

## Chandra on Himself



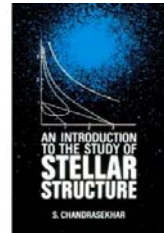
After the early preparatory years, my scientific work has followed a certain pattern motivated, principally, by a quest after perspectives....this quest has consisted in my choosing...a certain area

which appears amenable to cultivation and compatible with my taste, abilities and temperament. And when after some years of study, I feel that I have accumulated a sufficient body of knowledge and achieved a view of my own, I have the urge to present my point of view, *ab initio*, in a coherent account with order, form and structure...

## Seven periods in Chandra's life

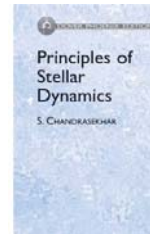
### 1. Stellar structure

*An Introduction to the Study of Stellar Structure*  
(1939)



### 2. Stellar dynamics

*Principles of Stellar Dynamics*  
(1943)



### 3. Theory of radiative transfer

*Radiative Transfer*  
(1950)



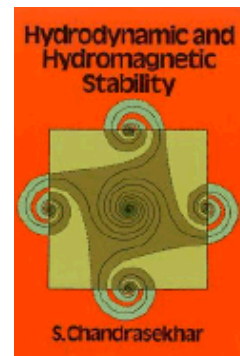
## Seven periods in Chandra's life

### 4. Hydrodynamic and Hydromagnetic Instability

*Hydrodynamic and Hydromagnetic Stability*  
(1961)

### 5. Equilibrium and stability of ellipsoidal figures of equilibrium

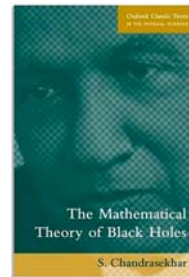
*Ellipsoidal figures of equilibrium*  
(1968)



## Seven periods in Chandra's life

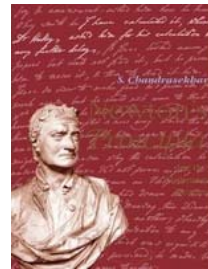
### 6. The General Theory of relativity

*The Mathematical theory of black holes*  
(1983)



### 7. Newton's Principia

*Newton's Principia for the Common Reader*  
(1995)



## The Indian Academia in the 20<sup>th</sup> Century

### Pre-independence (<1947)

Main centres of research were in the universities...

Astrophysics in physics departments

Allahabad University (Meghnad Saha)

Delhi University (Daulat Singh Kothari)



Relativity and cosmology in maths departments

Calcutta University (Nikhil Ranjan Sen)

Benares Hindu University (V. V. Narlikar)



**Post-independence (>1947)**

**The emphasis on research shifted to autonomous research institutes (ARIs)**

**Today A&A research is done mainly in these institutions:**

**Mumbai: TIFR**

**Bangalore : IIA, RRI, IISc**

**Pune: NCRA, IUCAA**

**Ahmedabad: PRL**

**Naini Tal: ARIES**

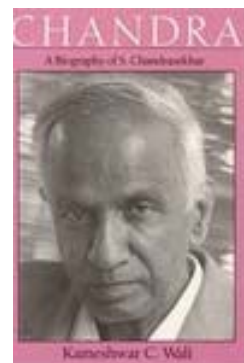
***Only IUCAA belongs to the university sector.***

## **Chandra and Saha**

**January 1930 meeting during  
the annual Indian Science Congress**

**Quote from Kameshwar Wali's book:**

***A few months later, 2-8 January 1930,  
Chandra attended the Indian Science  
Congress Association meeting held  
in Allahabad...***



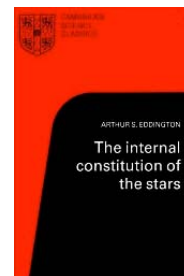
## Chandra and Saha

*....The host and the president of the physics section of the Congress was Meghnad Saha, the eminent Indian astrophysicist, whose theory of ionization a decade earlier had unlocked the door to the interpretation of stellar spectra in terms of laboratory spectra of atoms of terrestrial elements, providing information about the state of stellar atmospheres, their chemical composition, the density distribution of various elements, and then about the most important physical parameter – the temperature ...*



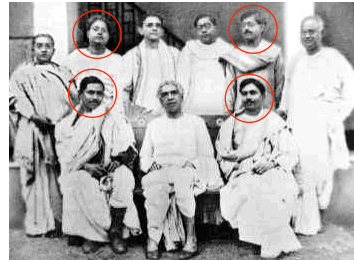
## Chandra and Saha

*...Chandra had learned all of this from Eddington's book "The Internal Constitution of Stars" and was aware of the high esteem Eddington had accorded to Saha and of Saha's election to the Royal Society in 1927. But Chandra was not aware that Saha was acquainted with his own work; so when he met Saha at the Congress and introduced himself, he was pleasantly surprised by Saha's compliment on his paper in the Proceedings of the Royal Society. Saha said that it was very suggestive and that one of his students was working on extending Chandra's ideas.*



## Chandra and Saha

- *He introduced Chandra to this student, who also seemed to know about his work, and he invited Chandra to his home for lunch with a small group of research workers all older than Chandra. The small lunch turned later into a dinner invitation with such distinguished senior Indian scientists as J.C. Ghosh, D.M. Bose, and J.N. Mukherjee. Saha persuaded Chandra to extend his stay in Allahabad so that he and his students could discuss more with him. Chandra, so young, did not expect to be treated almost as an equal by an internationally renowned scientist of Saha's stature.*



Bose (centre) with students: front row: Meghnad Saha, J.C. Ghosh, back row: S. Dutta, S.N. Bose, D.M. Bose, N.R. Sen, J.N. Mukherjee and N.C. Nag

## Interaction with VVN

The Vaidya solution in 1943 demonstrated that it is possible to use general relativity to describe a spherical object emitting energy in the form of radiation travelling with the speed of light...

P.C. Vaidya in *Current Science*, 12, 183, 1943

His supervisor (V.V. Narlikar) asked Chandra if GR will have solutions to offer for astrophysics...



## Chandra and VVN

Chandra replied “No”. He did not believe that situations relating to strong gravity would be found in astrophysics.

For strong gravity we need

$$\frac{2GM}{c^2 R} \cong 1.$$

- This can be achieved at modest masses provided the density is high and at modest densities provided the mass is high...

$$\frac{2GM}{c^2 R} = (32\pi/3)^{1/3} GM^{2/3} \rho^{1/3} \cong 1$$

The discovery of neutron stars and QSOs showed that such objects may well exist in the universe and so a new subject ‘**Relativistic Astrophysics**’ was born...

Chandra’s lack of belief in the impact of GR at that stage matched Eddington’s disbelief that Nature would permit black holes...

## Benares Hindu University

- Dr S. Radhakrishnan, the VC at BHU had conveyed through VVN an offer to Chandra to head a new observatory which would be set up by the industrial house of the Birlas under the control of BHU. Chandra declined because he was not sure that the academic environment at BHU would continue once its distinguished VC left.

His reservations were borne out...



## Osmania University

- Saleh Mohammed Alladin at Osmania had been a graduate student at the University of Chicago and in 1959 had attended the lectures by Chandra. He writes: *“Professor Chandrasekhar used to emphasize that mathematical work should not only be correct, but should also be elegantly expressed...”*
- The episode at Osmania which led to Alladin’s appointment...
- Chandra’s help to K.D. Abhyankar in telescope site selection and on his work on radiative transfer.





## Chandra's Indian Graduate Students

- Chandra had two students from India who got their Ph.D. under him:

- 1. S.K. Trehan (now deceased)
- 2. Bimla Buti



Trehan had joined the Panjab University at Chandigarh and set up a school on theoretical hydrodynamics and plasma physics in the Applied Maths Dept

- Bimla Buti recalls:

- Since Chicago University required single-author papers for a Ph.D. thesis, she had no joint papers with Chandra. Chandra had, however, helped on various occasions. She recalls his traits as follows.
- *He was an extremely disciplined person and expected discipline around him...*



*Without fail he would visit the library and glance through the latest journals*

*He was extremely hard working...However, he would find time for gardening, musical concerts, reading classic novels...*

*...he was particular about English grammar...*

*He had a terrific memory . At a social gathering, he would narrate stories about his interactions with other scientists...*

*I found him very friendly and affectionate...*

## **The Sun and the Neutron Stars**

- Chandra's work on white dwarfs set the trend for stars made of degenerate matter, e.g., neutron stars.
- S.M. Chitre and V. Canuto and considered equations of state for neutron-dominated matter in a highly compressed form...lead to maximum mass of the order of 2 solar masses.

Stability of solar models was discussed by Chitre using Chandra's perturbation technique. The eigenfrequencies so obtained were compared with the observed acoustic modes. The solar model can thus be made more precise to Compare the neutrino flux...

The conclusion was that the reduced flux has to do with neutrino physics and not with the solar model...

### **Antonov Instability**

- Discovered by Antonov in 1962.
- Padmanabhan saw that Chandra had discussed a similar situation back in 1939.
- Equations of stellar structure as written by him for an isothermal sphere reduce to a first order differential equation using variables  $u$  and  $v$ . Solutions are shown on a spiral curve in  $u,v$  plane.

Paddy found that

$$q = RE / GM^2$$

$R$  = radius,  $E$  = energy and  $M$  = mass

Relates to Antonov instability.  $Q = \text{const.}$

Are straight lines in  $u$ - $v$  plane. If these

Lines meet, there is Antonov instability.

Did Chandra know this result back in 1939?

Correspondence and direct meeting with  
Chandra failed to get him interested in the  
same problem 50 years later.

- Encounter with Ramanath Cowsik
- At a radio interview question on how one should approach the study of physics: through experiments or through a study of theoretical physics?

**Chandra replied: “Different students ...approach physics in their own unique ways. ...But what is important is that they dedicate themselves to academic life...”**

**It does not matter through which gate one enters a garden. Once you are in, you may wander enjoying a bloom here or a bough there...”**

**Chandra's talk at IUCAA dedication "The Series Paintings of Claude Monet and the Landscape of General Relativity" drew parallels between aesthetics of paintings and Mathematical equations.**

The Series Paintings of Claude Monet  
and the Landscape of General Relativity

S. Chandrasekhar



Inter-University Centre for Astronomy and Astrophysics  
Dedication Address: 28 December 1992

## **My first encounter with Chandra**

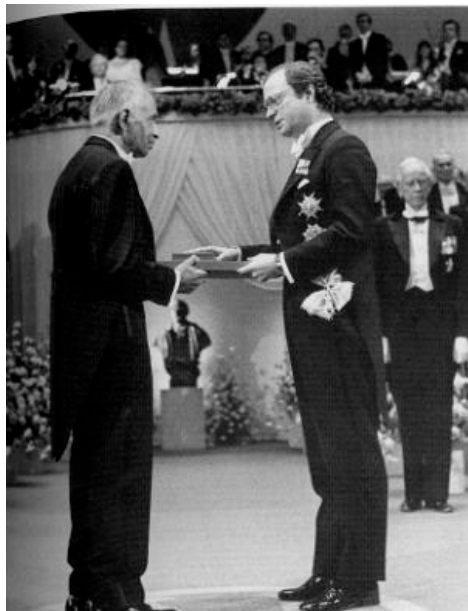
- 1962: GR3 Conference in Jablonna, near Warsaw.
- In my morning walk I came across an Indian delegate neatly dressed in a dark suit who introduced himself as Chandrasekhar...

What was an astrophysicist doing at the GR meeting? I wondered...



Chandra replied:

*“I am thinking of getting into general relativity as my next research area. As I am new to the subject, I decided to attend this conference so that I may assess for myself what are the interesting problems in this field.”*



*This was a reply from a young man of over 50.*