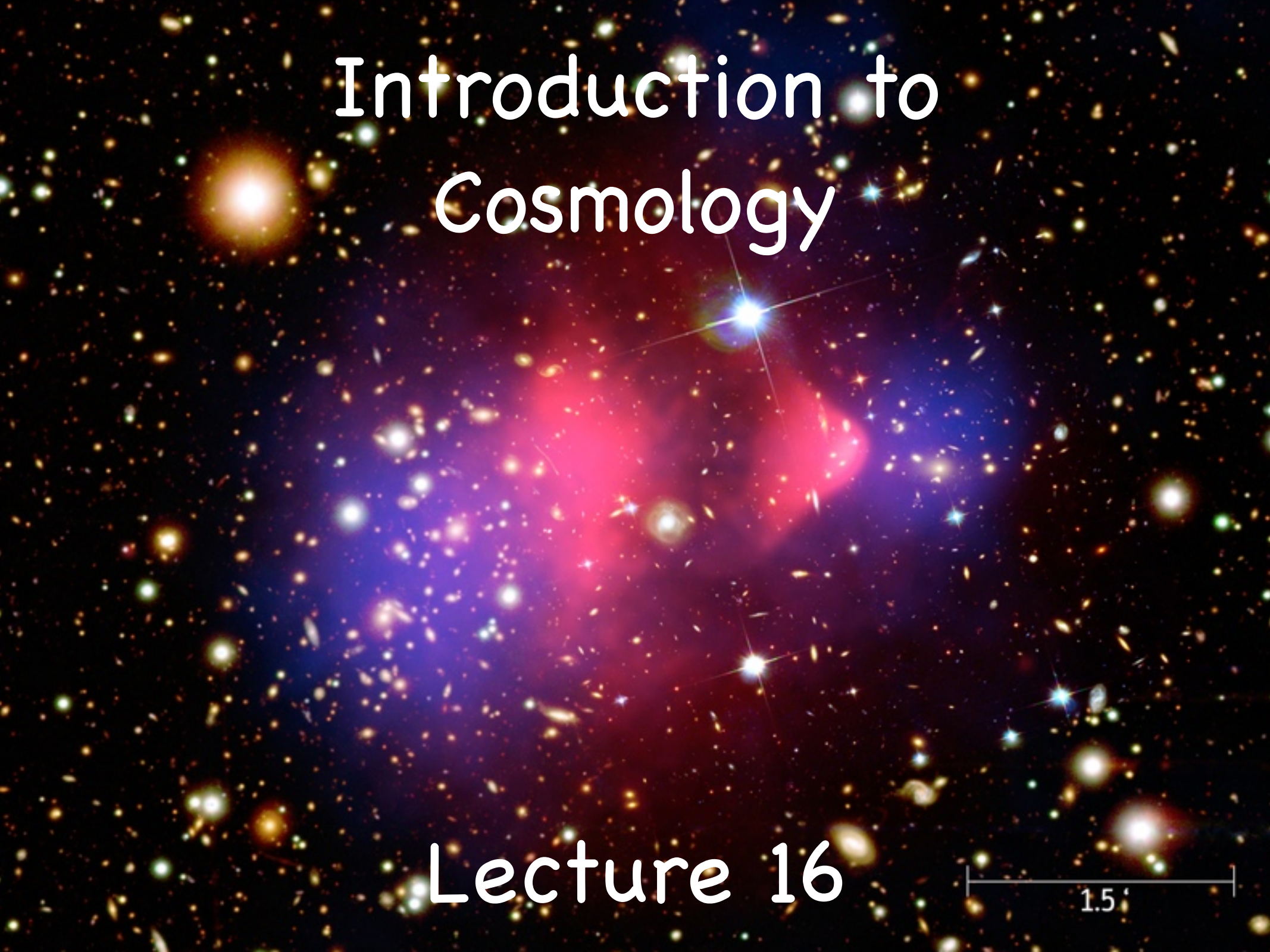
Introduction to Cosmology



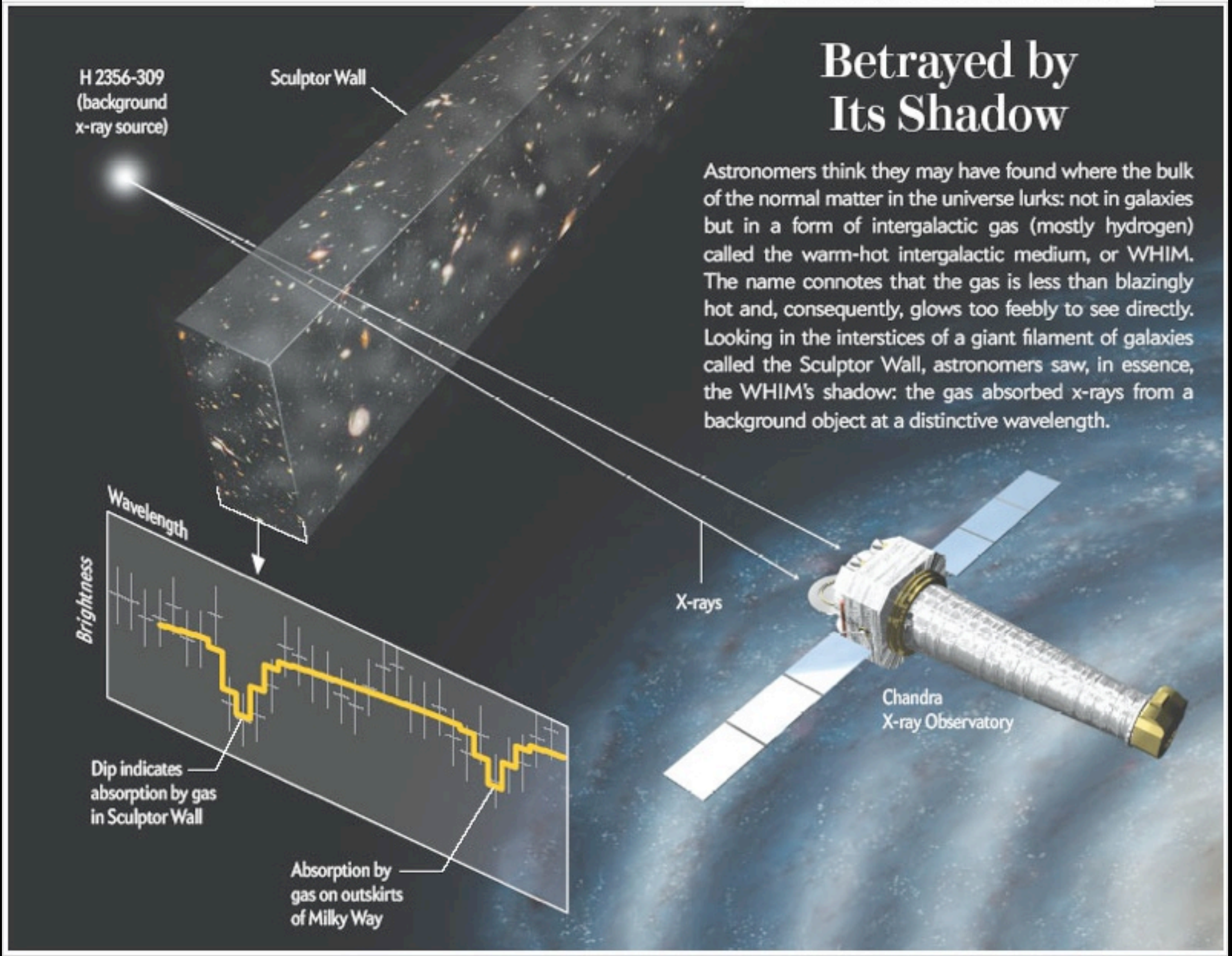
Lecture 16

Table 1.1: Cosmic Inventory

Component	$\boldsymbol{\Omega}$ (ρ/ρ_c)
Dark Energy	$\mathbf{0.691 \pm 0.006}$
Matter (baryonic and non-baryonic)	$\mathbf{0.312 \pm 0.009}$
Baryons (Total)	$\mathbf{0.0488 \pm 0.0004}$
Baryons in stars and stellar remnants	$\mathbf{\sim 0.003}$
Neutrinos	$\mathbf{\sim 0.001}$
Photons (CMB)	$\mathbf{5 \times 10^{-5}}$

Betrayed by Its Shadow

Astronomers think they may have found where the bulk of the normal matter in the universe lurks: not in galaxies but in a form of intergalactic gas (mostly hydrogen) called the warm-hot intergalactic medium, or WHIM. The name connotes that the gas is less than blazingly hot and, consequently, glows too feebly to see directly. Looking in the interstices of a giant filament of galaxies called the Sculptor Wall, astronomers saw, in essence, the WHIM's shadow: the gas absorbed x-rays from a background object at a distinctive wavelength.



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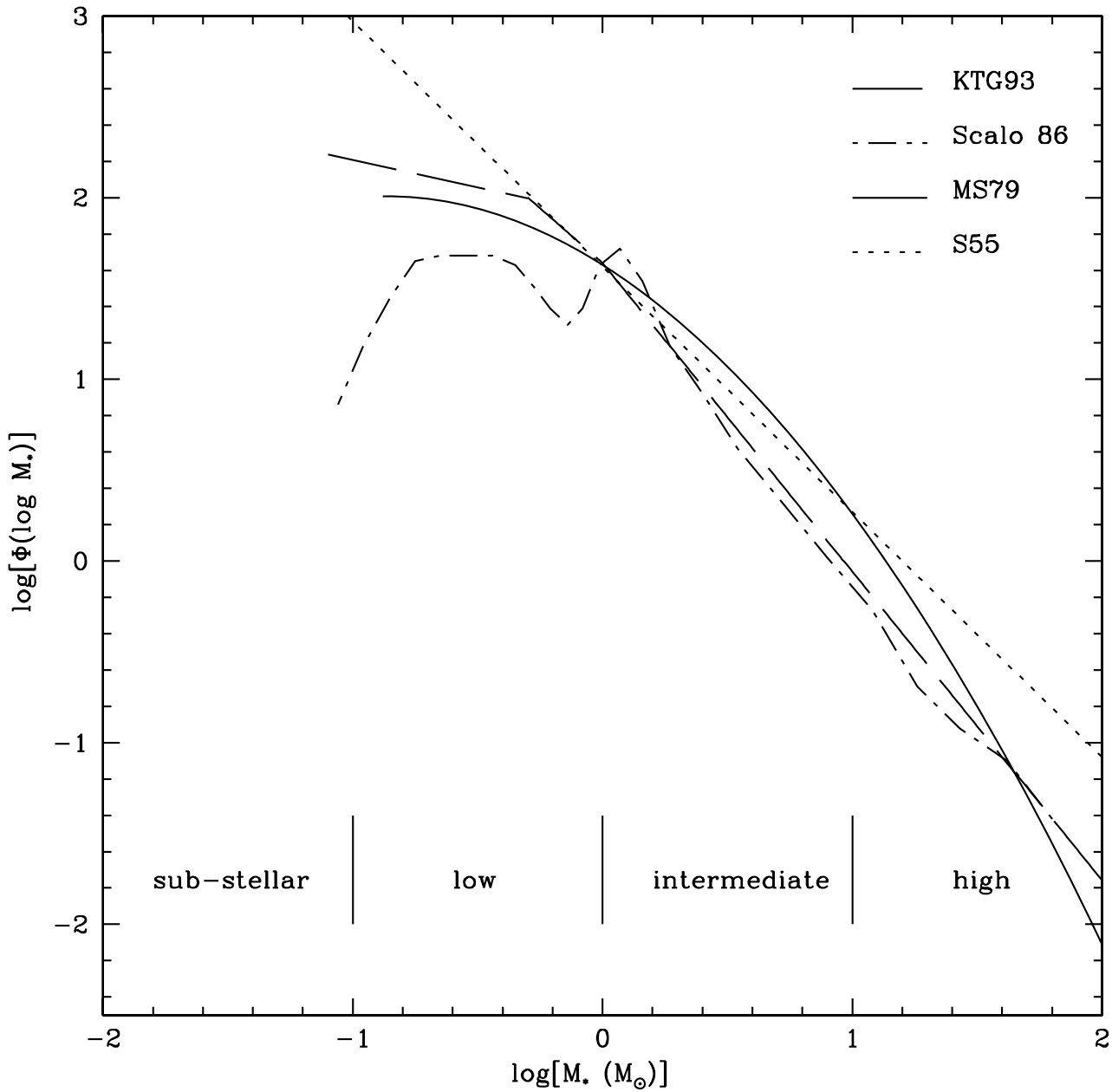
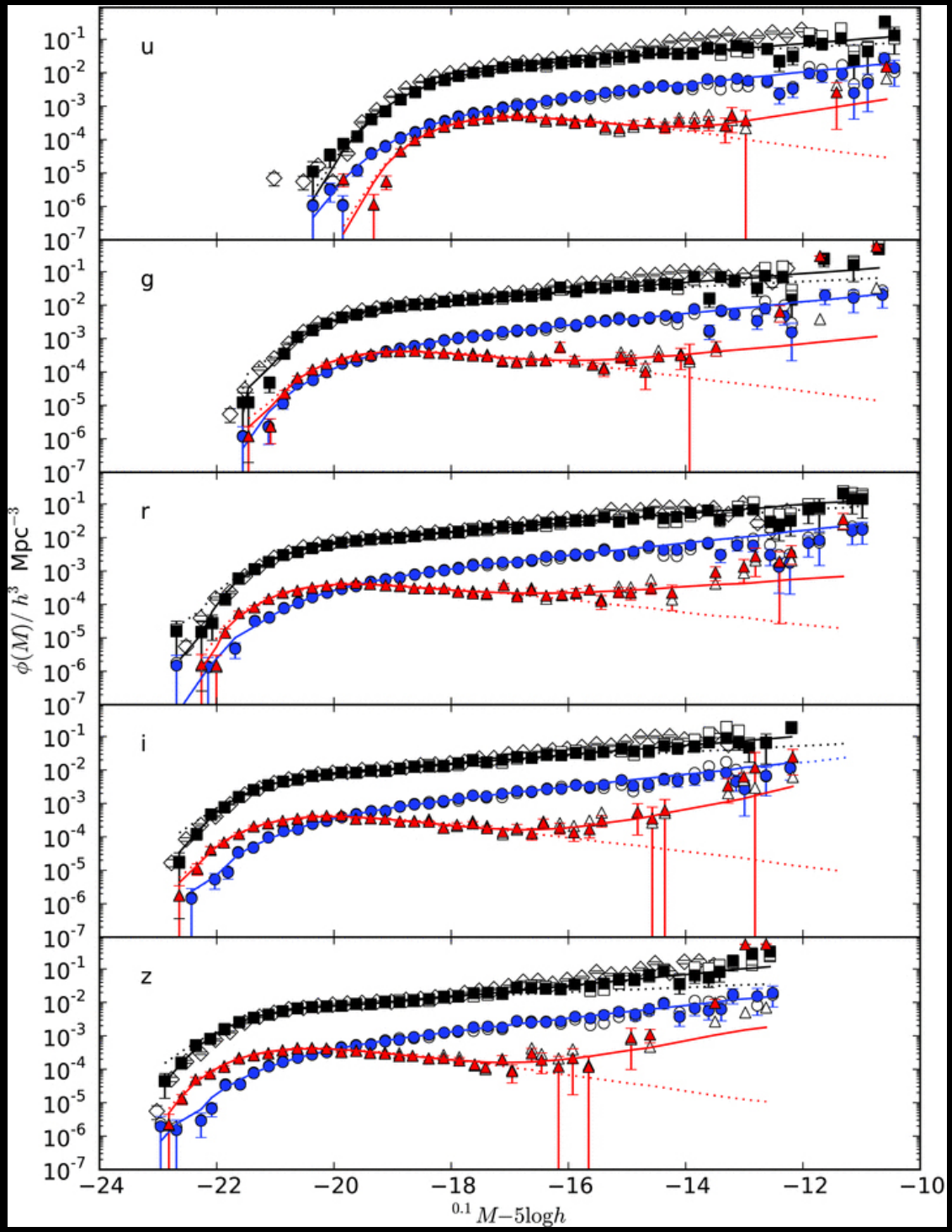
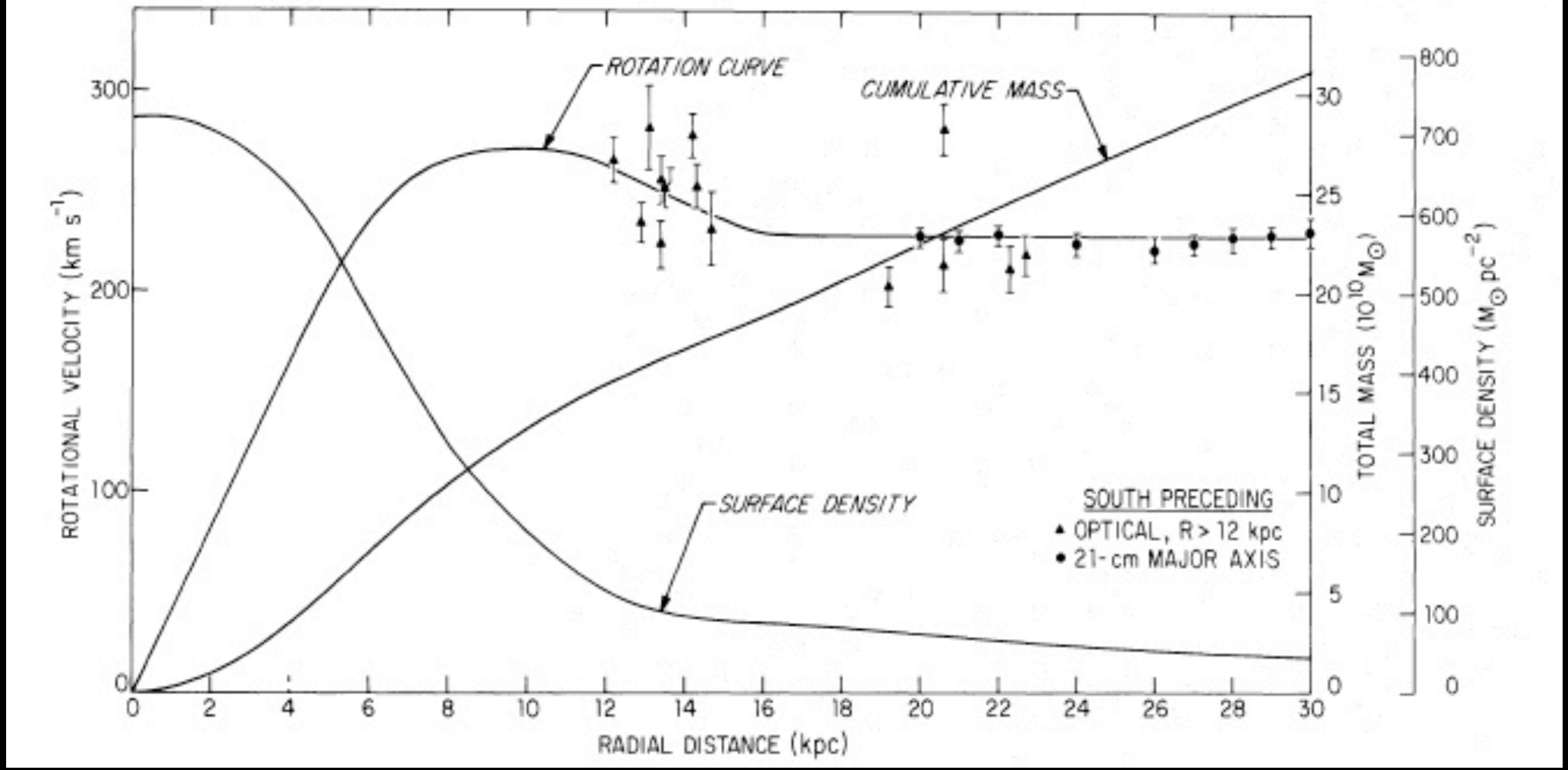
Stellar Initial Mass Functions



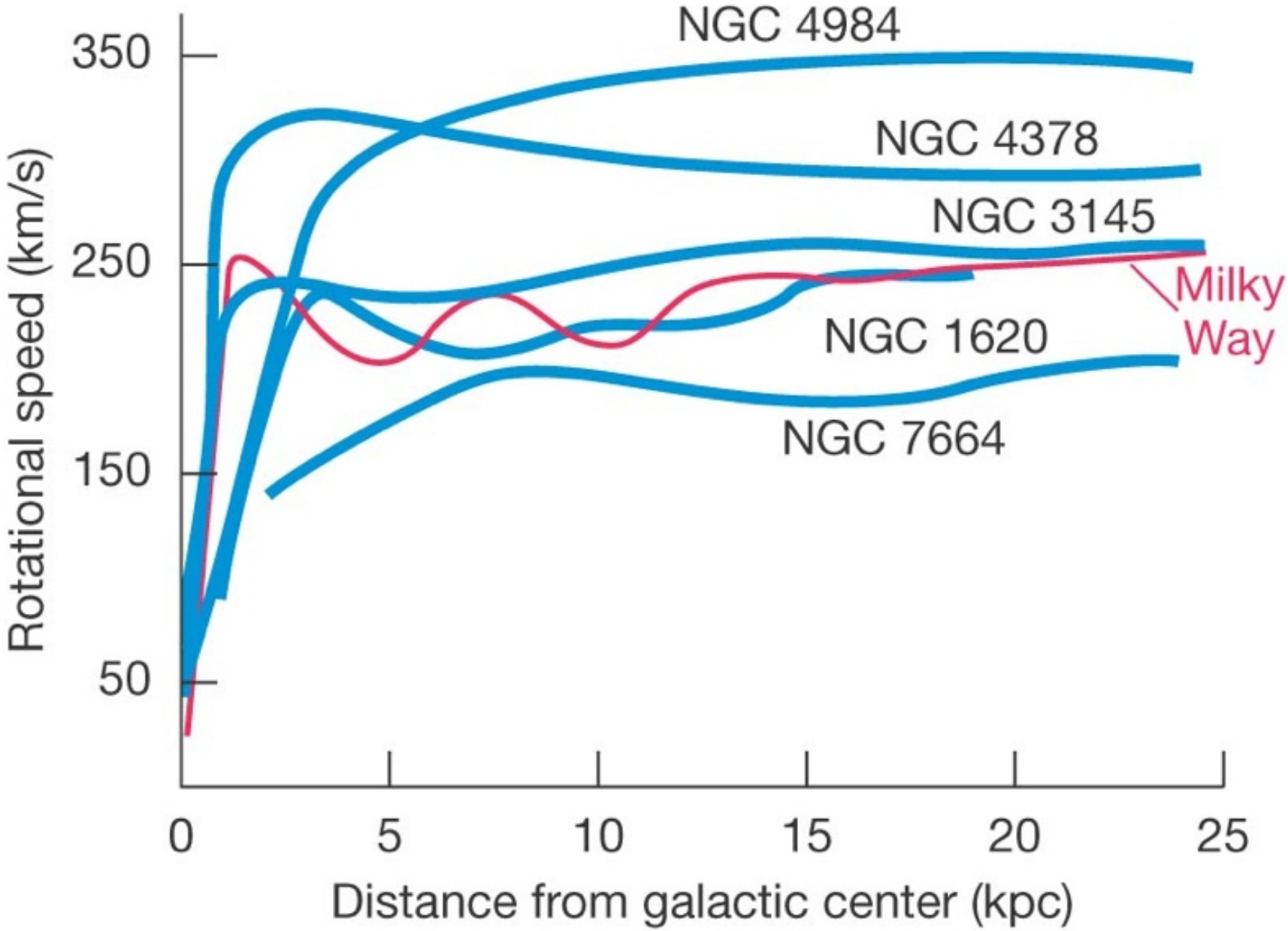
Meyer+ 1999

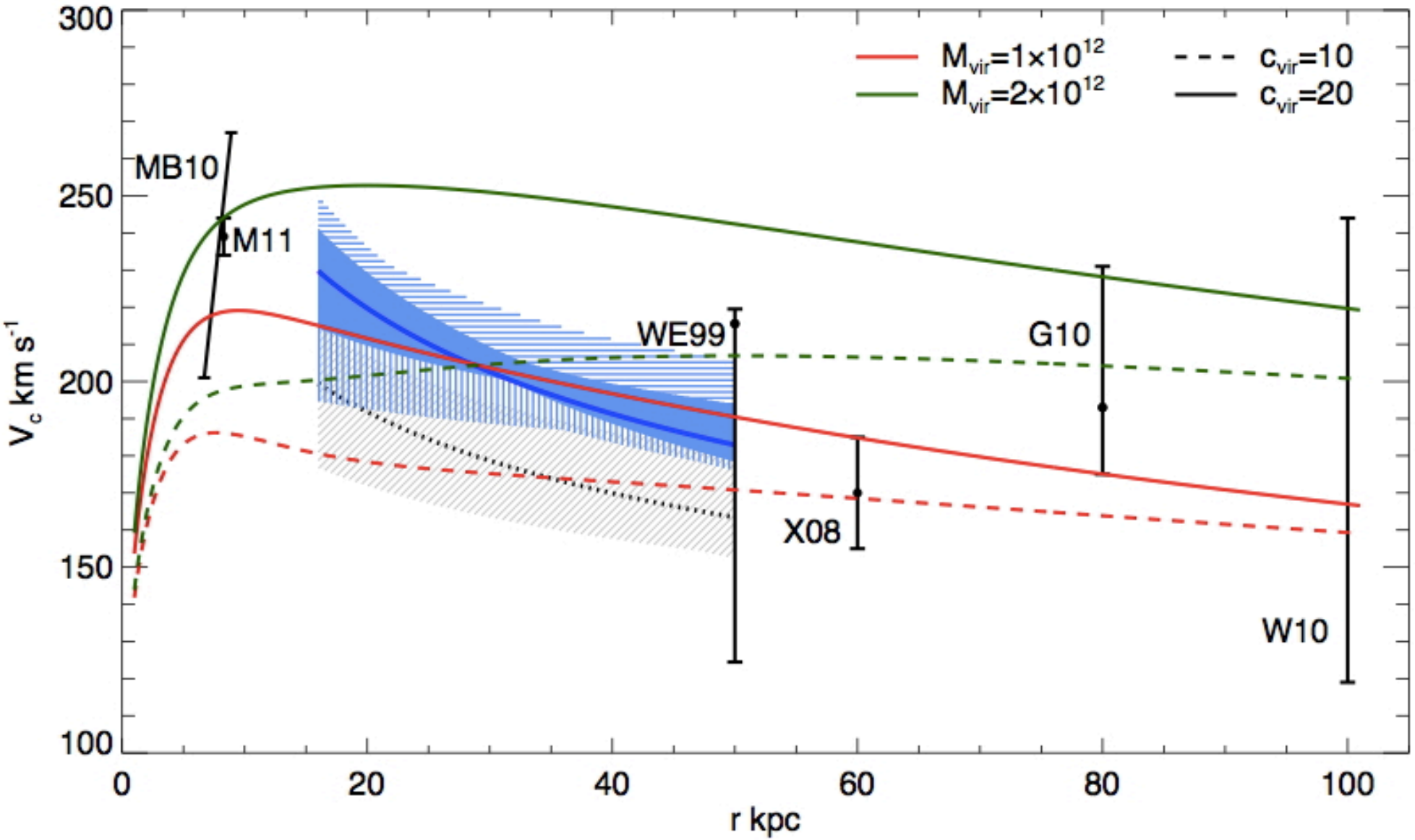


Loveday+ 2012

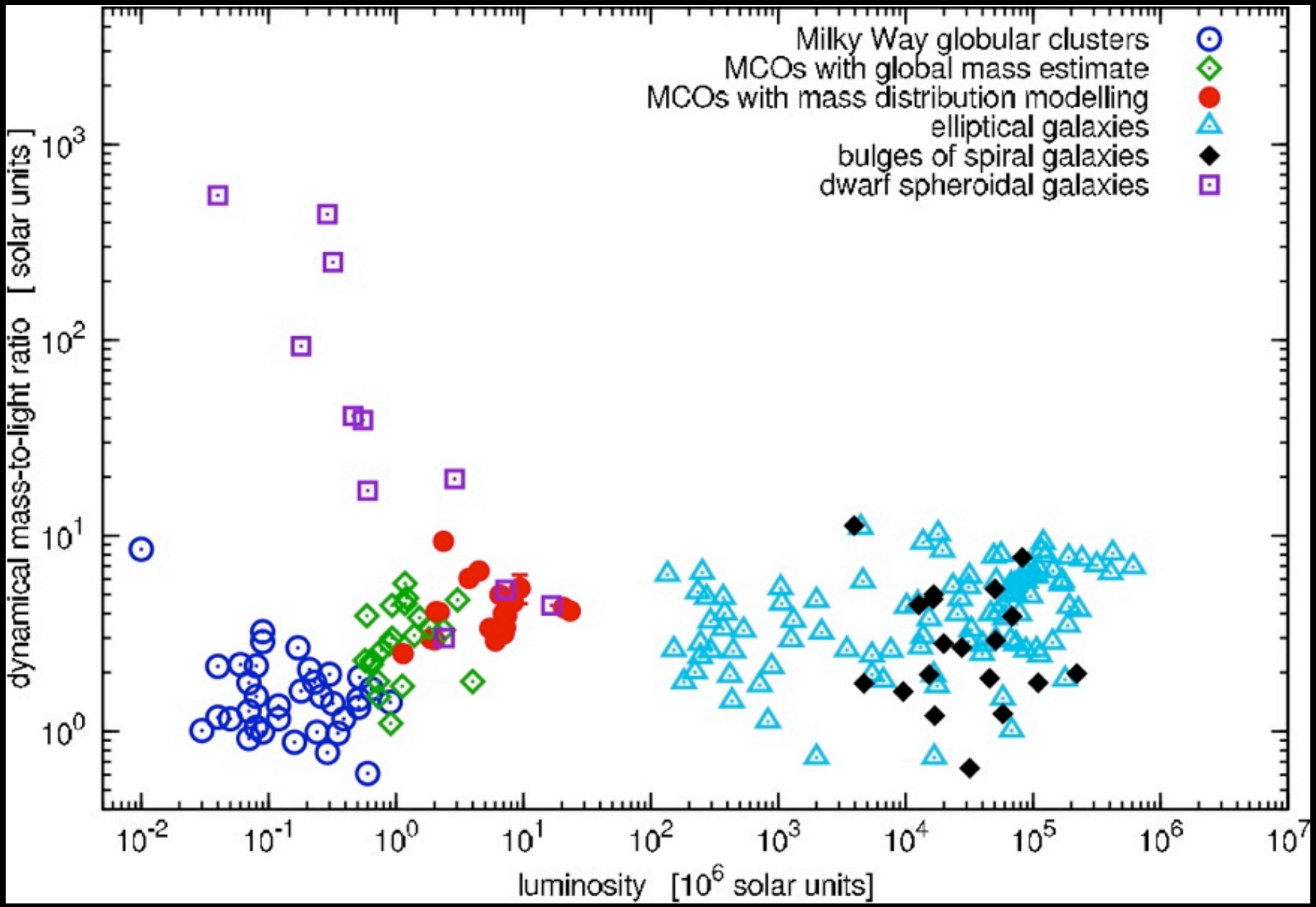


Roberts & Whitehurst 1975

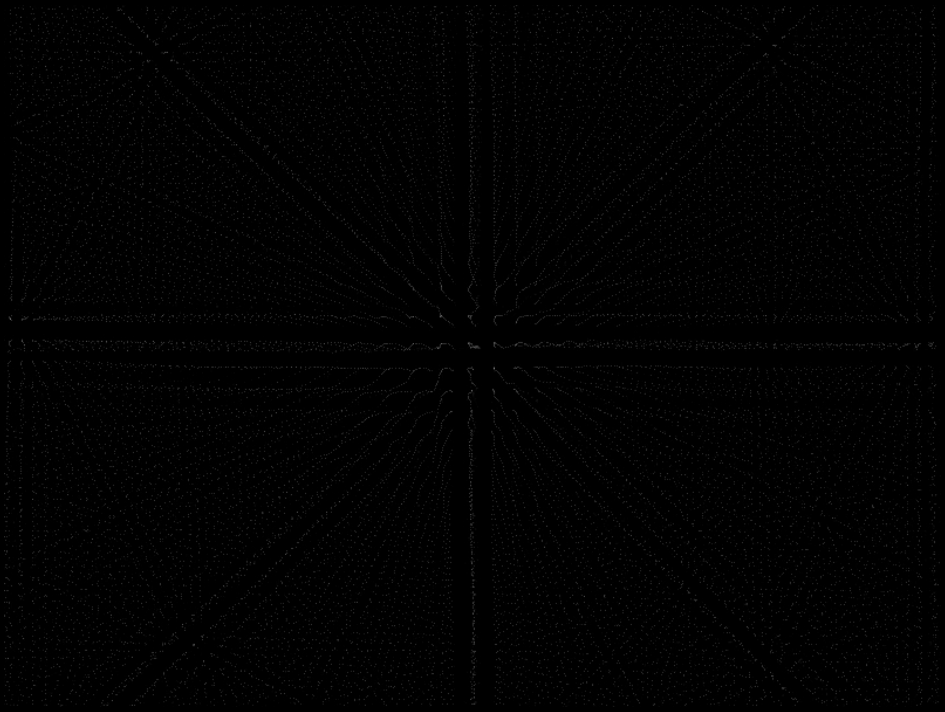

NGC 4984
NGC 4378
NGC 3145
Milky Way
NGC 1620
NGC 7664
350
250
150
50
Rotational speed (km/s)
0
5
10
15
20
25
Distance from galactic center (kpc)


300
250
200
150
100
0
20
40
60
80
100
V_c km s^{-1}
r kpc
$M_{vir}=1\times10^{12}$
$M_{vir}=2\times10^{12}$
$c_{vir}=10$
$c_{vir}=20$
MB10
M11
WE99
G10
X08
W10

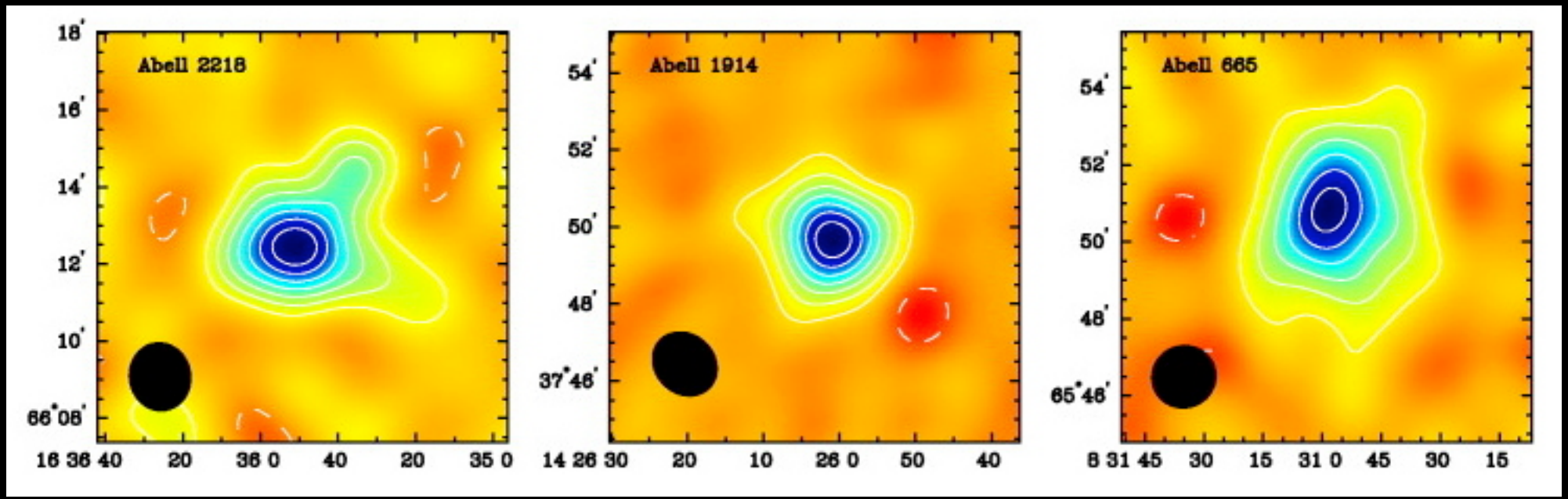
Deason+ 2012



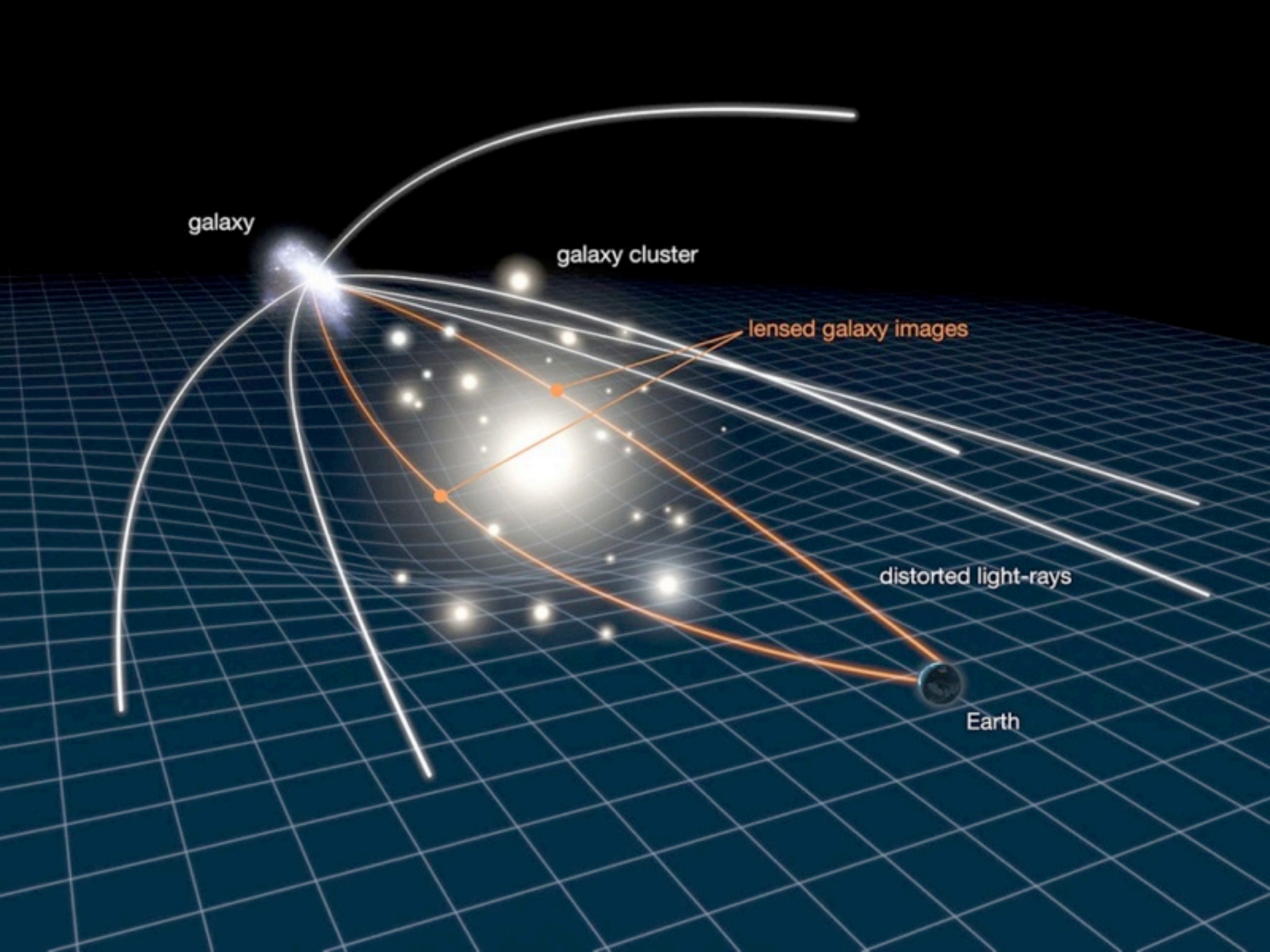
Dabringhousen+ 2008


0.0 Gyr

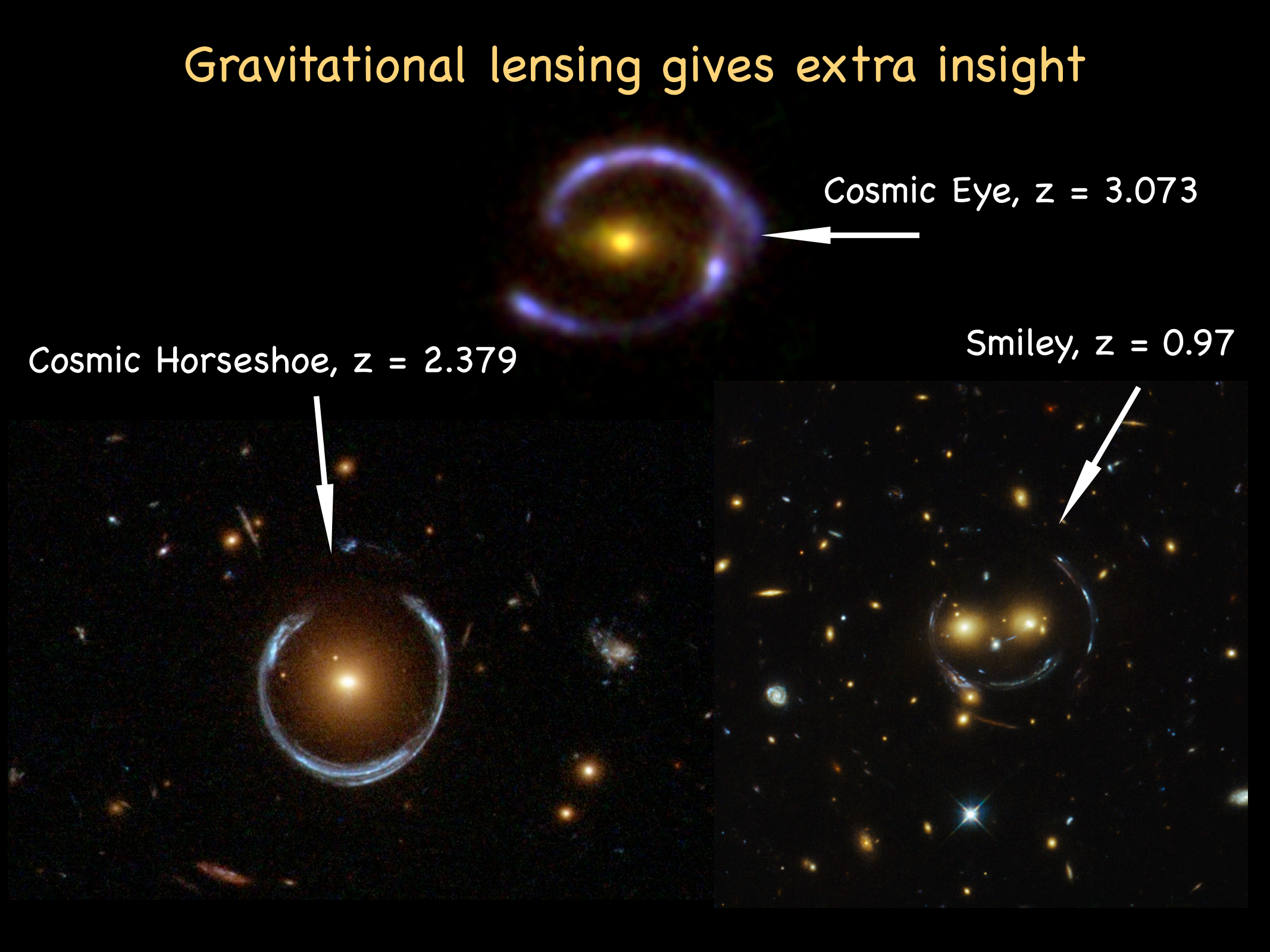
NASA, ESA, and the Hubble Heritage Team (STScI/AURA)


Abell 2218
18'
16'
14'
12'
10'
66°08'
16 36 40
20
36 0
40
20
35 0
Abell 1914
54'
52'
50'
48'
37°46'
14 26 30
20
10
26 0
50
40
Abell 665
54'
52'
50'
48'
65°48'
8 31 45
30
15
31 0
45
30
15

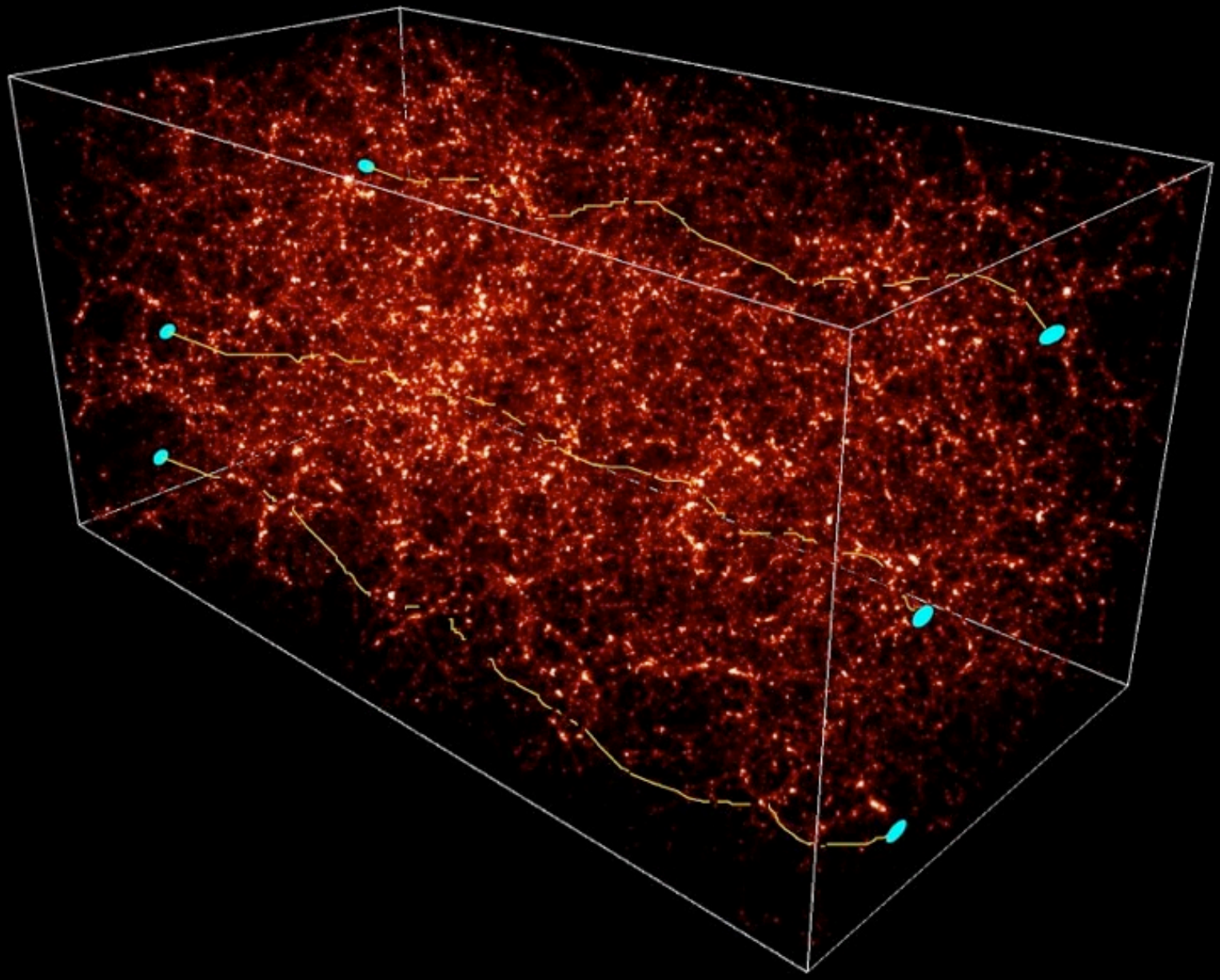
Grego+ 2001


galaxy
galaxy cluster
lensed galaxy images
distorted light-rays
Earth

Gravitational lensing gives extra insight



DEFLECTION OF LIGHT RAYS CROSSING THE UNIVERSE, EMITTED BY DISTANT GALAXIES



SIMULATION: COURTESY NIC GROUP, S. COLOMBI, IAP.

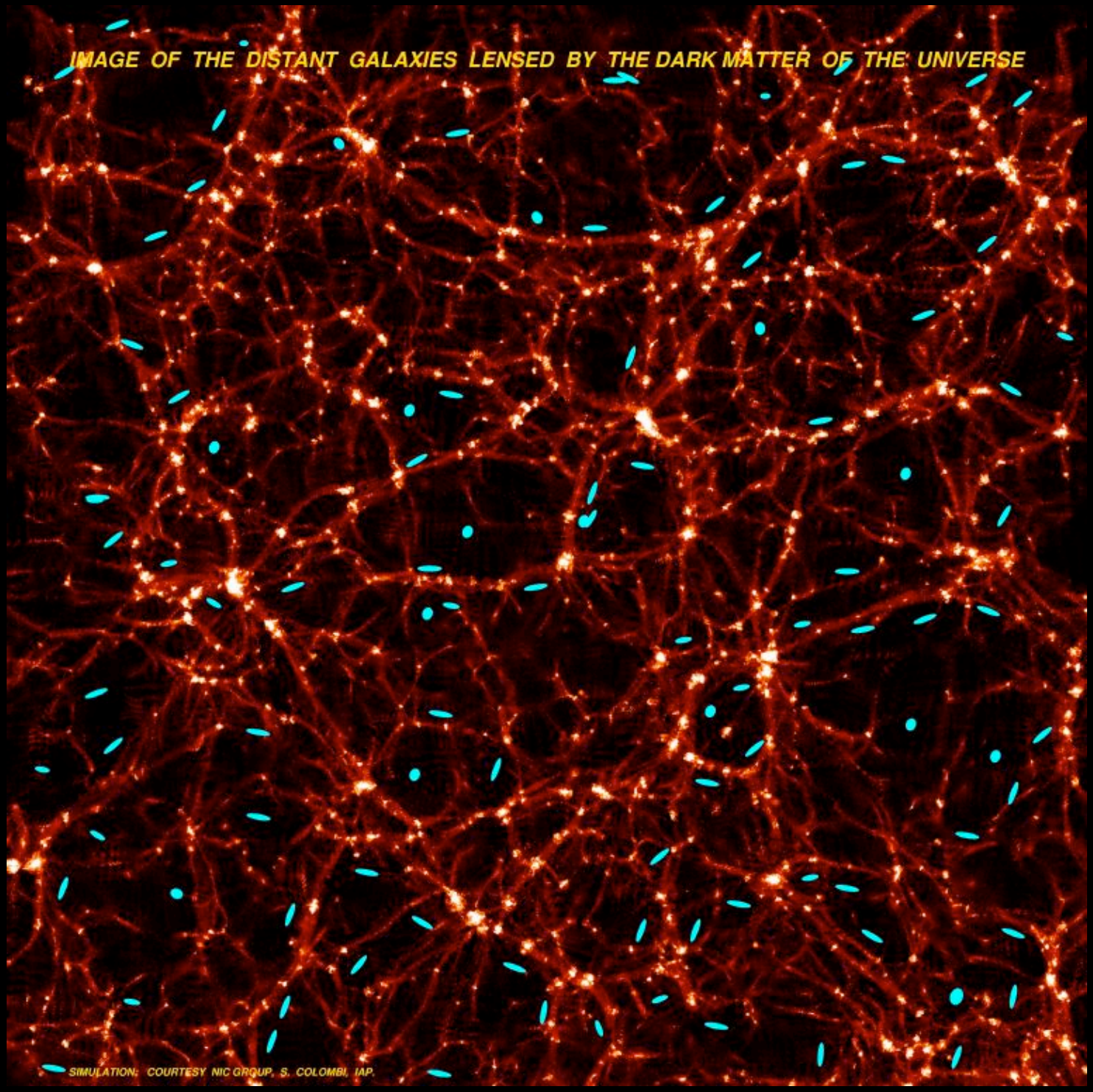
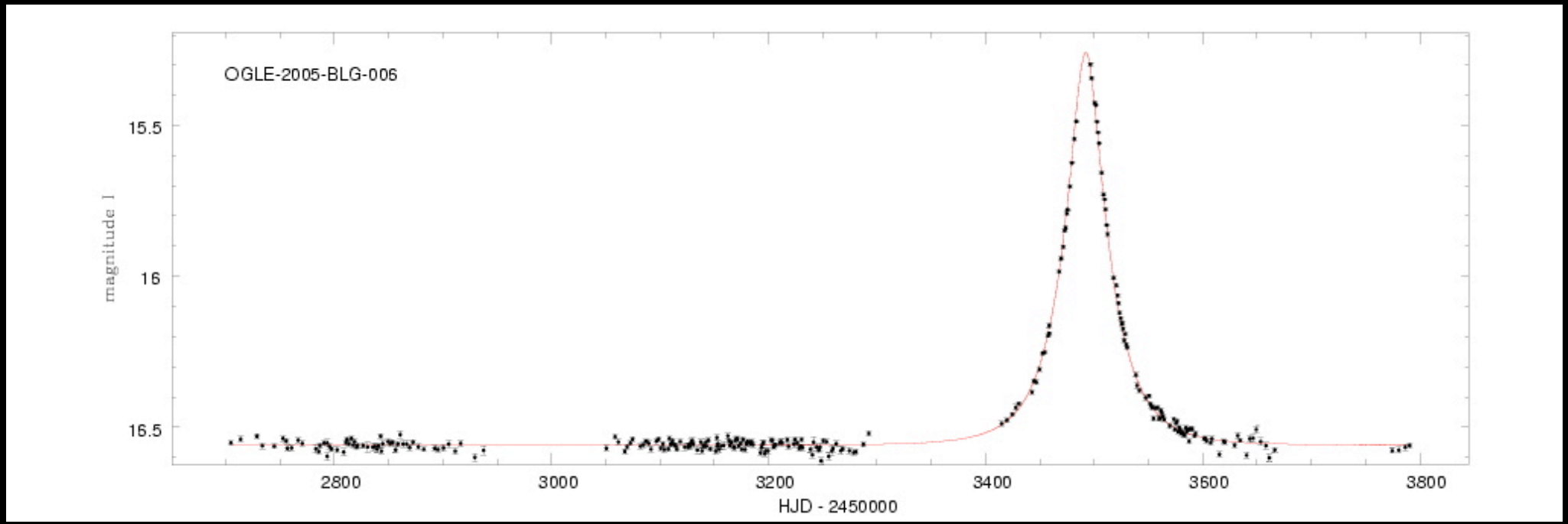
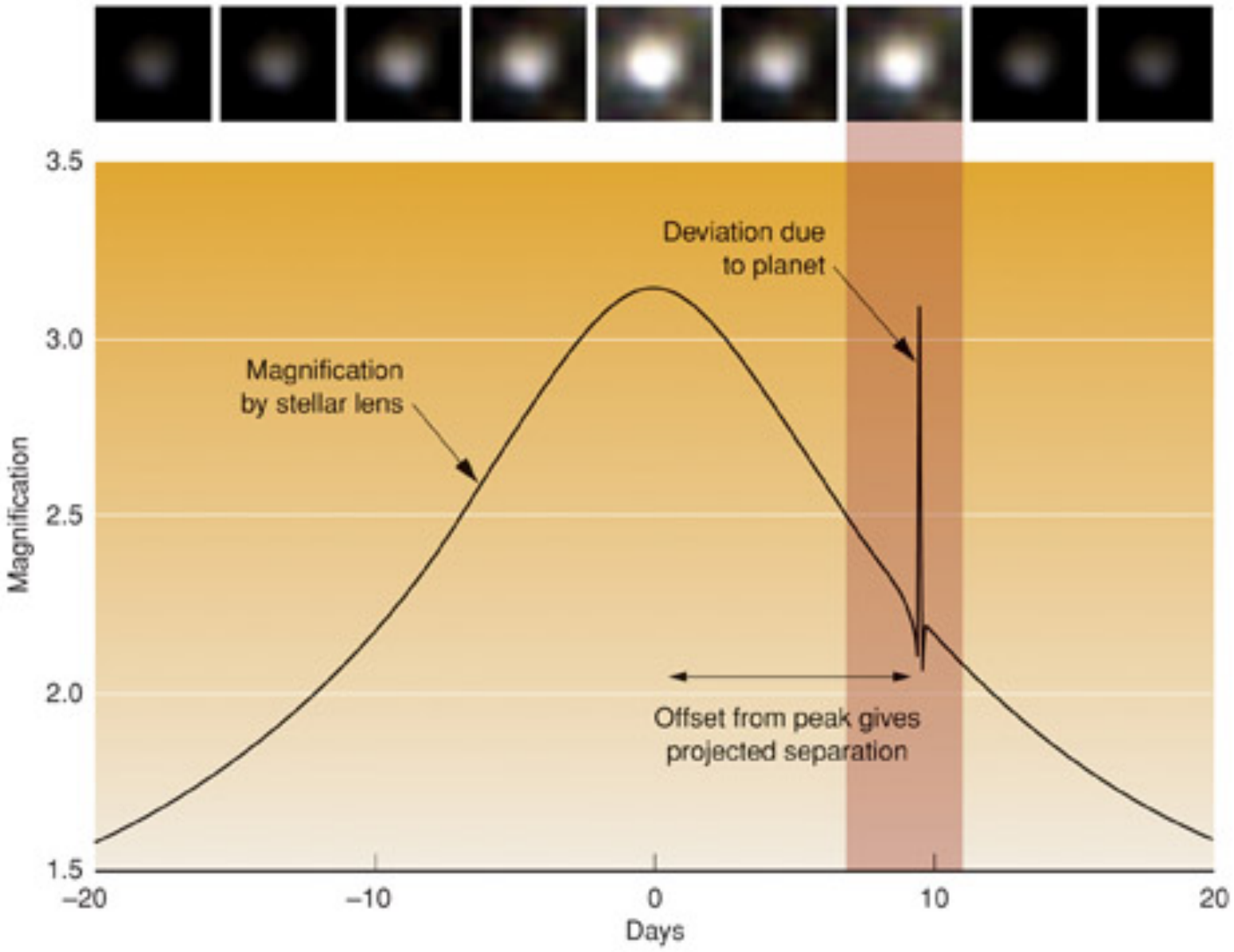


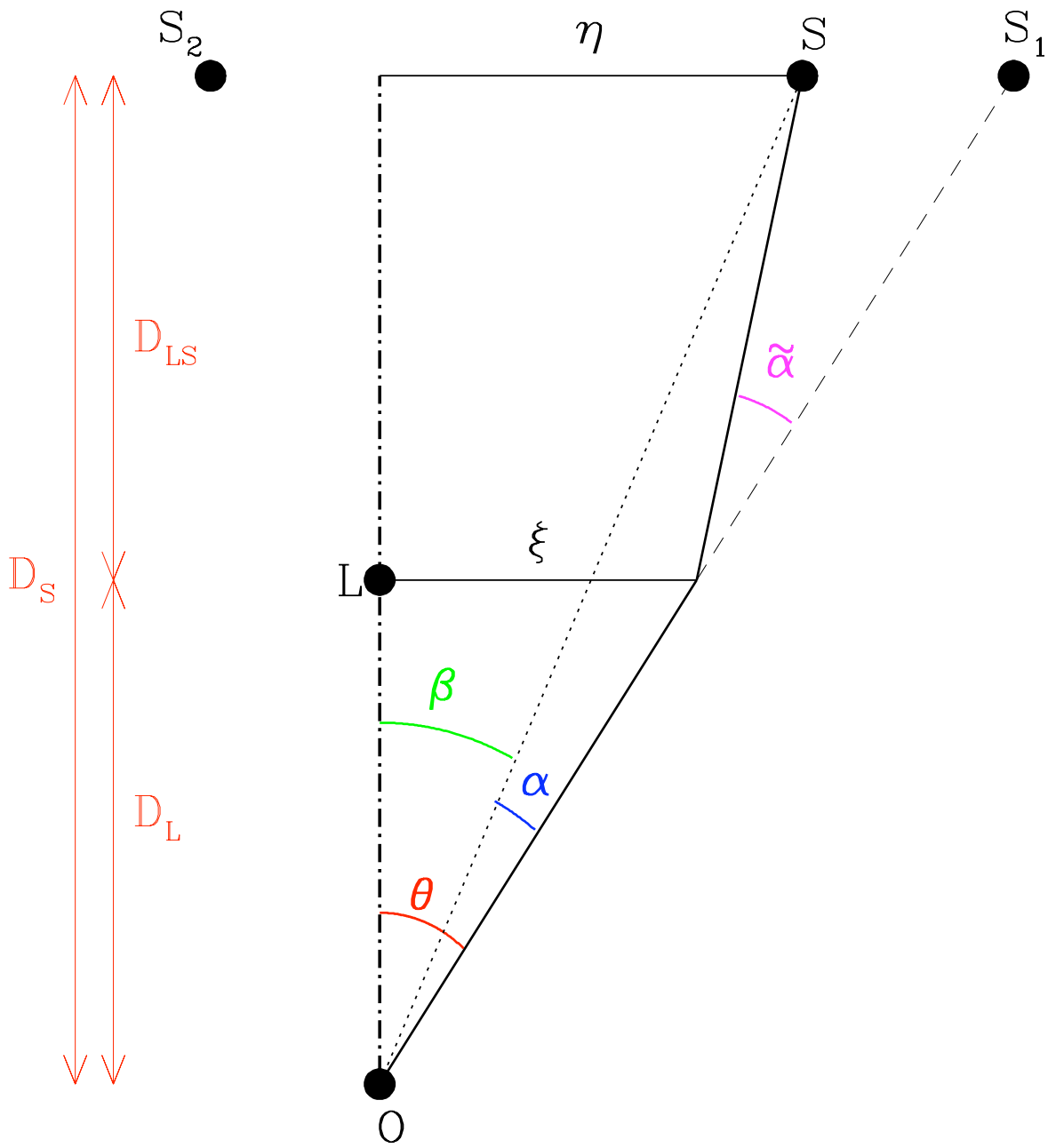
IMAGE OF THE DISTANT GALAXIES LENSED BY THE DARK MATTER OF THE UNIVERSE
SIMULATION: COURTESY NIC GROUP, S. COLOMBI, IAP.


OGLE-2005-BLG-006
15.5
16
16.5
magnitude I
2800
3000
3200
3400
3600
3800
HJD - 2450000

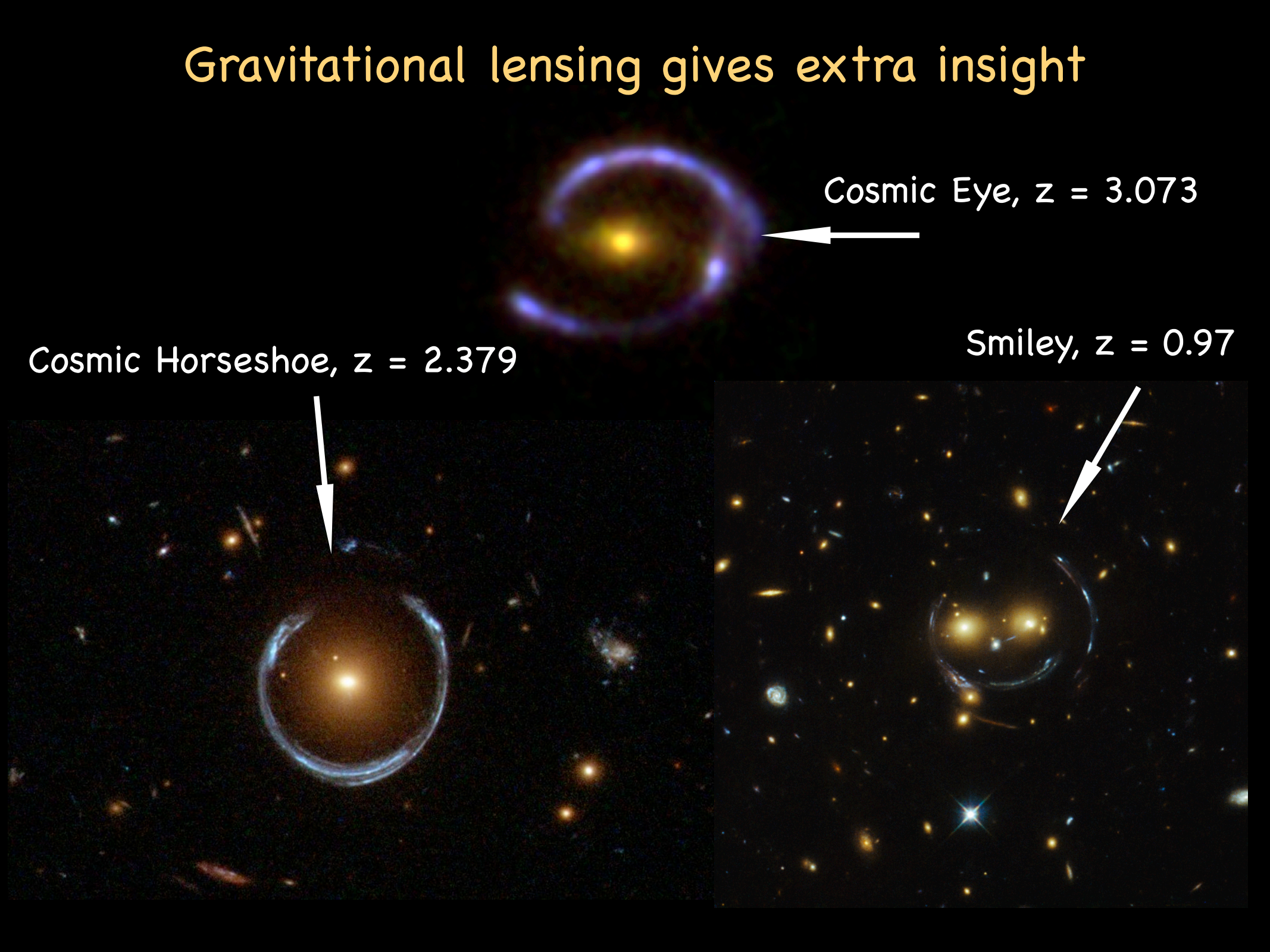
Planet searches

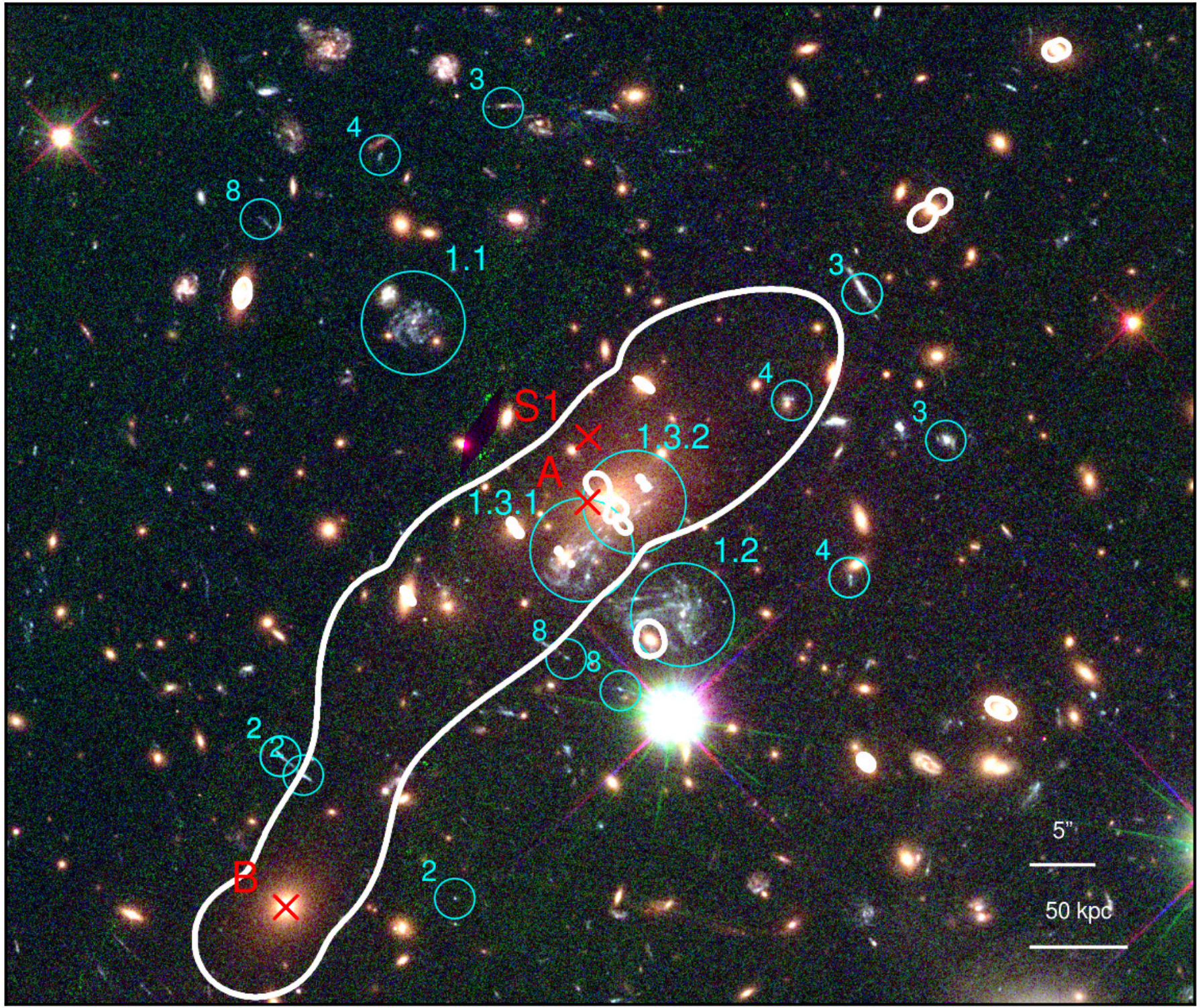
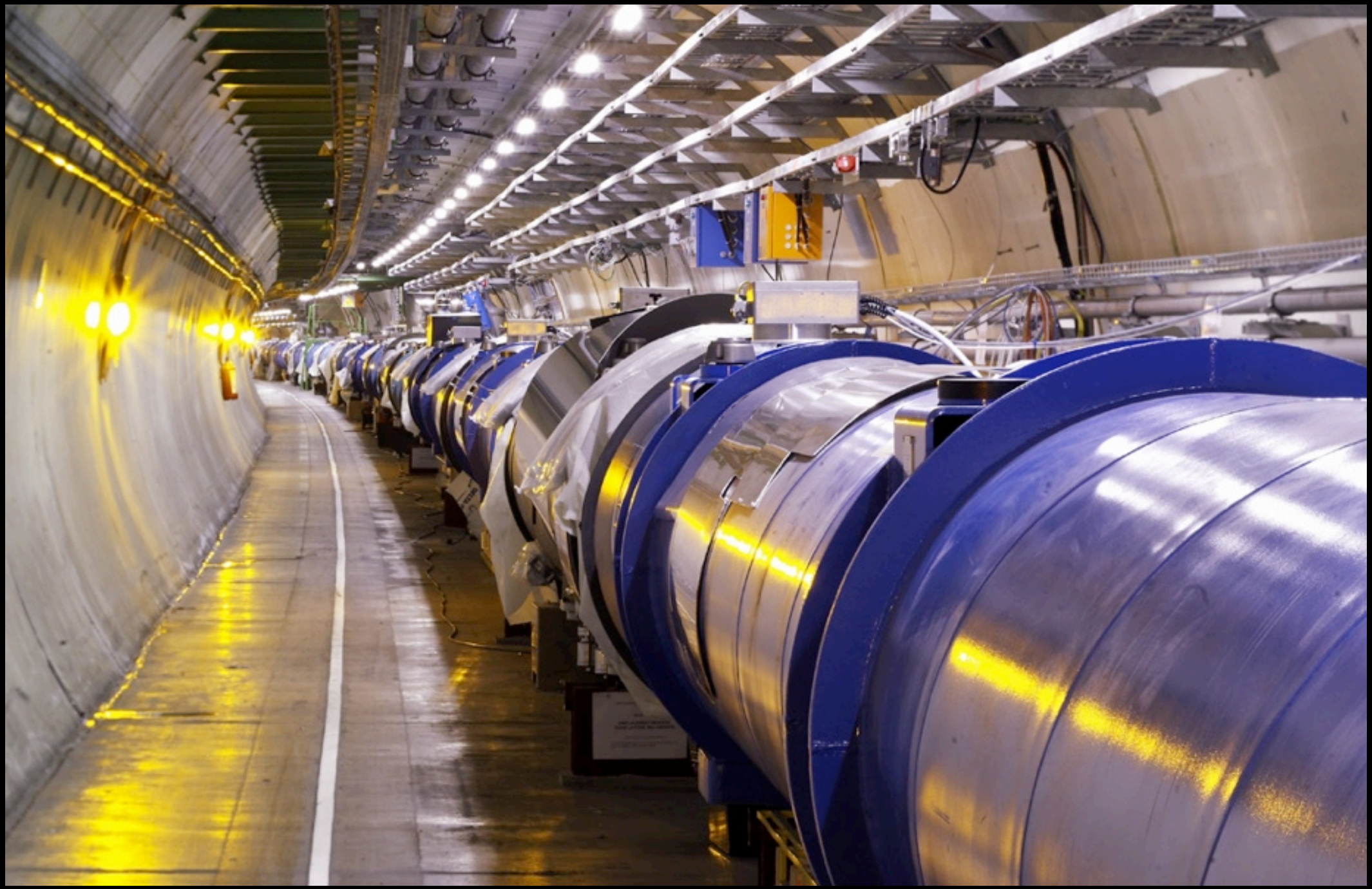
Star and planet act as microlenses




S2
η
S
S1
D_LS
D_S
D_L
α̃
ξ
L
β
α
θ
O

Gravitational lensing gives extra insight




3
4
8
1.1
3
S1
4
3
1.3.2
A
1.3.1
1.2
4
8
8
2
2
2
B
5”
50 kpc

ALICE
CMS
ATLAS
LHCb