THE OBSERVATORY

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MEETING OF THE ROYAL ASTRONOMICAL SOCIETY

Friday 2024 November 8 at $16^h\ 00^m$
in the Geological Society Lecture Theatre, Burlington House

Mike Lockwood, *President*
in the Chair

The President. This is a hybrid meeting. Questions may be asked at the end of the lecture so please put them in the Q and A session and Dr. Pam Rowell will put them to the meeting.

We have finally signed a 999-year lease on the property [applause]. I'd like to thank, on behalf of the Societies, Dr. Andrew McDonald of the Society of Antiquaries who did a lot of the spade work, and I'd also like to thank the courtyard Presidents, Treasurers, and CEOs both present and past. I also wish to thank Mike Edmunds and James Hammond, who, along with me, signed all the documents, and Richard who applied the stamp. I personally wish to thank Phil Diamond who stayed calm whilst I was panicking. They all deserve another round of applause [applause].

The first talk is by Professor Pilar Ruiz-Lapuente, presently a Research Professor at the Instituto de Física Fundamental in Madrid and a Visiting Professor at the Instituto de Ciéncies del Cosmos at the University of Barcelona. She did her graduate work at Garching and ESO and has held postdoctoral positions at the Institute of Astrophysics in Paris and at the Harvard Smithsonian Center for Astrophysics. Her first tenured position was Associate Professor at the University of Barcelona and she participated in the Supernova Cosmology Project (SCP) which resulted in the discovery of the expansion of the Universe, for which she shared the Gruber Cosmology Prize in 2007 and the Breakthrough Prize in Fundamental Physics in 2015. Previously she was awarded the Distinction for Research from the government of Catalonia in 2002. She has edited two books on type-Ia supernovae and dark energy and is the author of three popular books on the expansion of the Universe, and philosophical questions relating to physics and chemistry. At present, with the SCP she has found indications that the dark energy responsible for the accelerating expansion of the Universe is likely not to be the cosmological constant; she is also working on the Hubble tension. Please welcome Professor Ruiz-Lapuente to talk about 'What type-Ia supernovae are telling us about the Universe'.

Professor Pilar Ruiz-Lapuente. If we have to give an account of how the expansion of the Universe was discovered, there are certain achievements that we usually mention. First, in 1915, Vesto Slipher had seen that most galaxies (then called nebulae) seemed to move apart from us. This was derived from the shifts towards the red wavelengths of the characteristic spectral lines of such nebulae. The distance determination to those galaxies by Hubble provided a first value of the Hubble constant H_0 which was of 500 km $s^{-1}Mpc^{-1}$. Lemaître had also used Slipher's velocities and available distances to derive a larger value, 575 km $s^{-1}Mpc^{-1}$. The available predictions of cosmological models based on General Relativity developed by Friedmann and Lemaître allowed us to interpret the distance–recession-velocity diagram as that of an expanding Universe. The fact is that both Hubble and Lemaître aimed at obtaining the rate of the expansion of the Universe at about the same time. Nowadays, we know the result that the galaxies are moving away with velocities proportional to their distance as the Hubble–Lemaître law. The evolution in time of this law, which corresponds to the evolution of the rate of expansion of the Universe is the Hubble–Lemaître parameter $H(t)$. The value of H_0, the present value of $H(t)$, has gone down since the earliest determinations placed the galaxies too close, due to an inadequacy of the methods used. In the 1990s, there were several approaches proposed to obtain H_0 and discrepant values were in the range 50 to 100 km $s^{-1}Mpc^{-1}$. *The Hubble Space Telescope* Key Project in 2001 determined H_0 to be 72 ± 8 km $s^{-1}Mpc^{-1}$. However, later on, the value of H_0 measured from the fluctuations in the power spectrum of the CMB in 2018 gave $H_0 = 67{\cdot}4 \pm 0{\cdot}5$ km $s^{-1}Mpc^{-1}$. In contrast, H_0 is found to be between 69 and 74 km $s^{-1}Mpc^{-1}$ from various methods working on the distance ladder. In particular, the use of Cepheids by Riess and co-workers in their SH0ES programme gives $H_0 = 73{\cdot}3 \pm 0{\cdot}9$ km $s^{-1}Mpc^{-1}$, a discrepancy at the $5{\cdot}7\sigma$ level with the CMB value. Such a difference is nowadays referred to as the Hubble Tension. It seriously questions the ΛCDM model and some authors claim the need for new physics in the early Universe to make the *Planck* value compatible with that derived by methods involving low-z astrophysical distance indicators such as Cepheids. This year there have been some other issues questioning the ΛCDM model. In 2024, we had indications that dark energy might not be the cosmological constant, but a component whose equation of state varies with time. That would make dark energy different from vacuum energy. The Union3 SNe-Ia sample determined that the equation of state is at $1{\cdot}7$–$2{\cdot}6\sigma$ tension with vacuum energy. The DESy5 SN results also found tension at a similar significance level $\sim 2\sigma$. Those data together with the DESI BAO acoustic oscillations do not favour $w_0 = -1$, $w_1 = 0$ either (the parameters corresponding to a cosmological constant). The final significance level is around $3{\cdot}9\sigma$. Another important cosmological question is the isotropy of the Universe. The value of the Hubble–Lemaître parameter along redshift in different directions of the sky can tell us whether the cosmological principle holds. The cosmological samples of SNe Ia can give us very useful tests. In this summarized account, we will expand preferably on the key question of whether the Hubble tension exists. We will do it by reviewing our new method to go straight to the Hubble flow to test H_0, avoiding the three steps required if one wants to calibrate with Cepheids in a middle range of distance of 40 Mpc. The middle step requires the elaboration of a non-linear relation of the absolute magnitude of a fiducial SN Ia, M_{B0}, with rate of decline of the light-curve, *i.e.*, luminosity for a SN Ia of stretch 1, colour $B-V$ at maximum 0, and reference mass of the host galaxy. One can simplify the procedure and go straight to the Hubble flow by using SNe Ia twins. Fakhouri *et al.* in 2015 found that by using SN-Ia pairs with closely matching spectra

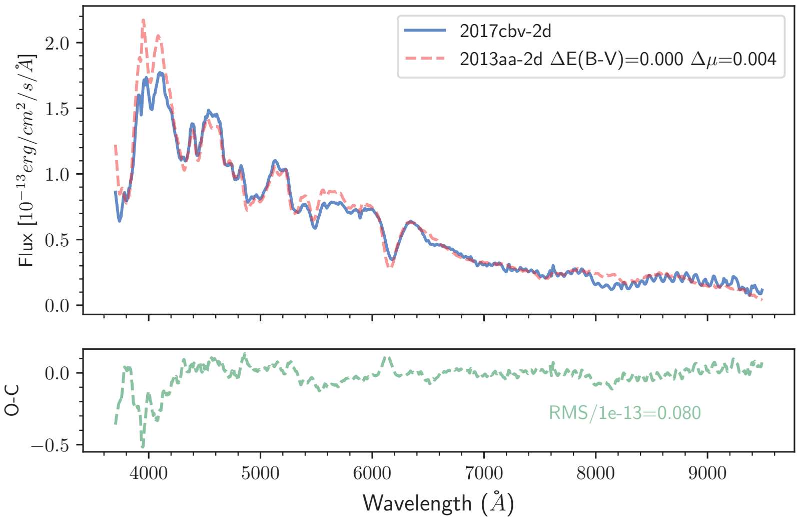

Fig. 1a
Comparison of early-time spectra of SN 2013aa and SN 2017cbv at 2 days before maximum light.

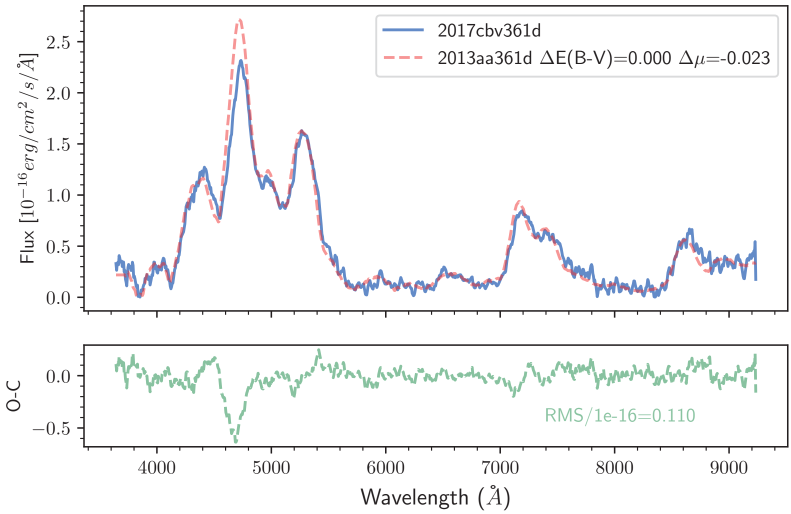

Fig. 1b
Comparison of late-time spectra of SN 2013aa and SN 2017cbv at 361 days past maximum light.

from the SN Factory sample, they achieved a reduced dispersion in brightness. They were able to standardize SNe Ia in the redshift range z between 0·03 and 0·08 to within 0·06–0·07 mag. Their aim was to determine with more precision the nature of dark energy. In our case, we want to use the similarity of SNe Ia not only in the light-curve but also in spectra along the evolution of the SNe Ia to measure its distance better. We called it the 'twins for life' approach and it provides a direct measurement of distance, intrinsic colour, and reddening caused by Galactic and extragalactic dust by the use of the whole spectrum of the SN Ia. It allows the consistent pairing of SNe Ia through all phases. The selection of twins is made of SNe Ia with a similar stretch, being then of similar luminosities, but in addition the 'twinness factor' can make more precise the distance estimate, with a modulus error of 0·04 mag in all filters, as we showed. This is 2% in relative distances. So, all this makes a very useful tool to obtain the right distance ladder. To the relative distance error of 2% one has to add the error of the anchor, of another 2%. Those anchors to serve as reference distances are chosen from nearby galaxies for which a consensus in the distance from various methods has been reached with the latest *JWST* measurements (NGC 5643, M101).

It has been proven that comparison of twin SNe Ia can provide a robust way to establish the extragalactic distance ladder. Here in Figs. 1 and 2 we show how we apply the method. The method has been applied to the twins in the galaxy NGC 5643: SN 2013aa and SN 2017cbv. The comparison using spectra before maximum and at the nebular phase shows that the error in the distance determination is of $\Delta\mu \sim 0{\cdot}000 \pm 0{\cdot}005$ mag.

We have already applied the method to galaxies in the Hubble flow, using SNe Ia from the Carnegie Supernova Project I. The SNe-Ia light-curves nearby and in the Hubble flow have the same rate of decline. They are also of the same spectral subtype and they are perfect twins. In Fig. 3, we show SN 2013aa compared with SN 2008bf in two phases (other phases give the same perfect match). The distance derived from this comparison is $76{\cdot}92 \pm 1$ Mpc. The perfect match of the spectra makes the blue and red lines almost indistinguishable. This has been applied to several galaxies in the Hubble flow and a value of H_0 has been obtained. From this work, it is clear that the Hubble tension is real. This is an important corroboration, since the method is very straight forward. The method goes from nearby galaxies to the Hubble flow with $d > 65$ Mpc without stopping in the middle. With the advent of very large samples (> 1000) of SNe Ia, it has been possible to determine in a better way the equation of state of dark energy. The latest suggestions are that dark energy might not be vacuum energy or the cosmological constant. The hints come mainly from two collaborations: the DESy5 SN with ~ 1500 SNe Ia in the redshift range $0{\cdot}10 < z < 1{\cdot}13$ and the Union3 (Rubin *et al.* 2023) sample of 2000 SNe Ia with z from 0·01 to 1·7. Whereas the discovery of dark energy involved 42 high-z SNe Ia by Perlmutter *et al.* in 1999, and ten high-z by Riess *et al.* in 1998, these new samples of thousands and the new ones to come are testing the present value of the equation of state w_0 and its evolution w_a. Both data samples do not favour anymore the cosmological constant (which has $w_0 = -1$ and $w_a = 0$). The results obtained from these samples favour $w_0 > -1$ and $w_a < -1$. Thus, dark energy is evolving in time and there are new proposed candidates discussed in the literature. More data are coming in 2025 and will bring us more information. With the large SNe-Ia samples, tests on the isotropy

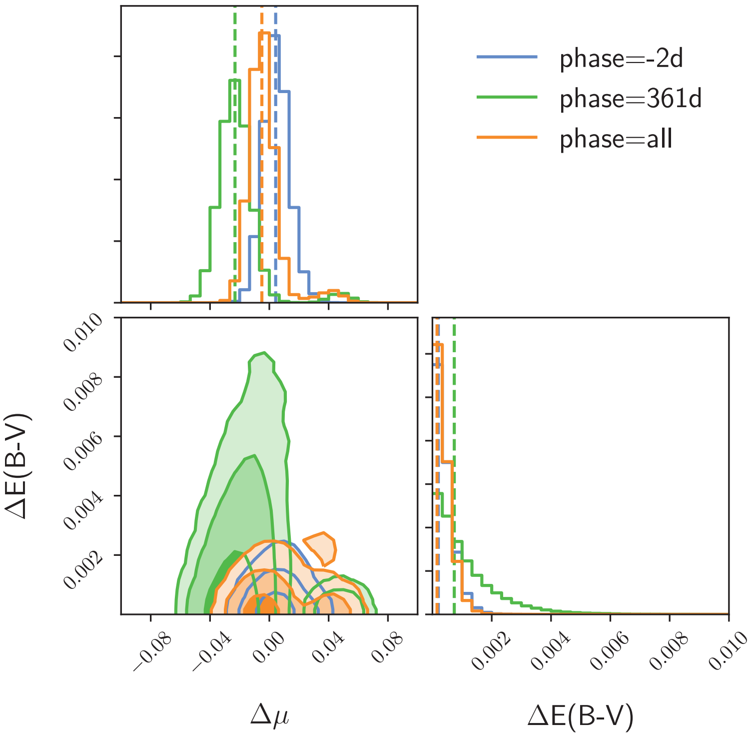

FIG. 2

The results for SN 2013aa and SN 2017cbv showing the corner plots with the 1σ, 2σ, and 3σ confidence regions favoured by each phase and those from the joint computation.

of the expansion of the Universe can be done. Samples such as the DESy5 SN and Pantheon+ have been analysed by various groups to see whether H_0 is the same along different directions in the sky. There is debate about it. Our present analysis points to an anisotropy at around ~ 2σ level in Pantheon+, but to isotropy in other samples. So, the question deserves further examination. Along these lines, we have reported work on SNe Ia using cosmological samples that are setting a new frame for our cosmological model. We first have presented our view on whether there is Hubble tension or not, from a new method developed by us that is able to achieve high accuracy in distance estimations. The purpose of this talk has been to give a brief account of what SNe Ia are telling us about our Universe. We have tested whether the ΛCDM model is well in accordance with what we learn from SNe Ia. In this respect, we think that there are reasons to suggest that some modifications are needed. Briefly: (*i*). The Hubble tension is real. We have seen with our use of 'SNe Ia twins for life' that a value such as the one provided by the CMB of $H_0 = 67{\cdot}4 \pm 0{\cdot}5$ km s^{-1}Mpc^{-1} is far from the H_0 indicated by our direct twin-to-twin distance ladder. Though the

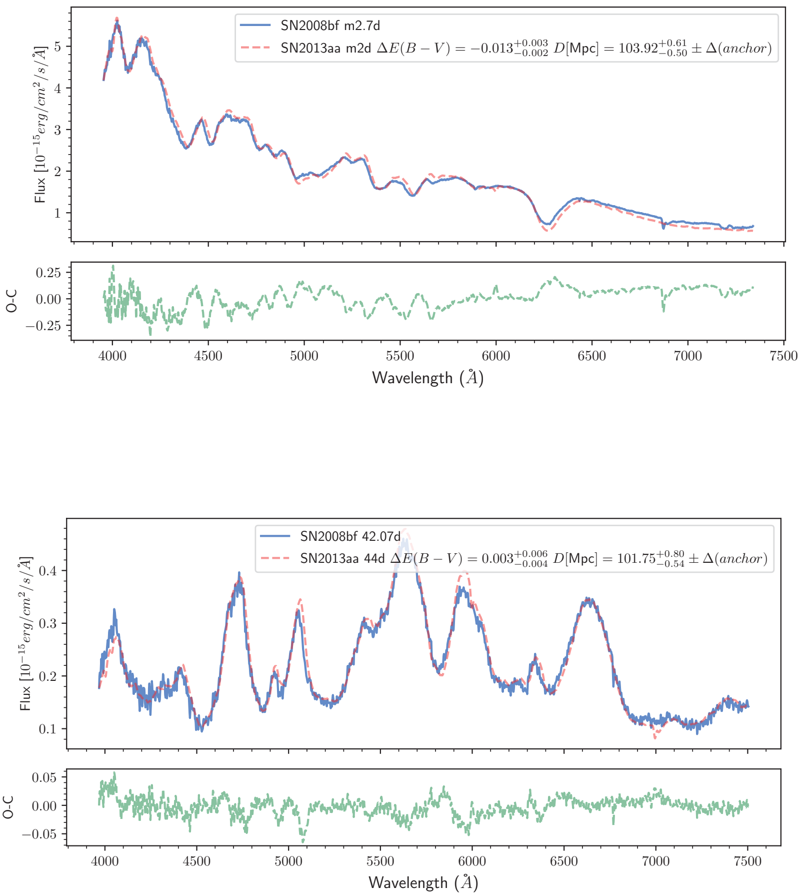

Fig. 3

(Top) Comparison of early time spectra of SN 2013aa and SN 2008bf at 2 days before maximum light. (Bottom) Comparison of the spectra of SN 2013aa and SN 2008bf at 42 days past maximum light.

sample needs to be enlarged, we find that our distances bring H_0 to the range 71 km s^{-1}Mpc^{-1}, with the error in process of evaluation. In fact, 67 km s^{-1}Mpc^{-1} can only be reached from highly significantly erroneous distances to SNe Ia and their galaxies in the Hubble flow. Some early dark energy might be needed to be added to our cosmological model. (*ii*). There is evidence that dark energy is not the cosmological constant, but it varies with time, though more SNe Ia are needed to see whether this still holds at a higher significance level. (*iii*). There is a lot of activity on testing the isotropy of the Hubble expansion along different directions in the sky. Contradicting results are found at this point by various authors, and further research is needed. The coming years will shed some light on the cosmological model of our Universe. We look forward to the new data to come and to theoretical ideas that will bring a better understanding of the Universe.

The President. Thank you very much. Are there any questions in the room?

Reverend Garth Barber. How robust is the assumption that SNe Ia are standard candles out to cosmological distances, say $z = 1$, given that you might have evolution of the fractional elements? And secondly we have heard that there are at least three models for supernova, including single degenerate, double degenerate, and core degenerate, and might the mix of the different types of supernova vary over cosmological time?

Professor Ruiz-Lapuente. We use a purely empirical relationship to calibrate the luminosities of supernovae independent from any model. Supernovae as old as those at high redshift are found nearby. Even if they are less luminous, their light-curves decay more rapidly and by the relation of maximum brightness to rate of decline we account for that.

The President. I have read quotes from Einstein saying that his biggest mistake was including the cosmological constant and also saying that his biggest mistake was taking it out again. Can you say which of these is correct?

Professor Ruiz-Lapuente. The first one was when talking with George Gamow. The second one never took place. At the time of Einstein's death nobody was advocating the return of the cosmological constant.

The President. Thank you very much again [applause].

The next speaker today is Dr. Or Graur, Associate Professor of Astrophysics at the University of Portsmouth's Institute of Cosmology and Gravitation, Research Associate at the American Museum of Natural History, and also an Honorary Research Professor at University College London. He conducts observations of supernovae and tidal-disruption events which are luminous flares caused by stars ripped apart by supermassive black holes, as well as cultural studies of the myths of the Milky Way. His popular science books include *Supernova* and *Galaxies*, both published by MIT. He is going to talk to us about 'Old Dogs, New Tricks: Late-time observations of type-Ia supernovae with the *Hubble Space Telescope*'.

Dr. Or Graur. Supernovae are the superheroes of the Universe, as recognized even by DC Comics, creators of superheroes such as Superman, Batman, Wonder Woman, and even a superhero called Supernova. Unlike this superhero, who can only fly and emit bright flashes of light, real supernovae play many important roles in the Universe. As the explosions of stars, they are the endpoint of stellar evolution for all stars more massive than eight times the mass of the Sun, as well as many white dwarfs. Core-collapse supernovae leave behind stellar remnants in the form of neutron stars and stellar-mass black holes. The explosions create many of the heavy elements in the Universe and disperse them into interstellar space, where they are recycled into the next generation of stars. The expanding explosion fronts, called supernova remnants, gouge holes in the inert gas of the interstellar medium (such as the Local Bubble through which the Sun is currently travelling) and accelerate cosmic rays to relativistic velocities. Finally, and perhaps most famously, certain supernovae, called type-Ia supernovae, are used as standard candles to measure extragalactic distances and constrain cosmology.

I want now to focus solely on type-Ia supernovae. Ever since my PhD, I have tried different methods to constrain the nature of the progenitors of these supernovae. While it is widely agreed that the exploding star is a carbon–oxygen white dwarf, it is still unclear how to blow up such an inherently stable star. Leading theories place the white dwarf in a binary system where it either steals gas from a non-degenerate companion (such as a red giant) or merges with a second white dwarf. There are several ways to constrain these progenitor scenarios, including searching for the companions in pre-explosion images or measuring the rates at which type-Ia supernovae occur in various types of galaxies. All of these methods span time-scales of hundreds of thousands of years before the explosion to thousands of years afterwards. One time-scale, however, remained unaddressed for many years: the behaviour of type-Ia supernova light-curves several years after explosion.

The light-curves of type-Ia supernovae are powered by the radioactive decay of iron-group elements created during the explosion. With a half-life of ~ 6 days, the decay of ^{56}Ni to ^{56}Co dominates the first days of the explosion. The light-curve then proceeds to be dominated by the decay of ^{56}Co to stable ^{56}Fe, which has a half-life of ~ 77 days. For most observers, this is where the story ends, as type-Ia supernovae are rarely followed for more than a few weeks, let alone a few months. However, in 2009, a team led by Ivo Seitenzahl suggested that, starting roughly 1000 days after the explosion, the fading of the supernovae would slow down as X-ray photons and electrons from the long-lived decay chains ^{57}Co → ^{57}Fe (half-life of ~ 272 days) and ^{55}Fe → ^{55}Mn (half-life of ~ 1000 days) would begin to dominate the energetics of the light-curve.

In 2016, I led a group that conducted *Hubble Space Telescope* observations of a nearby type-Ia supernova, SN 2012cg, out to 1055 days. We found that the light-curve did indeed slow down and was consistent with the combined radioactive decays of ^{56}Co → ^{56}Fe and ^{57}Co → ^{57}Fe (Fig. 4). These results were quickly corroborated by similar observations of SNe 2011fe and 2014J.

Theorists soon showed that the same light-curve, especially that of SN 2011fe, could be fit with other models that caused the light-curve to slow down: atomic 'freeze-out', a variable magnetic field in the supernova ejecta, or delayed deposition of energy into the ejecta. There are two ways to test the various models. First, where possible, continue to observe the same supernova out to > 2000 days, where a second kink due to the radioactive decay of ^{55}Fe → ^{55}Mn should become apparent. To date, only SN 2011fe has been followed that long, and observations purport to show the expected kink. The other tack is to study samples of supernovae and search for correlations between their light-curves and other intrinsic properties. There might be such a correlation between the rate at which the light-curves slow down and the intrinsic luminosity of the supernova, similar to the correlation used to standardize these supernovae for use in cosmology. However, at the moment, this claim rests on no more than five objects. A *Hubble Space Telescope* programme carried out by my postdoc Dr. Huei Sears is expected to triple this sample and either validate or reject this correlation.

From optical observations, I would like to move on to the near-infrared, where we have discovered a surprising plateau in the J and H bands from 150 to 500 days past maximum light (Fig. 5). A follow-up ground-based project carried out by Dr. Maxime Deckers doubled the number of objects on the plateau and showed conclusively that it was present in J and H, but not K. Dr. Deckers also showed that the onset of the plateau was due to a shift in the dominant ionization state of the supernova ejecta from doubly-ionized to singly-ionized

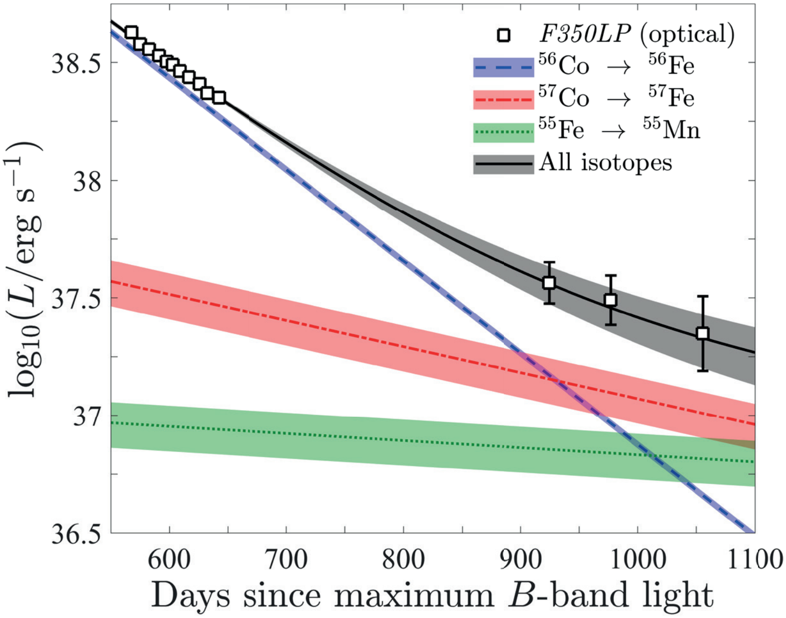

FIG. 4

Luminosity contributions in SN 2012cg from the decays of ^{56}Co (blue dashed), ^{57}Co (red dashed), and ^{55}Fe (green dotted). The total luminosity produced by these decay chains (black solid) fits the F350LP measurements with a χ^2 value of 2·1 for 12 degrees of freedom. (From Graur *et al.*, *ApJ*, **819**, 31, 2016.)

iron-group elements. As part of this process, ultraviolet photons are scattered to longer wavelengths, creating the plateaus in *J* and *H*.

Type-Ia supernovae come in several flavours. So-called 'normal' type-Ia supernovae are used in cosmology, but there are several other subtypes, from under-luminous 1991bg-like (Fig. 6) and Iax-like supernovae to over-luminous 1991T-like supernovae. Since all my previous *Hubble Space Telescope* observations had been of normal type-Ia supernovae, I set out to look for the near-infrared plateau in a 1991bg-like supernova called SN 2021qvv. I found no evidence of a plateau in that supernova, but noted that it was one of the dimmest of its kind ever observed. That leaves a window open for the plateau to appear in more luminous examples of this class.

Finally, I would like to discuss how my work on SN 2021qvv made me take a closer look at 1991bg-like supernovae, which I had mostly ignored in the past. To my surprise, I discovered that these supernovae were also standardizable, even though for decades it had been assumed that they were not. The trick was using the correct light-curve-shape parameter: the colour-stretch parameter s_{BV} instead of the more common s, x_1, or Δm_{15}. The fact that these supernovae were standardizable after all had been shown in the past by the Carnegie Supernova Project in a 2018 paper, but the wider community had failed to notice it.

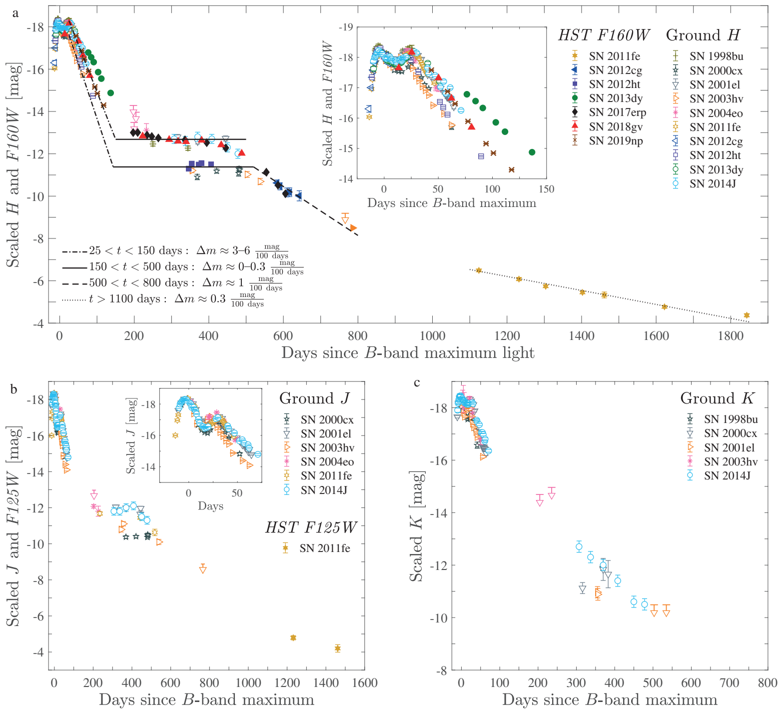

FIG. 5

SN Ia near-infrared light-curves. Although standard to ~ 0·1 mag at peak, the *H*-band light-curves (a) begin to branch out after the second peak, with decline rates in the range 3–6 mag/100 days. At ≈ 150 days, the light-curves settle into a plateau phase that lasts until ≈ 400–500 days, when they once again transition into a second decline phase with a rate of ≈ 1 mag/100 days. At the plateau phase, the SNe have a range of ~ 2 mag, where the brighter SNe had slower decline rates before entering the plateau. The measurements in this plot have been scaled to the light-curve of SN 2011fe. Using this scaling, the plateau phase is also apparent in the *J* band (b). Synthetic photometry of SN 2014J in the *K* band (c) show no hint of a plateau in this wavelength range. Black curves, meant to guide the eye, represent the distinct phases of the *H*-band light-curve. Representative decline rates along each phase are noted in the legend at the bottom of the upper panel. Error bars represent 1σ measurement uncertainties, while downward arrows indicate 3σ upper limits. (From Graur *et al.*, *Nature Astronomy*, **4**, 188, 2020.)

Now that two different groups have shown that 1991bg-like supernovae are standardizable, we can use them to construct a new cosmological distance ladder, one that would be independent from the ladder that uses Cepheids and normal type-Ia supernovae. A new ladder would then provide an independent measurement of H_0 and hopefully help settle the current Hubble Tension.

The President. Questions in the room?

Reverend Barber. With single-degenerate, double-degenerate, and core-degenerate types of supernovae, can you tell which is which from the spectrum and distance?

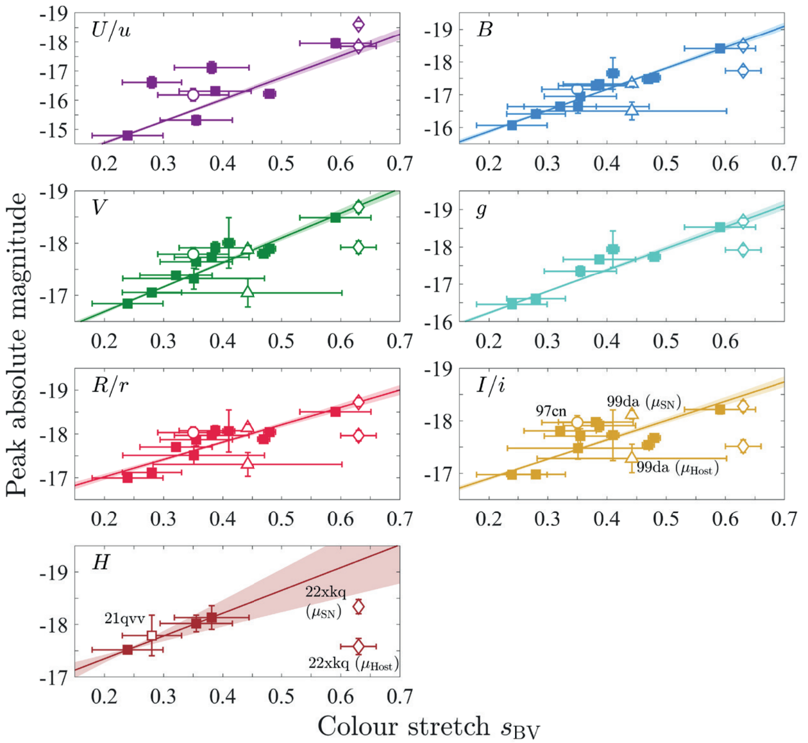

FIG. 6

Peak absolute magnitude *versus* colour stretch, s_{BV}. Magnitudes have been corrected for Galactic line-of-sight reddening. The shaded regions around the linear fits represent the 1σ uncertainties of the fits. The correlations, calculated using the calibration sample (filled squares), are statistically significant in all filters except U/u. SNe 1997cn, 1999da, and 2022xkq are shown as an open circle, triangle, and diamond, respectively. SNe 1999da and 2022xkq are shown twice, once when using a host-based distance modulus (μ_{Host}) and once when using a distance modulus derived by SN light-curve fitters (μ_{SN}). For clarity, the second measurements of SNe 1999da and 2022kxq are shown without their horizontal error bars. The *H*-band measurement of SN 2021qvv, shown as an open square, is not used in the fit. (From Graur *et al.*, *MNRAS*, **530**, 4950, 2024.)

Dr. Graur. One of the great hopes was that we would be able to tell between them using these late-time observations because each of the progenitor scenarios gives you a different composition for the white dwarf. You should get different amounts of these radioactive isotopes; I wasn't able to test this with my data, but Ben Shappee claims you can do this with 2011fe. That is why you have several lines on the plot. I'm not convinced by this yet, especially since we are not persuaded that you can explain this just by the radioactive decay change.

Reverend Barber. Is it a work in progress?

Dr. Graur. Yes.

The President. Any more questions? Just a semantic point. I don't think it is the supernovae that have the new tricks, I think it is the theorists!

Dr. Graur. Well, I'm an observer! [Laughter.]

The President. Thank you very much for your talk [applause].

Now we come to the George Darwin Lecture to be given by Professor Chiaki Kobayashi of the University of Hertfordshire. Professor Kobayashi is an internationally recognized leader in the field of the chemical evolution of galaxies and is a pioneer in the study of the origin of the elements, a subject which bridges nuclear physics and astrophysics. She was awarded a PhD from the University of Tokyo in 2002 and has worked in Germany and Austria as well as the UK. As well as running large-scale computer simulations of galaxies, she is also involved in a number of observational surveys with a particular focus on elemental abundances. She is well known for having created an astronomer's version of the periodic table. So I ask Professor Kobayashi to talk to us about 'The origins of elements in the Universe'.

Professor Chiaki Kobayashi. [When the Universe started with the Big Bang 13·8 billion years ago, only light elements such as hydrogen and helium were produced. Carbon and heavier elements that matter to human beings and modern technology were instead created inside stars. Computer simulations allow us to predict the complex history of the Universe starting from the formation of stars, the production of elements, and the evolution of the element distribution in galaxies. These theoretical predictions have been tested with detailed observations of stars in the Milky Way. Thanks to the *James Webb Space Telescope* it is now also possible to study elemental abundances in very early galaxies, which has brought a surprise, that might also be a clue to understanding the origin of elements in the early Universe.]

The President. Are there any questions?

Mr. Suryansh Saxena. Referring to the slide of supernovae and time-scale — what does this tell us about the elemental composition of the early Universe and how does it help in influencing the model we have for stellar and galactic structure now?

Professor Kobayashi. We know that massive stars produce more oxygen than iron. This figure shows how long this stage continues. The area between oxygen to iron is flat. From the earliest time to now, star formation takes place very quickly, and we can work out how many massive and low-mass stars can be formed. We can use this as a cosmic clock — how quickly star formation took place in each area of the galaxy — in the bulge, for instance. How much gas flows in from the outside to that area? As to the second question — how much gas is frozen into that area — how much outflow takes place? These things can be constrained by looking at other elements.

Mr. Howard Bromley. Do you have your periodic table for the isotopes as well?

Professor Kobayashi. I do!

Mr. Bromley. But not with you?

Professor Kobayashi. Not here. The nuclear physics is actually not that accurate for some isotopes so when I compare with observed isotope ratios in the metal lines, there is some mismatching still. The nuclear physics has to be exactly right. I'm still working with nuclear physicists to get the isotopic ratio of a similar table.

Professor Ian Crawford. In light of the neutron-star mergers and your more recent paper that you published since that periodic table, would you now revise the relative contribution of neutron-star mergers and type-II supernovae?

Professor Kobayashi. Core-collapse supernovae dominate at low metallicity but neutron-star mergers may dominate at high metallicity. I am now working with people on neutron-star mergers as the best prediction for how much of each element should be produced by each event. What is the mass ratio between the compact objects? The relative contribution between neutron-star mergers will be different with the new improvements from binary-star studies.

The President. In my undergraduate lectures I have always known that when it came to element abundances I would simplify and I have just learned by how much! [Laughter]. I used to make fun of Joni Mitchell — she sings in her song *Woodstock* "we are stardust" and then "we are golden". One of my students pointed out that gold is a very important component of our brains because of its electrical properties, so although we are not exactly golden it's an important part of us so it is interesting that it is still a mystery. One more round of applause for a wonderful lecture. [Applause.]

Finally, drinks will be back in our new house and the next monthly A and G Highlights meeting will be on Friday, December 13th. What can go wrong?

MEETING OF THE ROYAL ASTRONOMICAL SOCIETY

Friday 2024 December 13 at $16^{h}\ 00^{m}$
in the Geological Society Lecture Theatre, Burlington House

MIKE LOCKWOOD, *President*
in the Chair

The President. Welcome to the meeting. This is a hybrid meeting. Questions can be put in the Q and A and they will be read out by Dr. Pam Rowell. As you will know we are losing Phil Diamond in about six months. He will be an extremely hard act to follow but we are in the process of finding a successor.

Our first talk is from Deborah Kent from the University of St. Andrews. She is a reader in history and mathematics at the School of Mathematics and Statistics and is an affiliate at the Institute of History at the University of St. Andrews. Her research focusses on mathematical sciences in the 19th and 20th Centuries with a recent emphasis on 19th-Century eclipse expeditions including personal experience from two 21st-Century total eclipses. She is a librarian of the London Mathematical Society, a Council Member of the British Society for the History of Mathematics, and a member of the RAS. Her talk is entitled 'To Burlington House and the Kerguelen Islands: The 150th anniversary of RAS movements near and far'.

Dr. Deborah Kent. I'm delighted to be here to speak about the 150th anniversary of RAS activity in two very different places in 1873: the well-known Burlington House and the less-familiar and less-hospitable Kerguelen Islands.

Beginning in 1820, the Society first met in various locations, including the rooms of the Geological Society, then in Covent Garden and later in rented rooms in Lincoln's Inn Fields. On receiving the original Royal Charter on 1831 March 7, the (then) Astronomical Society of London became the Royal Astronomical Society. In 1834, the government provided RAS accommodation in Somerset House, which housed other learned societies. Space soon became a concern. To address this, the British government bought Burlington House in 1854 for £140,000 (in 2023 this equates to £293·4 million) to put public