Neutron star masses: dwarfs, giants and neighbors

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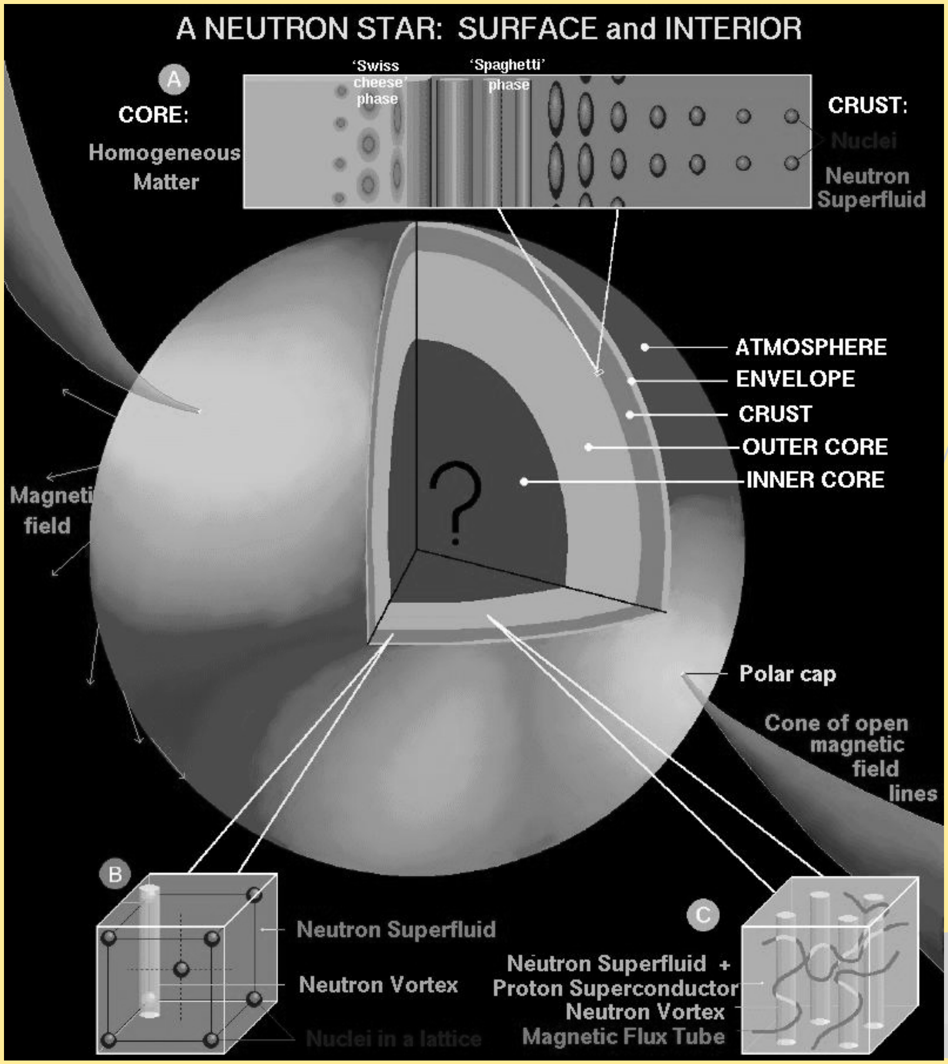
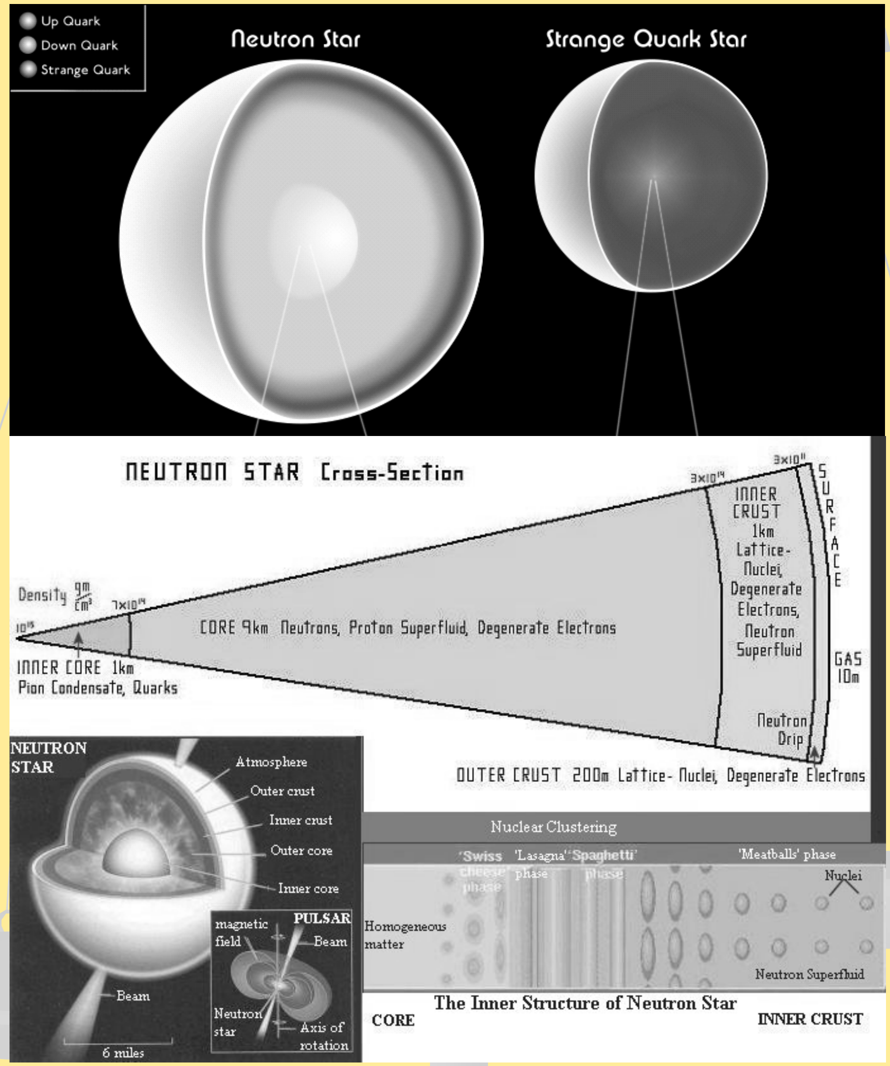
Plan of the talk

I. Intro
II. How to make a light NS
III. Getting bigger
IV. Slim neighbors
V. Conclusions

NS structure:
mass is a critical parameter!





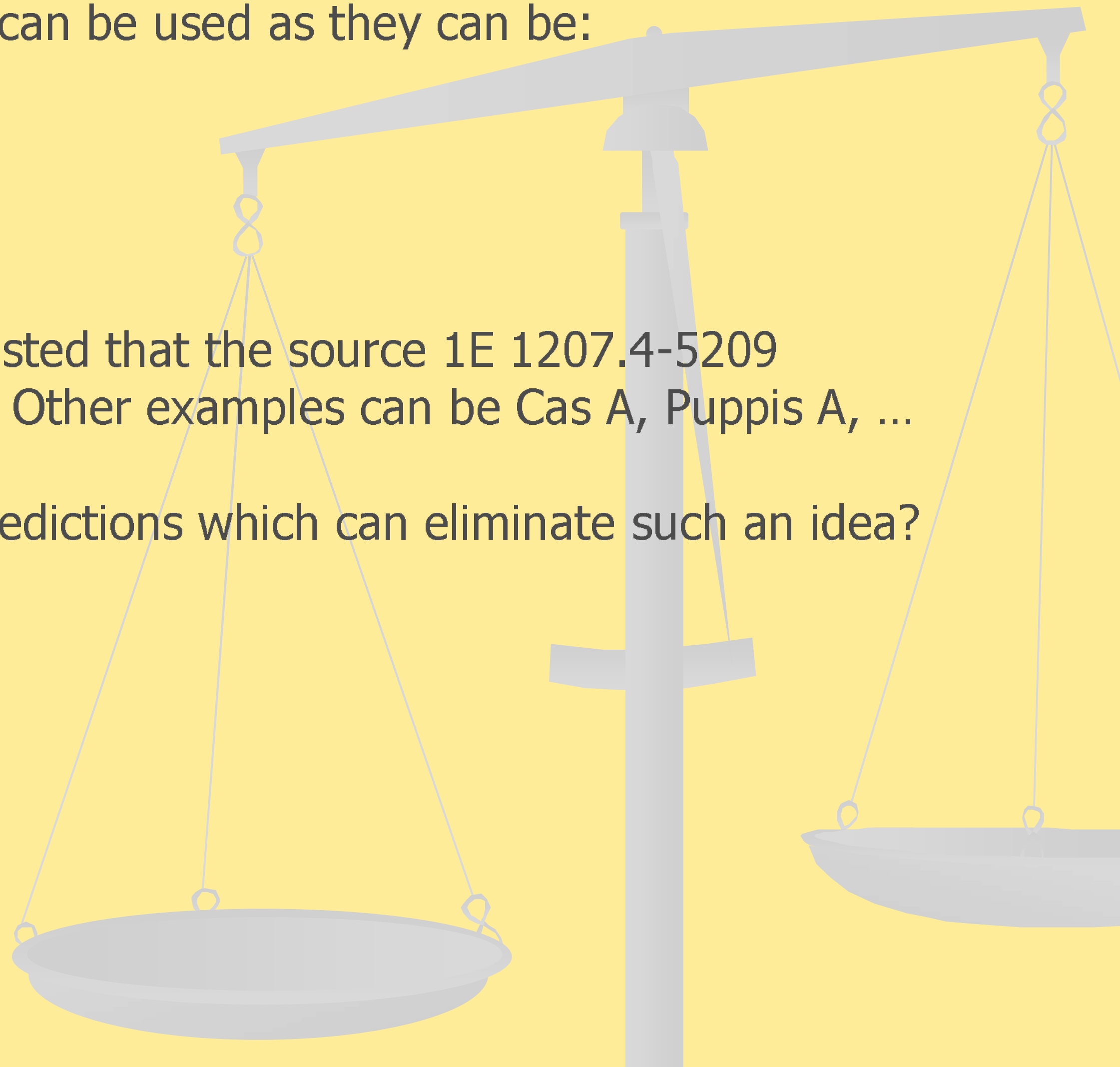
Why can we need low mass NSs?

➢ Low mass compact objects can be used as they can be:

- ✓ Large (if NSs)
- ✓ Small (if QS)
- ✓ Hot

For example, Xu (2004) suggested that the source 1E 1207.4-5209 can be a low-mass quark star. Other examples can be Cas A, Puppis A, …

Is it possible to make some predictions which can eliminate such an idea?



Low mass NS formation

- How to form a low mass NS?

- Low-mass compact objects (hadron stars, quark stars) with M<1 Msun can appear *only* due to fragmentation of rapidly rotating proto-neutron stars (Berezinsky et al. 1987, Imshennik 1992).

- Such low-mass stars receive large kicks due to an explosion of the lighter companion, or due to dynamical ejection of one of the lighter components in the case when three bodies are formed.

- As far as low-mass compact objects are expected to be slowly cooling in all popular models of thermal evolution, possible candidates are expected to be found among hot high velocity sources. Kick perpendicular to spin.

• Fast
• V perp. Spin

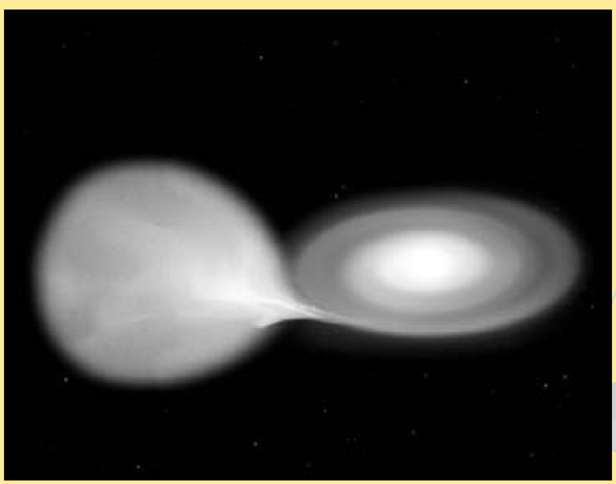
They should not be among CCOs

astro-ph/0403710

Getting bigger

We use a population synthesis code to estimate numbers of very massive neutron stars on different evolutionary stages. A neutron star increases its mass by accretion from a secondary companion. Significant growth of a neutron star mass due to accretion is possible only for certain values of initial parameters of the binary.

Here we show that significant part of massive neutron stars with $M>2M_{sun}$ can be observed as millisecond radio pulsars, as X-ray sources in pair with white dwarfs, and as accreting neutron stars with very low magnetic fields.



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NS Masses

We know several candidates to NS with high masses (M>1.8 M_{sun}):

- Vela X-1, M=1.88±0.13 or 2.27±0.17 M_{sun} (Quaintrell et al., 2003)
- 4U 1700-37, M=2.4±0.3 M_{sun} (Clark et al., 2002)
- 2S 0921-630/V395 Car, M=2.0-4.3 M_{sun} [1σ] (Shahbaz et al., 2004)
- J0751+1807, M=2.1+0.4/-0.5M_{sun}(Nice,Splaver,2004) binary radiopulsar!

In 1999 Ouyed and Butler discussed an EOS based on the model by (Skyrme 1962). A NS with such EOS has M_{max}=2.95M_{sun} for a non-rotating configuration and M_{max}=3.45M_{sun} for extreme rotation. This model defines the upper mass limit for our study.

We will discuss formation of very massive NS due to accretion processes in binary systems.

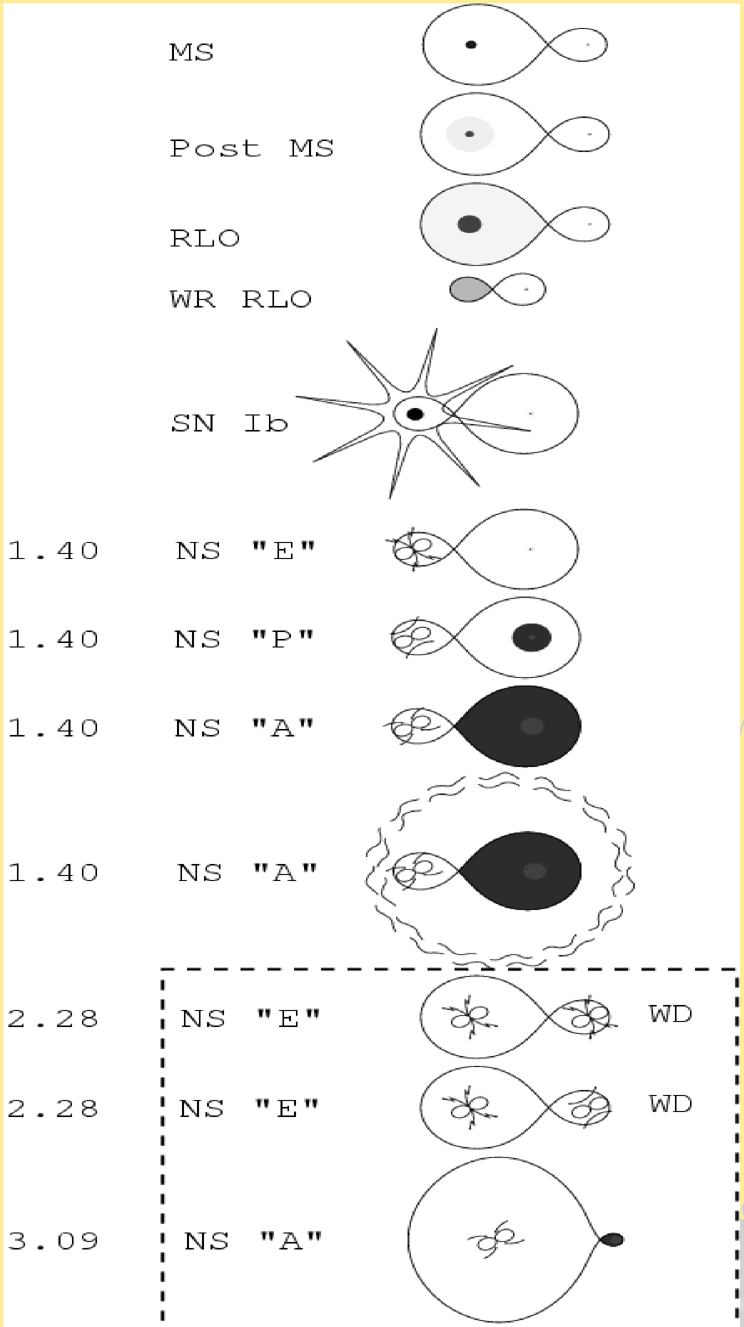
What is «Very Massive NS» ?

1.8 M_{sun} < Very Massive NS < 3.5 M_{sun}

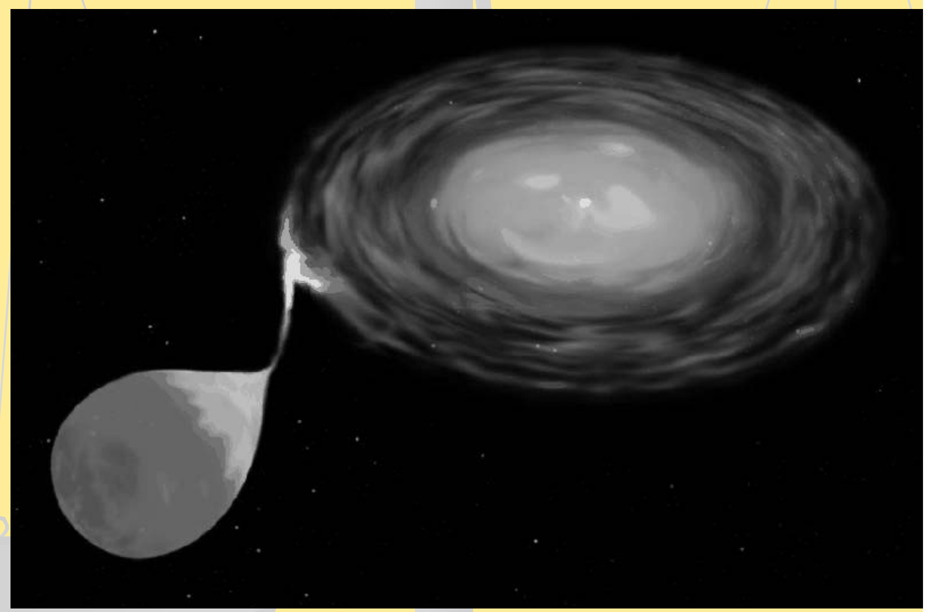
- 1.8M_{sun}: Upper limit of Fe-core/young NS according to modeling of supernova explosions (Woosley et al. 2002).

- ~3.5M_{sun}: Upper limit of rapidly rotating NS with Skyrme EOS (Ouyed 2004).

Evolution



For our calculations we use the “Scenario Machine” code developed at the SAI. Description of most of parameters of the code can be found in (Lipunov,Postnov,Prokhorov 1996)



Results

1 000 000 binaries was calculated in every Population Synthesis set

~10^4 very massive NS in the Galaxy
(formation rate ~6.7 10^{-7} 1/yr)
in the model with kick

[6 10^4 stars and the corresponding formation rate ~4 10^{-6} 1/yr for the zero kick].

State of NS	with kick	zero kick
Ejector	32%	39%
Propeller+Georotator	2%	8%
Accretor	66%	53%

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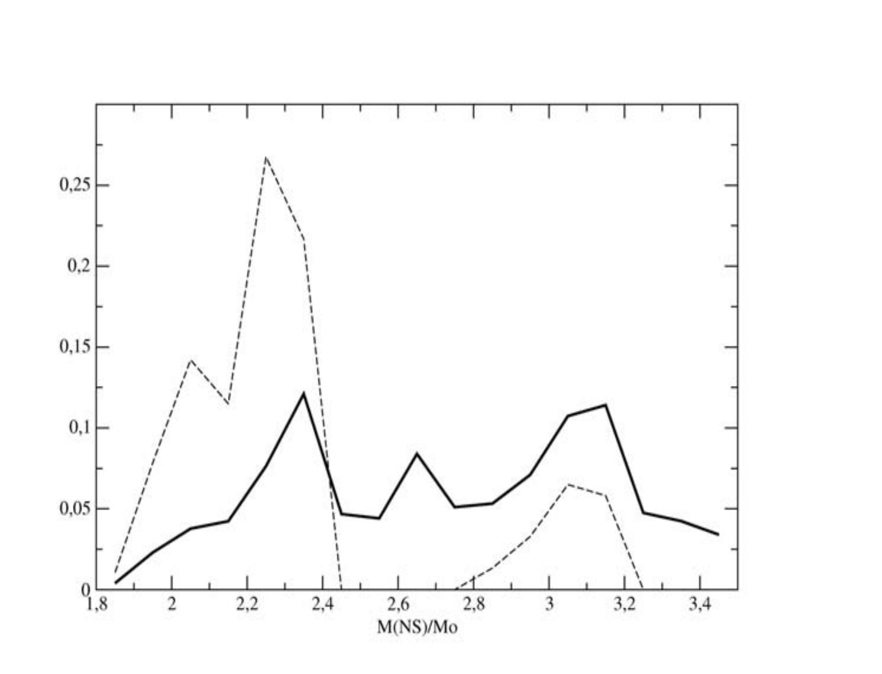
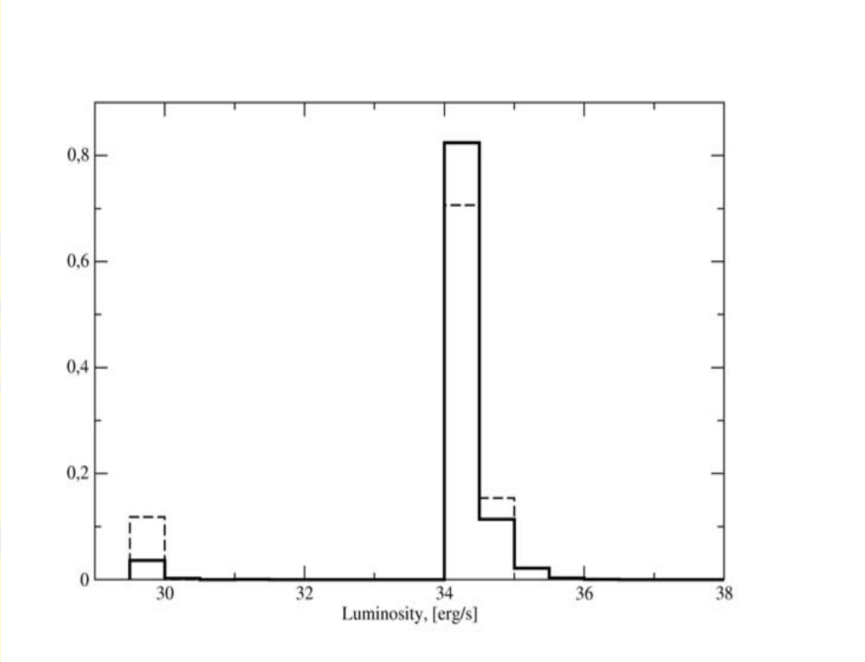
Results II





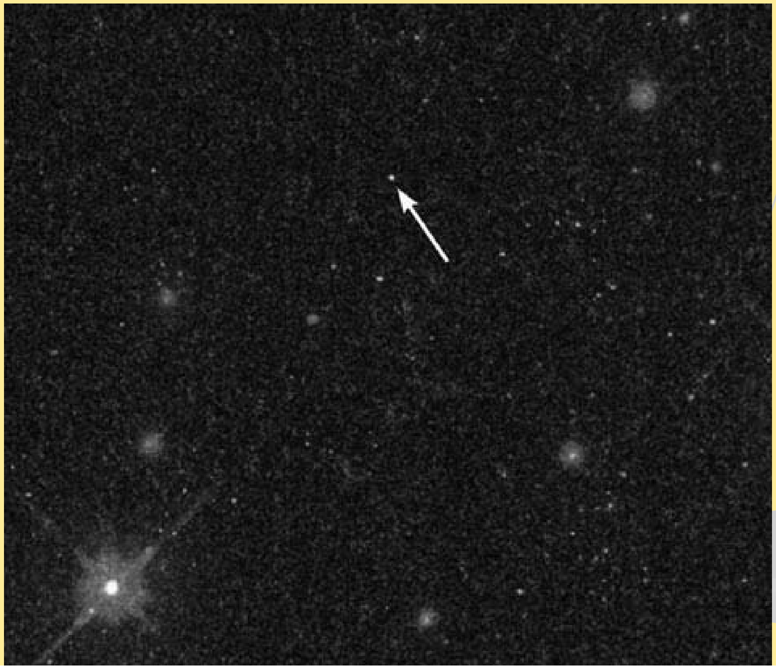
Mass distribution of very massive NS

Luminosity distribution of accreting very massive NS

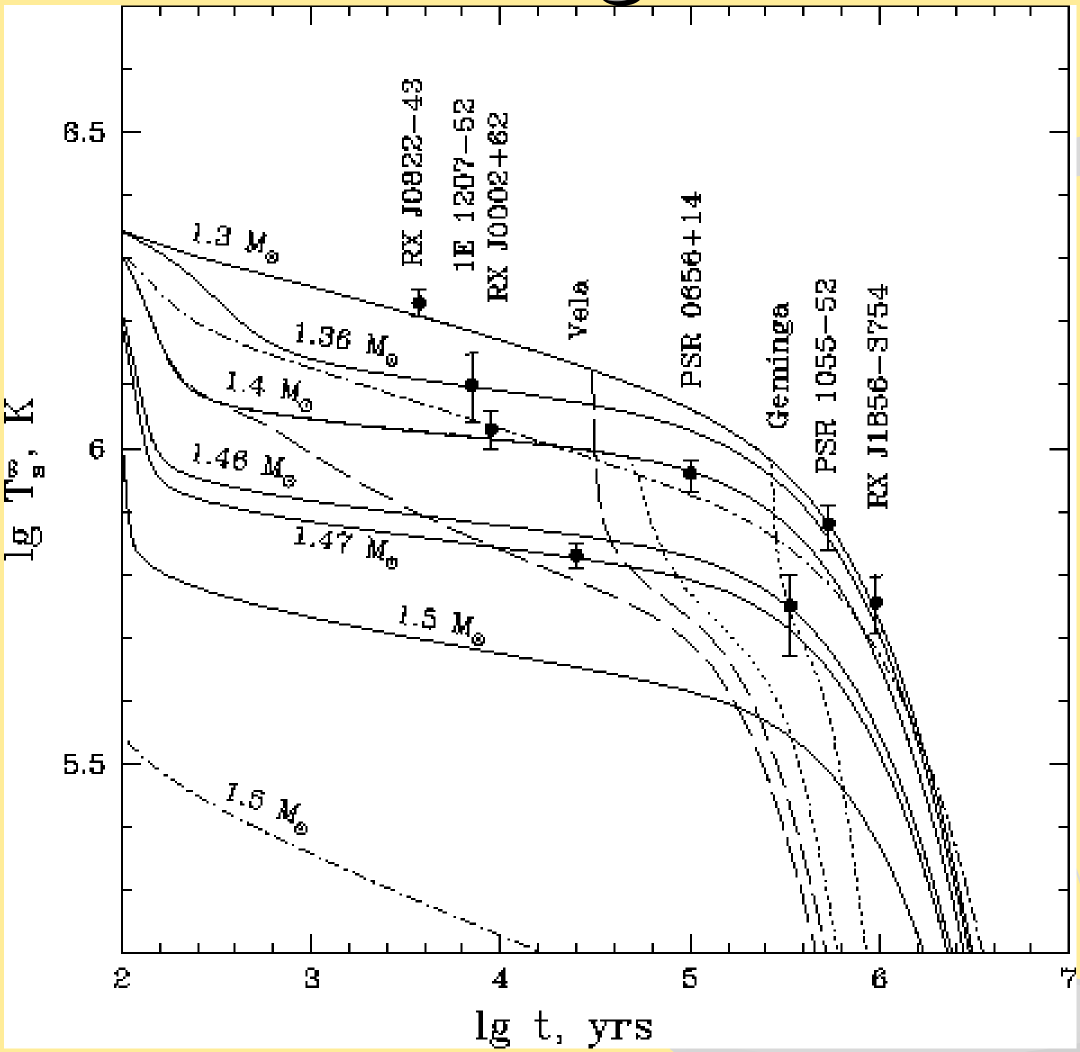
Dashed line: Zero natal kick of NS (just for illustration).
Solid line: Bimodal kick similar to (Arzoumanian et al. 2002).

Neighbors: young and slim

- Initial NS mass spectrum is unknown
- Mass spectrum of local NS is of particular interest
- It can be different from the global one
- We estimate this mass spectrum and …
- Propose a “mass constraint” which can be …
- Important for testing NS cooling curves



Masses are important for cooling calculations!

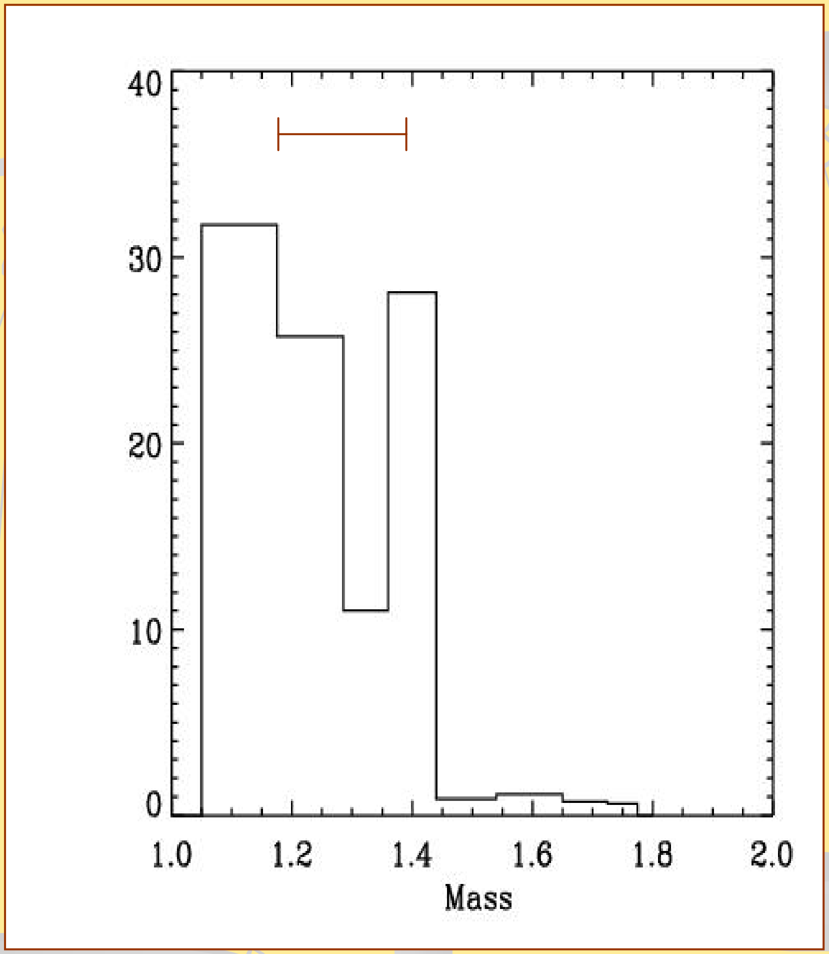


Kaminker et al. 2001

Mass spectrum of NSs

Mass spectrum of NSs is an important ingredient of the population synthesis of close-by young cooling NSs

- Mass spectrum of local young NSs can be different from the general one (in the Galaxy)
- Hipparcos data on near-by massive stars
- Progenitor vs NS mass: Timmes et al. (1996); Woosley et al. (2002)



astro-ph/0305599

(masses of secondary objects in NS+NS)

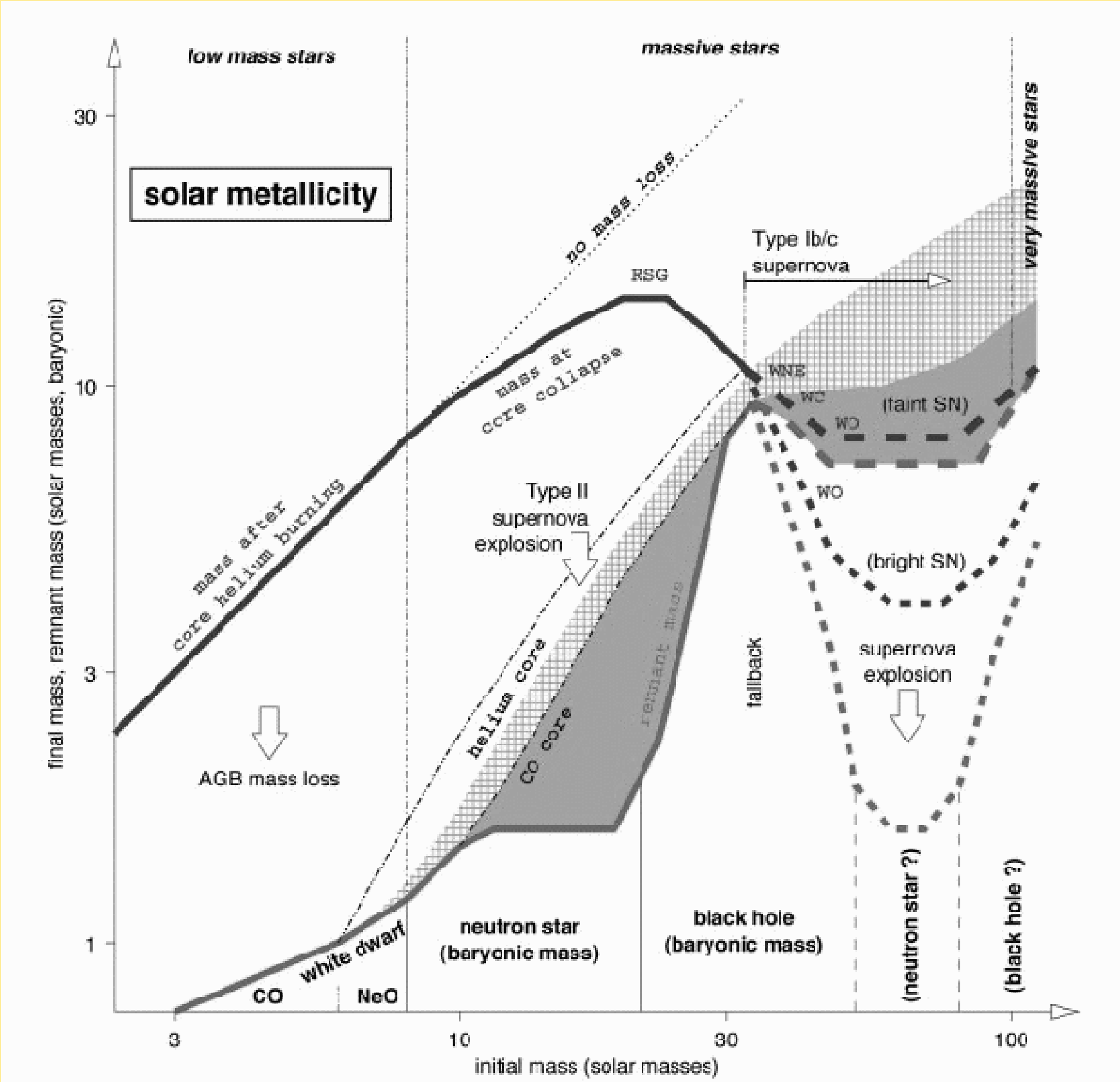
NS+NS binaries

Pulsar	Pulsar mass	Companion mass
B1913+16	1.44	1.39
B2127+11C	1.35	1.36
B1534+12	1.33	1.35
J0737-3039	1.34	1.25
J1756-2251	1.40	1.18

	(PSR+companion)/2
J1518+4904	1.35
J1811-1736	1.30
J1829+2456	1.25

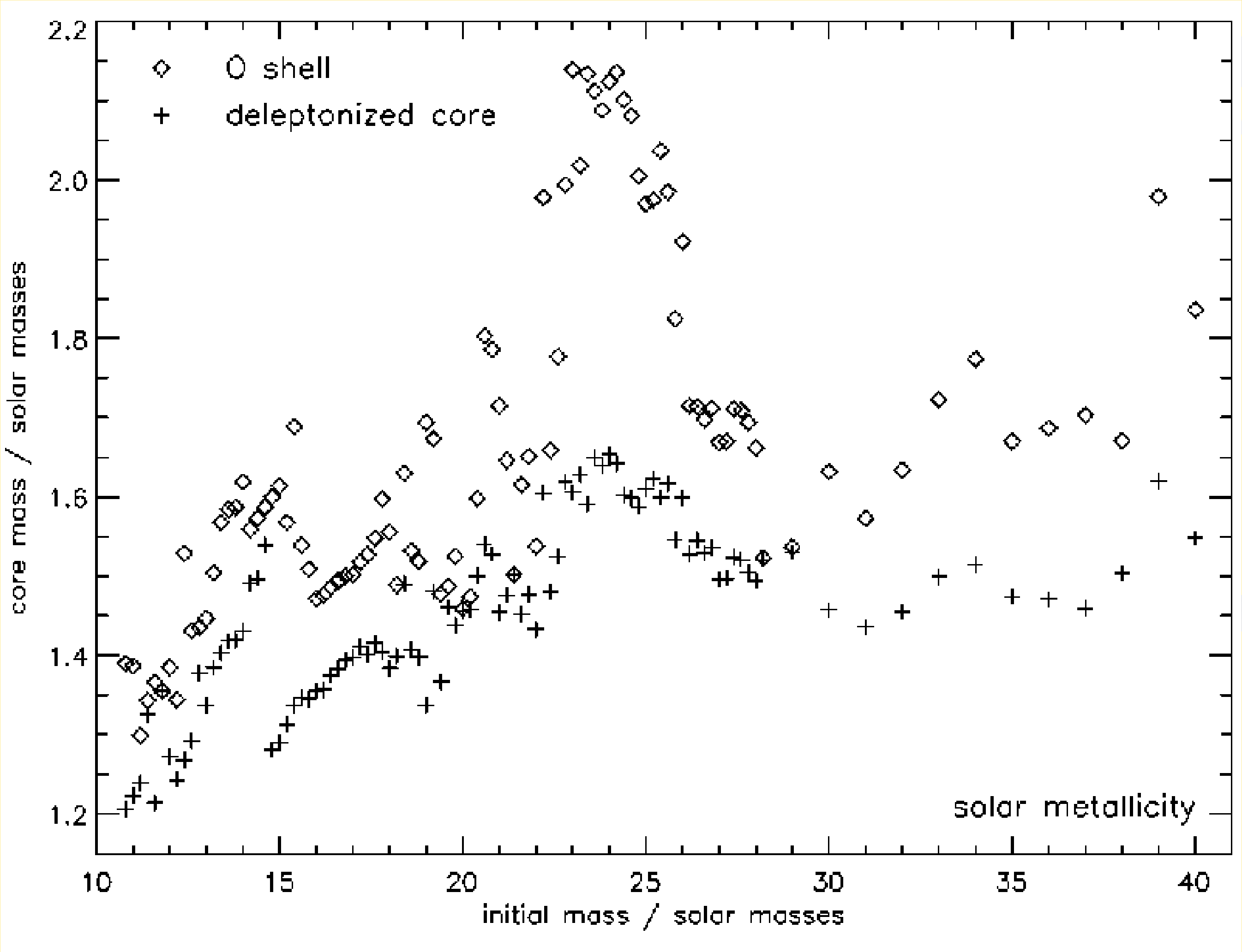
(David Nice, talk at Vancouver)

Progenitor mass vs. NS mass



Woosley et al. 2002

Core mass vs. initial mass



Woosley et al. 2002

Magnificent Seven

Name	Period, s
RX 1856	-
RX 0720	8.39
RBS 1223	10.31
RBS 1556	-
RX 0806	11.37
RX 0420	3.45
RBS 1774	9.44

Radioquiet
Close-by
Thermal emission
Long periods

SLIM !

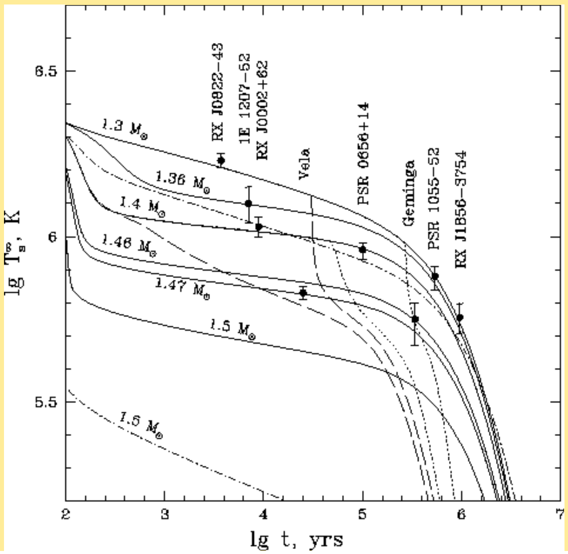
Thermally Emitting INSs => **ThE INSs or IConNs – Isolated Cooling NSs**

Mass constraint

- Mass spectrum has to be taken into account when discussing data on cooling
- Rare masses should not be used to explain the cooling data
- Most of data points on T-t plot should be explained by mases <(1.4-1.5) Msun

In particular:

- Vela and Geminga should not be very massive



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Conclusions

- ***It is possible to make light NS***
- ***It is possible to make very massive NS***
- ***Young close-by NSs are slim <1.4Msun***
- ***Mass constraint can be useful for cooling curves discussions***