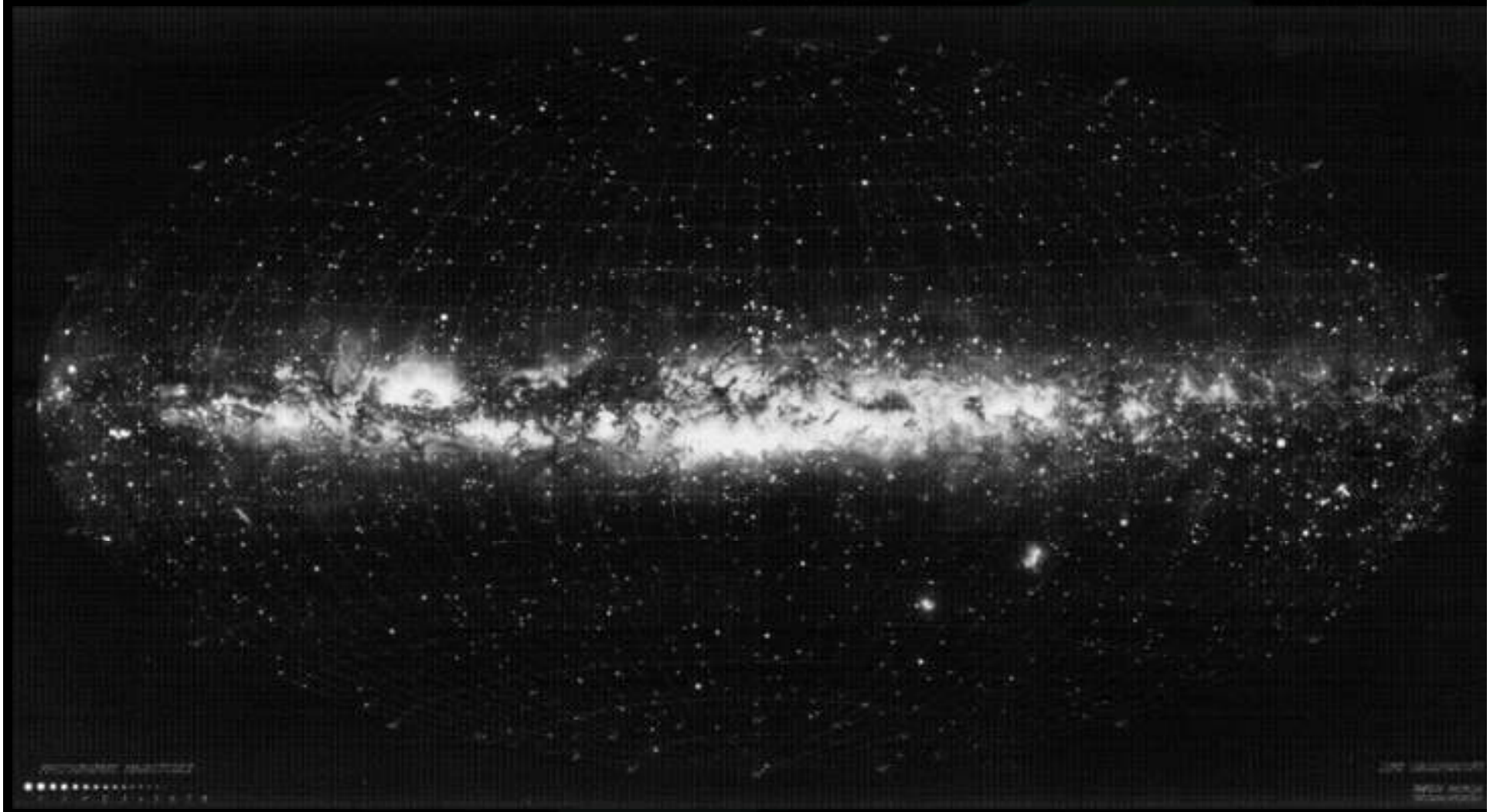
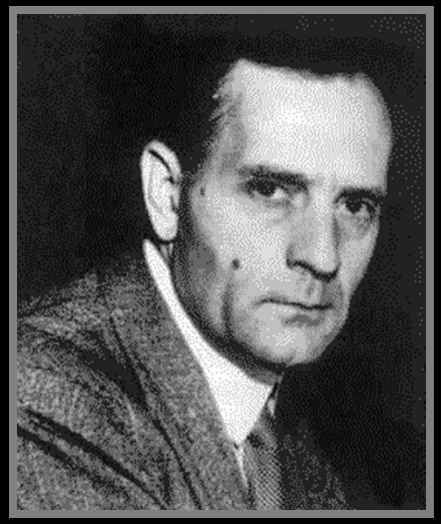
La aceleración del Universo a la luz de las supernovas

Mario Hamuy
Departamento de Astronomía
Universidad de Chile

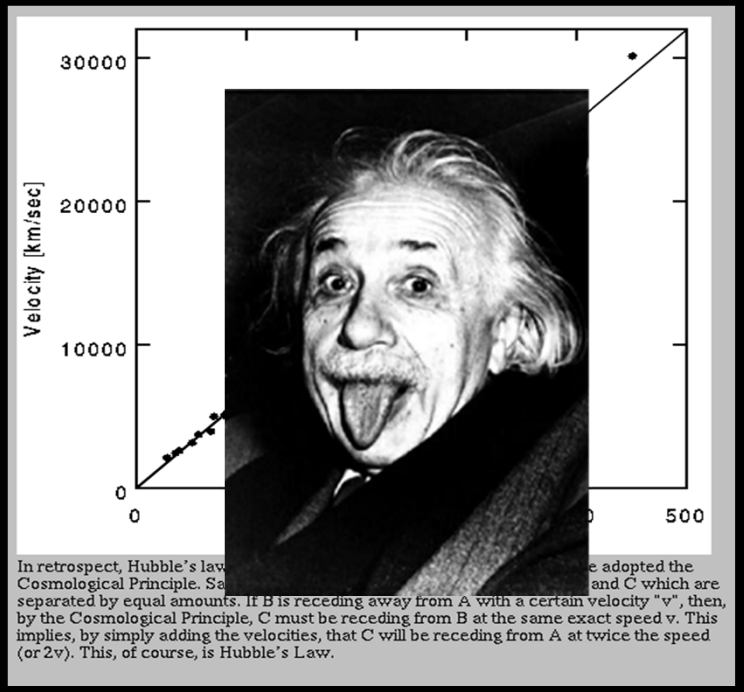
La galaxia Vía Láctea



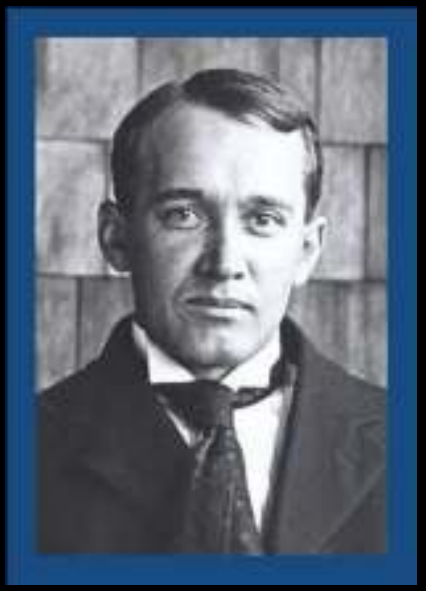
Universo en Expansión



Hubble (1889-1953)

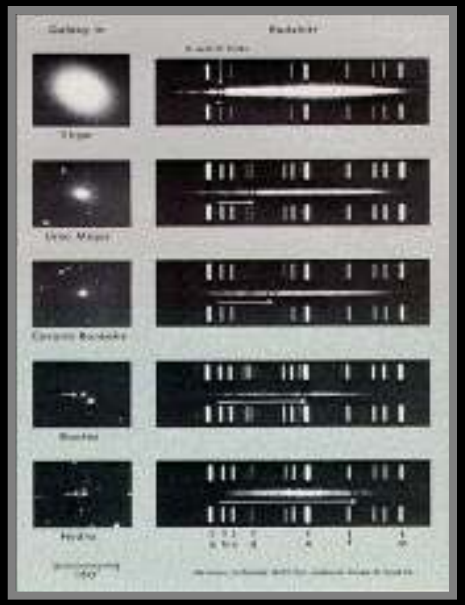


In retrospect, Hubble's law … e adopted the Cosmological Principle. Sa… and C which are separated by equal amounts. If B is receding away from A with a certain velocity "v", then, by the Cosmological Principle, C must be receding from B at the same exact speed v. This implies, by simply adding the velocities, that C will be receding from A at twice the speed (or 2v). This, of course, is Hubble's Law.

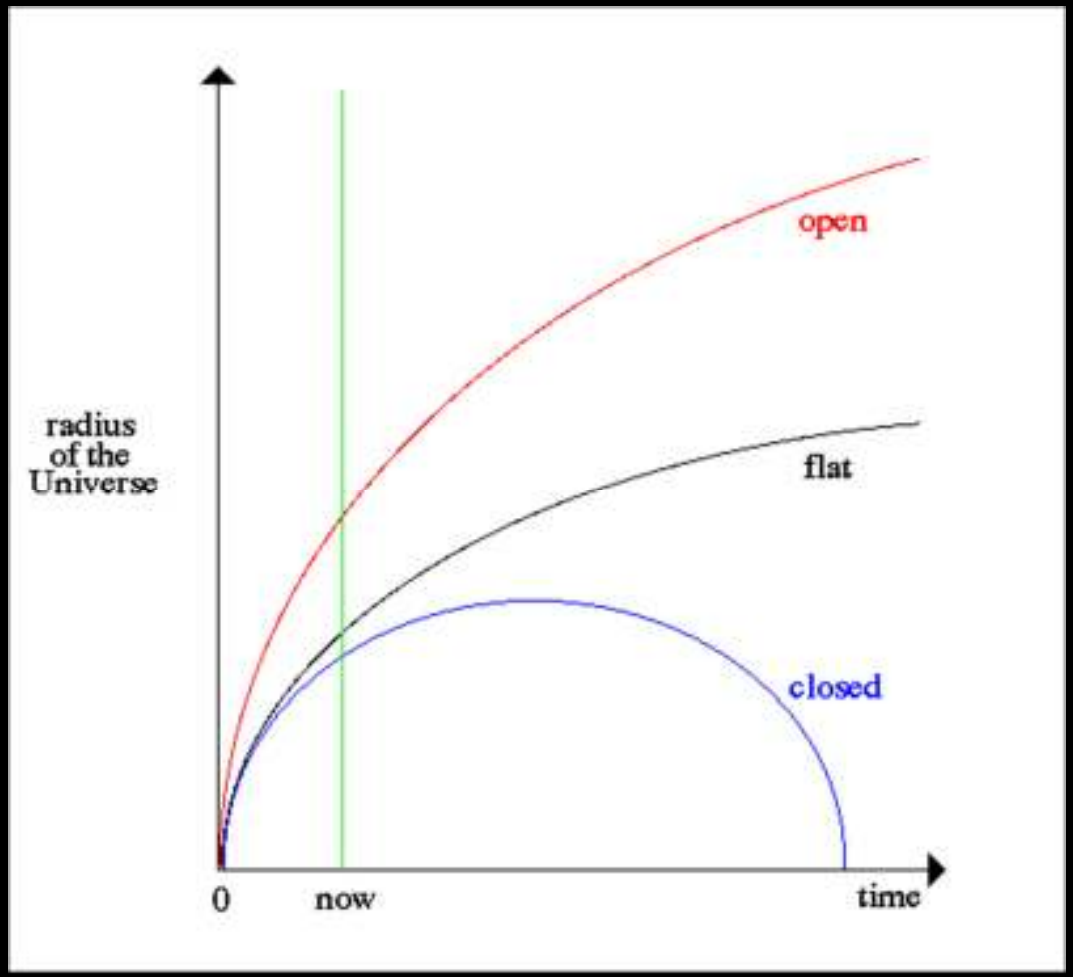


Slipher (1875-1969)

Estrella Cefeida

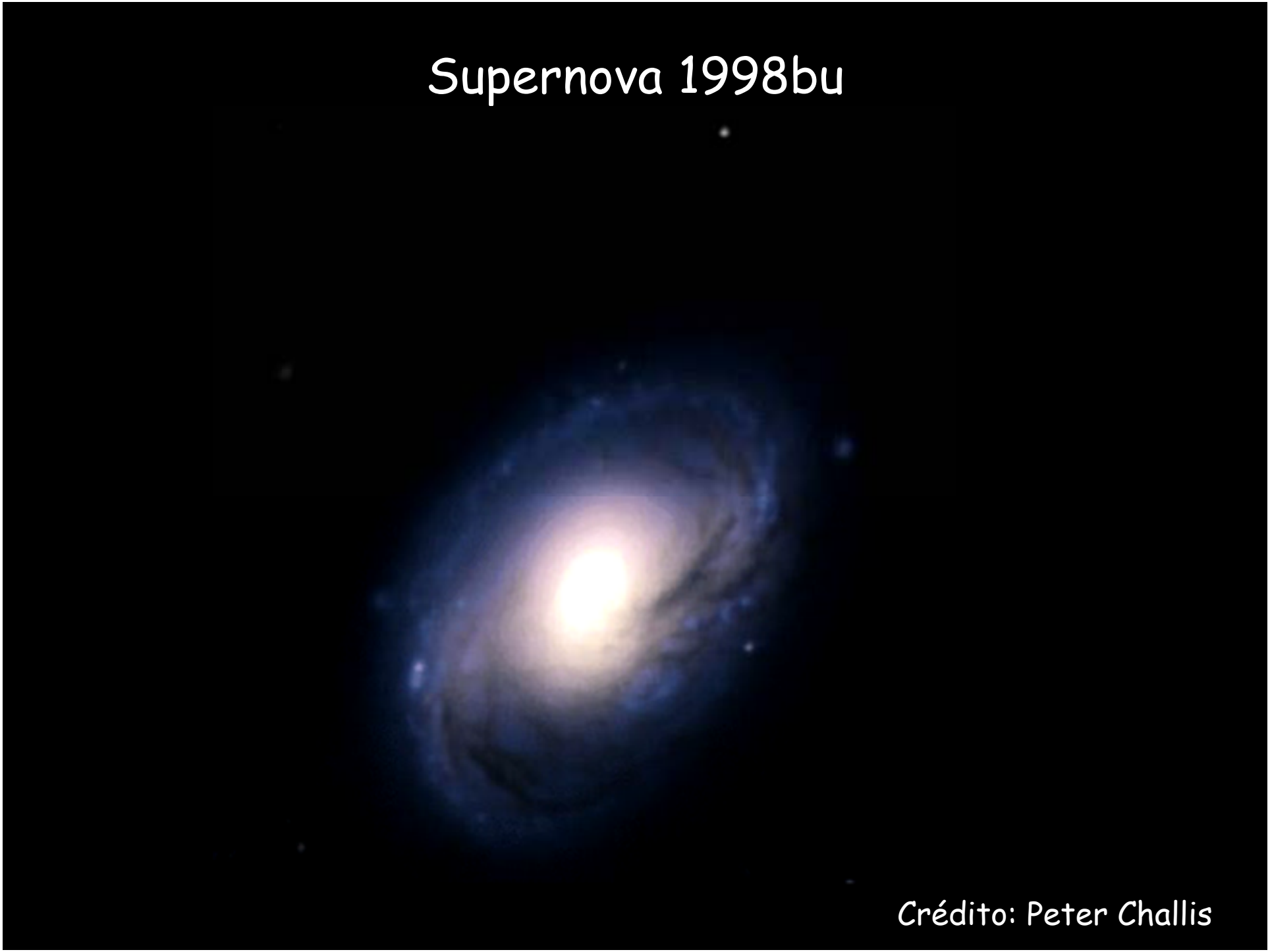


Destino del Universo?



Cosmología en el diagrama de Hubble

Supernova 1998bu



Crédito: Peter Challis

Workshop Santa Cruz – California - 1989

Supernovae Ia as Standard Candles

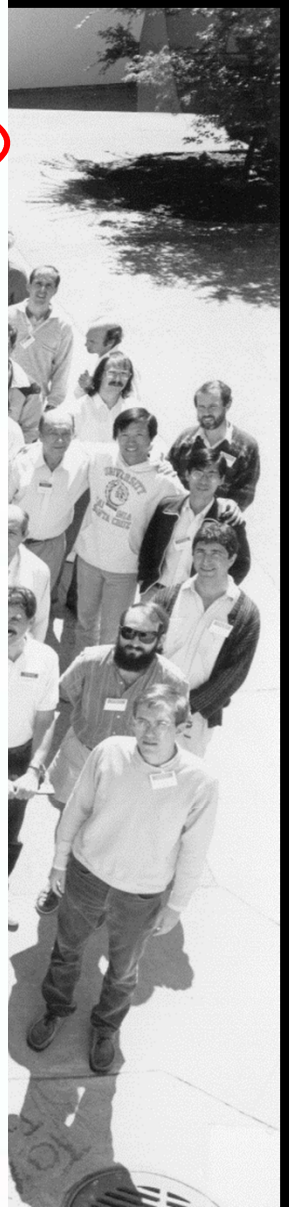
Bruno Leibundgut

1. Introduction

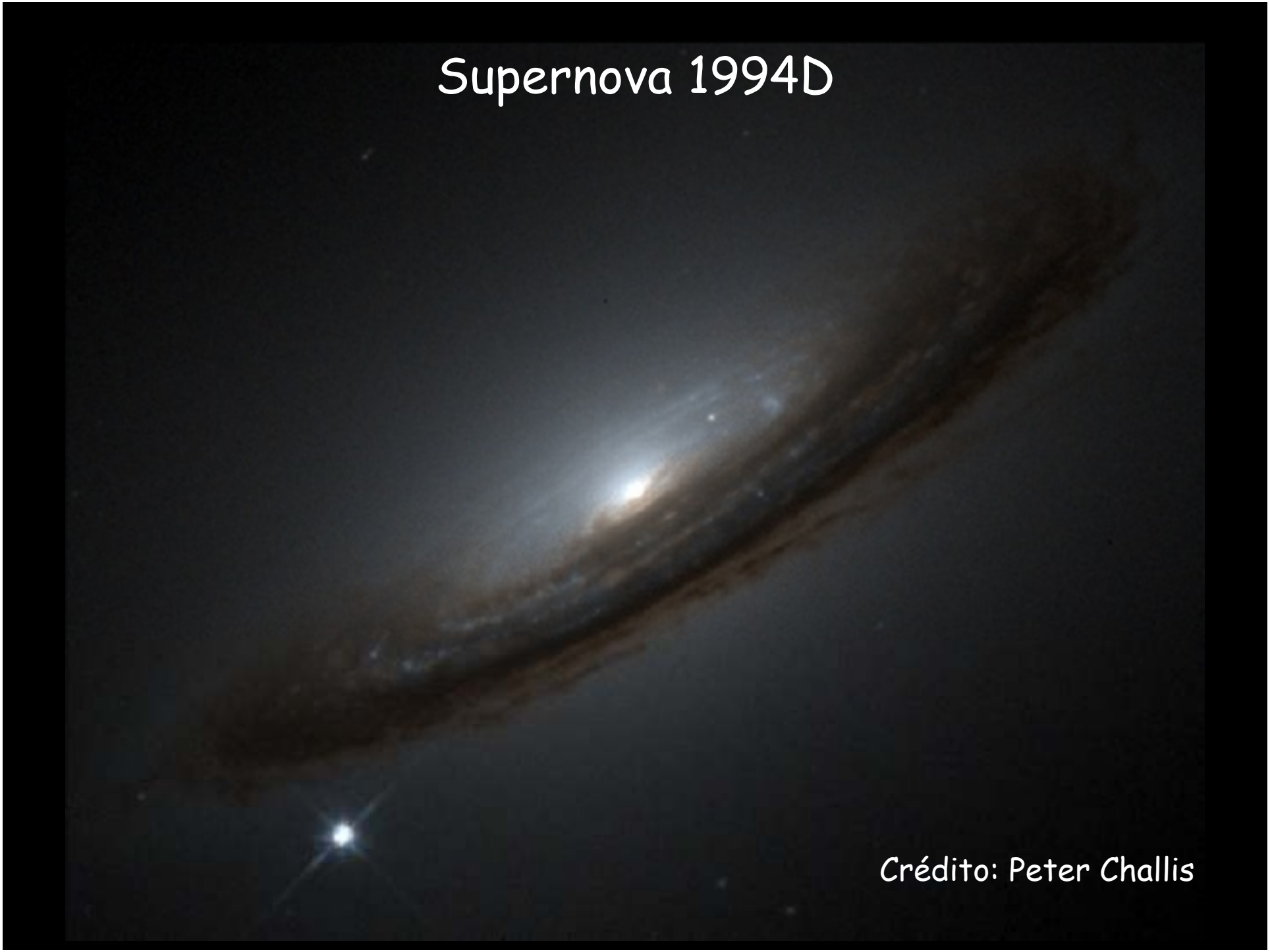
The use of Supernovae (SNe) as a mean of distance measurements was proposed already in the early times of supernova research. An extensive study by Baade (1938) of all available data at that time illustrates how SNe were used to infer cosmological parameters.

Although the recognition of various subtypes of SNe (Minkowski 1964, Kirshner et al. 1973, Oke and Searle 1974, Wheeler and Levreault 1985, Uomoto and Kirshner 1985) hampers the use of SNe In general for distance determinations, the possibility remains of using SNe of type II as "custom yardsticks" (Kirshner and Kwan 1974, Höflich 1987, Wagner 1988, Eastman and Kirshner 1989) and SNe of type Ia as standard candles (Tammann 1982, Leibundgut 1988, Leibundgut and Tammann 1989). The second method needs, of course, a good calibration of SNe Ia as objects with equal, if not identical, evolution of their light emission. Spectroscopic studies of SNe Ia have shown differences between individual events (Branch et al. 1988), but the photometric observations have exhibited astonishing uniformity (Leibundgut 1988). The exceptional case of the well studied SN 1986G in the peculiar galaxy NGC 5128 (Cen A; Phillips et al. 1987, Frogel et al. 1987, see also Cassé et al. 1988) poses a strong challenge to the significance of standard candles for SNe Ia. We would like to understand what caused the differences, for instance in the infrared light curves of SN 1986G compared to standard SNe Ia like SNe 1972E, 1981B, 1960N (Leibundgut 1988) and the dispersion of the expansion velocities in SNe Ia (Branch et al. 1988), before we really may rely on distances from SNe. The little knowledge on extinction in external galaxies complicates accurate determinations even further, but as will be shown below, it might still be acceptable to neglect this contaminating effect for most SNe Ia.

We will first demonstrate the photometric uniformity of SNe Ia and then outline their possible uses for cosmology. The observations of SN 1988U (Norgaard-Nielsen et al. 1989) provide a first test of the predictions.

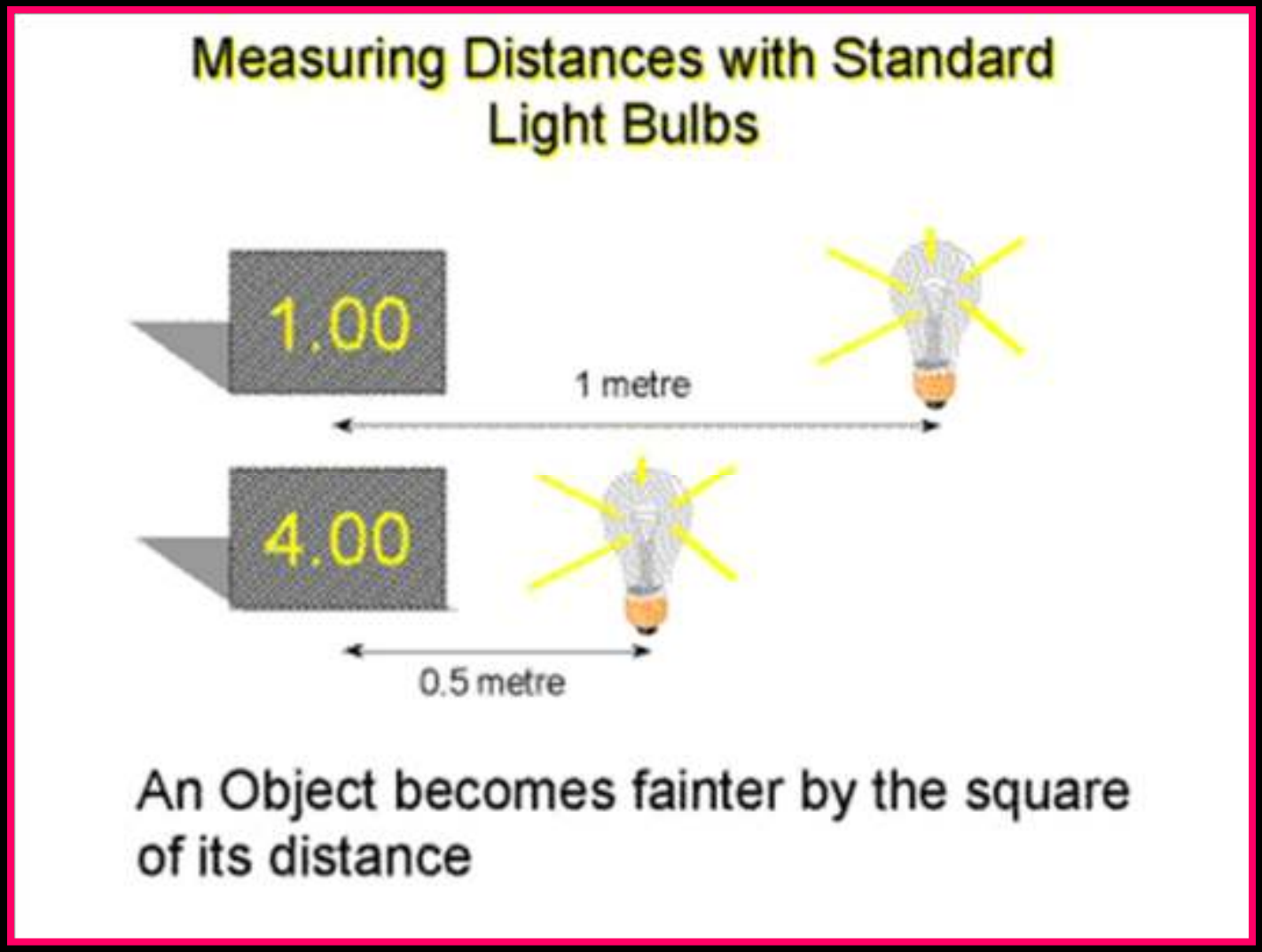


Supernova 1994D



Crédito: Peter Challis

Supernovas de tipo Ia como indicadores de distancias




Supernova

El proyecto Calán/Tololo (1989-1996) - Miembros


Roberto Avilés


Mark Phillips


Bob Schommer


Nick Suntzeff


Mario Hamuy


Roberto Antezana


José Maza


Lisa Wells


Marina Wischnjewski


Luis González


Paulina Lira

UNIDADES EJECUTORAS DE LA (S) INSTITUCION (ES) PATROCINANTE (S)

INSTITUCION/FACULTAD/DEPARTAMENTO

1.	OBSERVATORIO INTERAMERICANO DE CERRO TOLOLO.
2.	UNIVERSIDAD DE CHILE / DEPARTAMENTO DE ASTRONOMIA.
3.	
4.	
5.	
6.	
7.	

RESUMEN: (Debe darse una idea sucinta y clara del proyecto en un espacio que no exceda esta página)

ABSTRACT

We propose to start a photographic search for supernovae in the southern hemisphere for a period of three years. The survey will be carried out using the Curtis Schmidt telescope at Cerro Tololo Inter-American Observatory (CTIO) with IIaO plates. A careful review of the plates will be performed at the Department of Astronomy of the University of Chile (Cerro Calán). According to previous tests of the Calán/CTIO survey performed between June 1990-June 1991, we should be able to find one supernova brighter than B=19 every month. We will obtain follow-up photometry and spectroscopy of these objects using other CTIO telescopes for spectral classification and the measurement of the light curves. In the course of the three years we expect to find 20-25 Type Ia events in the redshift range 0.005-0.1, which will be used to study the Hubble diagram for these objects at this redshift range. A more detailed monitoring will be obtained for 1-2 bright supernovae per year, in the optical and infrared wavelengths.

Calán/Tololo - Patrullaje

Cámara Curtis-Schmidt
Cerro Tololo

La Serena → Santiago

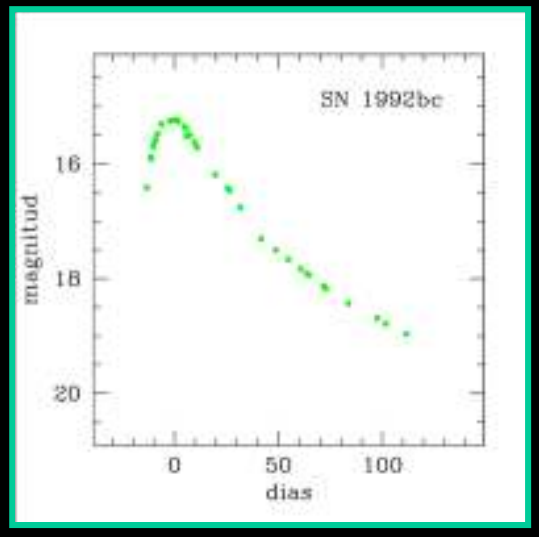
Placa fotográfica

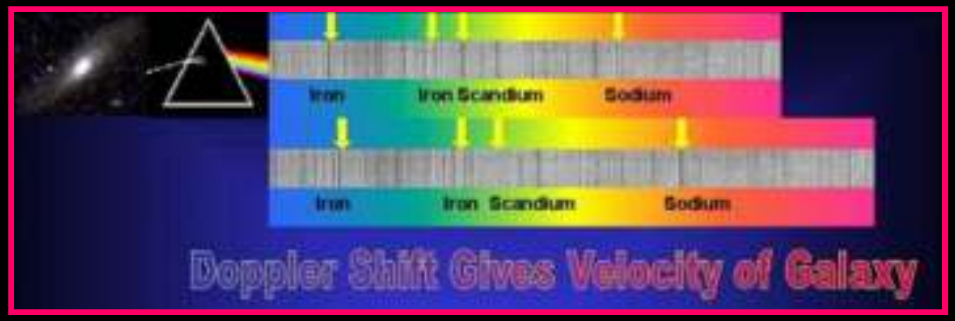
Blink Comparator
Cerro Calán

Supernova!

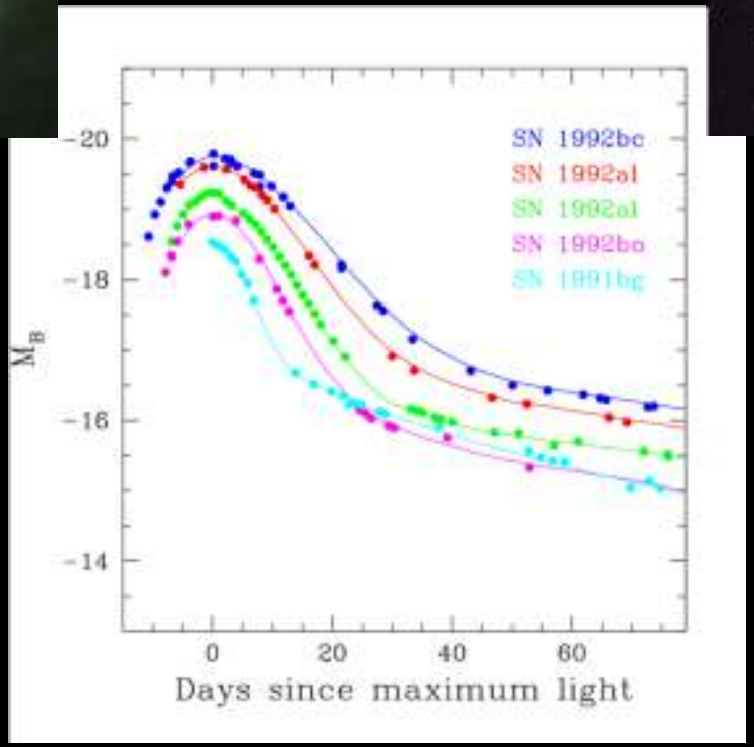
Santiago → La Serena

Calán/Tololo - Seguimiento



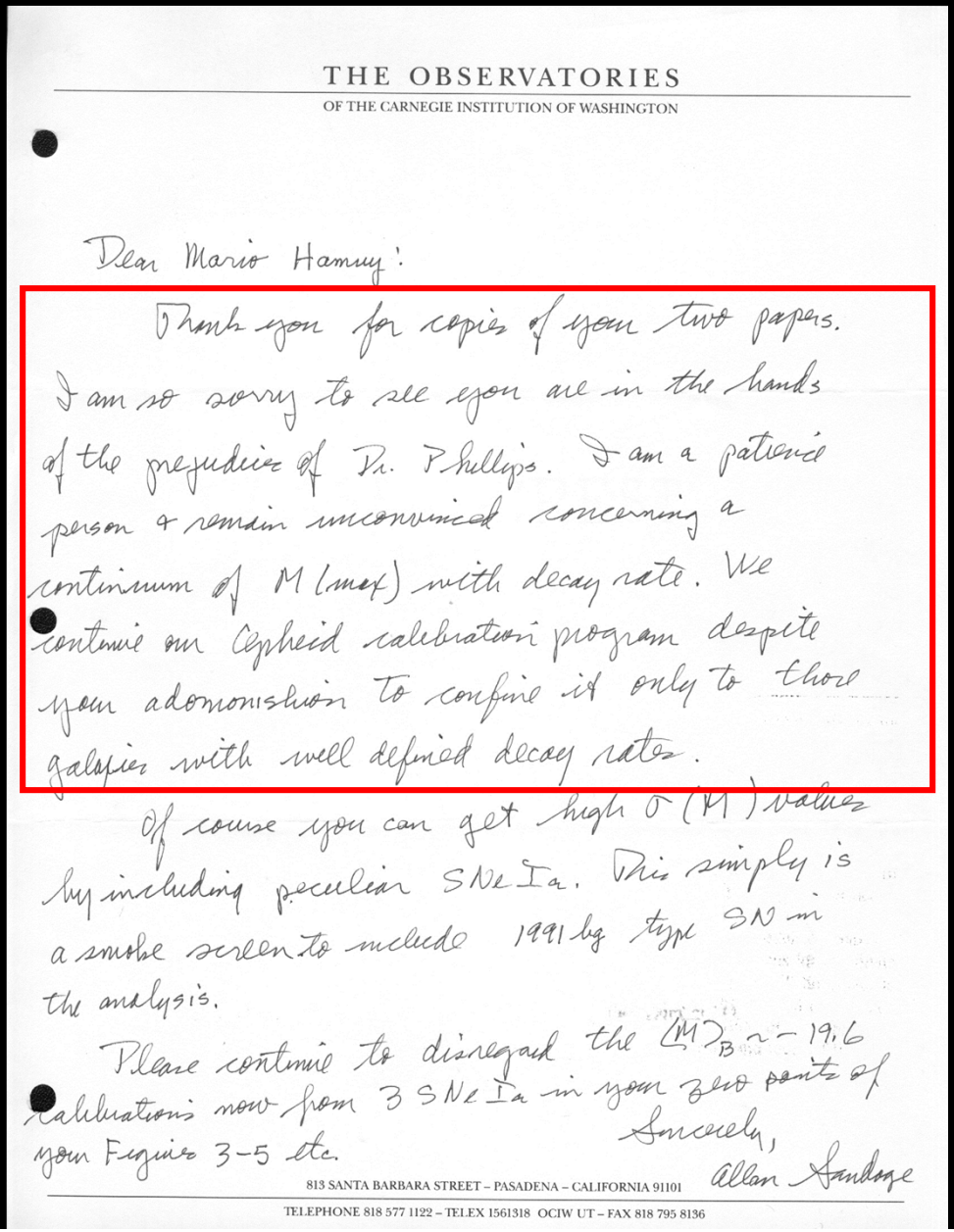


Calán/Tololo - Observaciones



Calán/Tololo – Primeros Resultados (1992)
Reunión Latinoamericana Viña del Mar

Calán/Tololo - Resultados (1996)



THE OBSERVATORIES
OF THE CARNEGIE INSTITUTION OF WASHINGTON

Dear Mario Hamuy:

Thank you for copies of your two papers. I am so sorry to see you are in the hands of the prejudice of Dr. Phillips. I am a patient person & remain unconvinced concerning a continuum of M (max) with decay rate. We continue our Cepheid calibration program despite your admonishion to confine it only to those galaxies with well defined decay rates.

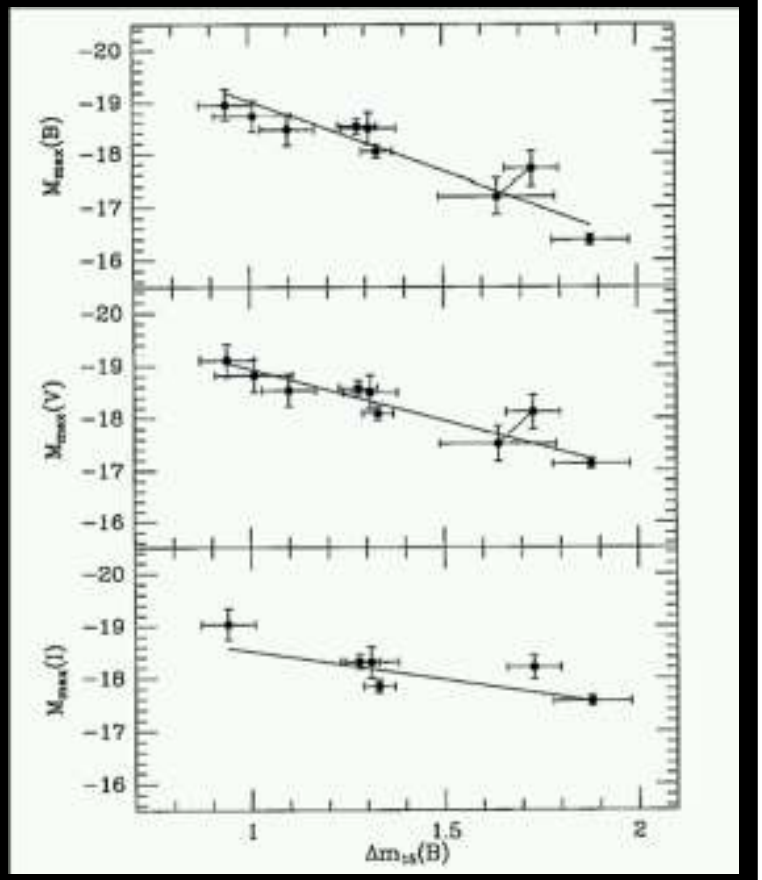
Of course you can get high $\sigma(M)$ values by including peculiar SNe Ia. This simply is a smoke screen to include 1991bg type SN in the analysis.

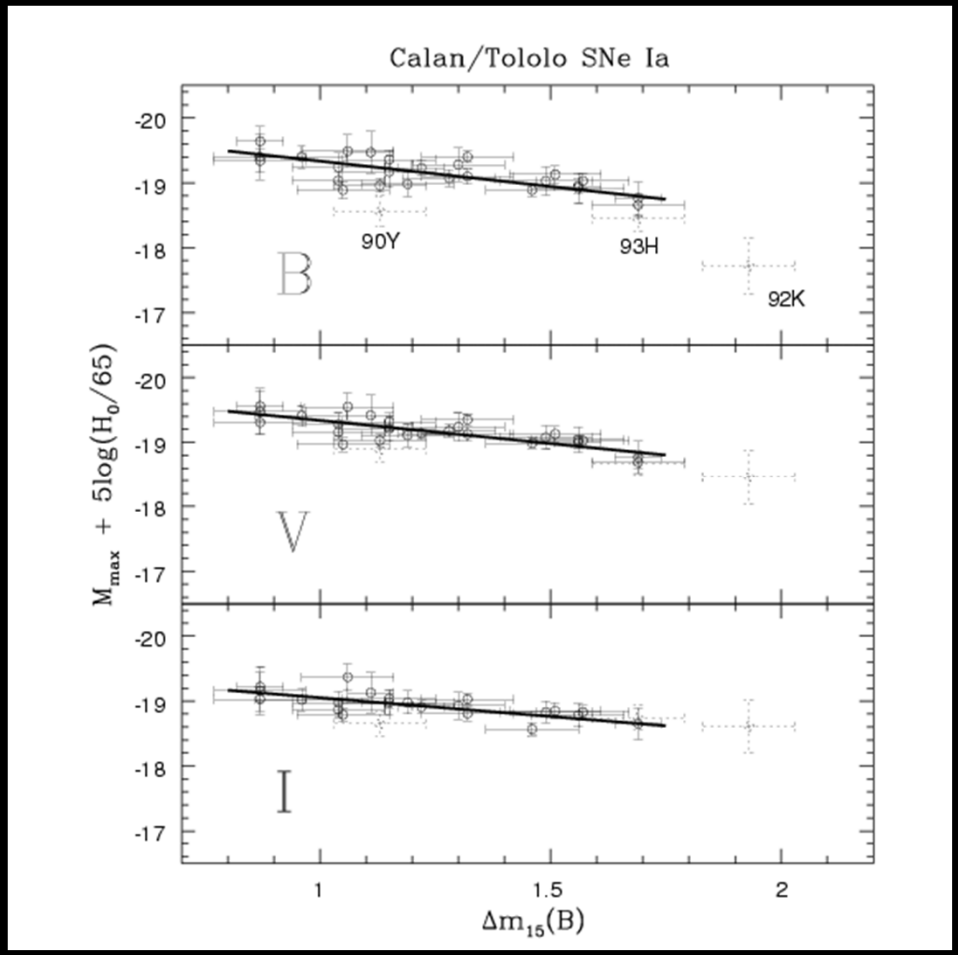
Please continue to disregard the $\langle M \rangle_B = -19.6$ calibrations now from 3 SNe Ia in your zero points of your Figure 3-5 etc.

Sincerely,
Allan Sandage

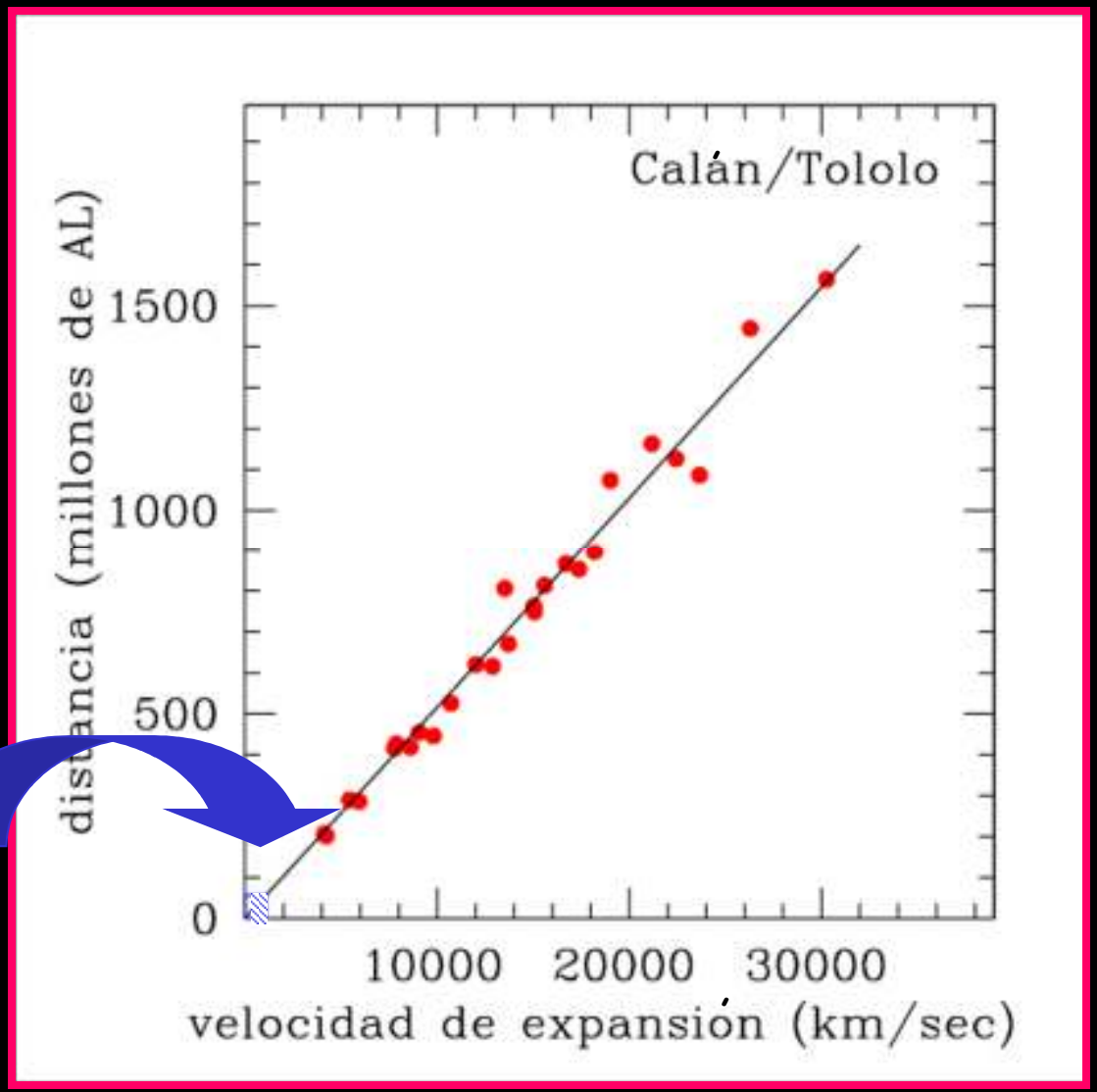
813 SANTA BARBARA STREET – PASADENA – CALIFORNIA 91101
TELEPHONE 818 577 1122 – TELEX 1561318 OCIW UT – FAX 818 795 8136

Relación de Phillips (1993)





Calán/Tololo – Resultados (1996)



Hubble

Las supernovas permiten medir distancias con gran precisión

El proyecto Calán/Tololo
Controversia sobre la constante de Hubble

- Determinación de la tasa de expansión del Universo: Ho= 63 km/s/Mpc

- Determinación de la edad del Universo: 13.700 millones de años

New Measurements On Age of Universe

By JOHN NOBLE WILFORD

Special to The New York Times

TUCSON, Ariz., Jan. 9 — In the continuing efforts to solve one of the foremost problems in cosmology, the velocity at which the universe is expanding, recent findings have yielded a fast rate, implying a relatively young and small universe. The results are perplexing because they suggest a universe 8 billion to 12 billion years old, which is younger than the oldest stars.

Another approach to the problem, based on measurements of distances to a certain type of supernova, or exploding star, has consistently produced slower expansion rates, suggesting a universe that may be 15 billion to 20 billion years old. Such estimates are necessarily imprecise because the age also depends on the average density of matter in the universe, which is another cosmic unknown.

Now astronomers have made new measurements that put the expansion rate somewhere between the extremes, though somewhat favoring the younger estimates. The results, reported here today at a meeting of the American Astronomical Society, could explain the previous discrepancies, scientists said, but were considered too preliminary to resolve the issue.

A research team led by Dr. Mario Hamuy and Dr. Mark Phillips, astronomers at the Cerro Tololo Inter-American Observatory in Chile, said their measurements of 25 supernovas had yielded an expansion rate of 60 to 70 kilometers per second per megaparsec. A megaparsec is 3.26 million light-years.

This value for the expansion rate ters of galaxies in the universe.

The importance of the new findings, scientists said, is that they could resolve the conflict between the young-universe and old-universe camps. Dr. Sandage has based his old-universe estimates on distance measurements to these type-Ia supernovas, assuming that all such objects had the same luminosity at peak brightness and thus served as "standard candles."

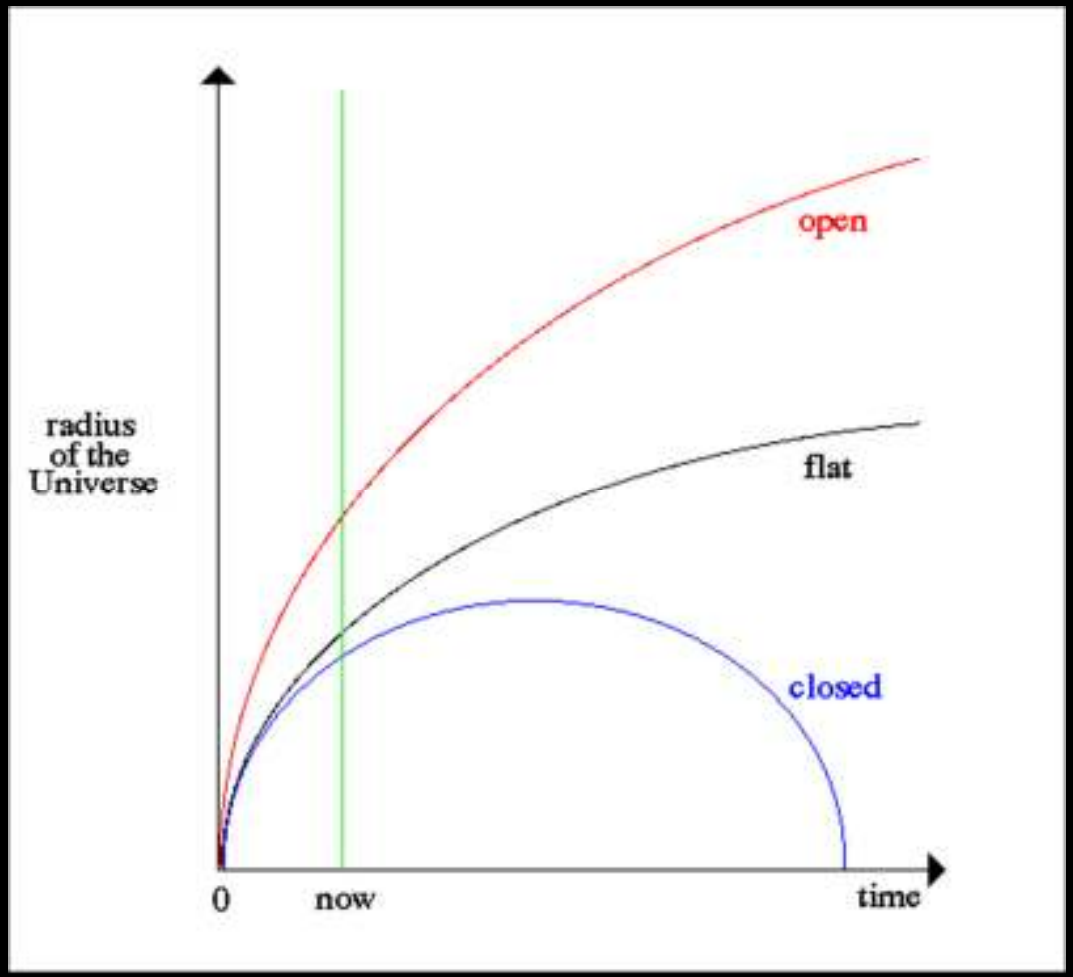
But Dr. Phillips said the new research showed a small but significant range in their intrinsic brightness, making them "far from perfect standard candles" without some compensation for these differences. The brighter ones appeared to occur in spiral galaxies or in galaxies with a substantial number of bright stars. The reasons have yet to be explained.

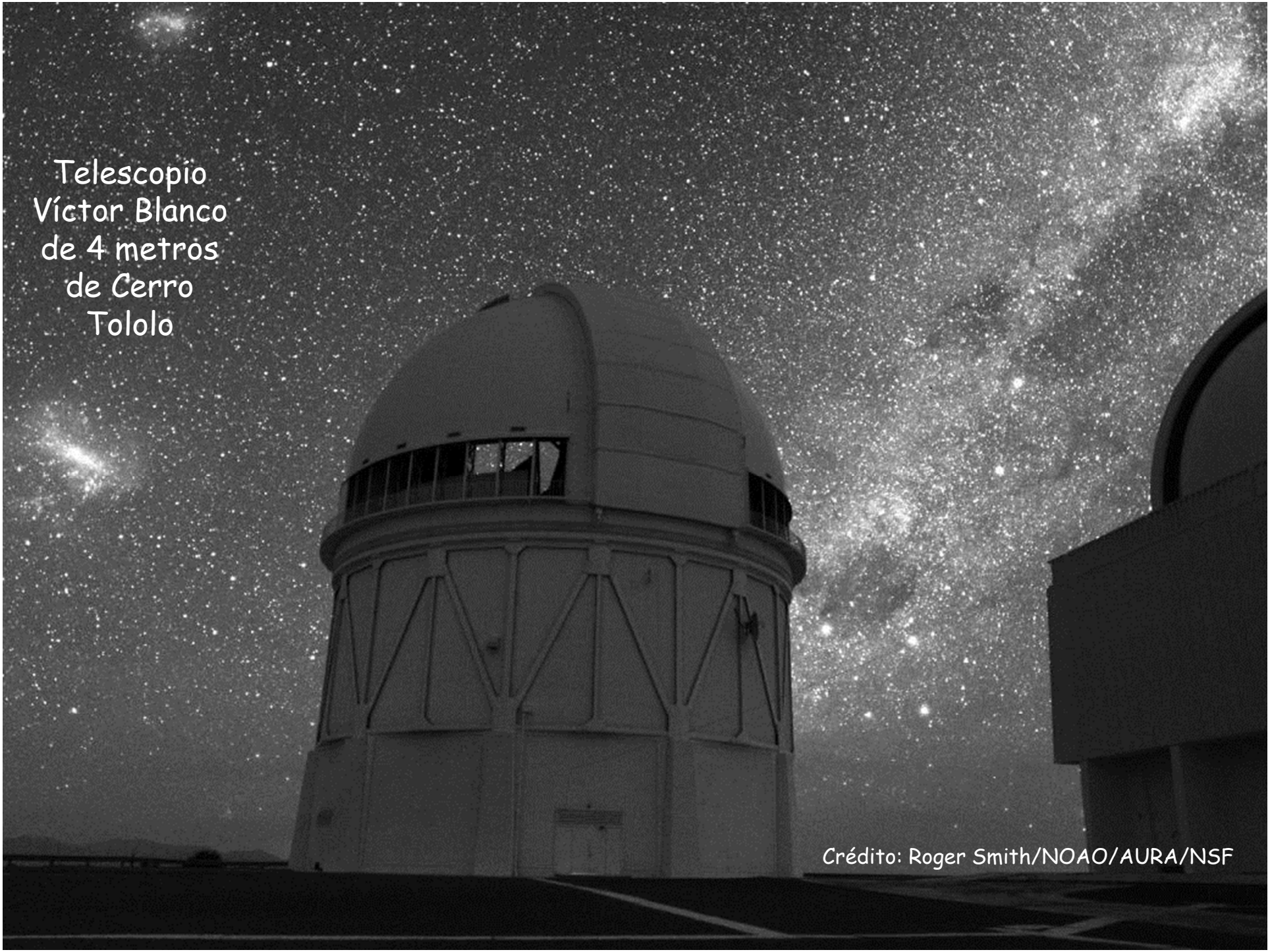
By correcting their calculations to take into account these differences, Dr. Phillips said the new measurements of distances to these supernovas should be accurate within 10 percent. And since the observed supernovas are at such great distances — some as much as one billion light-years away — they should be more reliable than other benchmarks, because they lie beyond local gravitational disturbances from the Milky Way galaxy that could affect estimates of the true cosmic expansion rate.

At a news conference, Dr. Phillips said it was too early to suggest that measurements of the Hubble constant might one day converge on these in-between numbers of 60 to 70.

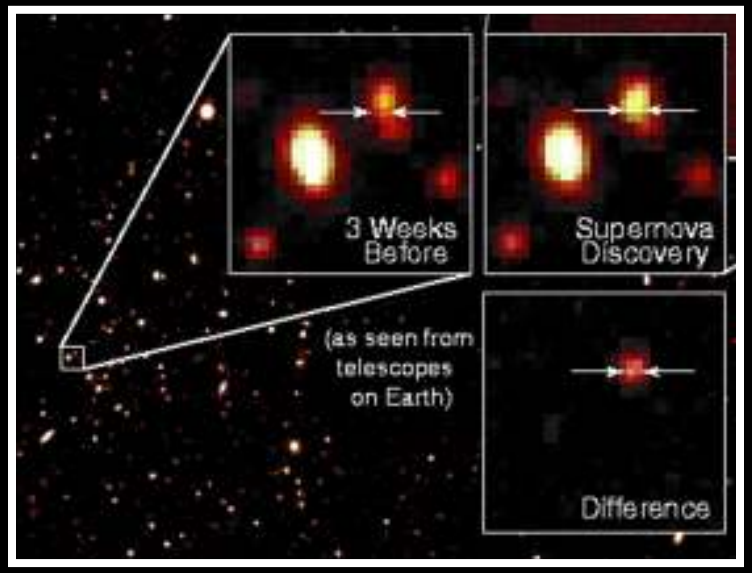
Dr. Wendy L. Freedman, an astronomer who is also at the Carnegie Observatories, reported that the orbiting Hubble telescope had now measured distances to 40 more Ce-

Destino del Universo?

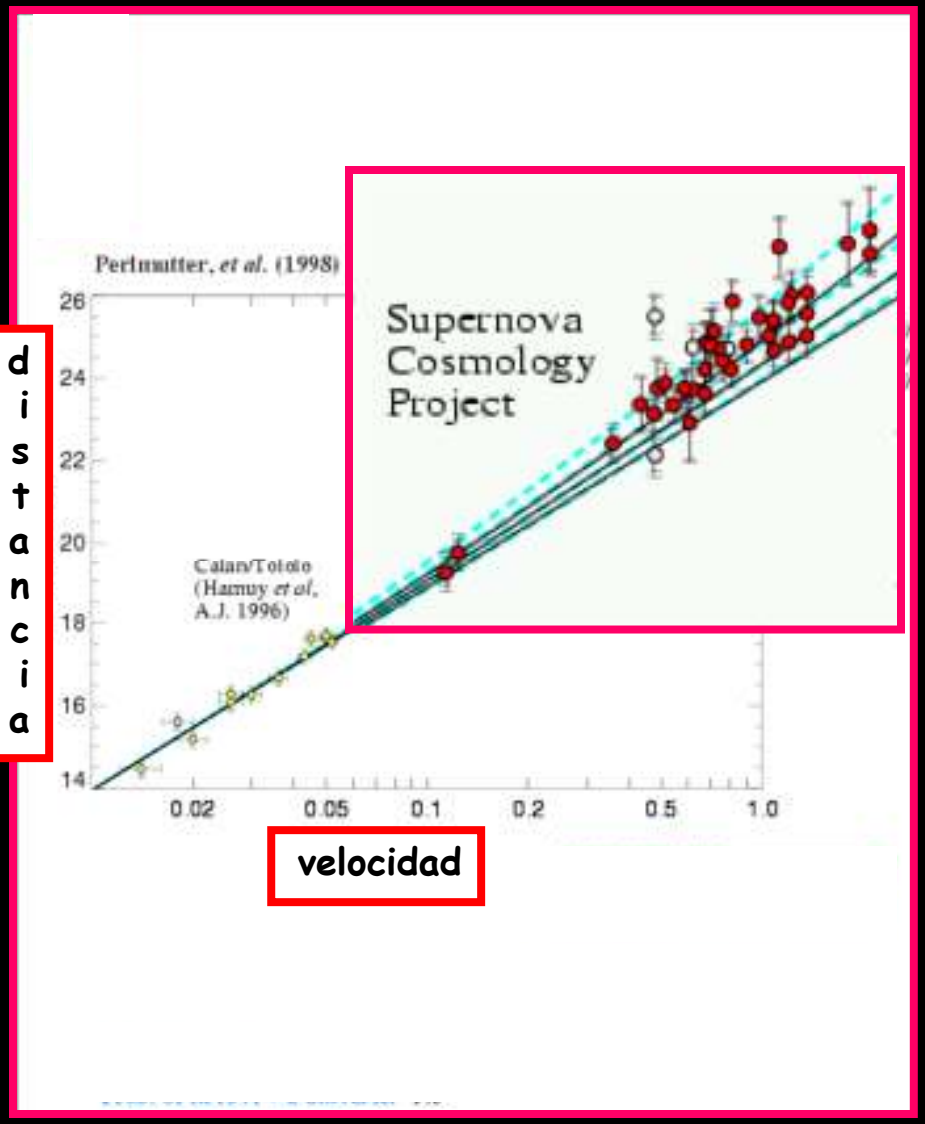



Telescopio
Víctor Blanco
de 4 metros
de Cerro
Tololo
Crédito: Roger Smith/NOAO/AURA/NSF

Búsqueda de Supernovas más lejanas

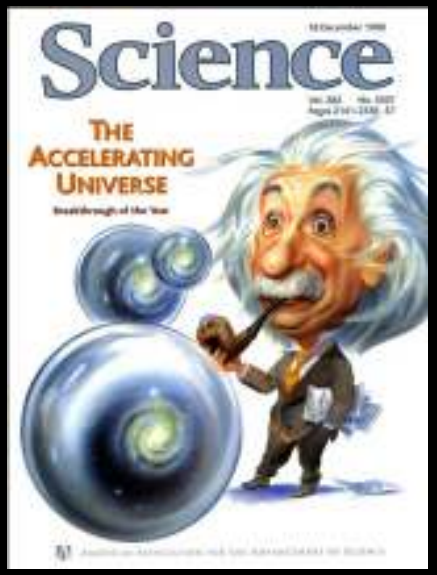


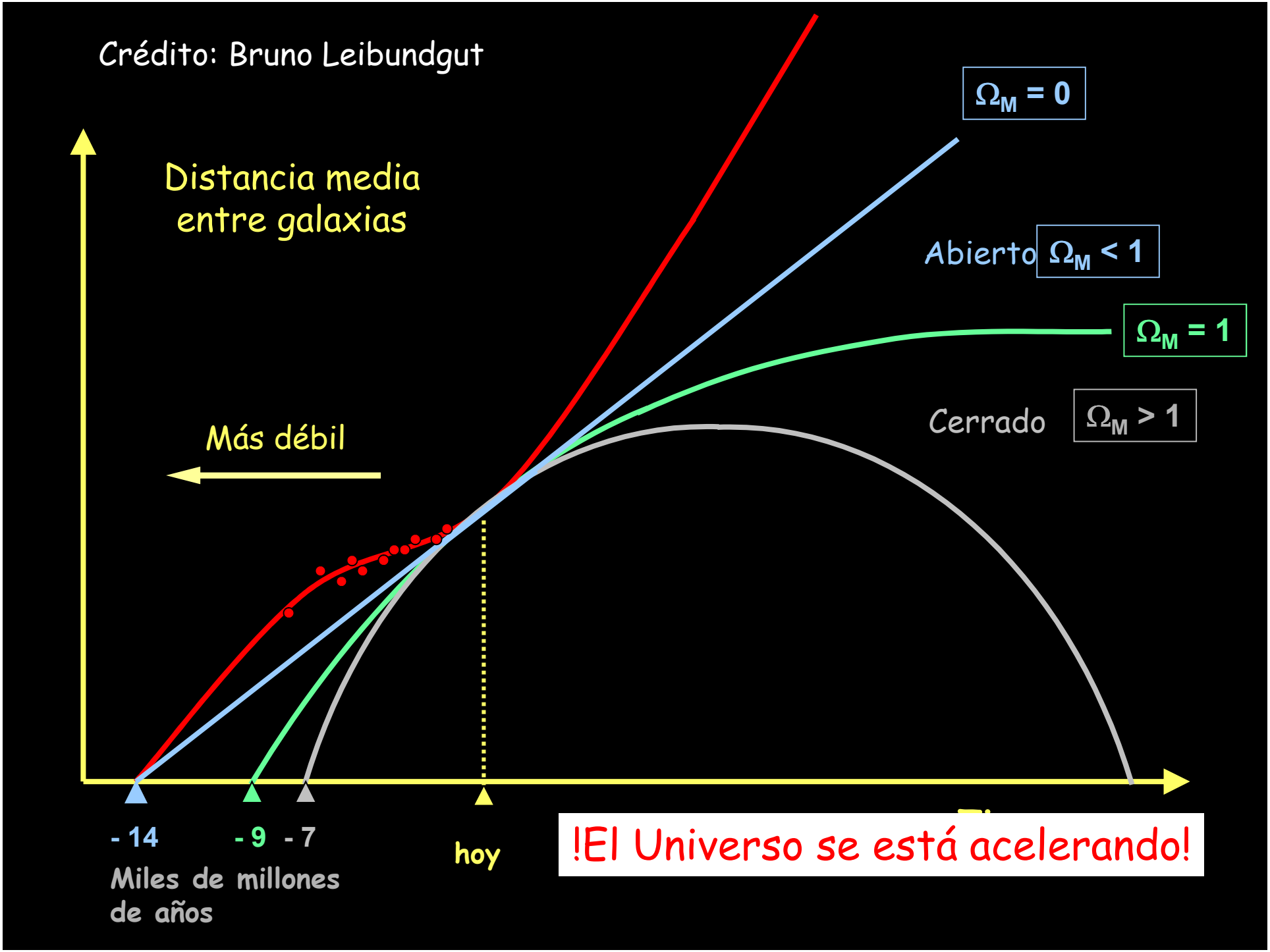
Cosmología en base a supernovas



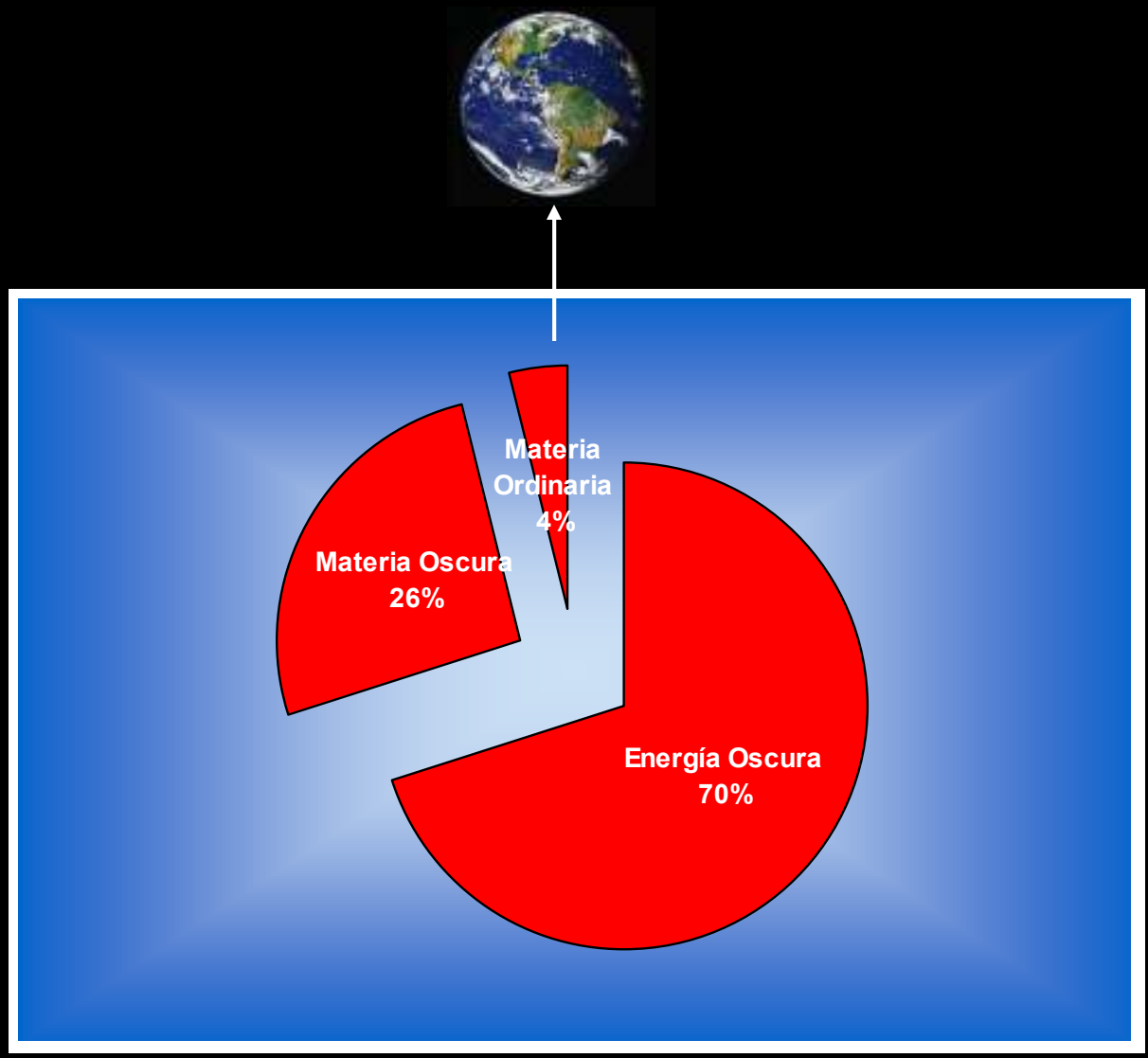
El Universo se expande aceleradamente!

Confirmado independientemente por dos grupos:
Riess, Schmidt, Clocchiatti, Leibundgut et al. 1998
Perlmutter et al. 1999




Crédito: Bruno Leibundgut
Distancia media entre galaxias
$\Omega_M = 0$
Abierto $\Omega_M < 1$
$\Omega_M = 1$
Cerrado $\Omega_M > 1$
Más débil
- 14
- 9
- 7
hoy
Miles de millones de años
¡El Universo se está acelerando!

Composición del Universo



Consecuencias de la observación de las supernovas tipo Ia

El Universo está en aceleración y la expansión continuará por siempre.
La mitad del experimento se hizo en Chile, por astrónomos chilenos y norte-americanos;
sin los datos del Calán/Tololo este descubrimiento de la aceleración no habría sido posible.

Existe un nuevo tipo de fuerza "antigravitatoria" en la naturaleza
que se suma a las cuatro fuerzas fundamentales.
El experimento de las supernovas ha producido una revolución en la astrofísica contemporánea.

La cantidad de energía asociada a esta fuerza constituye el 70% de toda la energía del Universo y se denomina
energía oscura.

The 2011 Nobel Prize in Physics
is awarded
"for the discovery of the accelerating expansion
of the Universe
through observations of distant supernovae"
to Saul Perlmutter, Brian P. Schmidt and Adam G. Riess.

"In the mean time, light curves of several nearby type Ia SNe were measured by the Calán/Tololo Supernova Survey led by Mario Hamuy, Mark Phillips, Nicholas Suntzeff (of the Cerro Tololo Inter-American Observatory in Chile) and Jose Maza (Universidad de Chile) [24]. This data was essential to demonstrate that type Ia SNe were useful as standard candles."

The Royal Swedish Academy of Sciences (Oct 4, 2011)

En el principio no había nada
ni espacio
ni tiempo.
El Universo entero concentrado
en el espacio del núcleo de un átomo,
y antes aún menos, mucho menor que un protón,
y aún menos todavía, un infinitamente denso punto matemático.
Y fue el Big Bang.
La Gran explosión.

De Canto Cósmico (1989)
Ernesto Cardenal