Scalar field dark energy reconstruction from SNe Ia data

Yerevan Physics Institute and
Universidade Federal do Maranhão
Piloyan Arpine
(in collaboration with Luca Amendola and Sergey Pavluchenko)

Plan

- Modern problems of physics
- Alternative theories of gravity
- General approaches on the way of searching DE
- Mock data analysis
- Real data analysis
- Conclusion

Why we do cosmology?

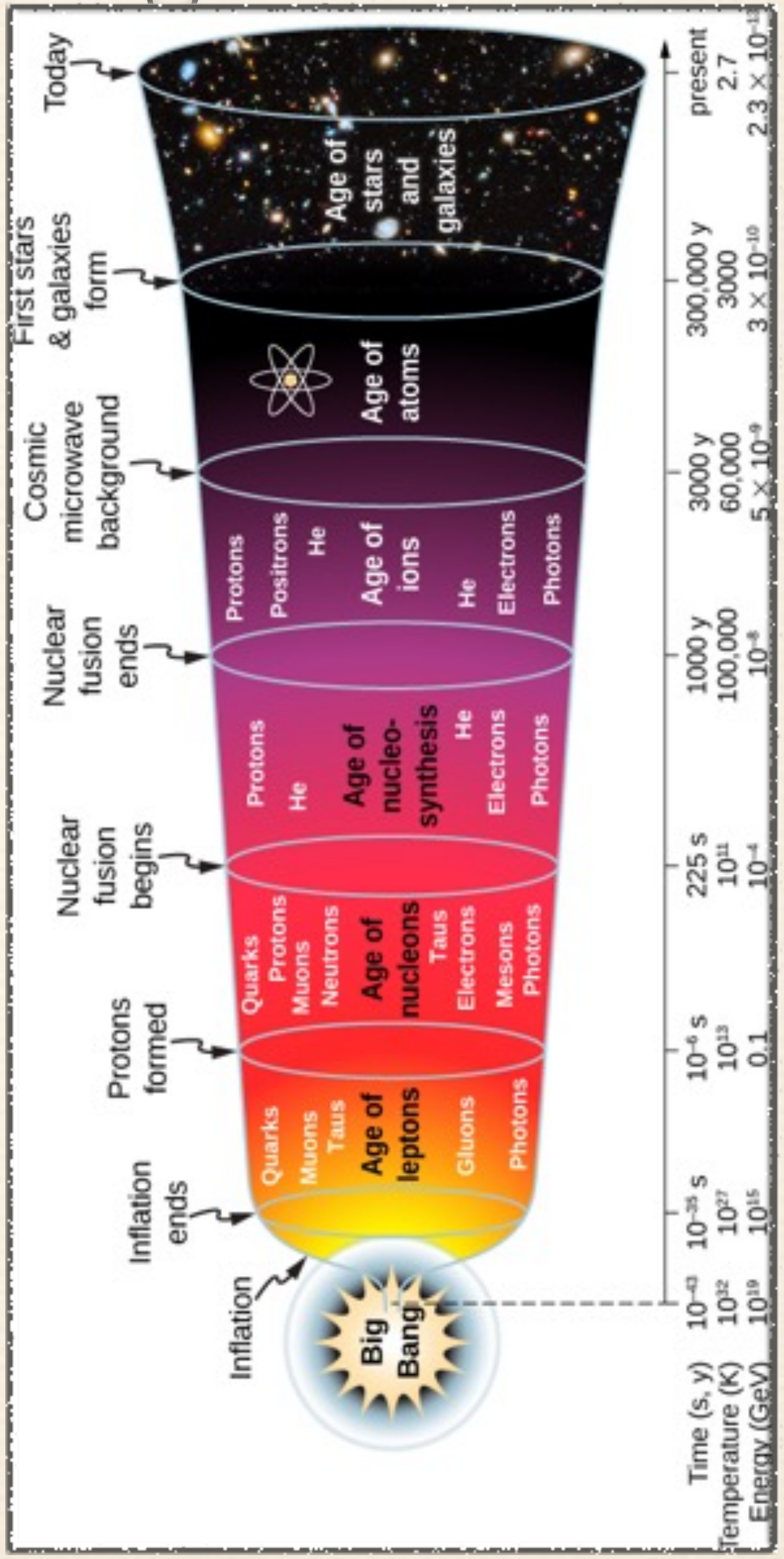
Why we are not satisfied by Einstein GR?

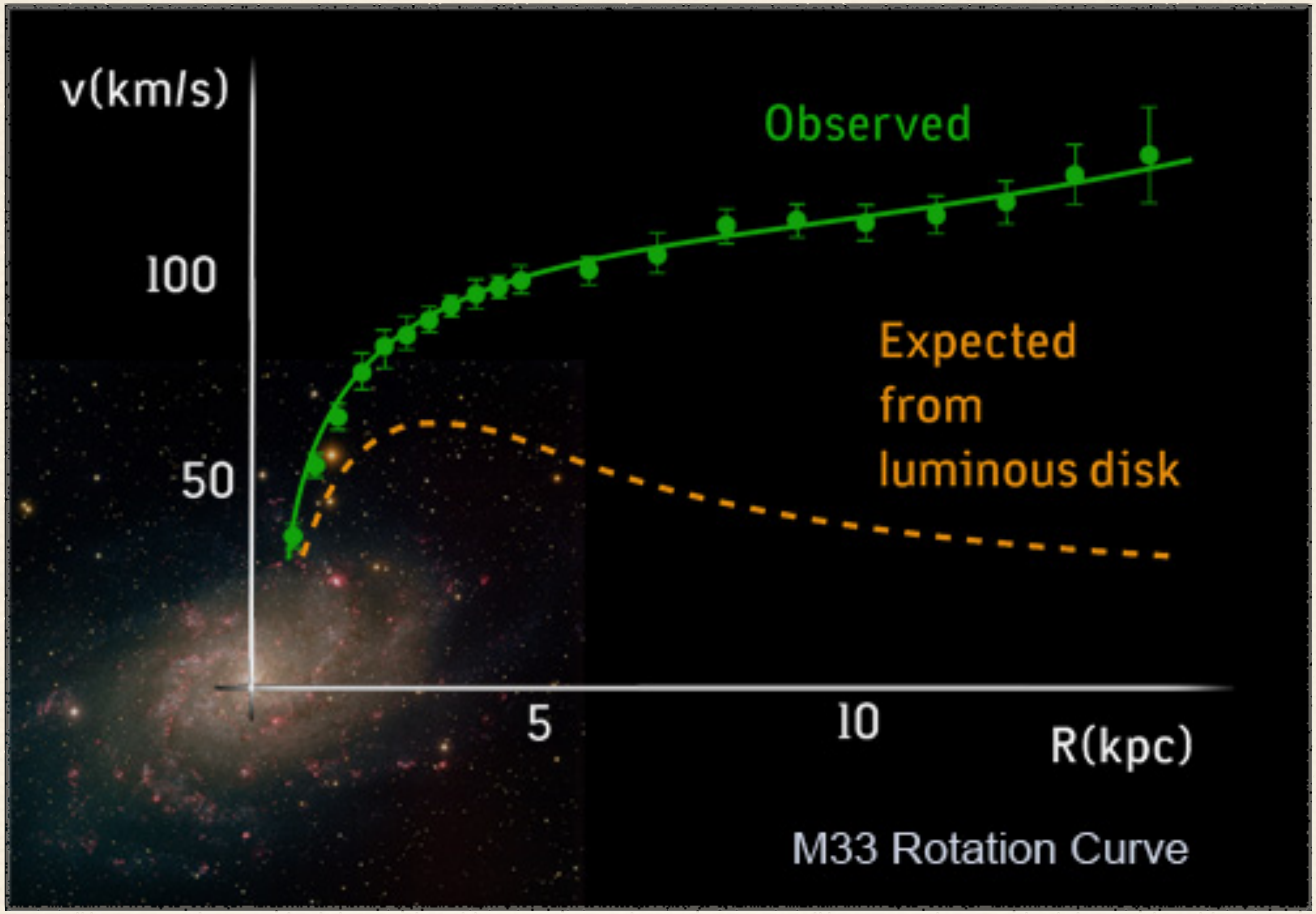
Modern physics problems and questions addressed by cosmologists

- We have several questions to be answered: DE, DM, Inflation, Hierarchy, Quantum gravity (black holes) and a dream of unification

- Can we touch all these questions?-is a bigger dream.

- We also have excellent working theory for many cases so the physicists are reasonably sceptic.

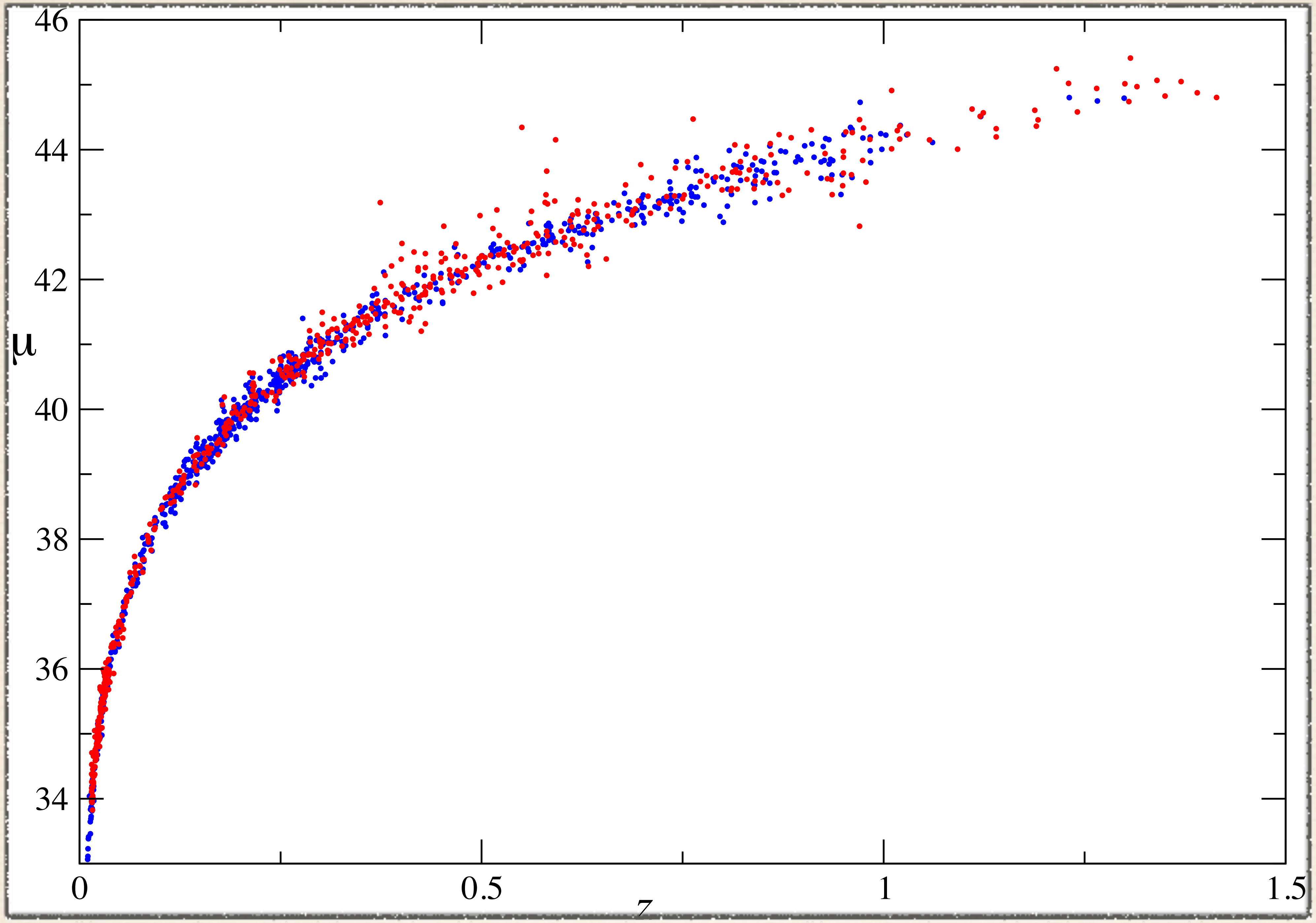




Galaxy Rotational curve

Dark Matter or …

Data and theory



Hubble Diagram

Datas are being fitted by a given model

Suggested theories

- Modified Theories of Gravity
- Dark Energy model
- Extra dimensional theories

GR and Lambda

data and logics wants more

General approaches

- Horndensky
- Series
- Naive

Equations of motion

- Friedmann equations

$$3H^2 = \rho_m + \frac{\dot{\phi}^2}{2} + V(\phi)$$

$$2\dot{H} = -\dot{\phi}^2 - \rho_m(1 + w_m)$$

- Lets write them in terms of z

$$H(z)^2(1+z)^2\left(\frac{d\phi}{dz}\right)^2 = 2(1+z)H(z)\frac{dH}{dz} - \rho_m(z)(1 + w_m(z))$$

$$(1+z)\frac{d\rho_m}{dz} = 3\rho_m(z)(1 + w_m(z))$$

$$V = 3H(z)^2 - (1+z)H(z)\frac{dH(z)}{dz} + \frac{\rho_m(z)}{2}(w_m(z) - 1)$$

Ia type SuperNova as a standard candle

The farer it is the fainter it gets

How we will use data from Ia Type SN

- Distance modulus
$$D_M = \frac{10^{\left(\frac{\mu}{5}+1\right)}}{1+z}$$
- Error propagation
$$\delta D_M = \delta\left(\frac{10^{\left(\frac{\mu}{5}+1\right)}}{1+z}\right) = \cdots = D_M\left(\frac{\ln 10\delta\mu}{5} + \frac{\delta z}{(1+z)}\right)$$
- Hubble $H(z) = \frac{1}{D'_M}$.
$$\delta H(z) = \delta\left(\frac{1}{D'_M}\right) = \frac{\delta D'_M}{(D'_M)^2}, \quad D'_M = \frac{D_{M,2} - D_{M,1}}{z_2 - z_1}$$
- error propagation
$$\delta(D'_M) = \delta\left(\frac{D_{M,2} - D_{M,1}}{z_2 - z_1}\right) = \cdots = \frac{\delta D_{M,2} + \delta D_{M,1}}{z_2 - z_1} + |D'_M|\frac{\delta z_2 + \delta z_1}{z_2 - z_1}$$

Reconstruction of the field

- Then we need to calculate

$$\frac{d\phi}{dz} = \sqrt{(\frac{d\phi}{dz})^2} \Rightarrow \delta\left(\frac{d\phi}{dz}\right) = \delta\left(\left(\frac{d\phi}{dz}\right)^2\right) / \left(2\frac{d\phi}{dz}\right);$$

$$\phi = \int \left(\frac{d\phi}{dz}\right) dz \cong \left(\frac{d\phi}{dz}\right) |_{z_{central}} \Delta z \Rightarrow \delta\phi = \Delta z \times \delta\left(\frac{d\phi}{dz}\right)$$

- Note that the reconstruction will be done up to unknown constant

Error propagation

- Potential

$$\tilde{V} \equiv \frac{8\pi G}{3H_0^2}V(z) = \frac{H(z)^2}{H_0^2} - \frac{H(z)H'(z)(1+z)}{3H_0^2} - \frac{\Omega_m^0(1+z)^3}{2}$$

- error

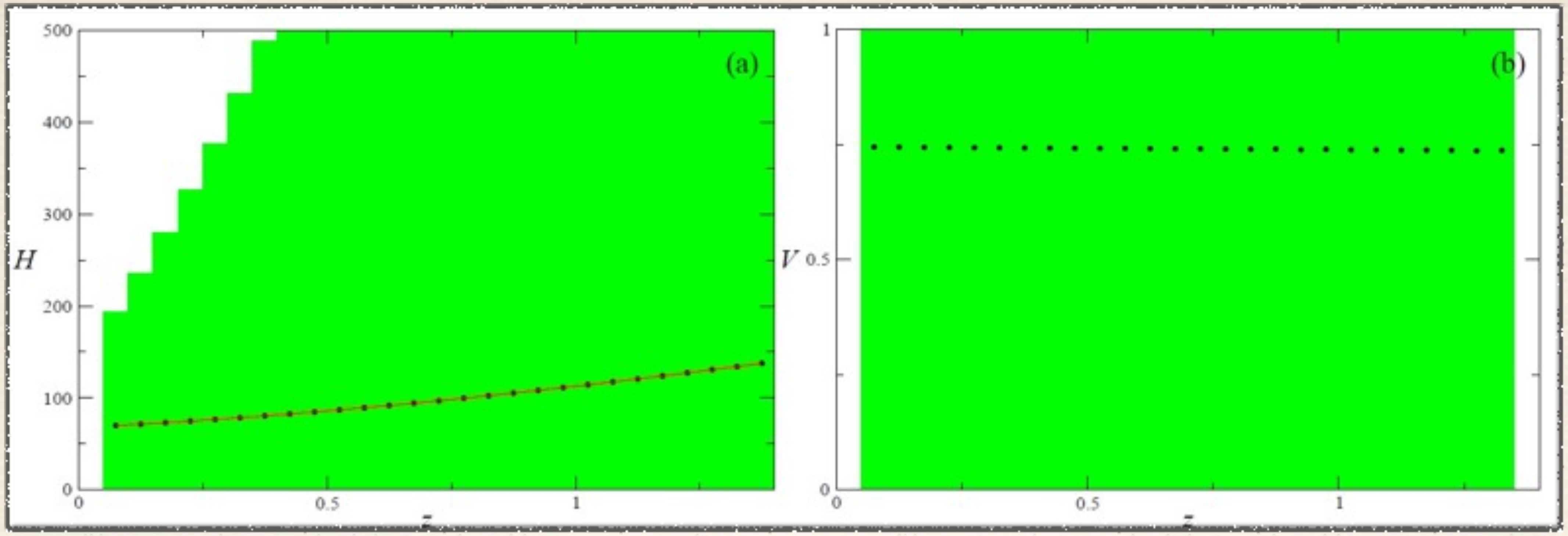
$$\delta\tilde{V} = \frac{2H\delta H}{H_0^2} + \frac{(1+z)H'\delta H + H(1+z)\delta H' + HH'\delta z}{3H_0^2} + \frac{3(1+z)^2\Omega_m^0\delta z}{2}$$

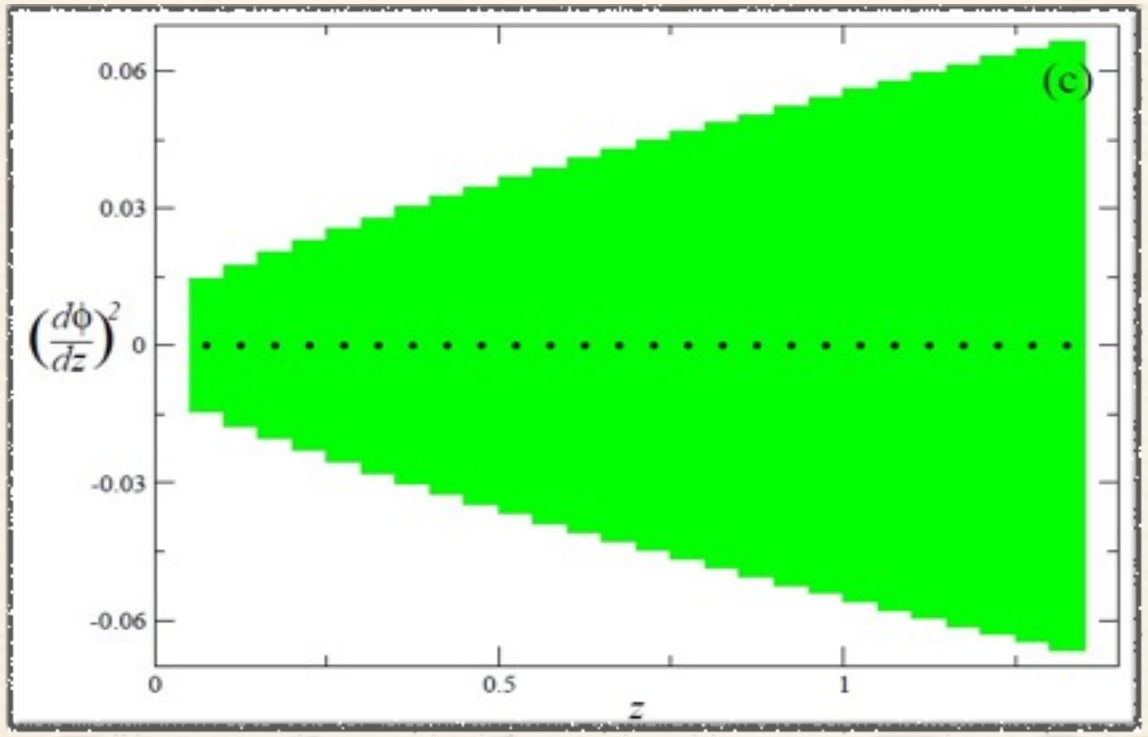
- kinetic energy

$$\left(\frac{d\tilde{\phi}}{dz}\right)^2 \equiv \frac{8\pi G}{3H_0^2}\left(\frac{d\phi}{dz}\right)^2 = \frac{2H'(z)}{3H(z)H_0^2(1+z)} - \frac{\Omega_m^0(1+z)}{H^2}$$

- error

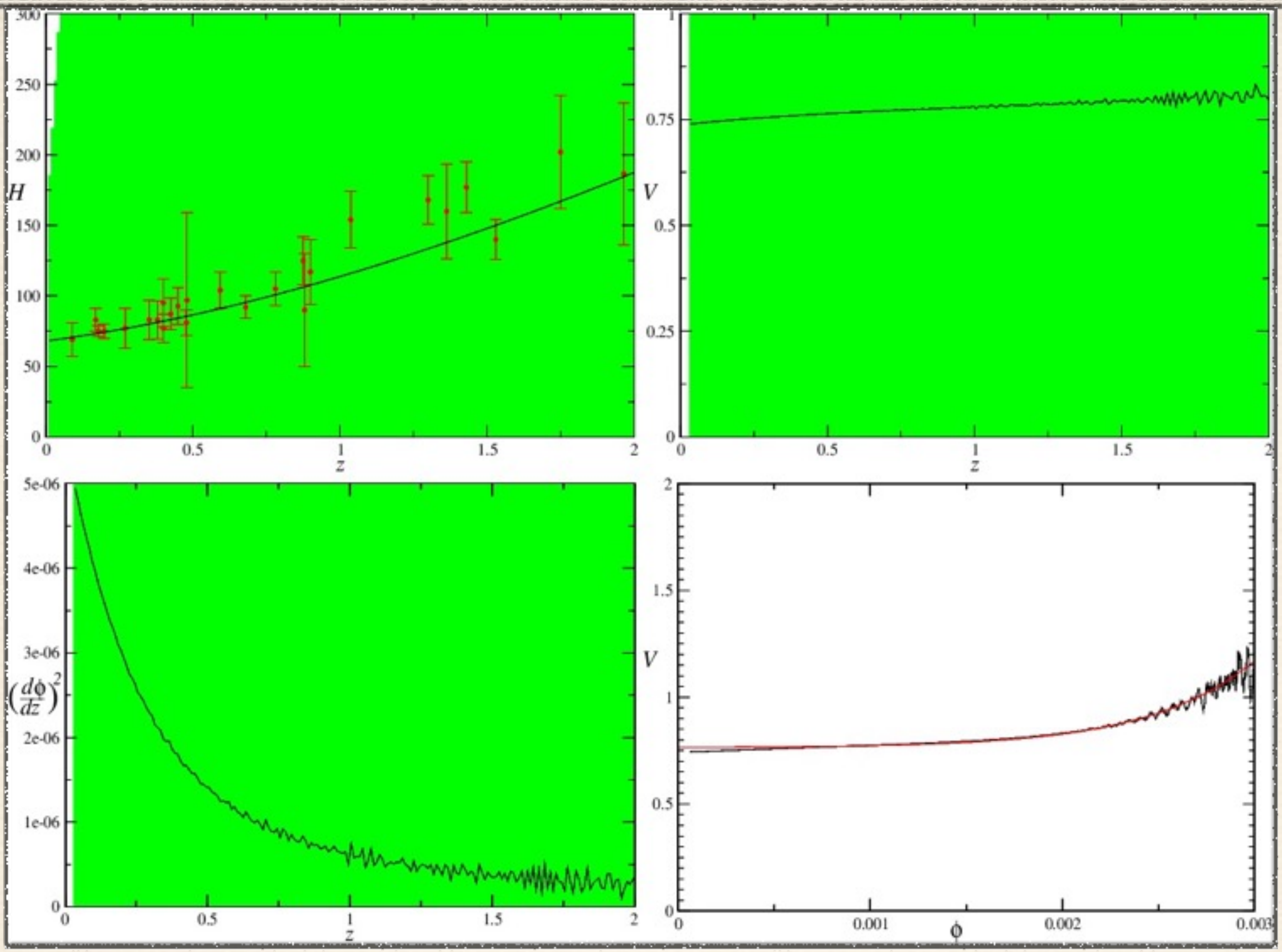
$$\delta\left(\left(\frac{d\tilde{\phi}}{dz}\right)^2\right) = \frac{2}{3H_0^2}\left[\frac{\delta H'}{H(1+z)} + \frac{H'\delta H}{H^2(1+z)} + \frac{H'\delta z}{H(1+z)^2}\right] + \Omega_m^0\left(\frac{\delta z}{H^2} + \frac{2(1+z)\delta H}{H^3}\right)$$





Mock data: LCDM

H_0=68, Om_m=0.25



Mock Data: exponential potential

wigglings are numerical effects, kinetic term is positive which is a good news

Real SN data

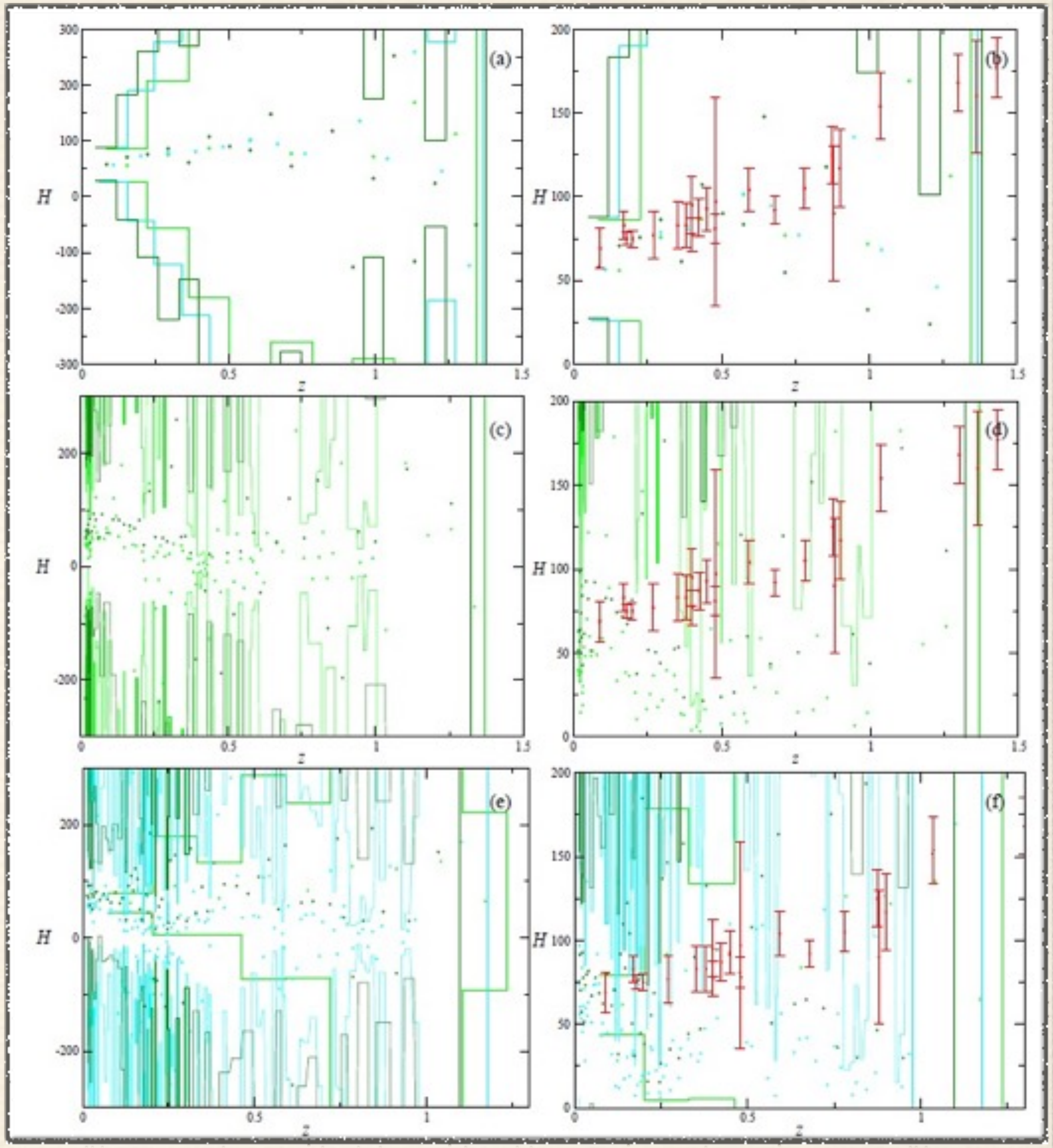
Union2.1(580 SNe Ia up to z=1.414) JLA (740 SNe Ia up to z=1.3)

1: Union2.1, equal-z:10 green,15 cyan,20 dark green

2: Union2.1, equal-N:5 green,10 dark green

3: JLA, equal-N:5 cyan, 10 dark green

We see reconstructed real data (Union2.1 (580 SN Ia up to z=1.414) and JLA (740 SN Ia up to z=1.3))
Equal-z binnin and equal SN number binning

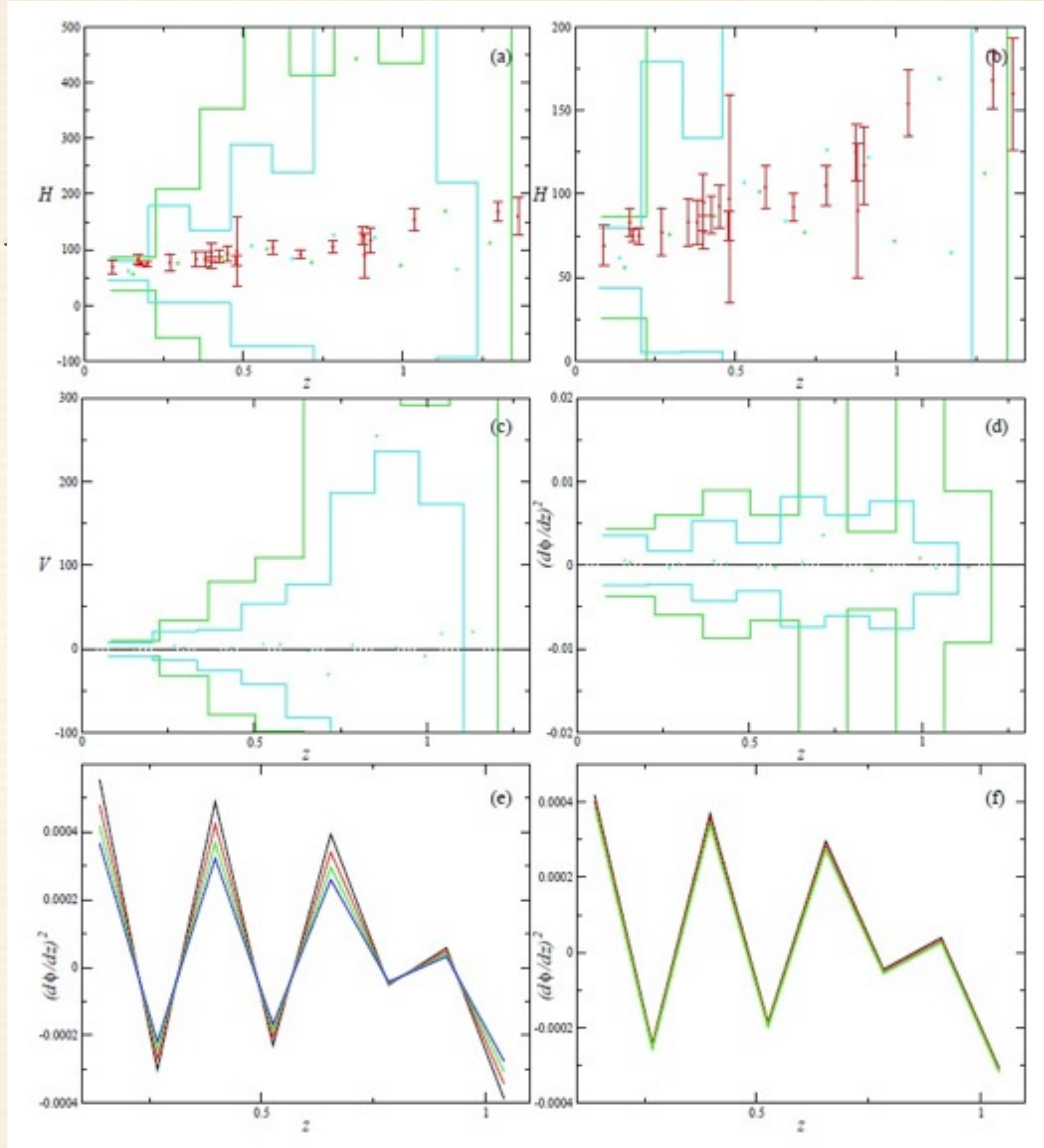


1: Equal-z with 10 bins. Union2.1-green, JLA-cyan ….

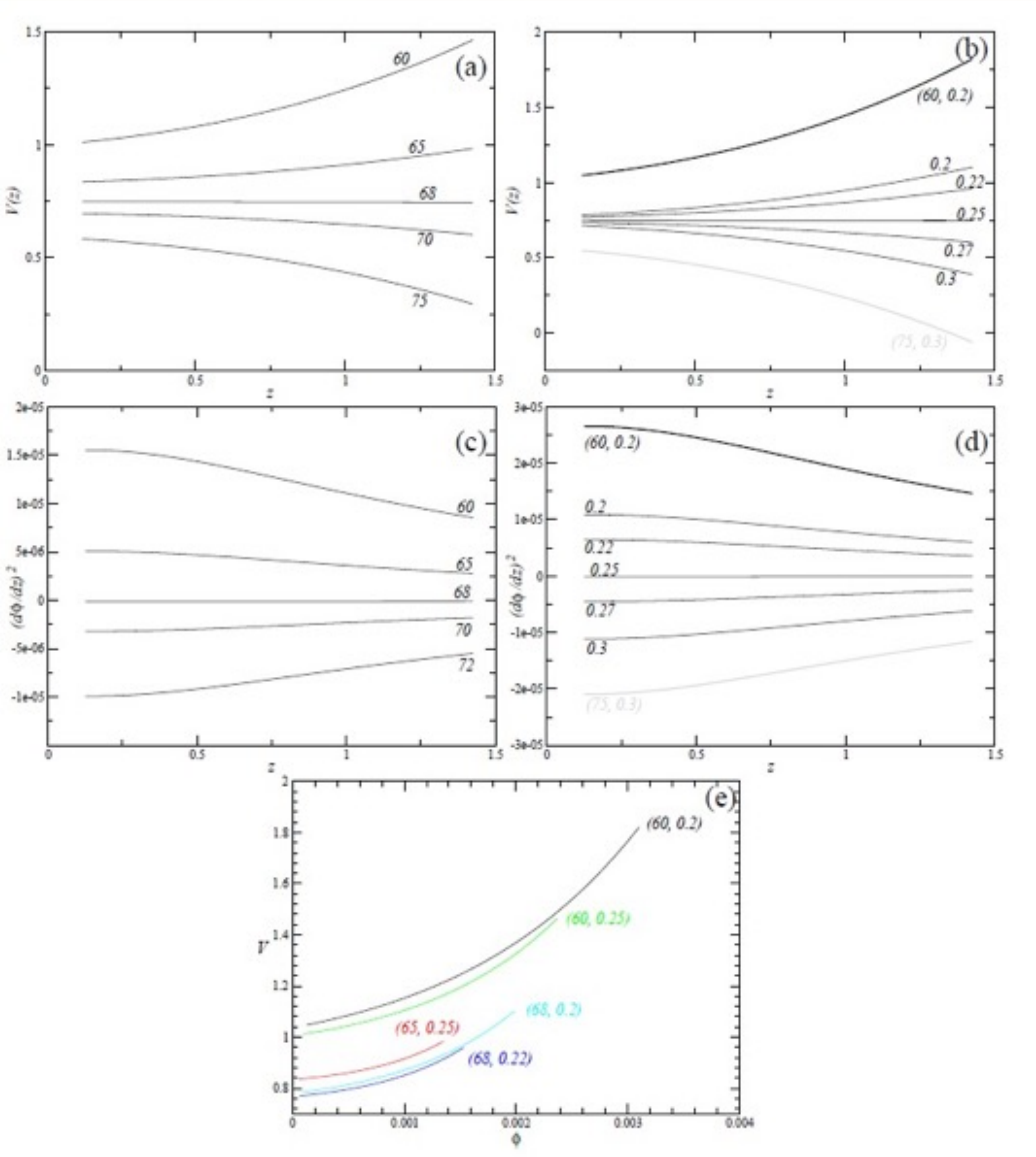
2: (e) Effect of H_0, black-60, red-64, green-68, blue-7

3: (f) Effect of Om ……………………………………..

For the real data we see that the method will not work and we have complete mess



Stability



So if we are mistaken with the choice of Om and H_0 We will get wrong reconstructed potential (fake potential)

Conclusion

- For good data the method may work
- For the real data it is a complete mess
- reconstruction result highly depends on the accuracy of H_0 and Ω_m

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Merci :)

Thank you for your attention