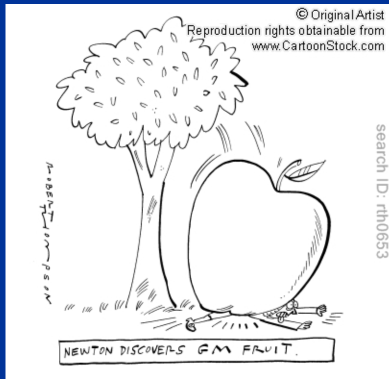

Constraints on time variation of G_N from Geometrical Test and Perturbation

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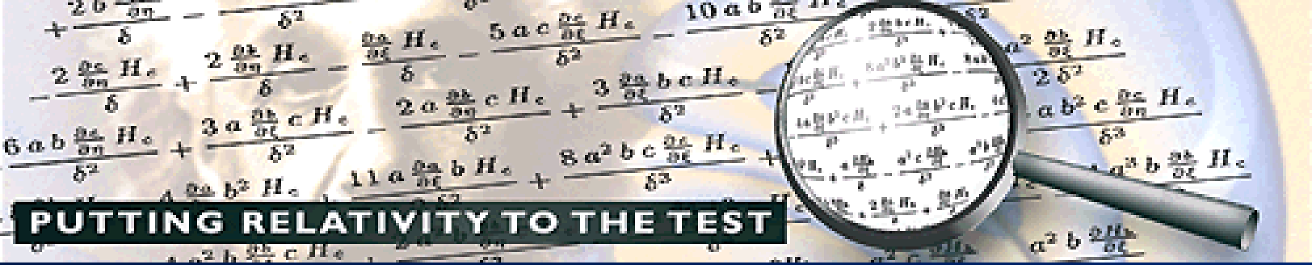
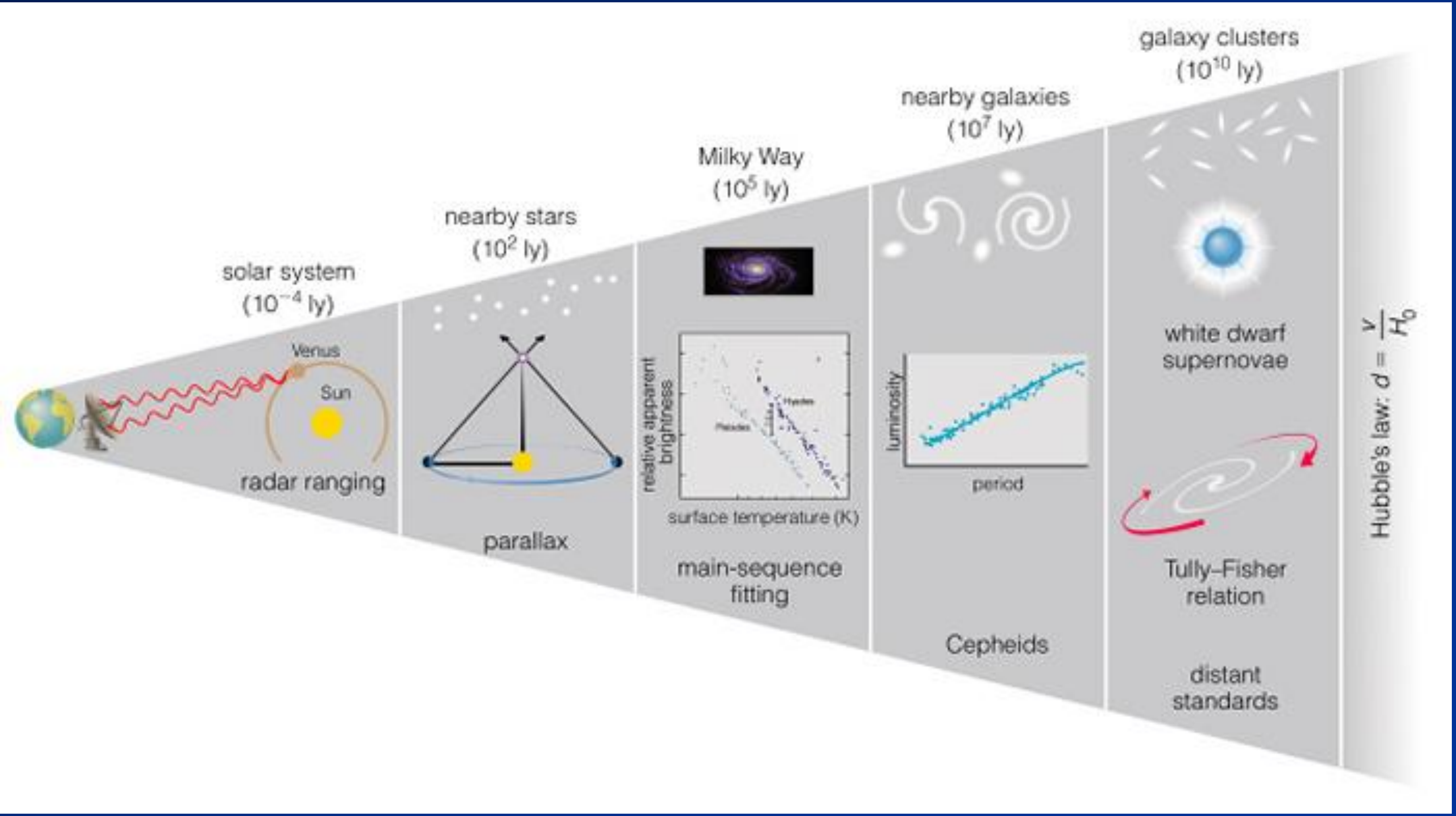


Outline

1. Age and Distance
2. Observations (SNe, Growth)
3. Constraints on G_N
4. Conclusion

Cosmic Distance Ladder

- 1parsec = 3.26 ly

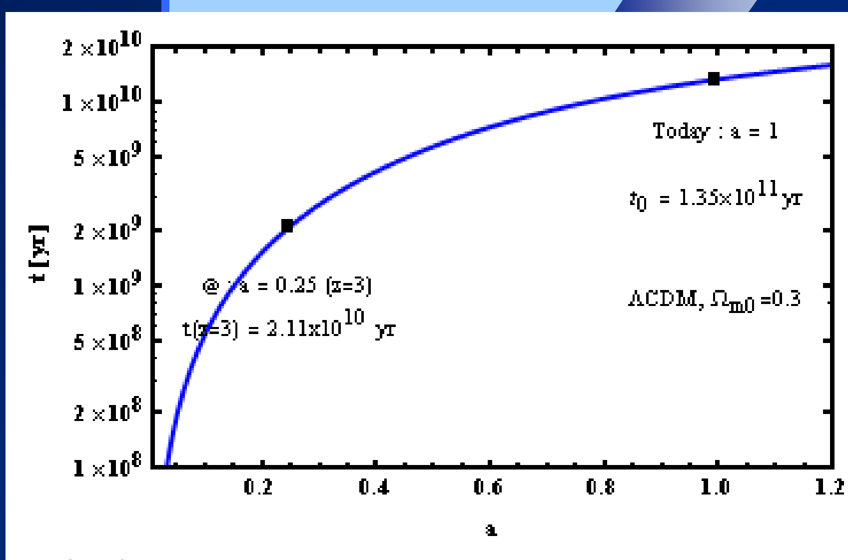


Age and Distance

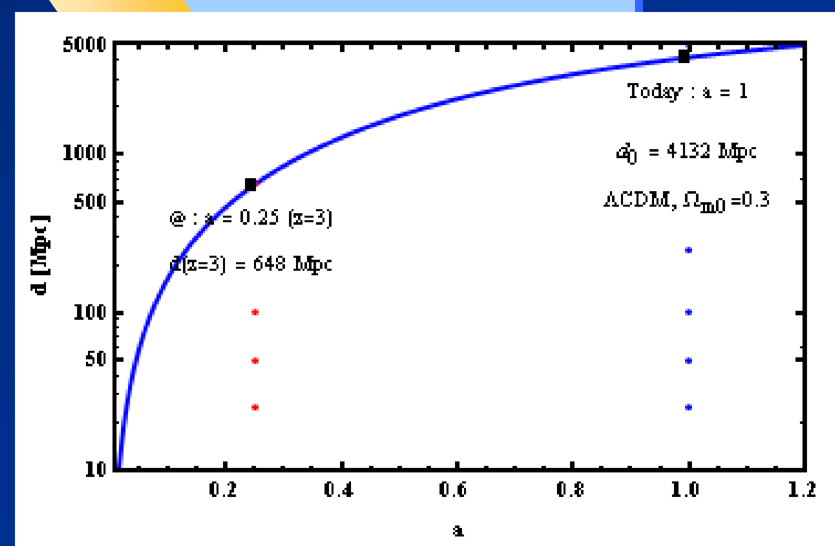
Need DE?

t0 and d0

t_0.



d_0



Discriminate DE from MG

Background can be same

$$
\begin{aligned}
H^2 - \delta H &= \frac{8\pi G_*}{3}\rho_m \;\rightarrow\; \delta H \equiv \frac{8\pi G_*}{3}\rho_X \\
H^2 &\equiv \frac{8\pi G_*}{3}\left(\rho_m + \rho_X\right) \\
\dot{H} &= -4\pi G_*\rho_m - 4\pi G_*(1+\omega_X)\rho_X \\
-\Omega_X\omega_X &= 1 + \frac{2}{3}\frac{\dot{H}}{H^2}
\end{aligned}
$$

MG vs DE

Subhorizon scale

Matter Growth

$$
\begin{aligned}
\frac{d\ln\delta_m}{d\ln a} &\equiv \Omega_m^{\gamma} \\
\gamma &\equiv \gamma_0 + \gamma_a(1-a) \\
\delta_m'' &+ \left(2 + \frac{H'}{H}\right)\delta_m' - \frac{4\pi G_{eff}\rho_m}{H^2}\delta_m = 0 \\
\text{where} \quad \delta_m' &\equiv \frac{d\delta_m}{d\ln a}
\end{aligned}
$$

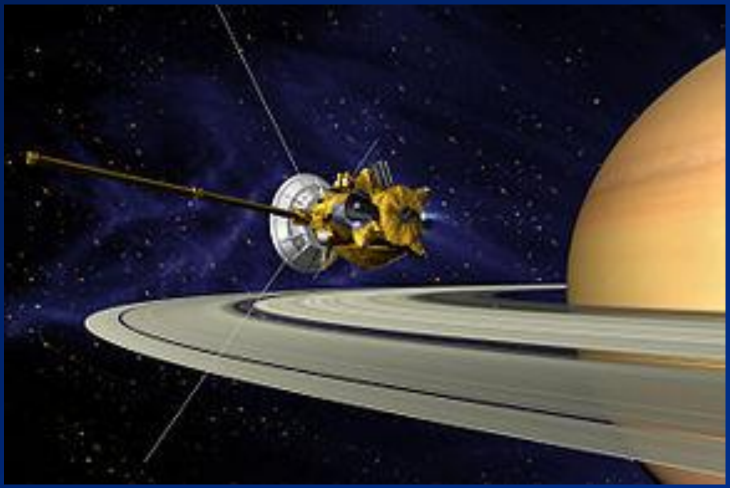
Matter growth different due to G_{eff}

Theoretical Prediction

Quantities	$\omega = \omega_0+\omega_a(1-a)$		γ
	ω_0	ω_a	
Λ	-1	0	0.56
Quintessence	~ -1	≠ 0	~ 0.56
DGP	-0.78	0.32	11/16 (0.69)
f(R)	-0.7	positive	0.43 -0.18 (1-a)
Scalar-Tensor-Gravity	flexible	flexible	Determined from ω

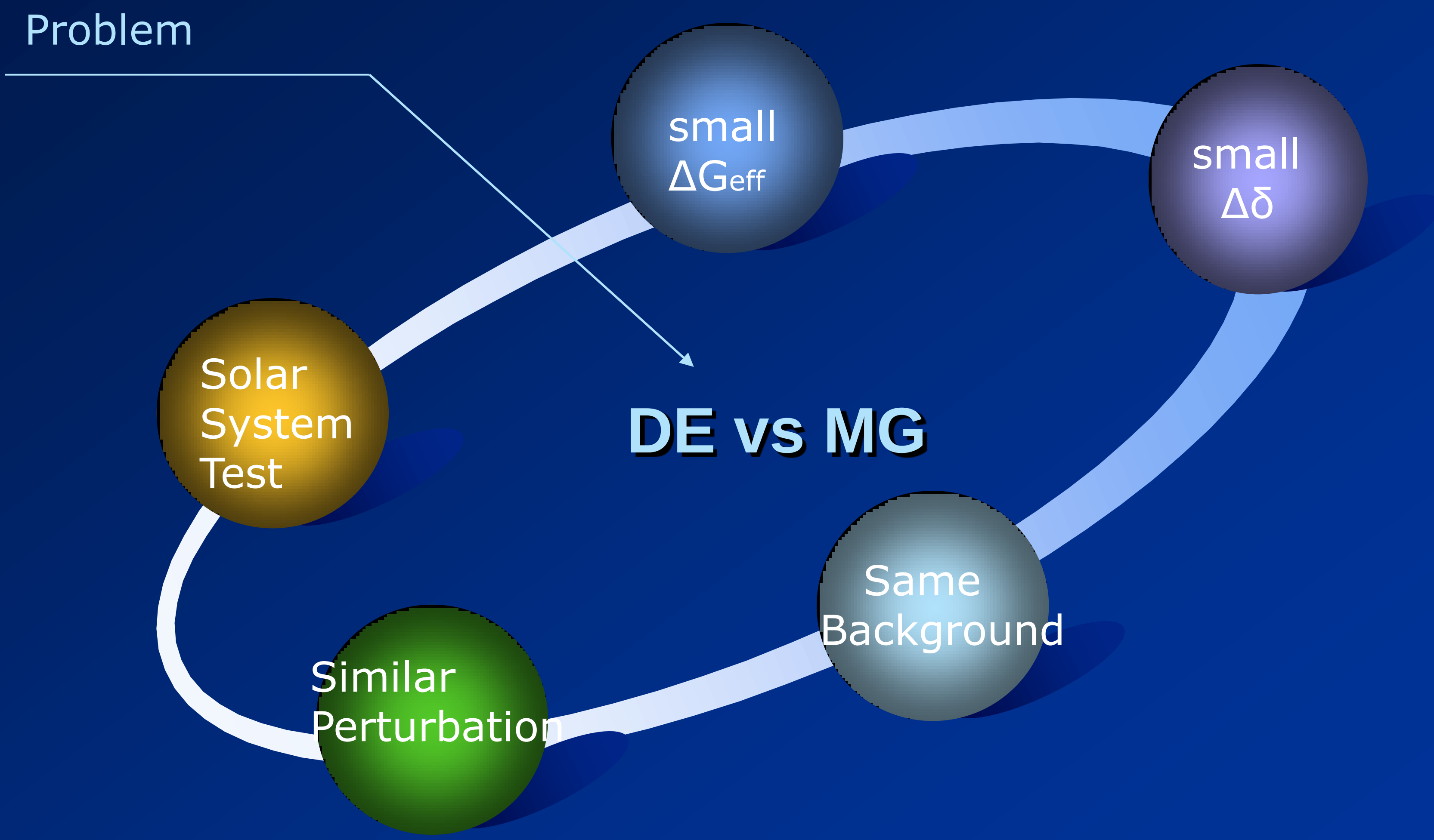
Cassini–Huygens Mission

- A joint NASA/ESA/ASI spacecraft mission studying the planet Saturn



$$\dot{G}/G = (-0.6 \pm 1.6) \times 10^{-12}\,\mathrm{yr}^{-1} = (-0.009 \pm 0.022)\,H_0,$$

Problem in Discriminating DE from MG



SNe Ia : Standard Candle

(Gaztanaga et.al 2001)

$$m(z) = M_0 + 5 \log d_L + 25 + \frac{15}{4(1+\omega)} \log(1+z)$$

SNe Ia

$$M_C \simeq \frac{3.1}{m'} \left(\frac{\hbar c}{G}\right)^{3/2}$$

$$L_p \sim G^{-\gamma},$$

$$M - M_0 = \frac{15}{4} \log\left(\frac{G}{G_0}\right)$$

$$G(z) \equiv G_0 (1+z)^{\frac{1}{1+\omega(z)}},$$

$$\frac{G}{G_0} \lesssim 1.08 \;\; ; \;\; \Omega_\Lambda \simeq 0.8 \; , \; \Omega_M \simeq 0.2$$

$$\frac{\dot{G}}{G} \simeq \left(1 - \frac{G_0}{G}\right) (\Delta t)^{-1}$$

$$\frac{\dot{G}}{G} \lesssim 12 \times 10^{-12} \; h_{70}/\mathrm{yr} \;\; ; \;\; \Omega_\Lambda \simeq 0.8 \; , \; \Omega_M \simeq 0.2$$

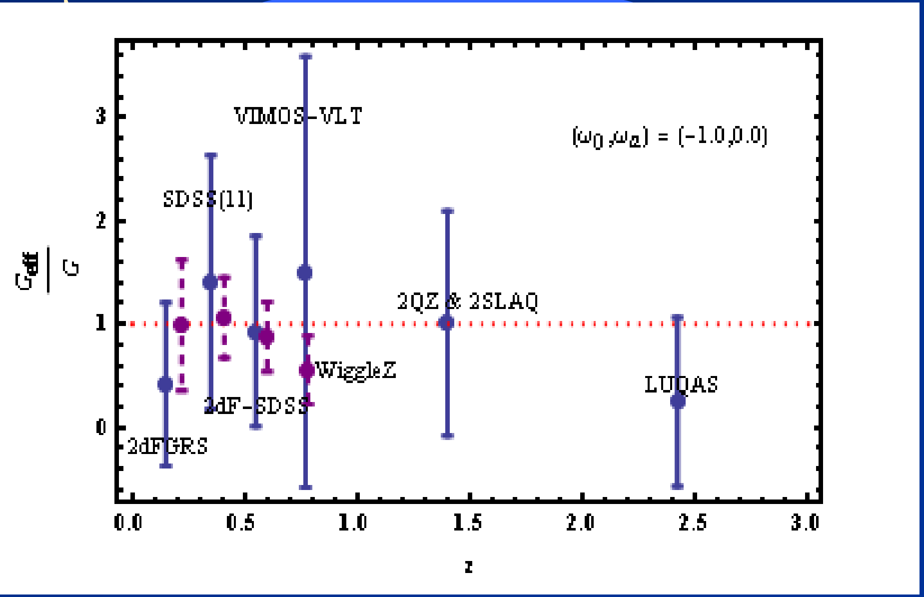
SNe Ia : explode when WD reaches Chandrasekhar Mass (Mc)
Relation btw CM and luminosity (L)
M : absolute magnitude @ z ~0.5

Matter Growth

Observations

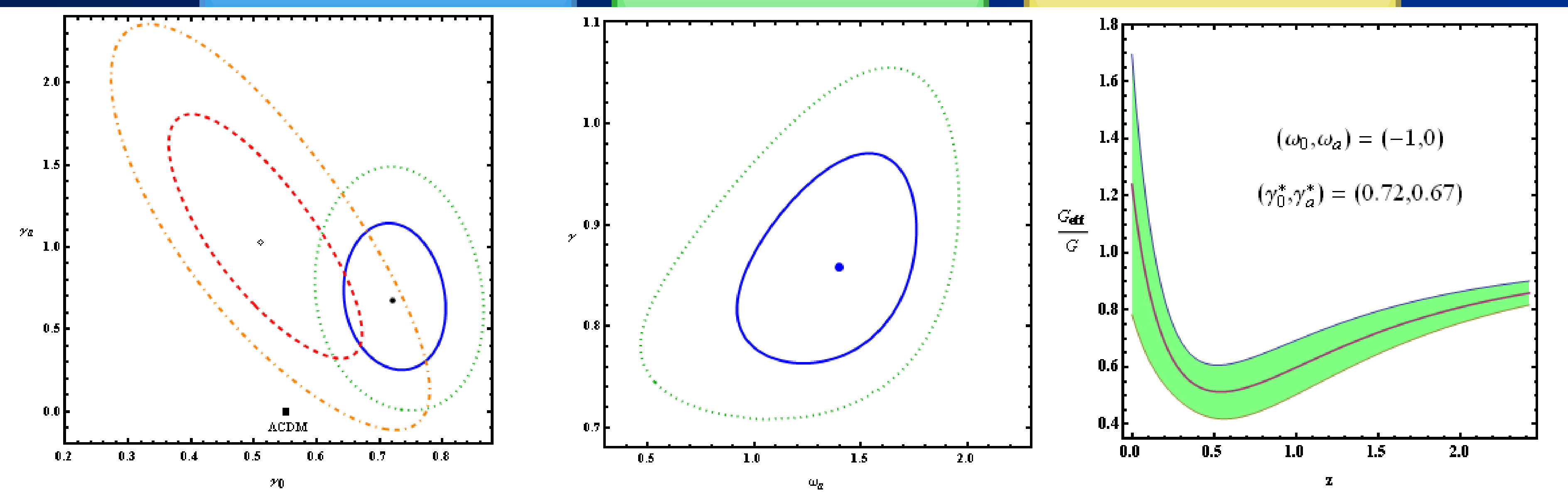
TABLE I: Data of the growth rate of clustering. The correspondence of the columns is as follows: number, redshift, observed growth rate, cosmological parameters used by different authors and references.

Index	z	$f_{obs,Ref}$	$(\Omega_{m,Ref}, \sigma_{8,Ref})$	Refs.
1	0.15	0.49 ± 0.14	(0.30, 0.90)	[16, 40, 41]
2	0.35	0.70 ± 0.18	(0.24, 0.76)	[42]
3	0.55	0.75 ± 0.18	(0.30, 1.00)	[43]
4	0.77	0.91 ± 0.36	(0.27, 0.78)	[16]
5	1.40	0.90 ± 0.24	(0.25, 0.84)	[44]
6	2.42	0.74 ± 0.24	(0.26, 0.93)	[19, 45]
7	3.00	1.46 ± 0.29	(0.30, 0.85)	[46]
8	0.22	0.60 ± 0.10	(0.27, 0.80)	[38]
9	0.41	0.70 ± 0.07	(0.27, 0.80)	[38]
10	0.60	0.73 ± 0.07	(0.27, 0.80)	[38]
11	0.78	0.70 ± 0.08	(0.27, 0.80)	[38]



Matter Growth Constraints

1 2 3



From current observations

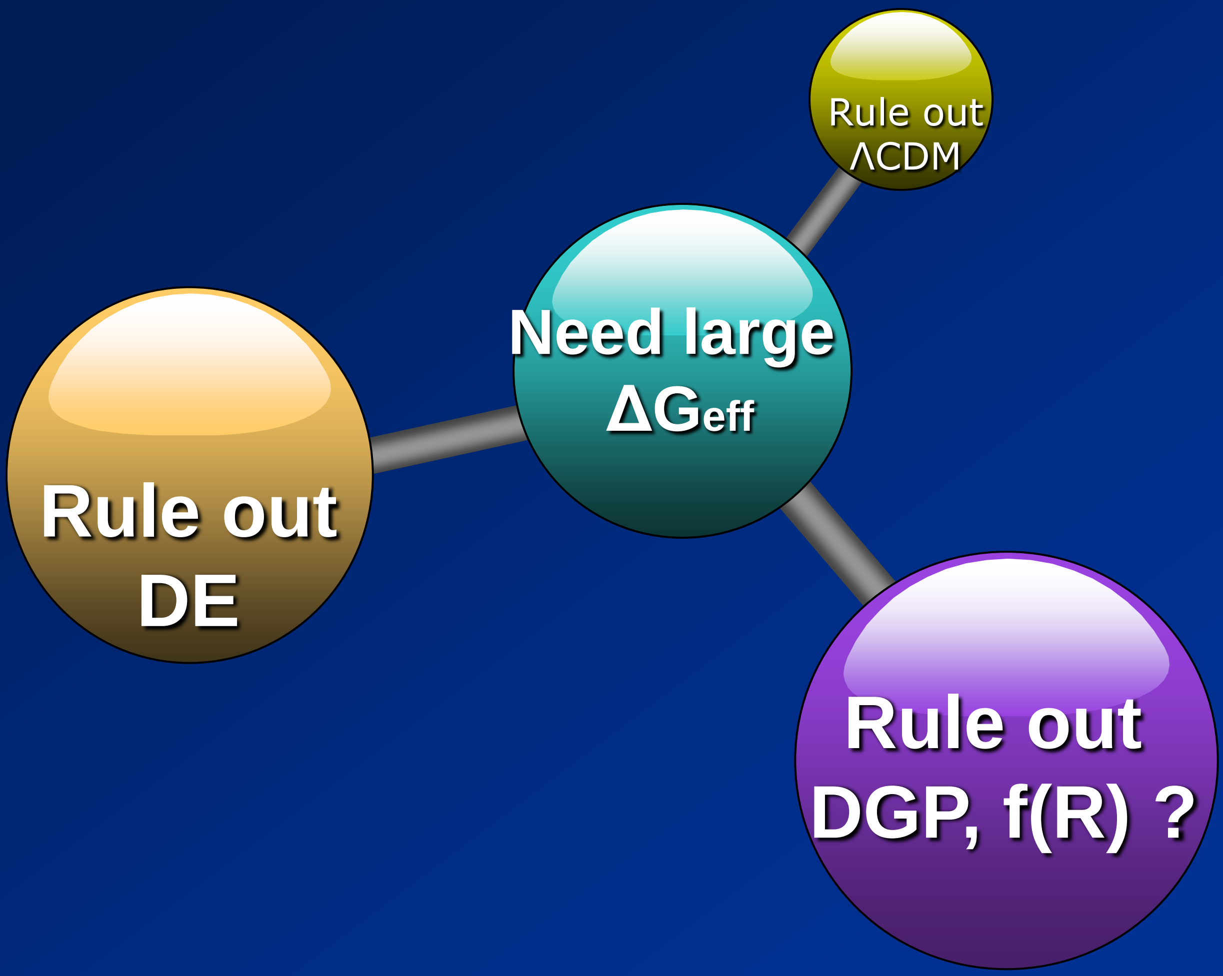
For ΛCDM, $\gamma \sim 0.56$

For DGP, wo=-0.78,wa=0.32, $\gamma \sim 0.68$

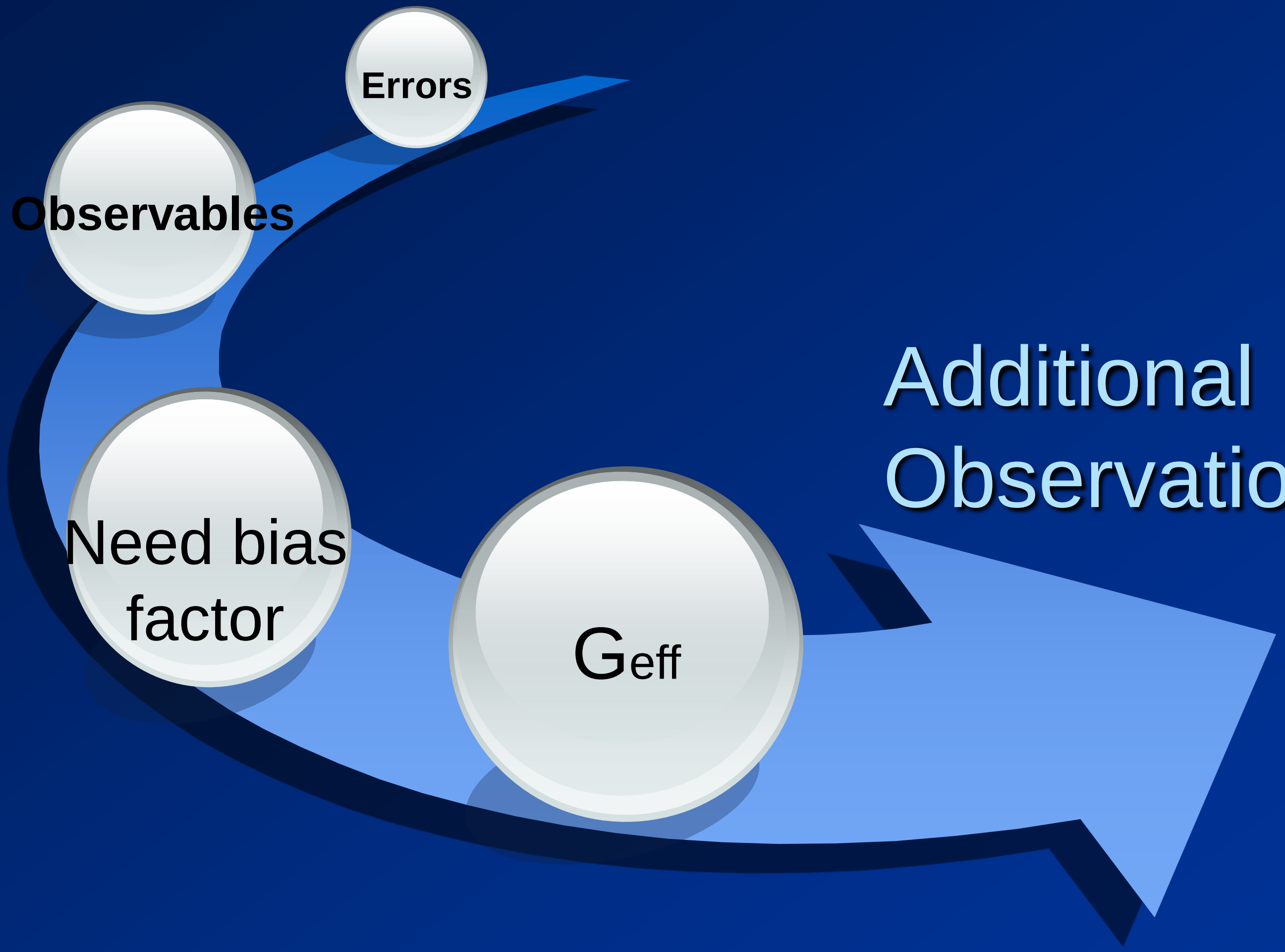
For STG, we may(?) produce large γ

Most of the known models rules out by 2-σ

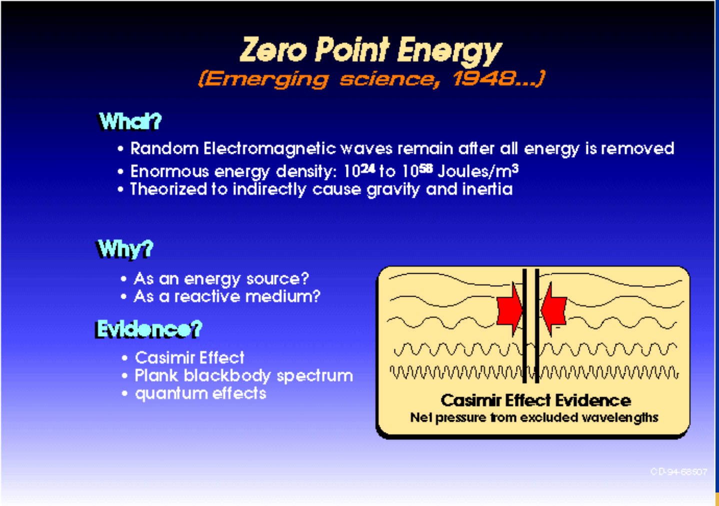
Conclusion



Challenges in observations



Additional Observations?


Zero Point Energy
(Emerging science, 1948...)
What?
• Random Electromagnetic waves remain after all energy is removed
• Enormous energy density: 10^{24} to 10^{58} Joules/m^3
• Theorized to indirectly cause gravity and inertia
Why?
• As an energy source?
• As a reactive medium?
Evidence?
• Casimir Effect
• Plank blackbody spectrum
• quantum effects
Casimir Effect Evidence
Net pressure from excluded wavelengths

Thank You !

感謝