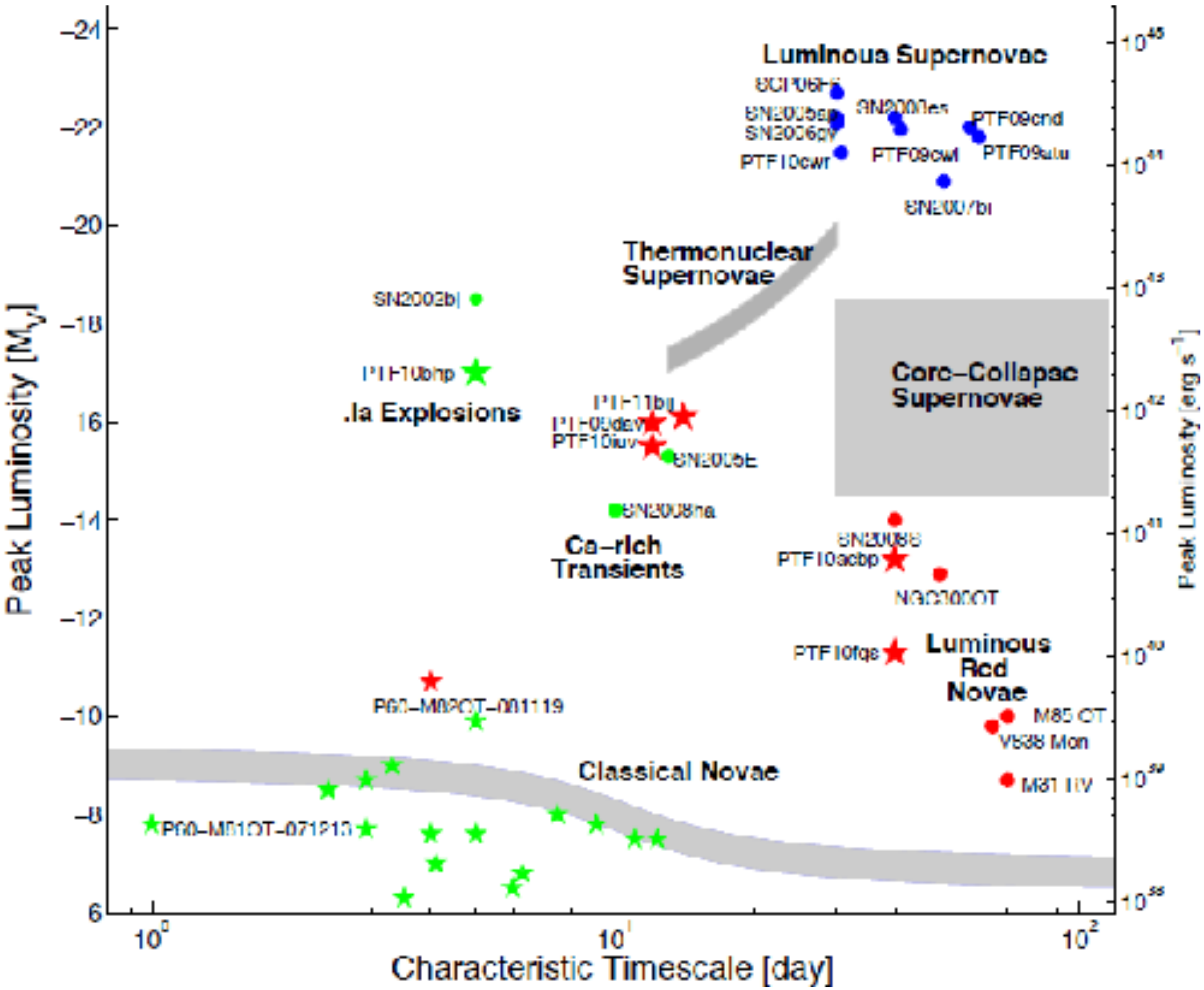
Novae with Gaia

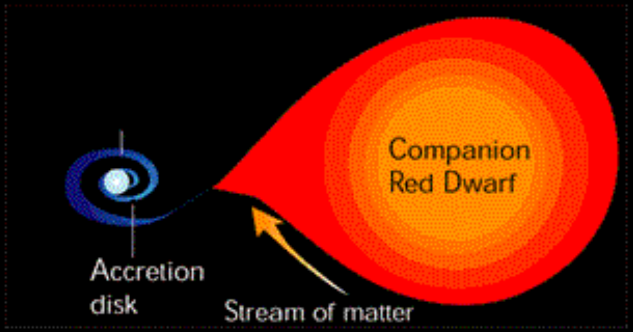
Massimo Della Valle
INAF-Capodimonte, Naples

Gaia Alerts, Liverpool 10-13 November



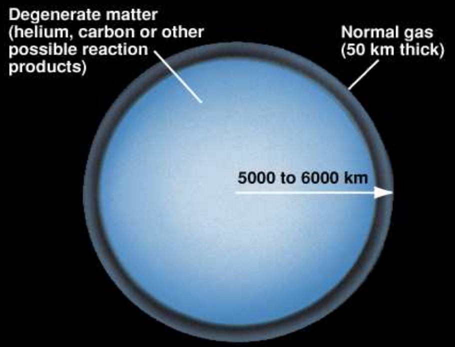
Luminous Supernovae
PTF09cnd
PTF10cwr
PTF09cwl
Thermonuclear Supernovae
Core−Collapse Supernovae
.Ia Explosions
PTF10iuv
Ca−rich Transients
PTF10acbp
PTF10fqs
Luminous Red Novae
M85 OT
Classical Novae
Peak Luminosity [M$_V$]
Peak Luminosity [erg s^{-1}]
Characteristic Timescale [day]
−20
−18
−12
−10
−8
6

Nova Phenomenon



White dwarf siphons off matter from companion star, creating accretion disk.

When pressure at bottom of accreted layer (mostly H) is $P > 10^{19}$ dyne cm^{-2}



- **violent TNR**
- **accreted shell ejected ($v \sim 1000\text{-}5000$ km s^{-1})**

All novae are recurrent at intervals of $\sim 10^1 - \sim 10^6$ yr.

$\Delta m_{acc} \sim R^4_{WD}/M_{WD}$

Why Novae ?

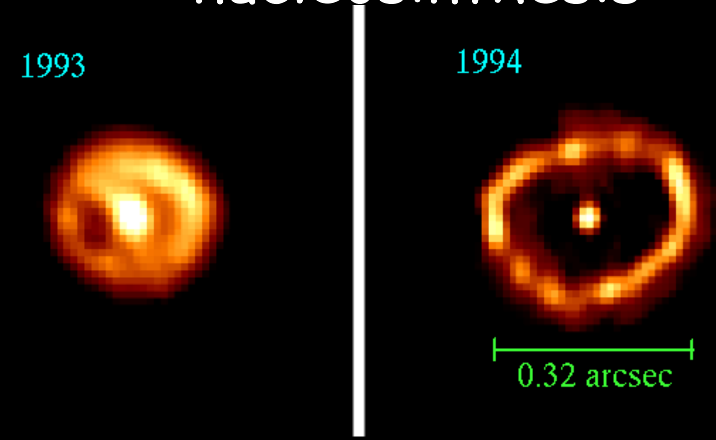
- White dwarf structure
- Nuclear reactions
- Hydrodinamics of explosive mass loss
- Common envelope structures

- Dust Formation
- Mass of the ejecta
- Abundances
- Distance Indicators

Summary

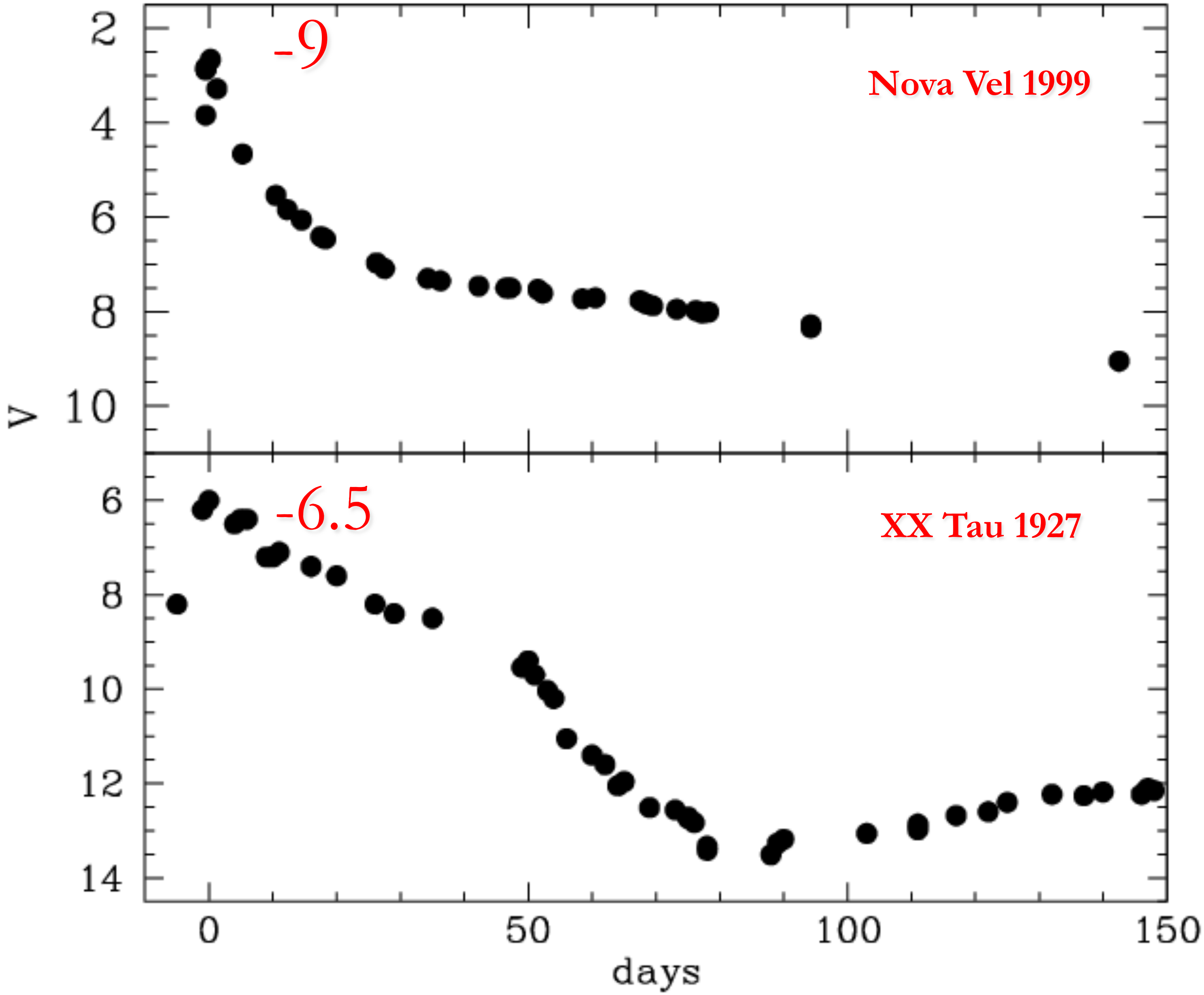
Novae as Distance Indicators

Novae and the MW nucleosinthesis



Nova as distance indicators

The usage of novae as distance indicators is based on the pioneering studies of McLaughin (1945) in the MW and Arp (1956) and Rosino (1964, 1973) in M31. They found that the absolute magnitude of novae at maximum correlates with the rate of decline.



-9
Nova Vel 1999
-6.5
XX Tau 1927
V
days

Novae are observed in extragalactic systems (M31, MCs, M33, M81, M101, Virgo, Fornax), calibrated via Cepheids and then used as secondary distance indicators

The Galactic MMRD

maximum magnitude vs. rate of decline relation

$M = 2.2 \times \log t3 - 10.5$ McLaughlin (1945)

$M = 2.0 \times \log t3 - 10.1$ Vorontsov-Velyaminov (1947)

$M = 3.7 \times \log t3 - 13.8$ Kopylov (1952)

$M = 2.3 \times \log t3 - 10.9$ Buscombe & de Vaucouleurs (1955)

$M = 2.5 \times \log t3 - 11.8$ Schmidt 1957

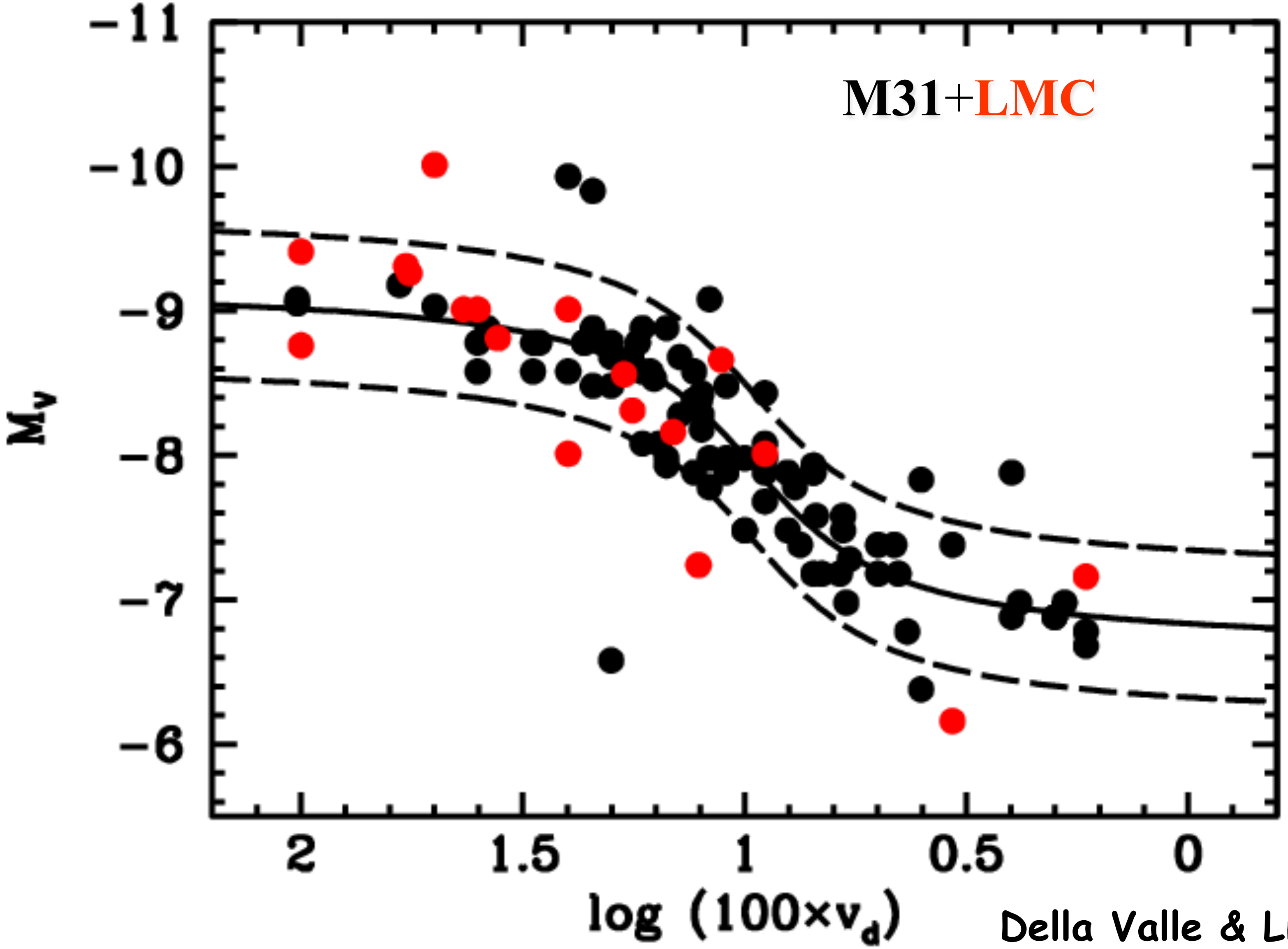
$M = 1.8 \times \log t2 - 11.5$ Pfau 1976

$M = 2.4 \times \log t3 - 11.3$ de Vaucouleurs 1978

$M = 2.41 \pm 0.23 \times \log t2 - 10.70 \pm 0.30$ Cohen 1985

$M = 2.54 \pm 0.35 \times \log t3 - 11.99 \pm 0.56$ Downes & Duerbeck 2000

MMRD



Della Valle & Livio 1995

Are Novae good enough ?

Novae are bright. They can reach an absolute magnitude at max of ~ -9 → 2-3 mag brighter than Cepheids of large periods

Cepheids are detected only in Spirals whereas novae can be detected also in Es → calibration of SN-Ia

There exists a good theoretical understanding of the MMRD relation

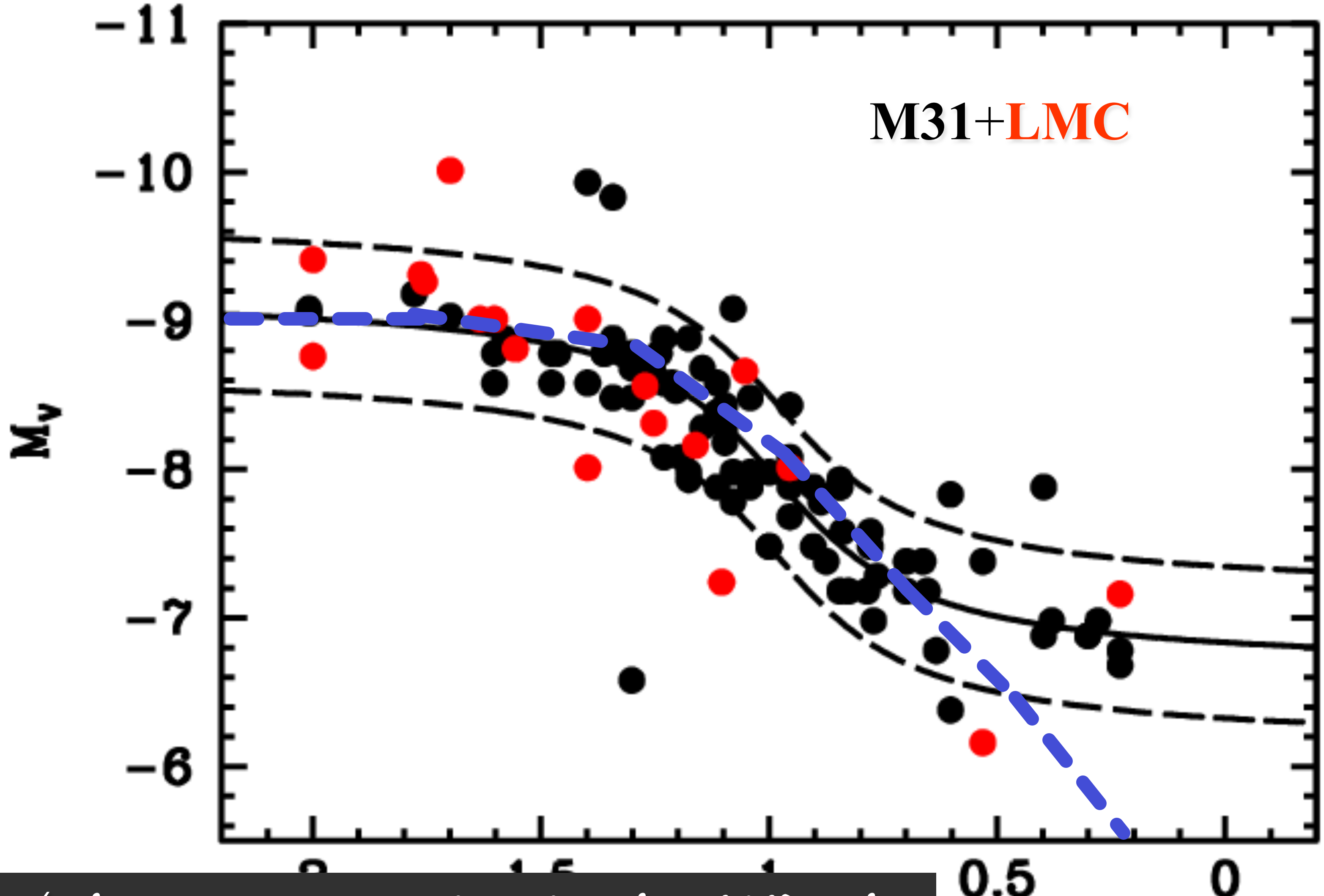
The physical parameters of the outburst are primarly determined by the:

- Mass of the WD
- Accretion rate
- Temperature of the WD
- Magnetic Field
- Composition of the accreted material
- Mixing Process between accreted envelope and underlying WD

The physical parameters of the outburst are primarly determined by the:

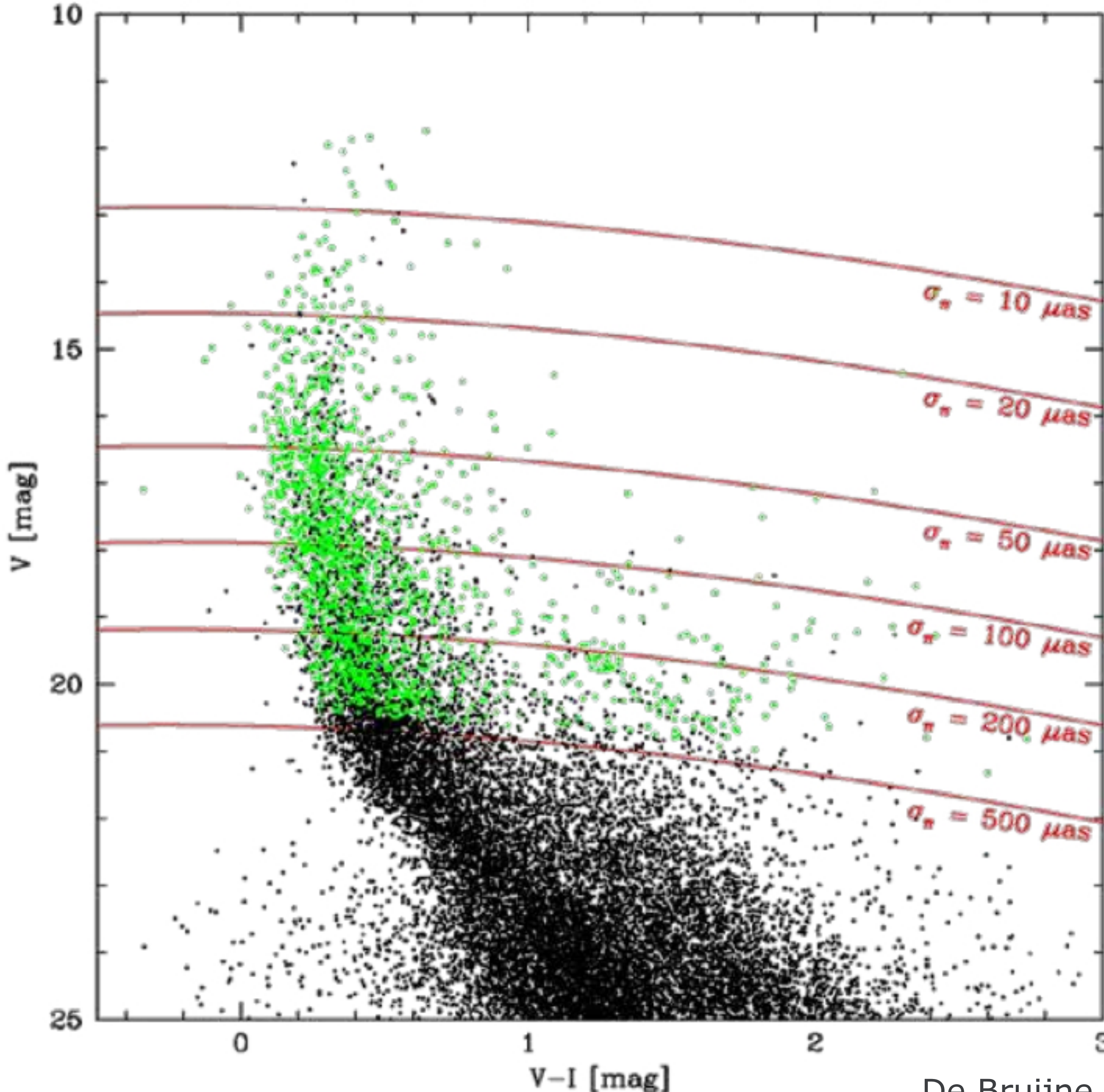
- Mass of the WD
- Accretion rate
- Temperature of the WD
- Magnetic Field
- Composition of the accreted material
- Mixing Process between accreted envelope and underlying WD

The "tool"



… '*the more massive is the WD the more powerful is the outburst*"

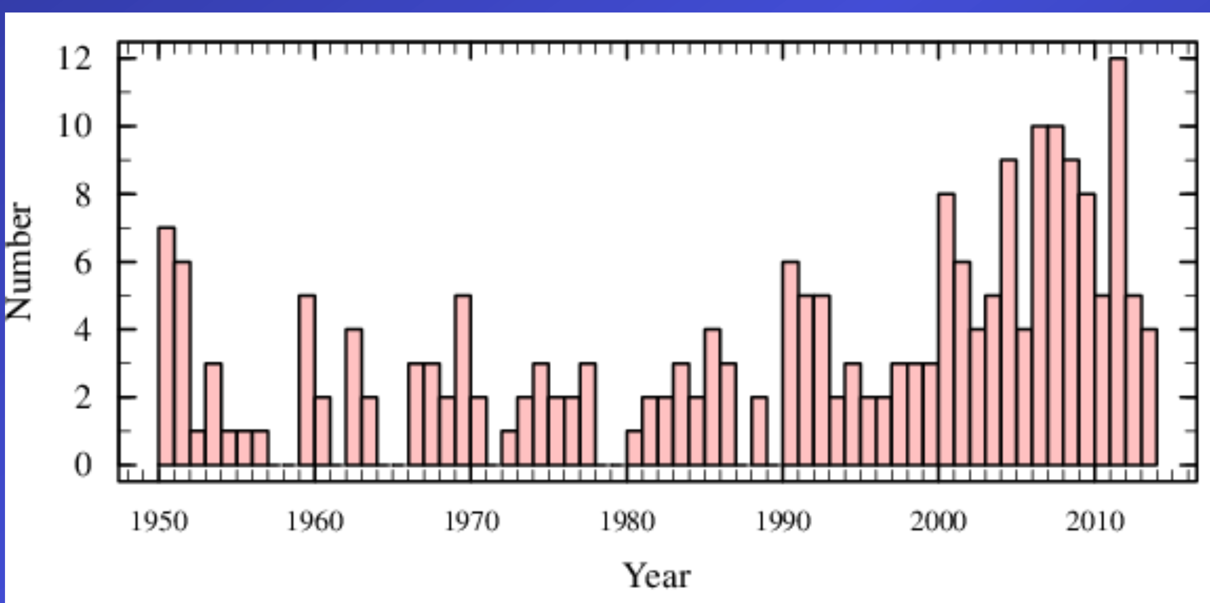
Della Valle & Livio 1995
Livio 1992

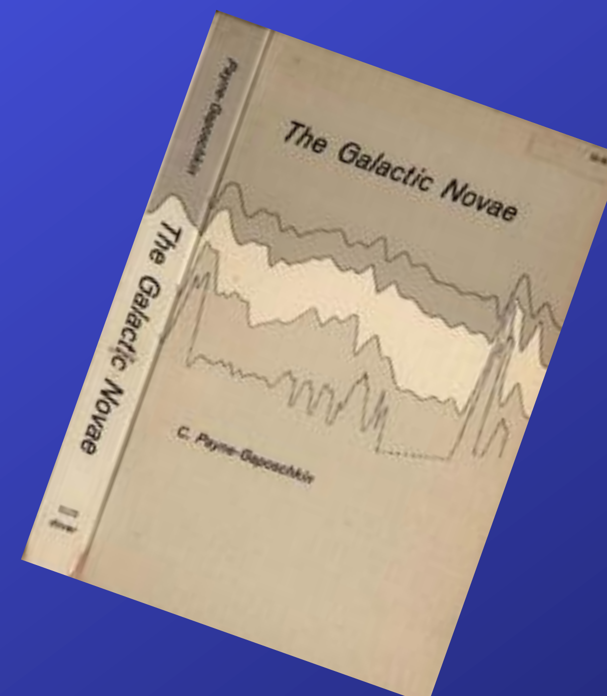


De Bruijne & de Marchi (2011)

1. Calibration of the Galactic MMRD based on the brightest “historical” Novae ($m_V^{min} < 10\text{-}12$) + “new objects” ~ 5-6/yr that can be observed at maximum (and during the early decline)

→ novae turn to “primary indicators”





2. GAIA Calibration of the $MMRD_{MW}$ + E-ELT observations of Novae in galaxies with (m-M) ~ 36 → H_o measurements

74±3%
Ia+NIR Cep
Freedman et al. 2012

74±8%
HII
Chavez et al. 2012

74±5%
Ia+Cep
Riess et al. 2009

72±6%
water maser
Reid et al. 2012

66±8%
Lensing
Paraficz et al. 2010

63-73 kms^{-1} Mpc^{-1}
WMAP- LAMBDA
data product

TABLE 1

H_o (km s^{-1} Mpc^{-1})	Technique	Reference
94 ± 11[a]	Lens 0957 + 561	Grogin & Narayan (1996)
81 ± 8	Cepheids in 4 Virgo spirals	van den Bergh (1995a)
80 ± 12	SB fluctuations	Jacoby et al. (1992)
78 ± 11	Globulars in M87	Whitmore et al. (1995)
76 ± 7	PN in Virgo Cluster	Jacoby (1996)
75 ± 8	PN in Fornax cluster	McMillan et al. (1993)
74 ± 14	Tip of RG branch	Sakai et al. (1996)
73 ± 6 ± 7	SNe II exp. photospheres	Kirshner (1996)
73 ± 6	D_n -σ (Vir, For, Leo)	Mould (1996)
70 - 74	Tully-Fisher	Giovanelli (1996)
70 ± 13	Novae in Virgo	Della Valle & Livio (1995)
66 ± 12	IR Tully-Fisher	Malhotra et al. (1996)
65 ± 6	SN Ia lightcurves	Riess et al. (1996)
64 ± 3	4 SNe Ia	Hamuy et al. (1996)
55 ± 17	Sunyaev - Zel'dovich effect	Birkinshaw & Hughes (1994)
55 - 60	SNe Ia (theory)	van den Bergh (1995b)
52 ± 9	SNe Ia (1937C)	Saha et al. (1994)
52 ± 8	SNe Ia (1972E)	Saha et al. (1995)
43 ± 11	Galaxy diameters	Sandage (1993a)

2. GAIA Calibration of the $MMRD_{MW}$ + E-ELT observations of Novae in galaxies with (m-M) ~ 36 → H_o measurements

(m-M) ~ 30

Infall correction toward Virgo ~ 100/400 km s^{-1}

Average recession velocity of the cluster ~ 900/1200 km s^{-1}

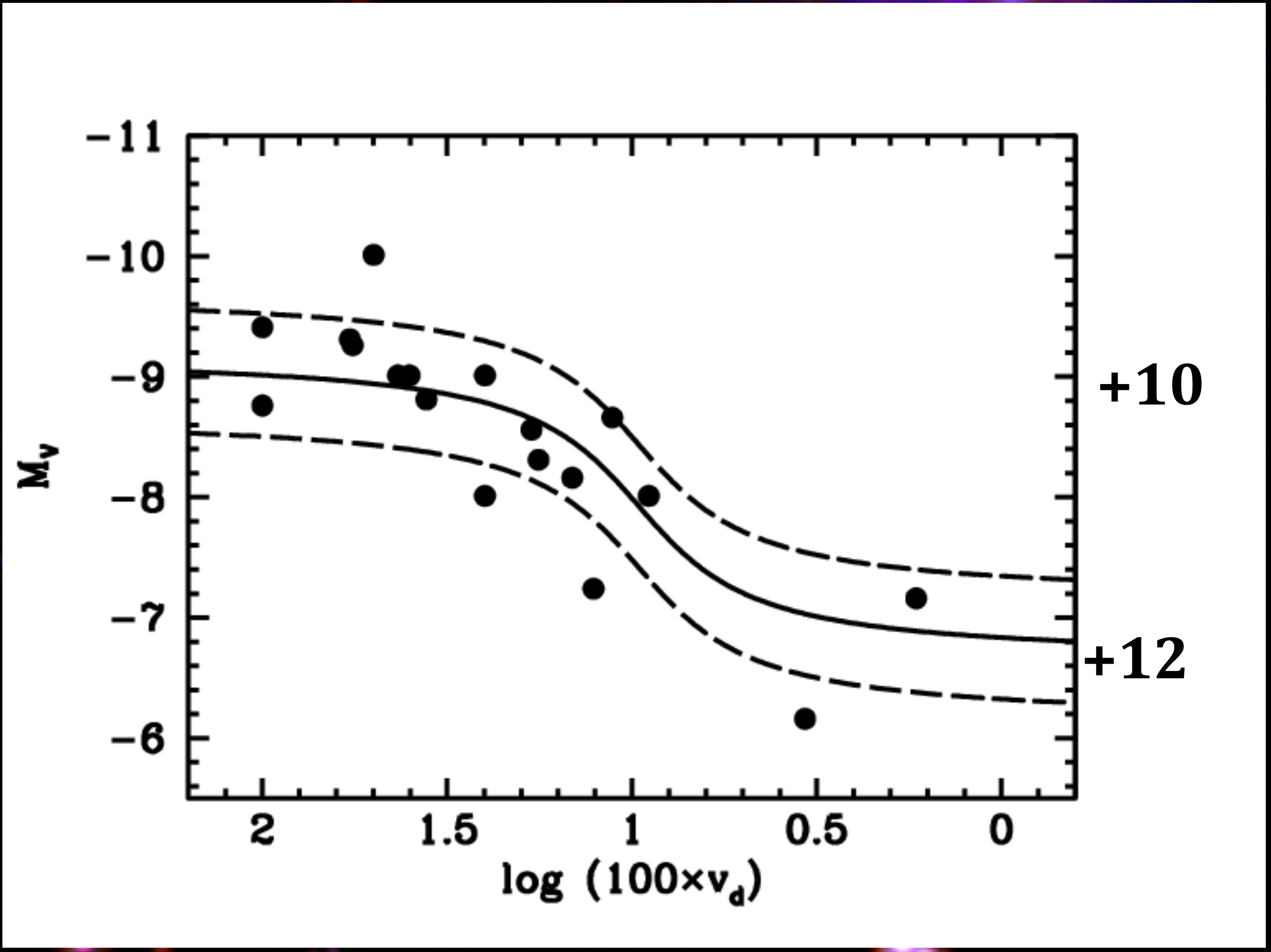
→ $\Delta H_o/H_o$ ~ 30%

(m-M) ~ 36 → ~ 11000 km s^{-1} → $\Delta H_o/H_o$ ~ 3%

3) Independent Calibration (from Cepheids) of the peak luminosity of SNe-Ia in Es/Ss

→ Distance
→ Progenitors (systematic differences at maximum light of SNe-Ia)

4. Direct measurement of the distance to LMC with nova parallaxes and calibration of the LMC MMRD

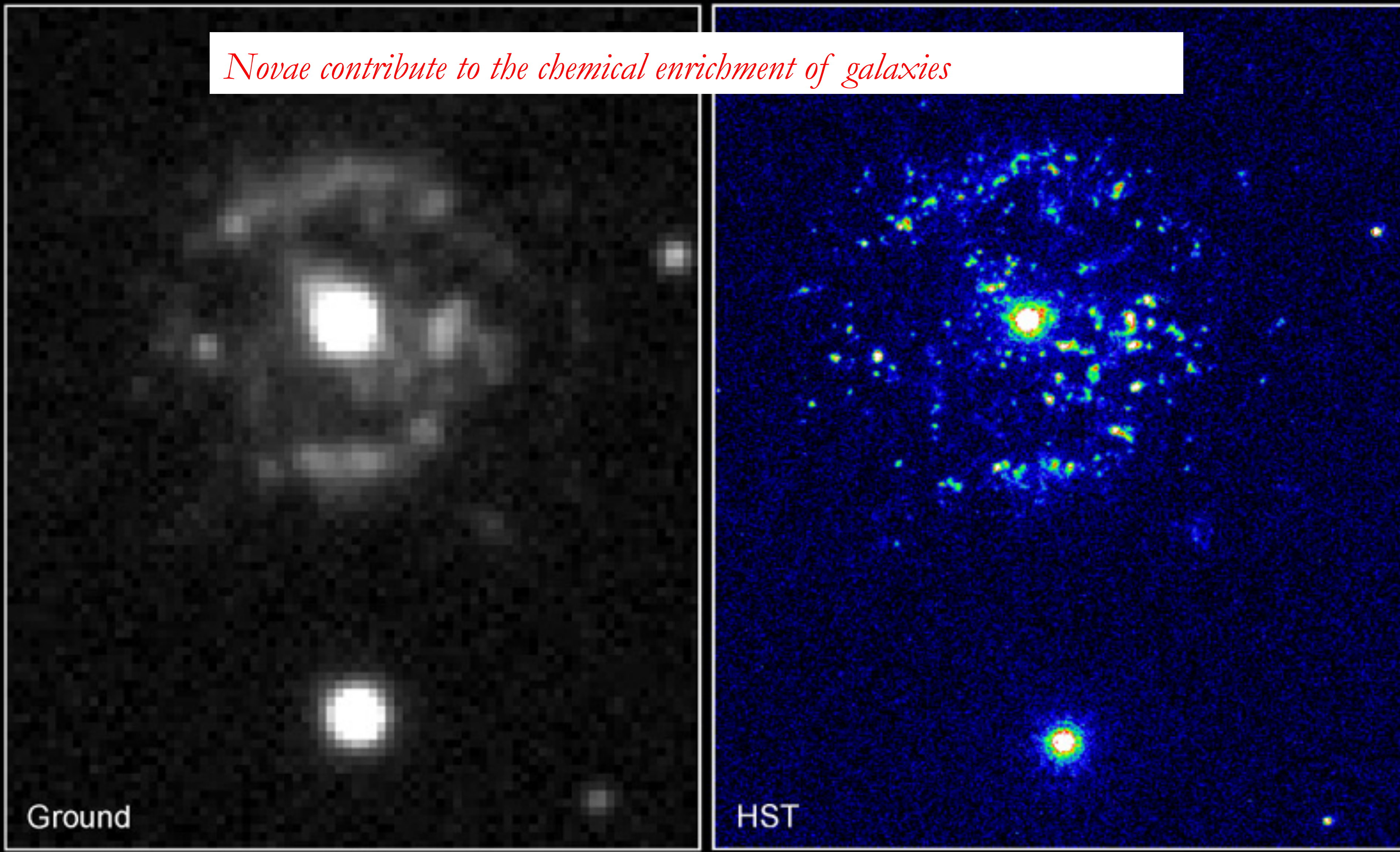


Why Novae ?

- White dwarf structure
- Nuclear reactions
- Hydrodinamics of explosive mass loss
- Common envelope structures

- Dust Formation
- Mass of the ejecta
- Abundances
- Distance Indicators

Novae contribute to the chemical enrichment of galaxies



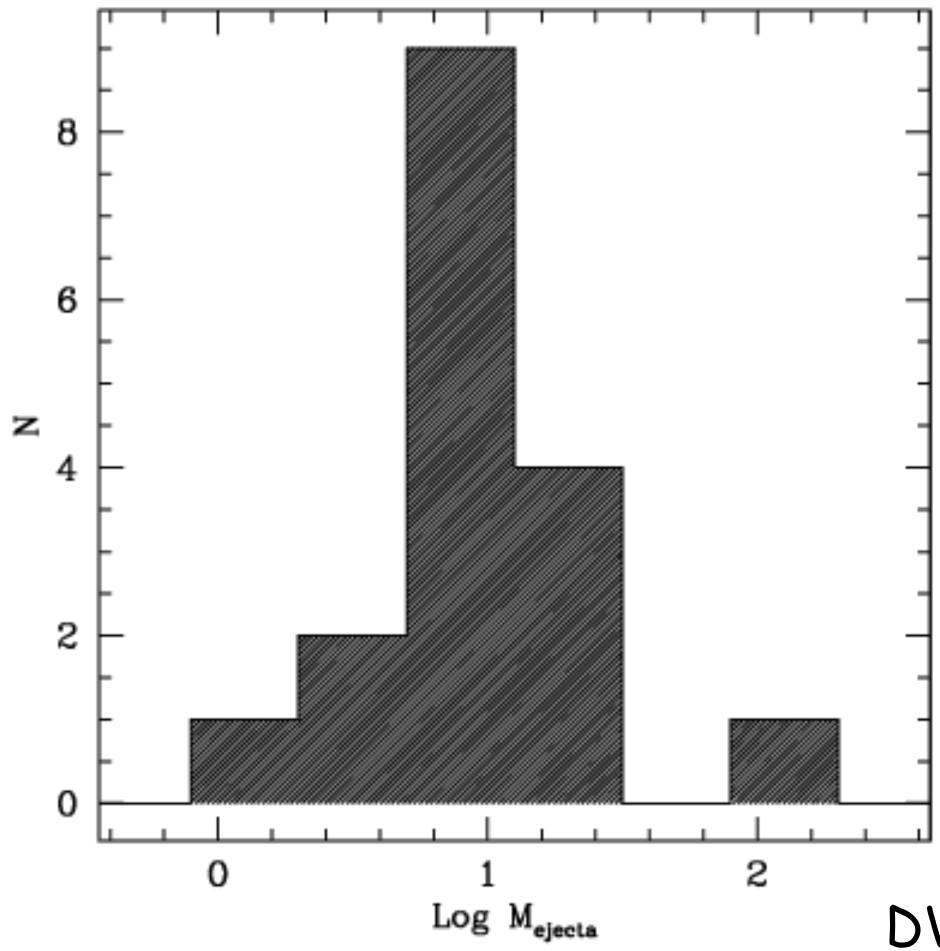
Recurring Nova T Pyxidis HST • WFPC2

PRC97-29 • ST ScI OPO • September 18, 1997

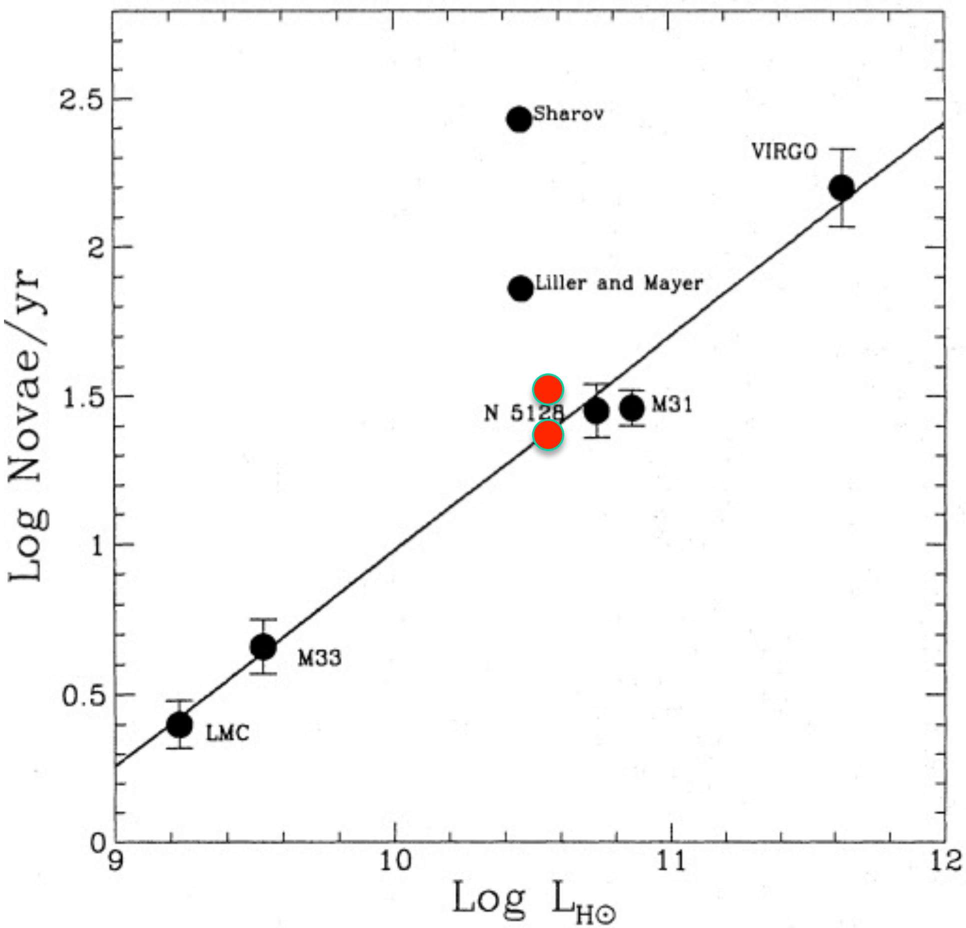
M. Shara and R. Williams (ST ScI), R. Gilmozzi (ESO) and NASA

Mass of ejected shell

$10^{-4/-5}\ M_\odot$



DV et al. 2002



24 novae/yr DV & Livio 1995

35 novae/yr Shafter 1997

$\times 10^{-4} \times 100$ yr-→ ~ 0.3 $M_{\odot}$

cf. ~ 1.4 $M_{\odot}$ from SNe-Ia

Fig. 1. The nova rate as a function of H-Luminosity of the parent galaxies

Novae can produce interesting concentrations of rare isotopes

(100-1000 times solar values)

- ^{13}C; ^{15}N — Sparks, Starrfield, Truran (1978); Williams (1985);
- ^{7}Li — Arnould and Norghard (1975); Starrfield et al. (1978); D'Antona and Matteucci (1991)
- ^{22}Na; ^{26}Al — Hillebrandt and Thielemann (1982); Kolb and Politano (1997)
- Ne — Livio and Truran (1994)

European
Southern
Observatory

eso1531 — Science Release

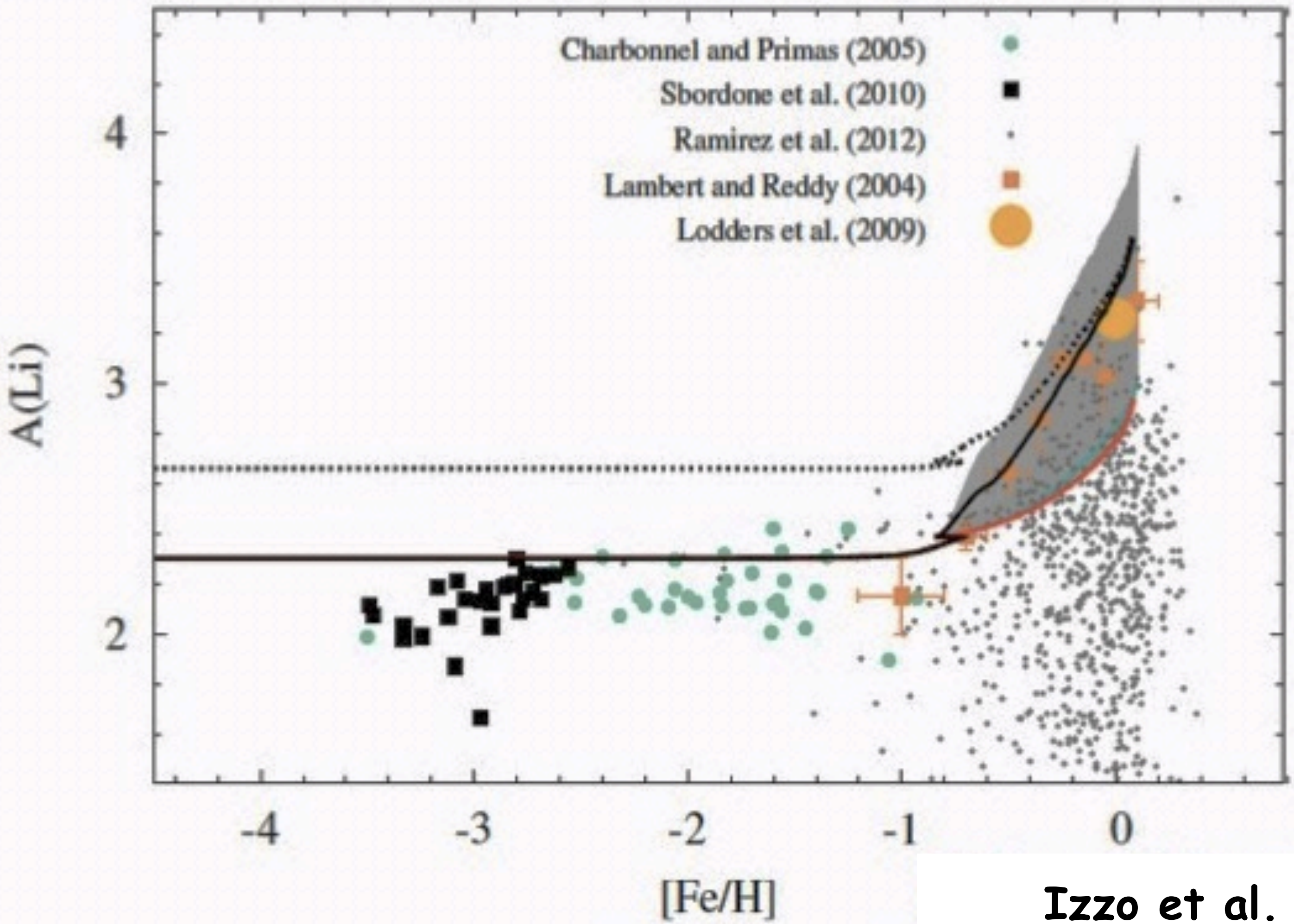
SPACE SCOOP

First Detection of Lithium from an Exploding Star

29 July 2015

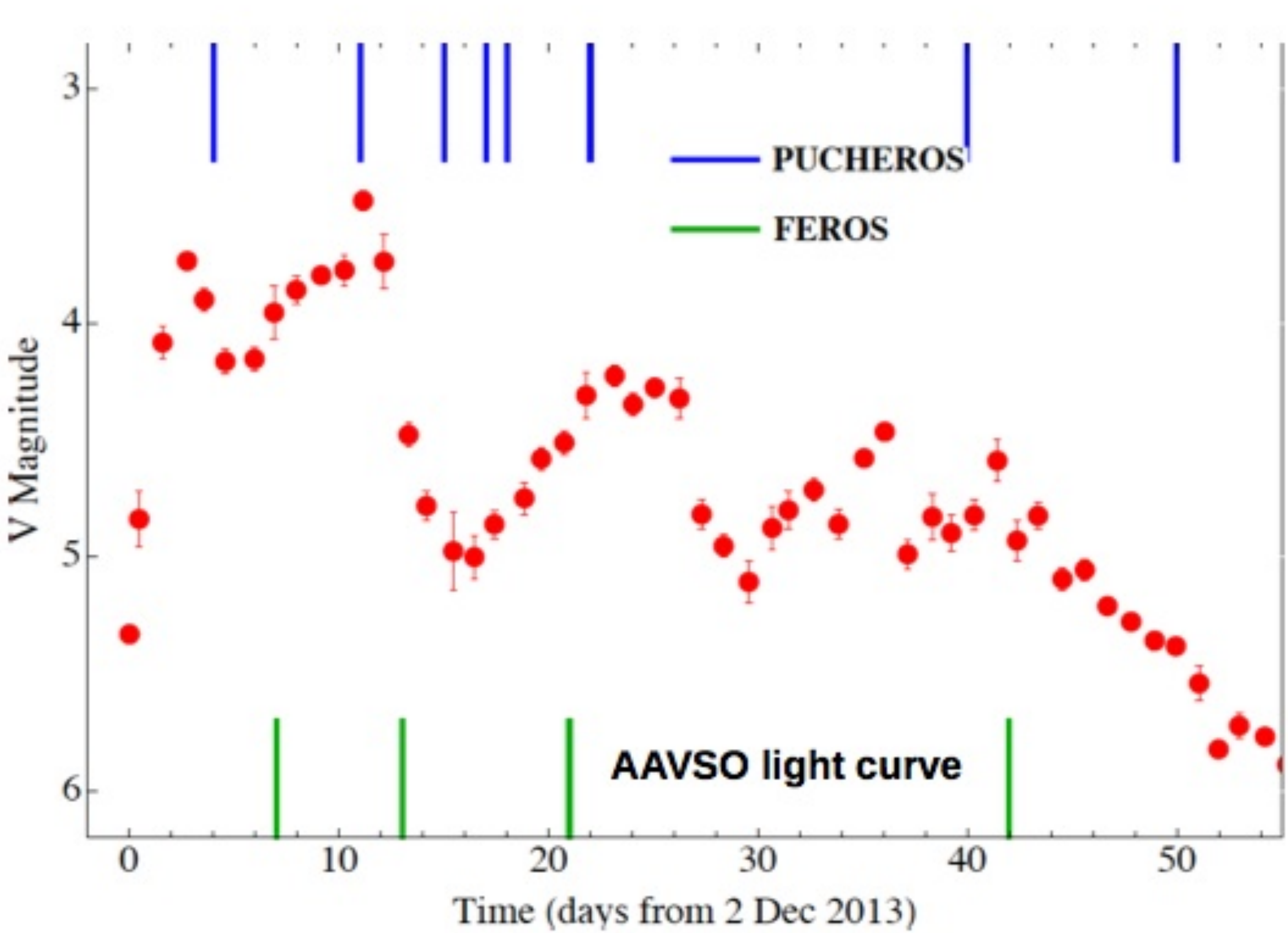
The chemical element lithium has been found for the first time in material ejected by a nova. Observations of Nova Centauri 2013 made using telescopes at ESO's La Silla Observatory, and near Santiago in Chile, help to explain the mystery of why many young stars seem to have more of this chemical element than expected. This new finding fills in a long-missing piece in the puzzle representing our galaxy's chemical evolution, and is a big step forward for astronomers trying to understand the amounts of different chemical elements in stars in the Milky Way.

Galactic Li enrichment by novae



Izzo et al. 2015

Observations

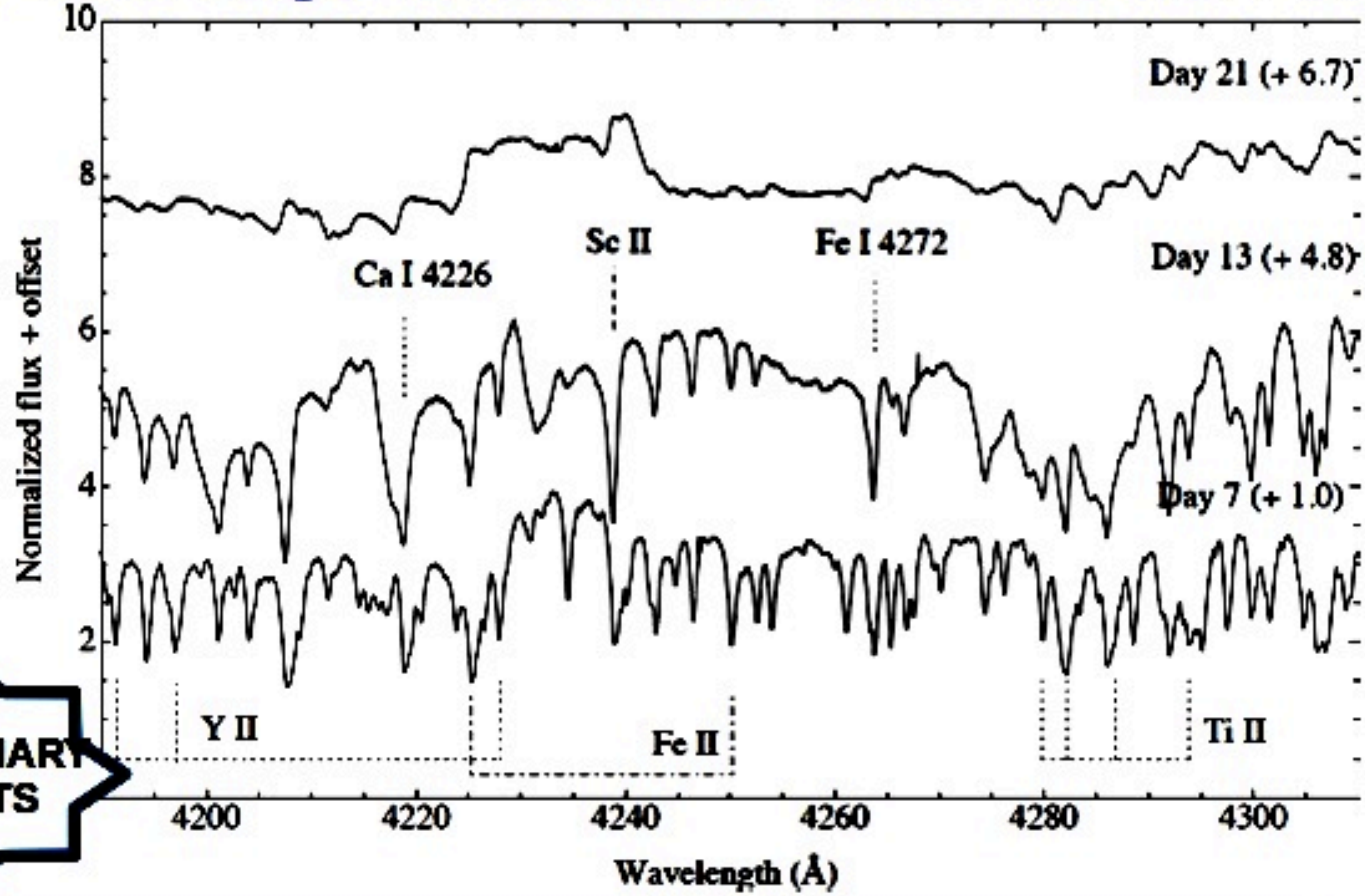


0.50m @PUC

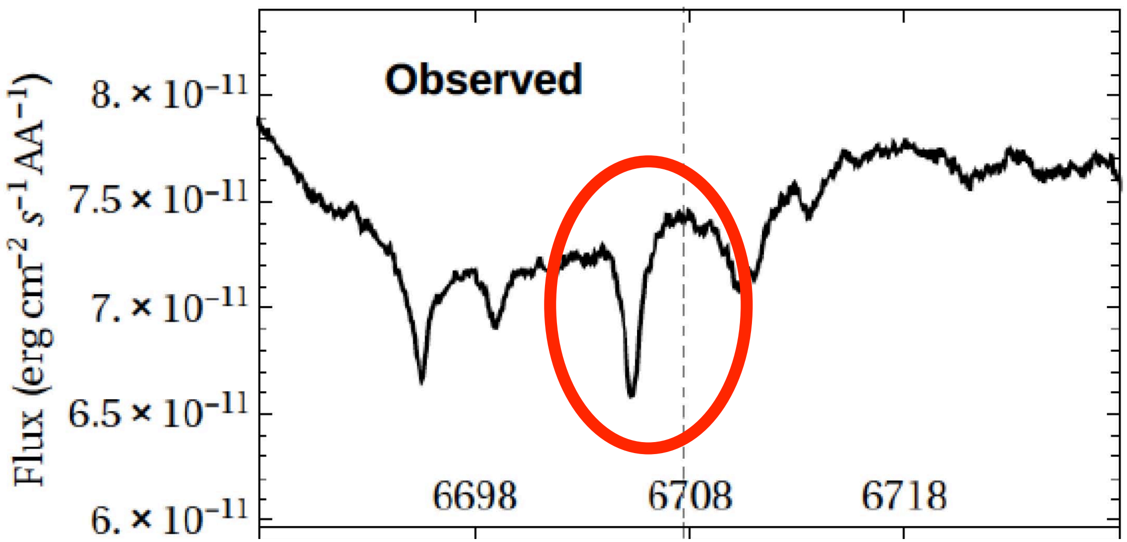
2.2m @La Silla

ID absorption features

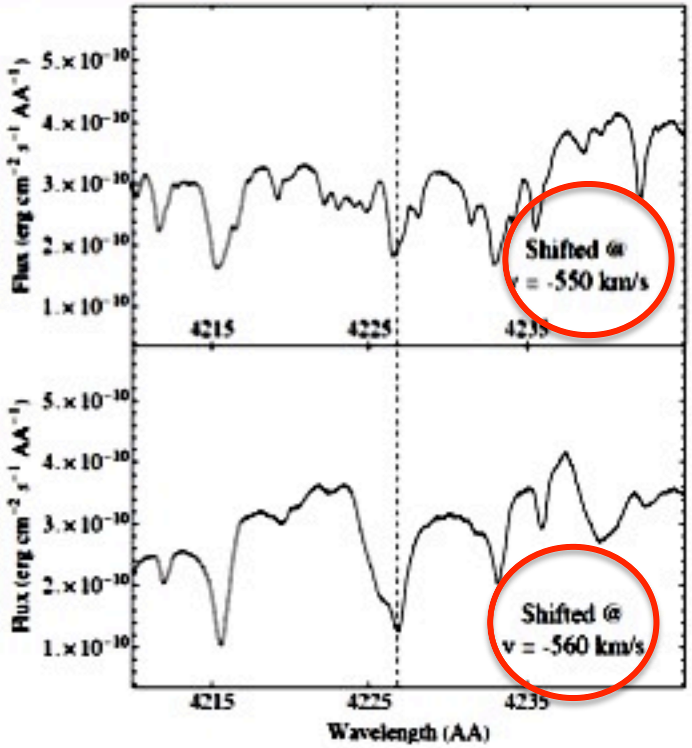
319 ID of singly-ionized heavy-elems with Ein < 6eV



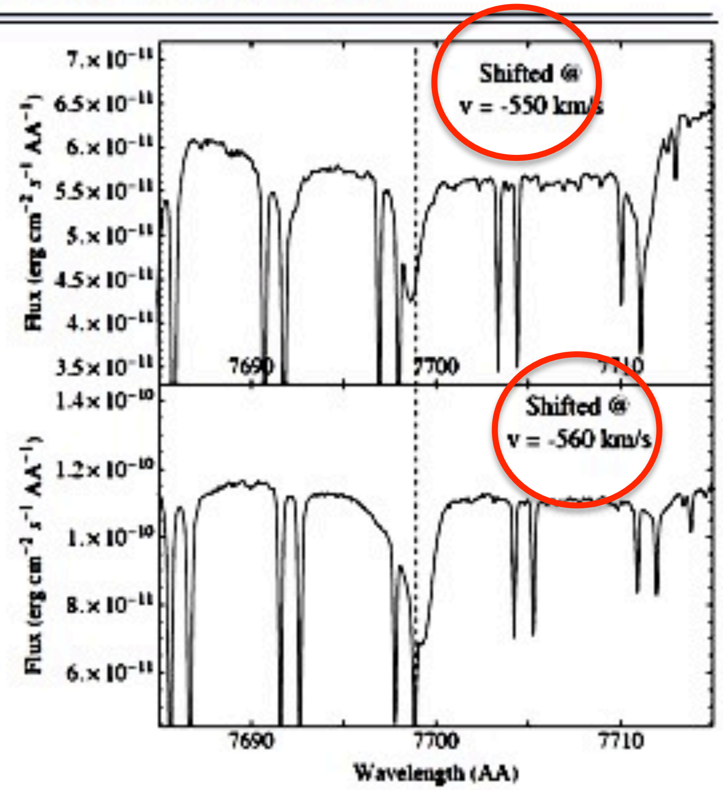
PRELIMINARY RESULTS


Observed
Flux (erg cm^{-2} s^{-1} AA^{-1})
8. × 10^{-11}
7.5 × 10^{-11}
7. × 10^{-11}
6.5 × 10^{-11}
6. × 10^{-11}
6698
6708
6718

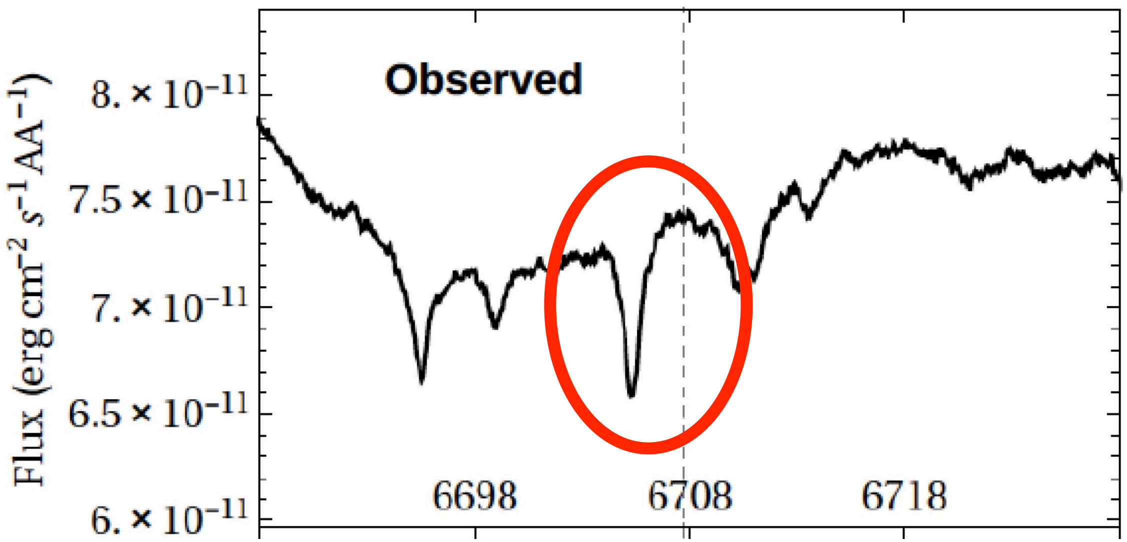
The case of Li I 6708



Ca I 4226



K I 7699



Observed
Flux (erg cm^{-2} s^{-1} AA^{-1})
8. × 10^{-11}
7.5 × 10^{-11}
7. × 10^{-11}
6.5 × 10^{-11}
6. × 10^{-11}
6698
6708
6718

Estimate of mass ejected

Mass Li = $0.3 - 4.8 \times 10^{-10}$ Msun

Estimate of mass ejected

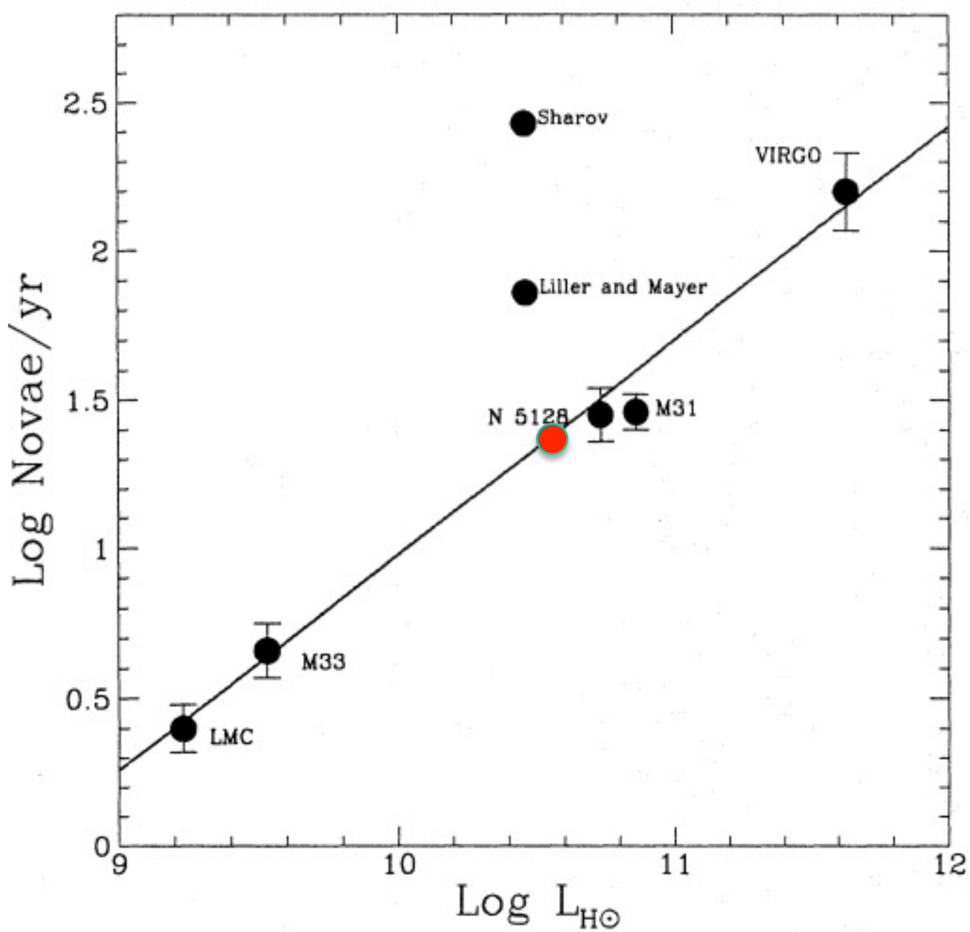
Mass Li = 0.3 – 4.8 x 10^{-10} Msun

+

"Slow" nova rate in the MW = 15–24 yr^{-1}

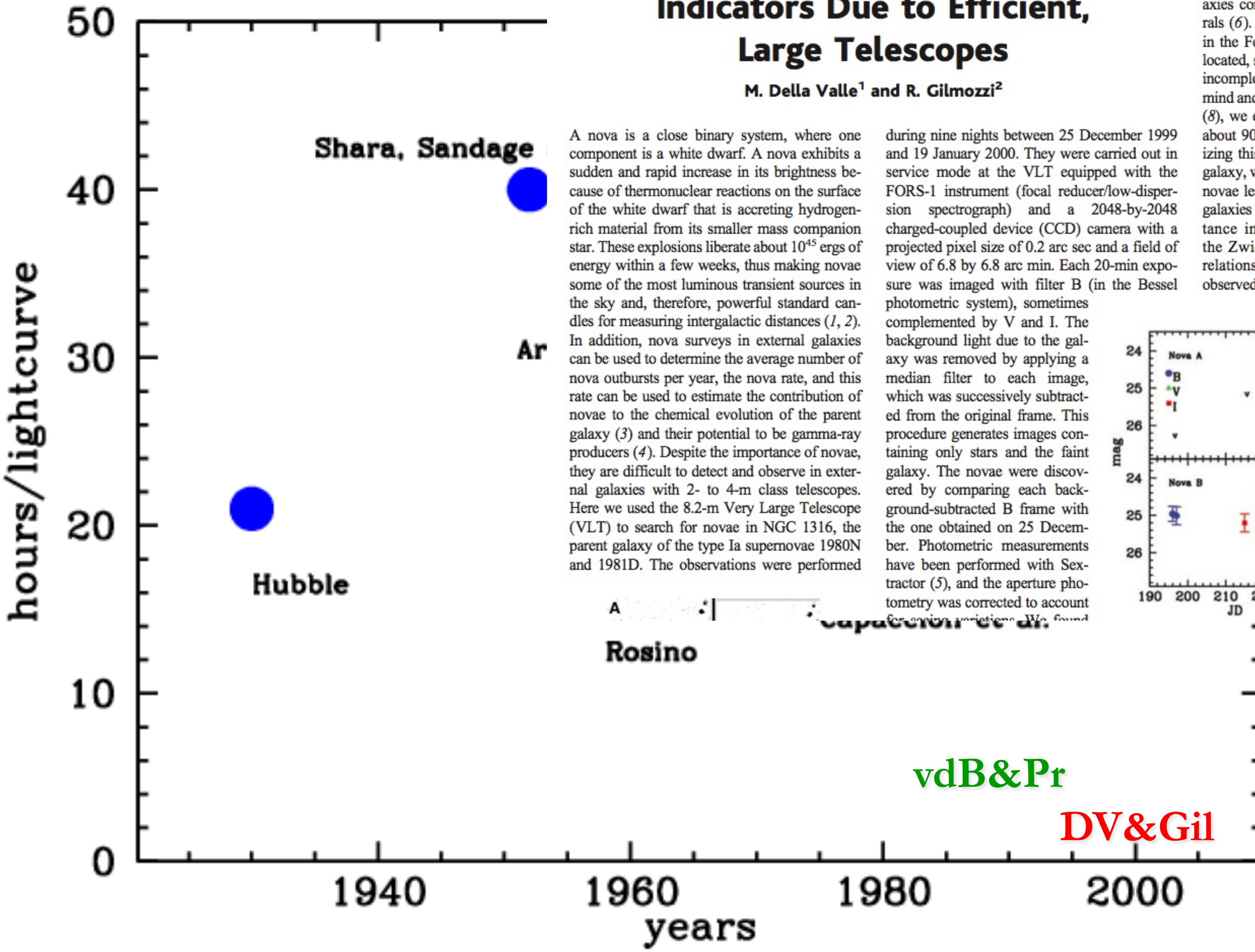
→ Mass Li,tot ≤ 17 MSun Gyr^{-1}

Direct measurements of the distance of Nova Systems will improve (~ 40%) the accuracy on abundances estimates (not only for Li !)



24 novae/yr DV & Livio 1995
35 novae/yr Shafter

Fig. 1. The nova rate as a function of H-Luminosity of the parent galaxies



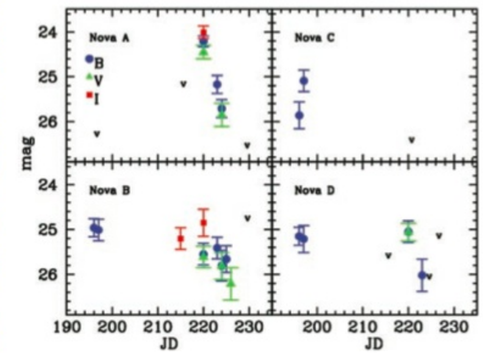
ASTRONOMY

Rebirth of Novae as Distance Indicators Due to Efficient, Large Telescopes

M. Della Valle[1] and R. Gilmozzi[2]

A nova is a close binary system, where one component is a white dwarf. A nova exhibits a sudden and rapid increase in its brightness because of thermonuclear reactions on the surface of the white dwarf that is accreting hydrogen-rich material from its smaller mass companion star. These explosions liberate about 10^{45} ergs of energy within a few weeks, thus making novae some of the most luminous transient sources in the sky and, therefore, powerful standard candles for measuring intergalactic distances (*1*, *2*). In addition, nova surveys in external galaxies can be used to determine the average number of nova outbursts per year, the nova rate, and this rate can be used to estimate the contribution of novae to the chemical evolution of the parent galaxy (*3*) and their potential to be gamma-ray producers (*4*). Despite the importance of novae, they are difficult to detect and observe in external galaxies with 2- to 4-m class telescopes. Here we used the 8.2-m Very Large Telescope (VLT) to search for novae in NGC 1316, the parent galaxy of the type Ia supernovae 1980N and 1981D. The observations were performed during nine nights between 25 December 1999 and 19 January 2000. They were carried out in service mode at the VLT equipped with the FORS-1 instrument (focal reducer/low-dispersion spectrograph) and a 2048-by-2048 charged-coupled device (CCD) camera with a projected pixel size of 0.2 arc sec and a field of view of 6.8 by 6.8 arc min. Each 20-min exposure was imaged with filter B (in the Bessel photometric system), sometimes complemented by V and I. The background light due to the galaxy was removed by applying a median filter to each image, which was successively subtracted from the original frame. This procedure generates images containing only stars and the faint galaxy. The novae were discovered by comparing each background-subtracted B frame with the one obtained on 25 December. Photometric measurements have been performed with Sextractor (*5*), and the aperture photometry was corrected to account

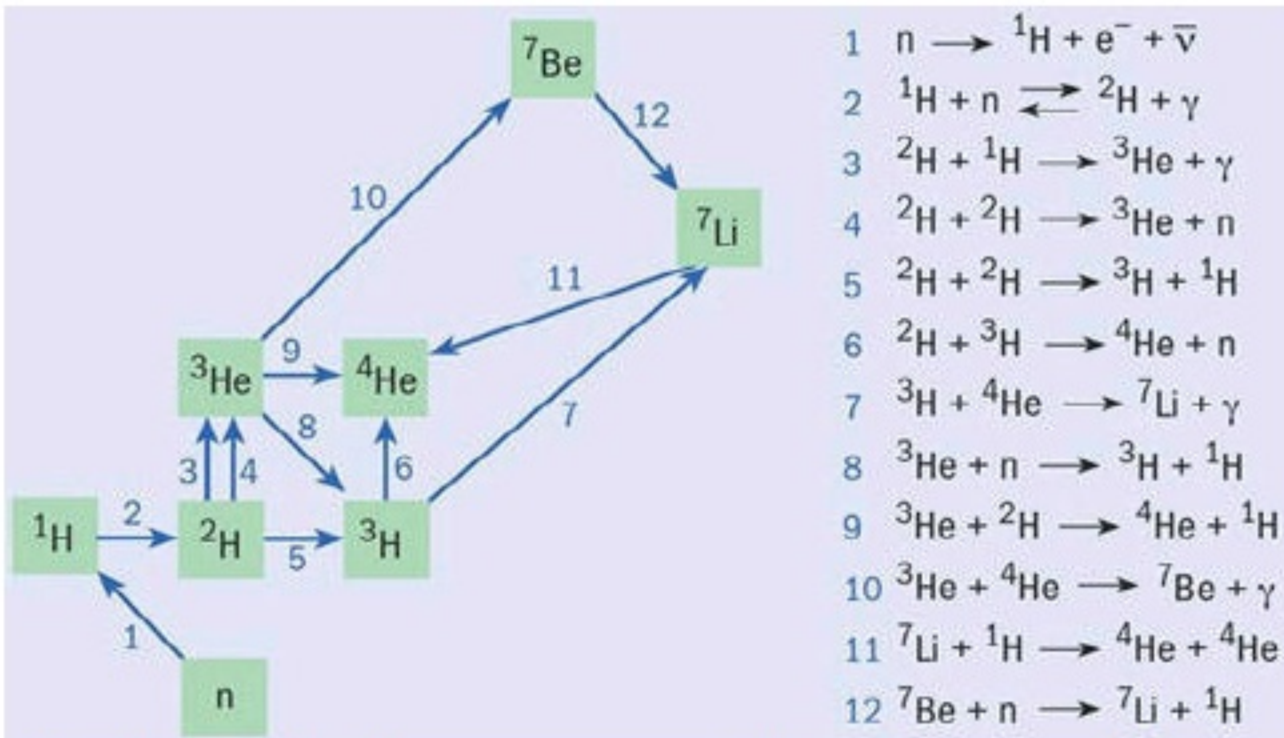
and $M_B \geq -19.10 \pm 0.35$ for supernova 1980N and supernova 1981D, respectively. This result is consistent with the existence of a ~0.2 to 0.3 mag deficiency in the luminosity at maximum of type Ia supernovae found in early type galaxies compared with supernovae found in spirals (*6*). Simulated VLT observations of novae in the Fornax cluster (*7*), where NGC 1316 is located, showed that our novae sample might be incomplete by as much as 20%. With this in mind and by applying the control time technique (*8*), we estimate a nova rate for NGC 1316 of about 90 to 180 novae per year. After normalizing this rate to the infrared luminosity of the galaxy, we find that NGC 1316 tends to produce novae less prolifically than some type of spiral galaxies (*9*, *10*). Novae can be used as distance indicators like cepheids by studying the Zwicky and Buscombe–de Vaucouleurs relationships in parent galaxies with well-observed type Ia supernovae. Novae that can be



A

Primordial lithium abundance

The primordial abundance of elements depends on the baryon/photon density ratio η :



Larger is the ratio, the more reactions there will be among baryons to produce deuterium, and consequently 4-helium, 3-helium and lithium via several channels

Primordial lithium abundance

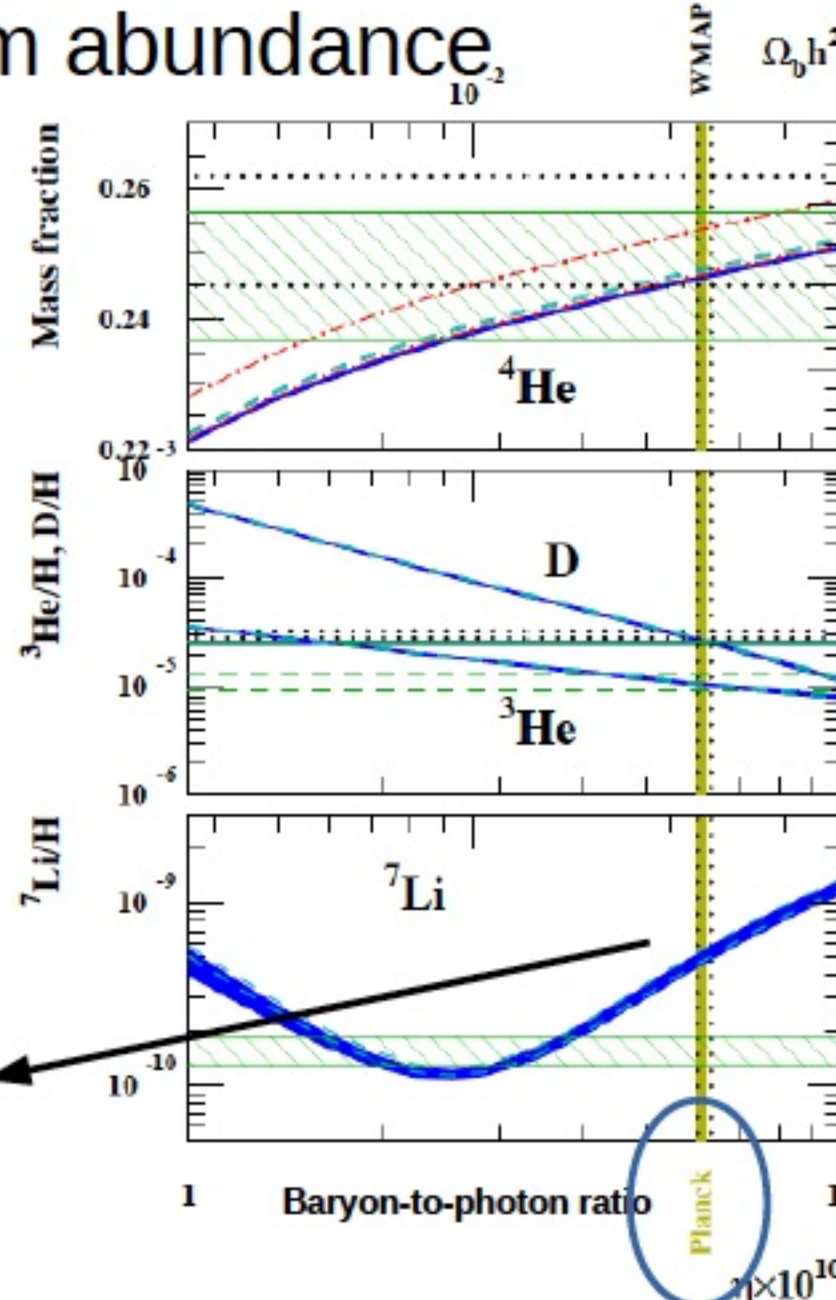
Calculated primordial abundances from Standard Big Bang Nucleosynthesis (and reaction rates) for :

4-Helium

Deuterium

3-Helium

7-Lithium



From Planck observation of η

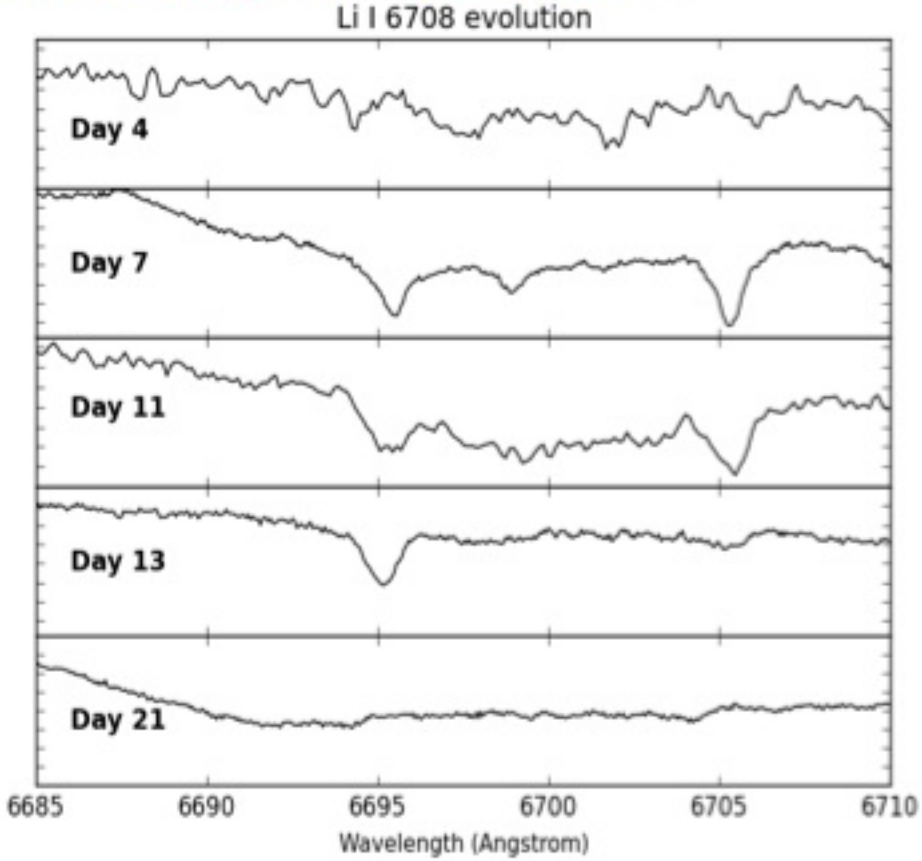
	This work	Observations
Y_p*	0.2461–0.2466	0.2465 ± 0.0097
D/H ($\times10^{-5}$)	2.57–2.72	2.53 ± 0.04
^{3}He/H ($\times10^{-5}$)	1.02–1.08	1.1 ± 0.2
^{7}Li/H ($\times10^{-10}$)	4.56–5.34	$1.58^{+0.35}_{-0.28}$

The case of Li I 6708

Detection of a feature @ 6695.6 on Day 7
→ Li I 6708 expanding @ -550 km/s

Observed for about two weeks

ID of other neutral resonance lines as
Ca I 4226
K I 7665-7699
... and Na I ...



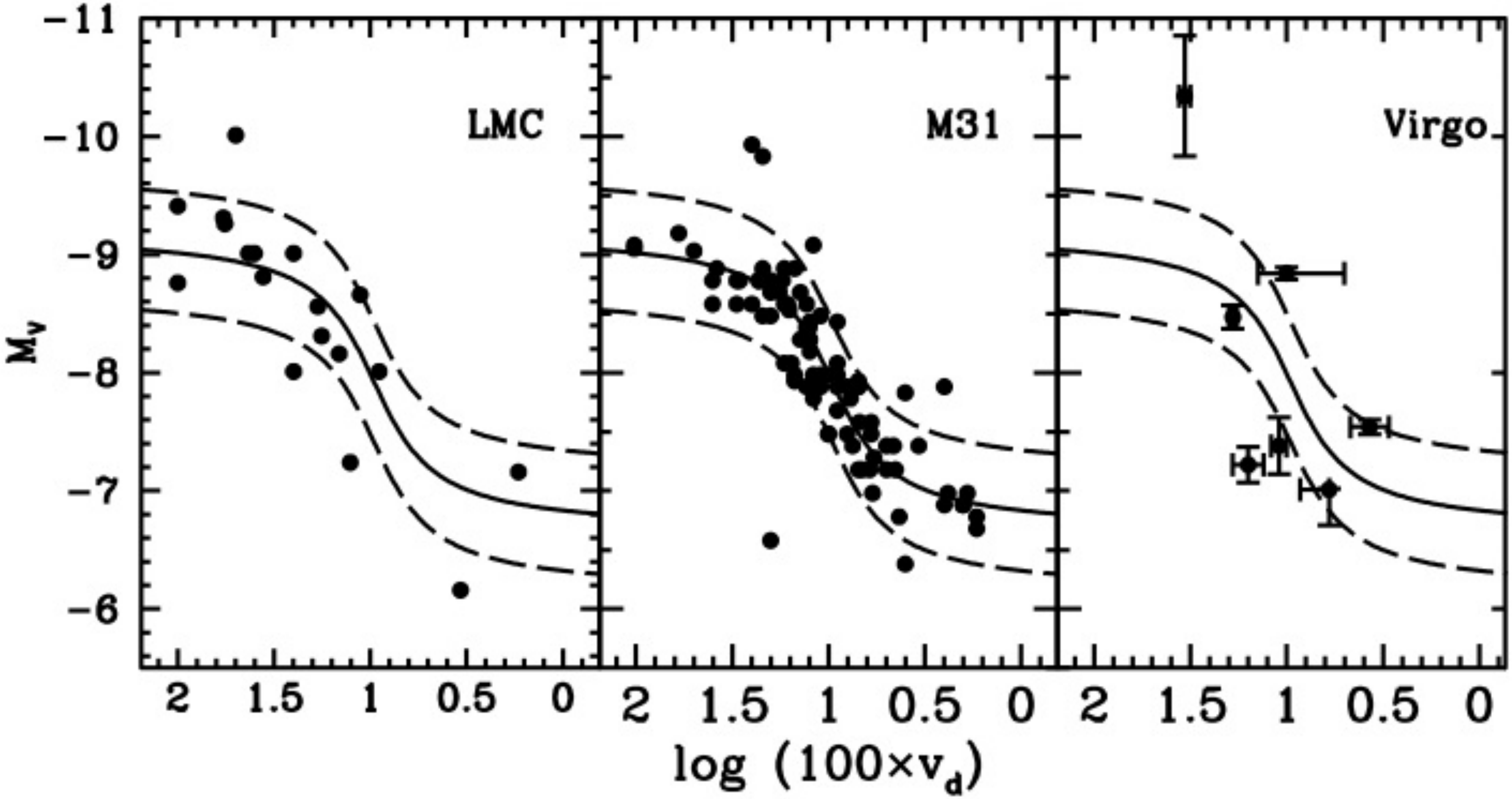
Conclusions and Perspectives

- V1369 Cen still represents a perfect laboratory for many nova studies !!!

- Open questions: possible multiple ejecta, complete analysis of early narrow absorptions, origin of high-energy emission ...

- ...Li presence → physics of explosion: 1) efficiency of convection and 2) timescales of TNR

- The Li yield inferred from V1369 Cen, and extended to all slow novae, is sufficient to explain the overabundance of Li in young star populations



LMC
M31
Virgo
M_V
−11
−10
−9
−8
−7
−6
2
1.5
1
0.5
0
log (100×v_d)

DRAFT VERSION JUNE 29, 2015
Preprint typeset using LaTeX style emulateapj v. 01/23/15

EARLY OPTICAL SPECTRA OF NOVA V1369 CEN SHOW PRESENCE OF LITHIUM

LUCA IZZO
Physics Department, Sapienza University of Rome, I-00185; ICRANET, Piazza della Repubblica 10, 65122, Pescara, Italy

MASSIMO DELLA VALLE
INAF, Osservatorio Astronomico di Capodimonte, salita Moiariello 16, 80131, Napoli; ICRANET, Piazza della Repubblica 10, 65122, Pescara, Italy

ELENA MASON
INAF, Osservatorio Astronomico di Trieste, via G.B. Tiepolo 11, I-34143 Trieste, Italy

FRANCESCA MATTEUCCI
Dipartimento di Fisica, Sezione di Astronomia, Universitá di Trieste, via G.B. Tiepolo 11, I-34143 Trieste, Italy

DONATELLA ROMANO
INAF, Osservatorio Astronomico di Bologna, via Ranzani 1, 40127, Bologna, Italy

LUCA PASQUINI
ESO, Karl-Schwarzschild-Strasse 2, 85748 Garching bei Munchen, Germany

LEONARDO VANZI
Department of Electrical Engineering and Center of Astro Engineering, PUC-Chile, Avenida Vicuña Mackenna 4860, Santiago, Chile

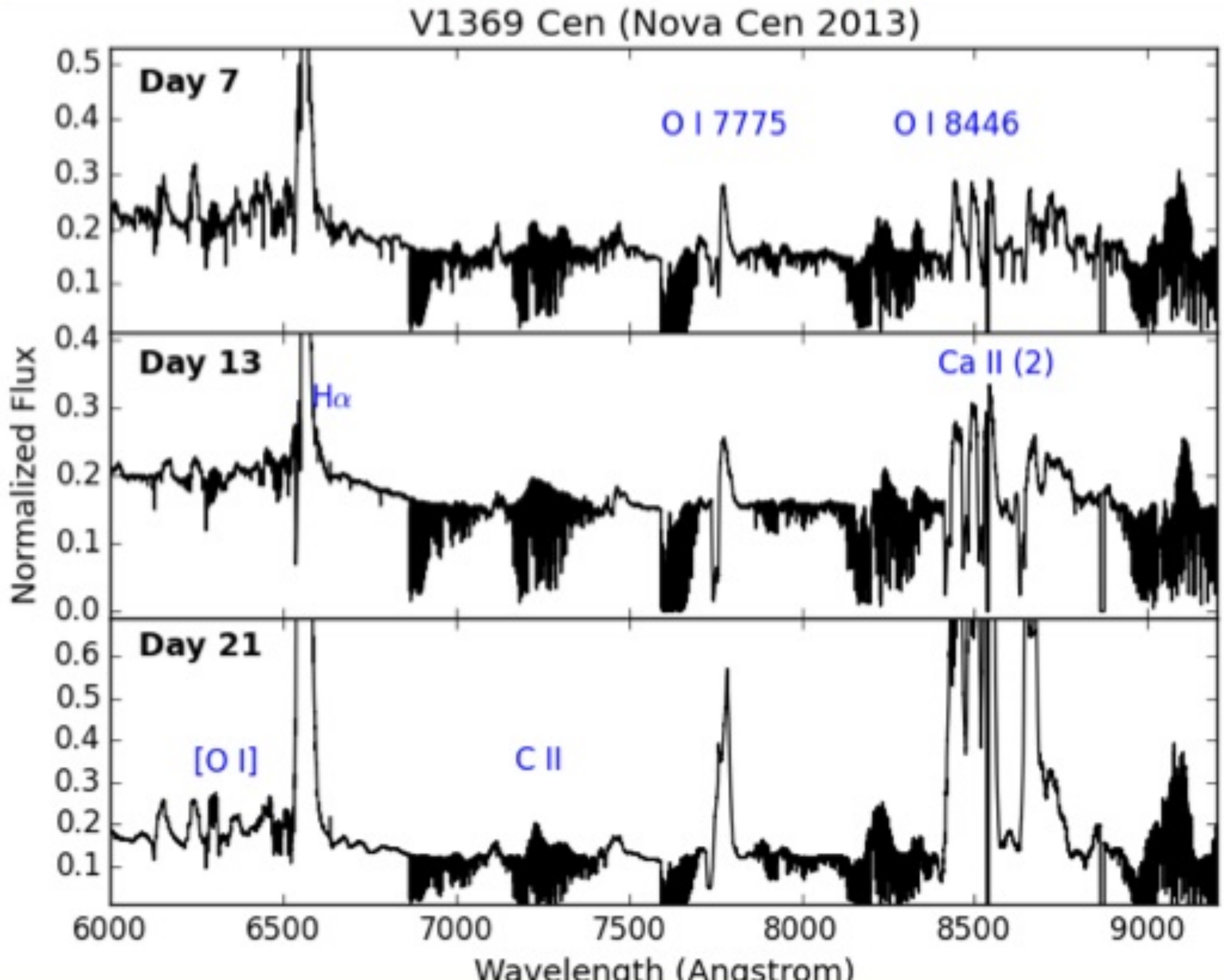
ANDRES JORDAN
Institute of Astrophysics and Center of Astro Engineering, PUC-Chile, Avenida Vicuña Mackenna 4860, Santiago, Chile

JOSÉ MIGUEL FERNANDEZ, PAZ BLUHM, RAFAEL BRAHM, NESTOR ESPINOZA
Institute of Astrophysics, PUC-Chile, Avenida Vicuña Mackenna 4860, Santiago, Chile

AND

ROBERT WILLIAMS
Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218, USA

Draft version June 29, 2015



V1369 Cen (Nova Cen 2013)
Day 7
O I 7775
O I 8446
Day 13
Hα
Ca II (2)
Day 21
[O I]
C II
Normalized Flux
Wavelength (Angstrom)
0.5
0.4
0.3
0.2
0.1
0.4
0.3
0.2
0.1
0.0
0.6
0.5
0.4
0.3
0.2
0.1
6000
6500
7000
7500
8000
8500
9000

Mission Home
- Summary
- Fact Sheet
- Objectives
- Mission Team

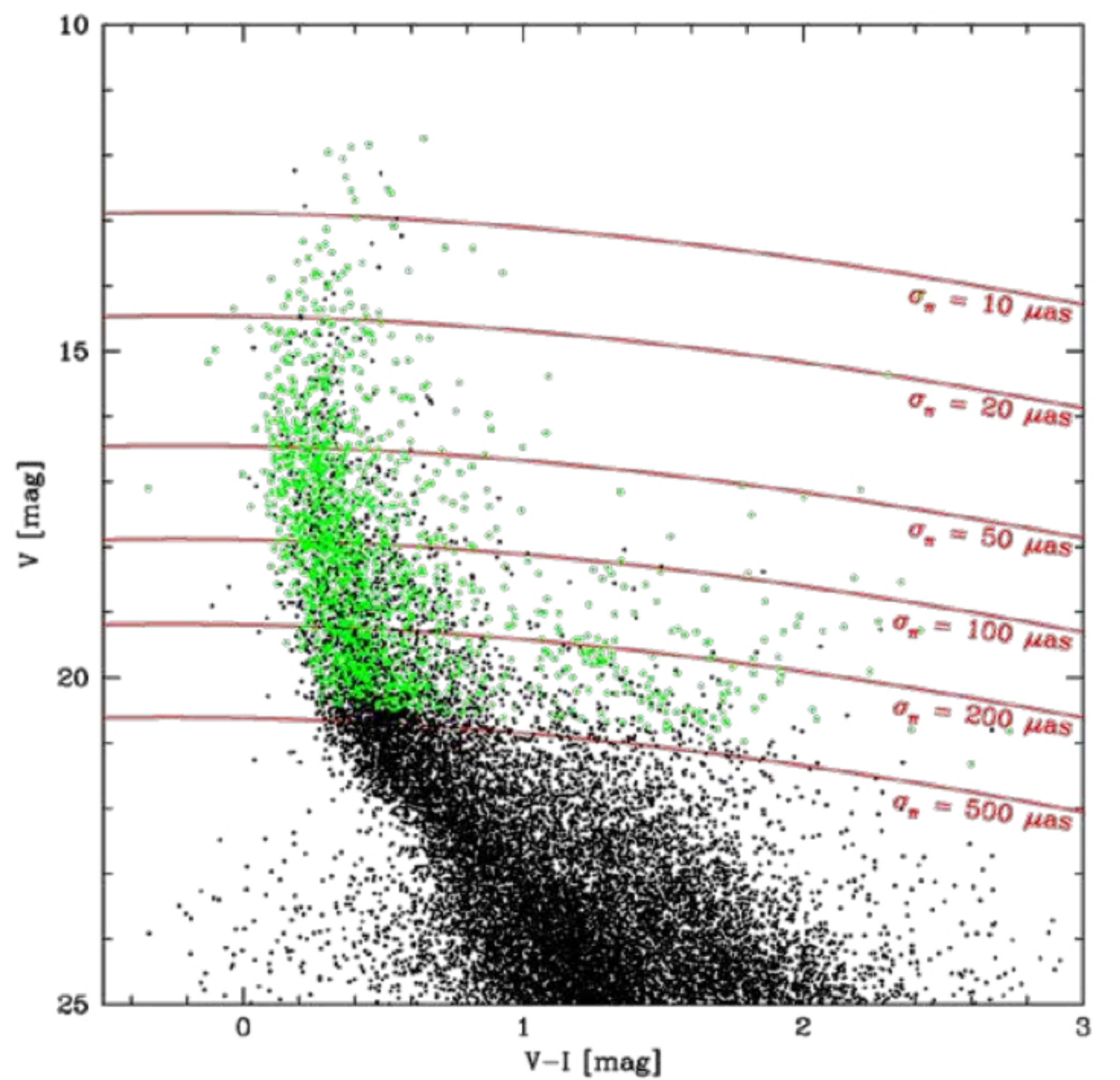
News

Mission Science
- Galactic Structure
- Stars
- Solar System
- Extra-solar Planets

Spacecraft
- Payload Module
- Service Module

Mission Operations
- Launch Vehicle
- Orbit/Navigation

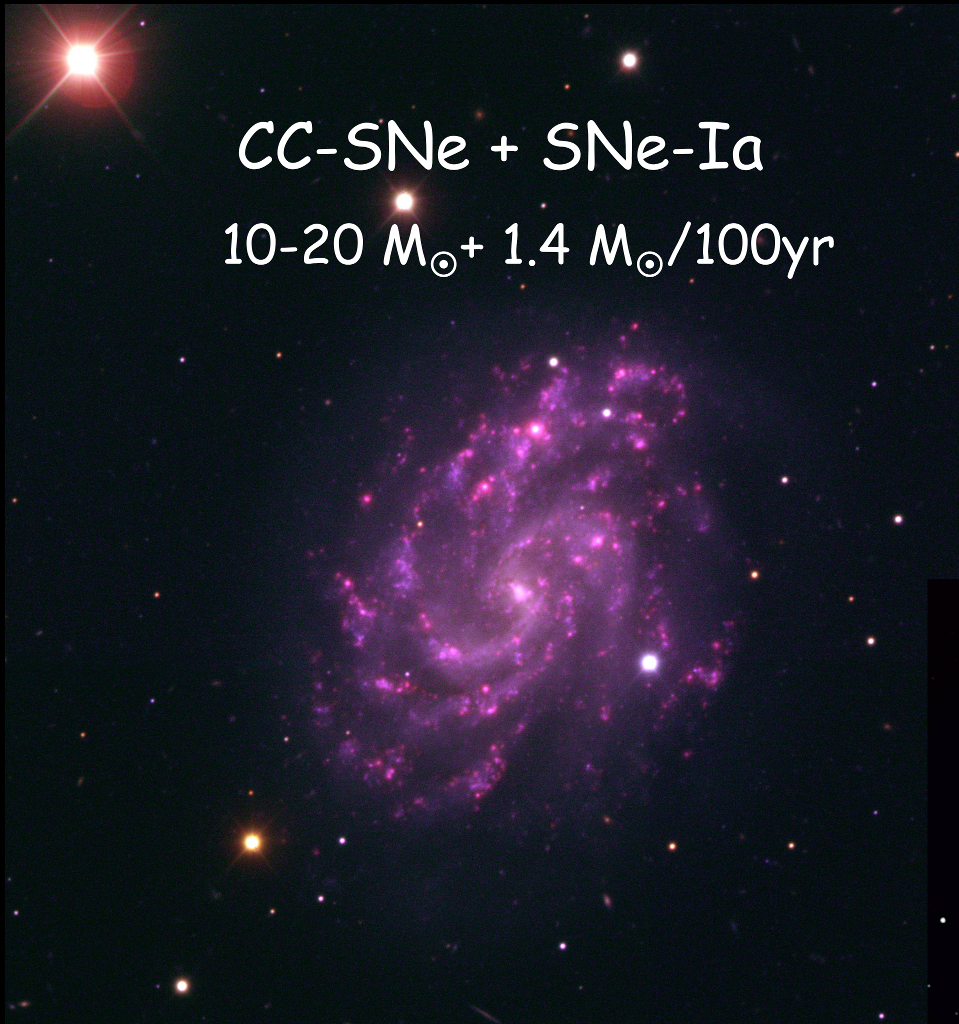
Services
- Publications
- Conferences
- Calendar

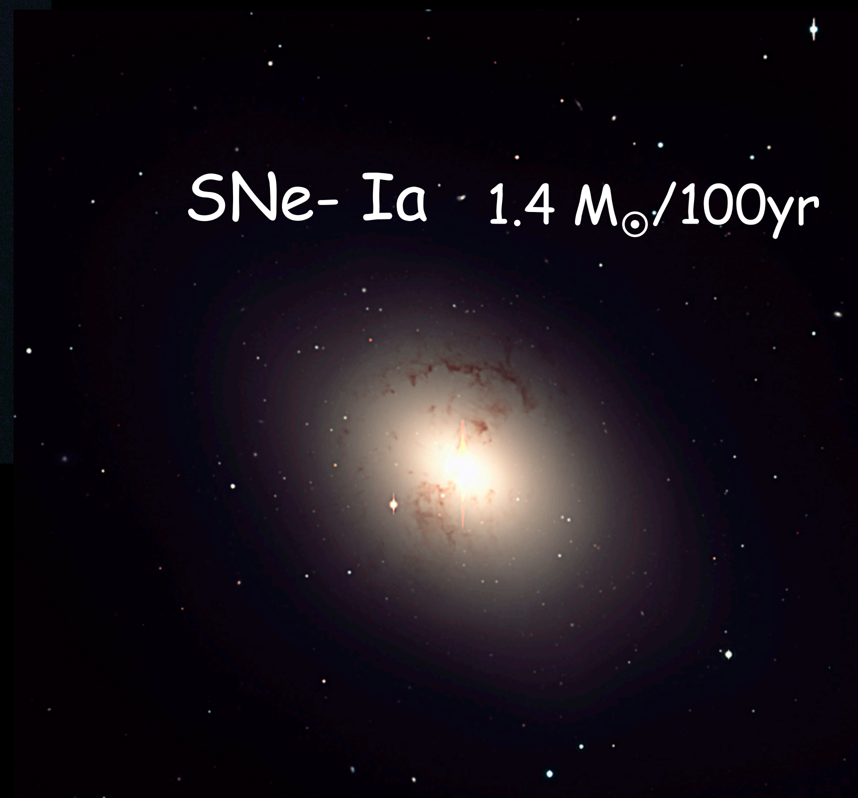


-2011 19:25:05 UT

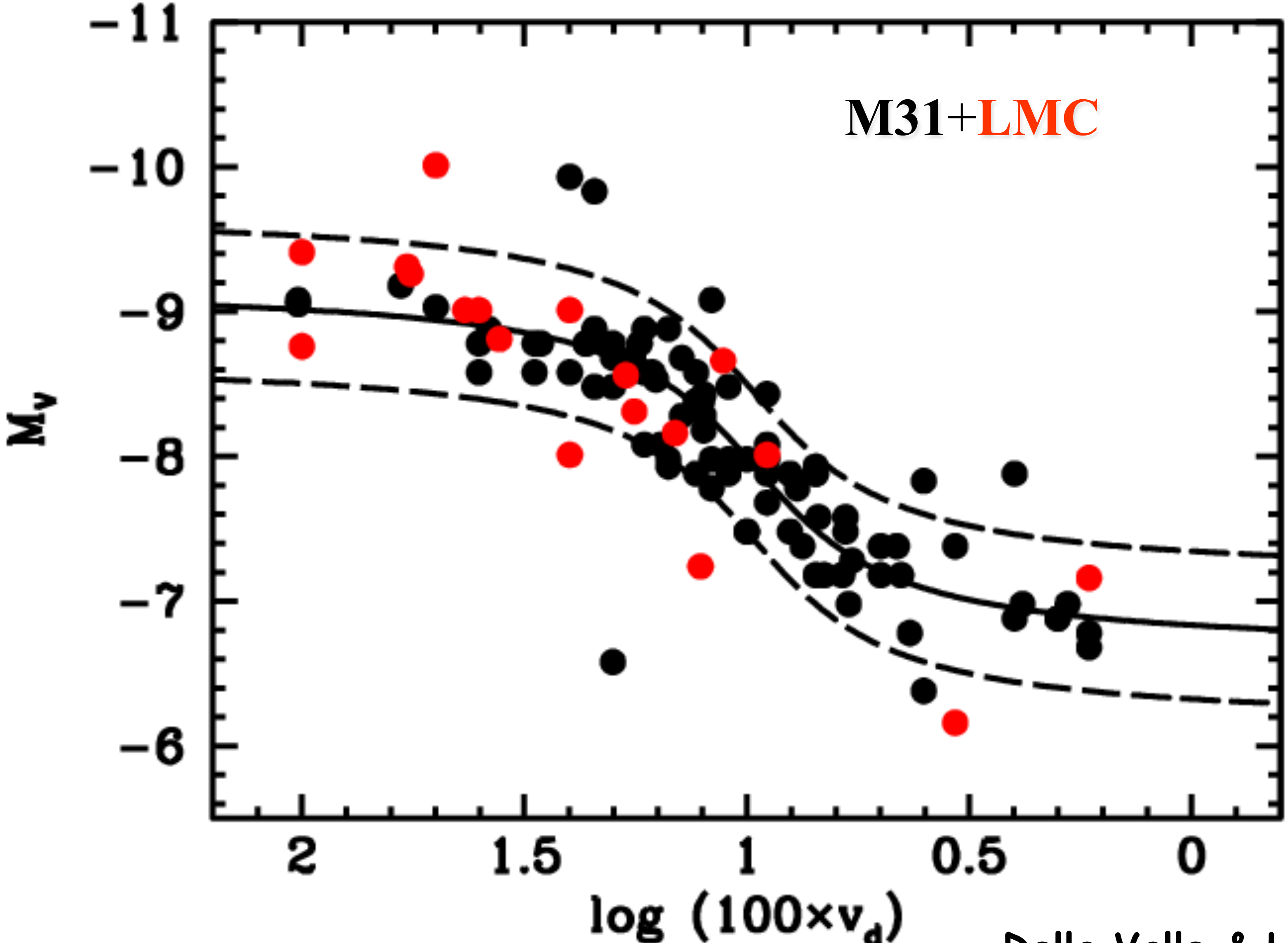
Email this

- tests of hierarchical structure formation theories
- inner bulge/bar dynamics


CC-SNe + SNe-Ia
10-20 $M_{\odot}$+ 1.4 $M_{\odot}$/100yr


SNe- Ia 1.4 $M_{\odot}$/100yr

The “tool”



Della Valle & Livio 1995