# A Planetary Scientist and Her Box of Pre-Solar Grains

Scientist Kuljeet Kaur is working on ‘experimental indirect astronomy’, which is one of the few ways to study the cosmos without telescopes.

Aashima Dogra

A rickshaw dropped me just outside the PRL scientists’ quarters. I entered my details in the security register and began searching for Kuljeet’s flat. When I found it, I realised I was perhaps a bit early. Her living room lay happily scattered with her six-year-old daughter Esha’s toys and stickers. The fragrance of freshly-made parathas filled the room. Though she wasn’t prepared, Kuljeet welcomed me warmly into her home. I watched her very patiently negotiate a few hours of quiet with her young child in exchange for some tablet time so we could do the interview.

Credit: Author provided

“It hasn’t been easy for me since I’m alone,” she said strongly, looking at me straight in the eye. Kuljeet describes the early years of her job at PRL as a divorcee and single parent the toughest time in her life. Though she has since remarried, she is still awaiting the day the new family can start their life together.

Even scientifically, Kuljeet lacks peers in the country. She said she is the only person in the country working on ‘experimental indirect astronomy’ which is one of the few ways to study the cosmos without telescopes. For a long time, there was no permanent staff in her team while she operated a giant sophisticated instrument to answer big questions such as ‘where do elements come from?’ and ‘what happened before the birth of our solar system?’

I realised over the course of our conversation that if anyone was strong enough to pull this off, it had to be Kuljeet.

**Sweat, blood and a broken NanoSIMS**

In 2007 Kuljeet returned to PRL, Ahmedabad (where she did her PhD) after spending three years doing postdoctoral research at Max Planck Institute in Germany and a brief stint at Washington University. She got right to the task of setting up a pioneering planetary science laboratory. The centrepiece of her lab would be the NanoSIMS – a highly sophisticated mass spectrometer, costing Rs 14 crores; a true national treasure considering there are only 22 of these in the world.

“When it reached India, the instrument fell down and broke,” Kuljeet began the story of her initial ordeal. The broken NanoSIMS was shipped back to France, where the manufacturers are located. It took around a year to return to PRL and to her dismay, Kuljeet found it still wasn’t completely fixed. ‘’No company will replace all the parts, so it started breaking again one by one. On one day the pump would stop working, the next day it would be the controller, and another day the regulator would break down.” With no permanent staff or technical/lab assistants at hand, Kuljeet repaired the NanoSIMS. “I was all alone. I was pregnant. I took no leave, no break…”

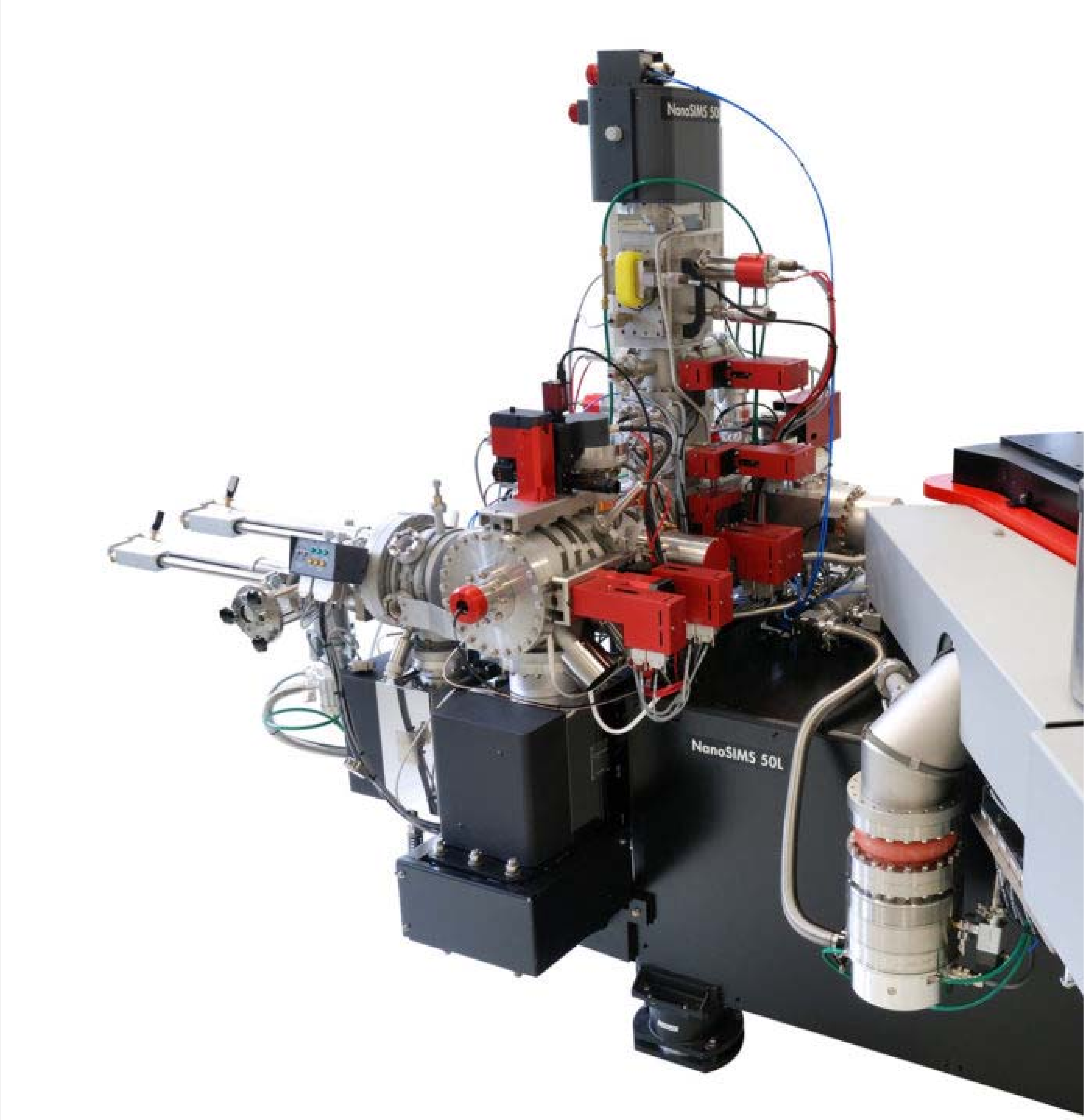
‘‘You should have seen me,” she chuckled good-naturedly. “With a big pregnant stomach – I was a divorcee at that time – I was fixing a broken instrument with screwdrivers and spanner, ultimate down (bad) time. I fixed the instrument with a lot of difficulties.”

Kuljeet did not take any kind of break during her pregnancy. She merely decided on the date she would have a C-section birth and then rested briefly before returning to work. “I made a PRL ID-card for Esha and from then on, my 40-day-old daughter was with me in the lab, sleeping there in the temperature of 19 degrees, night and day.”

“I have given my sweat, my blood and my daughter’s precious time to this instrument,” she confessed.

After this rough start, the situation slowly normalised and things began to look up for Kuljeet. The ordeal with the broken instrument had delayed her experiments to 2011 but she has caught up. Temporarily, she could get one permanent research staff thanks to funds from the Women’s Excellence Award she has received for her promising research. She updated me last week via email with the good news: “I have permanent staff with me now – so I am not alone in the laboratory – after 7-8 years!’’ Today, Kuljeet is proud of her studies published in “high impact journals – five in *Science*’’ including one on the activity of the young sun.

**What does the NanoSIMS do?**

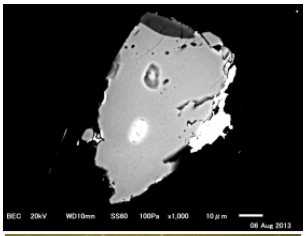


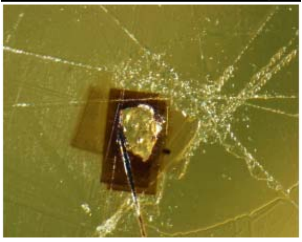

The NanoSIMS. Credit: CAMECA

“So this is the NanoSIMS,” she showed me a picture on her laptop. “This is my machine. It’s a beautiful instrument with 250 parameters – that’s a lot of tuning.”

The samples Kuljeet takes into her instrument are sometimes older than the Sun. The NanoSIMS can precisely separate different isotopes present in them based on their atomic mass. “I work with pre-solar grains. I analyse them in the NanoSIMS to look for isotopic ratios (heavy to light) which are signatures of events taking place when our sun was forming and the time before that,” she said.

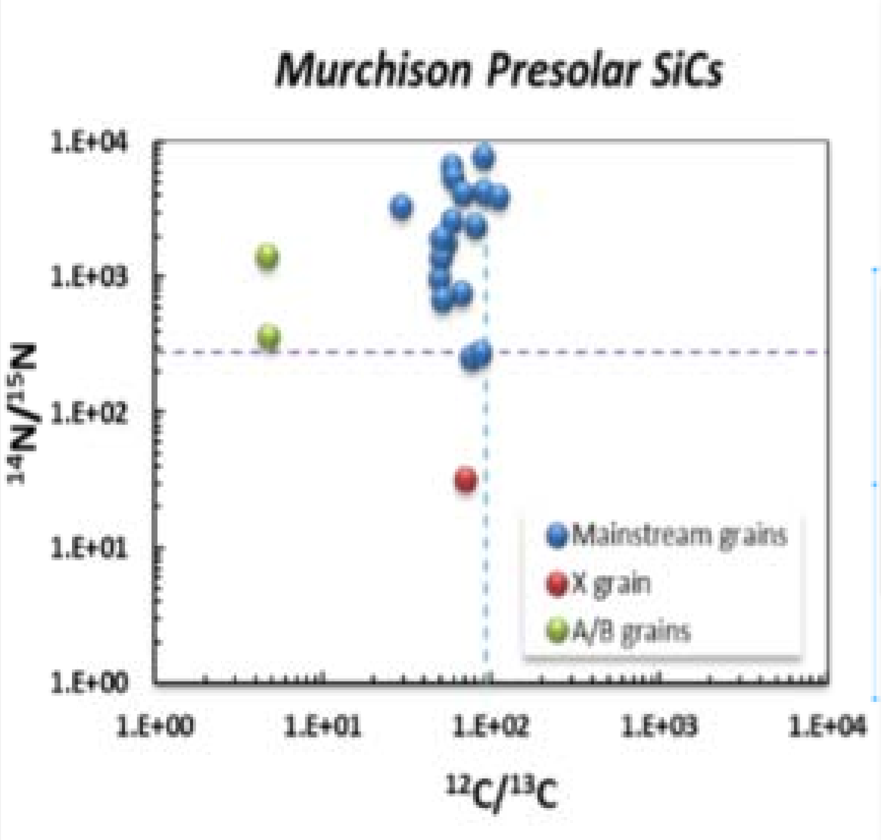
Before delving into the complex stuff, Kuljeet introduced to isotopes. “In your blood there is iron, in your teeth there is phosphate, in bones there’s calcium. If I want to separate these elements I could do some chemistry – it is not a big deal. But isotopes are different. A single element can have versions with different number of neutrons, hence different isotopes. For example, oxygen can come in 3 mass numbers – 16, 17 and 18. These are oxygen’s isotopes. If I want to separate 16, 17 and 18, I need a mass spectrometer.”



A piece of the Itokawa asteroid that Kuljheet is studying. Credit: Kuljeet Kaur

A mass spectrometer like the NanoSIMS has a large magnetic field with which it can spread out the sample into isotopes. This is possible as each of the isotopes has a different mass to charge ratio. What Kuljeet has in her hands is really a mass separator in the nano level. Once she has a ratio of heavy to light isotopes in the sample, she can tell where and when it might be coming from – is it from the baby sun or from another kind of star – and from which point in the stellar-solar evolution.



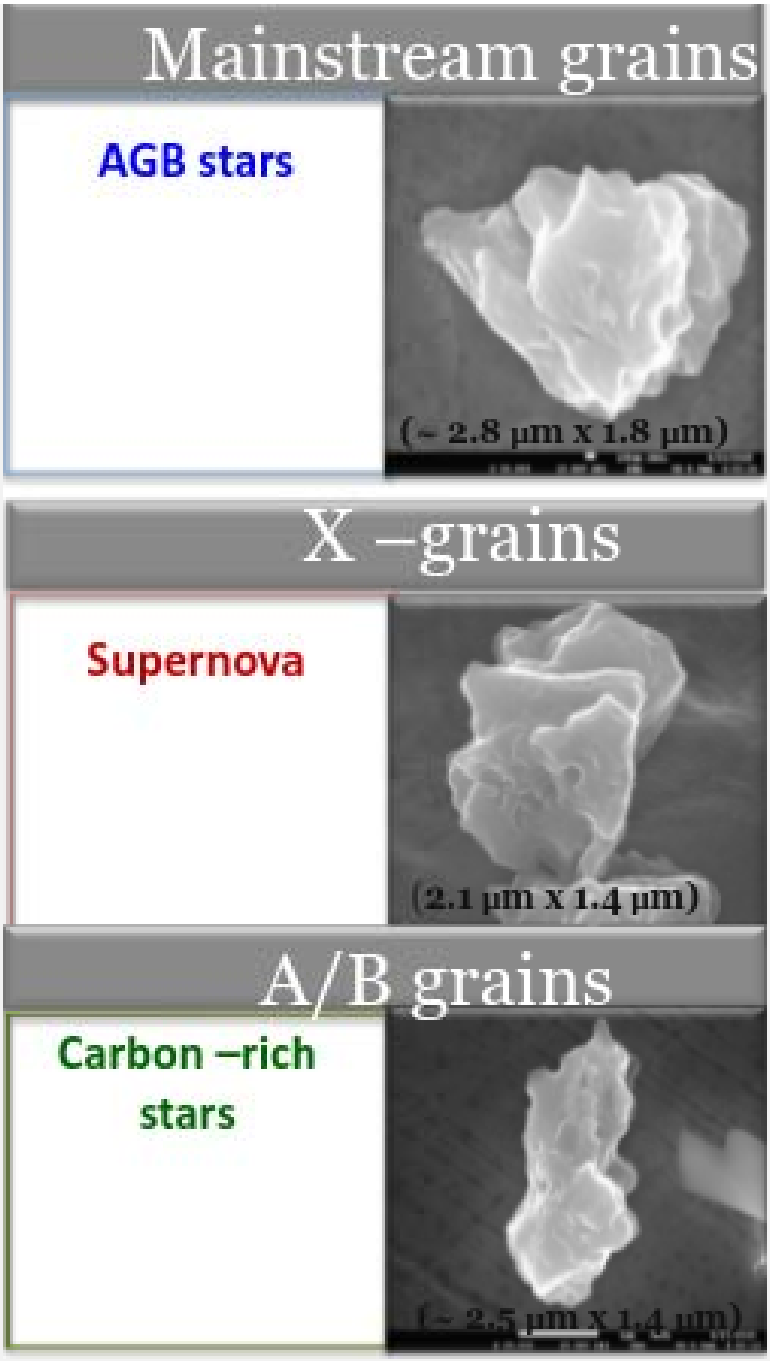

One of Kuljeet's graphs showing heavy to light ratio of Carbon and Nitrogen in different types of stars. Credit: Author provided

Supernovae are massive stars that end their life cycle with a dramatic explosion ejecting newly formed elements and other star stuff like gas and dust with a shockwave, commonly triggering the formation of new stars. The stars commonly observed to 'go supernova' are around 90 times heavier than the Sun.''I have worked on titanium isotopes, barium isotopes, silicon, nitrogen, carbon, oxygen, nickel, iron and most recently on chromium isotopes. These (chromium isotopes) are very special because supernovae are the only source of chromium – there is no other kind of stars that produce them. And they are made in the interior core of the supernova, like other transition metals like iron, not in outer layers where hydrogen, helium and oxygen can be found."

**Getting her hands on pre-solar grains**

"When a supernova explodes, the inner core has to come out. Nobody can tell us what the inner core is composed of, how fast the inner core is reacting, what is the mixing taking place between the different shells of a star. But presolar grains can."

Most of the pre-solar grains Kuljeet has worked were picked up from meteorites, often dubbed the poor man's space programme. "It comes to your house. It falls down right in front of you and you are lucky if it is a primitive one." There are also micro-meteorites that you can get from the depths of the ocean. Or if you fly a probe into the stratospheric region of the planet, there could be some dust that fell from comets passing close to Earth's orbit.



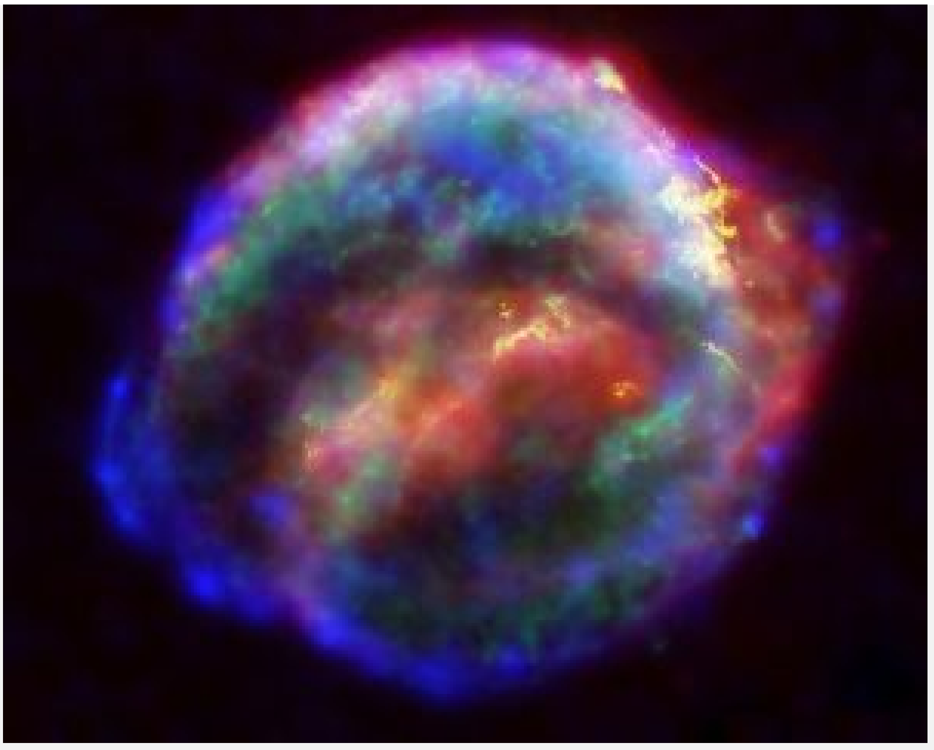

Solar Grains. Credit: Kuljeet Kaur

Besides relying on primitive meteorites that fall on Earth, Kuljeet has been constantly writing proposals to obtain grains collected in sample return missions on space voyages by the likes of NASA and the Japanese Space Agency JAXA. "I recently got samples from an asteroid named Itokawa which was brought to Earth by a JAXA sample return mission called Hayabusa. In India, I am the only one to touch an asteroid sample! Isn't that exciting?,'' she exclaimed.

During her time at Washington University, Kuljeet was part of the international team tasked with analysing samples retrieved from a sample return voyage to a comet called the Stardust mission. "You see these tracks?" she pointed at an image on her laptop. "These are the comet grains on it. I worked on one of these pieces. I removed the grain, put it on a thin film, got it into my NanoSIMS and analysed it. I touched the grain – not really, but with forceps.’’

## Where do elements come from?

In essence, Kuljeet’s work tries to point at something we have all wondered. We see elements everywhere, but where do they come from? Below Kuljeet explains the nucleosynthesis of elements, with which scientists like her are putting together the pieces of our galactic evolution.

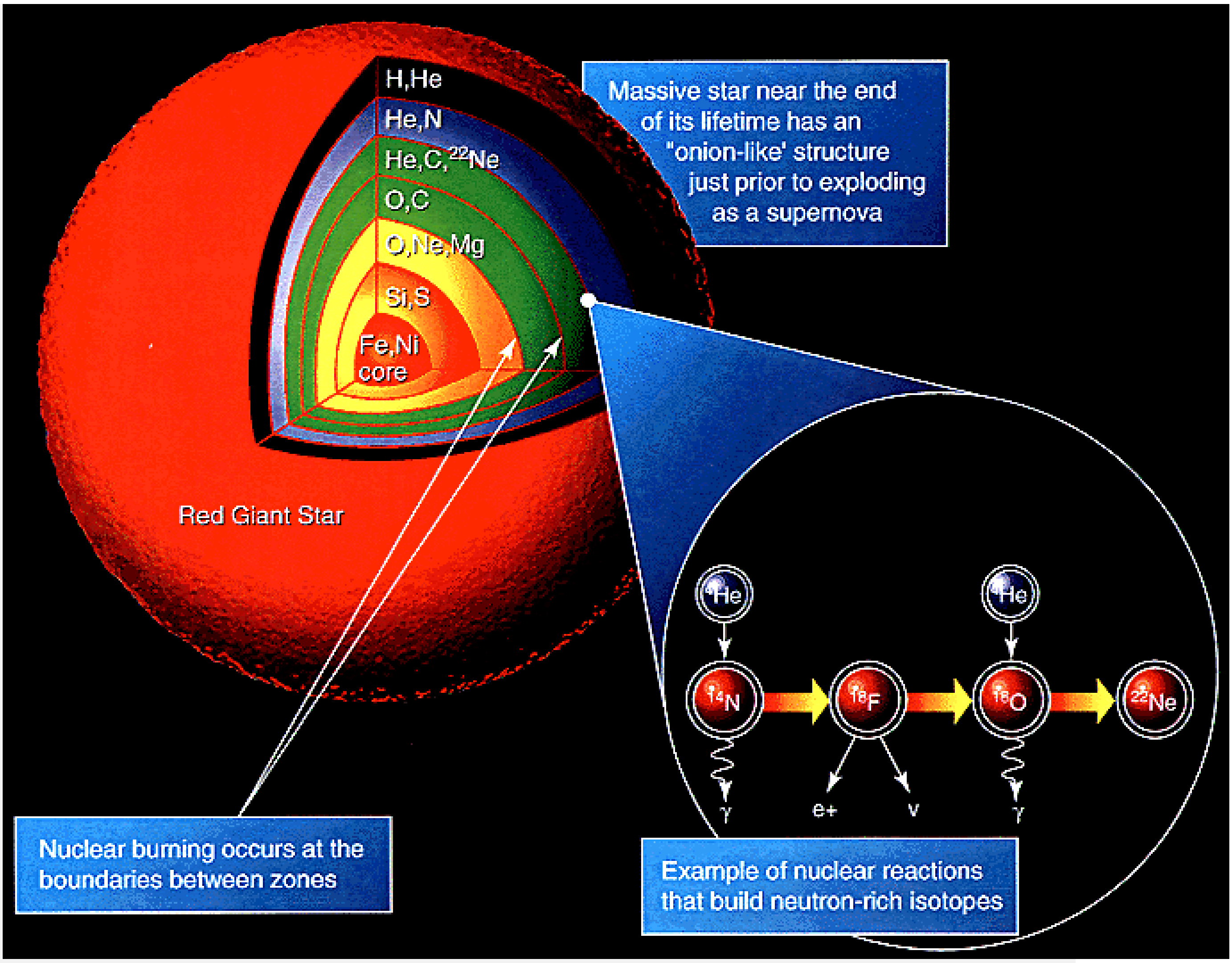


Composite image of Kepler’s supernova. Credit:NASA/ESA/JHU/R.Sankrit & W.Blair

“The reaction that goes on in any star is hydrogen + hydrogen = helium. Then, three heliums connect to form carbon if the star is a little bit more massive. Then it will rotate around in the core and there will be carbon, nitrogen, oxygen plus helium and hydrogen. This is all normal stars can do.”

“But a supernova has a more intense structure because it is heavier. If the stars have more mass, there is material to burn. After lots of carbon is formed and we still have more helium, there will be more carbon to burn. If it has a good enough carbon core then it will get denser and go beyond (on the periodic table).”

“All heavy elements that exist should have come from supernovae. And then there are the hundreds of normal stars that add on to the chemical evolution.”




Schema. Credit: Wikimedia commons

"For explanation sake, let's consider a time period of 1 billion years after the Big Bang with only two supernovae. Let's assume these produce a certain amount of iron isotopes that enter the cosmos where more and more stars are being born. These new stars will process pre-existing iron isotopes to take the chemical evolution further.  After 10 billion years there will be more supernovae, more elements being formed, but the early ones are also being processed in other stars. As they go into other stars, they are processed, meaning a neutron is being fitted into atoms. You feed a neutron to 54 isotope iron, it goes to 55, then it goes to 56. In this way, 56 iron is being enriched ('enrichment' signifies more than what you started with)."

"Galaxies are evolving in metallicity with time. It's a time process that we can date back."

For Kuljeet the fun of it all is in the fact that she can really go far back in time by working in her lab with isotopes found in pre-solar grains. "Just looking into data from my NanoSIMS I can see how the galaxy was evolving," she said.

**Facing the"two-body problem"**

During the course of her work, she has collaborated with several scientists around the world. With one of her collaborators, she is also married. Kuljeet married a fellow planetary scientist Ritesh Kumar Mishra three years ago. The two of them have coauthored at least four research papers but the young family lives apart.

“Esha is a bright kid but misses her father time to time and has a repetitive question: Why dad doesn’t stay with us?”

This unofficial rule of not allowing spouses to secure jobs at the same institute seems to run historically through academic institutions of our country. During this project itself, we have come face to face with this so-called ‘two-body problem’ too many times. Given that a large number of married women scientists we have interviewed are married to other scientists (15 out of 39), we identify this unofficial rule as one of the institutionally sexist policies that keep women from science.The answer to Esha’s question depends on the fate of a job application file that remains to be dealt with at PRL. According to Kuljeet, her husband, an applicant and alumni of the institute has all the right qualifications. “He is a Humboldt fellow at Heidelberg University in Germany. He was at Johnson Space Center, NASA for two years. We are looking forward (to having him in Ahmedabad) provided they feel that spouses can be accepted.”

Kuljeet and her daughter Esha. Credit: Author provided

You always crib about brain drain, here there is a person who has the merit and he’s trying to come back but he is not being taken just because he is my spouse.

Some institutes like IISER and IIT Kanpur have taken steps towards disregarding this rule by promoting the hiring of couples. But at PRL, as evidenced by Kuljeet’s case, something has got to give.

Kuljeet wonders: ‘‘He has several prestigious fellowships and if his application is not being considered — is it the spouse factor or a planetary scientist is not needed in India?’’

‘‘You always crib about brain drain, here there is a person who has the merit and he’s trying to come back but he is not being taken just because he is my spouse,’’ she said, obviously disgruntled at the double standards.

Srubabati, another scientist at PRL we have interviewed, faced a similar situation but in her case, the rule was lifted. “Sruba got lucky in the end. They also lived separately for many years,” Kuljeet said.

“I think we should be given an opportunity to have a better life for our children.’’

**I am a feminist, thanks to my father**

Kuljeet’s family, she is on the bottom left. Credit: Kuljeet Kaur

Something she heard one woman say at a women’s forum rings in Kuljeet’s ears. “She said ‘I cannot do everything because I don’t have a wife back at home.’” This statement attests that in most Indian families, wives are still expected to manage all of the household chores so that the husbands are free to fulfill their dreams. “Science is something you have to devote your life to. If you do all the work at home, you cannot go and do science too.”

To close the gender gap, Kuljeet recommends more fellowships for early career women in science are needed, as well as an increase in stipend so they can be financially independent and extension of PhD time for married women.

Most important, she said, is support from parents. “Not every woman has the support like I did. My parents and my sisters were with me during my divorce and my second marriage. Even now, when I have to go to conferences, my parents come to take care of Esha – but if I say I want to go away for a sports meeting, they tend to refuse. As long as it’s for science, they will be there but for anything else, it’s hard to get them here.” she said jokingly. “When your family supports you, you can be very strong.”

Kuljeet is grateful to her father for her interest and progress. “His name is Sardar Singh Marhas. He had three daughters who stood against his conservative family brooding over ruined marriage prospects to make way for higher education of his daughters. He started as an assistant in Bhabha Atomic Research Centre, Mumbai in the glass blowing section and then worked very hard to retire as Scientist E, the same scale on which I joined PRL.”

Kuljeet said her father is famous among her family for his progressive values, particularly for having said, “My daughters are not made for the kitchen”.

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