«Pure» supernovae Ia and accelerating expansion of the Universe

M.V. Pruzhinskaya, E.S. Gorbovskoy, V.M. Lipunov

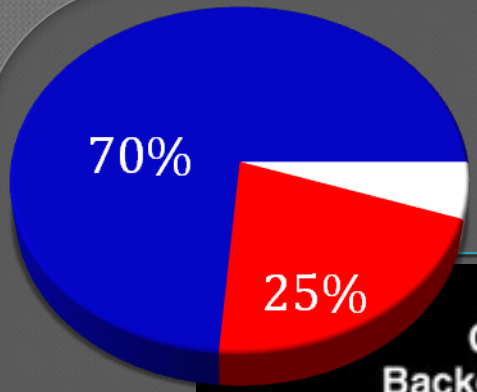
Lomonosov Moscow State University
Sternberg Astronomical Institute

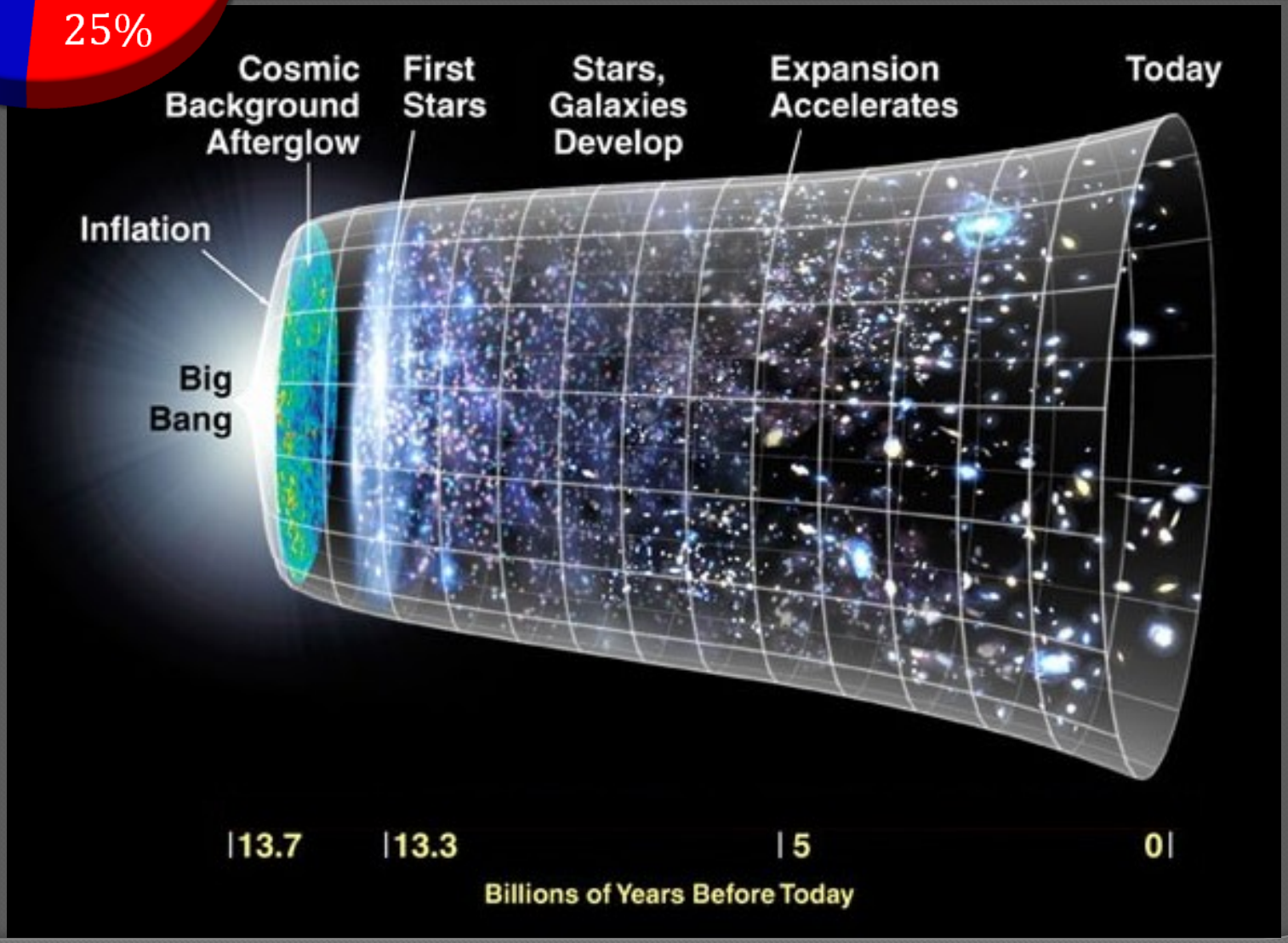
Observatoire de la Côte d'Azur, 2015

Outline

- Small introduction to Supernovae
- The detective story of one very important relation
- «Pure» supernovae and accelerating expansion of the Universe

Universe today





Great Debate. 1920

"Island Universes"

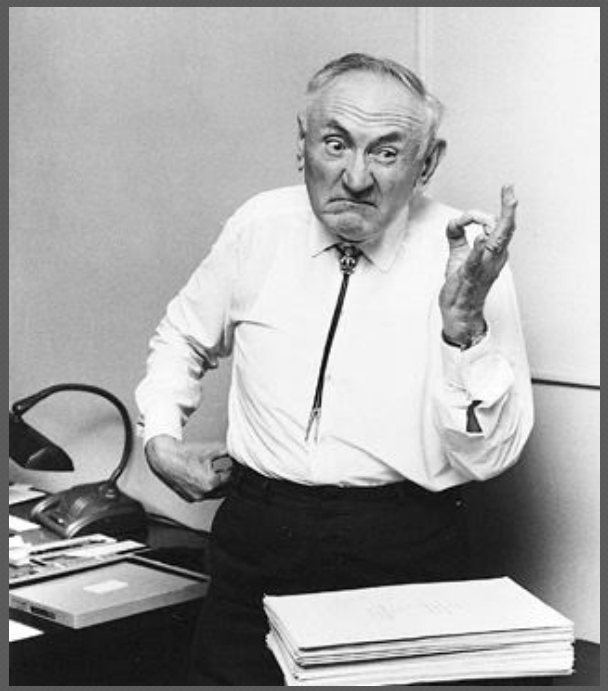
Harlow Shapley

Heber D. Curtis

Edwin Hubble

1933
term «Supernova»

Fritz Zwicky



Walter Baade

1936 - supernovae survey at Palomar Observatory

Supernovae

I
No H lines

II
H lines

Core collapse

Ia
Si lines

Ib
He lines

Ic
No He lines

IIb
Weak, disappearing H lines

IIn
Emission H lines

Spectral classification

Thermonuclear explosion

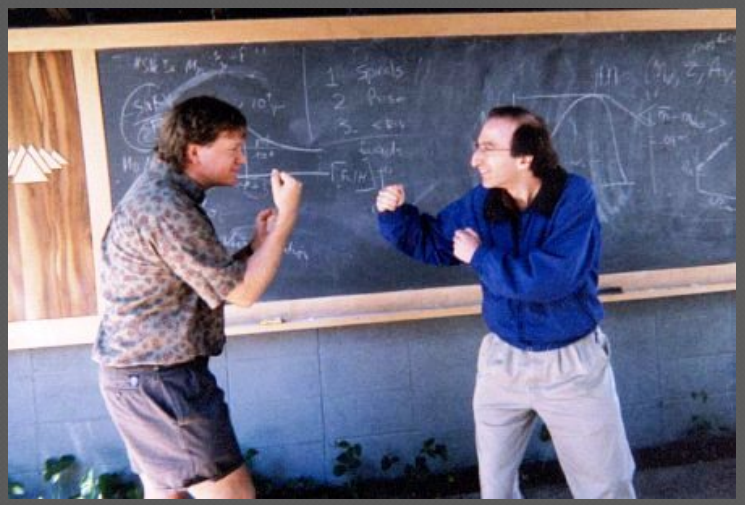
IIP
Plato

IIL
Linear

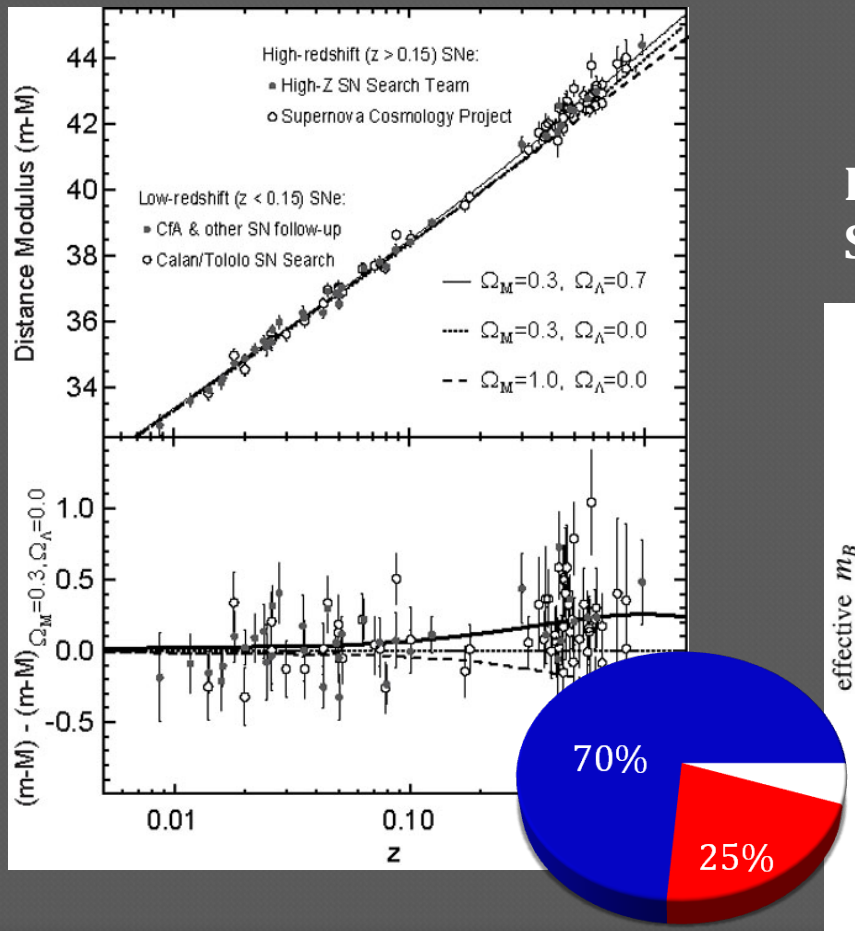
Light curve classification

Noble Prize 2011
B. Schmidt & A. Riess ; S. Perlmutter

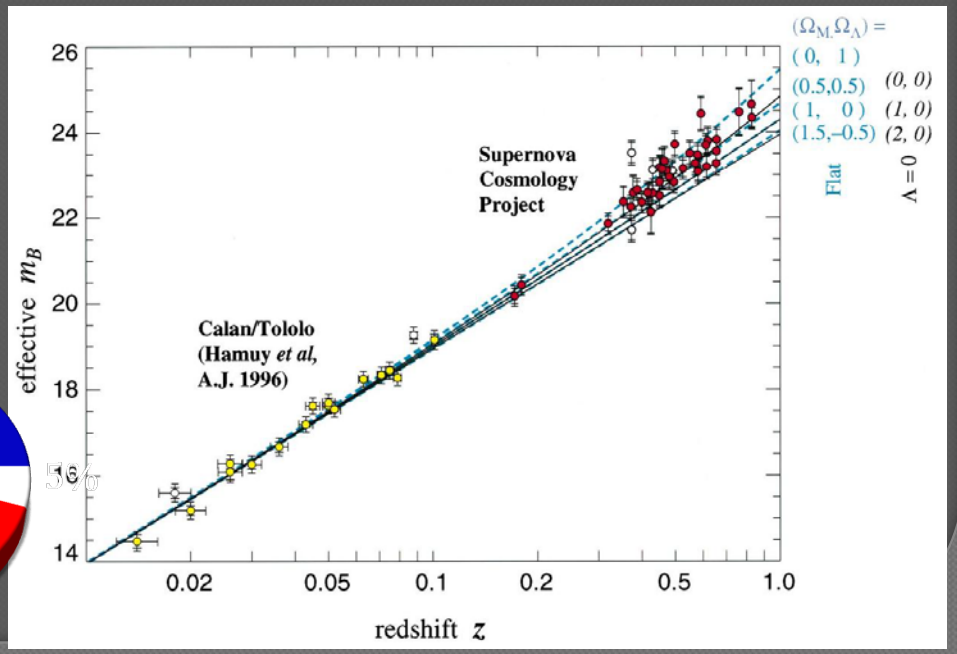
Brian P. Schmidt vs. Saul Perlmutter



Riess et al., 1998
High-z SN Search



Perlmutter et al., 1999
Supernova Cosmology Project

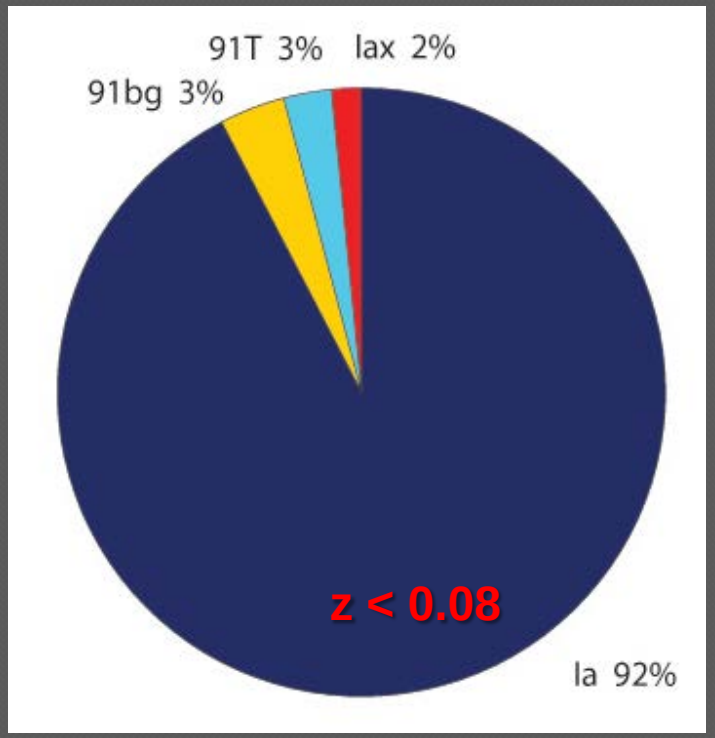


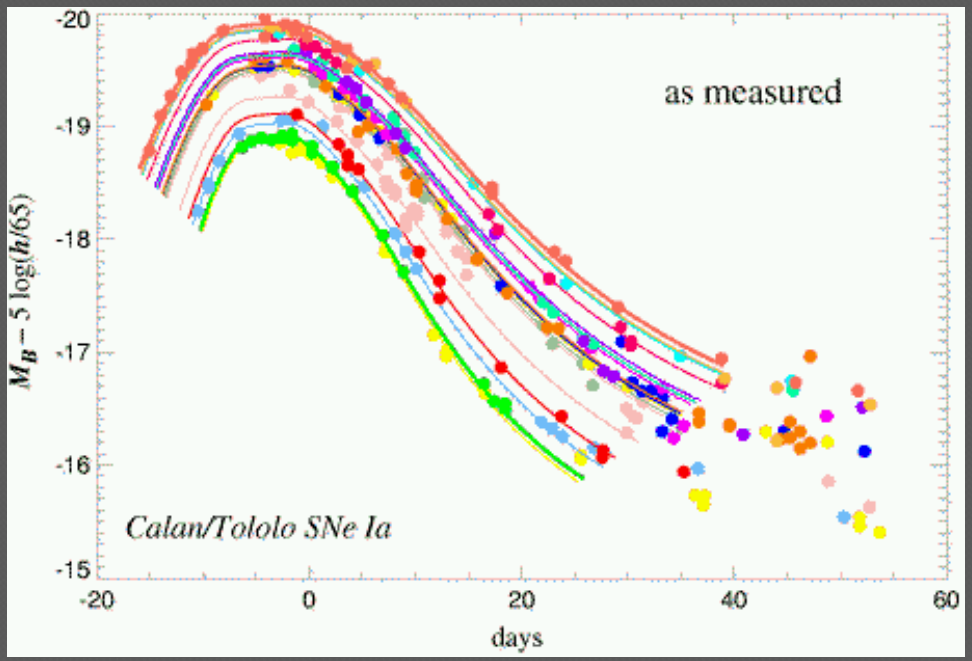
It would not be possible without…

…one very–very important relation

Standard candles?

Non, pas du tout.

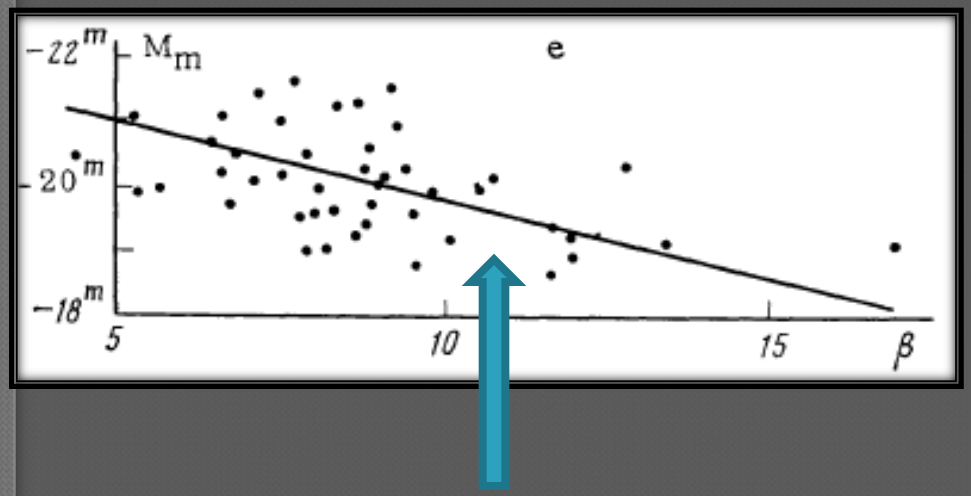




Rust-Pskovskii relation

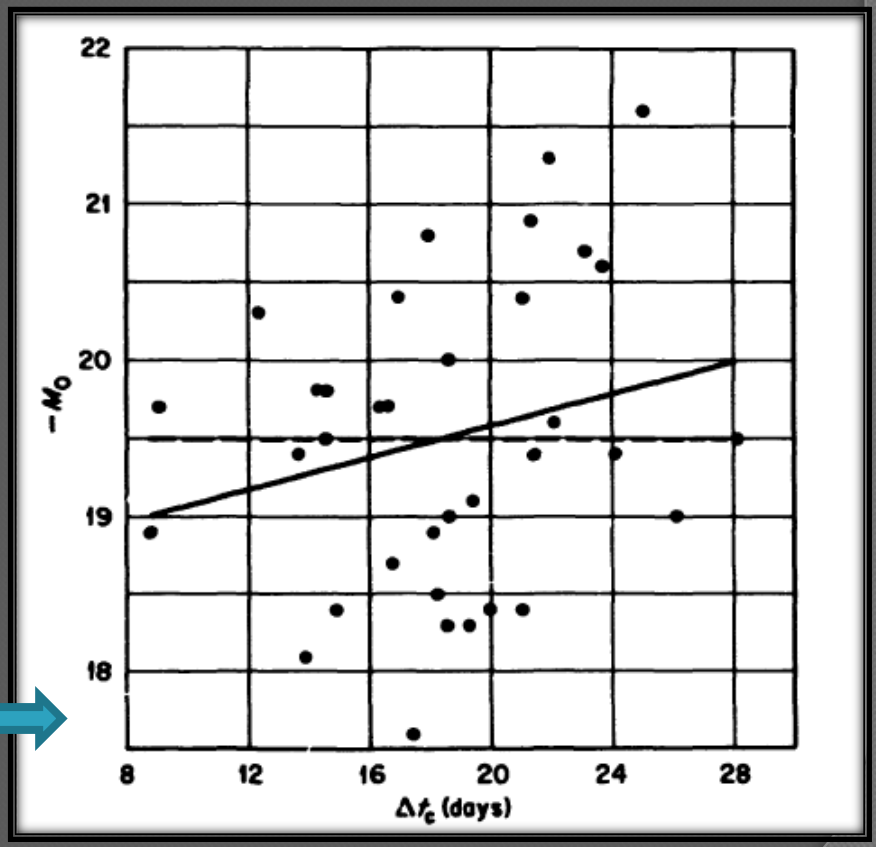
$-21.3+0.11\beta=M_{pg}\pm0.5$ (32 supernovae)

$M_0 = (-18.55 \pm 0.68) - (0.0512 \pm 0.0359)\Delta t_c$



Pskovskii Yu.P., 1977; 1984

Rust B.W., 1974; 1975



Yu. P. Pskovskii (1926-2004)

Bert W. Rust

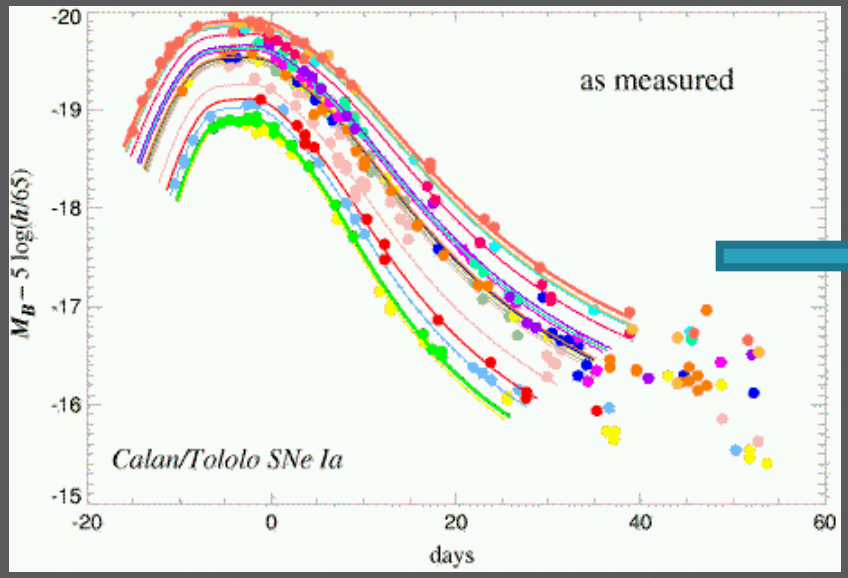
SN Ia are standardizable candles!

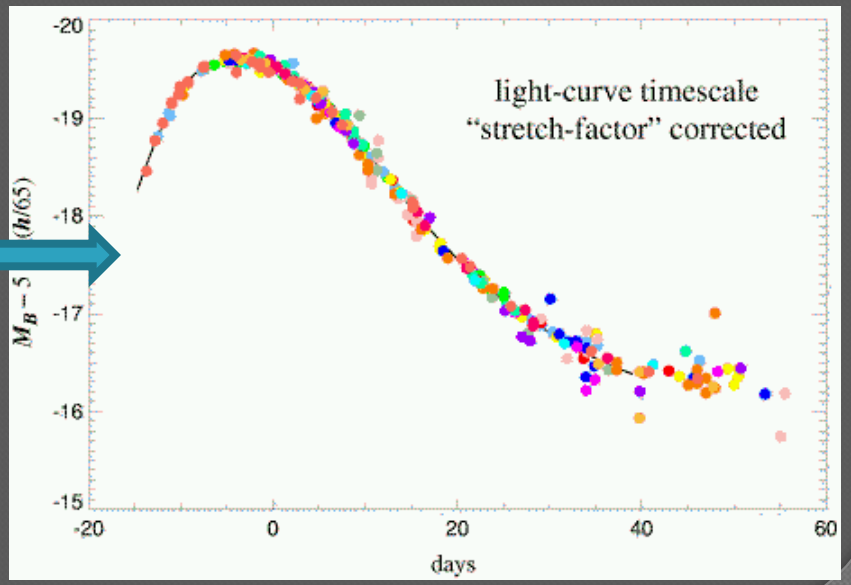
- Δm_{15} -method (Phillips,1993)
- MLCS (Riess, 1995)
- Stretch (Perlmutter, 1997)
- PRES (Prieto, 2005)
- SALT (Guy, 2005)
- GMAGIC (Wang, 2003)
- B. Rust et al. (2010)

$$M_B = \mathrm{M} - \alpha(s-1) + \beta c$$

$$c = (B-V)_{\max} + 0.057$$

$$\alpha, \beta, \mathrm{M} - \textit{parameters}$$





Are SN Ia standardizable candles?

- Absorption (in our Galaxy, in host galaxies)
- Chemical composition of star-progenitors
- Different mechanisms of Type Ia SNe explosions
- Evolution of the mass of white dwarfs with Hubble time
- Observational selection effects
- …

«Pure» supernovae Ia

1. There is no absorption
2. Identical chemical composition of star-progenitors
3. The mechanism of pure SNe explosions is the same: DD-mechanism!!!

1. Absorption

The gray dust absorption is wavelength-independent!

Type Ia Supernovae: Non-standard Candles of the Universe

A. I. Bogomazov[1] and A. V. Tutukov[2]

[1] *Sternberg Astronomical Institute, Moscow State University, Universitetskii pr. 13, Moscow, 119991 Russia*

[2] *Institute of Astronomy, Russian Academy of Sciences, Pyatnitskaya ul. 48, Moscow 119017, Russia*

Received November 30, 2010; in final form, January 13, 2011

Abstract—We analyze the influence of the evolution of light absorption by gray dust in the host galaxies of type Ia supernovae (SN Ia) and the evolution of the mean combined mass of close-binary carbon-oxygen white dwarfs merging due to gravitational waves (SN Ia precursors) on the interpretation of Hubble diagrams for SN Ia. A significant increase in the mean SN Ia energy due to the higher combined masses of merging dwarfs should be observable at redshifts $z > 2$. The observed relation between the distance moduli and redshifts of SN Ia can be interpreted not only as evidence for accelerated expansion of the Universe, but also as indicating time variations of the gray-dust absorption of light from these supernovae in various types of host galaxies, observational selection effects, and the decreasing mean combined masses of merging degenerate dwarfs.

Is the gray dust absorption able to produce the same effect of fainter distant SNe as the dark energy?

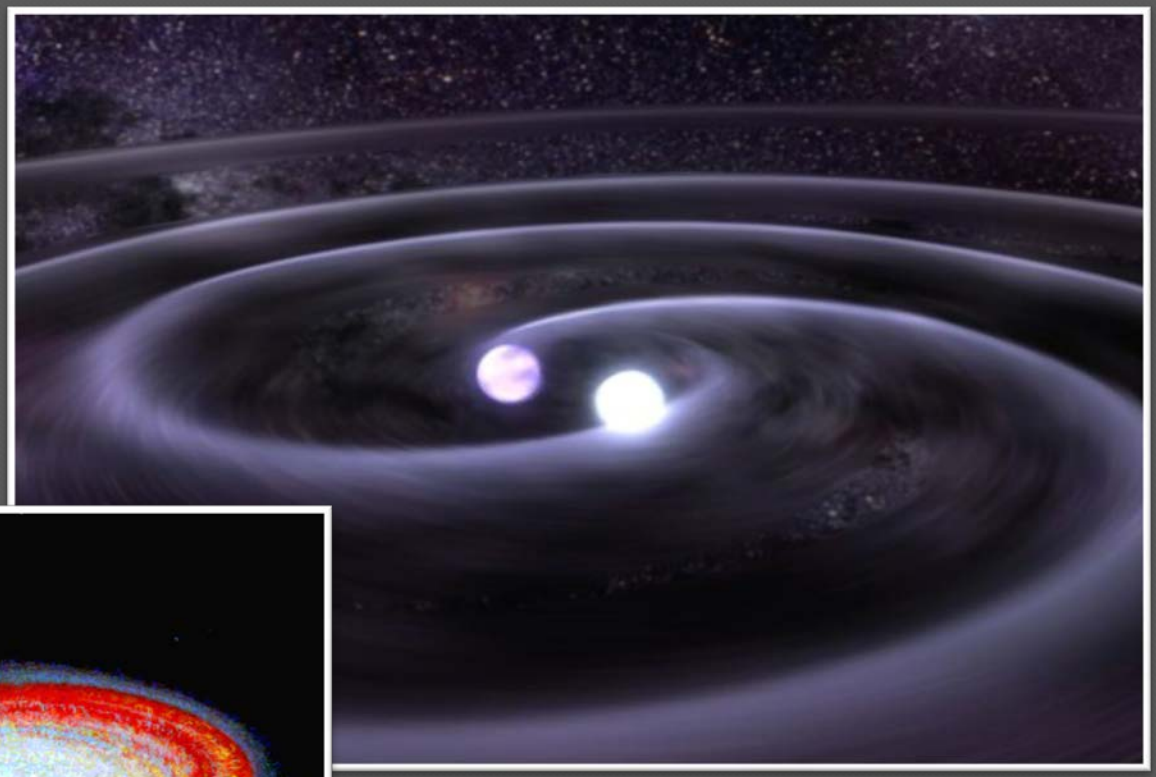
2. Chemical composition

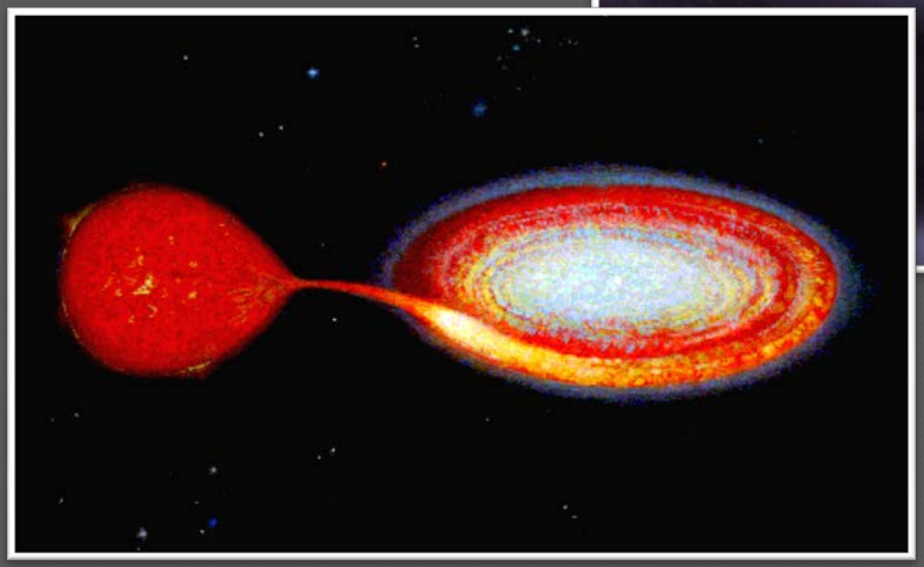
Low-metallicity population II stars

3. Mechanism of explosion

DD

Double degeneration
(Iben and Tutukov, 1984;
Webbink, 1984)

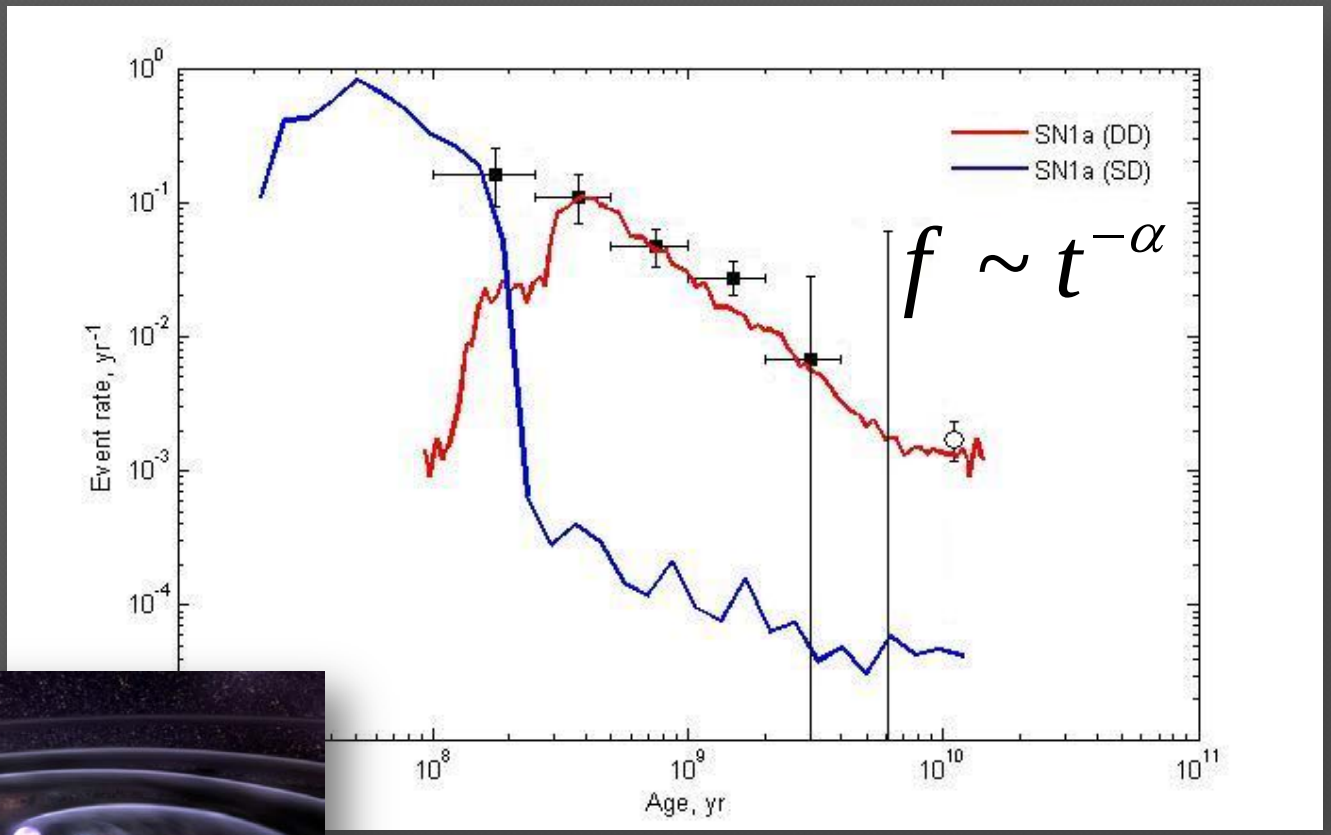


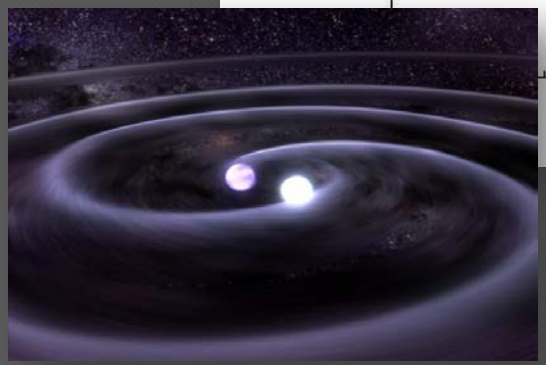


SD

Single degeneration
(Whelan and Iben, 1973)

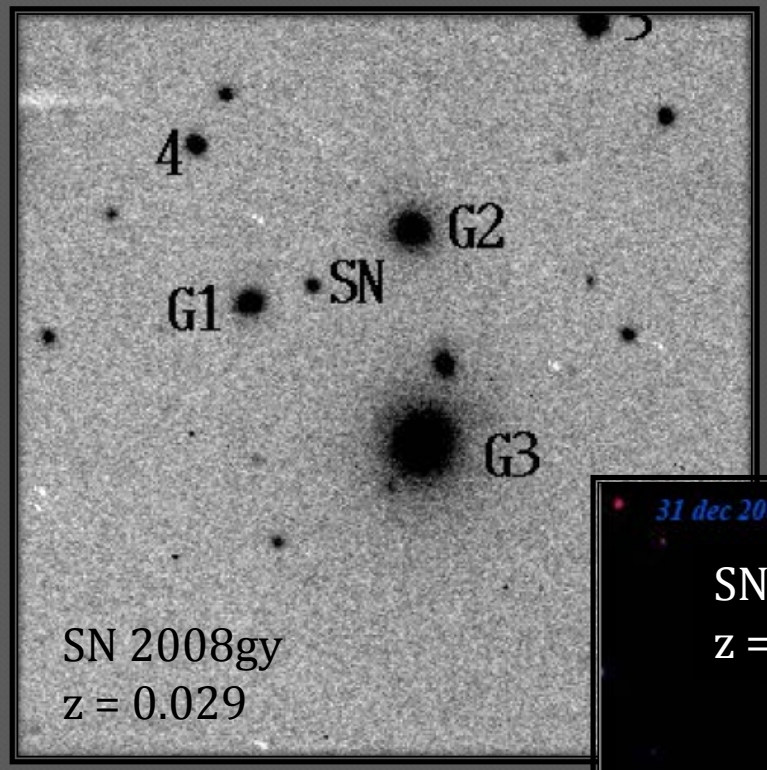
The mechanism of «pure» SNe explosions in E galaxies





Evolution of SN rates in a E galaxy (Jorgensen et al. 1997). The filled squares are the observational points (Mannucci et al. 2006 , Totani et al. 2008).

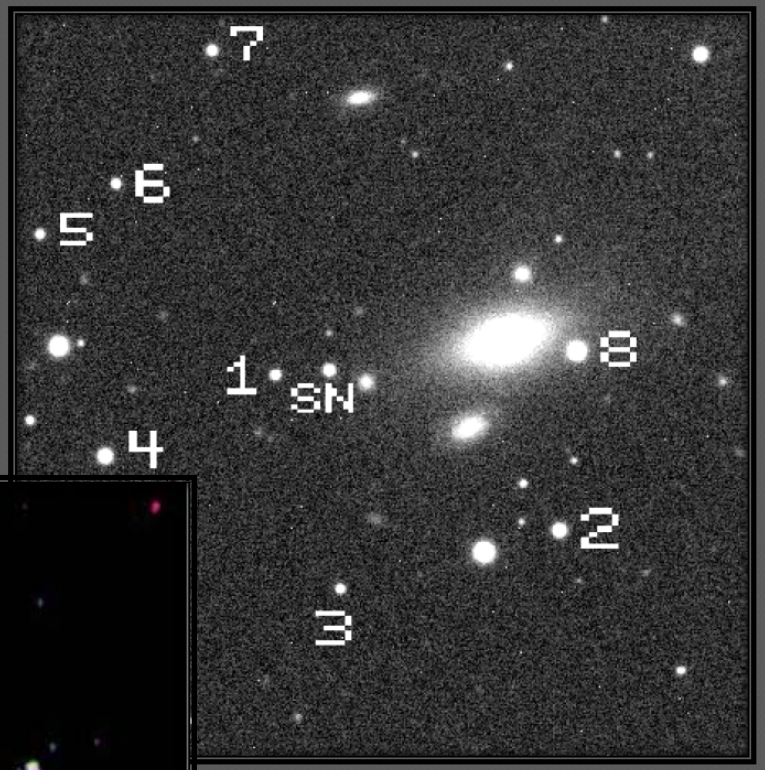
«Pure» SN in spiral galaxies > D25 (Kowalski et al., 2008)



SN 2008gy
z = 0.029

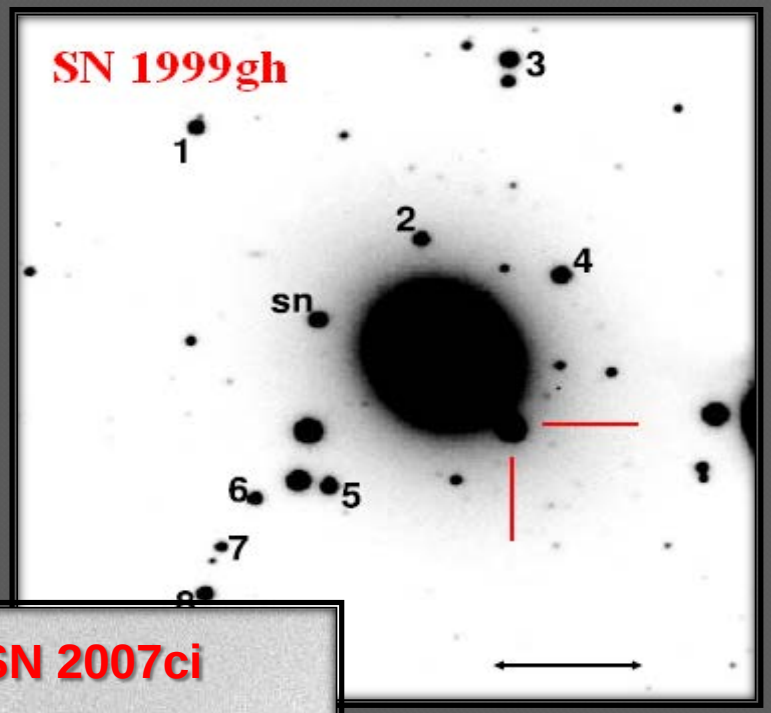
SN 2009nr
z = 0.011

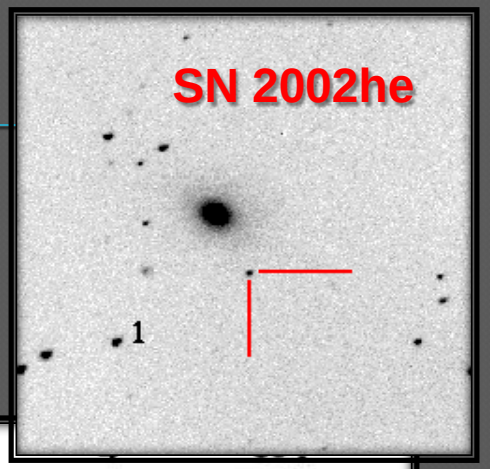
In the intergalactic space;
discovered by MASTER

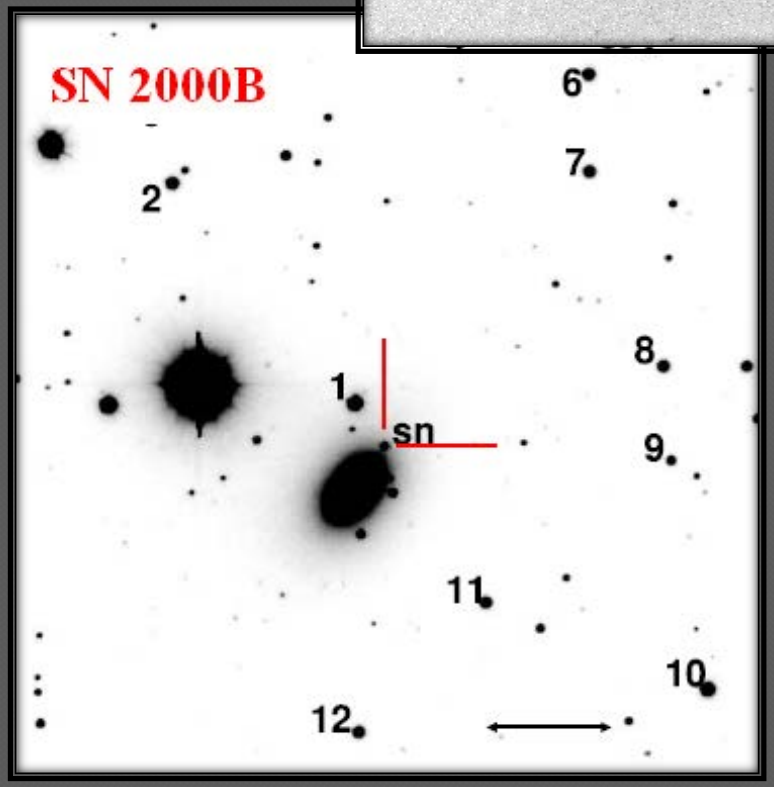


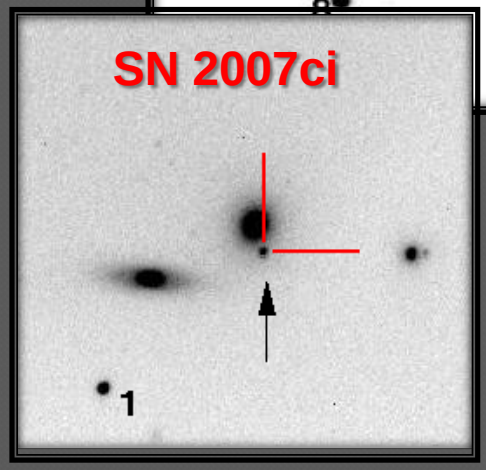
SN 2000bk
z = 0.0266
D = 33 kpc from
center of NGC 4520

«Pure» SN in E galaxies
(IAUC 8843, 8002, 7347, 7328)



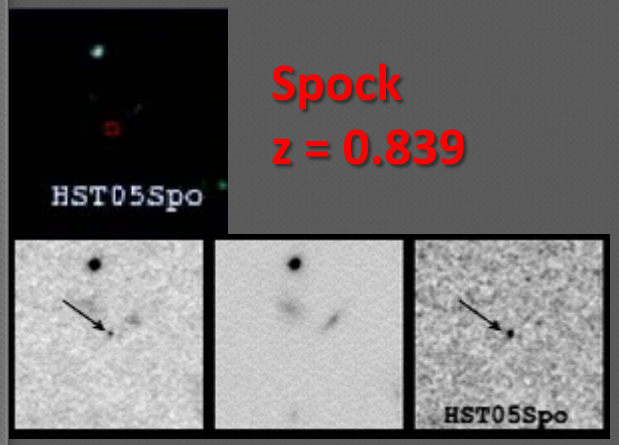




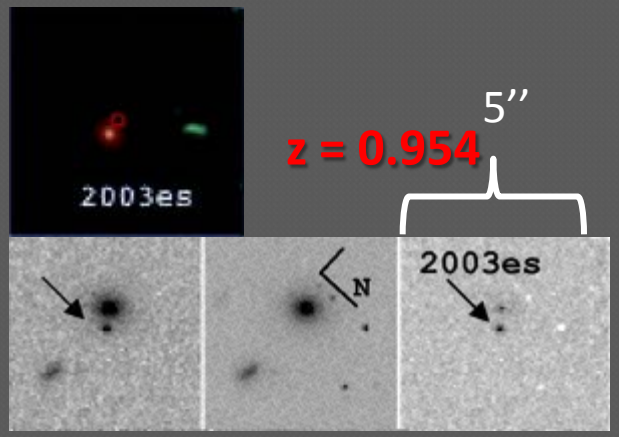


Distant «pure» SN, z > 1

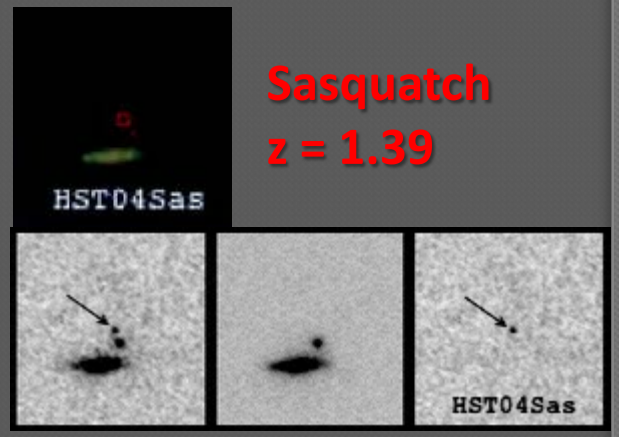
(Riess et al., 2004; Riess et al., 2007), Hubble telescope



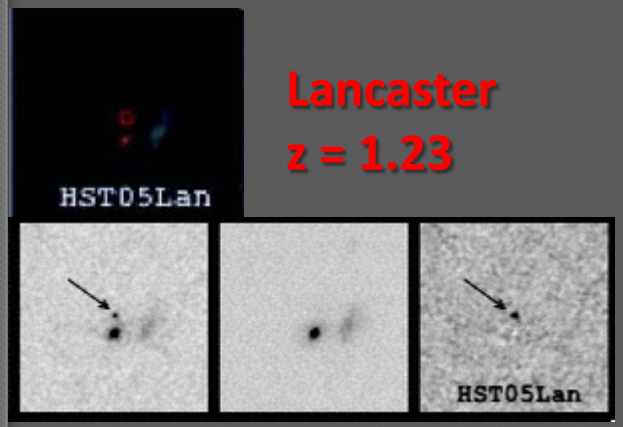
Spock
z = 0.839



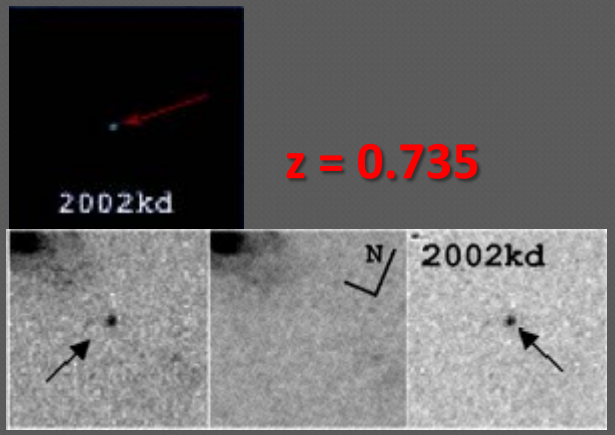
z = 0.954



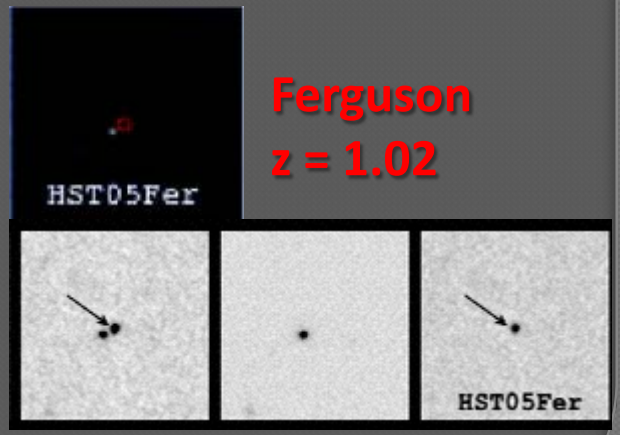
Sasquatch
z = 1.39



Lancaster
z = 1.23

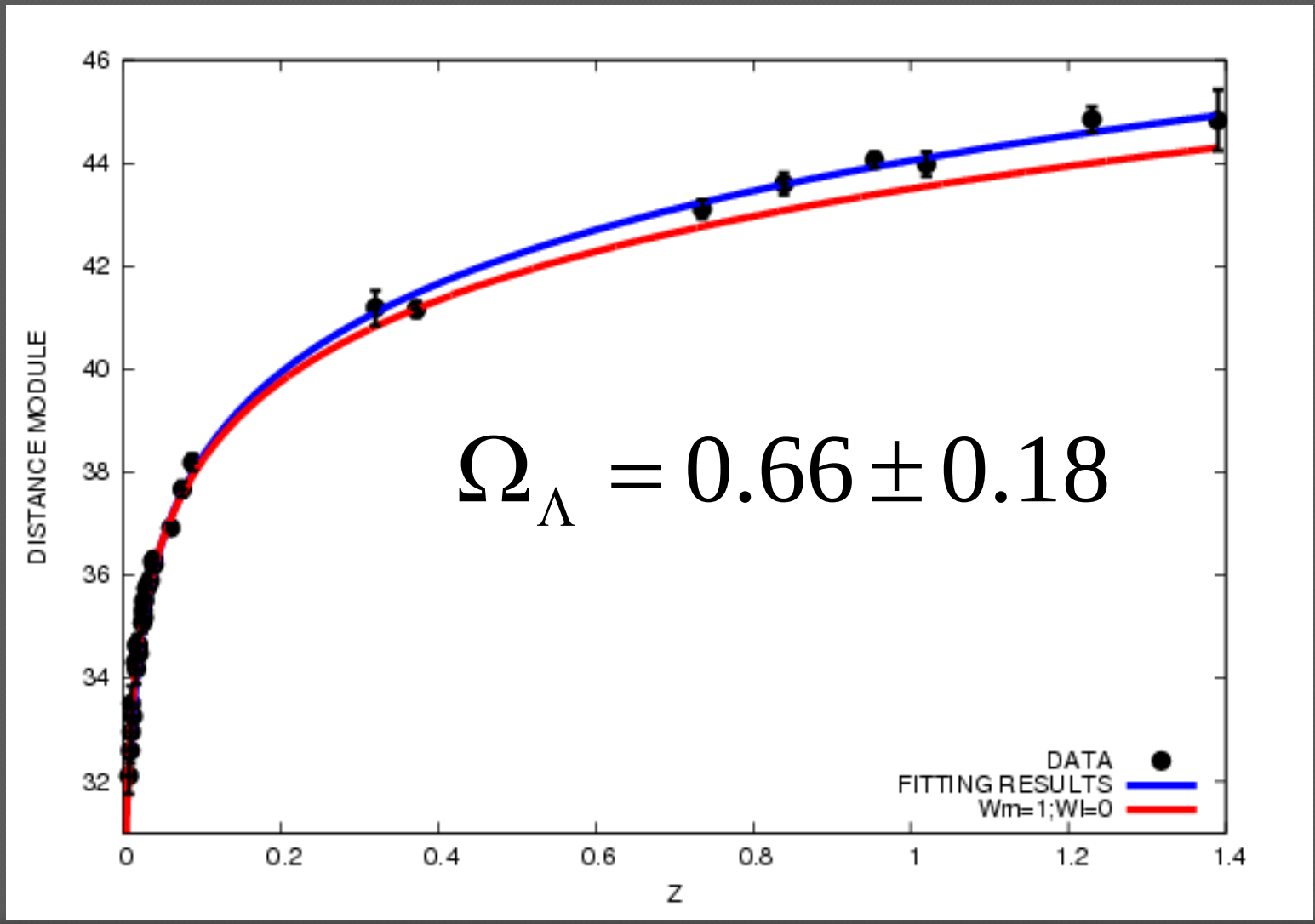


z = 0.735



Ferguson
z = 1.02

Hubble diagram for «pure» SN Ia



Conclusions

- Use of «pure» SN Ia can dramatically reduce the systematic errors related to chemical composition, explosion mechanisms, and gray dust.
- «Pure» SN Ia confirm Universe's accelerating expansion.
- The proposed class of «pure» SN Ia can be an effective tool to study the properties of Universe's accelerating expansion.

Thank you for attention!

Observatoire de la Côte d'Azur, 2015