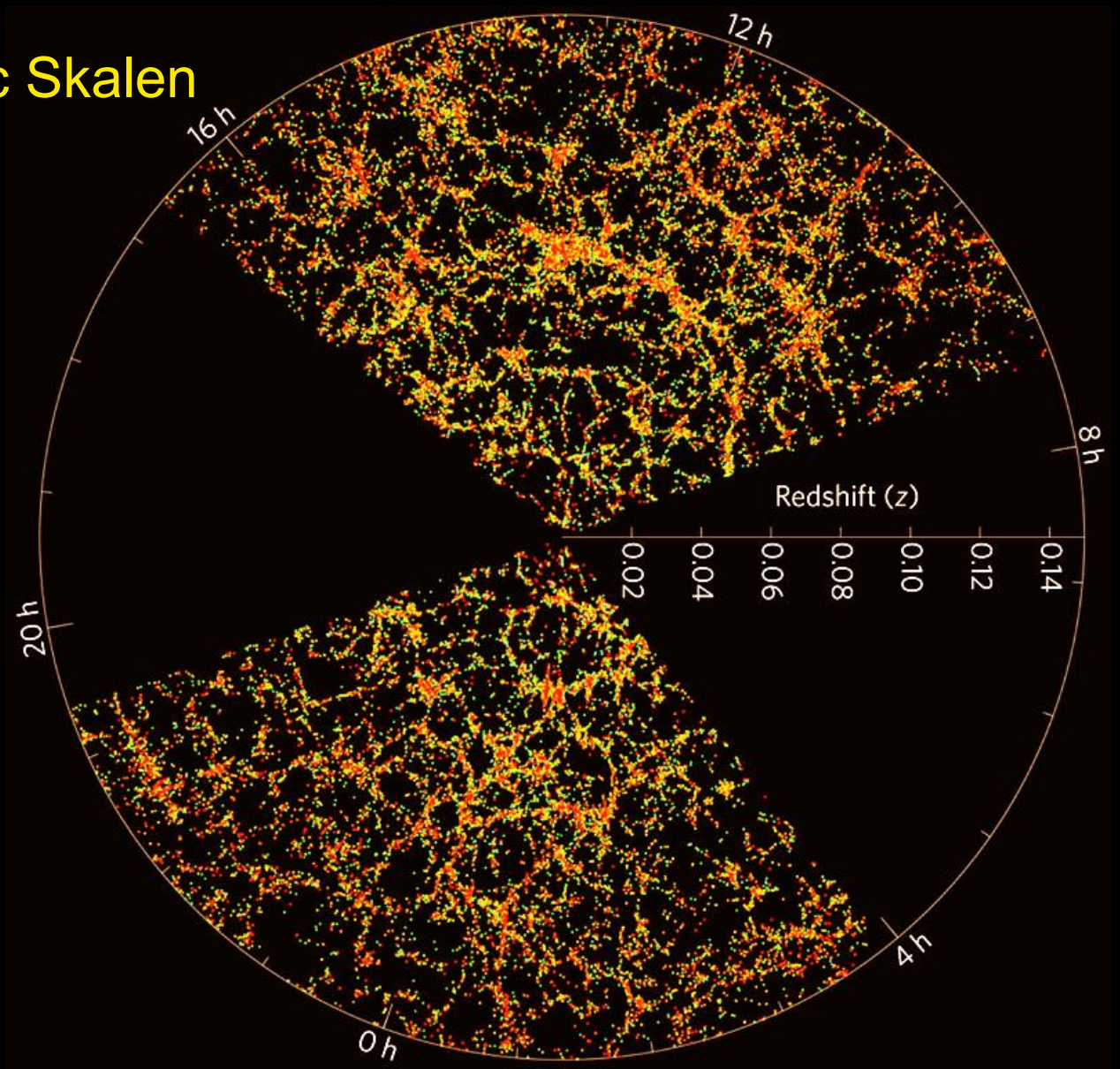
Galaxienhaufen Abell S0740



Räumliche Verteilung/„Clustering“

Inhomogen: <Mpc Skalen

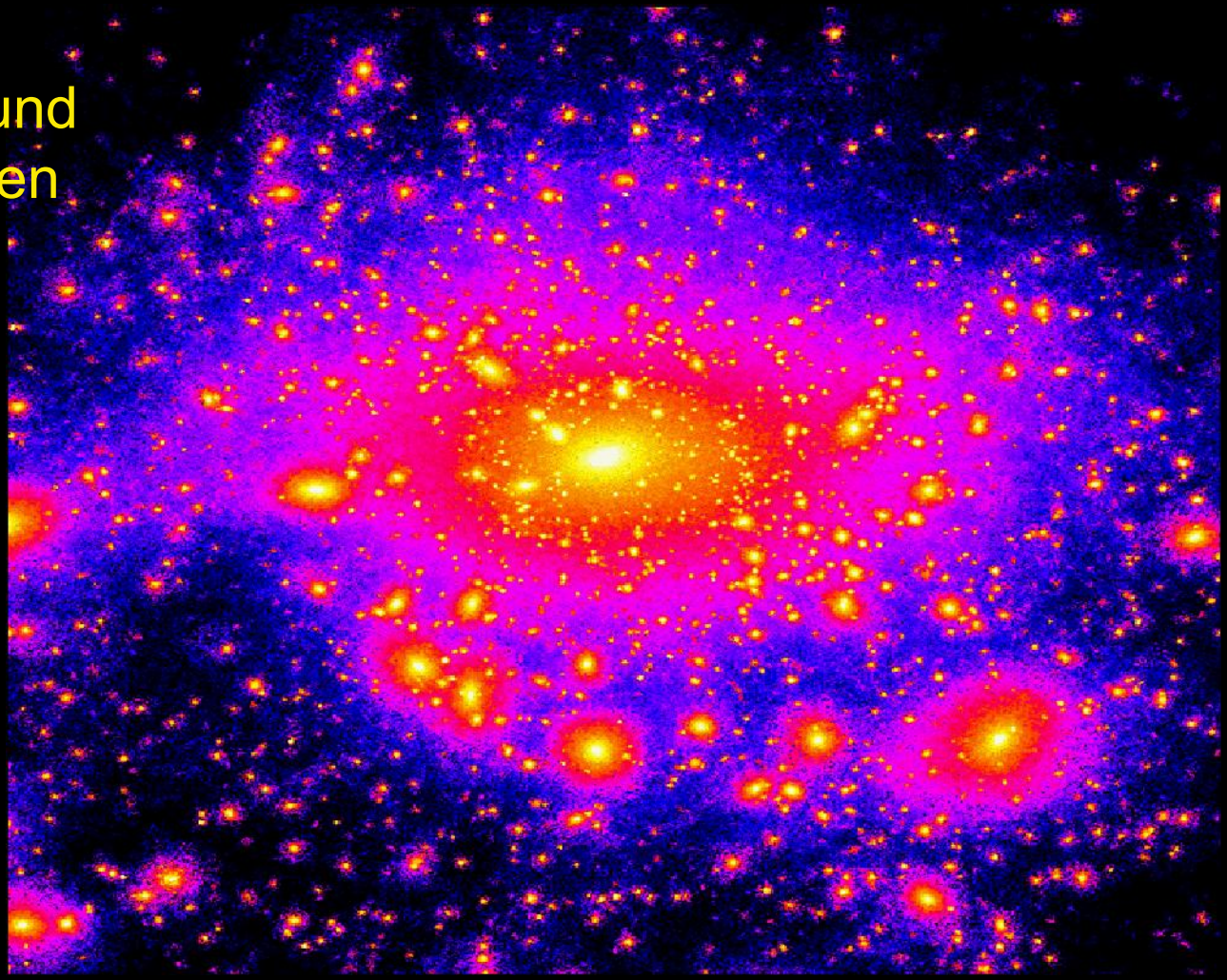
Homogen: global



Räumliche Verteilung/„Clustering“

DM Halos:

Zentrale Galaxie und Satellitengalaxien

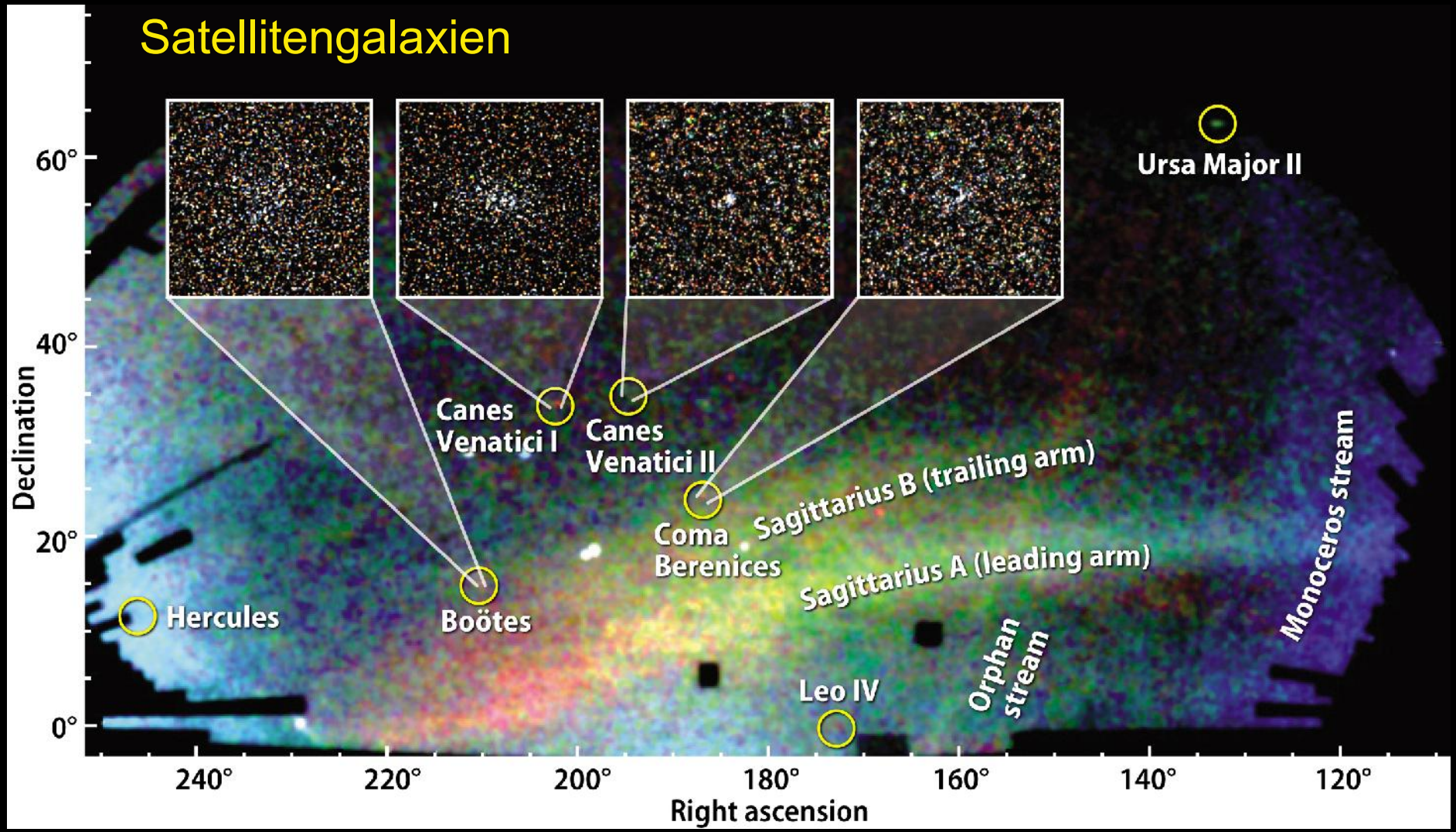


DM Simulation

Räumliche Verteilung/„Clustering“

DM Halos:

Zentrale Galaxie und
Satellitengalaxien

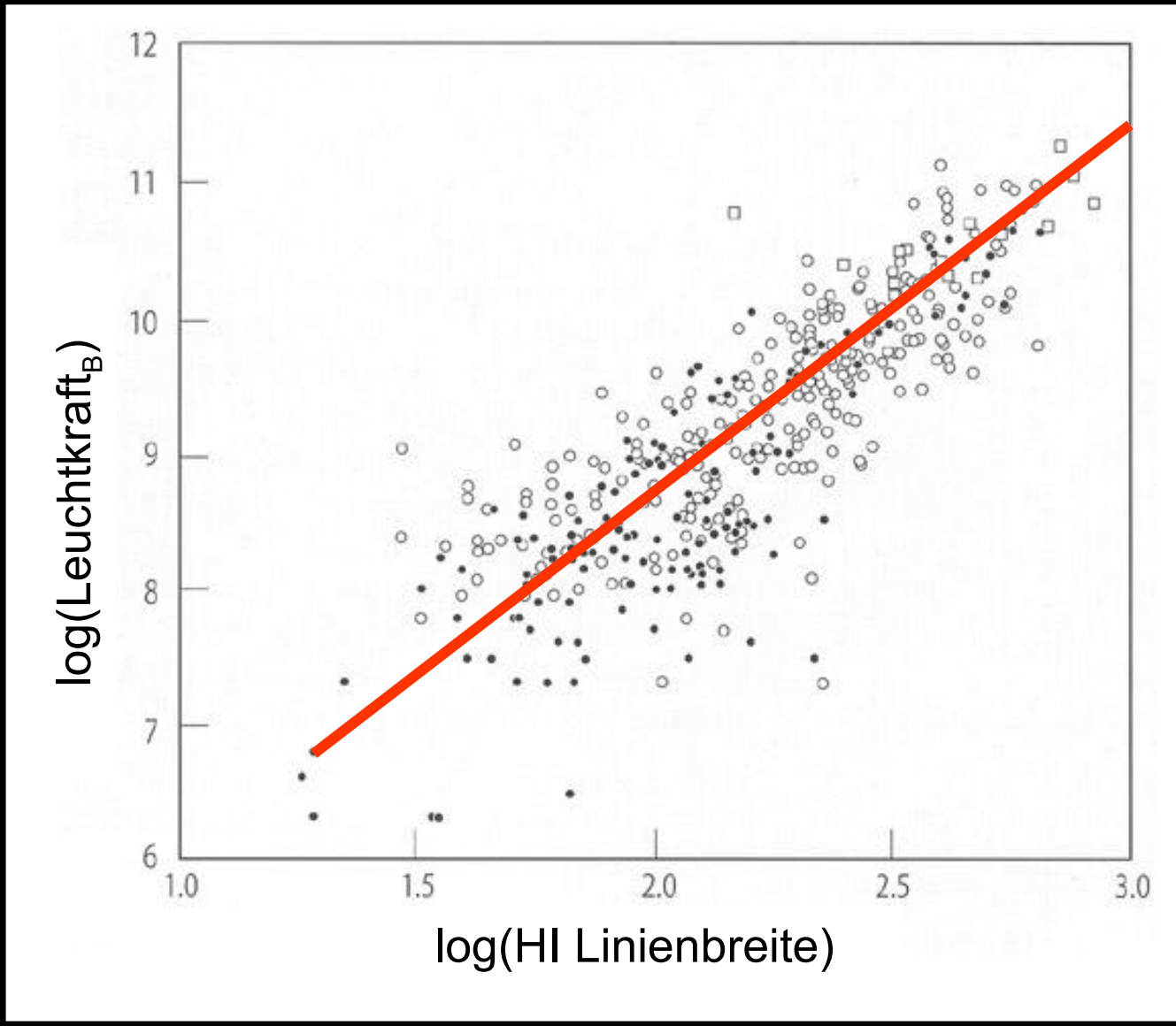


Skalenrelationen

Tully-Fisher-Relation:

Spiralgalaxien:

Leuchtkraft ~ max. Rotations-geschwindigkeit

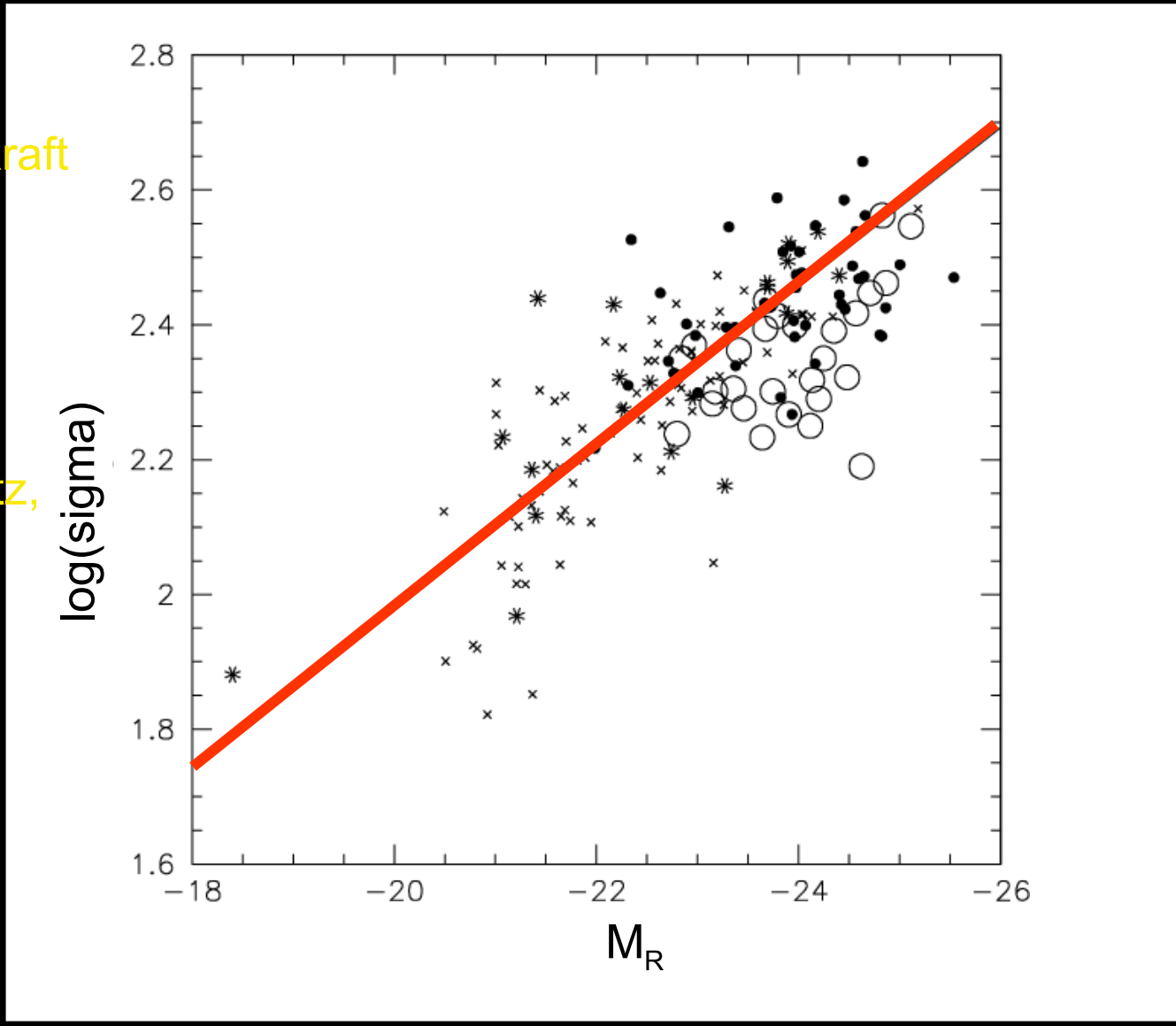


Skalenrelationen

Faber-Jackson-Relation:

Elliptische Galaxien:
Geschwindigkeits-
dispersion ~ Leuchtkraft

(ergibt sich aus Virialsatz,
2T=-U)



Skalenrelationen

Fundamental-Plane:

$$R_e,\ \sigma_0,\ \langle\mu\rangle_e$$

R_e = effektiver Radius

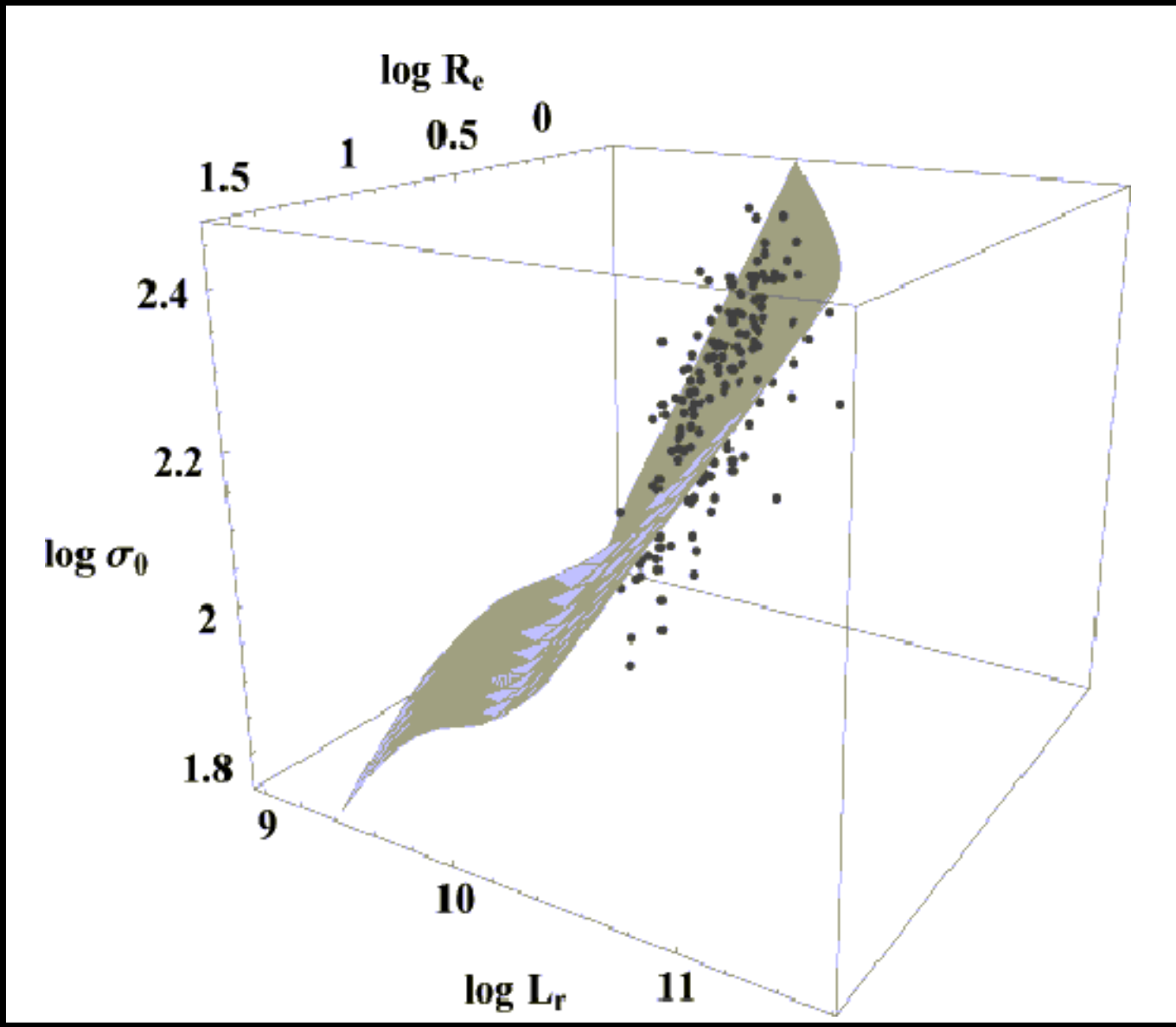
σ_0 = zentrale Geschwindigkeitsdispersion

$\langle\mu\rangle_e$ = mittl. Flächenhelligkeit innerhalb R_e

$$\log(R_e) = 0.34\langle\mu_e\rangle + 1.4\log\sigma_e + \text{const.}$$

Skalenrelationen

Fundamental-Plane



Skalenrelationen

Fundamental-Plane:

$$R_e,\ \sigma_0,\ \langle\mu\rangle_e$$

R_e = effektiver Radius

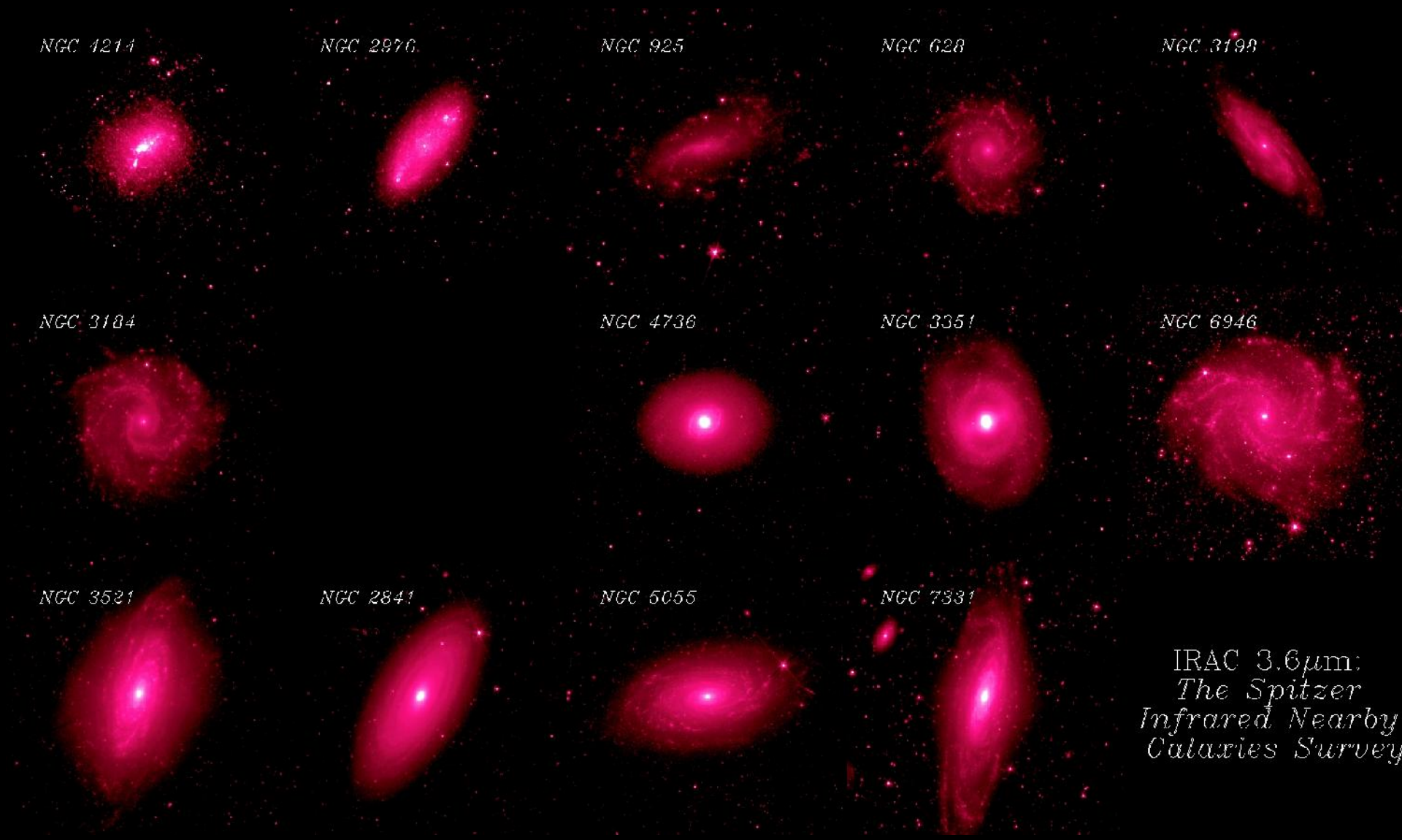
σ_0 = zentrale Geschwindigkeitsdispersion

$\langle\mu\rangle_e$ = mittl. Flächenhelligkeit innerhalb R_e

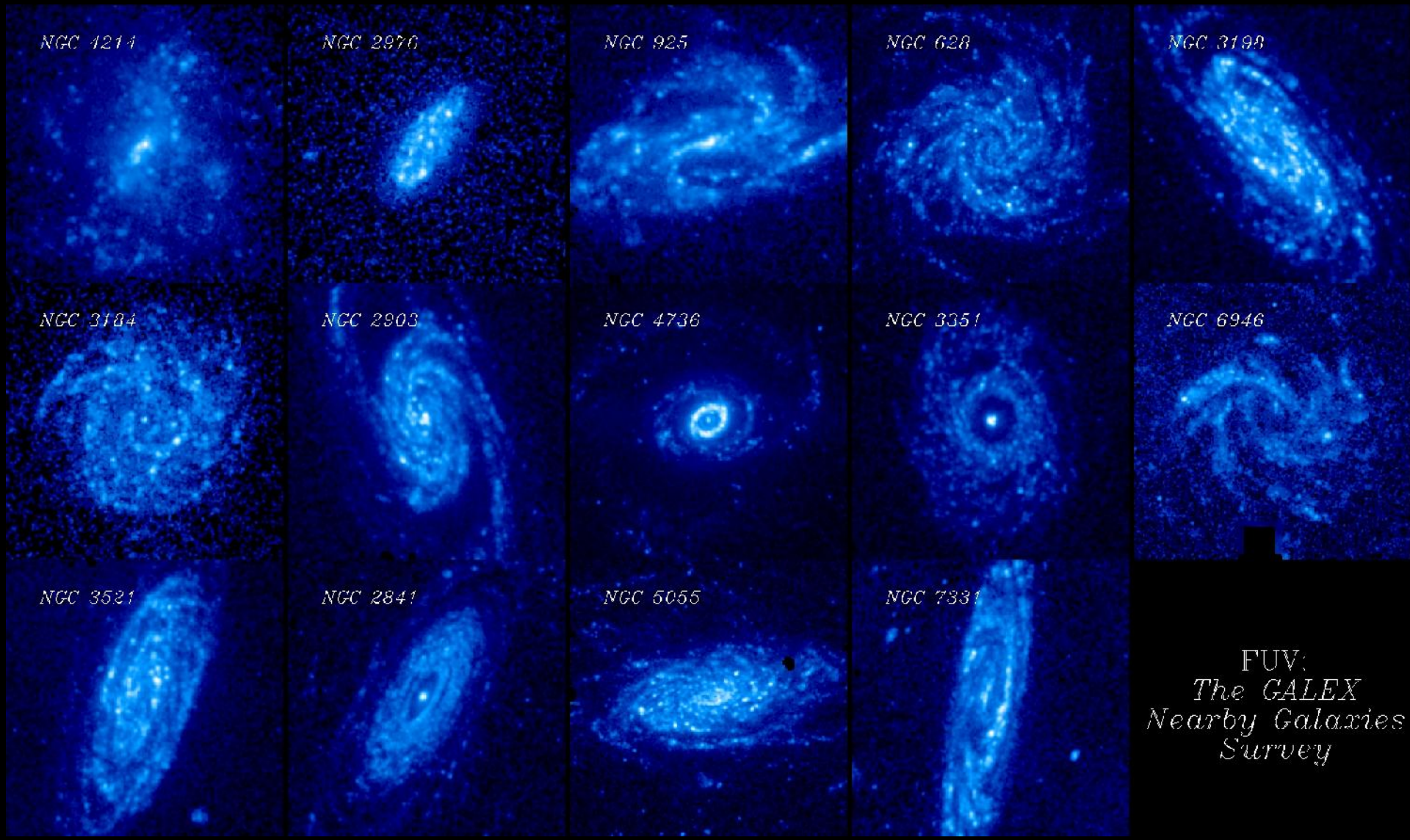
$$\log(R_e) = \cdot.34\langle\mu_e\rangle + 1.4\log\sigma_e + \text{const.}$$

Vertiefung: stellare Populationen

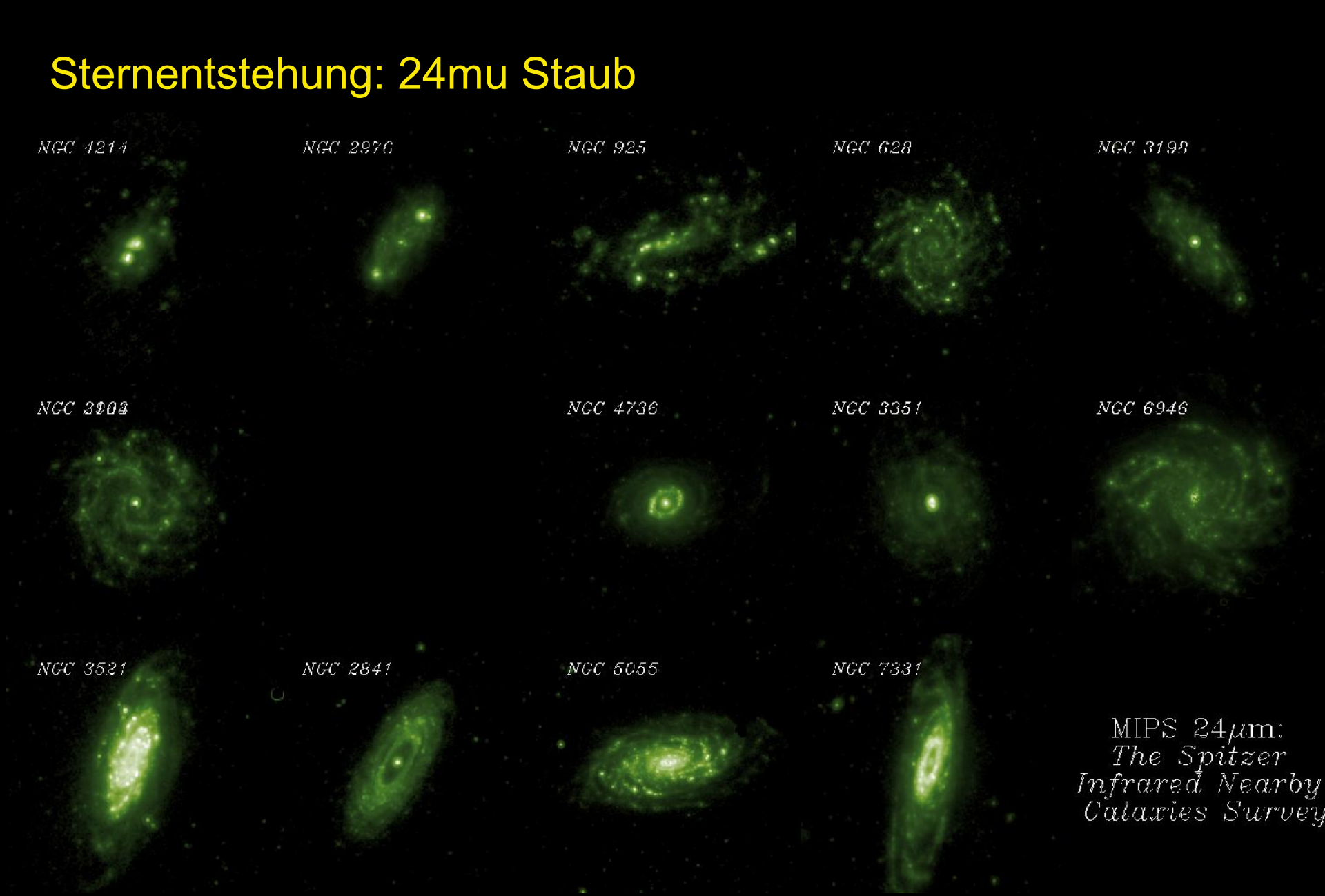
NIR = stellare Masse



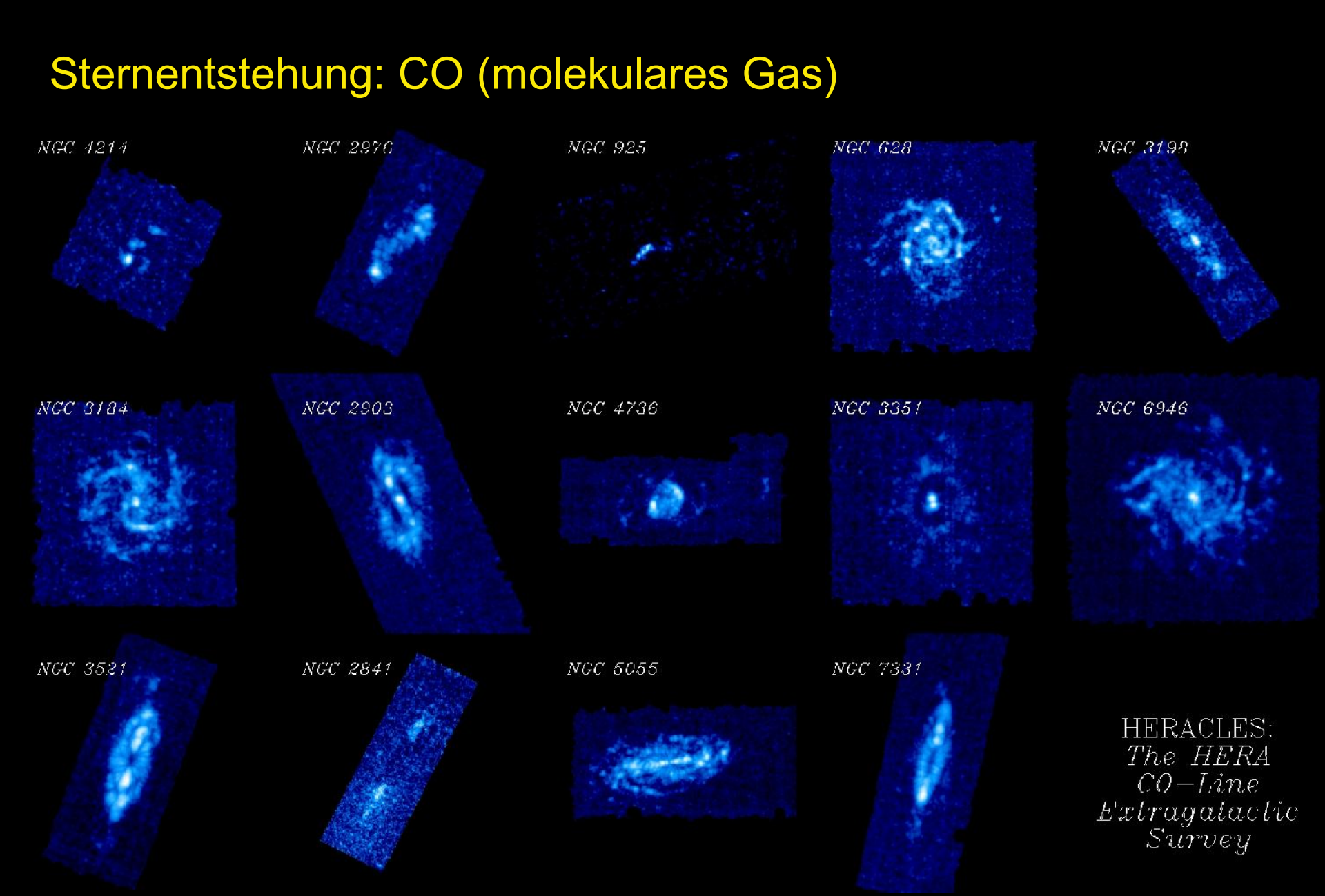
Sternentstehung: fernes UV



Sternentstehung: 24mu Staub



Sternentstehung: CO (molekulares Gas)



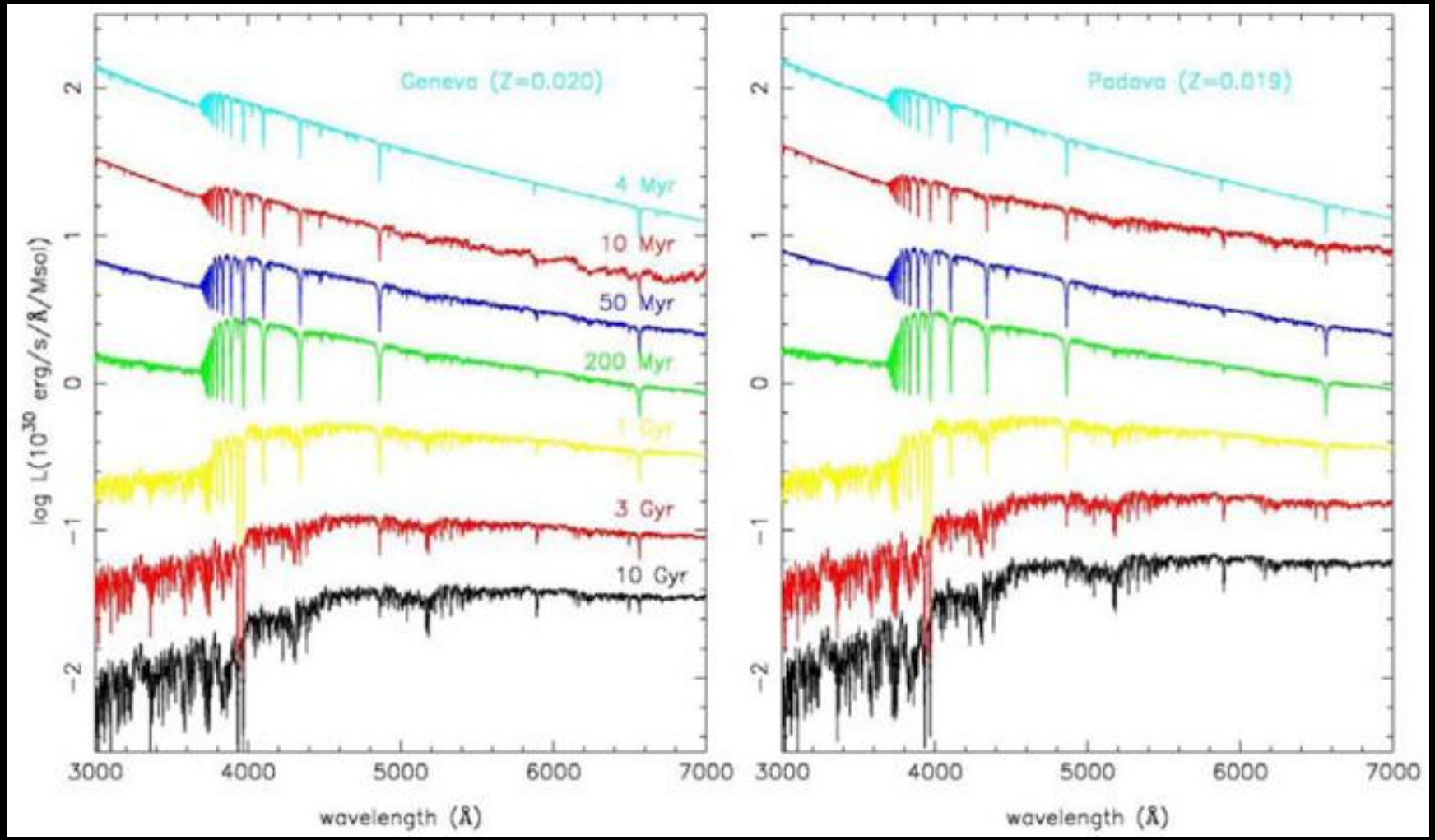
Sternentstehung & stellare Populationen

Sternentstehung:

- Indikatoren:
  - MIR Emission (stellare Winde=geheizter Staub)
  - UV Licht (direkte Emission)
  - Emissionslinien (direkte Emission des ISM)
  - junge Sterne

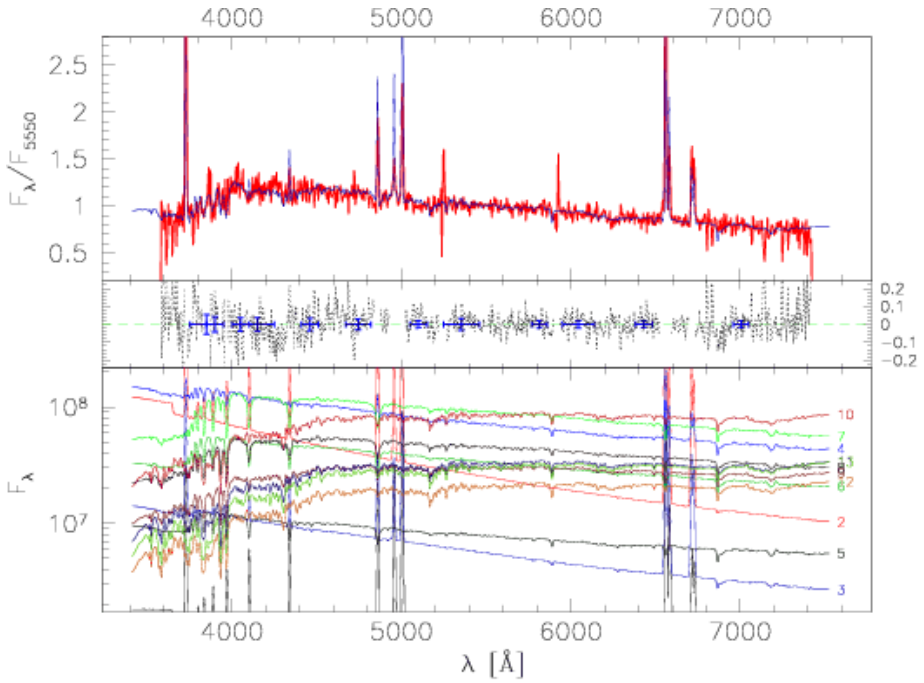
Sternentstehung & stellare Populationen

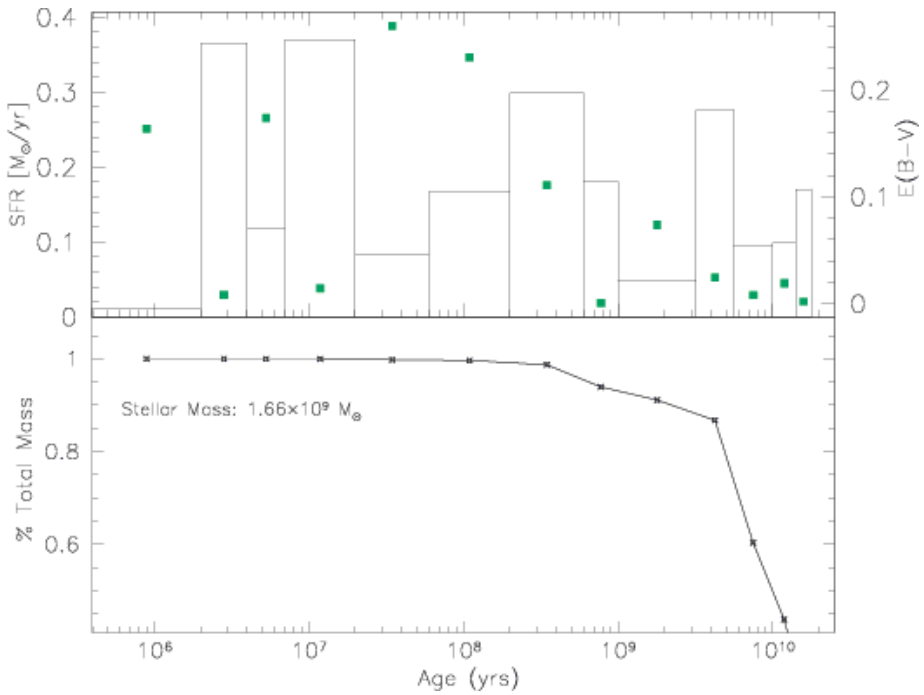
Spektralanalyse: Populationssynthese



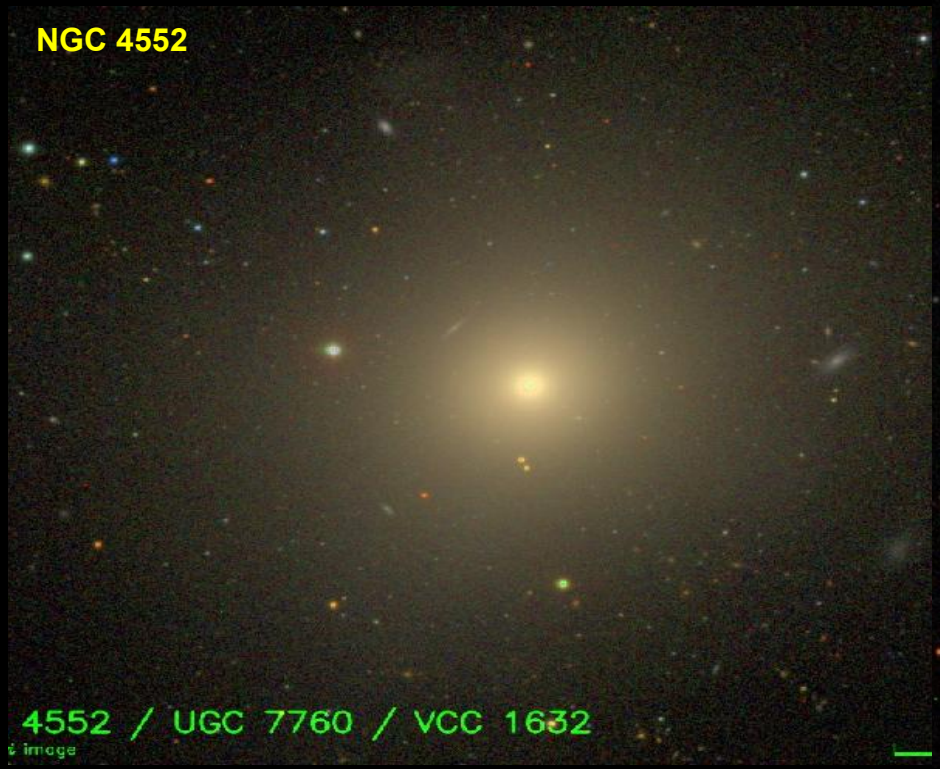
Sternentstehung & stellare Populationen

Spektralanalyse: Emissionlinien, Populationssynthese

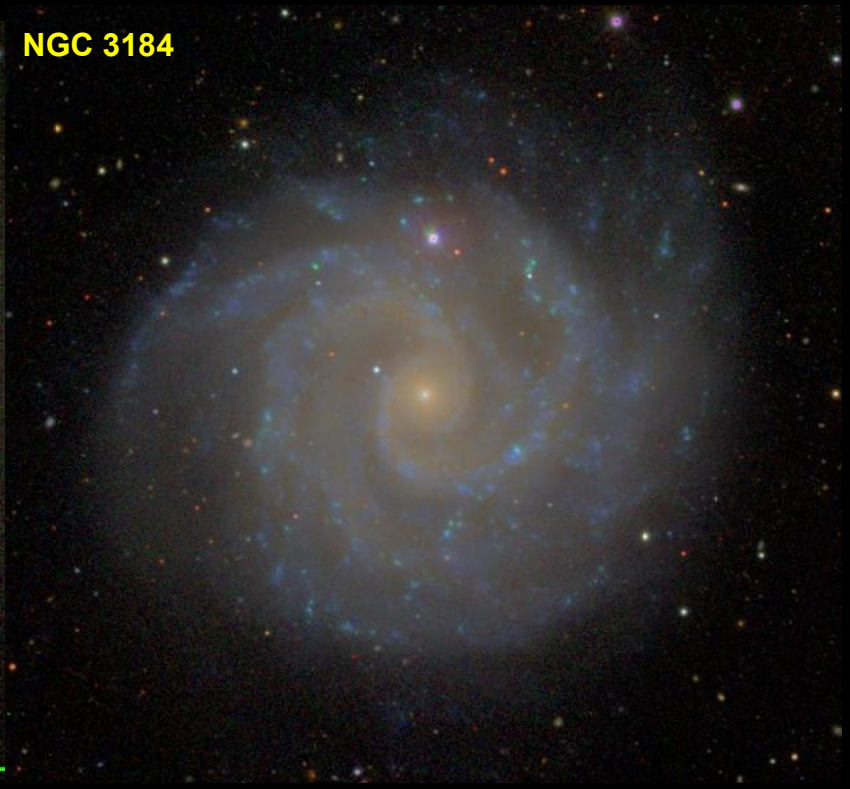




Sternentstehung & stellare Populationen



Elliptische Galaxie (E)



Spiralgalaxie (S…)

Sternentstehung & stellare Populationen

Spiralgalaxien

- Sternentstehung
- alte Sterne
- auch junge Sterne
- blaue Farben
- Staub, Gas
- kinematisch kalt
- flach
- eher weniger dichte Umgebung
- eher niedrigere Massen

Elliptische Galaxien

- Keine Sternentstehung
- alte Sterne
- keine jungen Sterne
- rote Farben
- wenig Staub, Gas
- kinematisch heiß
- rund
- eher dichtere Umgebungen
- eher höhere Massen
- Endzustand der Galaxienentwicklung