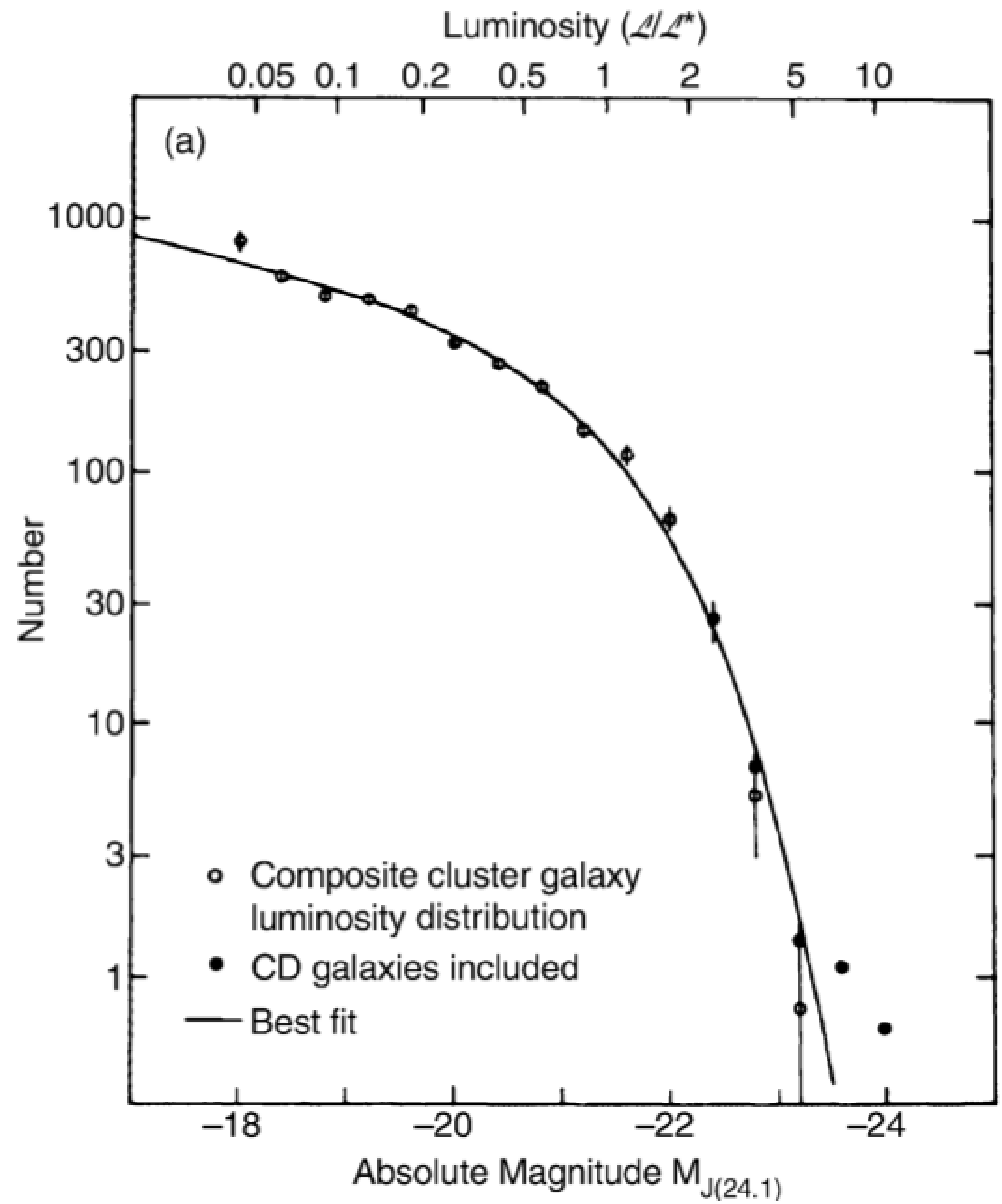
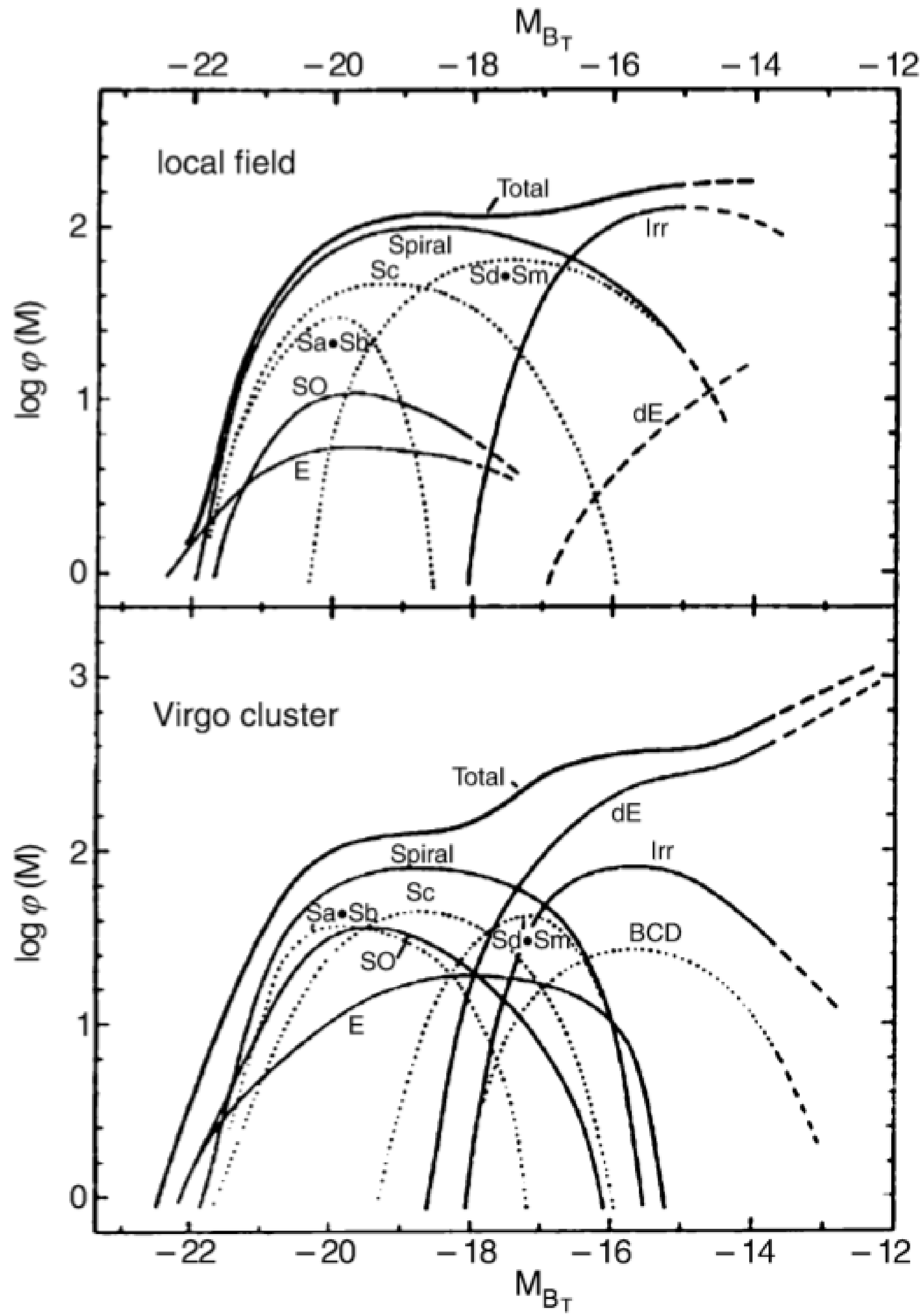
Galactic and Extragalatic Astronomy
AA 472/672
Spring Semester

Instructor: Manoneeta Chakraborty
Email: manoneeta@iiti.ac.in

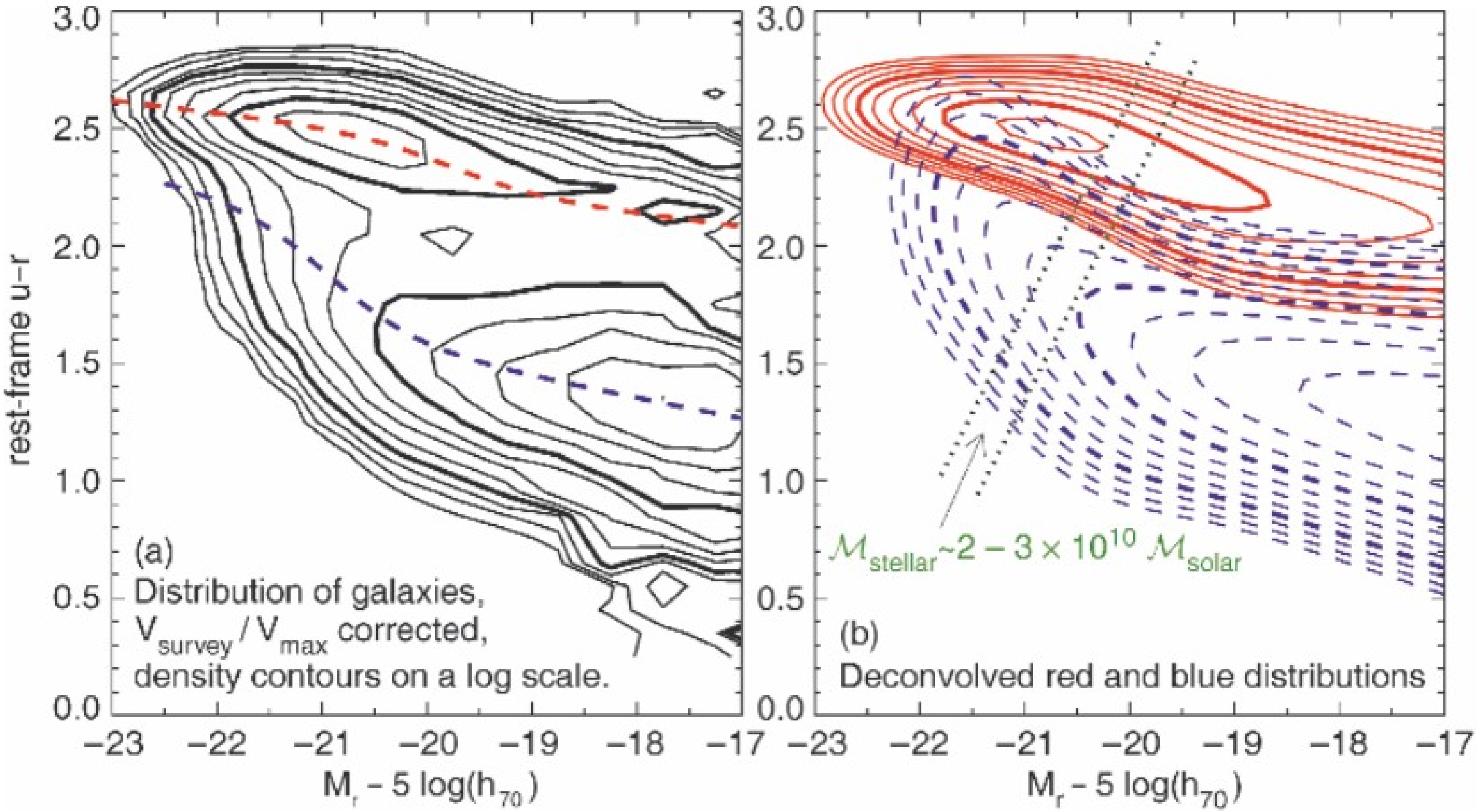
Reference : S&G, Schneider, http://www.astro.yale.edu/astro310/



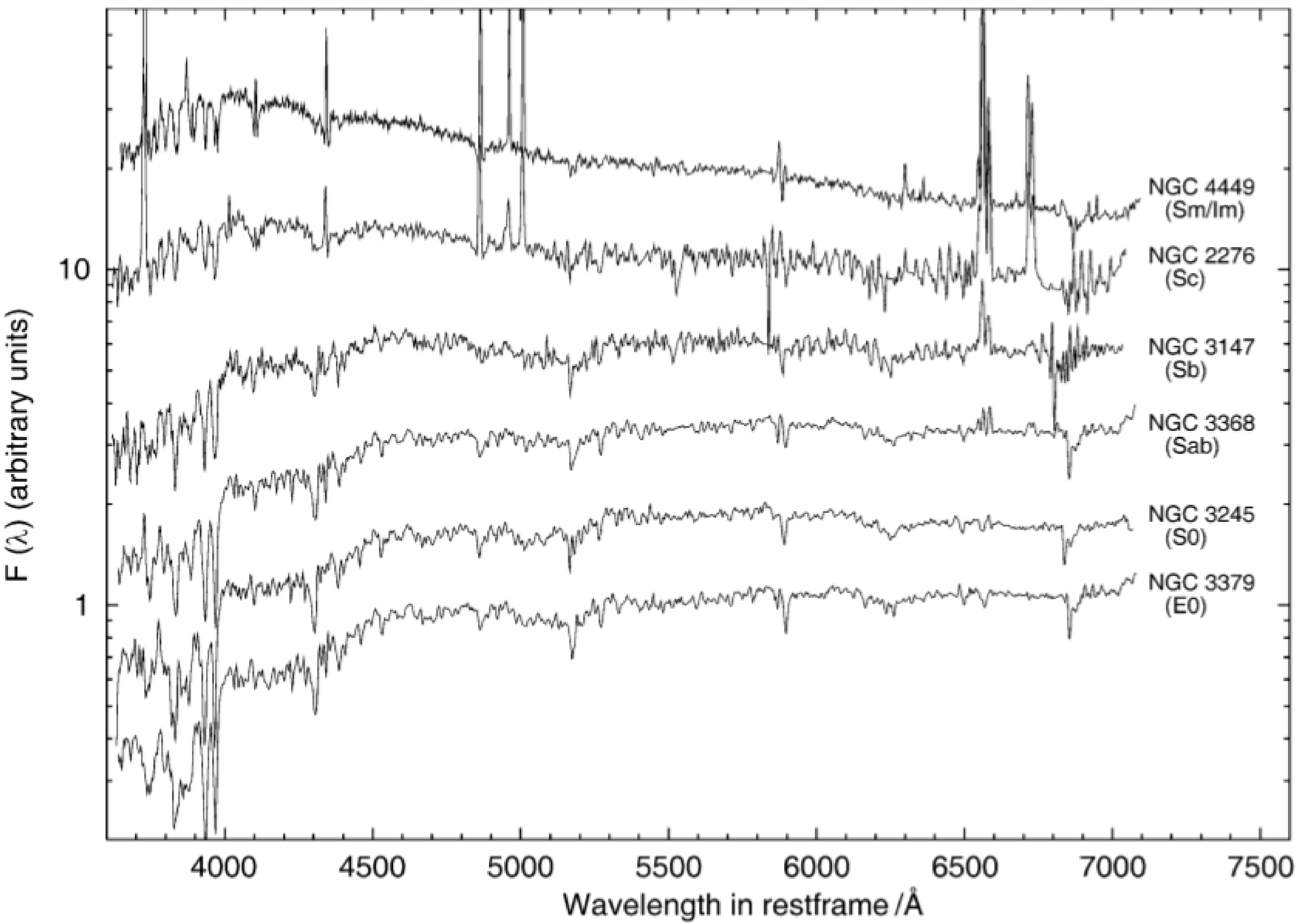
Luminosity ($\mathcal{L}/\mathcal{L}^*$)
0.05
0.1
0.2
0.5
1
2
5
10
(a)
1000
300
100
30
10
3
1
Number
Composite cluster galaxy luminosity distribution
CD galaxies included
Best fit
−18
−20
−22
−24
Absolute Magnitude $M_{J(24.1)}$



M_{B_T}
−22
−20
−18
−16
−14
−12
local field
Total
Spiral
Irr
Sc
Sd•Sm
Sa•Sb
SO
E
dE
log φ (M)
0
1
2
3
Virgo cluster
Total
dE
Spiral
Irr
Sc
Sa•Sb
SO
Sd•Sm
BCD
E
M_{B_T}



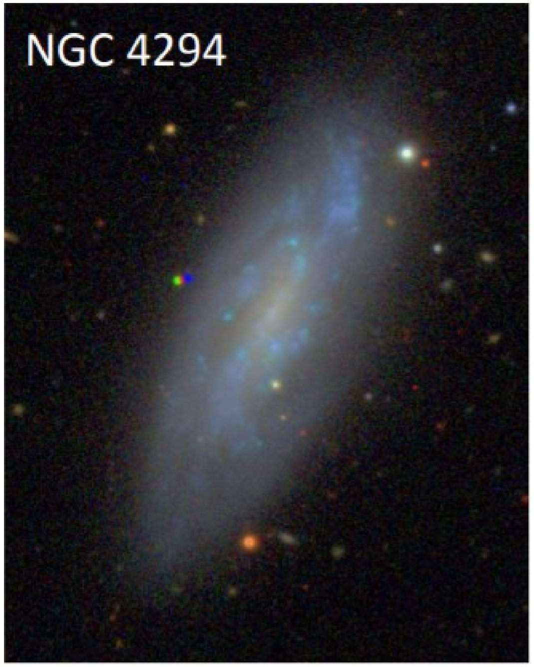
rest-frame u−r
(a)
Distribution of galaxies,
V_{survey} / V_{max} corrected,
density contours on a log scale.
$M_r - 5 \log(h_{70})$
$\mathcal{M}_{stellar} \sim 2 - 3 \times 10^{10}\ \mathcal{M}_{solar}$
(b)
Deconvolved red and blue distributions
$M_r - 5 \log(h_{70})$



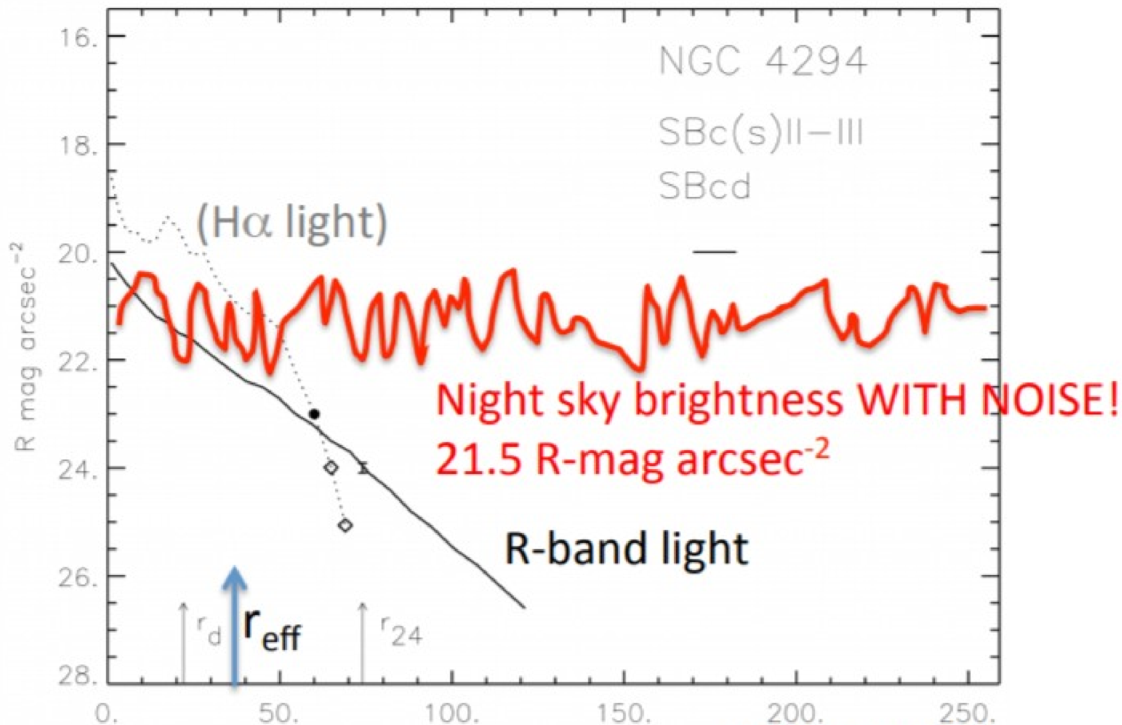
NGC 4449
(Sm/Im)
NGC 2276
(Sc)
NGC 3147
(Sb)
NGC 3368
(Sab)
NGC 3245
(S0)
NGC 3379
(E0)
F (λ) (arbitrary units)
10
1
4000
4500
5000
5500
6000
6500
7000
7500
Wavelength in restframe /Å

Observing Galaxies

- Photons detected in each pixel varies with time due to statistical nature of emission processes
- Noise from "sky" often exceeds average signal from astronomical source



SDSS Hogg website



Koopmann+2001

- Stars and the sky and other things produce photons in a random Poisson process, so that there are random variations in the number of photons which strike a detector each second

- The background sky brightness needs to be subtracted to obtain emission from major portion of the galaxy

- Both galaxy and background emission comes with random fluctuations

- Signal (avg #photons detected) $S \sim t$ (t= integration time) [Assuming stable emission]

- Noise ?

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- Signal (avg #photons detected) $S \sim t$ (t= integration time) [Assuming stable emission]

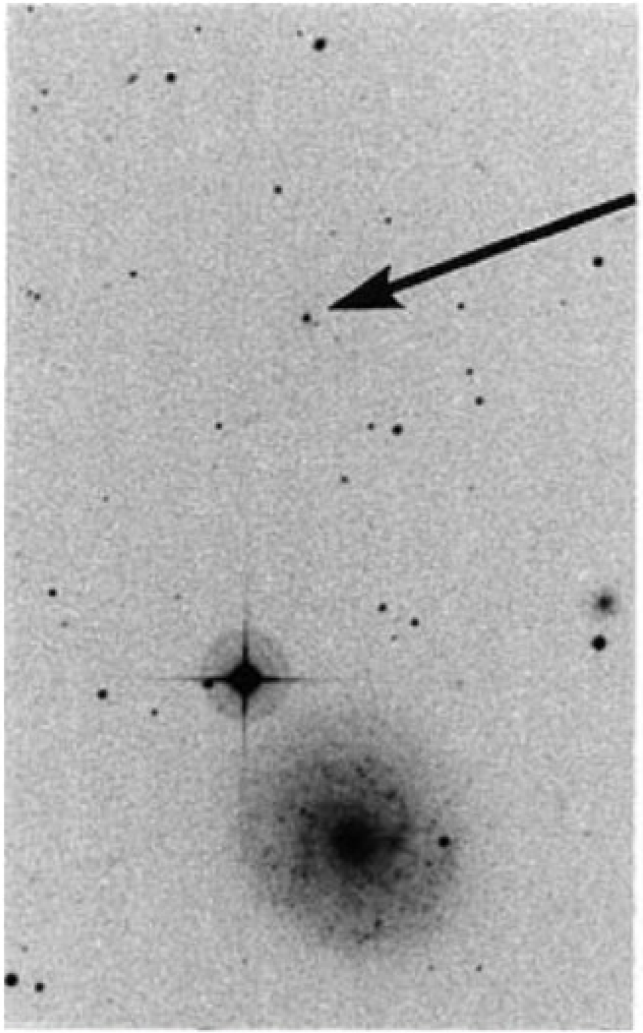
- Noise ?

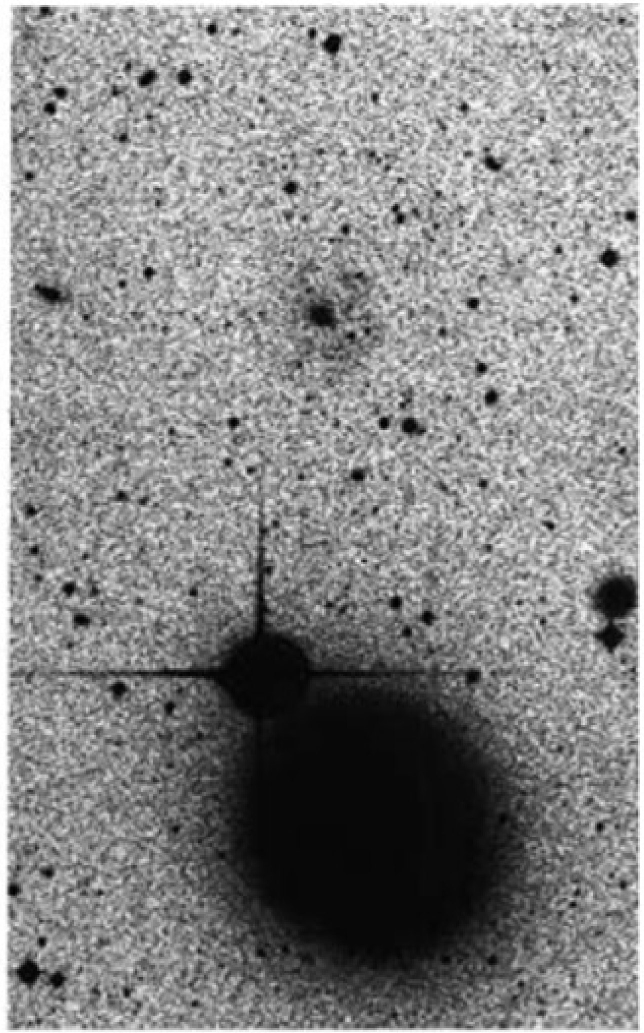
- Noise (variation in #photons detected) $N \sim \sqrt{S} \sim \sqrt{t}$

    - Signal-to-noise ratio $S/N \sim S/\sqrt{S} \sim \sqrt{S} \sim \sqrt{t}$

    → Increasing integration time helps to a certain extent → deeper observations

- Possibly there are lots of galaxies that are fainter than the night sky, and therefore very hard to detect!

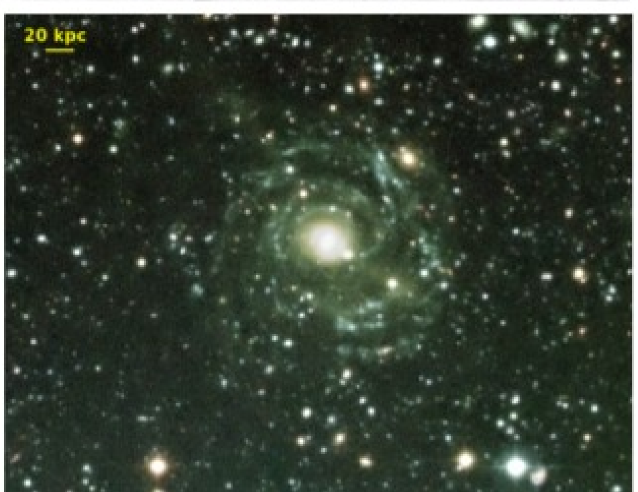




Low surface brightness galaxy Malin 1

$I(0)_{disk} = 26.5$ mag arcsec^{-2}
Center of disk is 100x (=5 mags) fainter than "Freeman's Law" !!

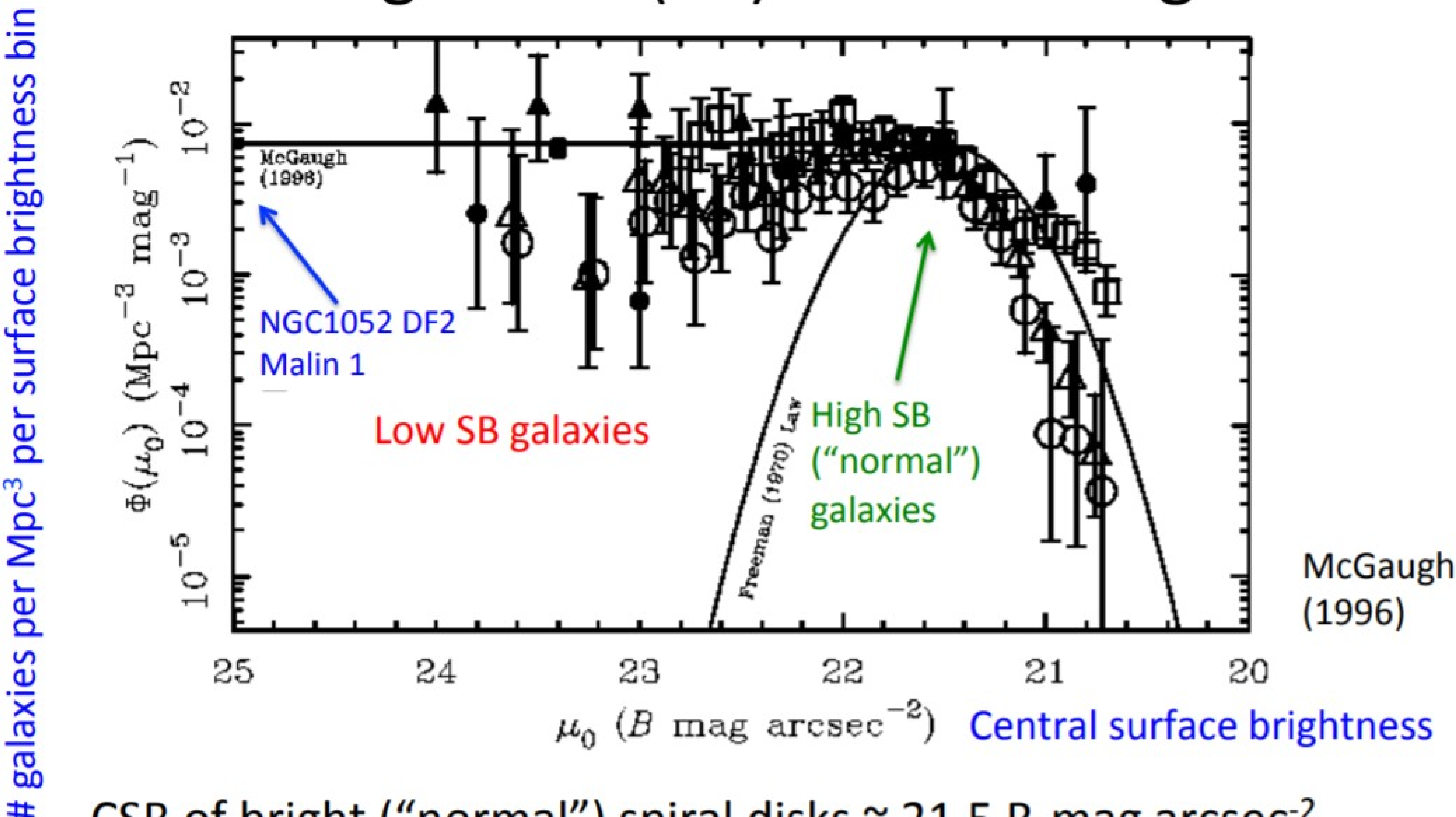
Yet V_{max} =300 km/s so it's a massive galaxy



very deep image of Malin 1

A large & massive spiral galaxy that is fainter than the night sky everywhere but very center (bulge)!

Surface brightness (SB) function of galaxies

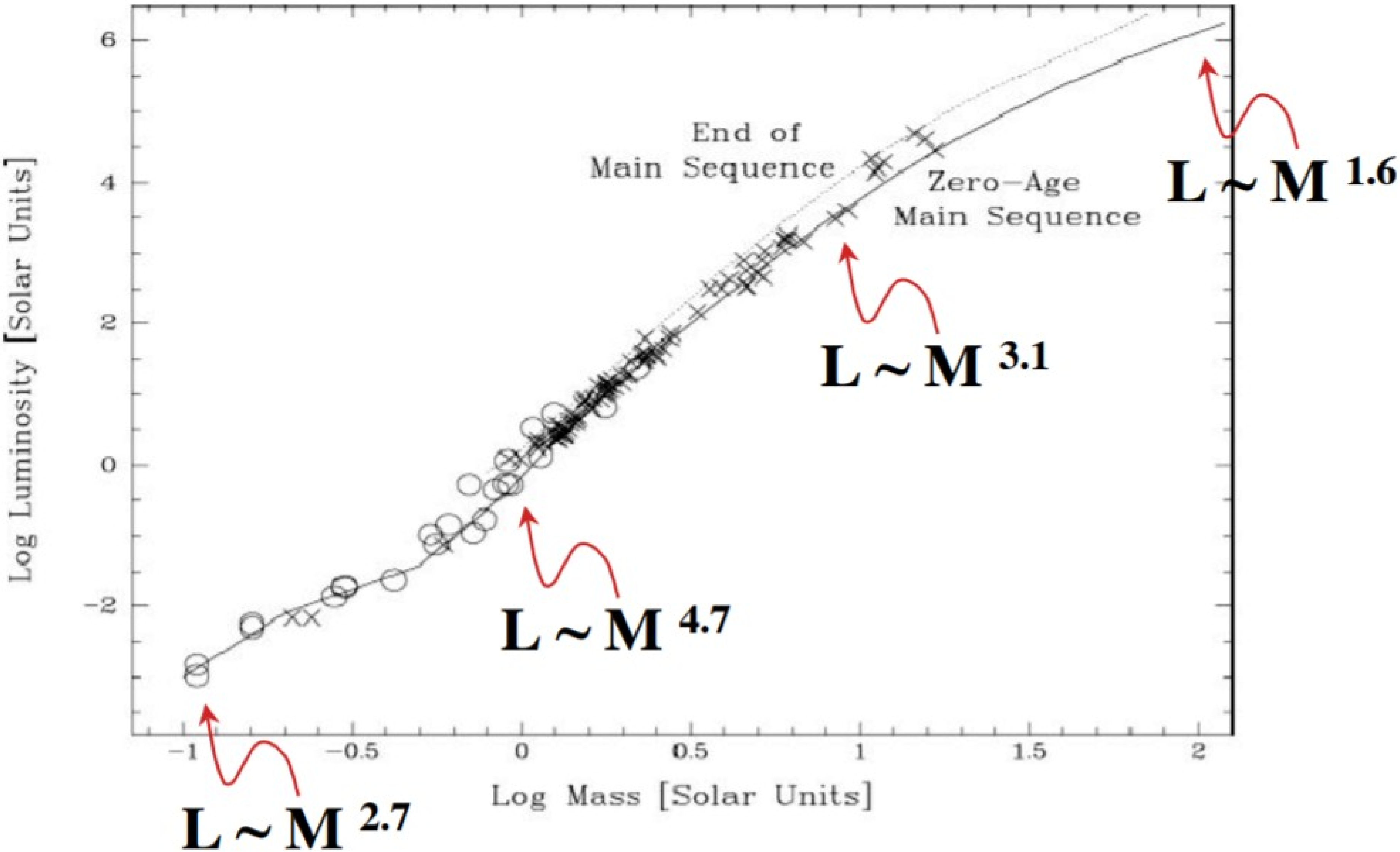


CSB of bright ("normal") spiral disks ~ 21.5 B-mag arcsec^{-2}

Low surface brightness galaxies are common

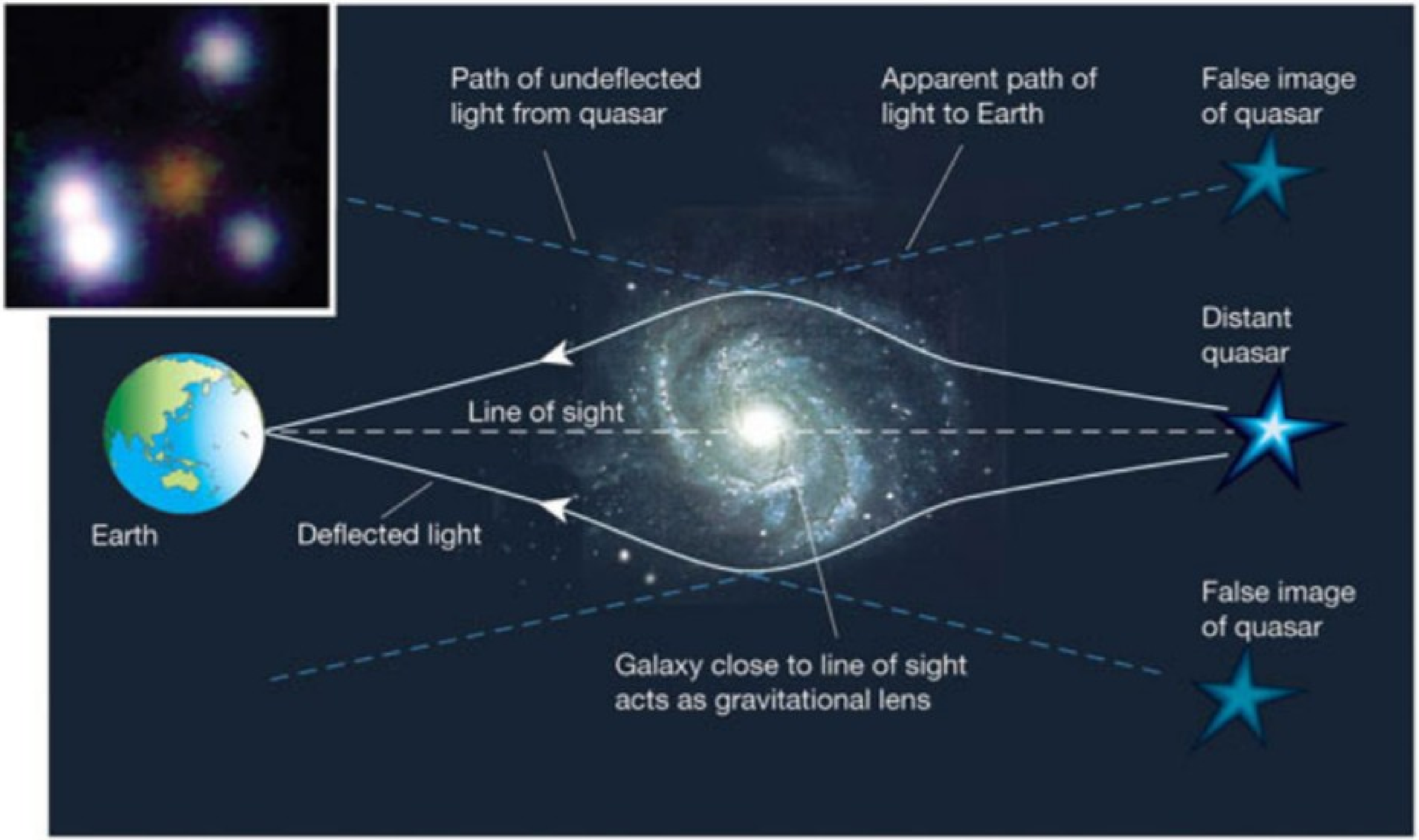
The Mass-Luminosity Relation

Use it to convert stellar luminosities into masses

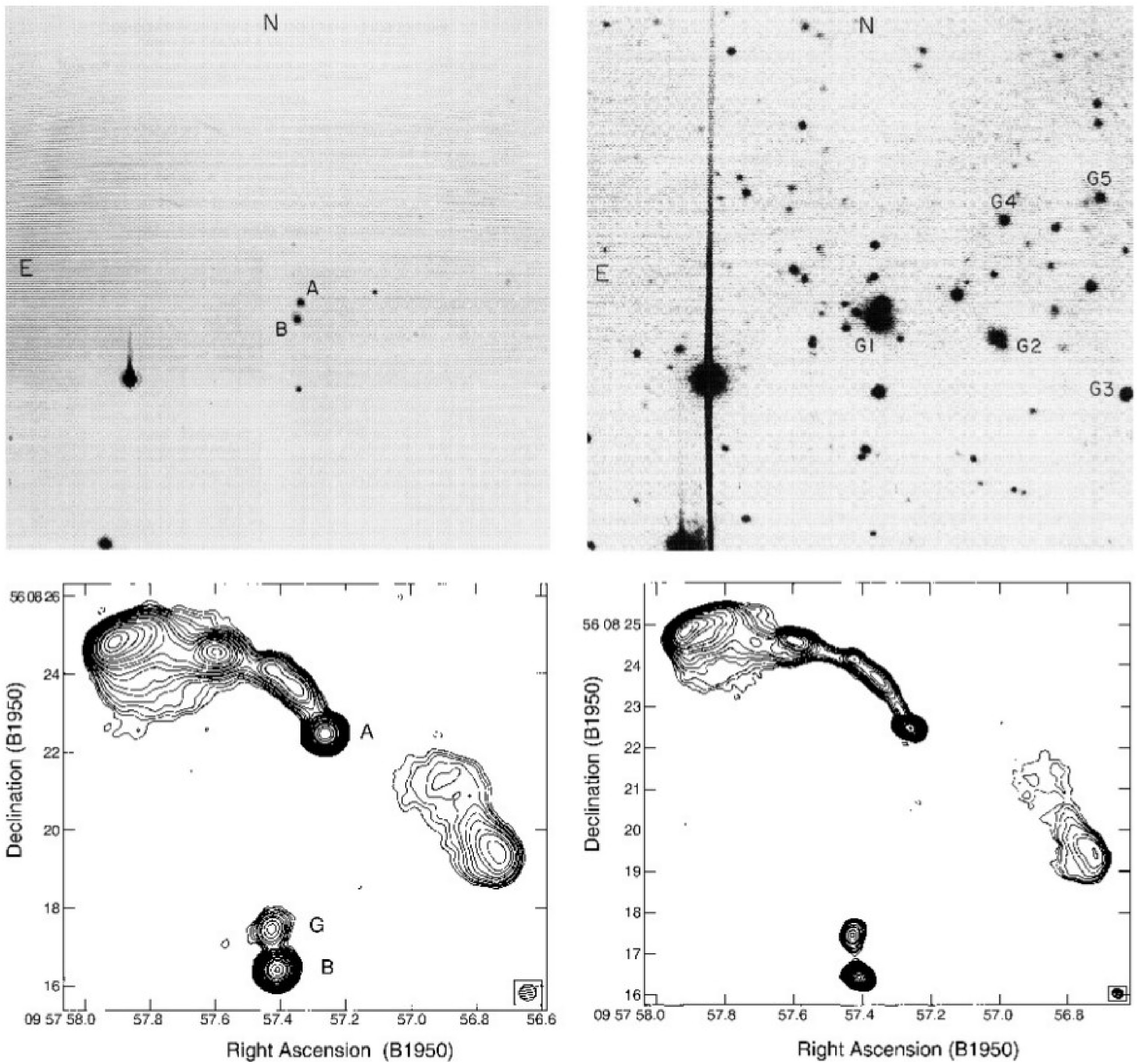


Lenses

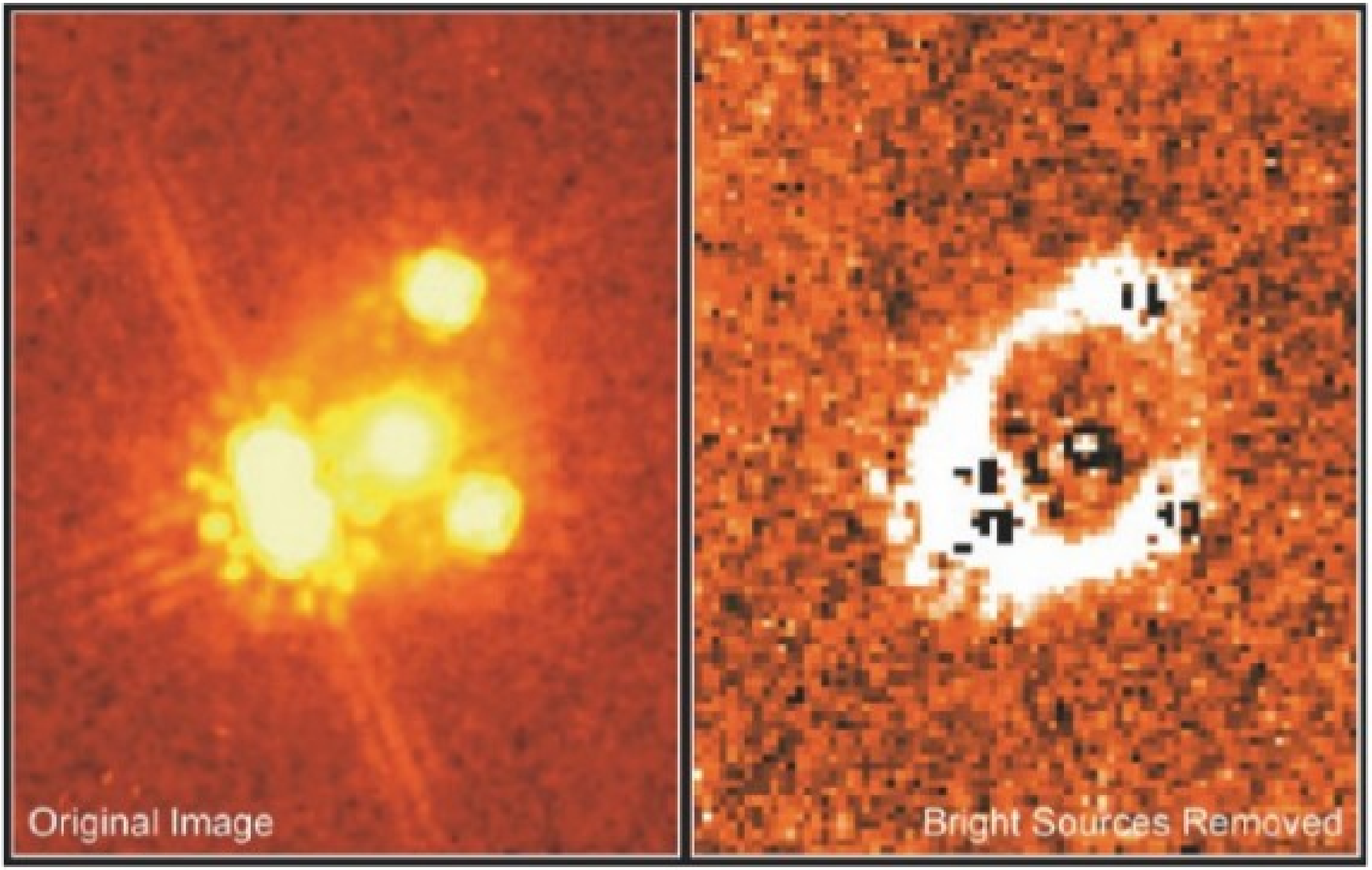
How gravitational lenses work



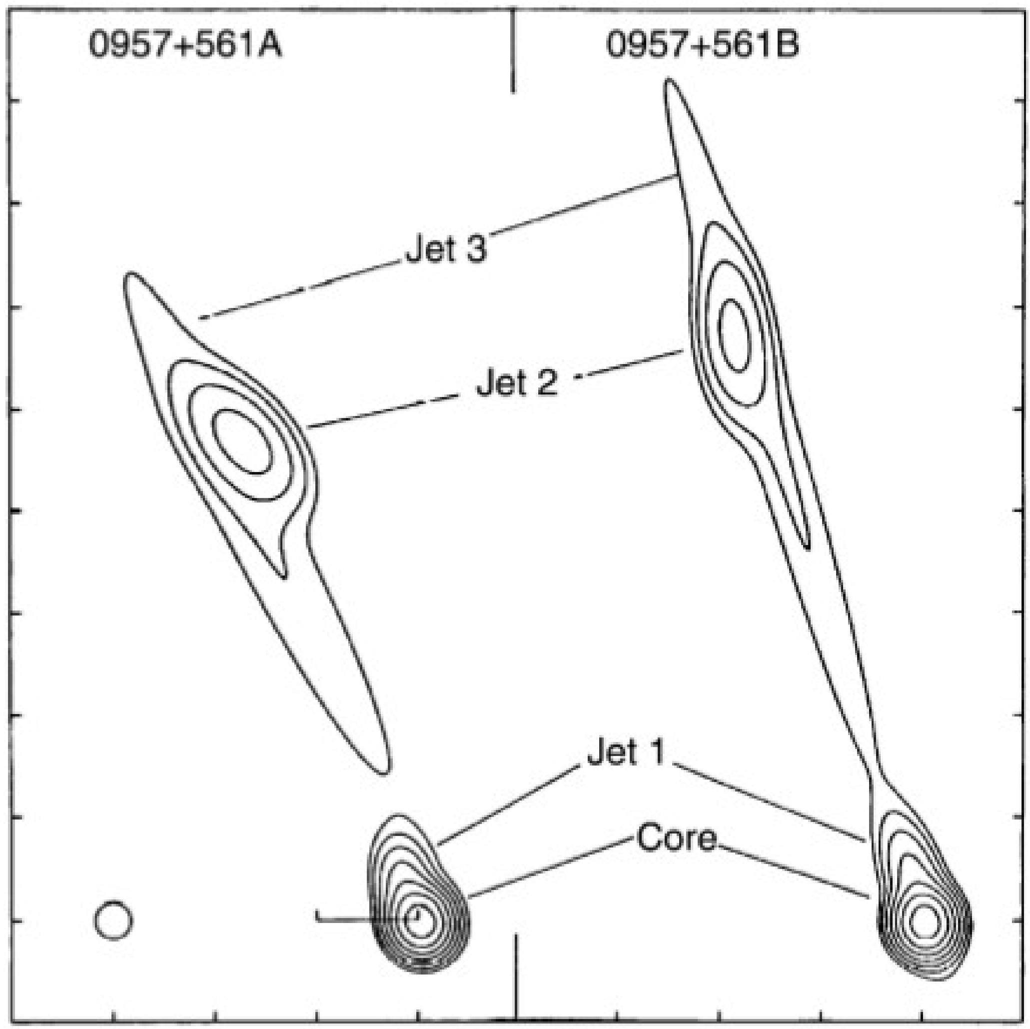
- Amount of bending depends on mass of “lens”
- Total mass of “lens” can be measured from amount of bending



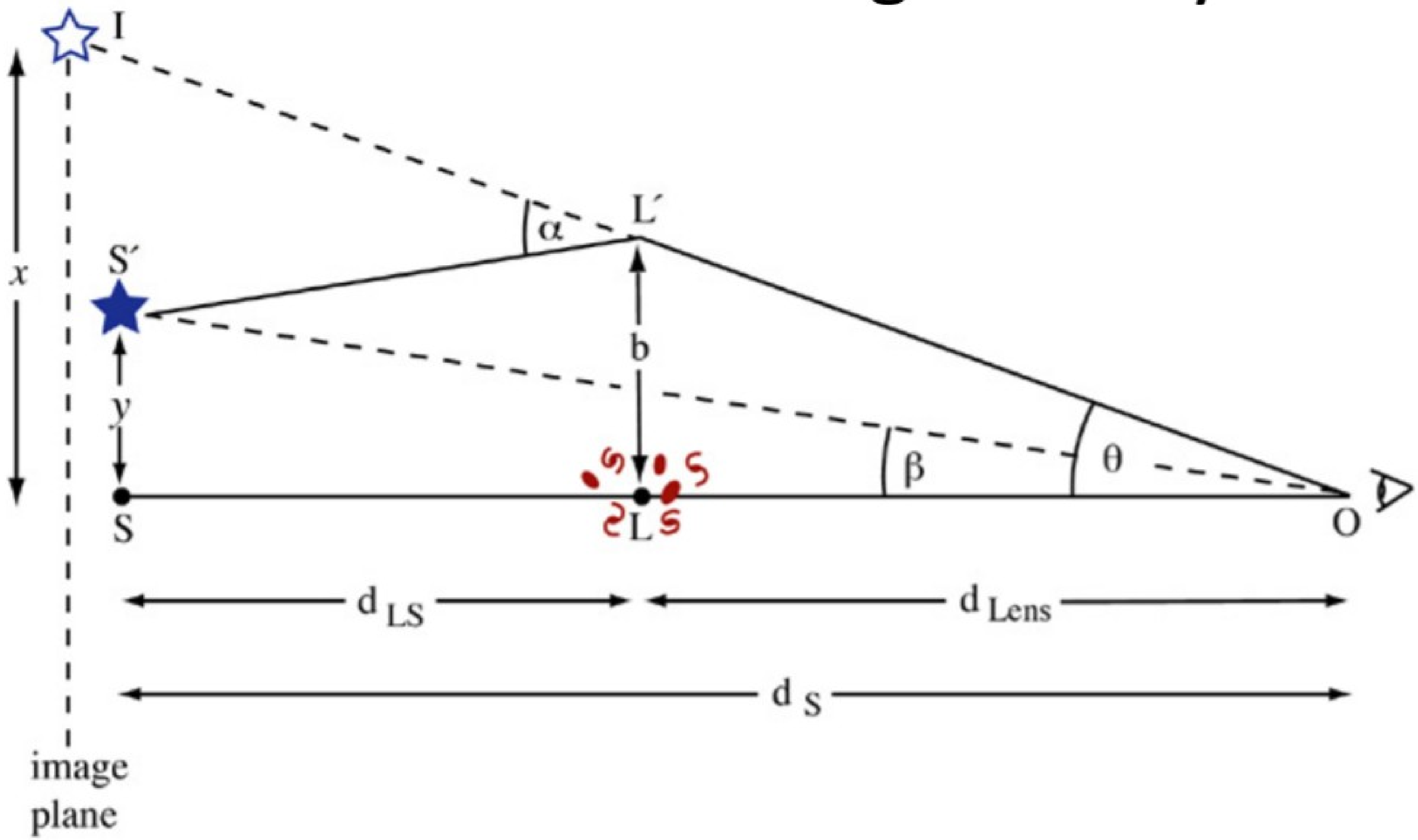
N
E
A
B
N
E
G1
G2
G3
G4
G5
56 08 26
24
22
20
18
16
Declination (B1950)
A
G
B
09 57 58.0
57.8
57.6
57.4
57.2
57.0
56.8
56.6
Right Ascension (B1950)
56 08 25
24
23
22
21
20
19
18
17
16
Declination (B1950)
09 57 58.0
57.8
57.6
57.4
57.2
57.0
56.8
Right Ascension (B1950)


Original Image
Bright Sources Removed

VLBI Observations of 0957 + 561



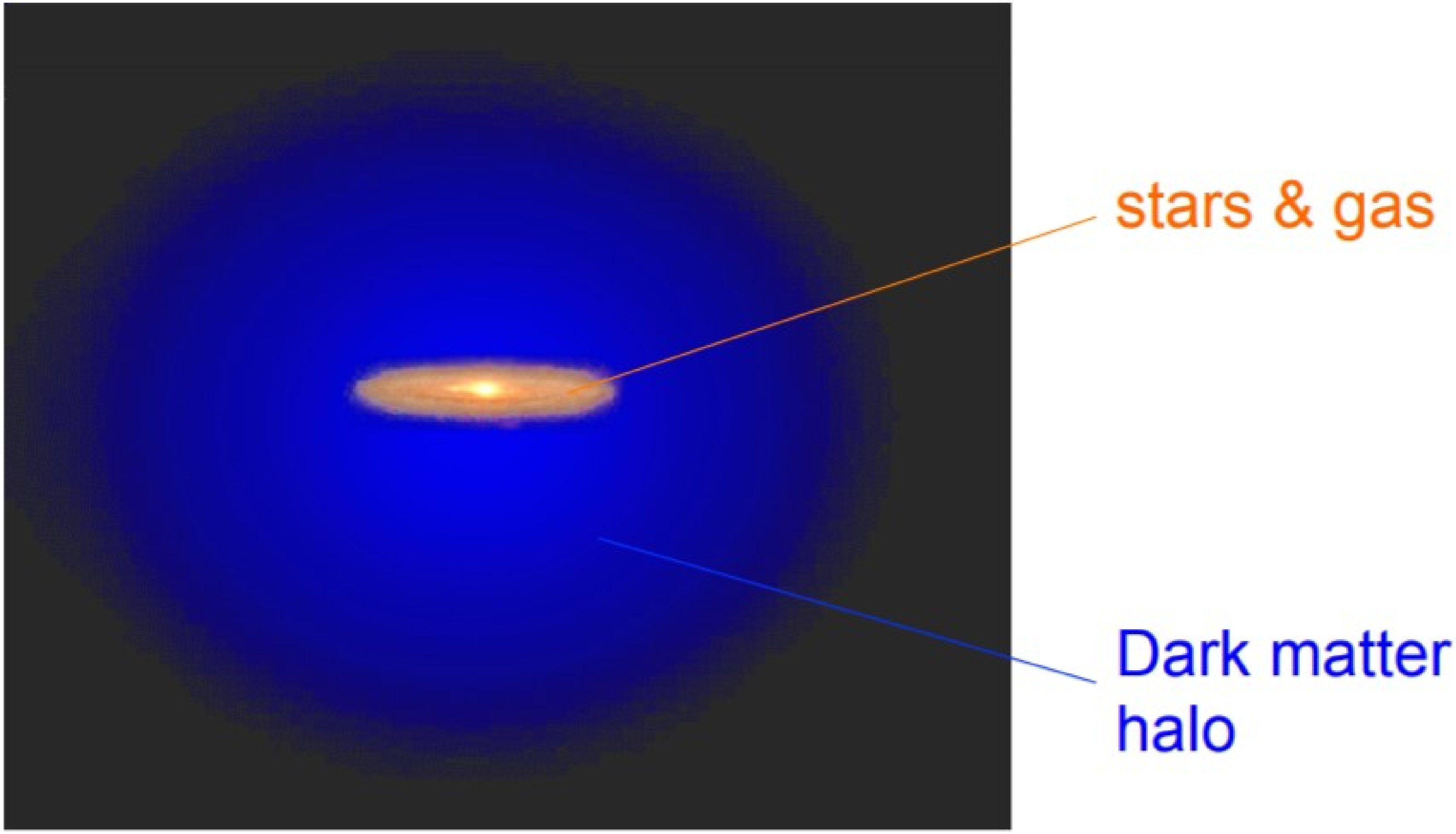
Gravitational lens geometry



Deflection angle α depends on mass M and distance of closest approach b

$\alpha \approx 4GM / bc^2 = 2R_S/b$

Cartoon of galaxy with dark matter halo



Normal matter is centrally concentrated in galaxies
(~15% of total mass)

Dark matter dominates in outer parts (~85% of total mass)

Galaxy masses (and mass distribution) from gravitational lensing

Advantages of lensing:

• Don't need tracer particles in galaxies, can probe potential well beyond location of baryonic tracers (stars & gas) in galaxies → DM

• Doesn't depend on dynamical state of stuff in galaxy, works if galaxy not in equilibrium & orbits of stars & gas disturbed

Disadvantages of lensing:

• Individual galaxies cause weak lensing, with only modest distortions (~1%) to image shapes → must do statistical analysis, requiring 100's-1000's of background galaxies (hard)

• Can't get accurate total mass of individual galaxy from weak lensing, but can get statistical average mass of sample of foreground galaxies by combining weak lensing signals around many foreground galaxies

Make a numerical model describing both the distribution of stars and the way we observe them, to explore the Malmquist bias. If we observe stars down to a fixed apparent brightness, we do not get a fair mixture of all the stars in the sky, but we include more of the most luminous stars. The following method of 'Monte Carlo simulation' is frequently used when a mathematical analysis would be too complex.

(a) Your model sky consists of G-type stars in regions A (70 pc $<$ d $<$ 90 pc), B (90 pc $<$ d $<$ 110 pc), and C (110 pc $<$ d $<$ 130 pc). If the density is uniform, and you have ten stars in region B, how many are in regions A and C (round to the nearest integer)? For simplicity, let all the stars in region A be at d = 80 pc, those in B at 100 pc, and those in C at 120 pc.

G stars do not all have exactly the same luminosity; if the variation corresponds to about 0.3 magnitudes, what fractional change in luminosity is this?

(b) For each of your stars, roll a die, note the number N_1 on the upturned face, and give your star $M_V = M_{V,\odot} + 0.2(N_1 - 3.5)$. You can write a code to calculate this. Next, you can write a code using more stars, place them randomly in space, and choose the absolute magnitudes from a Gaussian random distribution, with mean $M_{V,\odot}$ and variance 0.3.

To 'observe' your sky, use a 'telescope' that can 'see' only stars brighter than apparent magnitude $m_V = 10$; these stars are your sample. How different is their mean absolute magnitude from that for all the stars that you placed in your sky? What is the average distance of all the stars in your sample? Suppose you assumed that your sample stars each had the average luminosity for all the stars in your sky, and then calculated their distances from their apparent magnitudes: what would you find for their average distance? In which sense would you make an error?