Large-scale Structure: the numerical version

Lecture 4:
Dark Energy and type Ia Supernovae. MCMC in practice (in numerical).

Dragan Huterer

ICTP Trieste/SAIFR Cosmology School
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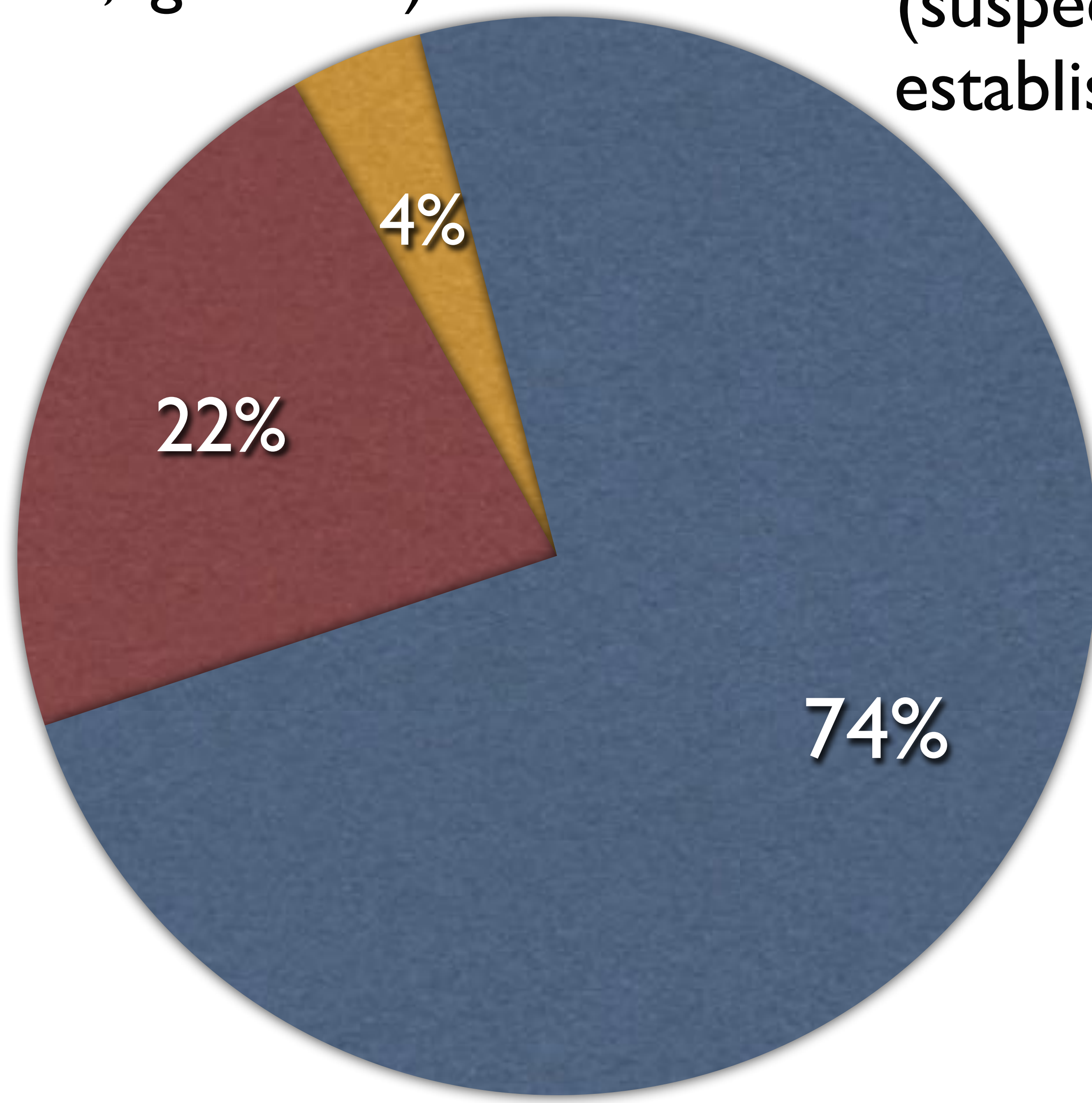
MICHIGAN
Max-Planck-Institut für Astrophysik
Alexander von Humboldt Stiftung / Foundation

Makeup of universe today

Baryonic Matter
(stars 0.4%, gas 3.6%)

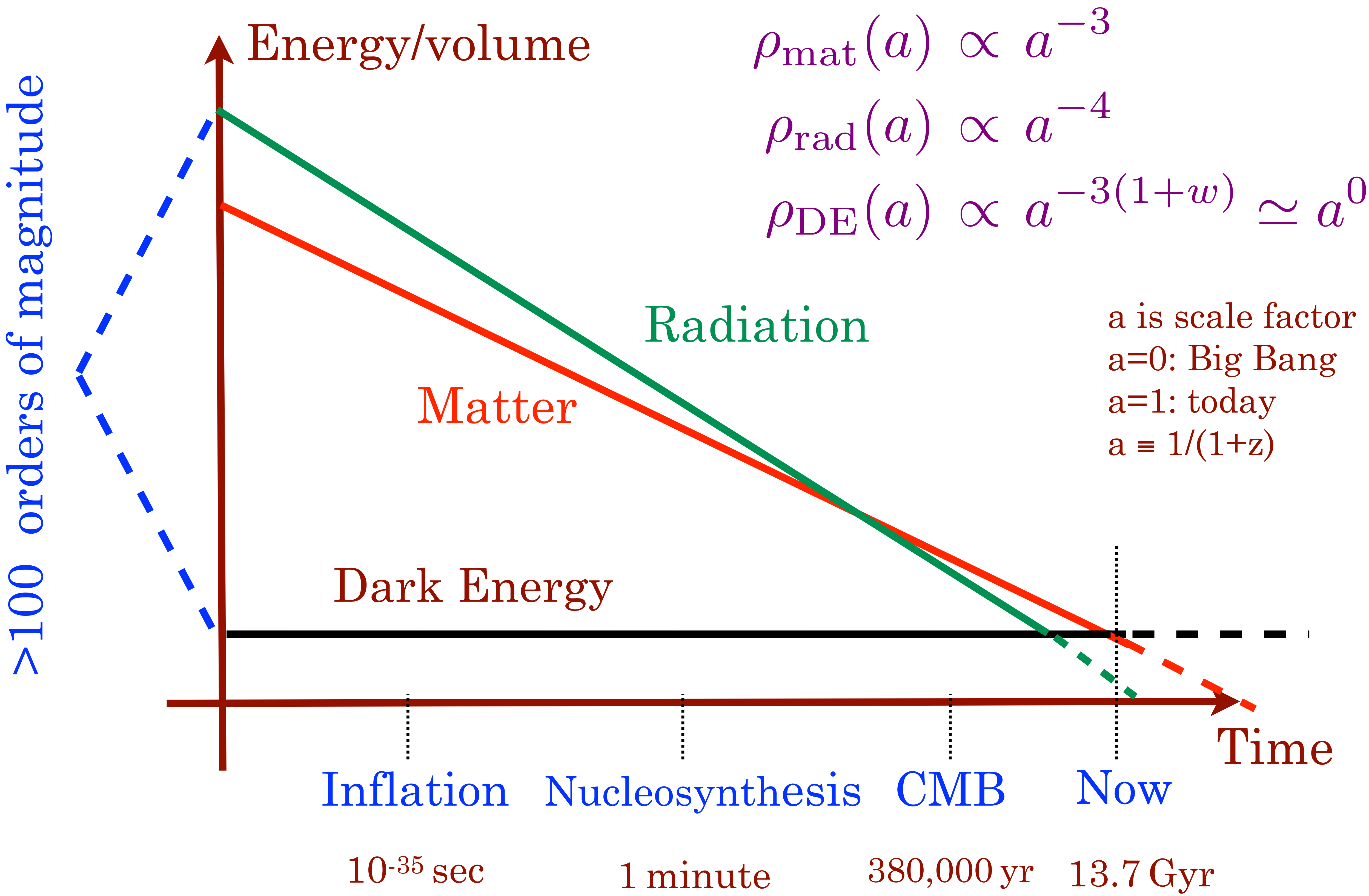
Dark Energy
(suspected since 1980s
established since 1998)



Dark Matter
(suspected since 1930s
established since 1970s)

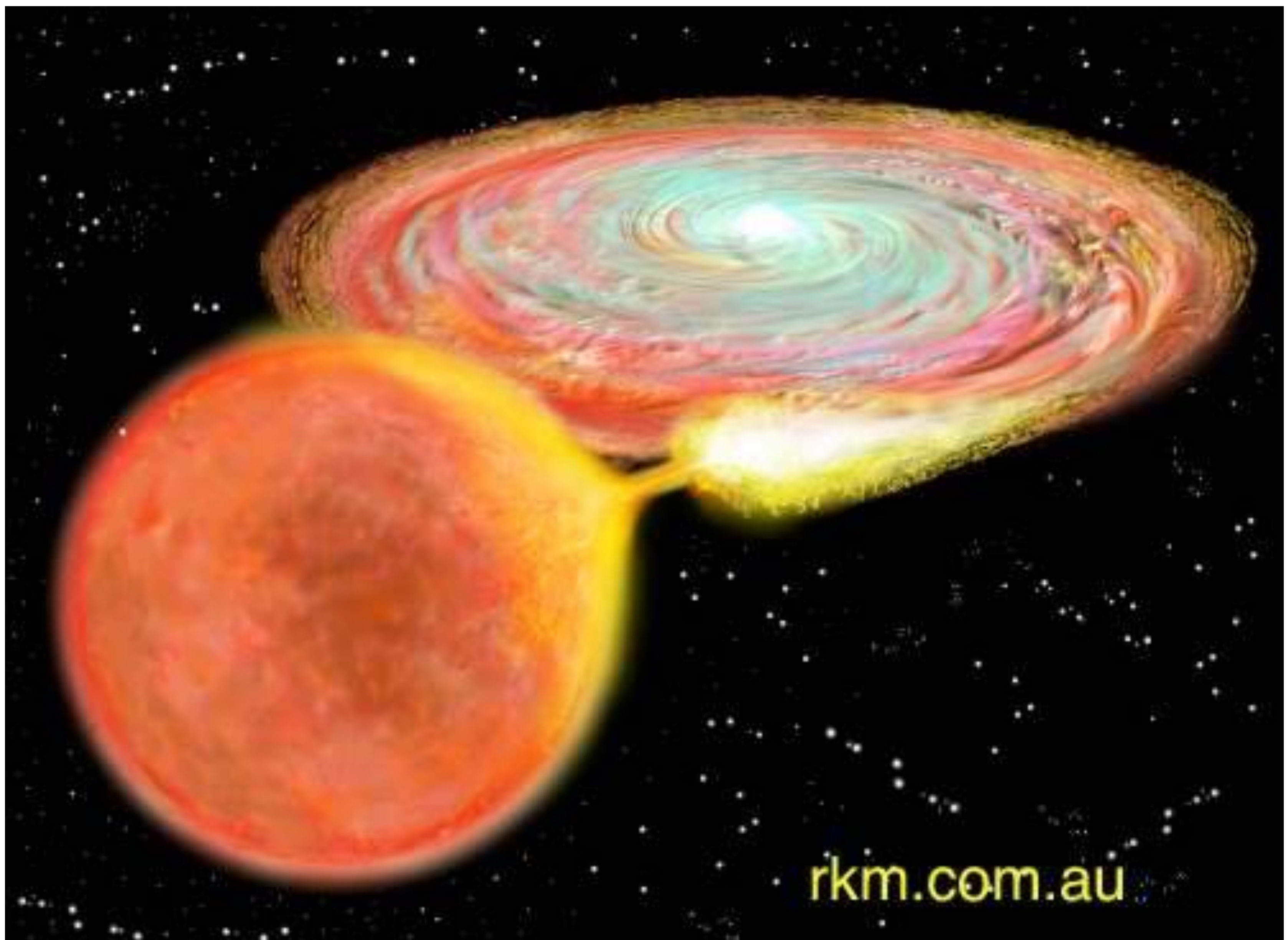
Also:
radiation (0.01%)

Fine-tuning problem I: Coincidence problem



Type Ia Supernovae

A white dwarf accretes matter from a companion.



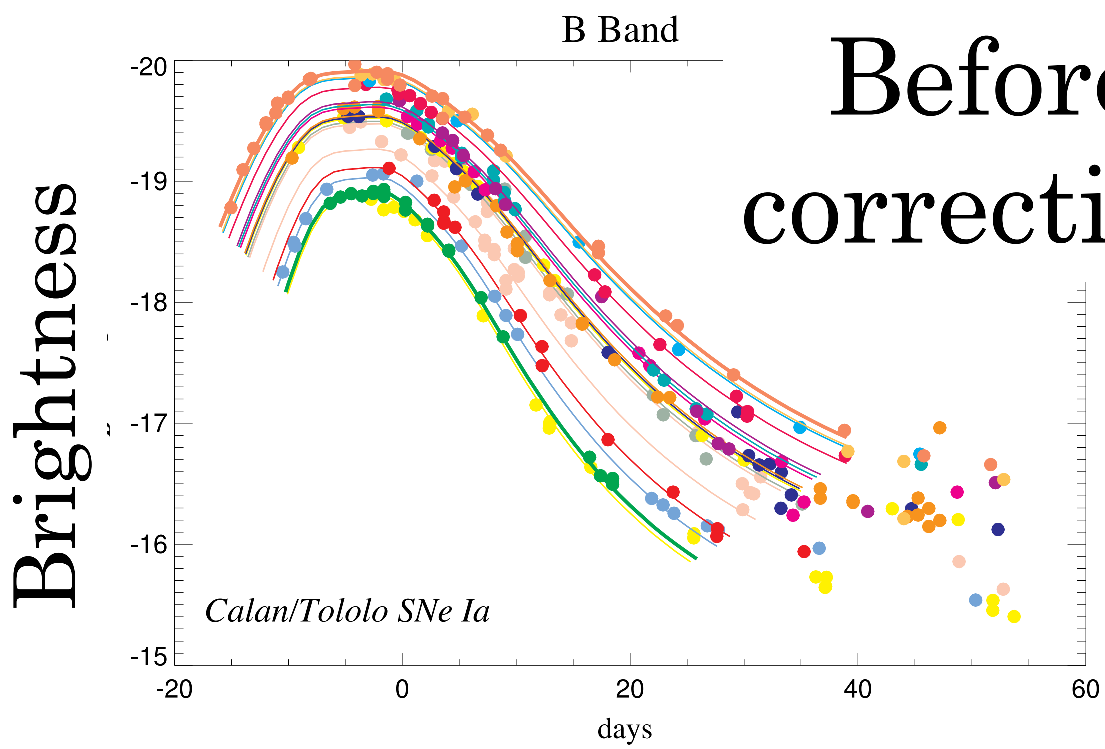
SNe Ia are "Standard Candles"

(car headlights example)

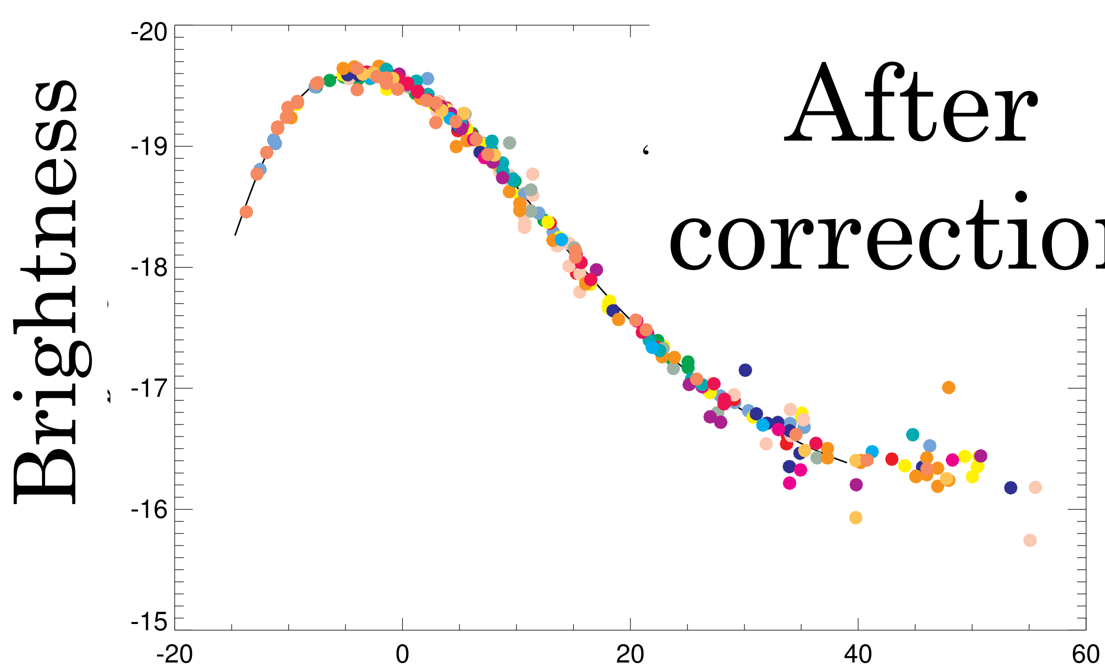
If you know the intrinsic brightness of the headlights, you can estimate how far away the car is

A way to measure (relative) distances to objects far away

Standardizing the candles



Before correction



After correction

Days

Kim, *et al.* (1997)

"Broader is Brighter"

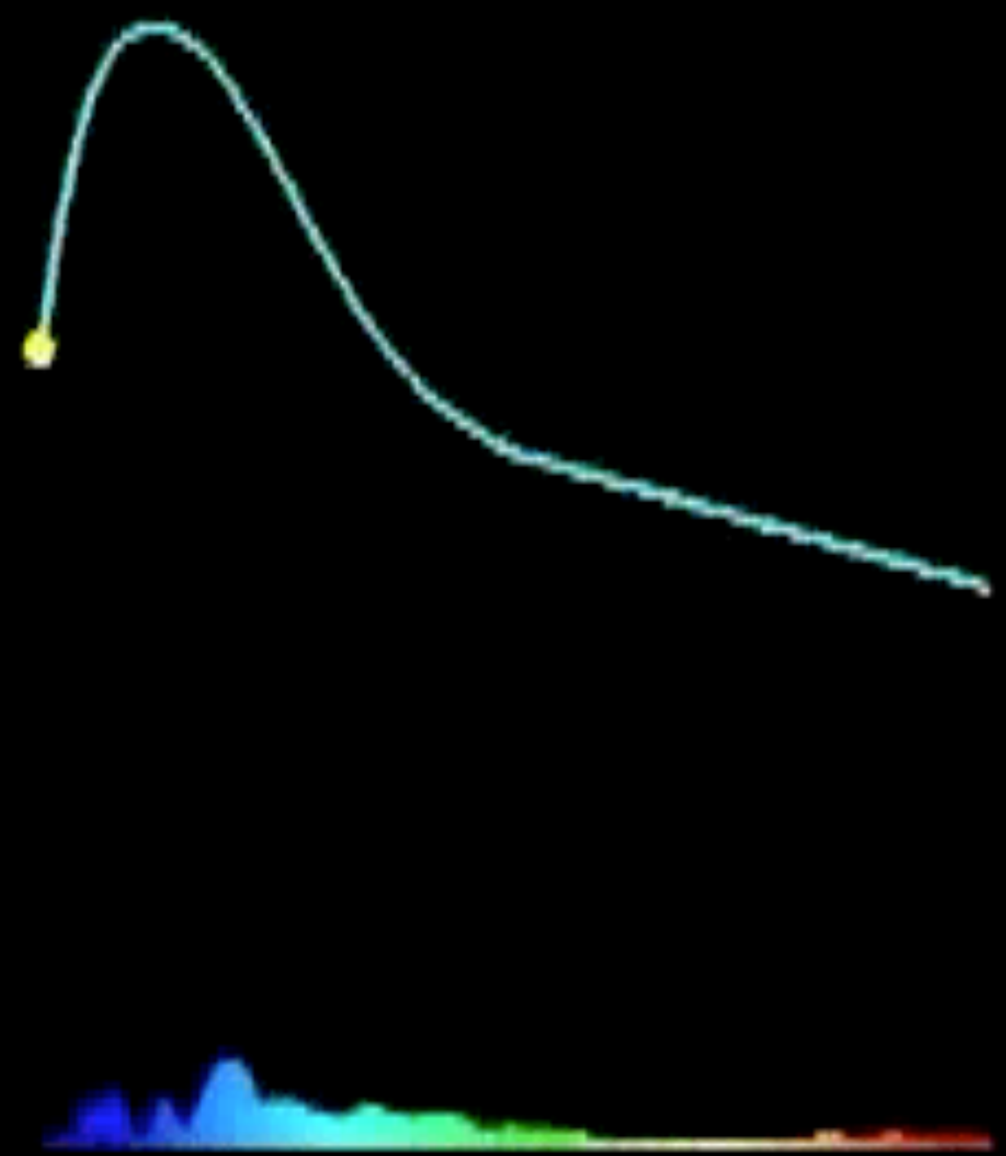
But how do you find SNe?

Rate: 1 SN per galaxy per 100 yrs!

Solution:

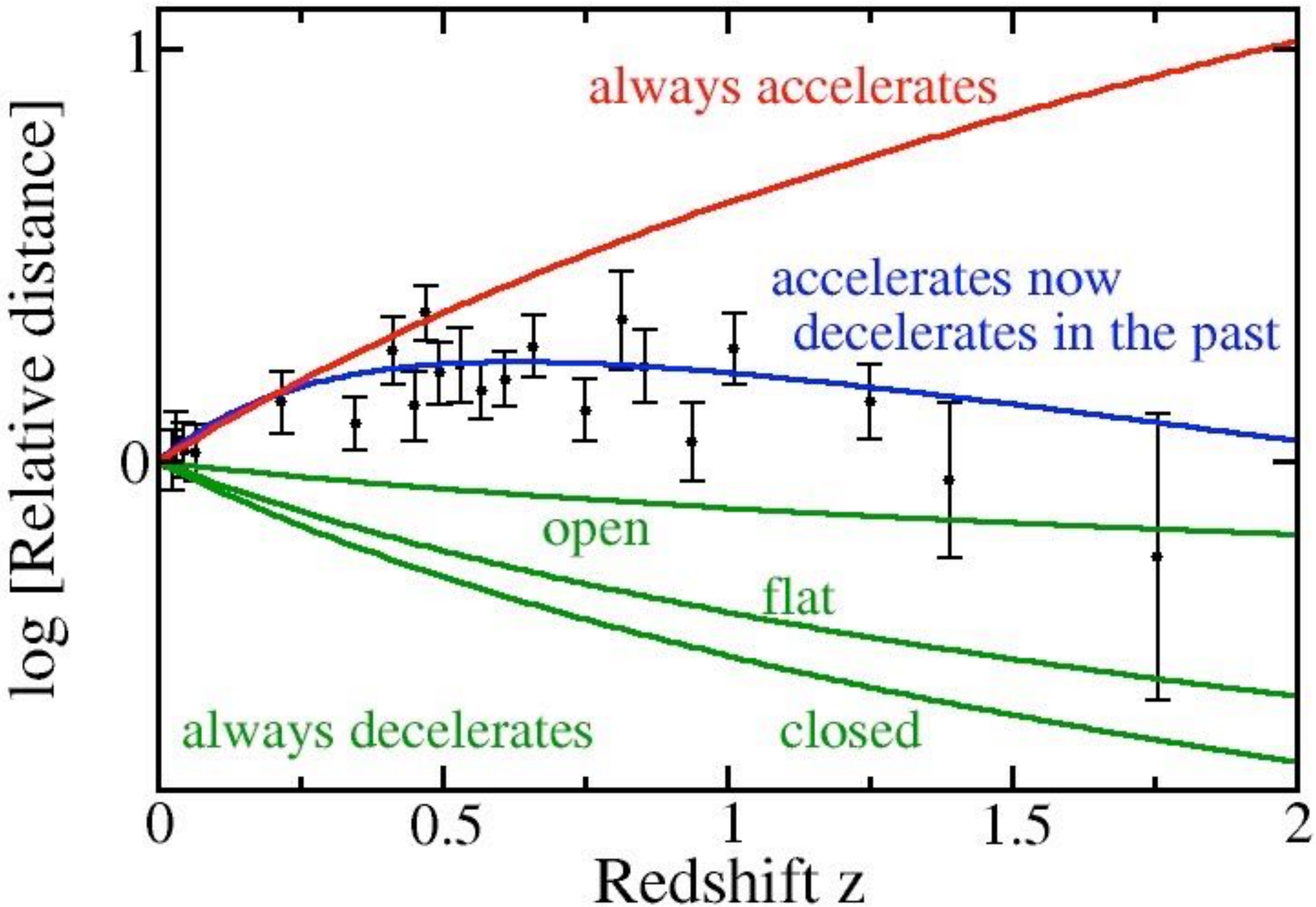
1. use world's large telescopes,
2. schedule them to find, then "follow-up" SNe
3. put in heroic hard work

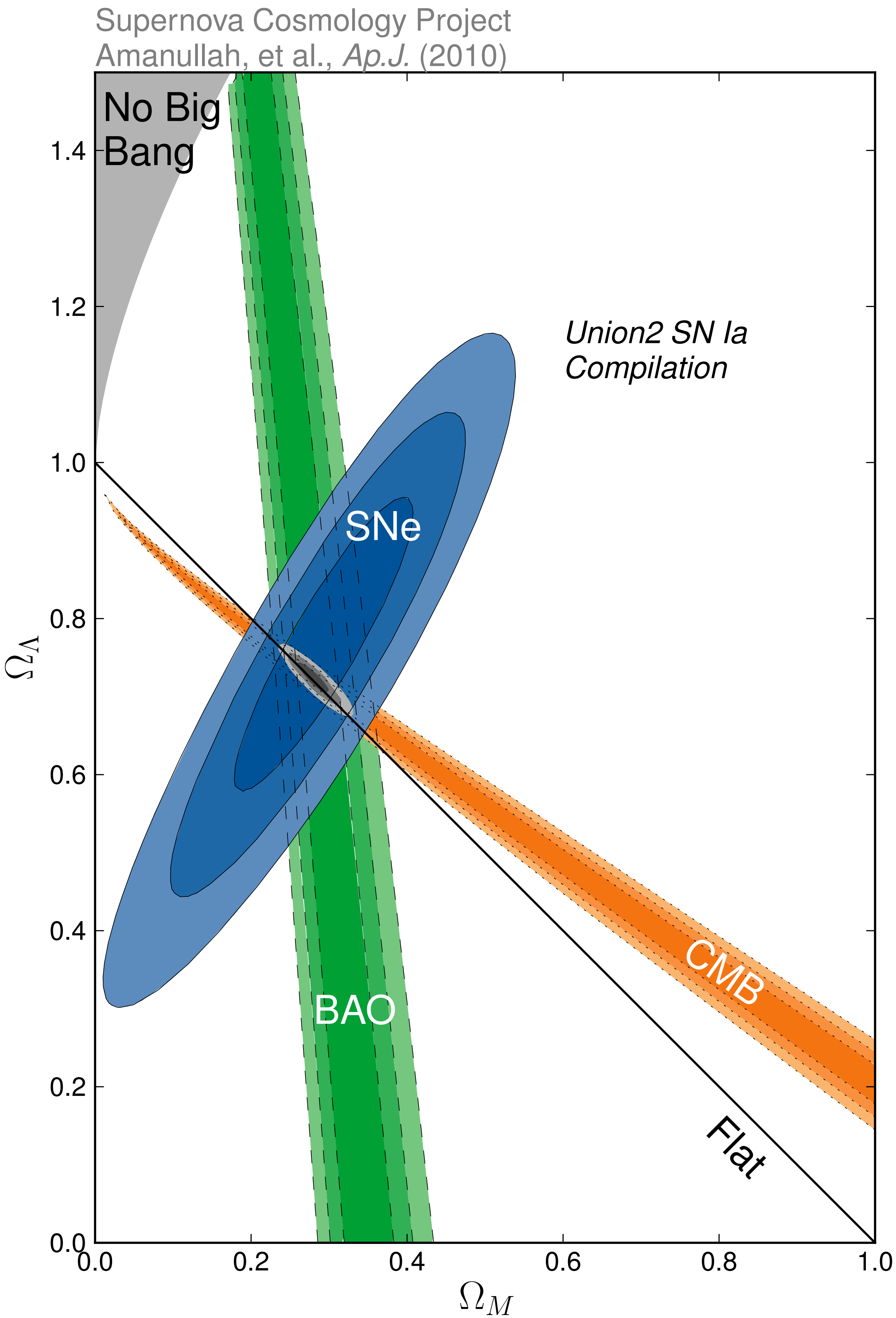
Motivation: to measure geometry of the universe

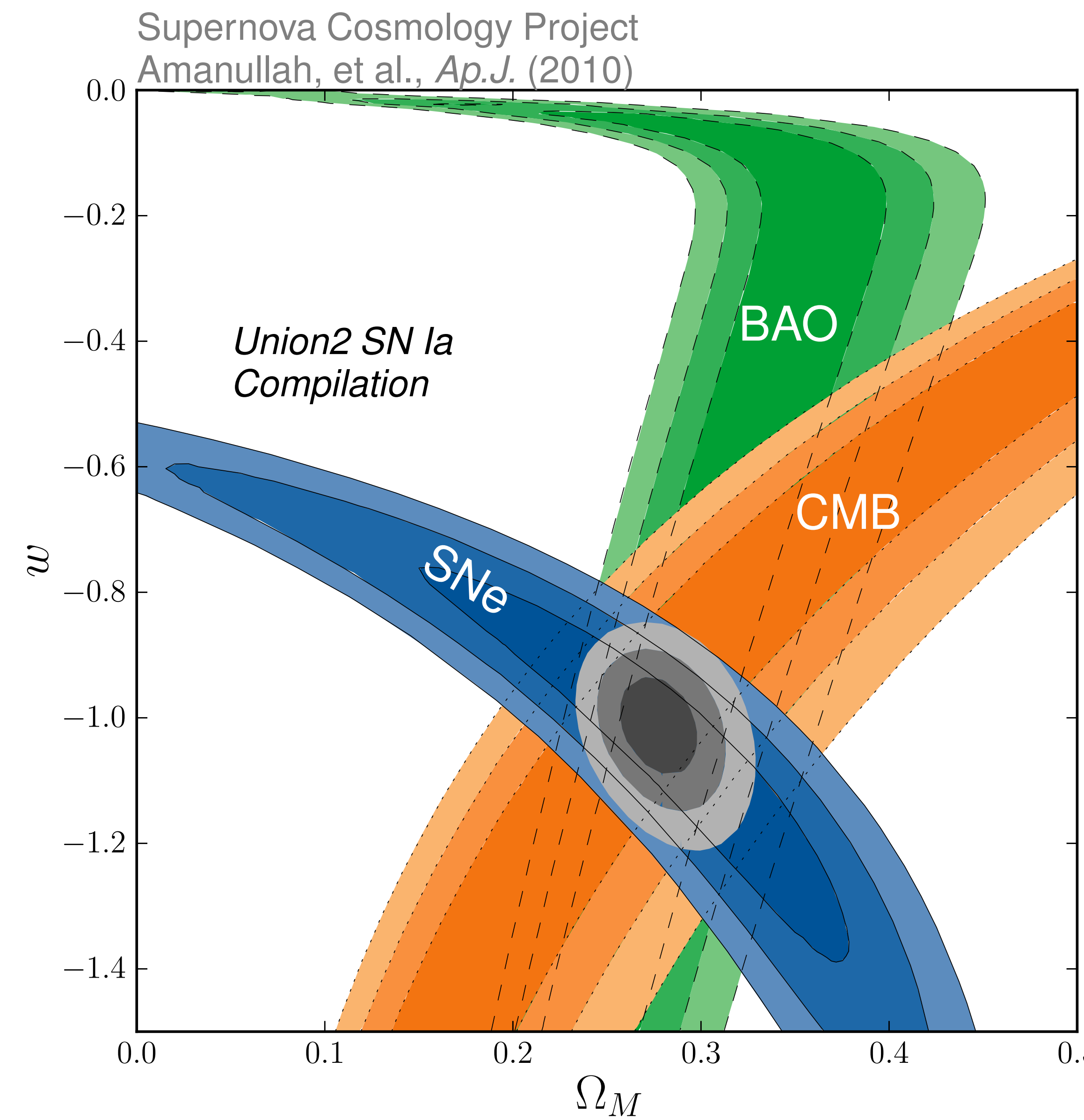


Supernova Hubble diagram

(binned; each error bar denotes ~20 SN)







$$\Omega_{\rm DE} \equiv \frac{\rho_{\rm DE}}{\rho_{\rm crit}}$$

$$w \equiv \frac{p_{\rm DE}}{\rho_{\rm DE}}$$

Supernova analysis - it's simple!

The difference between the apparent and absolute magnitude is the *distance modulus*. So

$$\mathrm{DM} \equiv m - M = 2.5\log_{10}\left(\frac{L}{f}\right) + \mathrm{const} = 5\log_{10}\left(\frac{d_L}{10\,\mathrm{pc}}\right) \tag{590}$$

where, note, we have taken care of the constants correctly, so that DM = 0 at 10 parsecs.

This equation can be re-written as

$$\begin{aligned} m &= M + 5\log_{10}\left(\frac{d_L}{1\,\mathrm{Mpc}}\right) + 25 & (591)\\ &= M + 5\log_{10}(H_0 d_L) - 5\log_{10}(H_0 \times 1\,\mathrm{Mpc}) + 25 & (592)\\ &\equiv 5\log_{10}(H_0 d_L) + \mathcal{M} & (593) \end{aligned}$$

where the "script-M" factor is defined as

$$\mathcal{M} \equiv M - 5\log_{10}(H_0 \times 1\,\mathrm{Mpc}) + 25. \tag{594}$$

To summarize

$$\boxed{m = 5\log_{10}(H_0 d_L) + \mathcal{M}} \tag{595}$$

Parameters are therefore: Omega_m, Omega_L (or w), etc,
plus a single nuisance parameter $\mathscr{M}$

Further reading

Popular articles:

"The Once and Future Cosmos", Scientific American special issue, December 2002

Standard semi-technical review:

Frieman, Turner & Huterer, Ann. Rev. Astron. Astrophys., www.arxiv.org/abs/arXiv:0803.0982

Modern semi-technical review, data-oriented: Huterer & Shafer, www.arxiv.org/abs/arXiv:1709.01091