
The Araucaria Project
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H_0 uncertainty and universe equation of state

Hubble constant uncertainty →
EoS parameter w

$$\frac{\delta w}{w} \approx 2\frac{\delta H_0}{H_0}$$

$$w = \frac{p}{c^2 \rho}$$

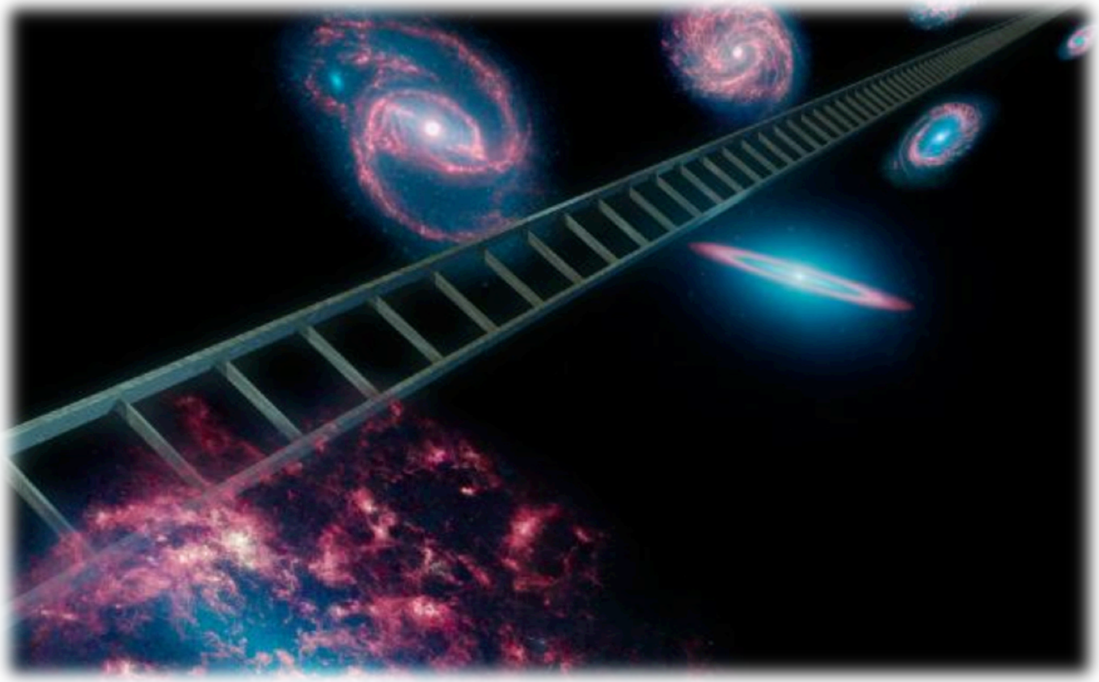
despite enormous effort still: **$\delta H_0 > 5\%$ →** **$\delta w > 0.1$**

Direct 1% H_0 determination !

The value of the Hubble Constant changed by 100 % over the time, but at any moment every measurement of it was claimed to be 10 % accurate !

The determination of the Hubble Constant is (almost) always claimed to be more precise that any distance determination to nearby galaxies.

Alistair Walker



The principal sources of error in the calibration of the cosmic distance scale

- population effects
- extinction (internal extinction, reddening law)
- the zero point
- physics of the distance indicators

⇓

Calibration of the Cepheid PL relation

⇒ Calibration of the local distance scale

⇒ Stellar evolution and pulsation

Eclipsing binaries

$$d(pc) = 1.337 \times 10^{-5} \times r(km) / \varphi(mas)$$

Light + RV curves analysis

=> ~ 1 % radii (e.g. Andersen 1991)

Late-type eclipsing binaries

$$d(pc) = 1.337 \times 10^{-5} \times r(km) / \varphi(mas)$$

φ is derived from the surface brightness - color relation, very well established for late-type stars based on interferometric data (di Benedetto 1998, 2005; Kervella et al. 2004)

$$S_V = 2.656 + 1.483 \times (V - K)_0 - 0.044 \times (V - K)_0^2$$

$$\phi \ [\mathrm{mas}] = 10^{0.2 \cdot (S - m_0)}$$

Currently rms on such relation is 0.03 mag (2 % !)

nature International weekly journal of science

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日本語要約

An eclipsing-binary distance to the Large Magellanic Cloud accurate to two per cent

G. Pietrzyński, D. Graczyk, W. Gieren, I. B. Thompson, B. Pilecki, A. Udalski, I. Soszyński, S. Kozłowski, P. Konorski, K. Suchomska, G. Bono, P. G. Prada Moroni, S. Villanova, N. Nardetto, F. Bresolin, R. P. Kudritzki, J. Storm, A. Gallenne, R. Smolec, D. Minniti, M. Kubiak, M. K. Szymański, R. Poleski, Ł. Wyrzykowski, K. Ulaczyk + *et al.*

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Nature **495**, 76–79 (07 March 2013) | doi:10.1038/nature11878

Received 19 August 2012 | Accepted 20 December 2012 | Published online 06 March 2013

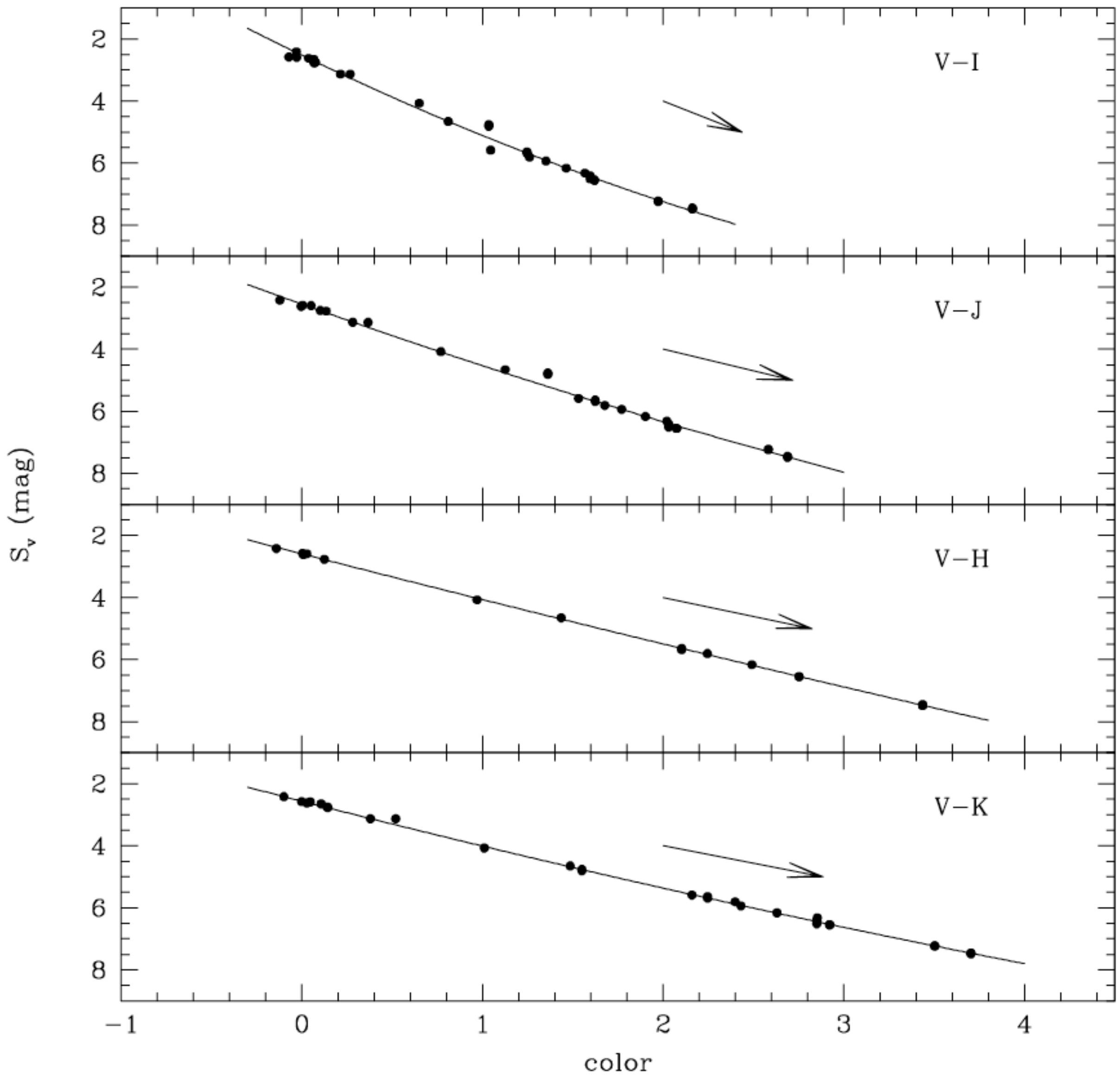
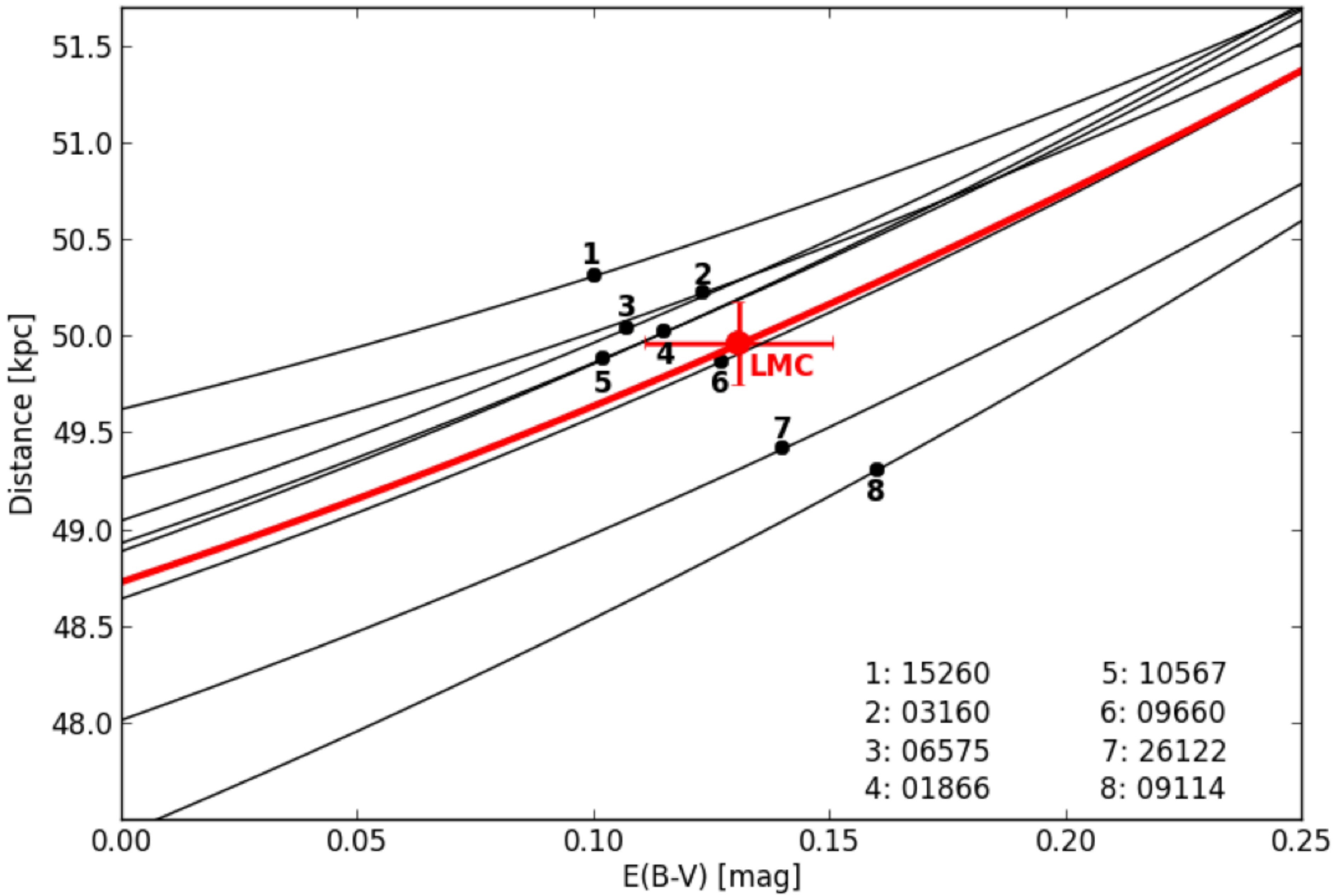


FIG. 9.—Surface brightnesses of nearby stars in the V band is plotted against $V-I$, $V-J$, $V-H$, and $V-K$ colors. The solid lines are quadratic least-squares fits to the data, the coefficients of the fits are listed in Table 9. The arrows correspond to a reddening A_V of 1 mag.



Distance [kpc]
E(B-V) [mag]
51.5
51.0
50.5
50.0
49.5
49.0
48.5
48.0
0.00
0.05
0.10
0.15
0.20
0.25
1
2
3
4
5
6
7
8
LMC
1: 15260
2: 03160
3: 06575
4: 01866
5: 10567
6: 09660
7: 26122
8: 09114

$$\phi\ [\mathrm{mas}] = 10^{0.2\cdot(S-m_0)}$$

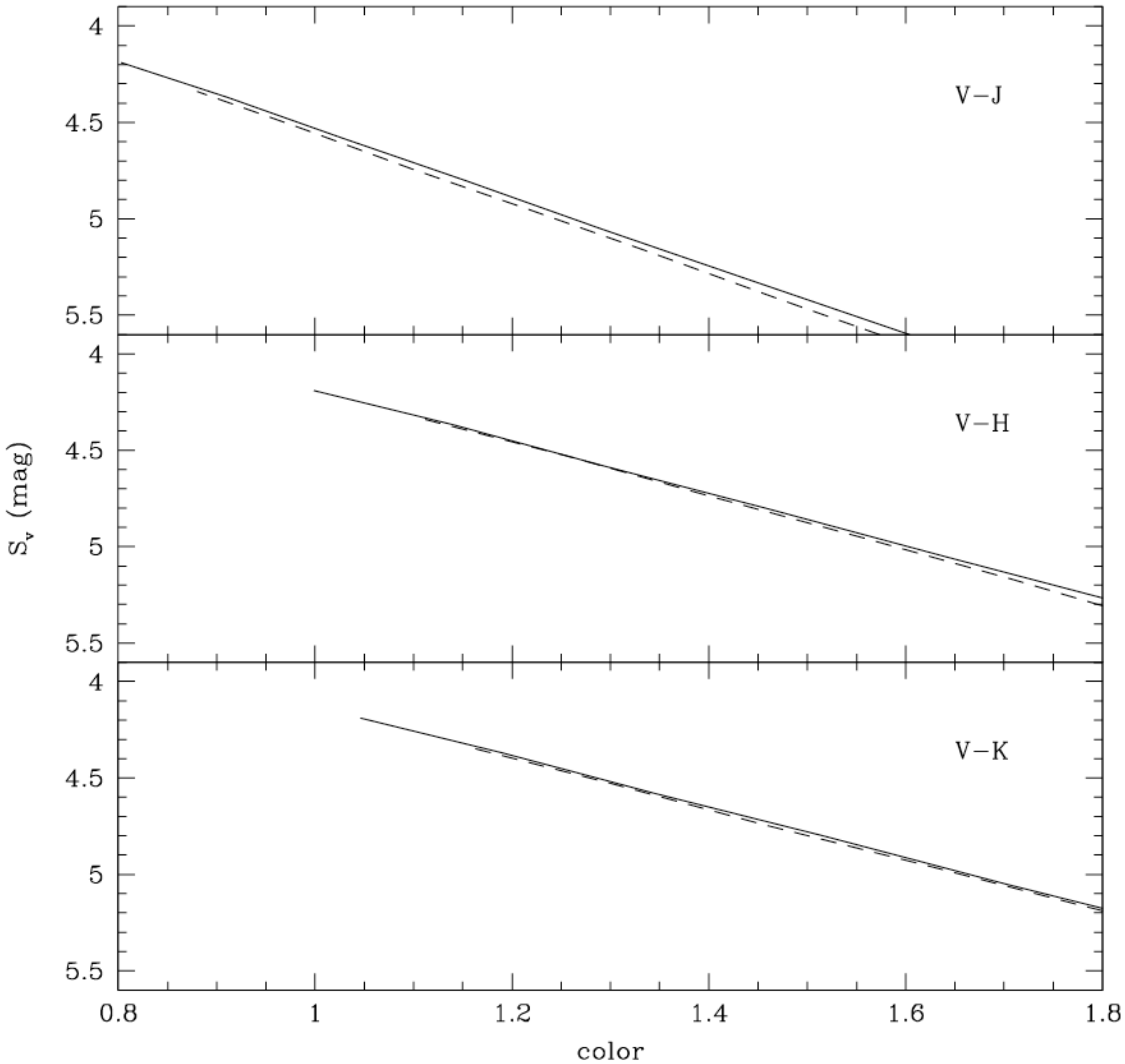
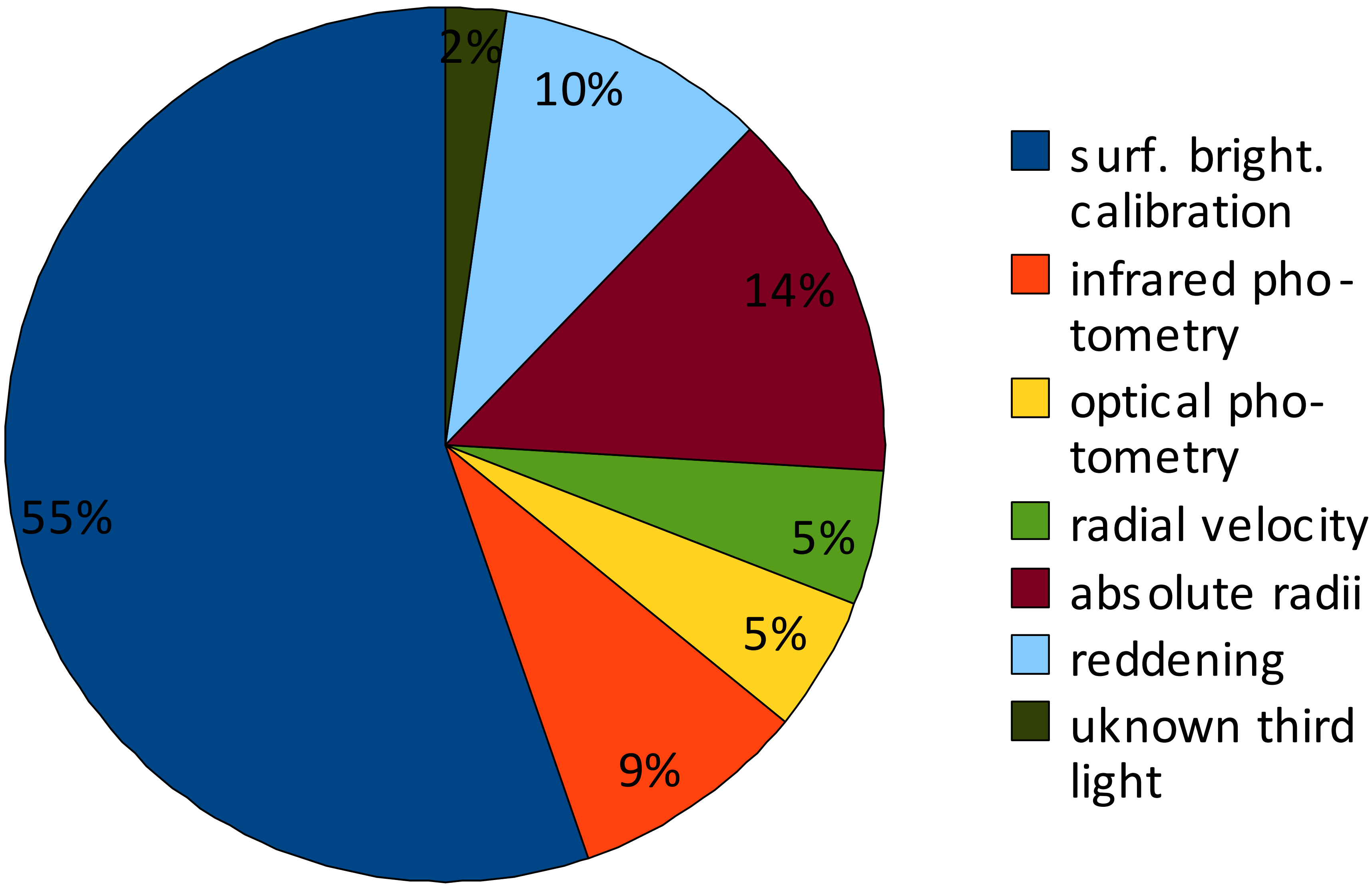
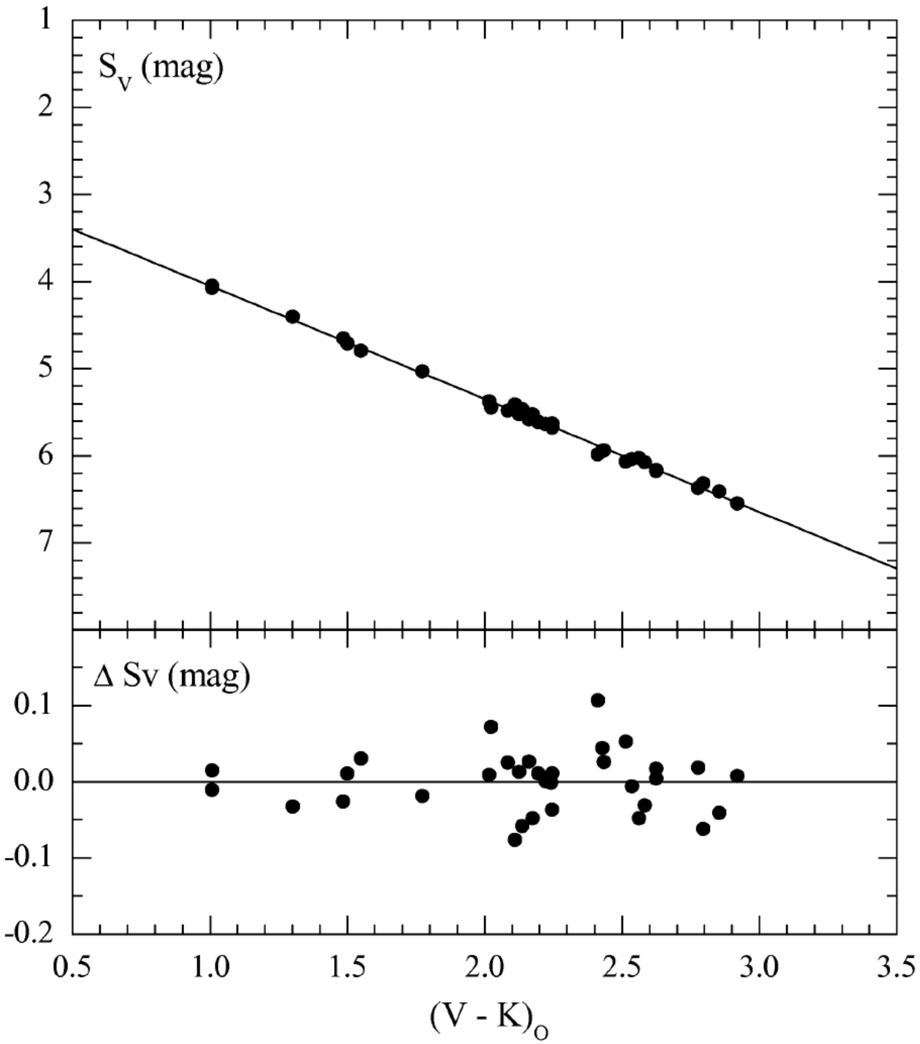


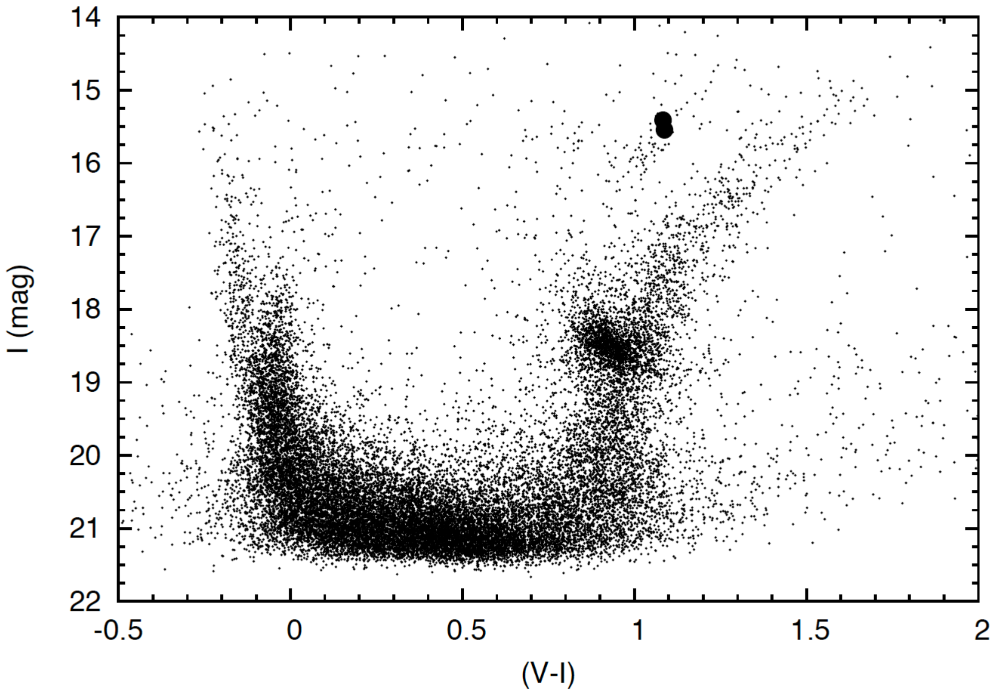
FIG. 10.—Synthetic relations S_V–$(V-K)$ for [Fe/H] = 0 (*solid lines*) and [Fe/H] = −2.0 (*dotted lines*).

The distance error budget (2.5 % total error)



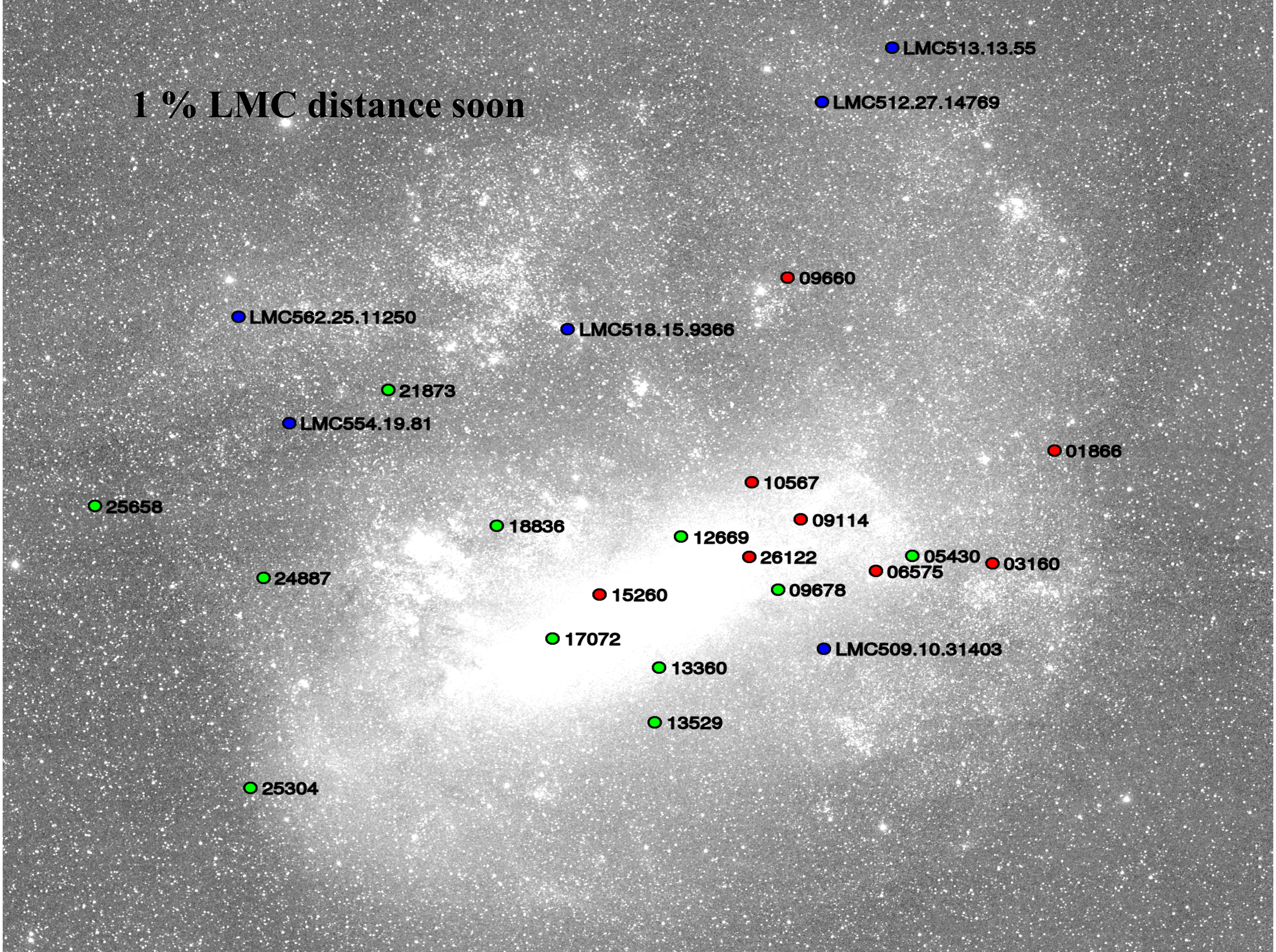
Improving $S_V \Leftrightarrow (V-K)_0$ relation



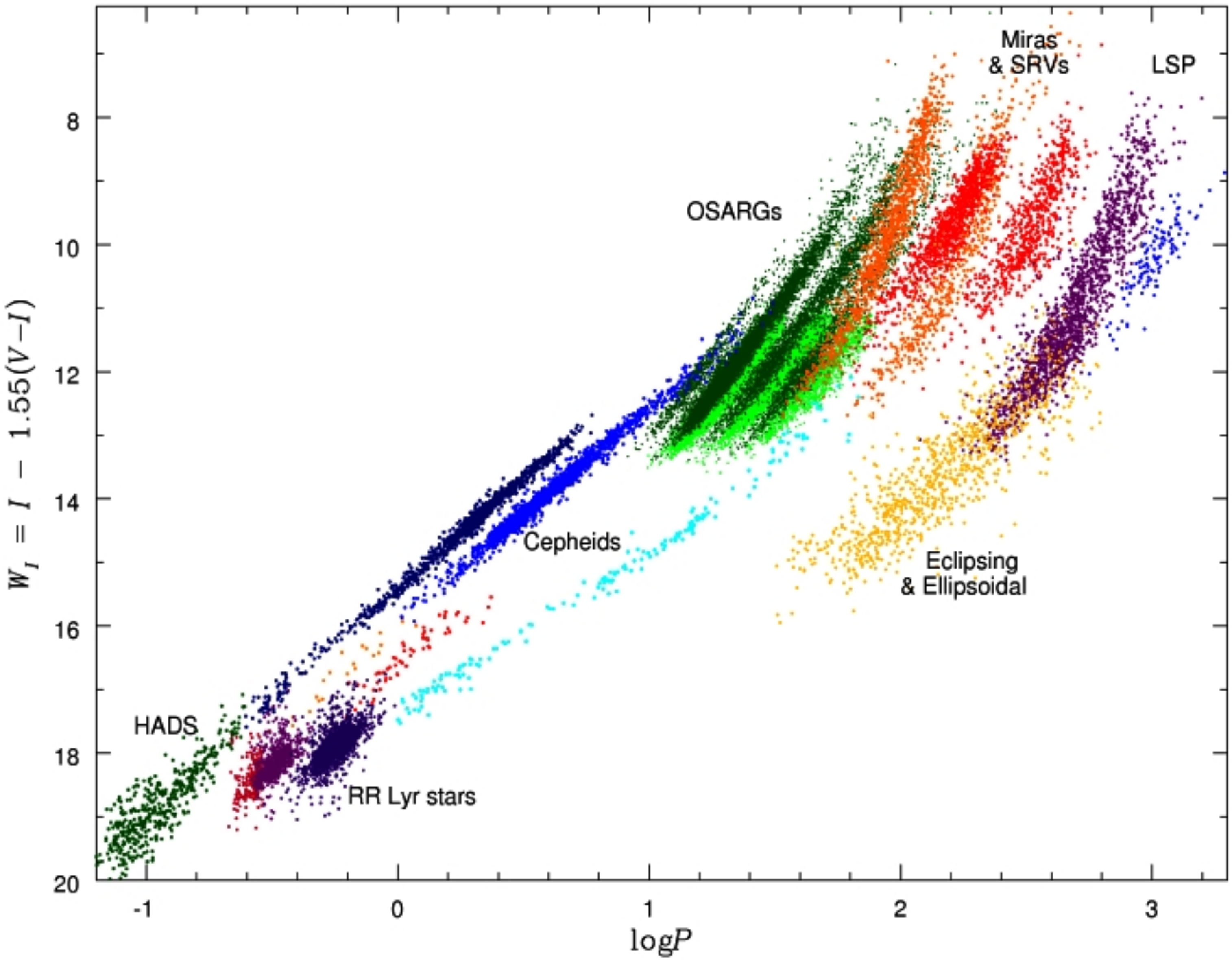


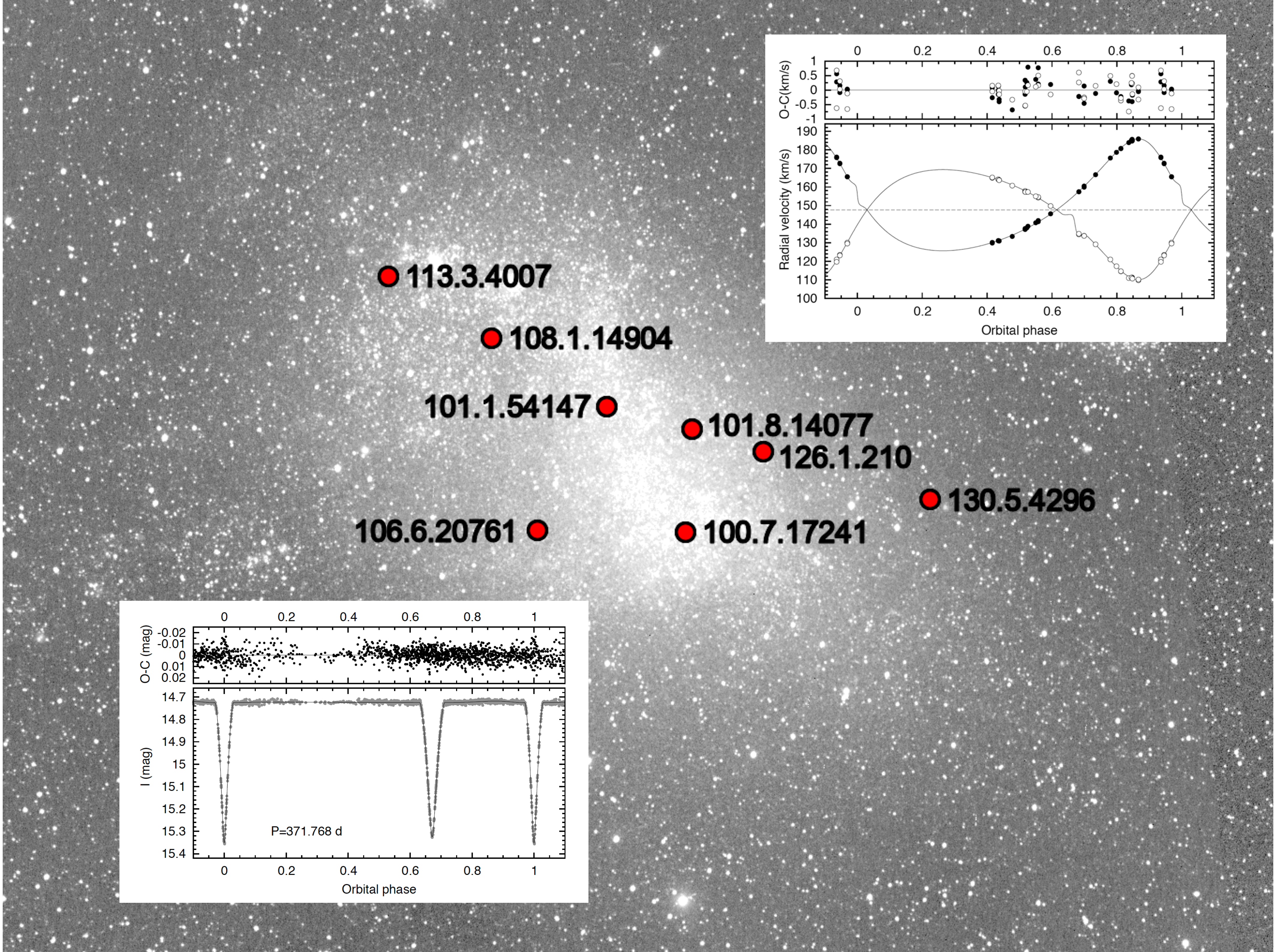
Nardetto, Gallenne, et al.

1 % LMC distance soon

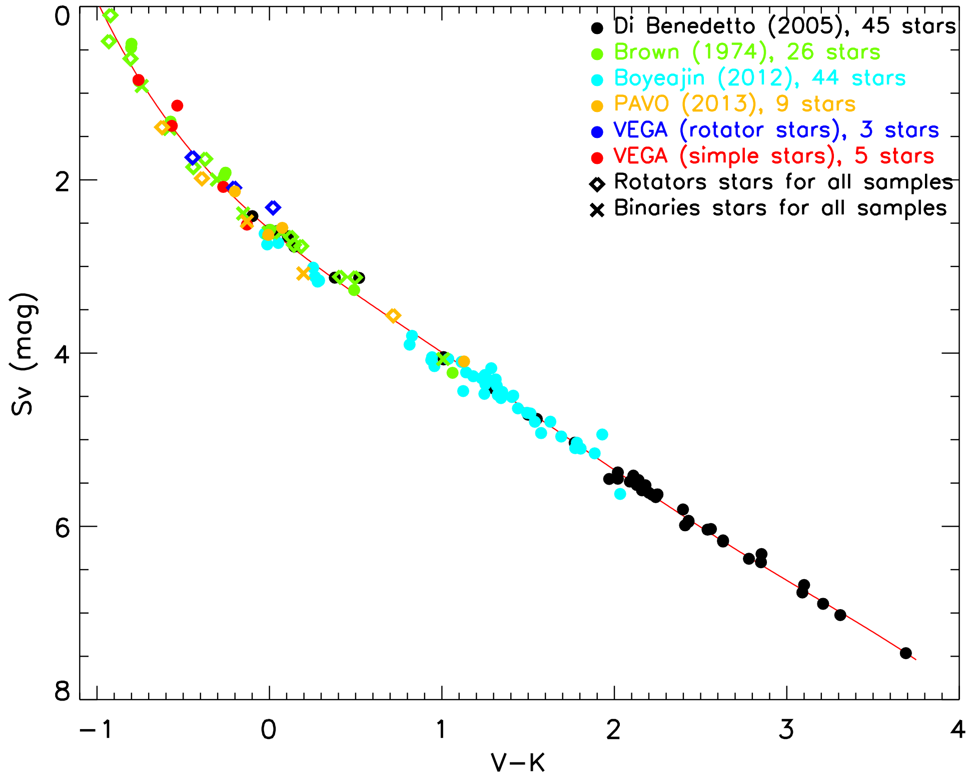


OGLE Pulsating Stars




113.3.4007
108.1.14904
101.1.54147
101.8.14077
126.1.210
130.5.4296
106.6.20761
100.7.17241
O-C(km/s)
Radial velocity (km/s)
Orbital phase
O-C (mag)
I (mag)
P=371.768 d
Orbital phase

$S_V \Leftrightarrow (V-K)_0$ for early type stars

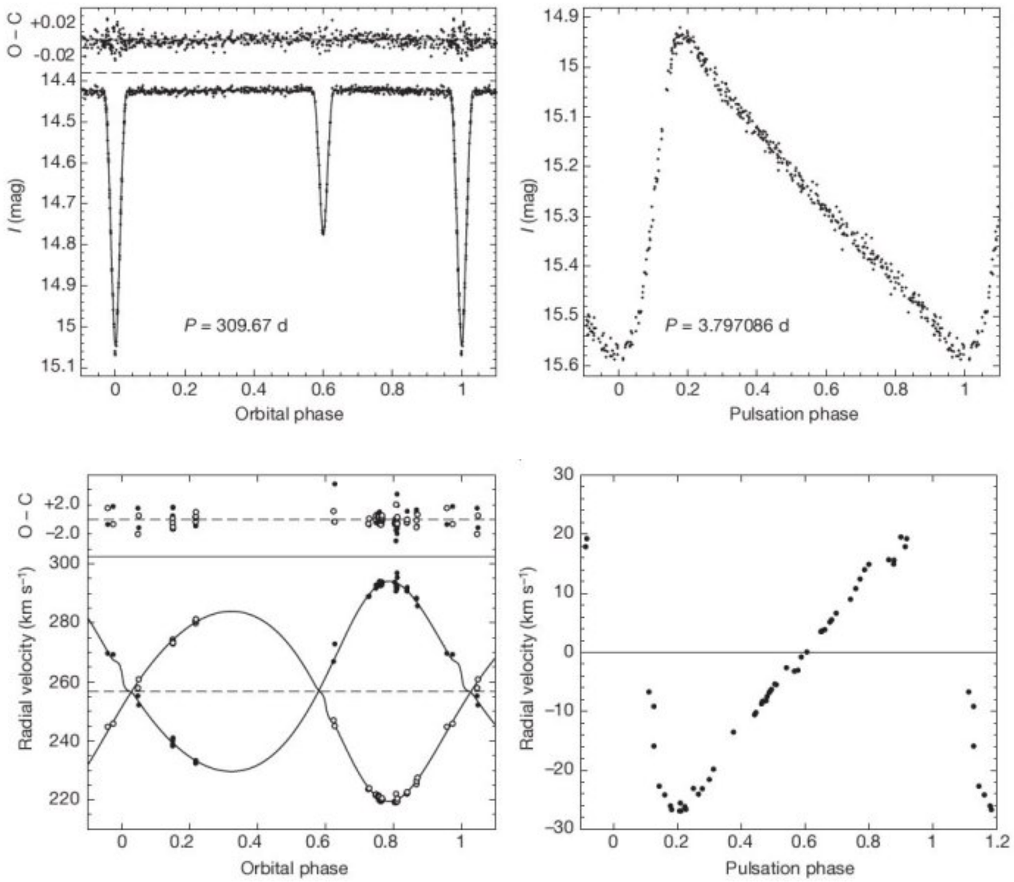


Challouf, Nardetto, et al. (VEGA)

Very precise calibration of the Cepheid P-L relation !

A must for 1 % H_0 right now at least 5 % contribution

OGLE-CEP-0227



- ⇒ Dynamical mass
- ⇒ Cepheid PL calibration
- ⇒ BW method calibration
- ⇒ precise distance
- ⇒ pulsation theory
- ⇒ evolutionary models

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The dynamical mass of a classical Cepheid variable star in an eclipsing binary system

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Nature **468**, 542–544 (25 November 2010) | doi:10.1038/nature09598
Received 06 July 2010 | Accepted 19 October 2010 | Published online 24 November 2010

日本語要約
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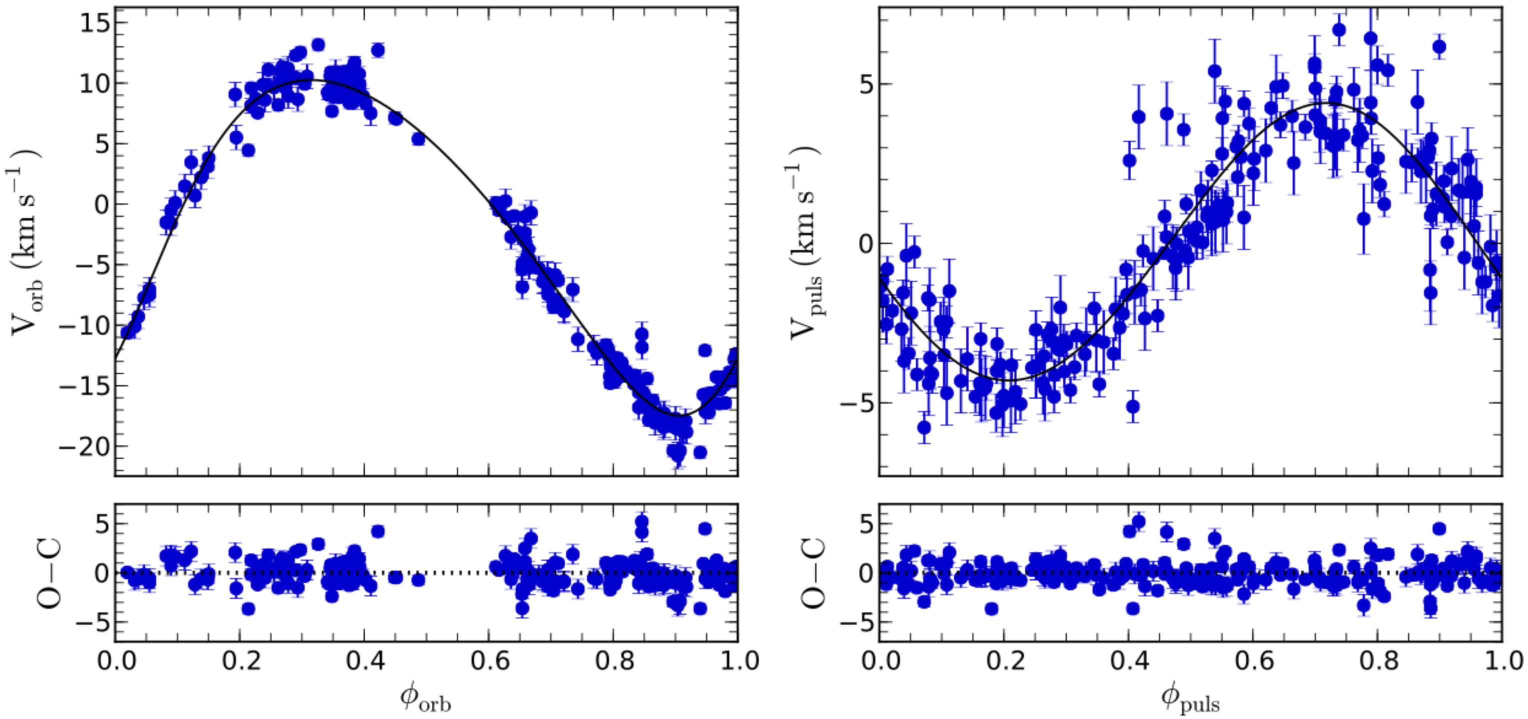
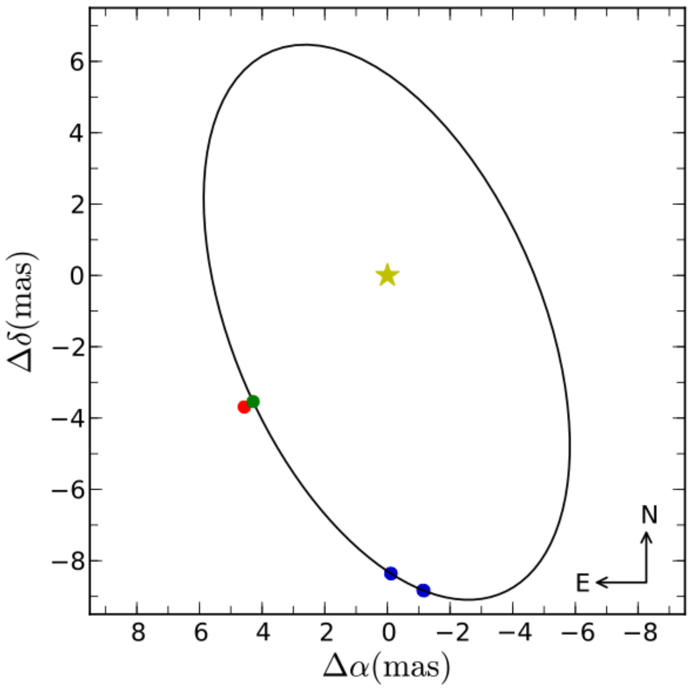
Stellar pulsation theory provides a means of determining the masses of pulsating classical Cepheid supergiants—it is the pulsation that causes their luminosity to vary. Such pulsational masses are found to be smaller than the masses derived from stellar evolution theory: this is the Cepheid mass discrepancy problem[1, 2], for which a solution is missing[3, 4, 5]. An independent, accurate dynamical mass determination for a classical Cepheid variable star (as opposed to type-II Cepheids, low-mass stars with a very different evolutionary history) in a binary system is needed in order to determine which is correct. The accuracy of previous efforts to establish a dynamical Cepheid mass from Galactic single-lined non-eclipsing binaries was typically about 15–30% (refs 6, 7), which is not good enough to resolve the mass discrepancy problem. In spite of many observational efforts[8, 9], no firm detection of a classical Cepheid in an eclipsing double-lined binary has hitherto been reported. Here we report the discovery of a classical Cepheid in a well detached, double-lined eclipsing binary in the Large Magellanic Cloud. We determine the mass to a precision of 1% and show that it agrees with its pulsation mass, providing strong evidence that pulsation theory correctly and precisely predicts the masses of classical Cepheids.

Subject terms: Astronomy



Gallenne, Kervella, et al.



Interferometry => Cosmology

- Sv – color relation (eclipsing binaries, Cepheids, etc)

  => the best zero point

  => very precise determination of the metallicity effect

  => independent way of using Cepheids for distance determination (BW technique)

- New opportunities to study basic physics of stellar distance indicators

  => Cepheids masses (and other parameters) to 1 %

  => p factor determination

The principal sources of error in the calibration of the cosmic distance scale

- population effects SOON
- extinction DONE
- the zero point 2 % DONE 1 % SOON
- physics of the distance indicators YES !

↓

Calibration of the Cepheid PL relation at 1 %

H_0 1-1.5 % soon ?