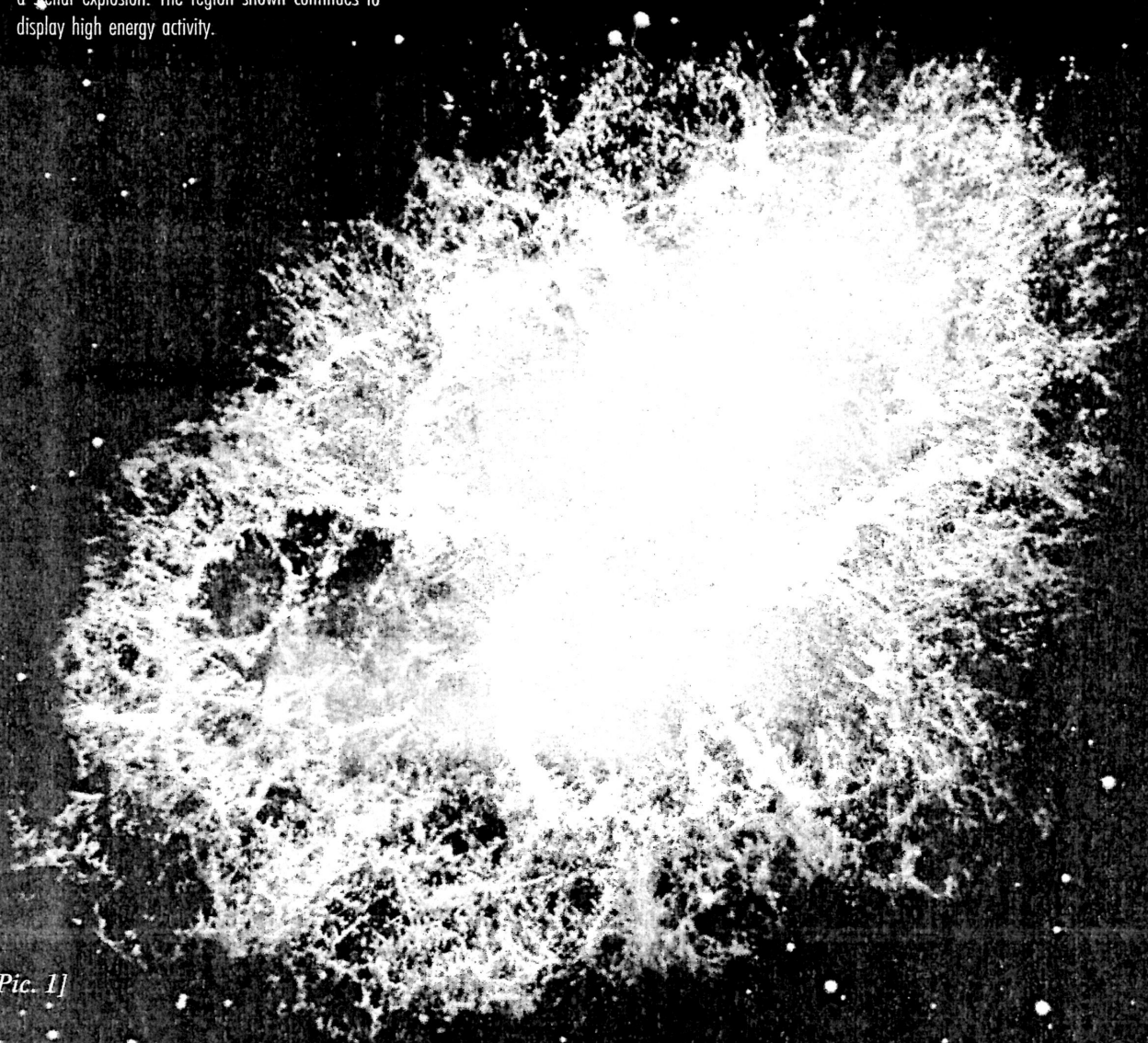


The photograph of Crab Nebula (courtesy of NASA). The filamentary structure indicates the aftermath of a stellar explosion. The region shown continues to display high energy activity.



[Pic. 1]

If the Golden Age of Indian Astronomy was marked by the arrival of Aryabhata in the fifth century A.D., it can be said to have closed in the twelfth century with the genius Bhaskaracharya who was not only a mathematician and astronomer but also a poet.

Spheres of the Master

Jayant Narlikar

In his book *Siddhantashiromani* (verse 58 of Part 4) Bhaskara mentions that he was born in the Shaka year 1036 (1114 A.D.) and in *Goladhyaya* he even gives us some information about his family. So we know that he came from the lineage of Shandilya and his home town was *Vijjalavid*. He learnt all the shastras from his father Maheshwara who was himself a noted astrologer and scholar. But where was *Vijjalavid*? Historians differ in their judgement identifying the place with present day locations. Some argue in favour of Beed in Marathwada, a town about 64 km from Ahmednagar. Others favour Bedar near Hyderabad, also mentioned by Faizi in Emperor Akbar's court. On the other hand the Late Dr Bhau Daji Telang has given persuasive arguments identifying Bhaskara's birthplace within the Malegaon-Chalisgaon-Jalgaon zone.

These are a few of the many suggestions, indicating that we still do not know for certain where Bhaskara's birthplace was. Nevertheless, let us highlight some of his work, which has, fortunately, survived the ravages of time.

Siddhantashiromani, his major work, is divided into four parts: The first is *Leelavati*, which we shall return to soon. Next comes *Beejaganita*, or algebra, followed by *Ganitadhyaya*, dealing with trigonometry. The last part, *Goladhyaya* deals with what is known today as spherical astronomy - the mathematical techniques of measurements of stellar positions using trigonometry on the celestial sphere.

In those days the belief-system called astrology held sway in Indian society (some maintain that it continues to do so even today) and many scholars took to learning maths including algebra and trigonometry so that they could calculate the positions of stars and planets in the sky. This was because it was assumed that these heavenly bodies, depending on their positions in the sky, control the destinies of humans on the Earth. Bhaskara, however, went beyond these numerical exercises and did original work on diophantine equations. Although these equations have a Greek name, their Greek origin was anticipated much earlier in India in the Vedic times.

A famous example of how Bhaskara had already solved a problem that was to baffle European mathematicians in the seventeenth century is the following. In the year 1657, the distinguished French mathematician Pierre de Fermat sent a problem to his friend Bernard Frenicle de Bessy. The problem asked for a solution of the equation

$$61 X^2 + 1 = Y^2,$$

where X and Y are integers (i.e., whole numbers). They could not find a solution to this problem.

It has now been known that the problem was known to Bhaskara and he had already solved it. His solution takes our breath away: the smallest numbers that foot the bill are

$$X = 22,61,53,980 \text{ and } Y = 1,76,63,19,049$$

How on Earth did he find these numbers in days when the computer was not even dreamed of? The method used by him is called the *Chakravala*. We will not describe it here: but those interested may look for it in Bhaskara's *magnum opus*.

Any account of Bhaskara's mathematical work will be incomplete without mention of *Leelavati*, his book of mathematical problems supposedly addressed to his daughter of the same name. It is commonly believed that mathematics is a complex subject requiring abstract reasoning, which may appeal to only a select few. *Leelavati* corrects that impression, by presenting the reader with attractive problems poetically described and relating to contemporary life. Consider the following example:

The square root of half the total number of a swarm of bees went to a Malati tree, followed by another eight ninth of the total. One bee was trapped inside a lotus flower, while his mate came humming in response to his call. O Lady, tell me how many bees were there in all?

This problem can be solved algebraically by using a quadratic equation, the answer being that there were 72 bees in all.

Picture 2 describes another such problem: *In a hole at the foot of a pole resided a snake while at the top sat a peacock. The peacock saw the snake approach the hole while its distance from the foot of the pole was 27 hands. The pole itself was nine hands tall. The peacock jumped towards the snake and moving with the same speed as the snake but in an oblique direction, caught the snake before he could enter his hole. So tell me quickly how far was the snake from his hole at that time?*

Bhaskara was interested in applying mathematical techniques to astronomy and his work as presented in *Grahaganitam* and *Goladhyaya* are the culmination of the series of works in spherical astronomy by preceding astronomers like Aryabhata, Brahmagupta, Mahavira, and others. He seems close to developing the idea of calculus, writing formulae [similar to $d \sin x = \cos x dx$] that follow from the differential calculus. He also seems aware that the

"We owe a lot to the Indians, who taught us how to count, without which no worthwhile scientific discovery could have been made."
-Albert Einstein

'derivative' vanishes at the maxima or minima of the function, again a concept from modern differential calculus.

Having described the interests and prowess of Bhaskara, we now come to a baffling issue. To begin with let us ask a question that sounds like a quiz:

What is common amongst the following: Chinese court astrologers of the Sung Dynasty, the natives on the American continent and a learned physician from the Middle East, all belonging to the eleventh century?

The cryptic answer is: *"They were all witnesses to a spectacular cosmic event, which is still unfolding, an event that was first witnessed on the Earth on July 4, 1054, but whose aftermath is being studied even today, and will continue to be investigated by astronomers in the years to come"*.

Let us begin with the Chinese, to whom we are indebted for maintaining records that date back nine and a half centuries.

In the *History of Sung Dynasty* by Ho Peng Yoke, published in 1962 the following event is described:

On a Chi-Chhou day in the fifth month of the year of Chi-Ho reign period, 'a guest star' appeared at the south east of Thien-Kaun measuring several inches. After more than a year it faded away.

What could this event be? How did it come to be noticed? What was meant by a guest star?

For answers we have to go back a millennium, to the then prevalent Chinese tradition in which the ruling emperor looked to the sky for any "warnings" from the Almighty, just in case he happened to stray from the straight and narrow path of fairness and justice. Lest he had to pay a heavy penalty for inadvertently missing such a warning, the emperor made sure that a careful watch was kept on the heavens. It was the duty of the court astrologer to maintain a vigil and inform the emperor of anything unusual. It was in that context that the above event was noticed and duly recorded as stated above. And July 4, 1054 is the date as per the modern calendar corresponding to the Chinese record. The word 'guest star' indi-

cates that the star did not exist in the sky prior to the event; more correctly, it had not been observable before. Similarly, after the event was 'over', the star disappeared from the heavens, no longer being observable. The Chinese had the custom of describing such transient objects as guests in the sky. The sighting of this object was also recorded in Japan, where too the astrologers kept fairly meticulous records of the heavens.

Indeed, the star which had been previously too faint to be seen, became so bright initially that it could be seen even in daylight for twenty three days, while at night it was visible much longer, being five times as bright as the planet Venus in the early morning (or late evening) for about six months. When it was at its brightest, one could read by its light at night.

The recorded direction of the object, points to Zeta Tauri in the constellation of the Bull. What do we see there today?

Of course, by naked eye we do not see anything. An astronomical photograph (see picture 1) shows a remarkable cloud-like structure with several filaments sticking out. Because its shape reminded the astronomers who took the first photographs, of a crab, the object was given the name 'Crab Nebula'. It is believed to depict the aftermath of a

stellar explosion. Certainly, whatever is going on there now must be still pretty violent, judging by its highly disturbed appearance.

Moreover, it later turned out that some such event was seen by the Native Americans in the Navajo Canyon in America, who recorded it in pictures on rocks. Further, there exists information about this event in the writings of Ibn Butan, a Christian physician from Baghdad. In short, this spectacular event attracted attention across both the hemispheres.

Why don't we find records of the event in India? Even though July is a Monsoon month, surely partially clear skies are not that rare and people on the subcontinent must have seen it. An astronomer of the standing of Bhaskara would have known and worried about an event like this that had happened a century ago. Why is there no mention of this spectacular event in any records pertaining to him?



A pictorial description of the mathematical problem set by Bhaskara (see text for details). The painting is from the set by C.H. Patil and G. A. Gangal in the book *Leelavati Punardarshan* by Professor N.H. Phadke. [Pic. 2]