Title: Toughest Student Questions: Dr. David Marsh

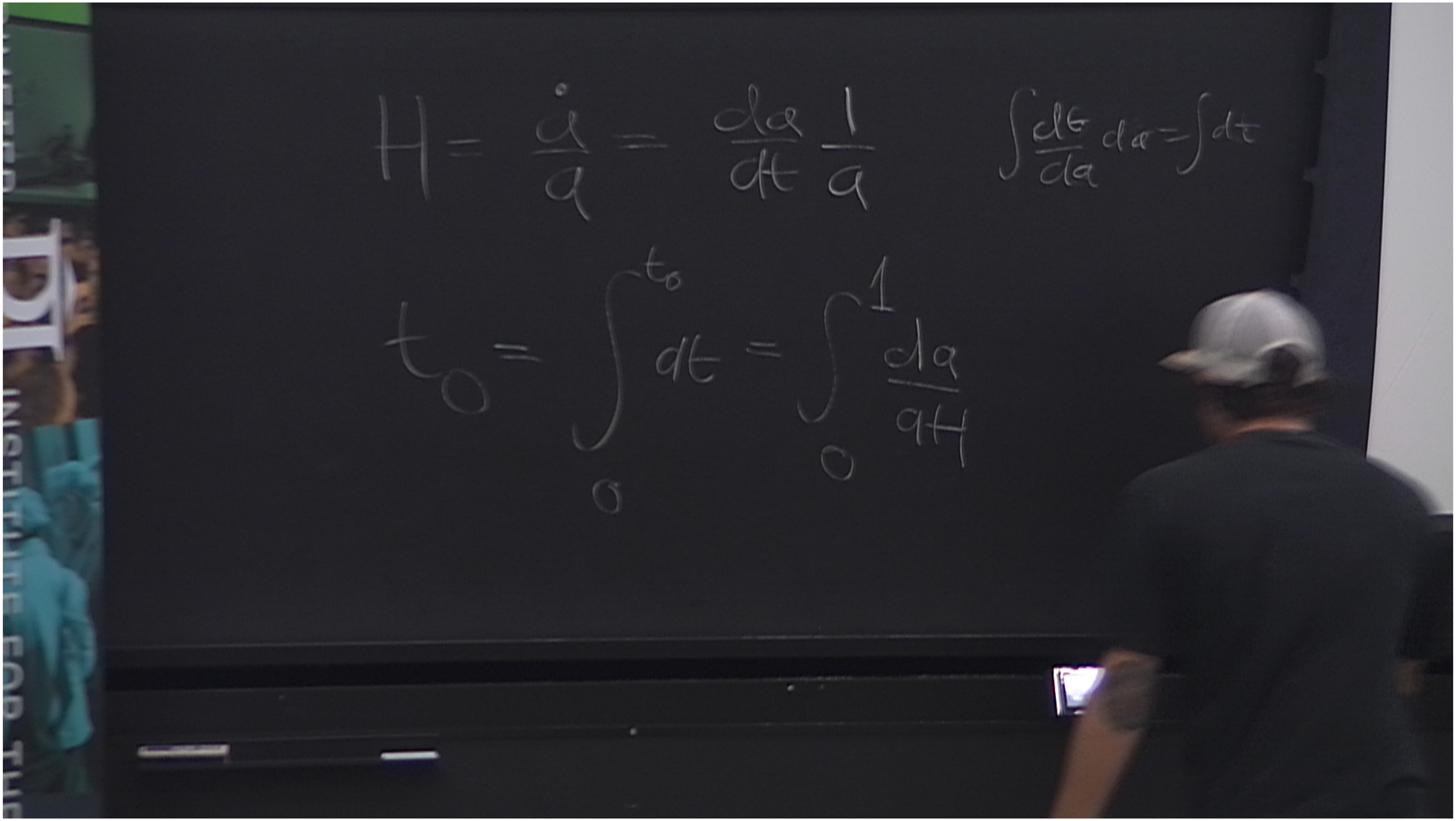
Date: Jul 10, 2015 11:00 AM

URL: http://pirsa.org/15070074

Abstract:

Your Memories on Facebook

Wonko, we care about you and the memories that you share here. You posted this photo exactly 1 year ago. We thought that you'd like to look back on it today.


$H = \frac{\dot{a}}{a} = \frac{da}{dt}\frac{1}{a}$
$\int \frac{dt}{da} da = \int dt$
$t_0 = \int_0^{t_0} dt = \int_0^1 \frac{da}{aH}$

$$H^2 = \frac{8\pi G}{3}\rho$$

$$\rho_m = \frac{\rho_{m,0}}{a^3} \qquad \rho_\Lambda = \rho_{\Lambda,0}$$

$$\rho_{tot,0} = \frac{3H_0^2}{8\pi G}$$

$$H^2 = \frac{8\pi G}{3}\rho \; ; \; \frac{H^2}{H_0^2} = \frac{\Omega_m}{a^3} + \Omega_\Lambda$$

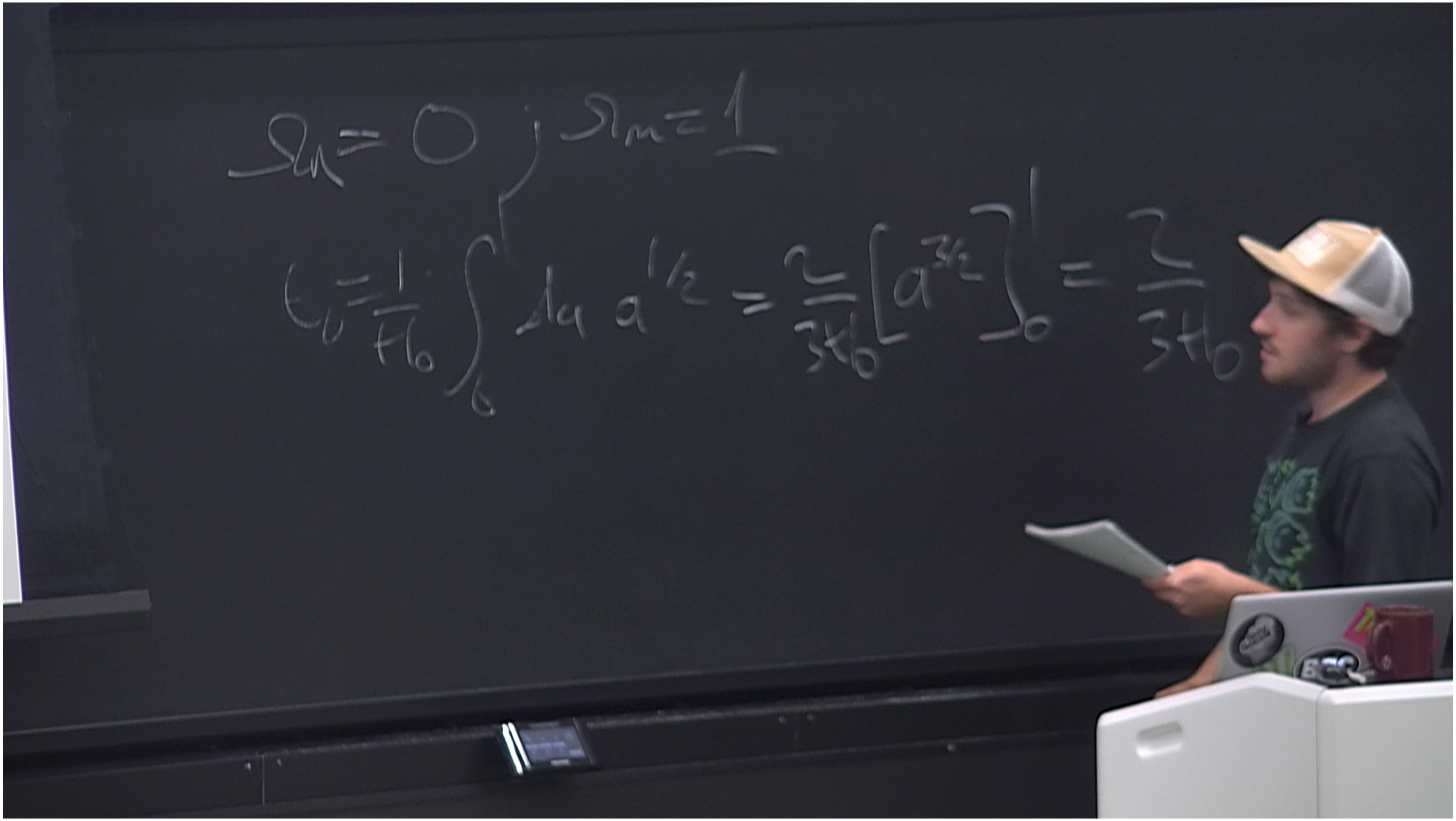
$$\rho_m = \frac{\rho_{m,0}}{a^3} \qquad \rho_\Lambda = \rho_{\Lambda,0}$$

$$\rho_{tot,0} = \frac{3H_0^2}{8\pi G} \qquad H = H_0\sqrt{\frac{\Omega_m}{a^3} + \Omega_\Lambda}$$

$\Omega_M = \frac{\cdots}{\rho_{tot,0}}$, $\Omega_\Lambda = \frac{\cdots}{\rho_{tot,0}}$

$= 0.32$ $\qquad$ $= 0.68$

$$\boxed{t_0 = \frac{1}{H_0}\int_0^1 da \, \frac{1}{a\sqrt{\frac{\Omega_M}{a^3}+\Omega_\Lambda}}}$$

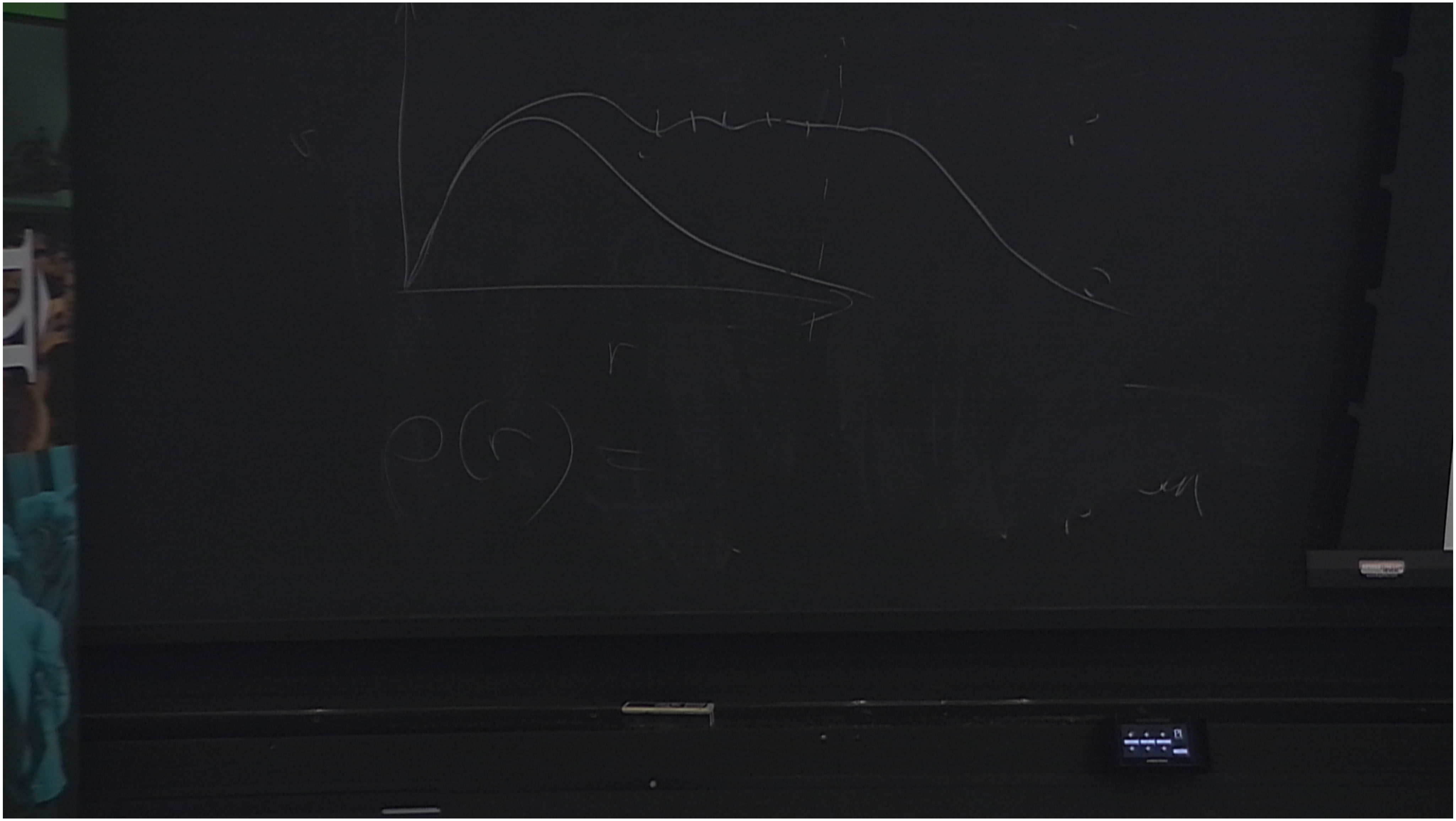

$\Omega_\Lambda = 0 \; ; \; \Omega_m = 1$
$t_0 = \frac{1}{H_0}\int_0^1 da\, a^{1/2} = \frac{2}{3H_0}\left[a^{3/2}\right]_0^1 = \frac{2}{3H_0}$

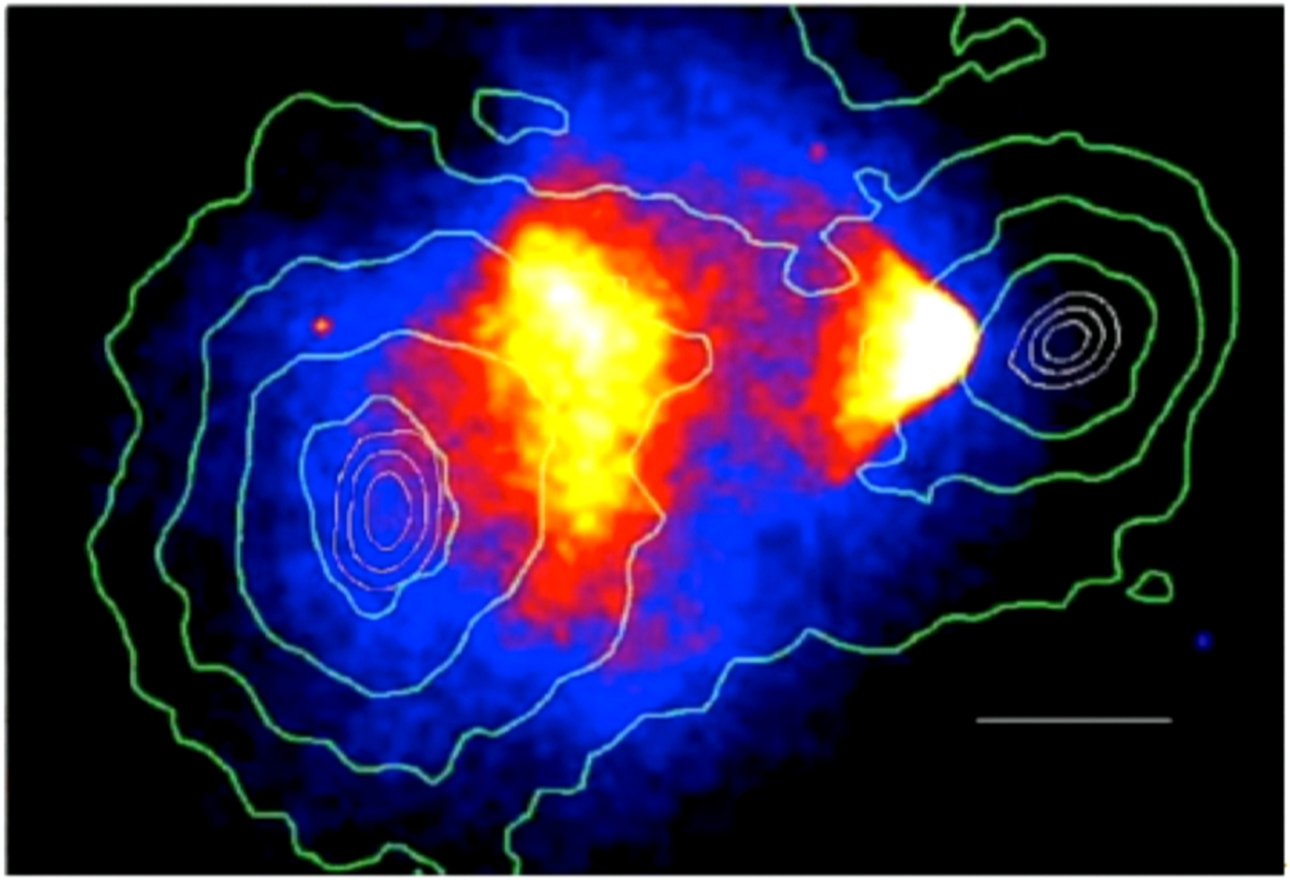
$$\Omega_\Lambda = 0 \; ; \; \Omega_m = 1$$

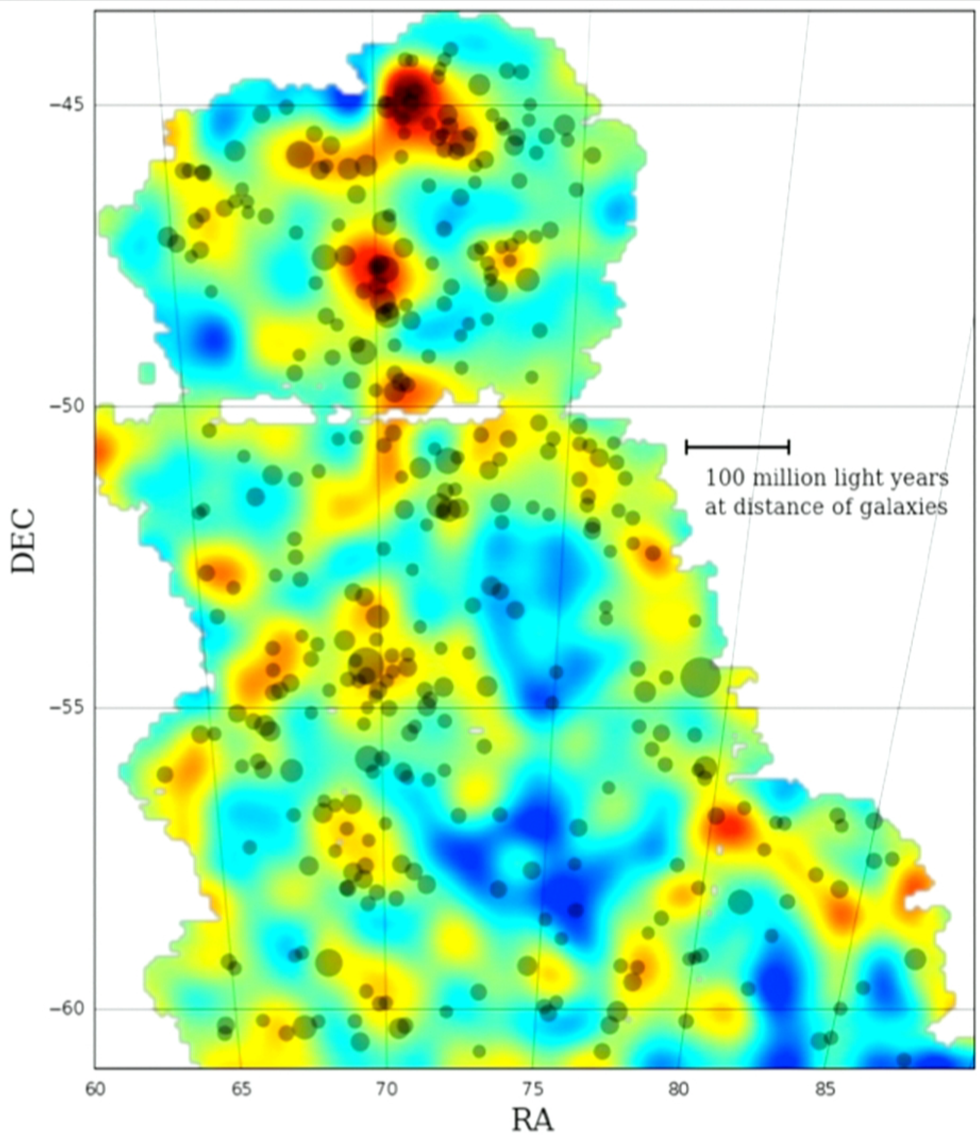
$$t_0 = \frac{1}{H_0}\int_0^1 da\, a^{1/2} = \frac{2}{3H_0}\left[a^{3/2}\right]_0^1 = \frac{2}{3H_0}$$

$$t_0 = \frac{0.94677}{H_0}$$

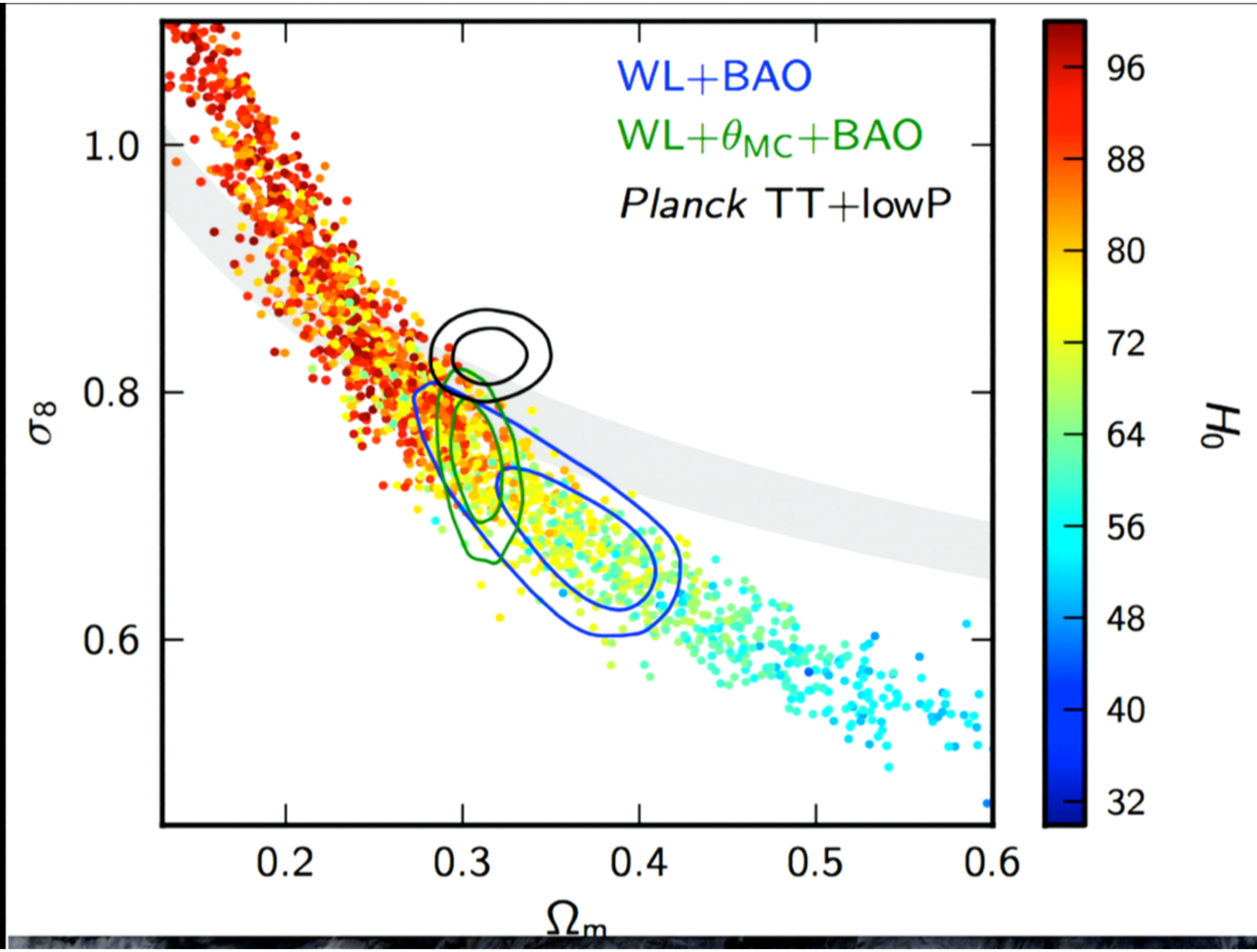
Gravitational Lensing and DM

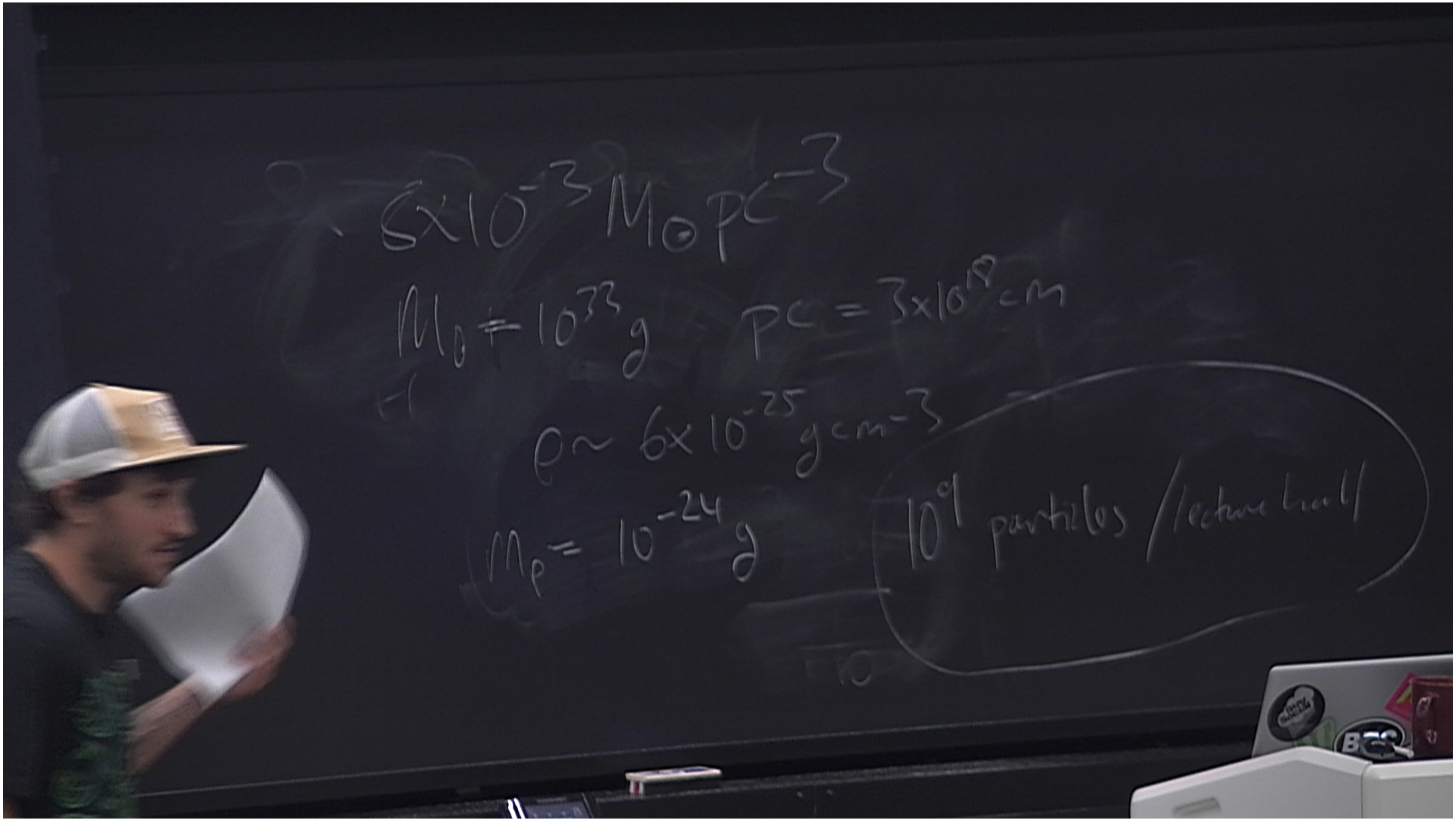


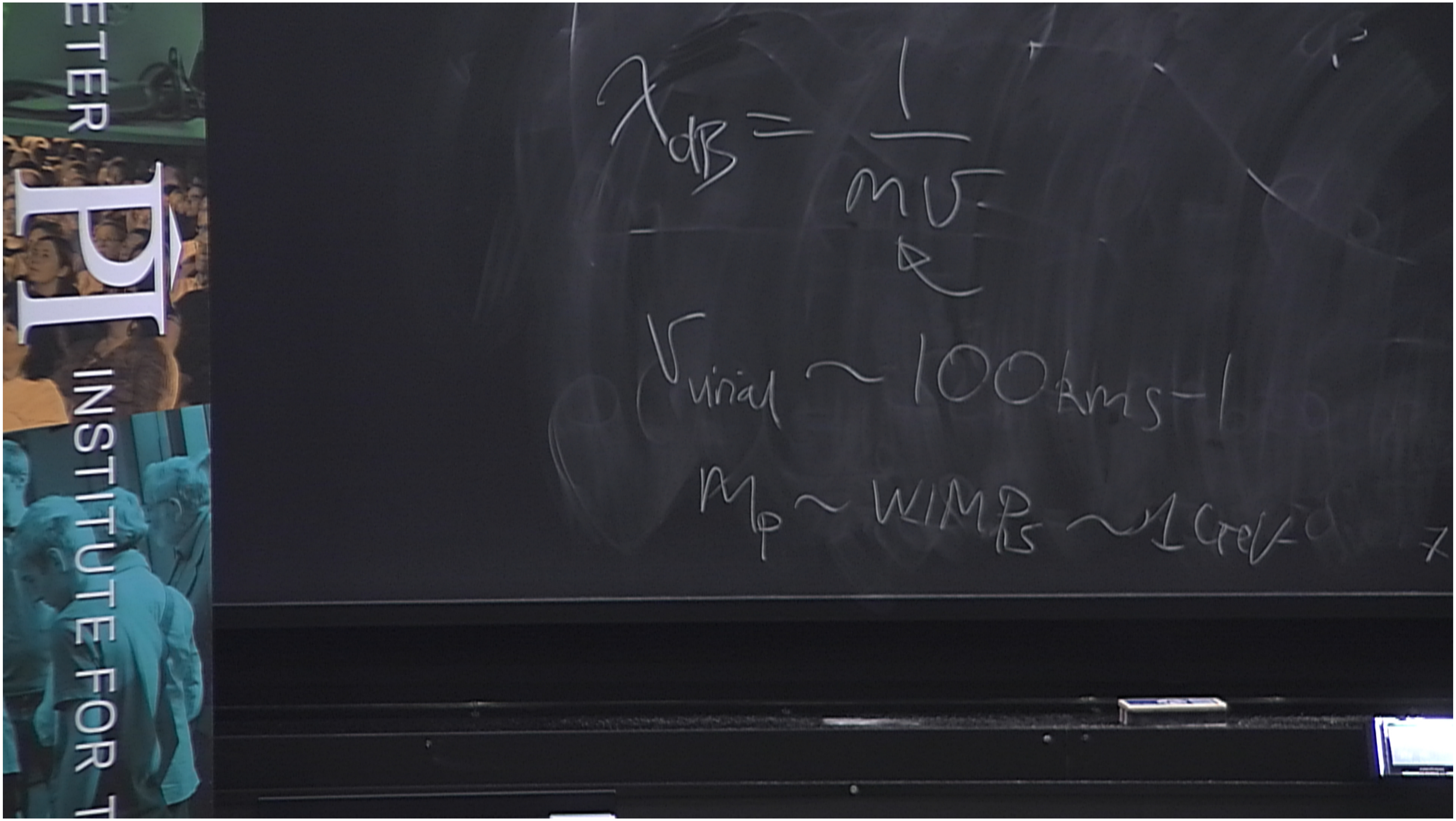




100 million light years
at distance of galaxies
DEC
RA
−45
−50
−55
−60
60
65
70
75
80
85


WL+BAO
WL+θ_{MC}+BAO
Planck TT+lowP
σ_8
1.0
0.8
0.6
0.2
0.3
0.4
0.5
0.6
Ω_m
96
88
80
72
64
56
48
40
32
H_0

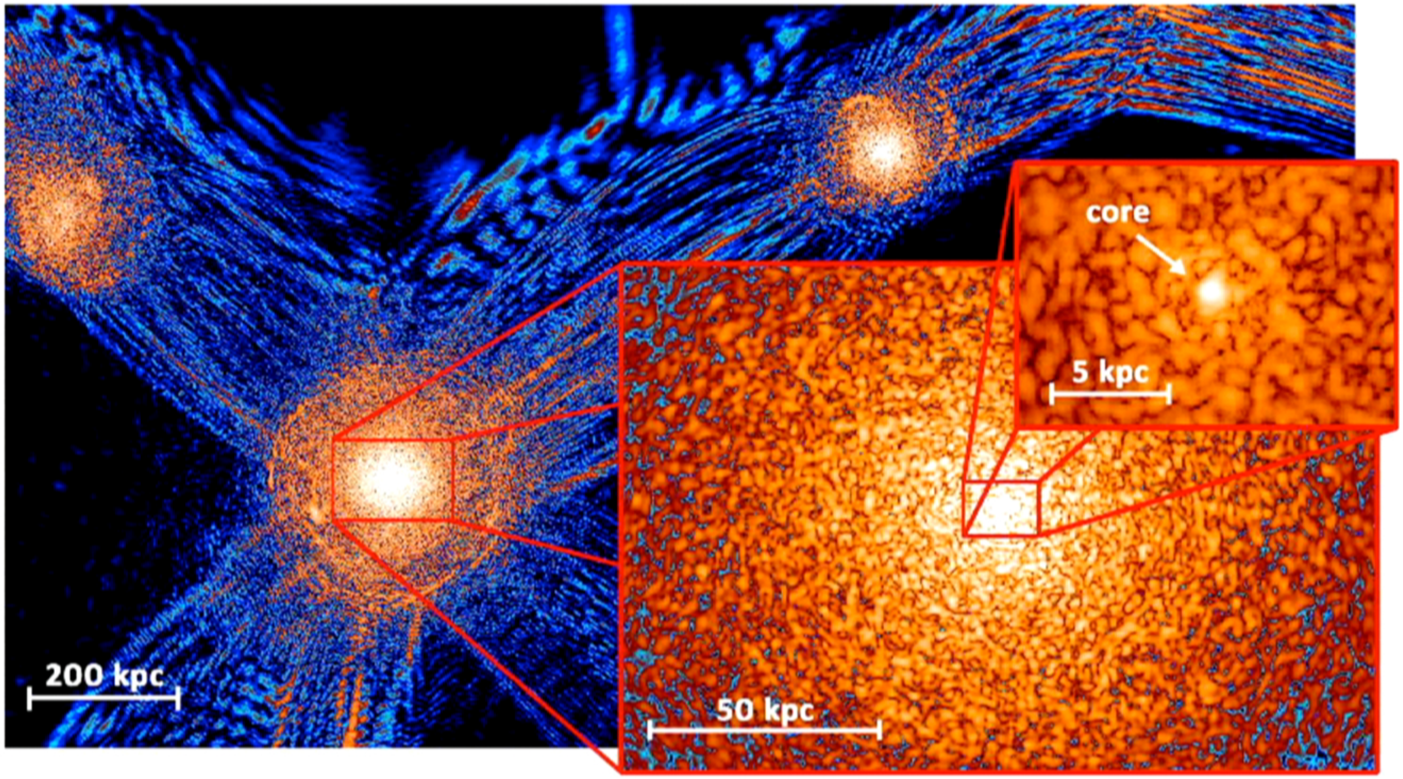

5x10-3 M⊙ pc-3
M⊙ = 1033 g
pc = 3x1018 cm
ρ ~ 6x10-25 g cm-3
mp = 10-24 g
109 particles / lecture hall

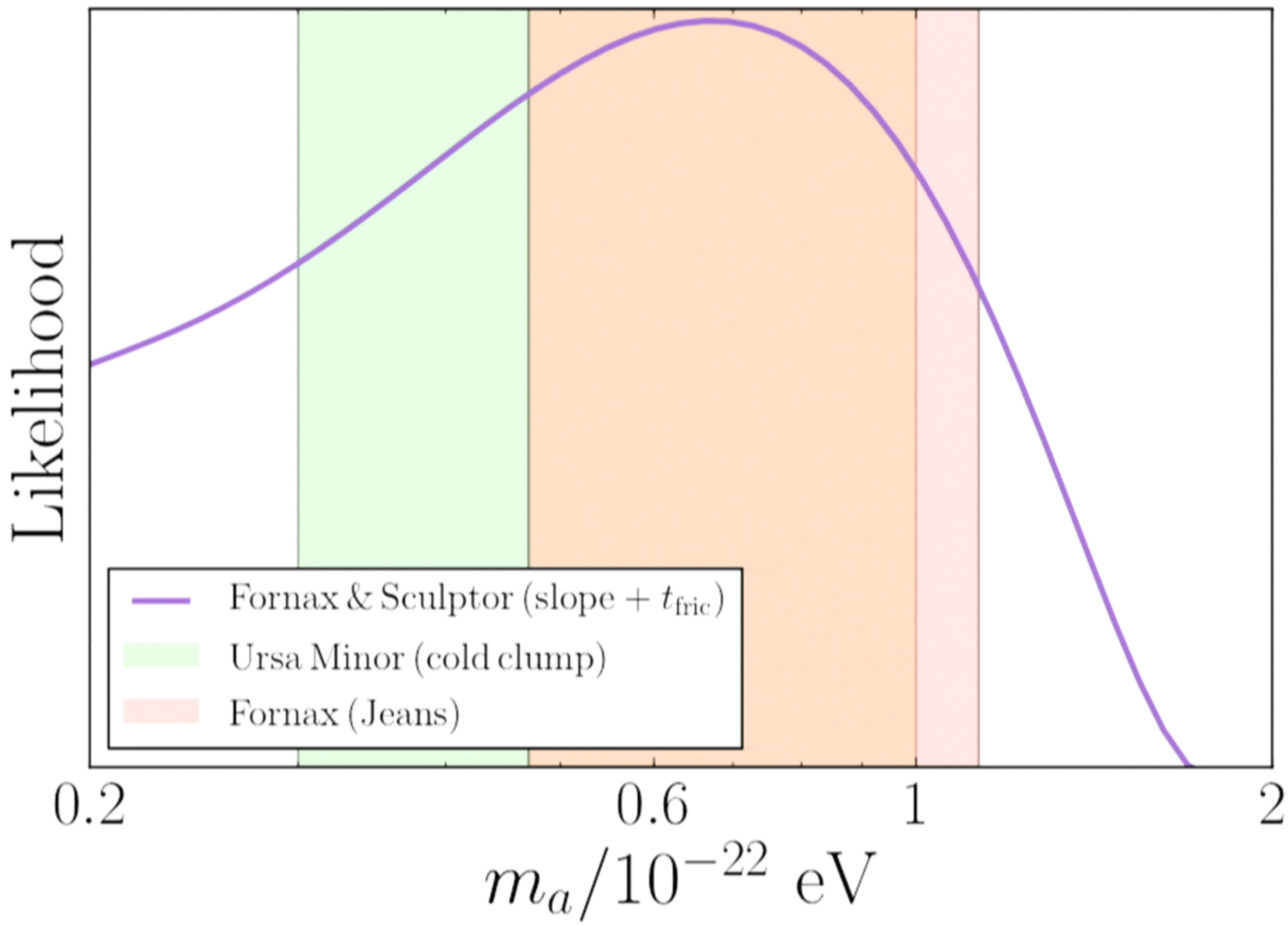

PI
INSTITUTE FOR
$\lambda_{dB} = \frac{1}{m v}$
$v_{virial} \sim 100\, km\, s^{-1}$
$m_\varphi \sim$ WIMPs ~ 1 GeV

LETTERS
PUBLISHED ONLINE: 22 JUNE 2014 | DOI: 10.1038/NPHYS2996
nature physics

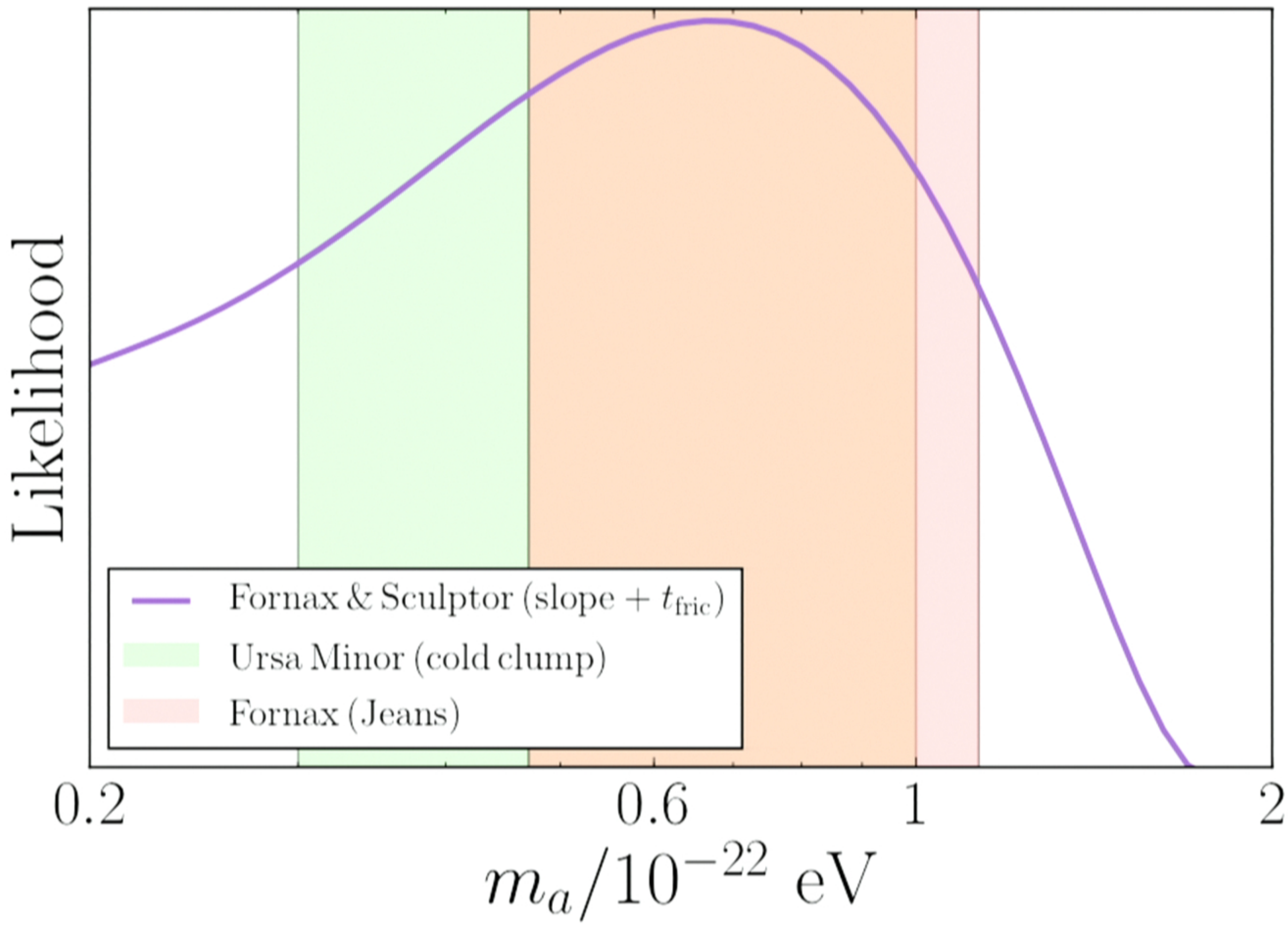
Cosmic structure as the quantum interference of a coherent dark wave

Hsi-Yu Schive[1], Tzihong Chiueh[1,2]* and Tom Broadhurst[3,4]

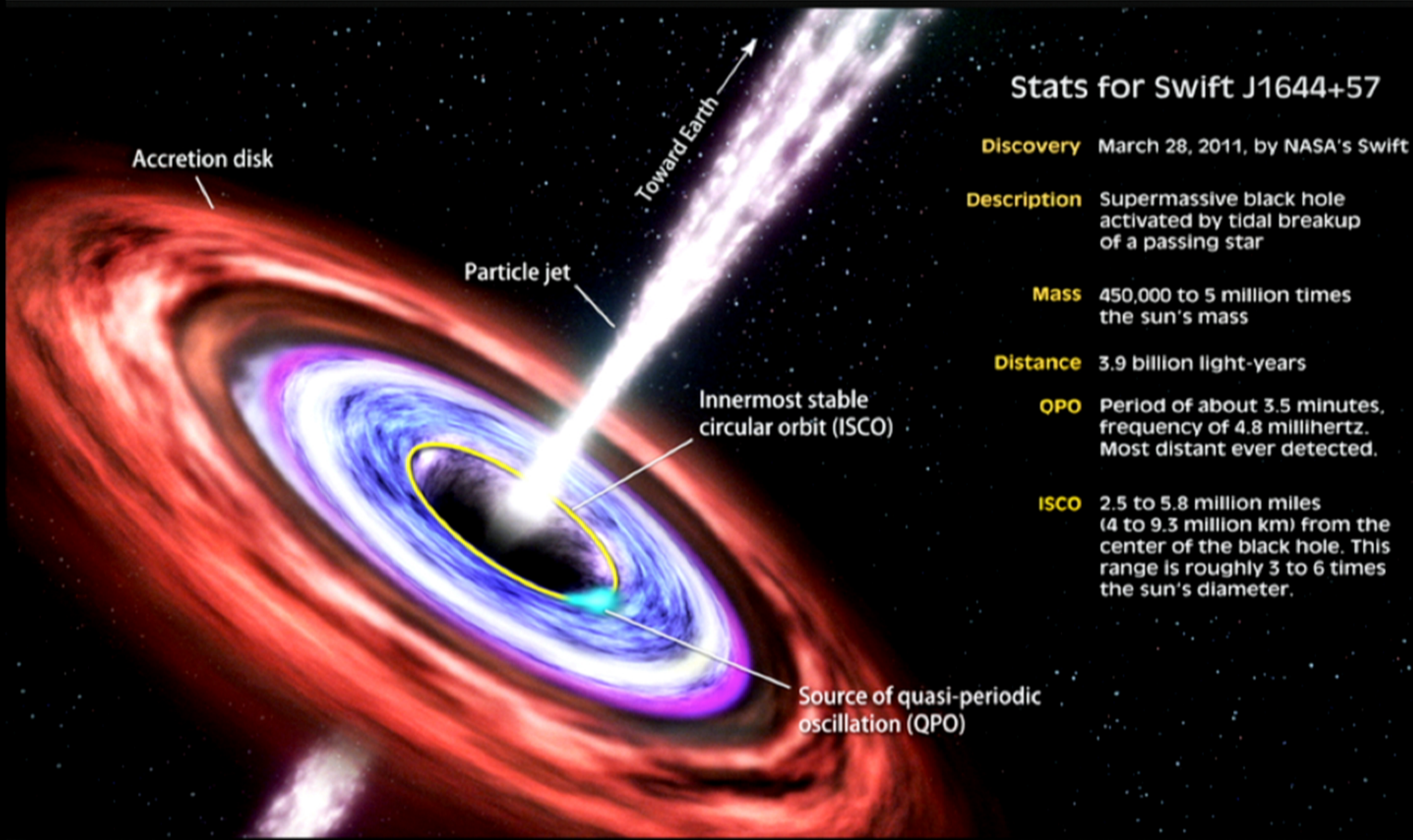




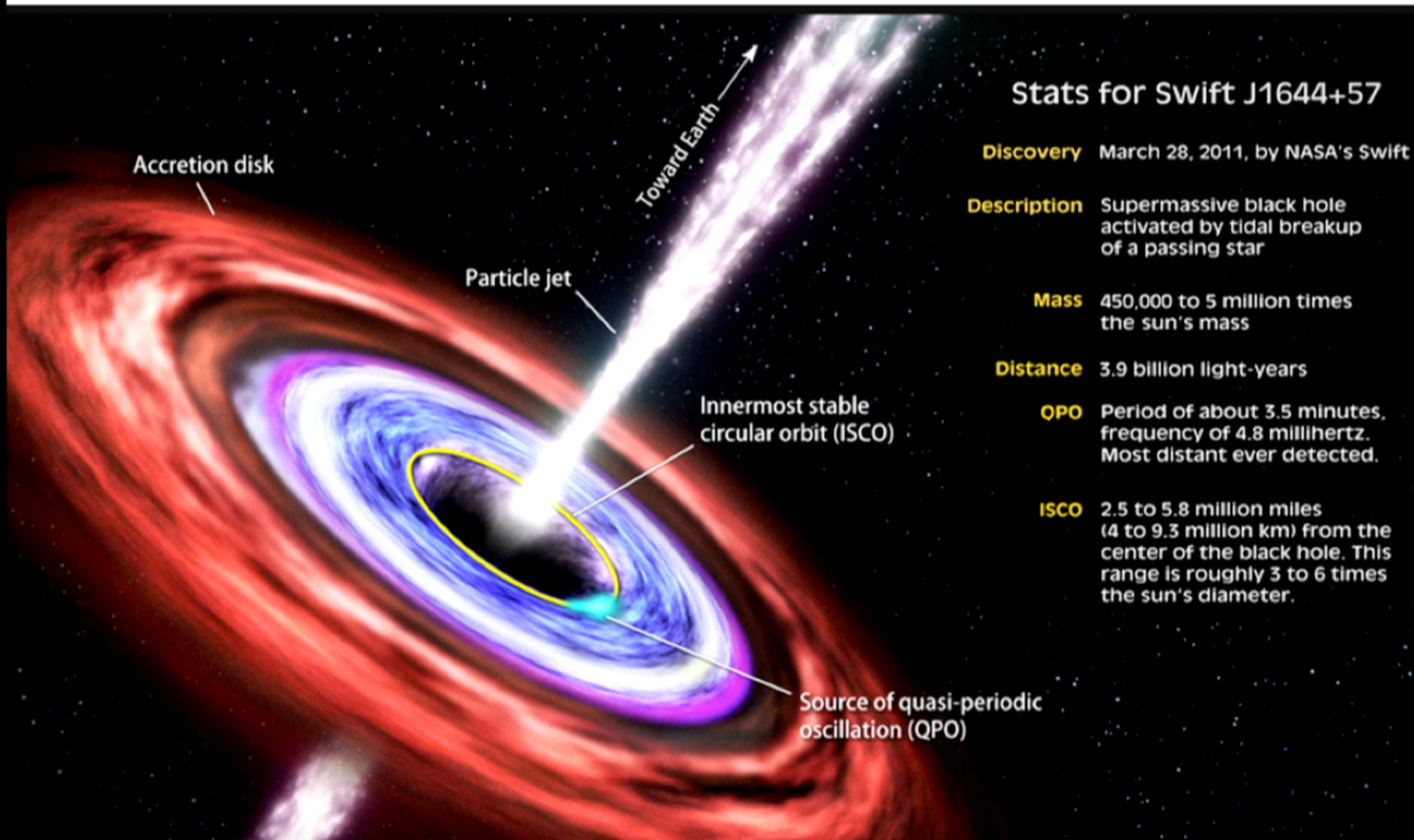
Likelihood
Fornax & Sculptor (slope + $t_{\rm fric}$)
Ursa Minor (cold clump)
Fornax (Jeans)
0.2
0.6
1
2
$m_a/10^{-22}$ eV

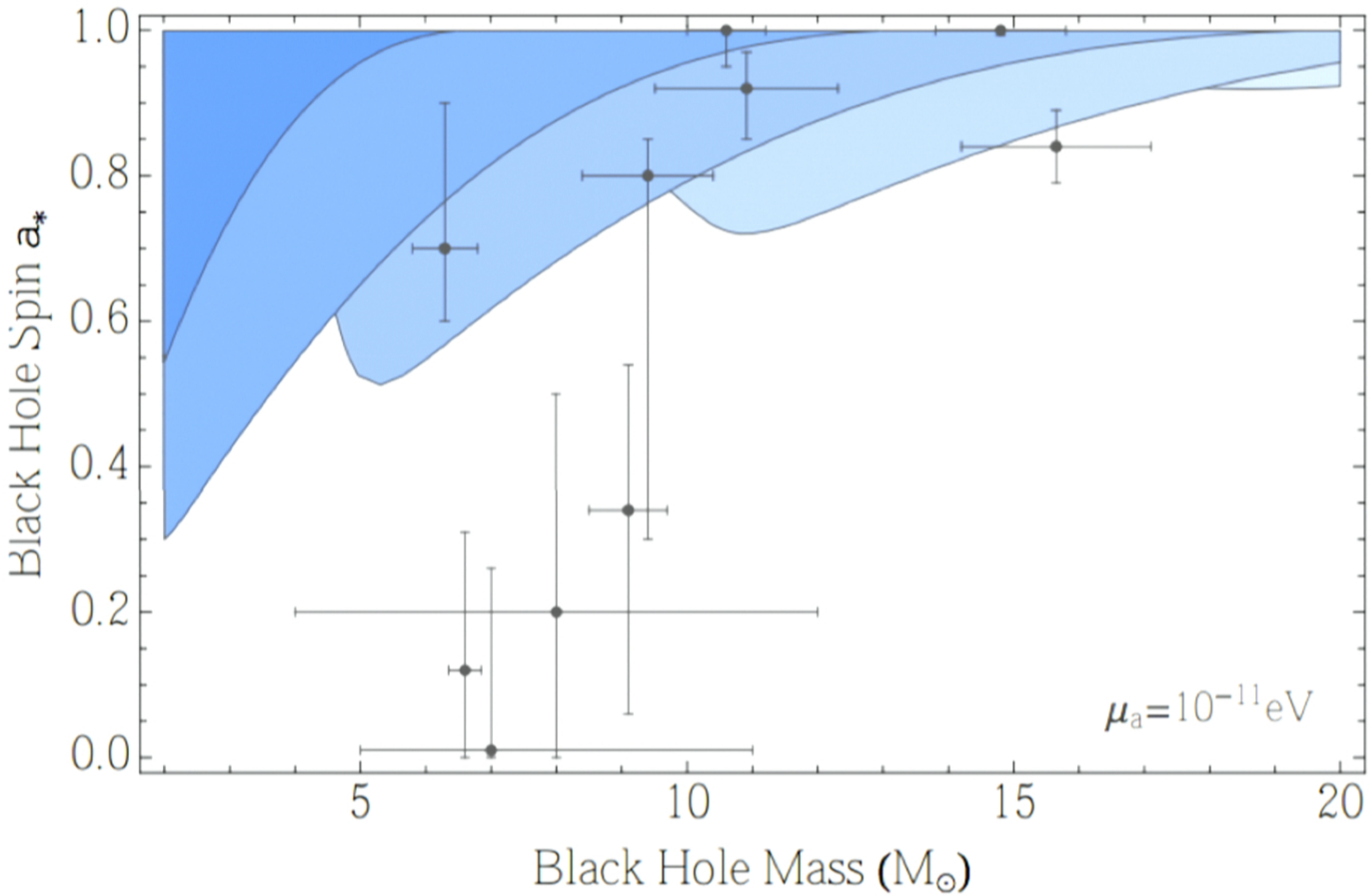


Likelihood
Fornax & Sculptor (slope + $t_{\rm fric}$)
Ursa Minor (cold clump)
Fornax (Jeans)
0.2
0.6
1
2
$m_a/10^{-22}$ eV

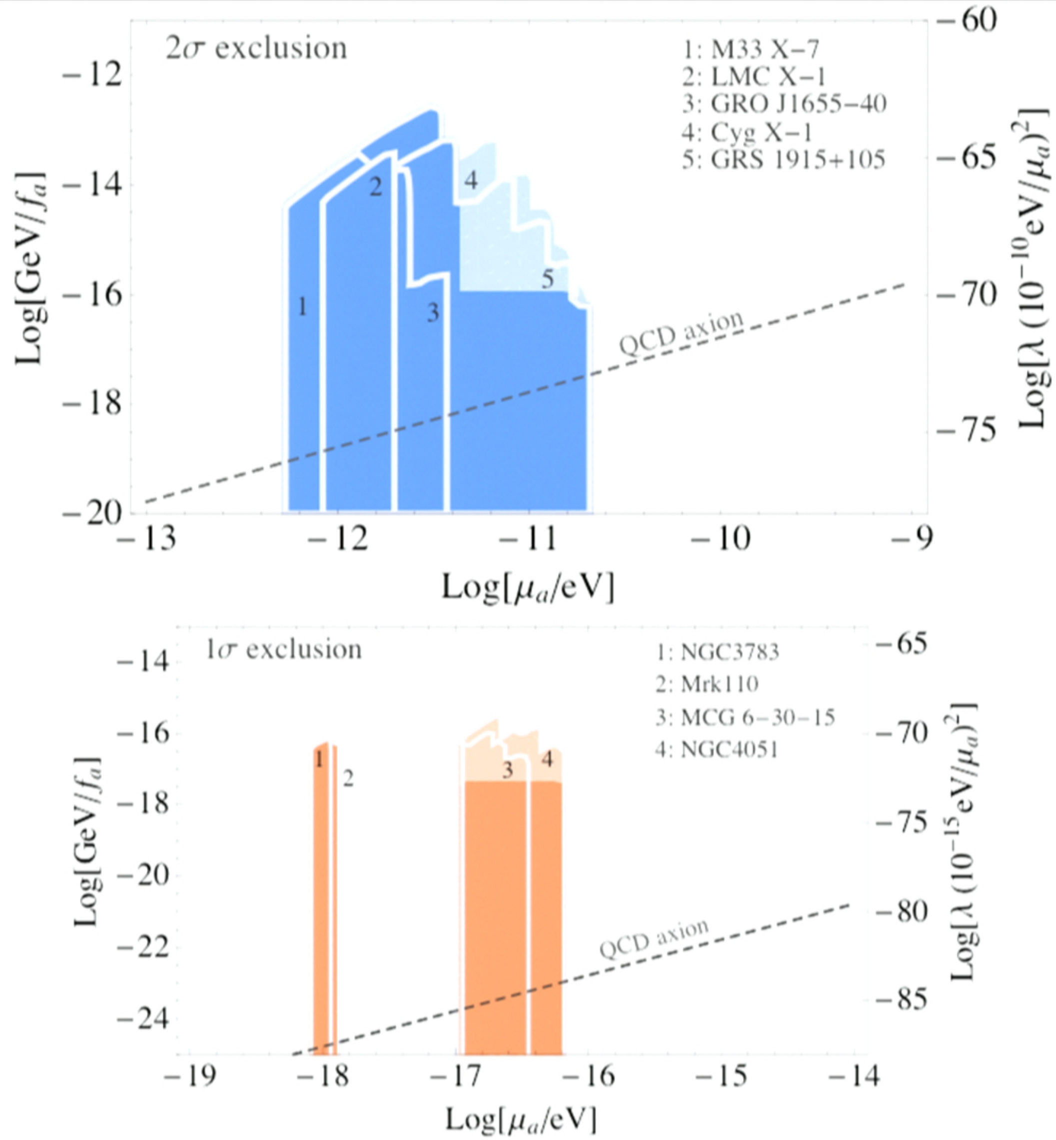


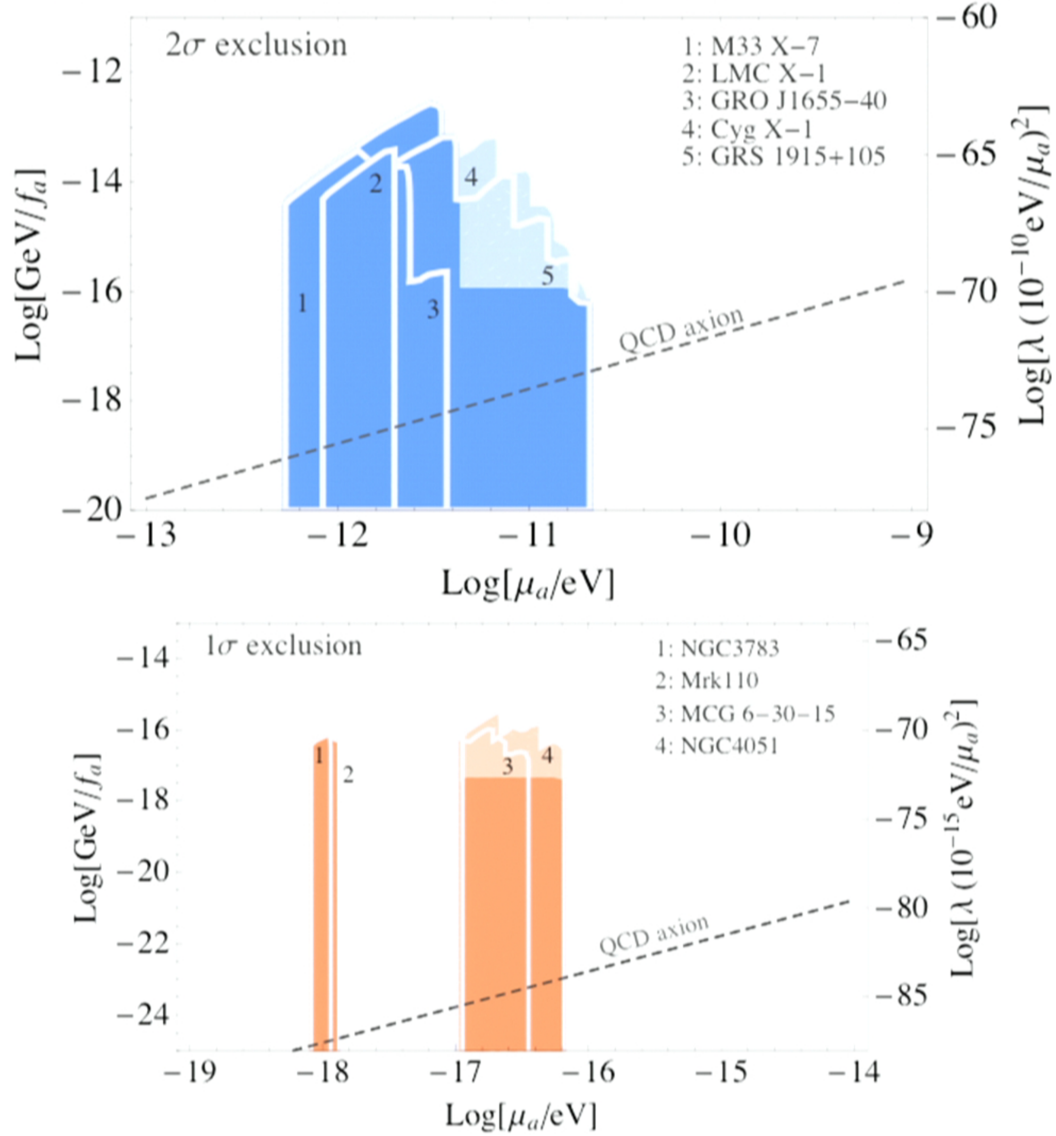
Stats for Swift J1644+57
Discovery March 28, 2011, by NASA's Swift
Description Supermassive black hole activated by tidal breakup of a passing star
Mass 450,000 to 5 million times the sun's mass
Distance 3.9 billion light-years
QPO Period of about 3.5 minutes, frequency of 4.8 millihertz. Most distant ever detected.
ISCO 2.5 to 5.8 million miles (4 to 9.3 million km) from the center of the black hole. This range is roughly 3 to 6 times the sun's diameter.
Accretion disk
Toward Earth
Particle jet
Innermost stable circular orbit (ISCO)
Source of quasi-periodic oscillation (QPO)


Stats for Swift J1644+57
Discovery March 28, 2011, by NASA's Swift
Description Supermassive black hole activated by tidal breakup of a passing star
Mass 450,000 to 5 million times the sun's mass
Distance 3.9 billion light-years
QPO Period of about 3.5 minutes, frequency of 4.8 millihertz. Most distant ever detected.
ISCO 2.5 to 5.8 million miles (4 to 9.3 million km) from the center of the black hole. This range is roughly 3 to 6 times the sun's diameter.
Accretion disk
Toward Earth
Particle jet
Innermost stable circular orbit (ISCO)
Source of quasi-periodic oscillation (QPO)



Black Hole Spin a_*
1.0
0.8
0.6
0.4
0.2
0.0
5
10
15
20
Black Hole Mass ($M_\odot$)
$\mu_a = 10^{-11}$eV


2σ exclusion
1: M33 X-7
2: LMC X-1
3: GRO J1655-40
4: Cyg X-1
5: GRS 1915+105
QCD axion
Log[GeV/f_a]
Log[μ_a/eV]
Log[λ (10^{-10}eV/μ_a)^2]
1σ exclusion
1: NGC3783
2: Mrk110
3: MCG 6-30-15
4: NGC4051
QCD axion
Log[GeV/f_a]
Log[μ_a/eV]
Log[λ (10^{-15}eV/μ_a)^2]



2σ exclusion
1: M33 X-7
2: LMC X-1
3: GRO J1655-40
4: Cyg X-1
5: GRS 1915+105
QCD axion
Log[GeV/f_a]
Log[λ (10^{-10}eV/μ_a)^2]
Log[μ_a/eV]
1σ exclusion
1: NGC3783
2: Mrk110
3: MCG 6-30-15
4: NGC4051
QCD axion
Log[GeV/f_a]
Log[λ (10^{-15}eV/μ_a)^2]
Log[μ_a/eV]