Doing a Book Pre-LaTeX

- Cut and Paste . . .

I. Star Deaths and the Formation of Compact Objects

1. What are Compact Objects?

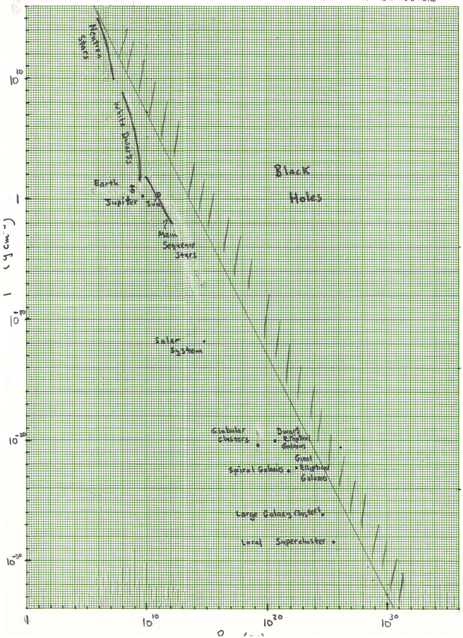
A look on compact objects logically begins where a book on normal stellar evolution leaves off. Compact objects -- white dwarfs, neutron stars, and black holes -- are "born" when normal stars "die," i.e., when most of the available nuclear fuel has been consumed.

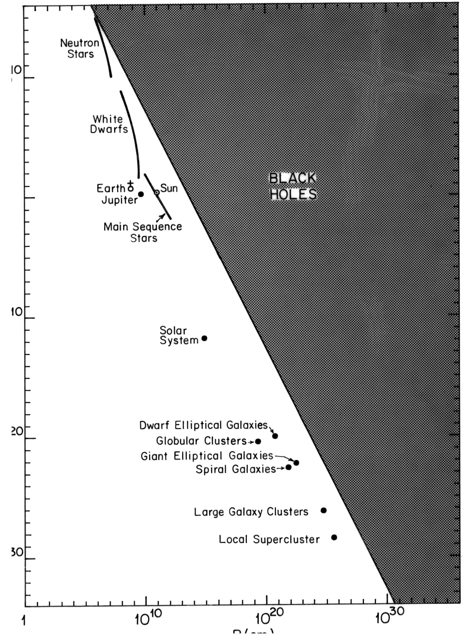
All three species of compact object differ from normal stars in two fundamental ways. First, since they do not burn nuclear fuel, they cannot support themselves against gravitational collapse by generating thermal pressure. Instead, white dwarfs are supported by the pressure of degenerate electrons, while neutron stars are supported largely by the pressure of degenerate neutrons. Black holes, on the other hand, are completely collapsed stars, i.e. stars which could not find *any* means to hold back the inward pull of gravity, and therefore collapsed to singularities. With the exception of the spontaneously radiating "mini" black holes with masses $M \lesssim 10^{15}$ gm and radii $\lesssim 1$ Å, all three compact stars are

EQUATION CONVERSION CHART

CHAPTER	OLD VERSION	NEW VERSION
2	1.1 - 1.10	2.1.1 - 2.1.10
	Added 2.1.11	
	1.11 - 1.20	2.1.12 - 2.2.21
	2.1 - 2.6	2.2.1 - 2.2.6
	Deleted 2.7	
	2.8 - 2.9	2.2.7 - 2.2.8
	3.1 - 3.15	2.3.1 - 2.3.15
	3.16*- 3.18*	2.3.16 - 2.3.18
	3.16 - 3.20	2.3.19 - 2.3.23
	3.21	2.3.29
	3.22	2.3.30
	3.23 - 3.27	2.3.24 - 2.3.28
	Added --------------	2.3.31 - 2.3.35
	4.1 - 4.35	2.4.1 - 2.4.35
	Added --------------	2.4.36 - 2.4.42
	5.1 - 7.7	2.5.1 - 2.7.7
Tables:	2.2	2.1
	2.3	2.2

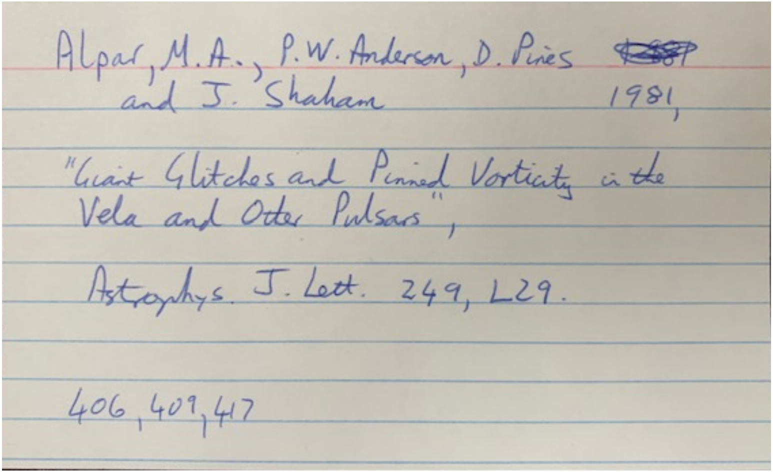
1. Show n.s, wd and mseq lines as dark, solid
2. Shade entire black hole domain




Neutron Stars
White Dwarfs
Earth
Jupiter
Sun
Main Sequence Stars
BLACK HOLES
Solar System
Dwarf Elliptical Galaxies
Globular Clusters
Giant Elliptical Galaxies
Spiral Galaxies
Large Galaxy Clusters
Local Supercluster
1
10^{10}
10^{20}
10^{30}

Index Cards?

Index Cards?


Alpar, M.A., P.W. Anderson, D. Pines
and J. Shaham 1981,
"Giant Glitches and Pinned Vorticity in the
Vela and Other Pulsars",
Astrophys. J. Lett. 249, L29.
406, 409, 417

A
B
C
D
E
F
G
H
I
JK

What's in a Title?

Black Holes, White Dwarfs and Neutron Stars:
The Physics of Compact Objects

THE PHYSICS OF ~~COMPACT OBJECTS:~~

WHITE DWARFS, NEUTRON STARS, AND BLACK HOLES

Stuart L. Shapiro and Saul A. Teukolsky
Cornell University
Ithaca, NY

Table of Contents - preface -

I. STAR DEATHS AND THE FORMATION OF COMPACT OBJECTS

1. What are Compact Objects?

A book on compact objects logically begins where a book on normal stellar evolution leaves off. Compact objects -- white dwarfs, neutron stars, and black holes -- are "born" when normal stars "die", i.e., when most of the ~~available~~ nuclear fuel has been consumed.

All three species of compact object differ from normal stars in two fundamental ways. First, since they do not burn nuclear fuel, they cannot support themselves against gravitational collapse by generating thermal pressure. Instead, white dwarfs are supported by the pressure of degenerate electrons, while neutron stars are supported largely by the pressure of degenerate neutrons. Black holes, on the other hand, are completely collapsed stars, i.e. stars which could not find any means to hold back the inward pull of gravity and therefore collapsed to singularities. With the exception of the spontaneously radiating 'mini' black holes with masses $M \lesssim 10^{15}$ gm and radii $\lesssim 1Å$, all three compact ~~stars~~ objects are essentially static over the lifetime of the Universe. They represent the final stage of stellar evolution.

The second ~~distinguishing~~ characteristic distinguishing compact objects from normal stars is ~~that compact objects are characterized by~~ their exceedingly small size. Relative to normal stars of comparable mass, compact objects have ~~radii for their masses and, hence,~~ stronger surface gravitational fields. This fact is dramatically illustrated in Table 1.1.

Because of the enormous density range spanned by compact objects, their analysis requires a deep physical understanding of

You Need a Thick Skin . . .

Chapter 14 ~~[illegible]~~. ~~[illegible]~~ p578 Identity as Jeans' theorem.
(This whole section seems irrelevant to the topic in hand.
i.e. accretion onto compact objects for which fluid
model is generally assumed.)
p588 Mention relation to solar wind.

OK. I think Curt Michel did a paper on Bondi accretion
in Schwarzschild metric. (Astrophys. Sp. Sci. ?? ≃1972)
ref p.615 Ref. Pringle's. Annual Review.
p624. But $\alpha << 1$, probably in dwarf novae prior to
out-burst.
p.632 Elementary consequences of the black body formula are
not major triumphs of accretion disk theory!

Chapter 15.
p691. Further critique of propeller mechanism by

T. Gold

p 4. You omit the black hole formation process that I consider most likely for forming massive black holes in the centers of globular clusters: star collisions and the accumulation of debris from them. If globular clusters managed to get as dense as they are, it is only a small step to this condition, and the evidence favors such objects being there.

The preface is too self-lauding.

√ p 216

18. Page 477d: There seems to be a glitch in your prose at the beginning of this page.

19. Page 507: In connection with the Penrose process it is worth mentioning the extraction of rotational energy by magnetic fields; see my discussion above of black hole electrodynamics and the hole-as-bubble paradigm.

20. Page 639: When I was in Moscow last month, Sunyaev pointed out to me that Trumper has obtained excellent observational data on the high-energy end of the spectrum of Cygnus X-1. Sunyaev and Trumper have a paper in press, or perhaps published by now, describing the excellent agreement between the observational data and the Comptonization models.

21. Page 714: It is worth emphasizing that ΔE and ε refer to the energy radiated in one dynamical time T; if the system evolves for longer than one dynamical time, ε and ΔE will be correspondingly larger but h will be unchanged.

22. Page 716: Nobody thinks of using quartz these days; rather the materials being used are aluminum, sapphire, and niobium.

23. Page 716: The rms noise in the best first-generation bars was $h \approx 10^{-16}$, rather than 10^{-17}; and when one takes account of the statistical factors, the strongest bursts which could have been detected with any confidence would have been $h \approx 3 \times 10^{-16}$.

24. Page 716: I would suggest that you ask the reader to compute the strength of the waves to be expected from a non-head-on collision of two black holes at the Hubble distance. The reader can show that the amplitude of the waves depends on the mass of the smaller hole, while the frequency depends on the mass of the larger hole. The conclusion of greatest interest would be that for two black holes of one hundred solar masses the wave strength would be 10^{-21} at the Hubble distance. One can then invite the reader to speculate as to how frequently such black-hole collisions occur within the entire universe.

25. Page 717: With recent developments in the reflectivity of mirrors (reflectivities 100 times better than one had thought possible last year), and with Drever's recent invention of ways to recycle light into an interferometer, the design sensitivities for kilometer-scale interferometers are now 10^{-22} rather than 10^{-21}. It is worth emphasizing, however, that these sensitivities require third-generation instruments rather than the

Center for Astrophysics
60 Garden Street
Cambridge, Massachusetts 02138

Harvard College Observatory Smithsonian Astrophysical Observatory

Send whole book.

Also send Saul.

Will keep both for one year.

Bill P.

THE UNIVERSITY OF CHICAGO
THE ENRICO FERMI INSTITUTE
933 EAST 56TH STREET
CHICAGO • ILLINOIS 60637
AREA CODE 312-753-8507

Laboratory for Astrophysics
and Space Research

January 28, 1982

Prof. Saul Teukolsky
Center for Astrophysics
Harvard College Observatory
60 Garden Street
Cambridge, Massachusetts 02138

Dear Saul,

I apologize for being so negligent in responding to your queries concerning various historical remarks relating to the theory of white dwarfs, black holes, etc., in your forthcoming book. As you suspected, I was, at the time you called, involved in the last stages of my own book. Besides, it is always difficult to adjust oneself to the different spans even of one's own life. But I have now read your various sections with some care and you are certainly fair; and there are no factual statements which are incorrect. Nevertheless, you can appreciate that there are some overtones which I probably mis-hear and which others -- perhaps more objective? -- cannot. Therefore, the following comments are to be considered confidential to the extent that they are my personal reactions, and I certainly do not wish others, who understand me less than you do, to misunderstand.

First, Baade and Zwicky are generally credited with having suggested neutron stars with respect to super nova explosions. It was never clear to me at the time, and it still is not clear to me, that their statement was fully made with awareness of the following facts, namely:

First, one has to be concerned with a sufficiently massive star; second, that there is no intermediate stage, before nuclear densities, at which the collapse could be arrested; and third, that the formation of neutron stars depends upon a sufficient amount of mass being ejected.

read the discussions included after Eddington's paper in Fifteenth Colloque International D'Astrophysique, "Novae and White Dwarfs: III. White Dwarfs", by G. P. Kuiper, S. Chandrasekhar, and Sir Arthur Eddington, 41-50, Hermann & Co., Paris, 1941.

And finally, if you will pardon my making so personal a reference, that none of the citations which went along with the award of the Gold Medal of the Royal Astronomical Society (1953), or the Bruce Medal of the Astronomical Society of the Pacific (1952), or the Rumford Medal of the American Academy of Arts and Sciences (1957), or the Royal Medal of the Royal Society(1962), included any reference to my work on the theory of white dwarfs; the reference was always to some other area, indicating, it seems to me, a fear of recognizing what they believed was a controversial result.

Of course, you understand that my remarks in the last paragraph would not have been made if I did not have some confidence that they would not be misinterpreted. And even now, I am not certain that I have not transgressed normal protocol. In any event please do not bother to respond.

On a more cheerful note, the last pages of my book on "The Mathematical Theory of Black Holes" went off to the publishers two days ago; and tomorrow we leave for India -- principally to see the high peaks of the Himalayas.

With best wishes also to your wife,

Yours sincerely,

Chandra

S. Chandrasekhar

What Did Chandra Really Think?

- Skeptical of Baade & Zwicky:
  - Mechanism (but binding energy ...)
- Oppenheimer & Volkoff, Oppenheimer & Snyder
  - Ignored mass limit, no proper citation

What Did Chandra Really Think?

- Skeptical of Baade & Zwicky:
  - Mechanism (but binding energy . . .)
- Oppenheimer & Volkoff, Oppenheimer & Snyder
  - Ignored mass limit, no proper citation
- Hurt by Eddington
  - ". . . no serious astronomer really accepted my results"
  - No award (lists 4) cited white dwarf work (because controversial?)

What Did Chandra Really Think?

- Skeptical of Baade & Zwicky:
  - Mechanism (but binding energy . . .)
- Oppenheimer & Volkoff, Oppenheimer & Snyder
  - Ignored mass limit, no proper citation
- Hurt by Eddington
  - “. . . no serious astronomer really accepted my results”
  - No award (lists 4) cited white dwarf work (because controversial?)
- Nobel Prize 1 year later, “for his theoretical studies of the physical processes of importance to the structure and evolution of the stars”