Cosmological constraints from cosmic chronometer

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Determination Cosmological parameter

$$H(t) = H_0\sqrt{\Omega_M(1+z)^3 + \Omega_\Lambda(1+z)^{3(1+w)} + \Omega_K(1+z)^2}$$

Matter parameter $\Omega_M = \frac{\rho_M}{\rho_c}$

Dark energy density parameter $\Omega_\Lambda = \frac{\rho_\Lambda}{\rho_c}$

Curvature $\Omega_K = 1 - \Omega_M - \Omega_\Lambda$

$$\rho_c \equiv \frac{3c^2H^2}{8\pi G}$$

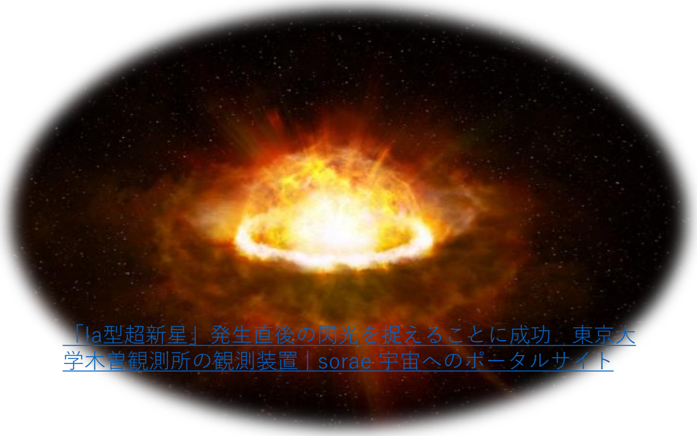
The current critical density

w :The dark energy equation-of-state parameter

Data used in this project

- Supernova and Cosmic chronometer

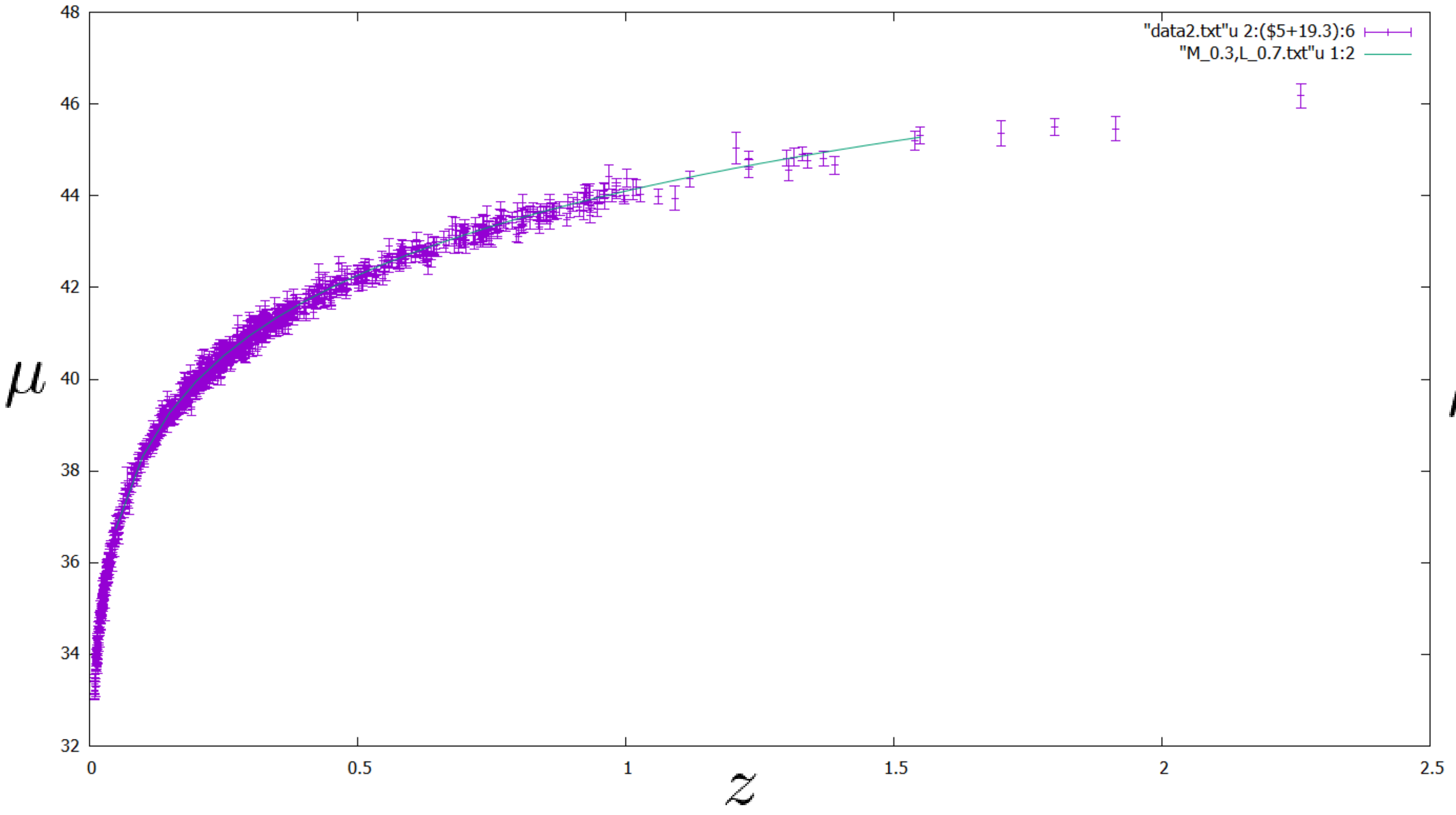
Supernova



「Ia型超新星」発生直後の閃光を捉えることに成功　東京大学木曽観測所の観測装置 | sorae 宇宙へのポータルサイト

Based on the luminosity distance

$$d_L = (1+z)\int_0^z \frac{dz'}{H(z')}$$



- a wide range of redshifts (z=0.01~2.26)
- The number of the data is 1048.

$$\mu = m - M = 5\log_{10}\frac{d_L}{1Mpc} + 25$$

μ : distance modulus
m : apparent magnitude
M : absolute magnitude

Cosmic chronometer

Based on relative galaxy age

$$H(z) = -\frac{1}{(1+z)}\frac{dz}{dt} \approx -\frac{1}{1+z}\frac{\Delta z}{\Delta t}$$

☆Conditions for selection

- Passive stellar populations
- evolve on a timescale much larger than their differential ages

ex)massive , early , passively-evolving galaxies

How to use cosmic chronometer

$$H(z) = -\frac{1}{(1+z)}\frac{dz}{dt} \approx -\frac{1}{1+z}\frac{\Delta z}{\Delta t}$$

- Only measure differential age $\frac{\Delta z}{\Delta t}$.

☆We used to constrain cosmological parameters.

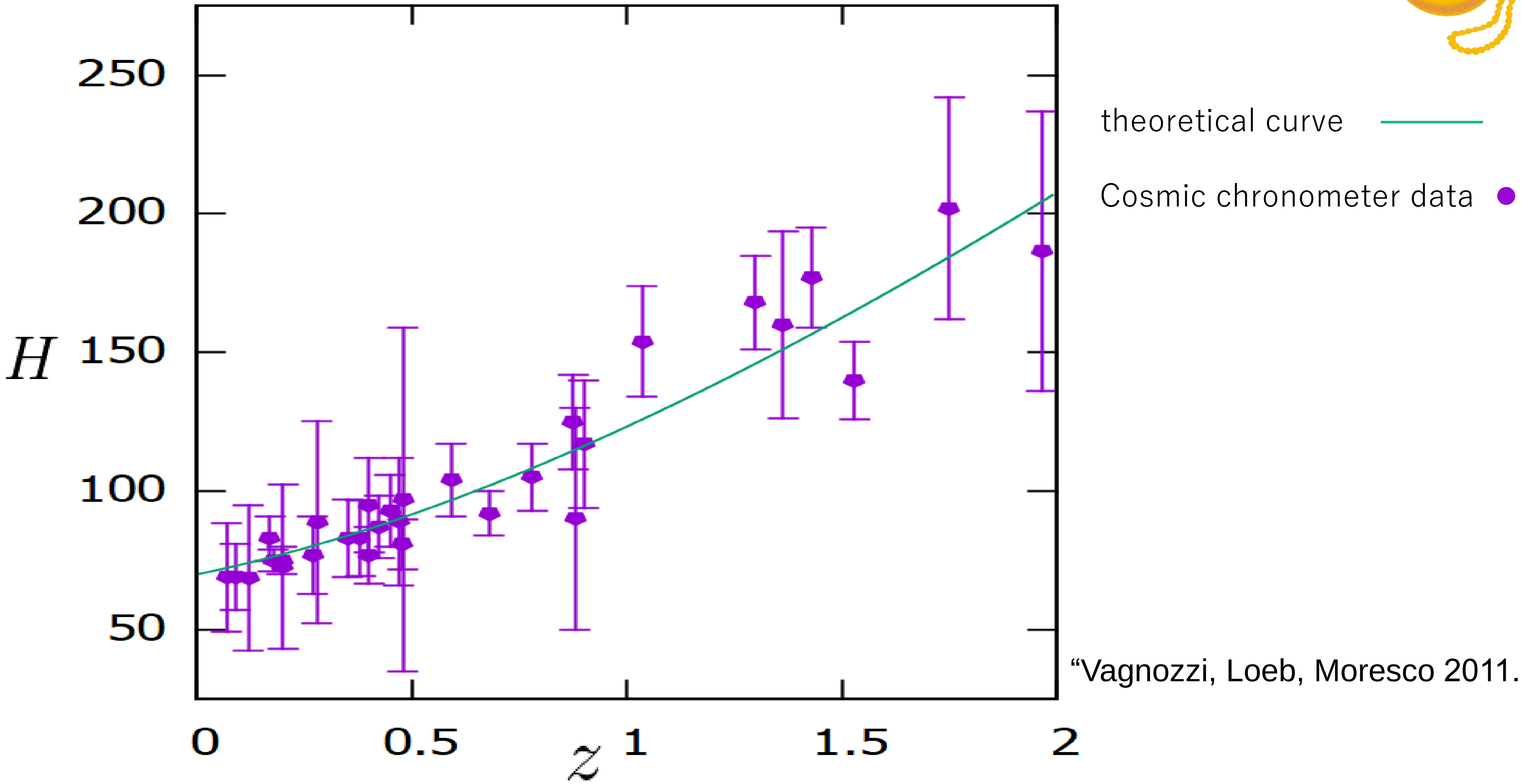
- The standard ΛCDM model
- Scenarios with some dark energy characterized by its equation of state

Usefulness of Cosmic chronometer data

The effect of observational systematics on the CC dataset is relatively small, but the total error is larger than that of SN data.

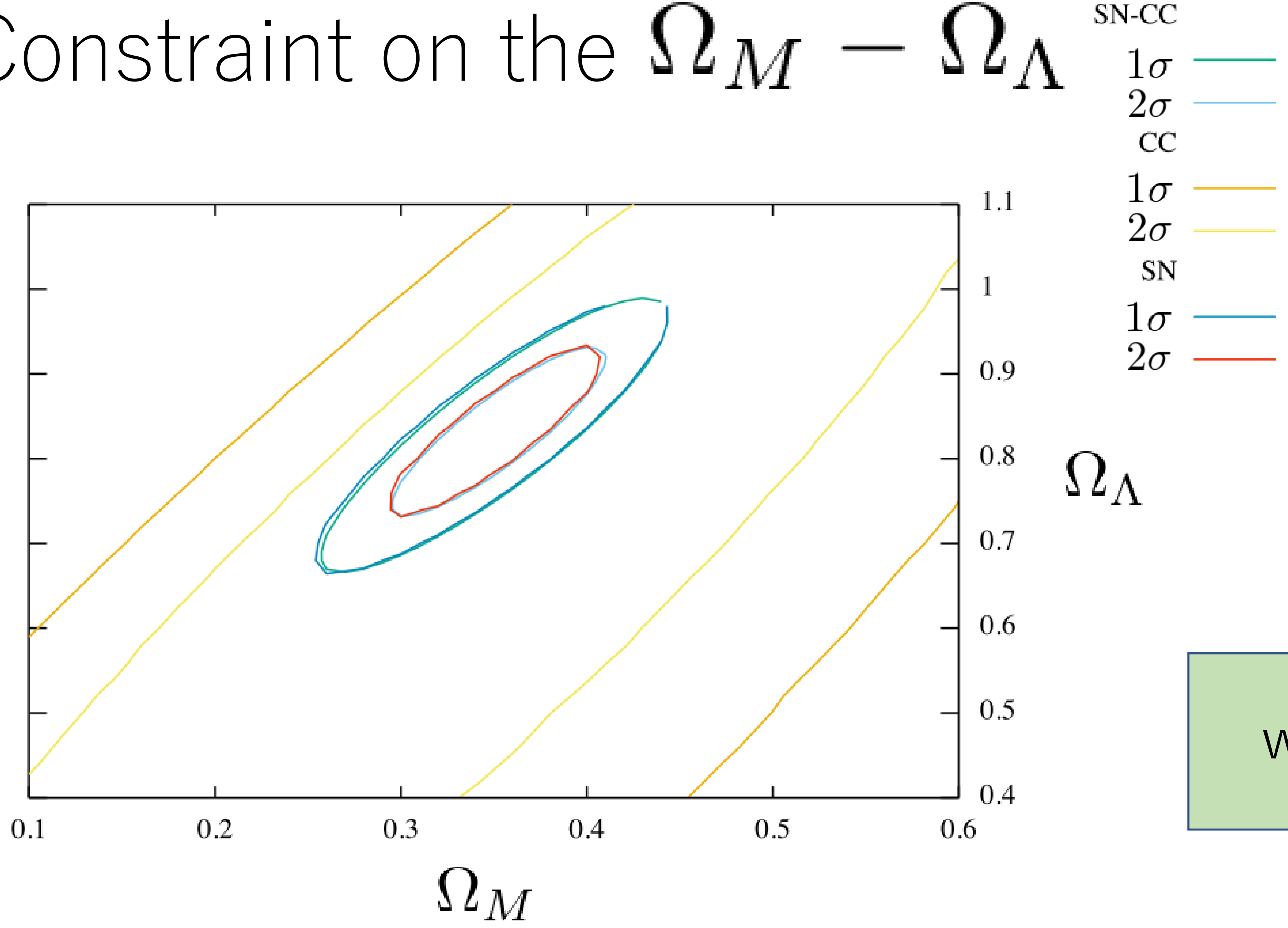
CC determines $H(z)$ with $\sim$10% uncertainties $(z < 2)$

H as a function of z



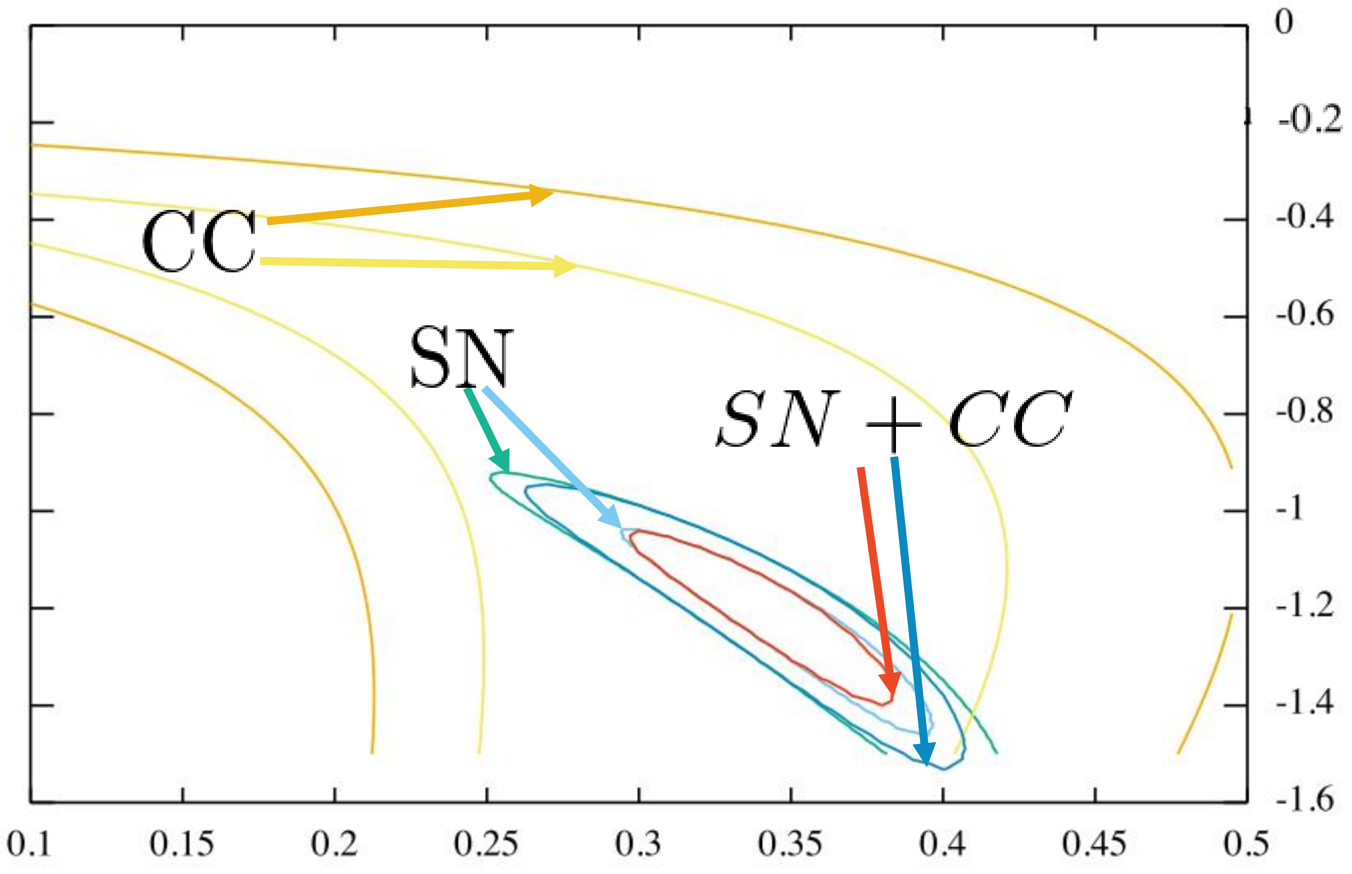
“Vagnozzi, Loeb, Moresco 2011.11645”

Constraint on the $\Omega_M - \Omega_\Lambda$



w=-1

Constraint on the $\Omega_M - w$



$$\Omega_\Lambda = 1 - \Omega_M$$

CC limit range >>SN limit range

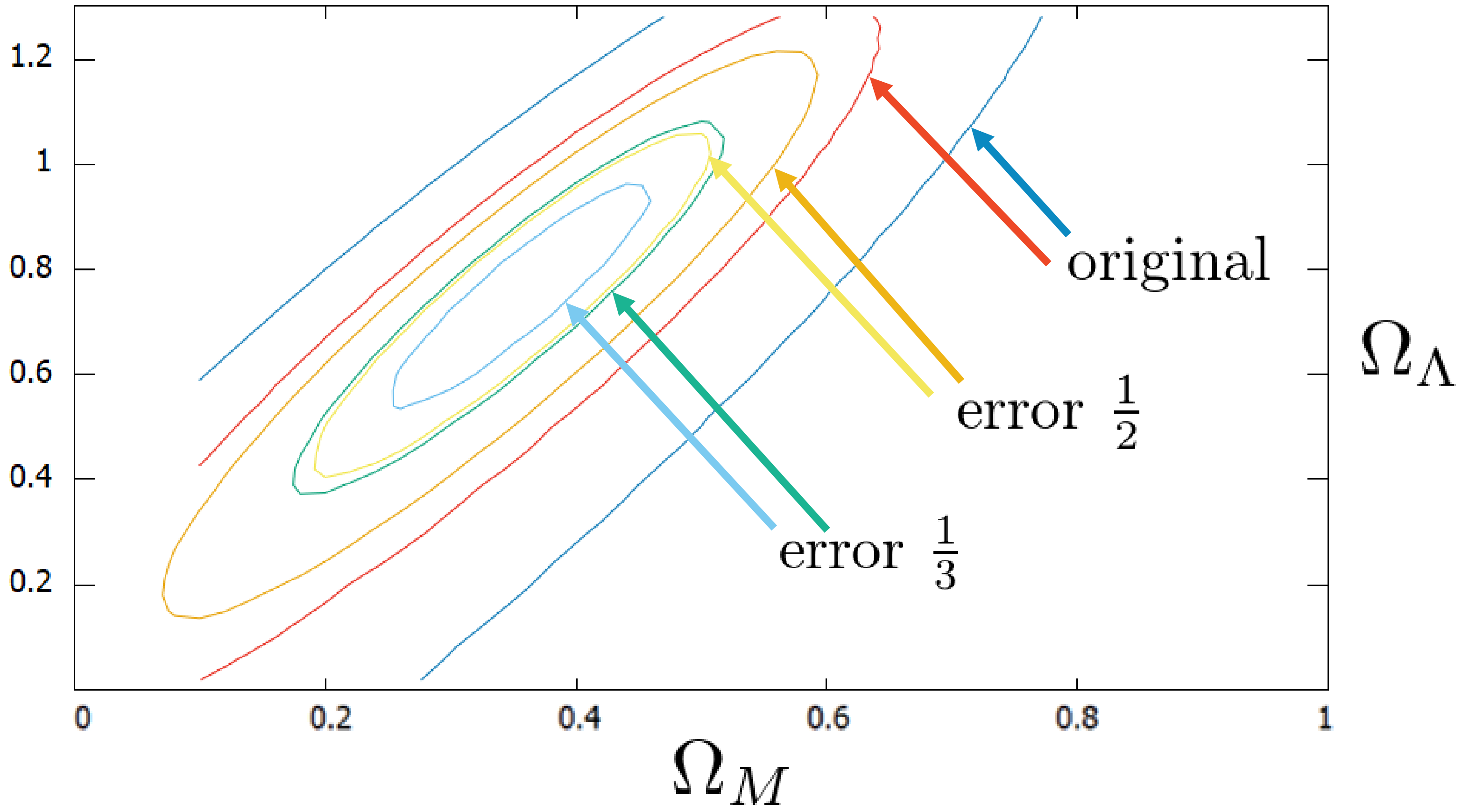
Assumption of improved observation techniques

Cosmic chronometer

CC data error

➡1/2

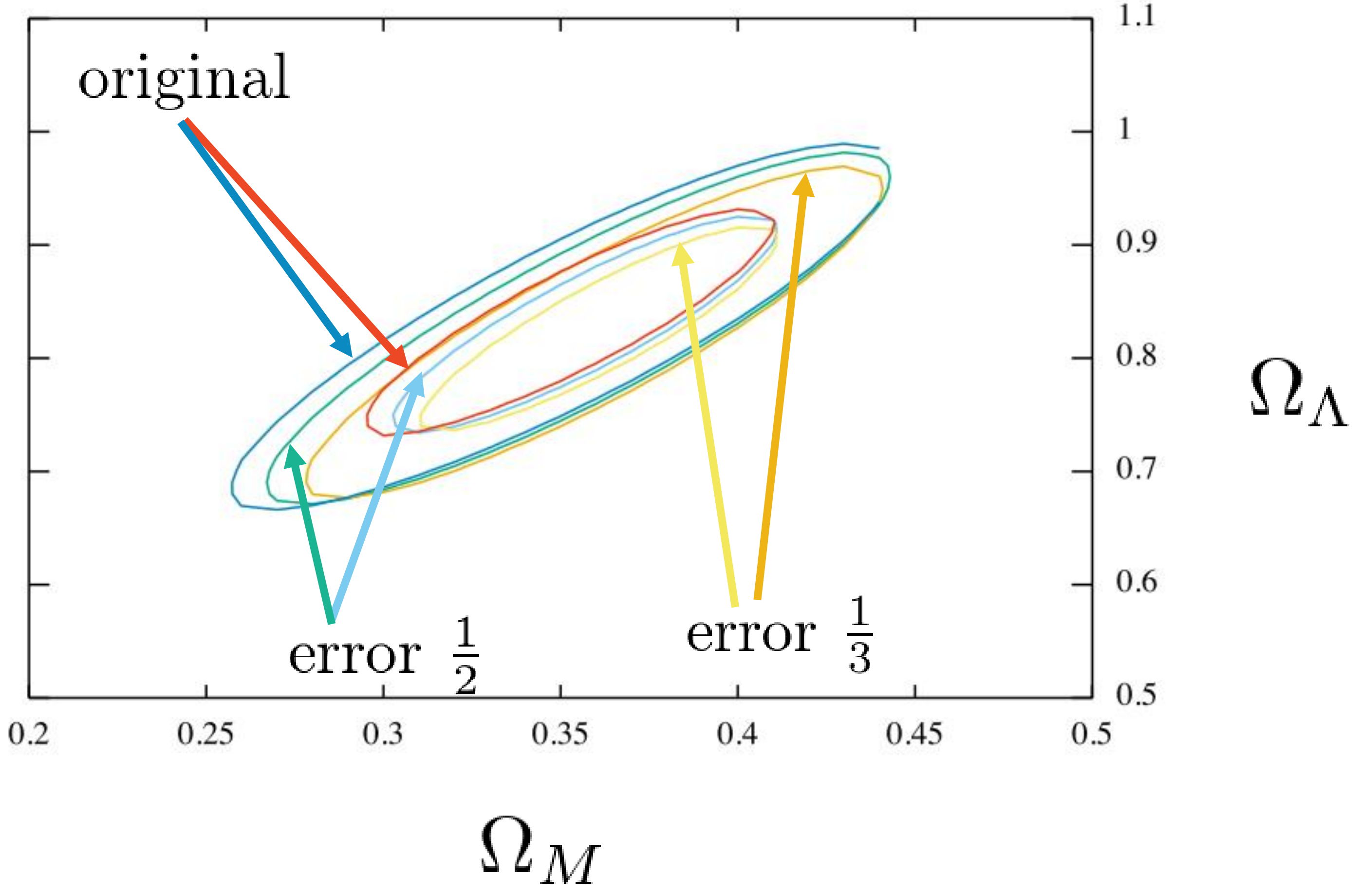
➡1/3



Assumption of improved observation techniques

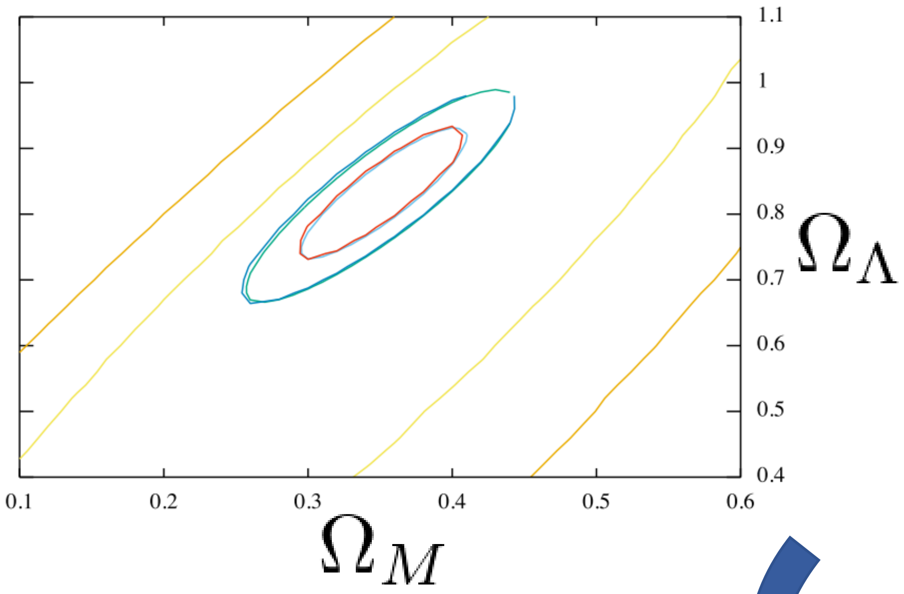
Cosmic chronometer & supernova

CC data error
➡1/2
➡1/3

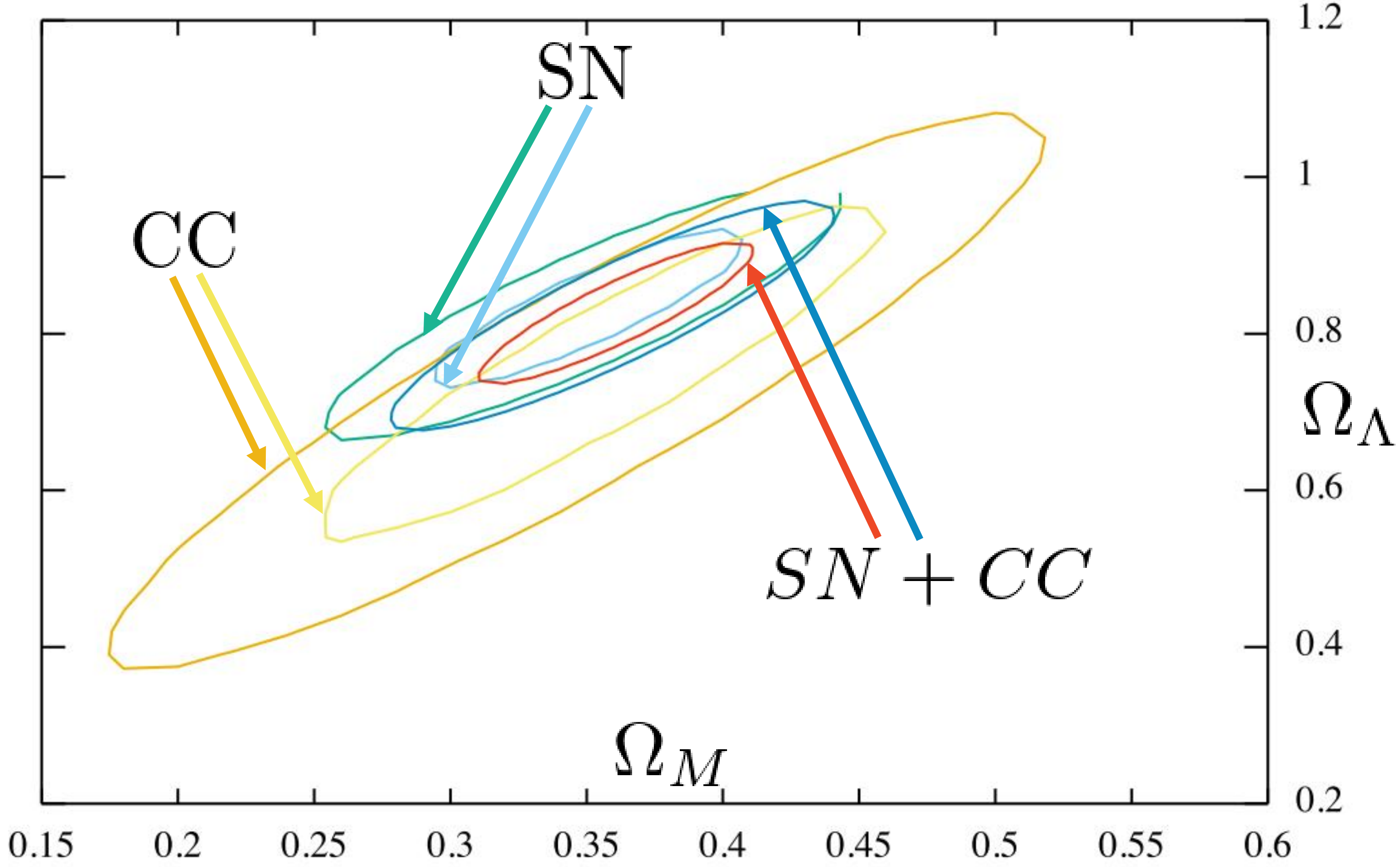


Assumption of improved observation techniques

Cosmic chronometer & supernova



Error $\frac{1}{3}$ effect



Assumption of improved observation techniques

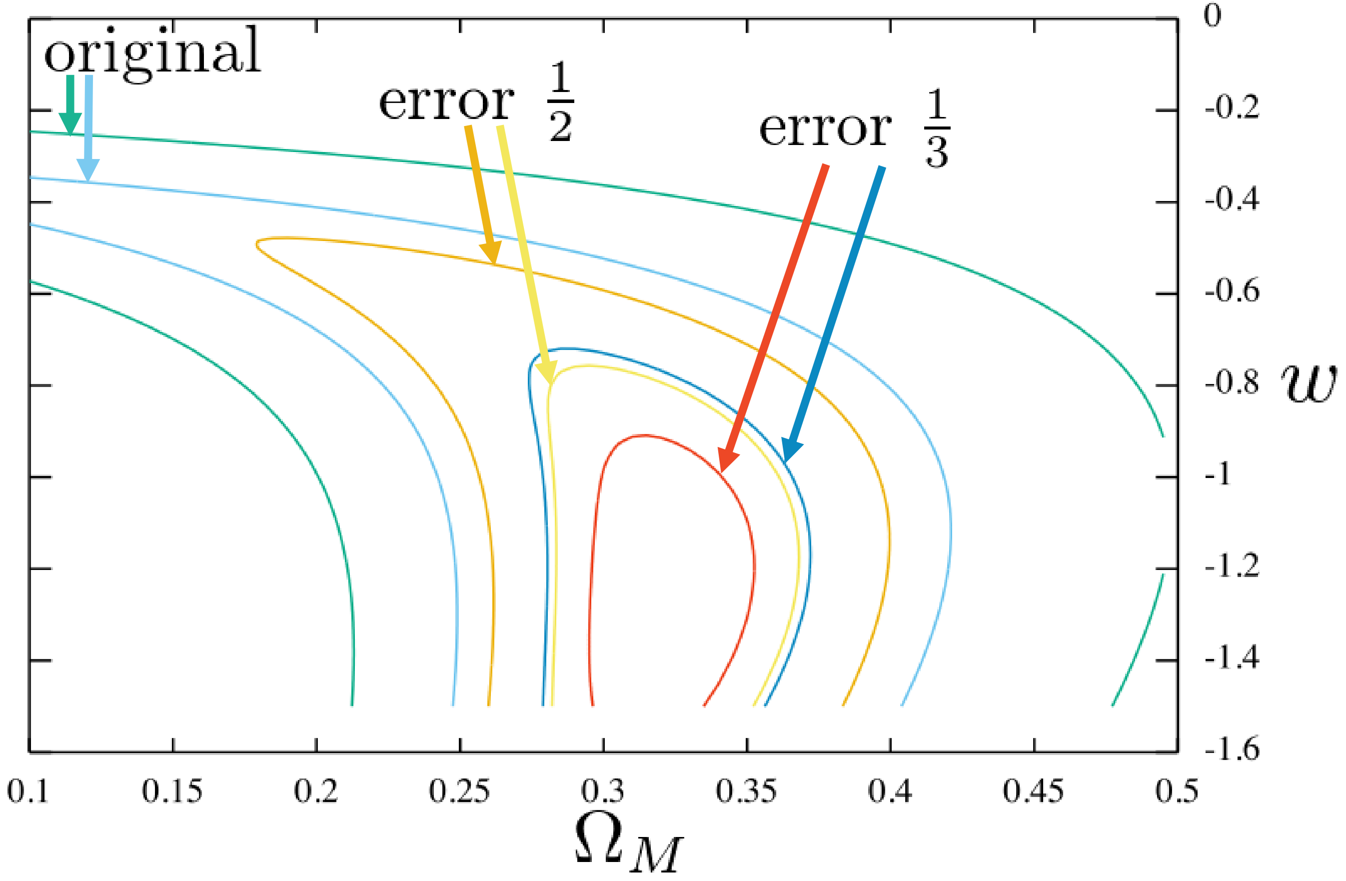
Cosmic chronometer

$$\Omega_M - w$$

CC data error

➡1/2

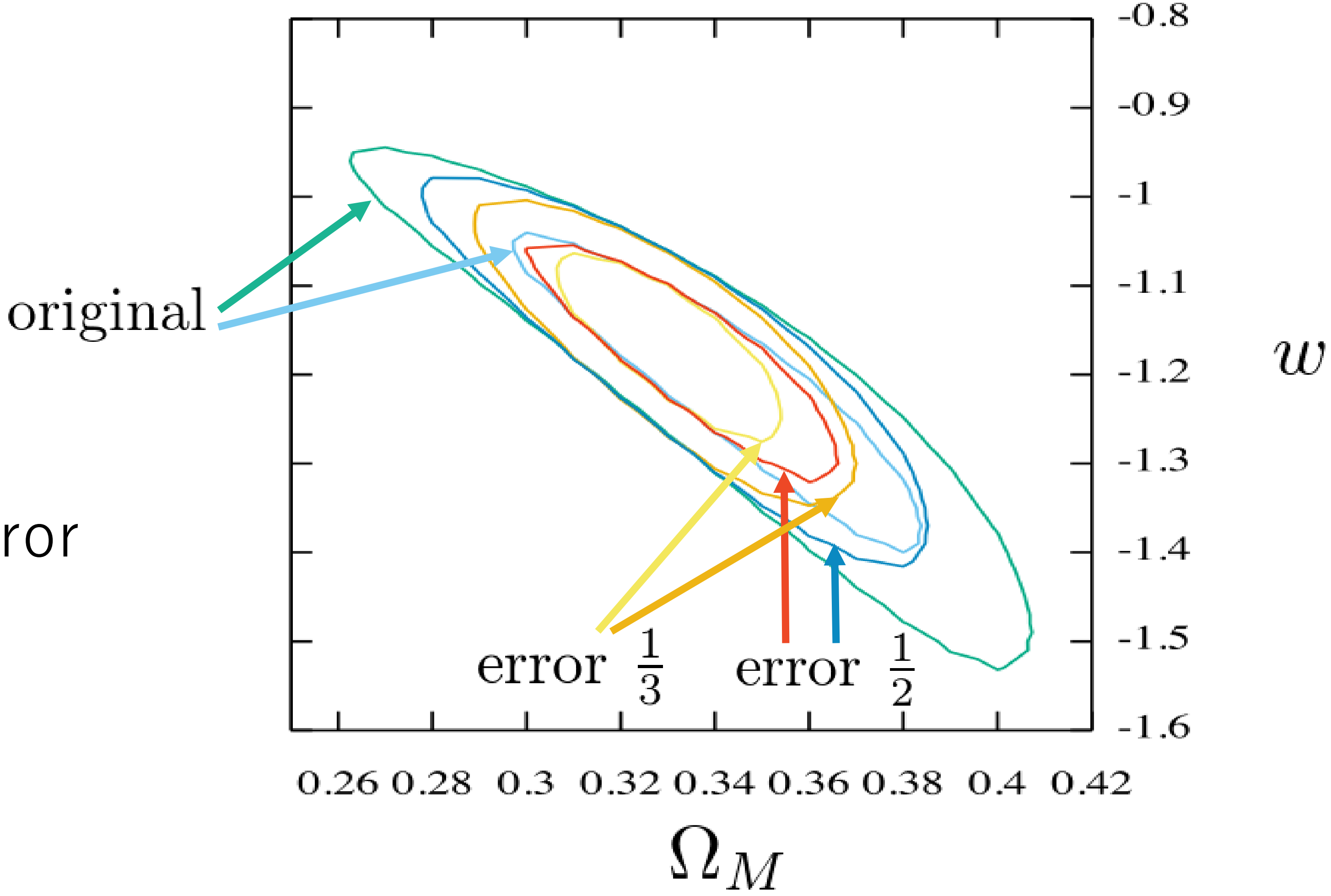
➡1/3



Assumption of improved observation techniques

Cosmic chronometer & supernova

$$\Omega_M - w$$



CC data error

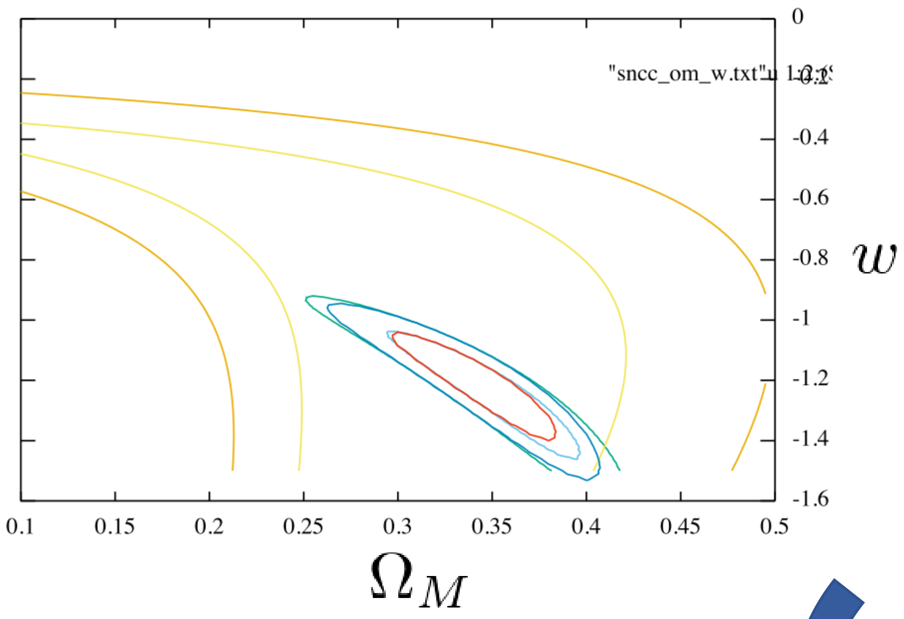
➡1/2

➡1/3

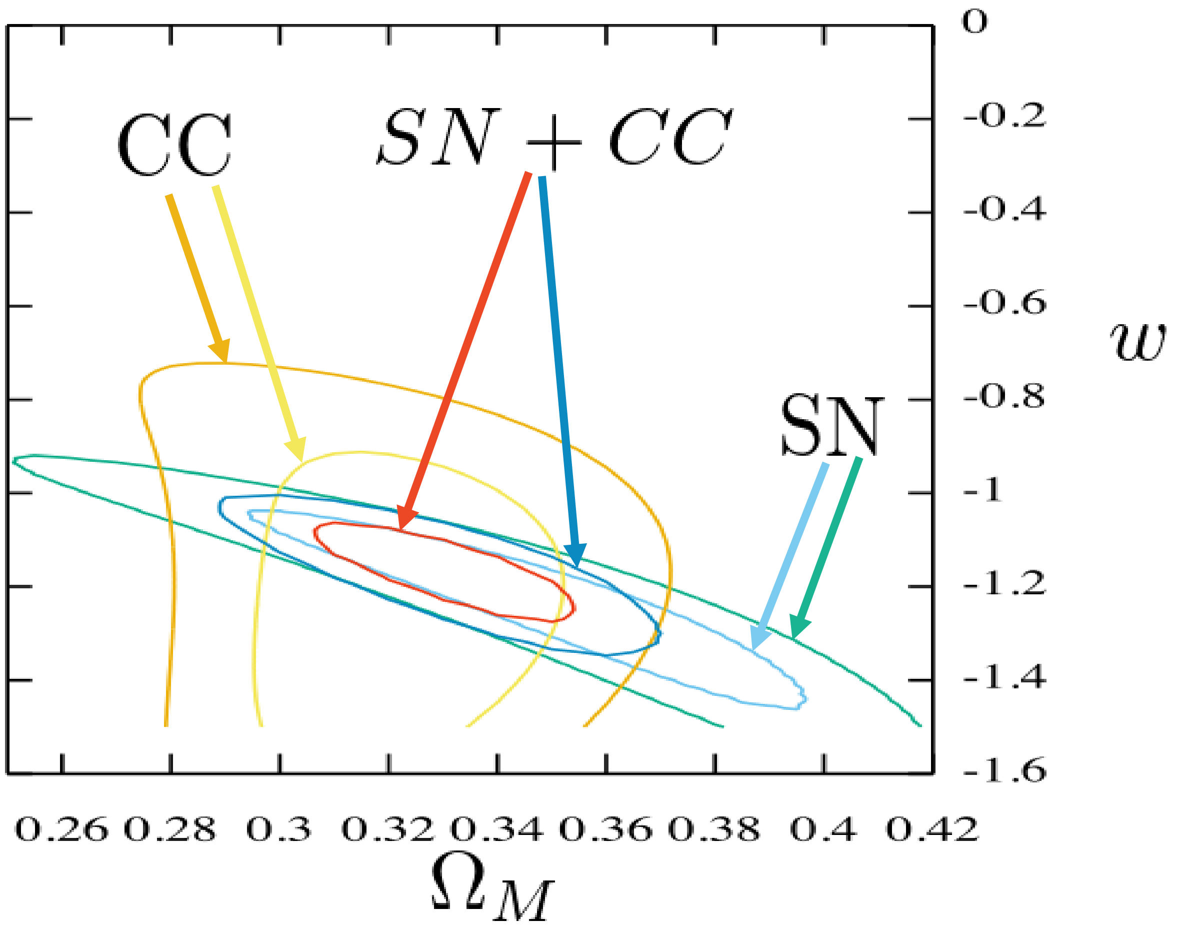
Assumption of improved observation techniques

Cosmic chronometer & supernova

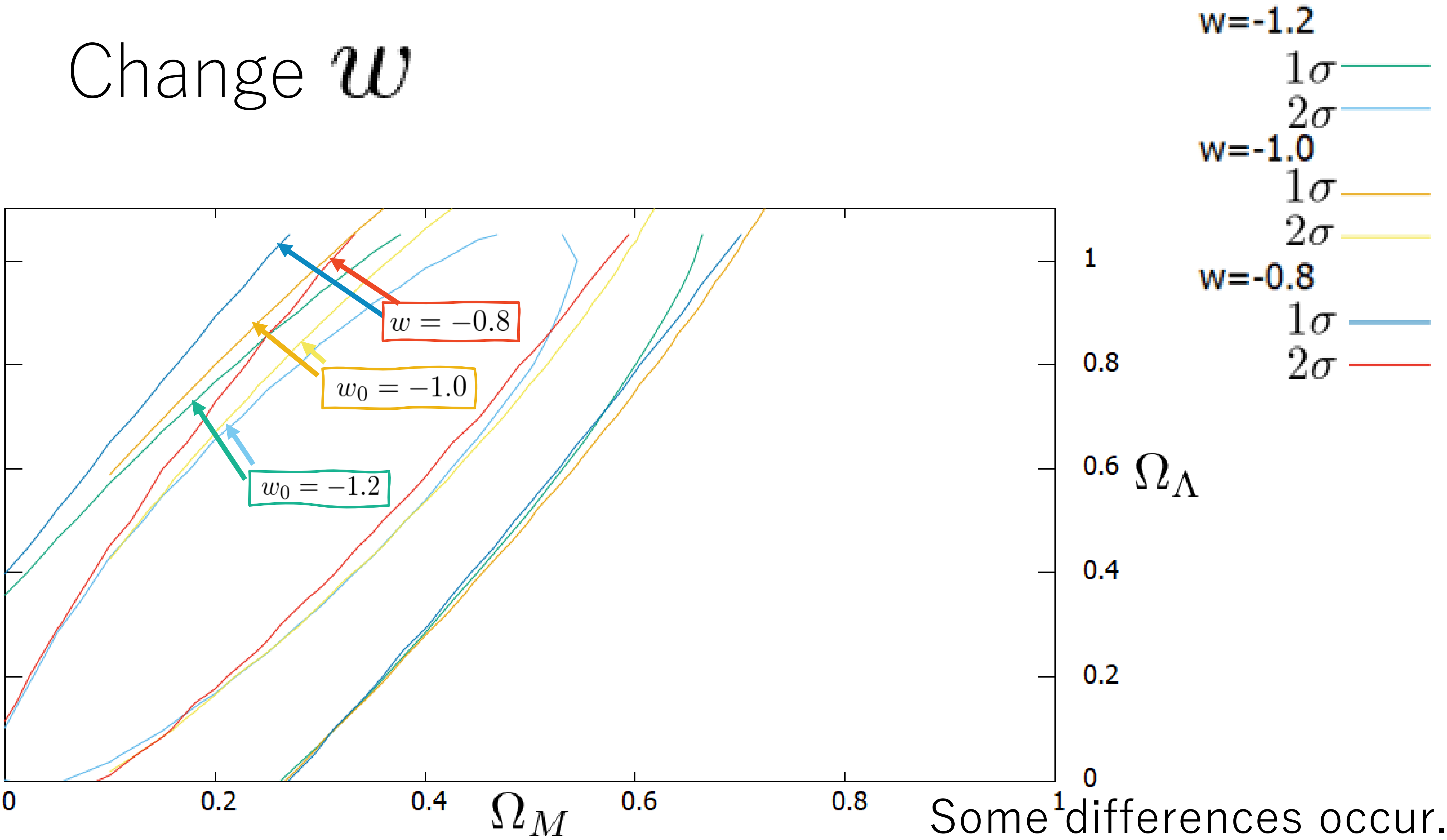
$$\Omega_M - w$$



Error $\frac{1}{3}$ effect



Change w



Some differences occur.

Time-dependent w

➡Chevallier–Polarski–Linder (CPL) Parametrization

The equation of state : $w_X(z) = w_0 + (1-a)w_1 = w_0 + \frac{z}{1+z}w_1$

The density
of the dark energy : $\rho_X(z) = \rho_{W_0}(1+z)^{3(1+w_0+w_1)} \exp[-\frac{3w_1 z}{1+z}]$

$$H(z) = H_0\sqrt{\Omega_M(1+z)^3 + \Omega_\Lambda(1+z)^{3(1+w_0+w_1)} \exp[-3w_1\frac{z}{1+z}] + \Omega_K(1+z)^2}$$

CPL parametrization

present value：
$(a = 1)(z = 0)$

$$w_X(0) = w_0$$

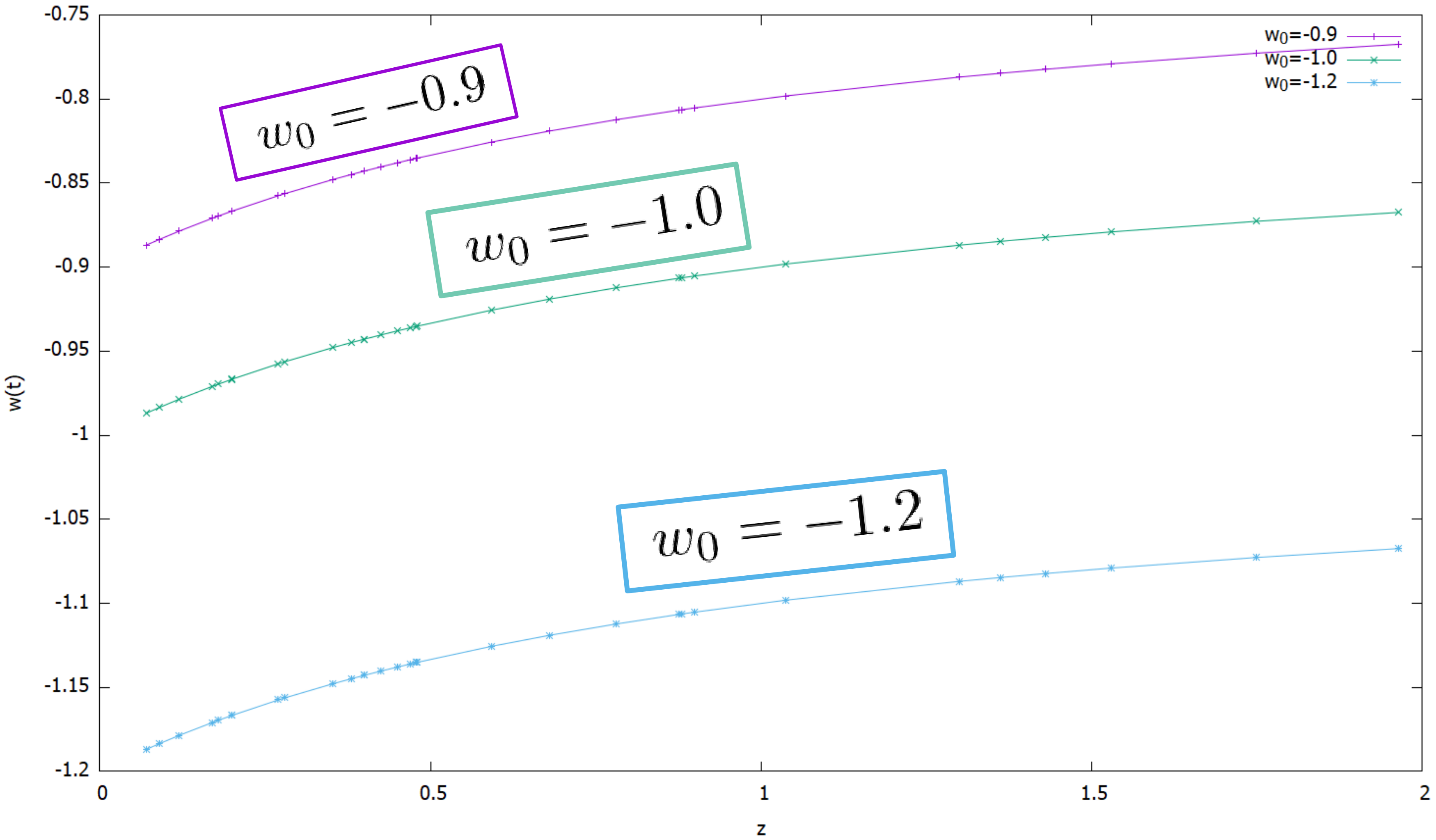
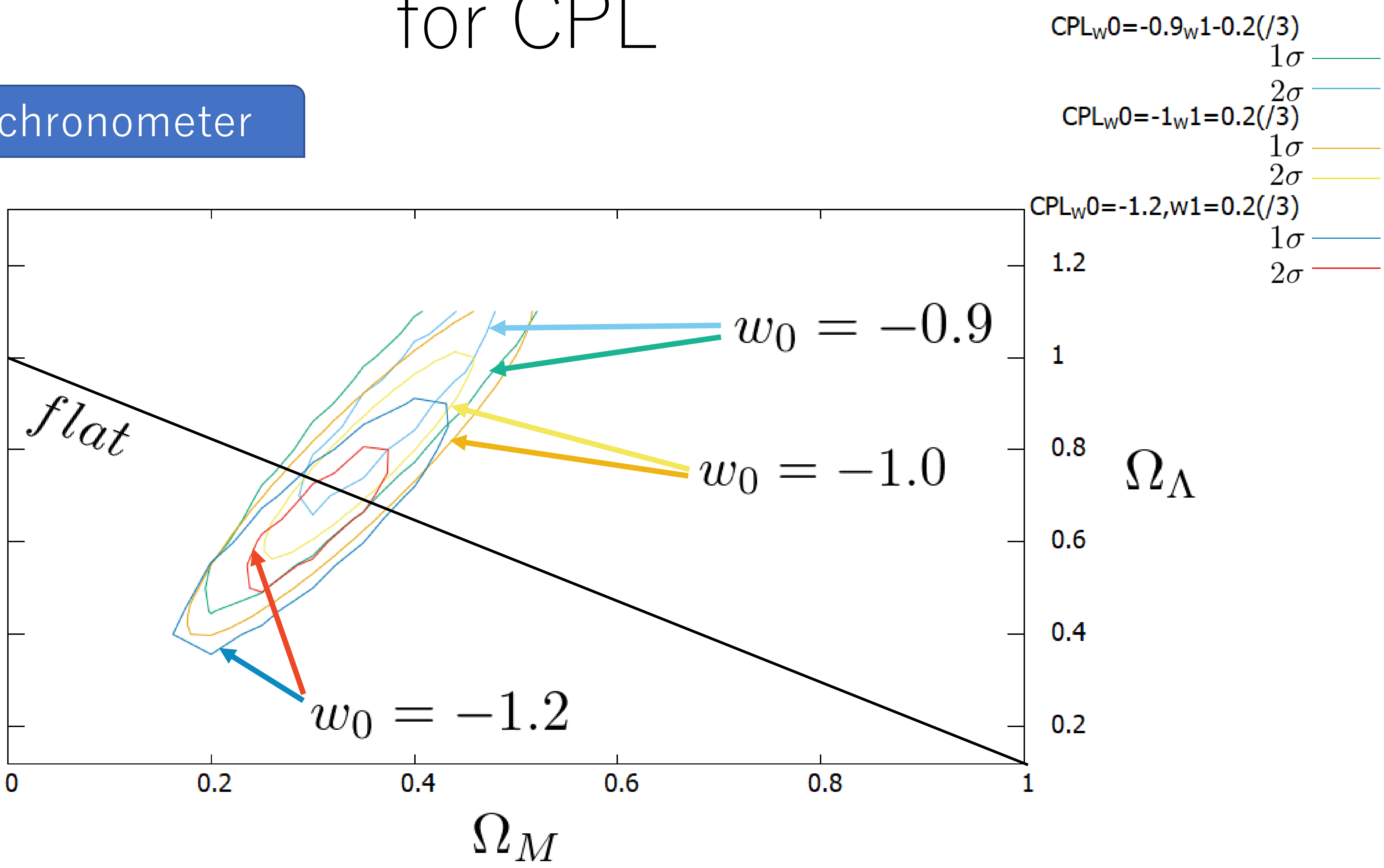


Figure z-w using cc data (w1=0.2)

for CPL

Cosmic chronometer



CC data error

➡1/3

Conclusion

- We have investigated constraints on the density parameters and the equation of state of dark energy from cosmic chronometer .
- Time-dependent w affects the constraint on the curvature of the Universe.
- If cosmic chronometer observational techniques improve, cosmological parameters can be more tightly constrained.

Thank you for listening.

μ ：distance modulus
m ：apparent magnitude
M ：absolute magnitude

$$\mu = m - M = 5\log_{10}\frac{d_L}{1Mpc} + 25$$

$$m \equiv -2.5\log_{10}\frac{f}{f_0}$$

$$M \equiv -2.5\log_{10}\frac{L}{L_0}$$

- Kazunori Kohri , Yoshihiko Oyama , Toyokazu Sekiguchi and Tomo Takahashi 1608.01601

“Vagnozzi, Loeb, Moresco 2011.11645”

theoretical curve

$$H(t) = H_0\sqrt{\Omega_M(1+z)^3 + \Omega_\Lambda + \Omega_K(1+z)^2}$$

$$\Omega_M = 0.3$$

$$\Omega_\Lambda = 0.7$$

$$\Omega_K = 1 - \Omega_M - \Omega_\Lambda$$

$$H_0 = 70$$

Plan

- SN and SN+CC for CPL
- Change w_1