UNIVERSITY OF TURKU

Magnetars!

Kristen E. Gardner

UTU - Department of Physics and Astronomy

What is a Magnetar?

Definition:

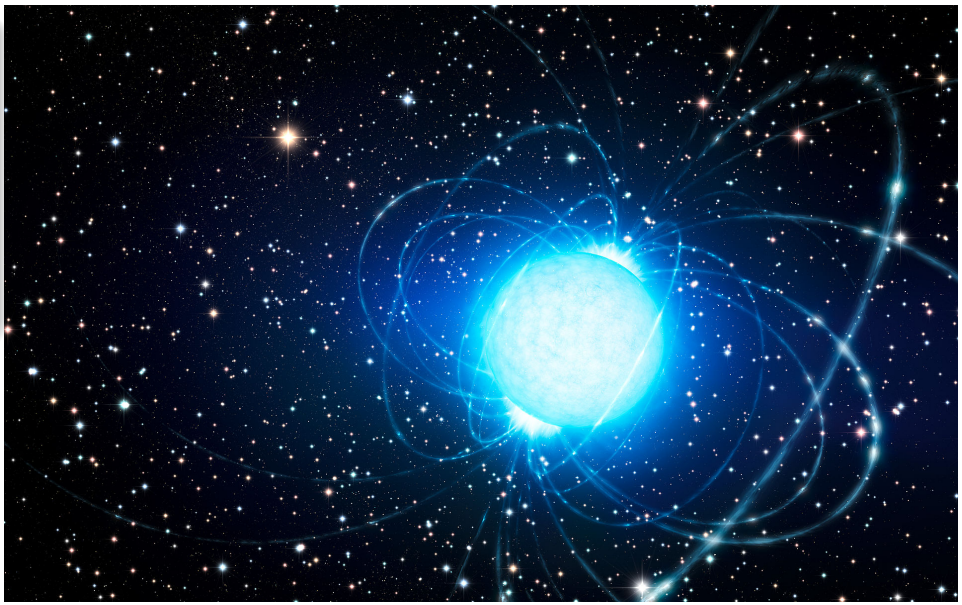

Figure: Artistic depiction of a magnetar

What is a Magnetar?

Definition:

- neutron star

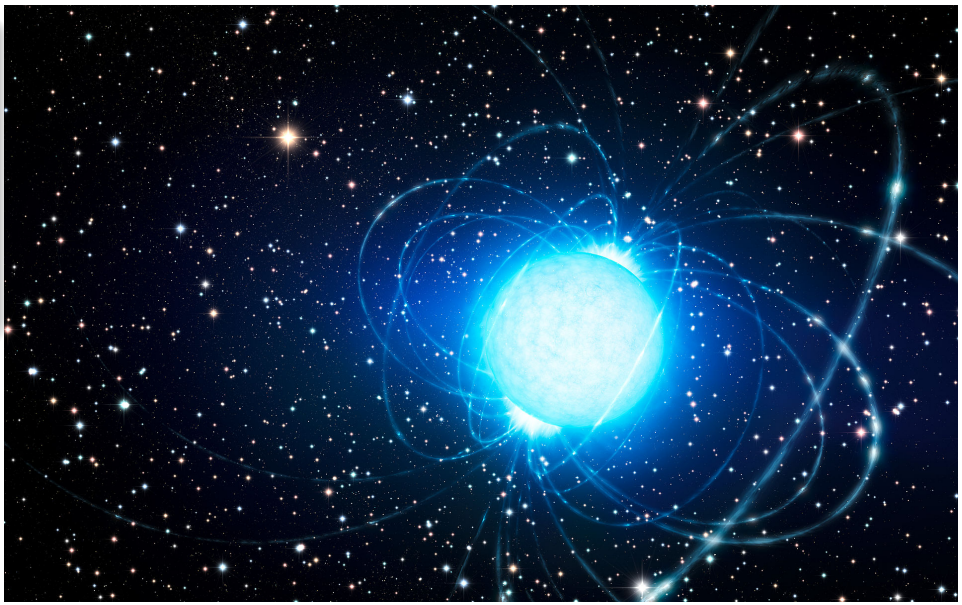

Figure: Artistic depiction of a magnetar

What is a Magnetar?

Definition:

- neutron star
- massive magnetic field ($\geq 10^{13}$ G)

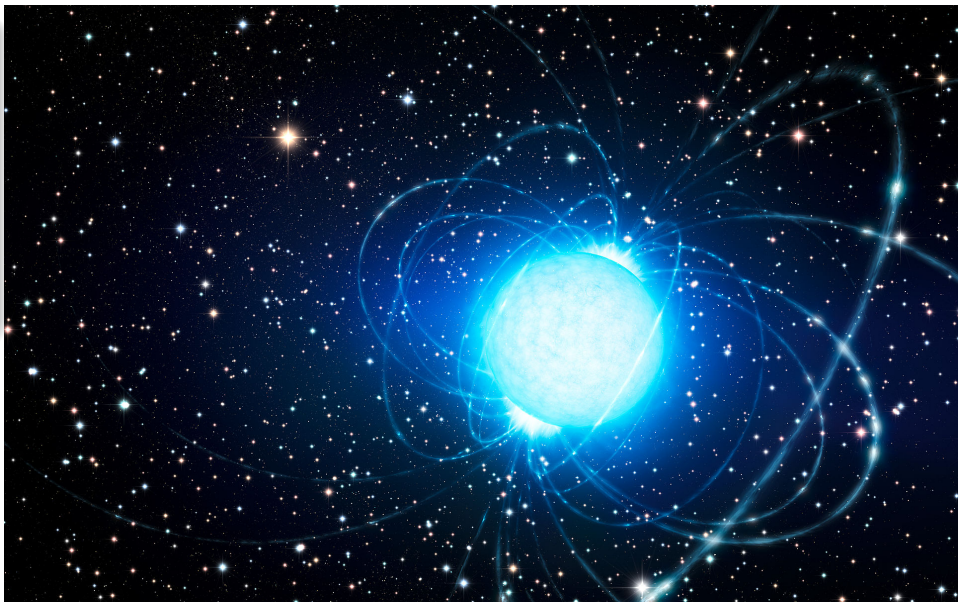

Figure: Artistic depiction of a magnetar

Discovery of Magnetars

Definition:

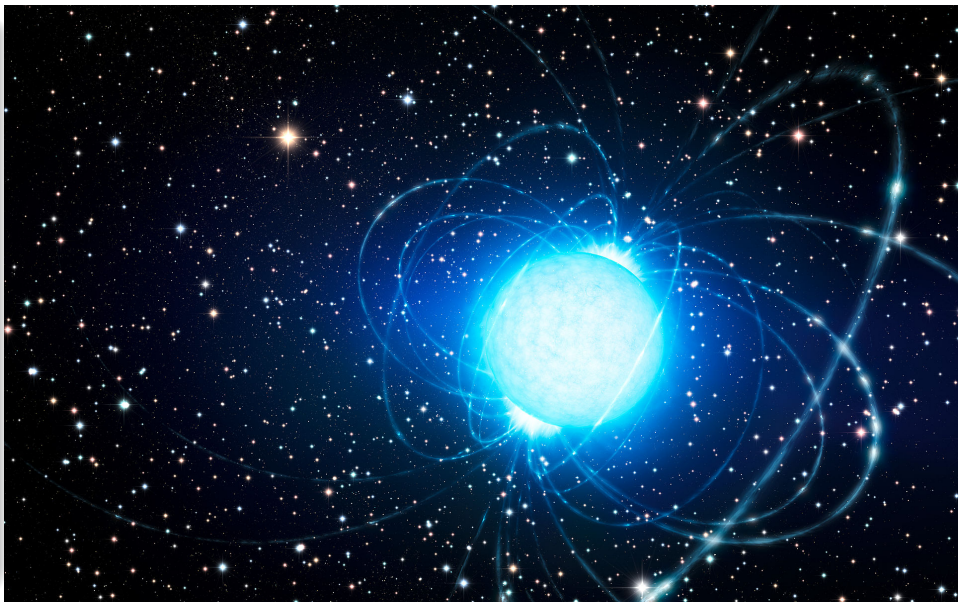

Figure: Artistic depiction of a magnetar

Discovery of Magnetars

Definition:

- proposed in 1992 by Duncan Thompson [1]

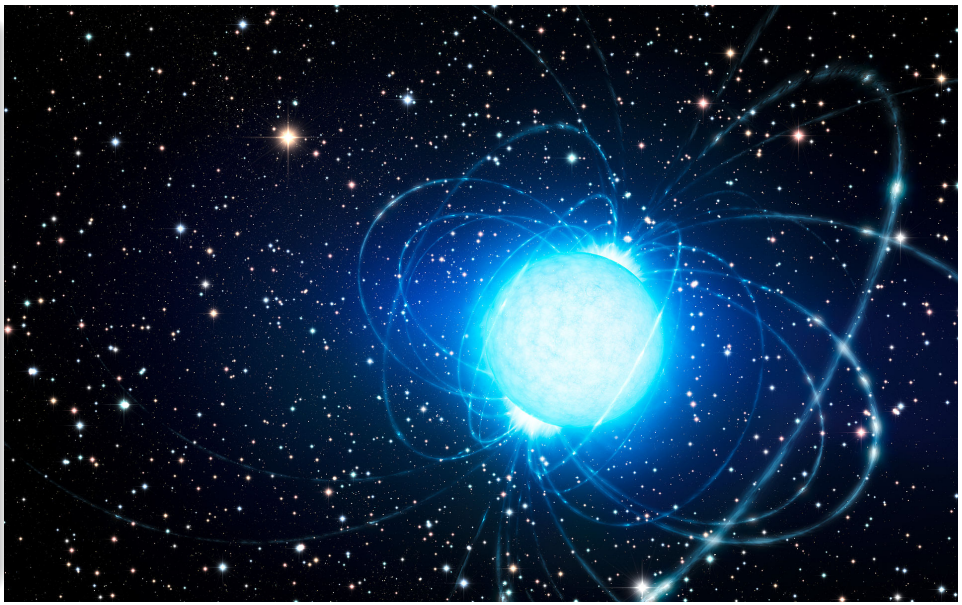

Figure: Artistic depiction of a magnetar

Discovery of Magnetars

Definition:

- proposed in 1992 by Duncan Thompson [1]
- SGR 0525-66 found in 1979 (only known outside MW)

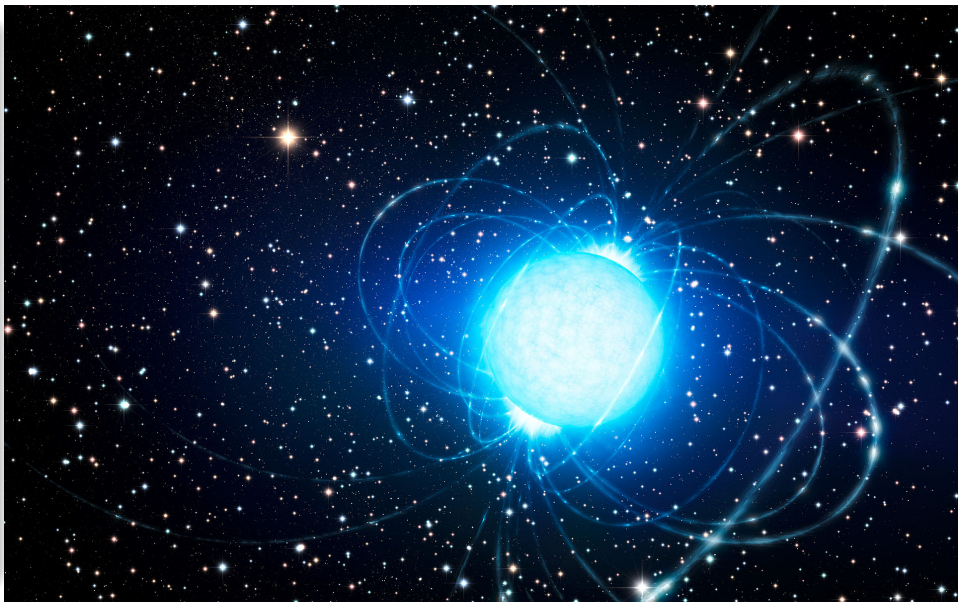

Figure: Artistic depiction of a magnetar

Discovery of Magnetars

Definition:

- proposed in 1992 by Duncan Thompson [1]
- SGR 0525-66 found in 1979 (only known outside MW)
- short X-Ray bursts

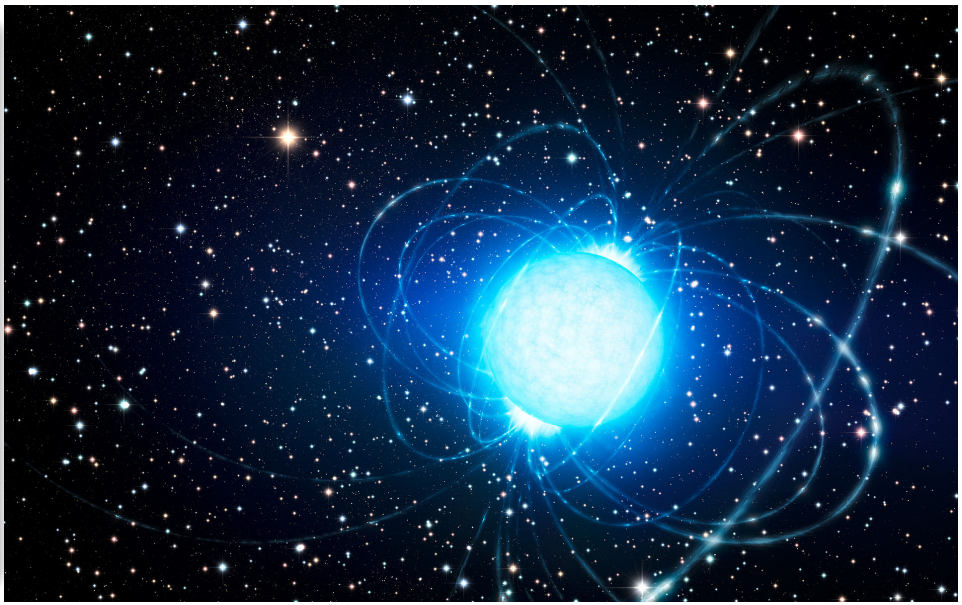

Figure: Artistic depiction of a magnetar

Discovery of Magnetars

Definition:

- proposed in 1992 by Duncan Thompson [1]
- SGR 0525-66 found in 1979 (only known outside MW)
- short X-Ray bursts
- selection bias

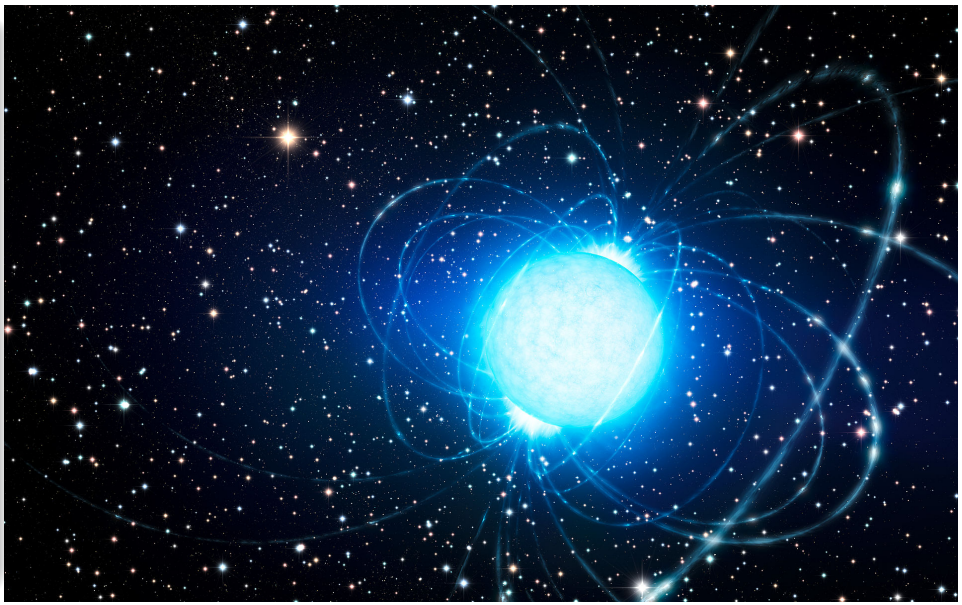

Figure: Artistic depiction of a magnetar

Basic Properties

Description:

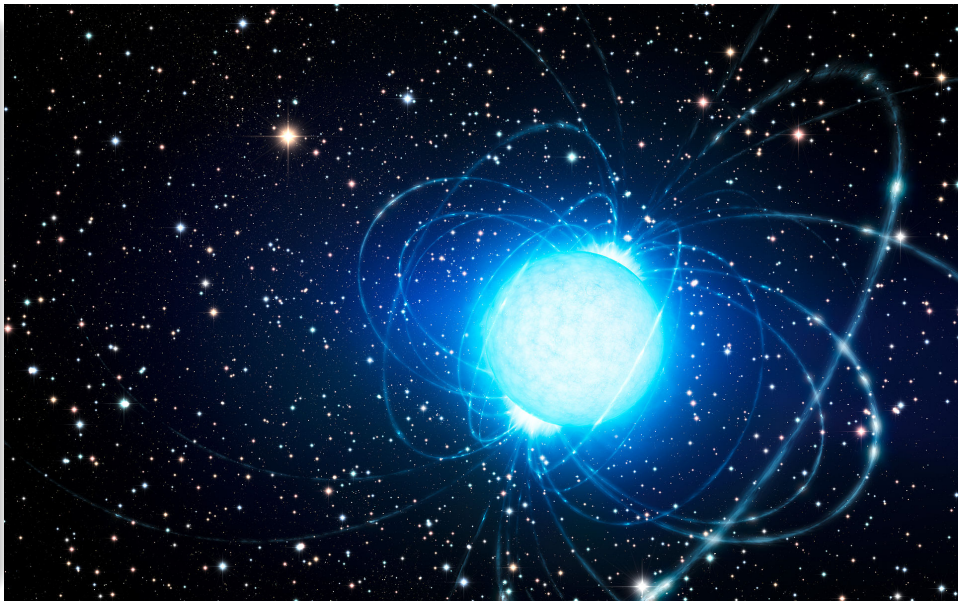

Figure: Artistic depiction of a magnetar

Cases:

Basic Properties

Description:

- young neutron star

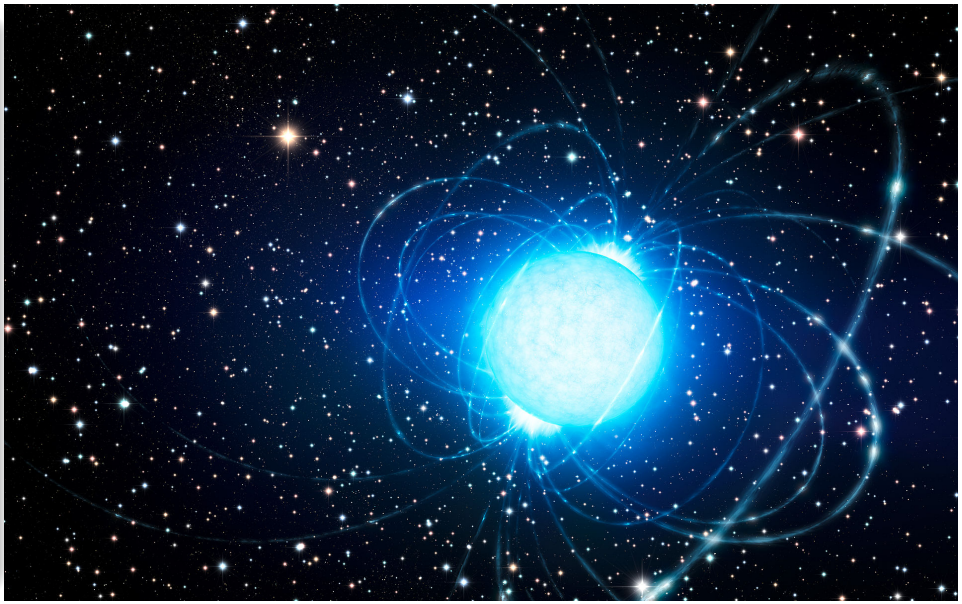

Figure: Artistic depiction of a magnetar

Cases:

Basic Properties

Description:

- young neutron star
- spinning down, timescale $\sim$1 kyr

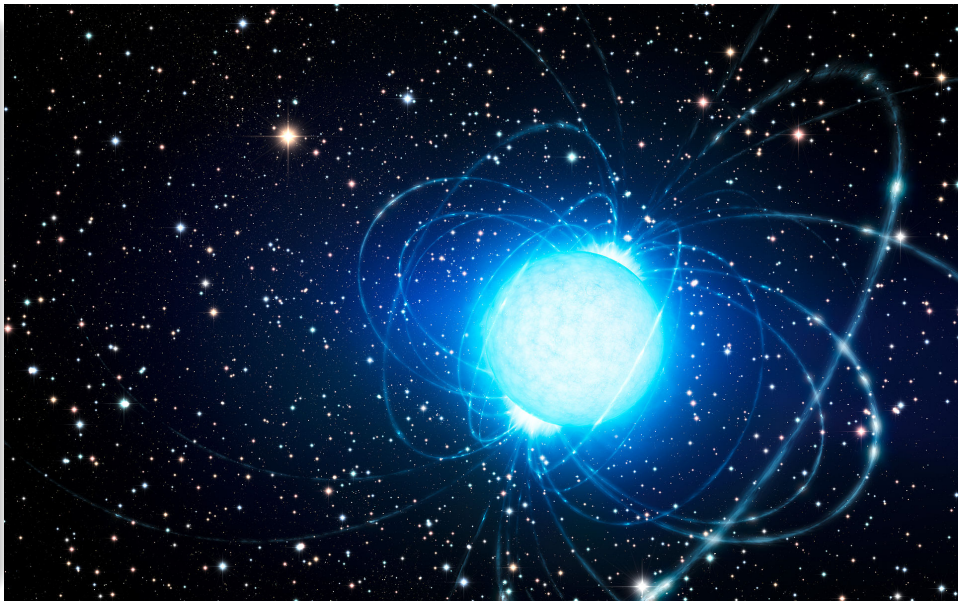

Figure: Artistic depiction of a magnetar

Cases:

Basic Properties

Description:

- young neutron star
- spinning down, timescale $\sim$1 kyr
- high-B field ($\geq 10^{13}$ G)

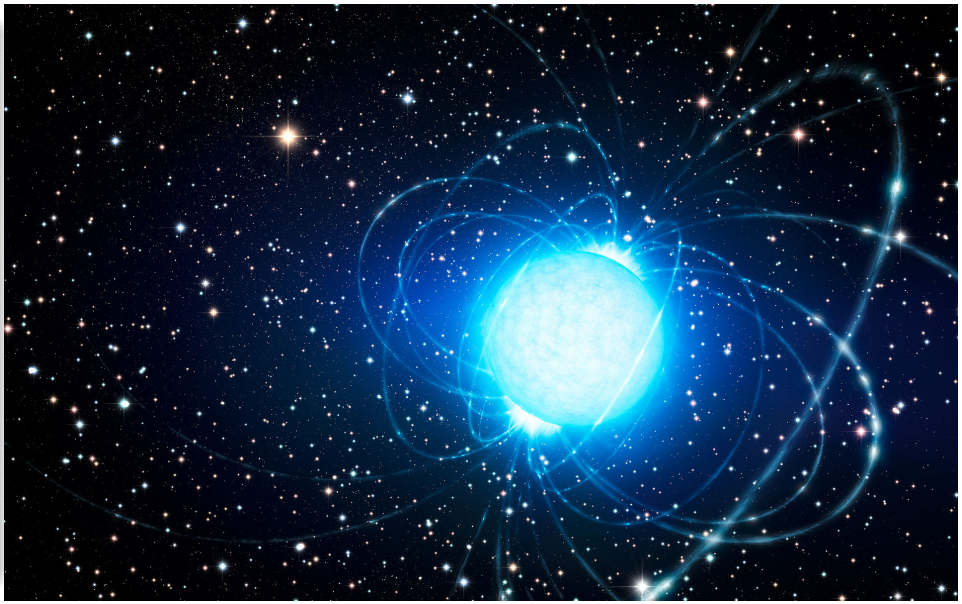

Figure: Artistic depiction of a magnetar

Cases:

Basic Properties

Description:

- young neutron star
- spinning down, timescale $\sim$1 kyr
- high-B field ($\geq 10^{13}$ G)
- rotational period range of 2-12s

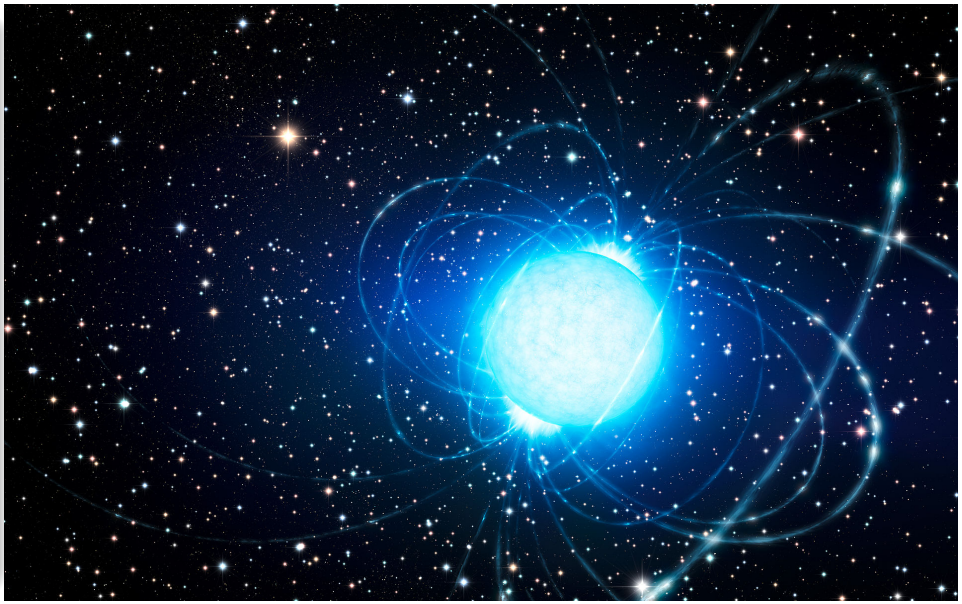

Figure: Artistic depiction of a magnetar

Cases:

Basic Properties

Description:

- young neutron star
- spinning down, timescale $\sim$1 kyr
- high-B field ($\geq 10^{13}$ G)
- rotational period range of 2-12s

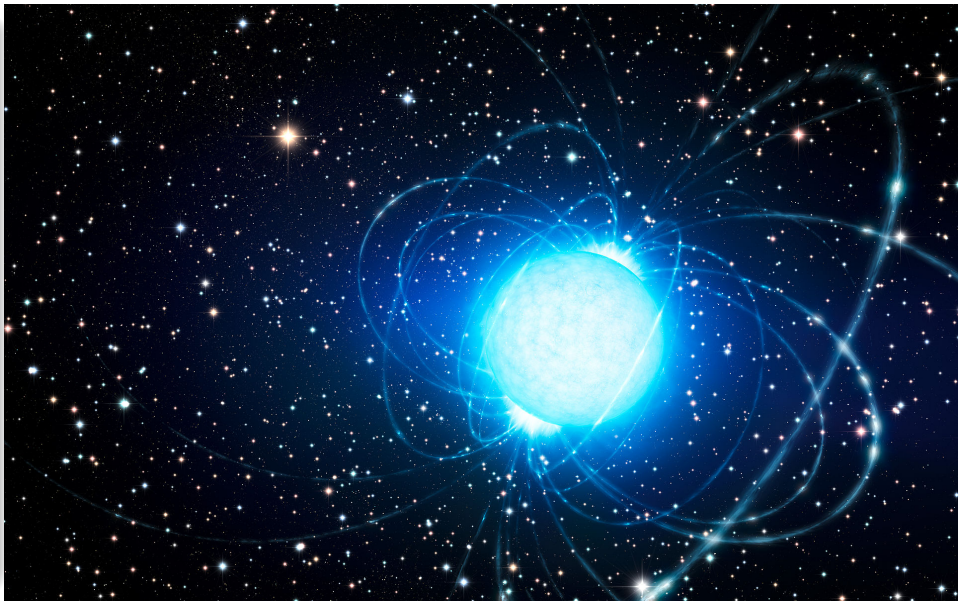

Figure: Artistic depiction of a magnetar

Cases:

- bi-modal population of transients and persistents

Basic Properties

Description:

- young neutron star
- spinning down, timescale $\sim$1 kyr
- high-B field ($\geq 10^{13}$ G)
- rotational period range of 2-12s

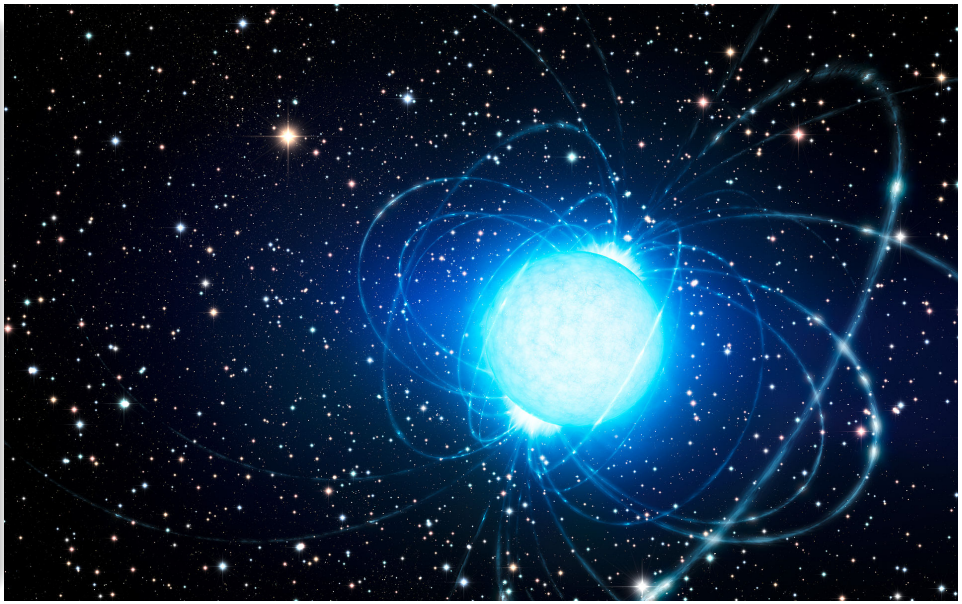

Figure: Artistic depiction of a magnetar

Cases:

- bi-modal population of transients and persistents
- cross-species magnetar/pulsar

Distinctions

Neutron Star

- radius on order of 10 km
- 1.1 - 2.16 solar masses
- $10^9 - 10^{13}$ G (for non-magnetars)

Magnetars

Radio Pulsars

Distinctions

Neutron Star

- radius on order of 10 km
- 1.1 - 2.16 solar masses
- $10^9 - 10^{13}$ G (for non-magnetars)

Magnetars

- 2-12s rotational period

Radio Pulsars

Distinctions

Neutron Star

- radius on order of 10 km
- 1.1 - 2.16 solar masses
- $10^9 - 10^{13}$ G (for non-magnetars)

Magnetars

- 2-12s rotational period

Radio Pulsars

- $\sim$100 ms rotational period

Distinctions

Neutron Star

- radius on order of 10 km
- 1.1 - 2.16 solar masses
- $10^9 - 10^{13}$ G (for non-magnetars)

Magnetars

- 2-12s rotational period
- spin-down $\rightarrow$ quiescent X-ray emission and gamma-ray bursts

Radio Pulsars

- $\sim$100 ms rotational period

Distinctions

Neutron Star

- radius on order of 10 km
- 1.1 - 2.16 solar masses
- $10^9 - 10^{13}$ G (for non-magnetars)

Magnetars

- 2-12s rotational period
- spin-down $\rightarrow$ quiescent X-ray emission and gamma-ray bursts

Radio Pulsars

- $\sim$100 ms rotational period
- spin-down $\rightarrow$ radio emission, and non-thermal X/gamma-ray radiation

Neutron Star Types

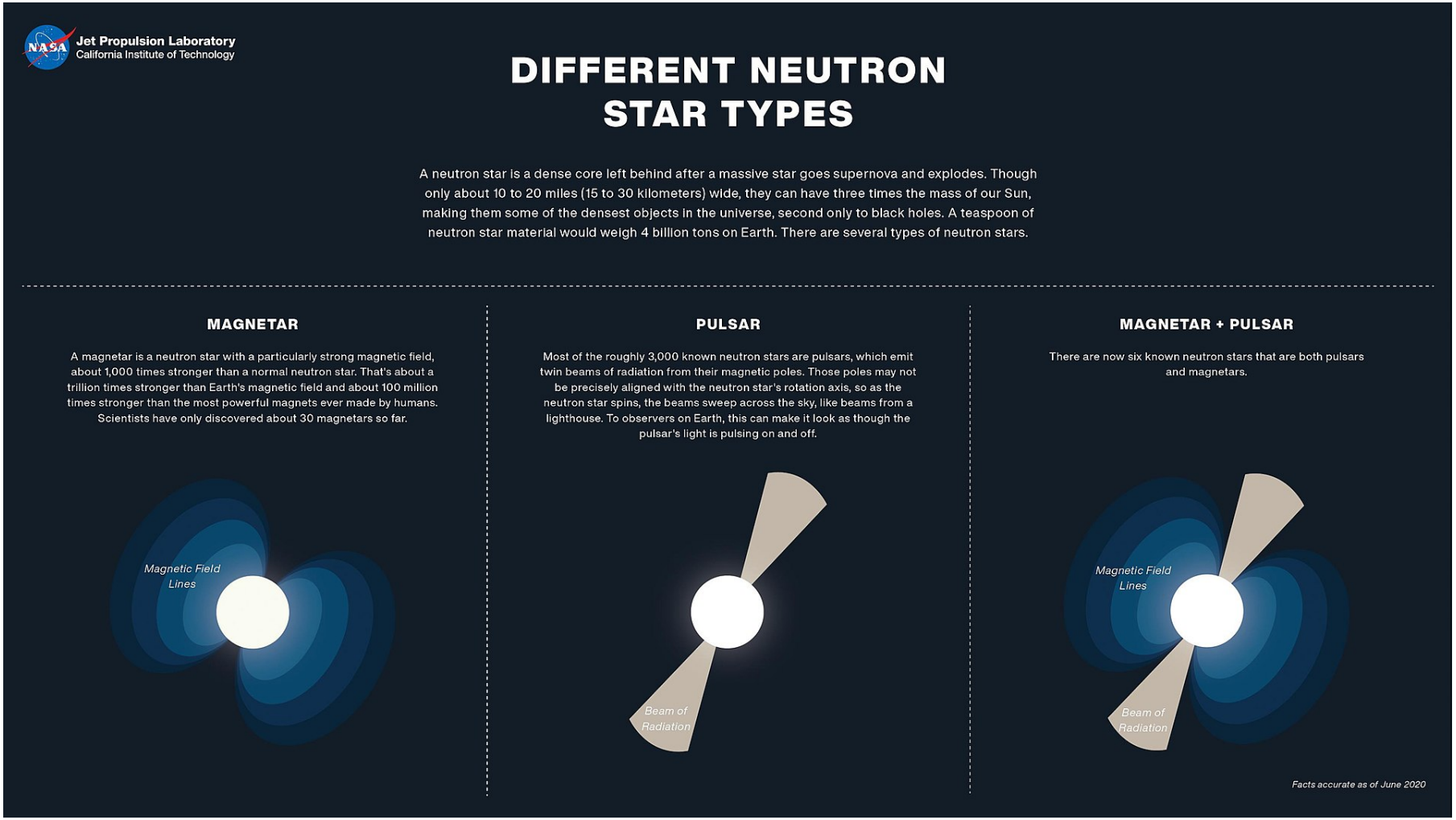

Figure: Neutron star types, courtesy of JPL [cite here]

Distribution in Space

Observations:

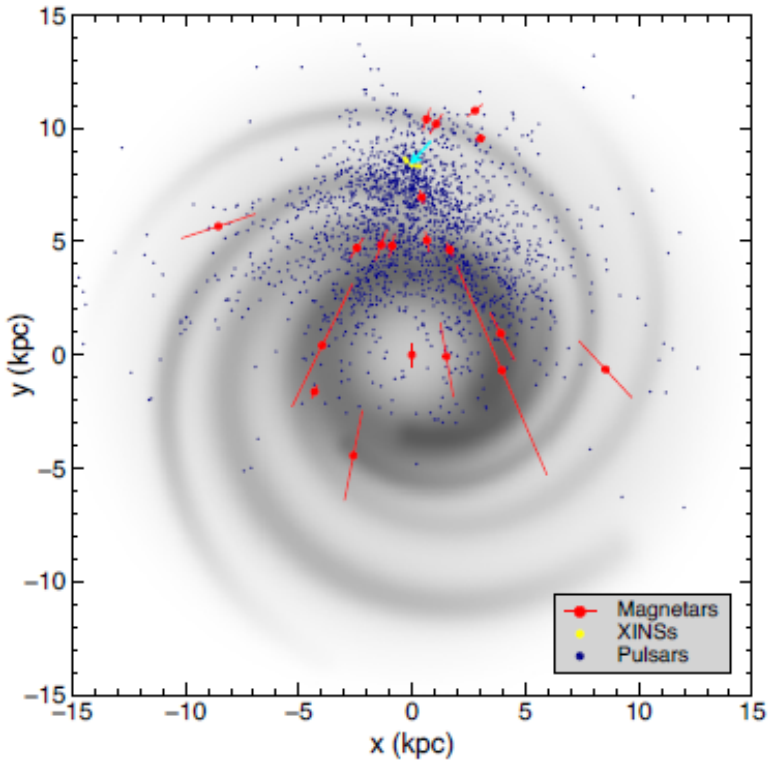

Figure: Top down view of the Milky Way with known Magnetars (and distance uncertainties) in red.

Distribution in Space

Observations:

- generally within the galactic plane

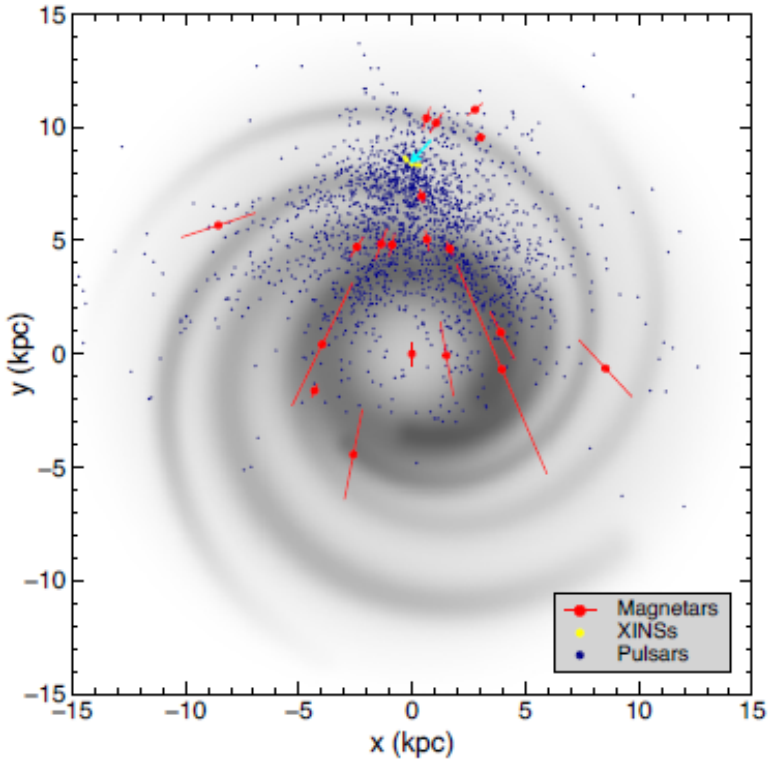

Figure: Top down view of the Milky Way with known Magnetars (and distance uncertainties) in red.

Distribution in Space

Observations:

- generally within the galactic plane
- mean speed of 200 km s^{-}1, $\sigma = 100$ km s^{-}1

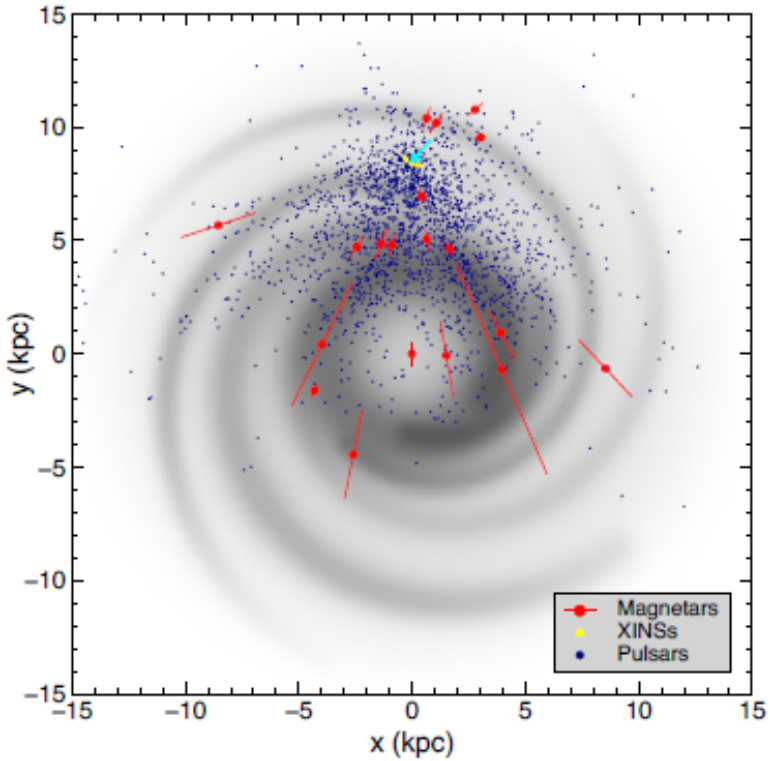

Figure: Top down view of the Milky Way with known Magnetars (and distance uncertainties) in red.

Distribution in Space

Observations:

- generally within the galactic plane
- mean speed of 200 km s^{-}1, $\sigma = 100$ km s^{-}1
- selection bias

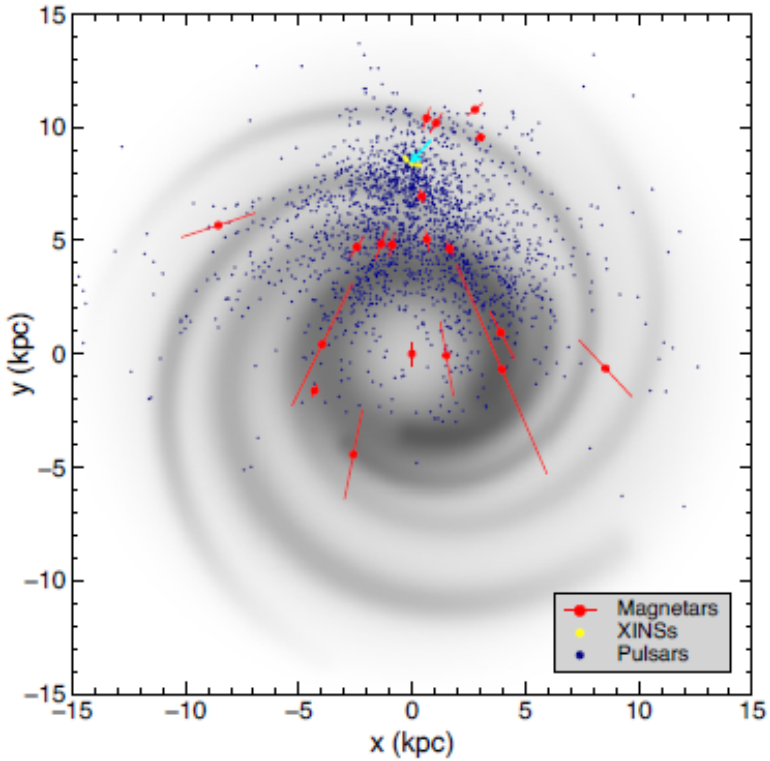

Figure: Top down view of the Milky Way with known Magnetars (and distance uncertainties) in red.

The Magnetars

Name	P (s)	B (10^{14} G)	Age (kyr)	E (10^{33} erg s^{-1})	D (kpc)	L (10^{33} erg s^{-1})	Band
CXOU J010043.1-721134	8.02	3.9	6.8	1.4	62.4	65	...
4U 0142+61	8.69	1.3	68	0.12	3.6	105	OIR/H
SGR 0418+5729	9.08	0.06	36000	0.00021	2	0.00096	...
SGR 0501+4516	5.76	1.9	15	1.2	2	0.81	OIR/H
SGR 0526-66	8.05	5.6	3.4	2.9	53.6	189	...
1E 1048.1-5937	6.46	3.9	4.5	3.3	9.0	49	OIR
(PSR J1119-6127)	0.41	4.1	1.6	2300	8.4	0.2	R/H
1E 1547.0-5408	2.07	3.2	0.69	210	4.5	1.3	O?/R/H
PSR J1622-4950	4.33	2.7	4.0	8.3	9	0.4	R
SGR 1627-41	2.59	2.2	2.2	43	11	3.6	...
CXOU J164710.2-455216	10.6	<0.66	>420	<0.013	3.9	0.45	...
1RXS J170849.0-400910	11.01	4.7	9.0	0.58	3.8	42	O?/H
CXOU J171405.7-381031	3.82	5.0	0.95	45	13	56	...
SGR J1745-2900	3.76	2.3	4.3	10	8.3	<0.11	R/H
SGR 1806-20	7.55	20	0.24	45	8.7	163	OIR/H
XTE J1810-197	5.54	2.1	11	1.8	3.5	0.043	OIR/R
Swift J1822.3-1606	8.44	0.14	6300	0.0014	1.6	>0.0004	...
SGR 1833-0832	7.56	1.6	34	0.32	...	...	...
Swift J1834.9-0846	2.48	1.4	4.9	21	4.2	<0.0084	...
1E 1841-045	11.79	7.0	4.6	0.99	8.5	184	...
(PSR J1846-0258)	0.327	0.49	0.73	8100	6.0	19	...
3XMM J185246.6+003317	11.56	<0.41	>1300	<0.0036	7	< 0.006	...
SGR 1900+14	5.20	7.0	0.9	26	12.5	90	H
SGR 1935+2154	3.24	2.2	3.6	17	...	...	...
1E 2259+586	6.98	0.59	230	0.056	3.2	17	OIR/H
SGR 0755-2933	...	...	...	...	...	...	...
SGR 1801-23	...	...	...	...	...	...	...
SGR 1808-20	...	...	...	...	...	...	...
AX J1818.8-1559	...	...	...	...	...	...	...
AX J1845.0-0258	6.97	...	...	...	...	2.9	...
SGR 2013+34	...	...	...	...	...	...	...

Figure: So far...

Supernova Remnant Associations

Basics:

Consequences:

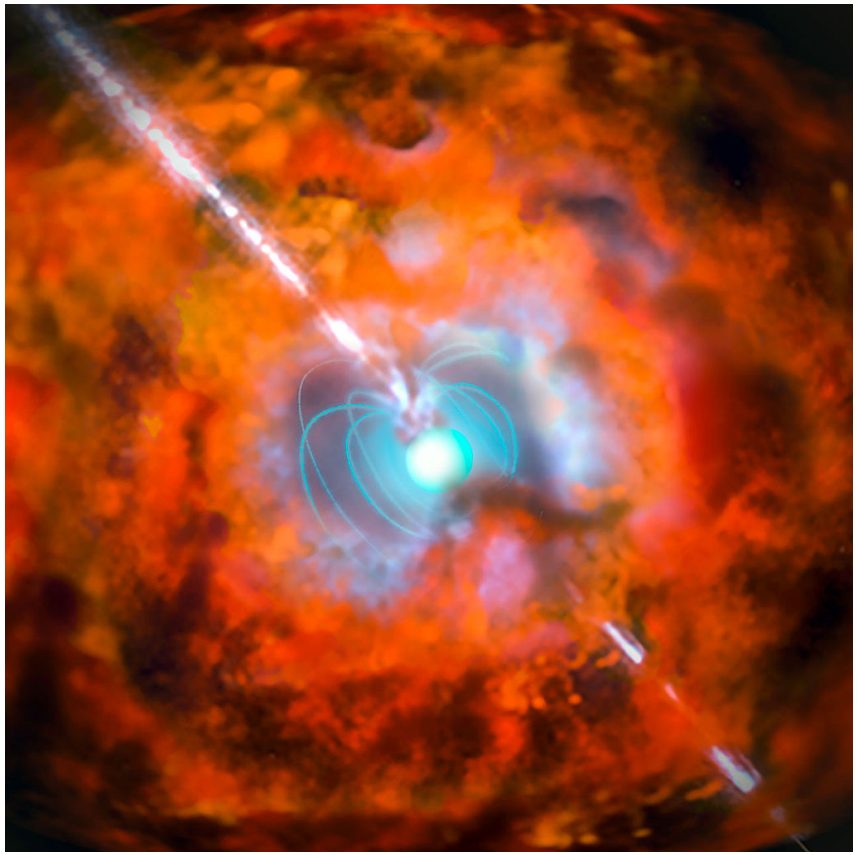

Figure: Artist's depiction of supernova remnant and magnetar [Cite here]

Supernova Remnant Associations

Basics:

- 8/23 magnetars

Consequences:

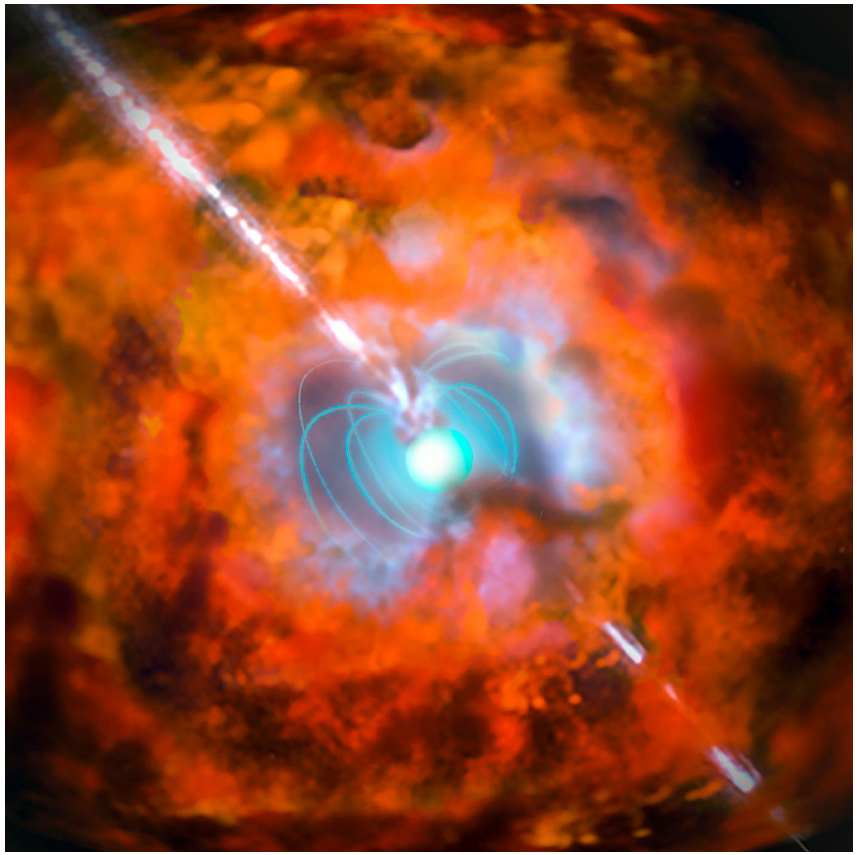

Figure: Artist's depiction of supernova remnant and magnetar [Cite here]

Supernova Remnant Associations

Basics:

- 8/23 magnetars
- 2 other possible associations

Consequences:

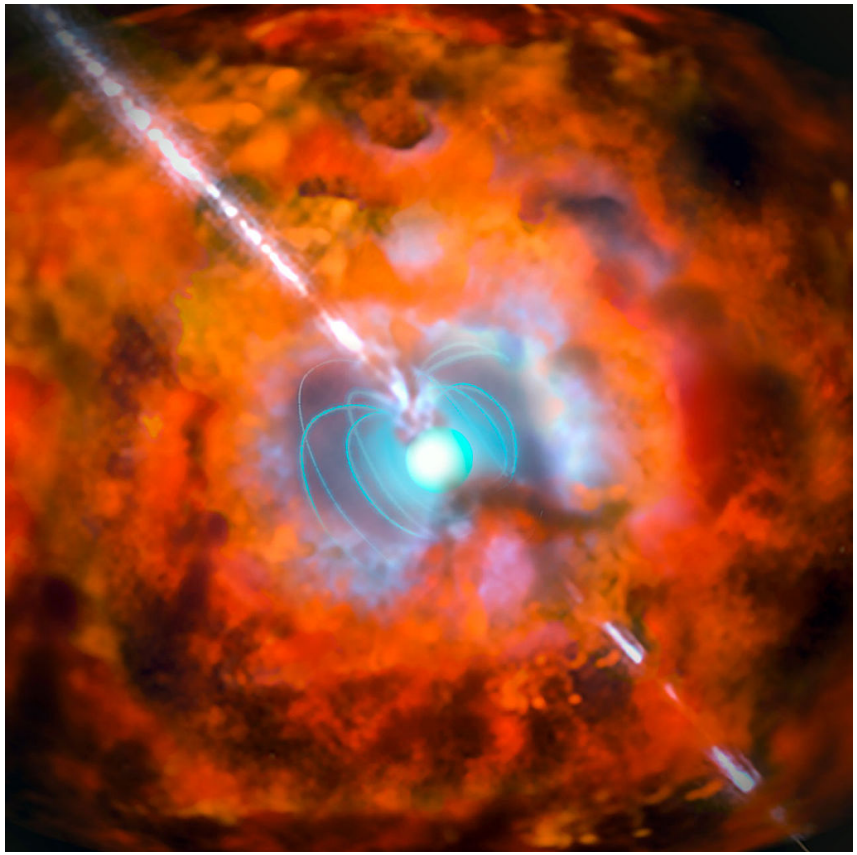

Figure: Artist's depiction of supernova remnant and magnetar [Cite here]

Supernova Remnant Associations

Basics:

- 8/23 magnetars
- 2 other possible associations
- provides additional evidence to youth requirement

Consequences:

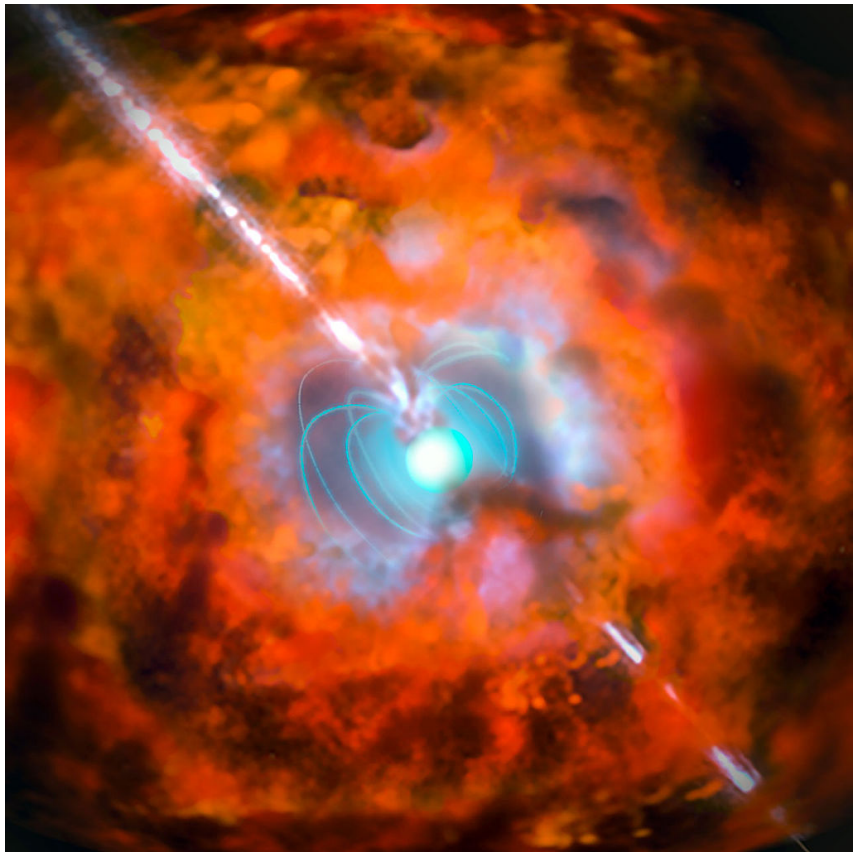

Figure: Artist's depiction of supernova remnant and magnetar [Cite here]

Supernova Remnant Associations

Basics:

- 8/23 magnetars
- 2 other possible associations
- provides additional evidence to youth requirement

Consequences:

- unexpected characteristics

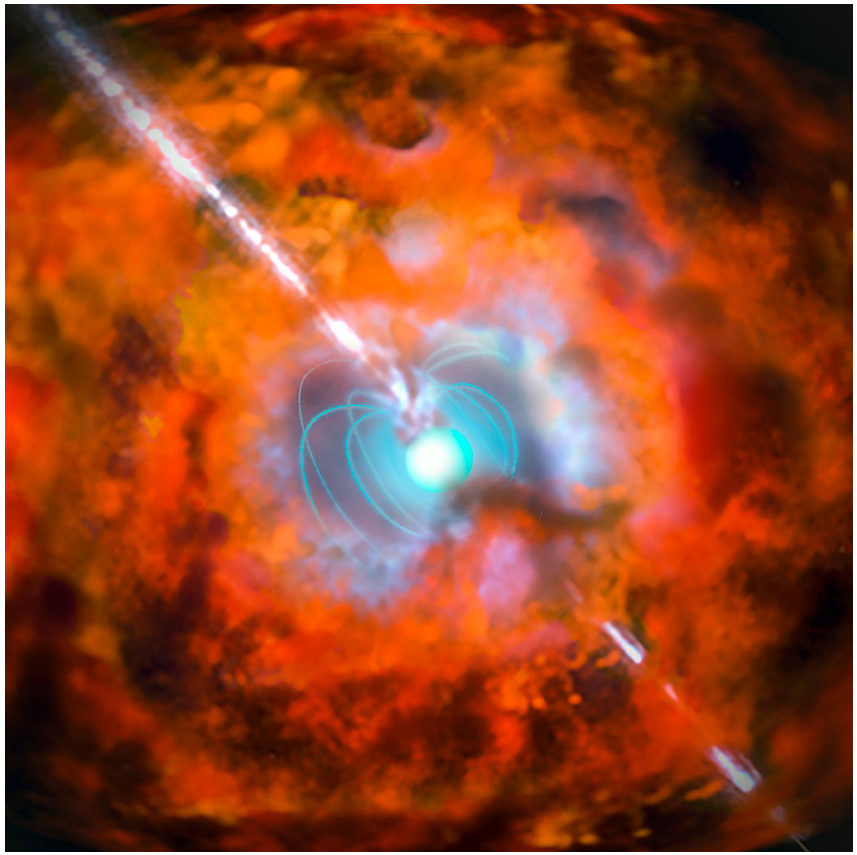

Figure: Artist's depiction of supernova remnant and magnetar [Cite here]

Supernova Remnant Associations

Basics:

- 8/23 magnetars
- 2 other possible associations
- provides additional evidence to youth requirement

Consequences:

- unexpected characteristics
- challenges dynamo model and fossil field theory

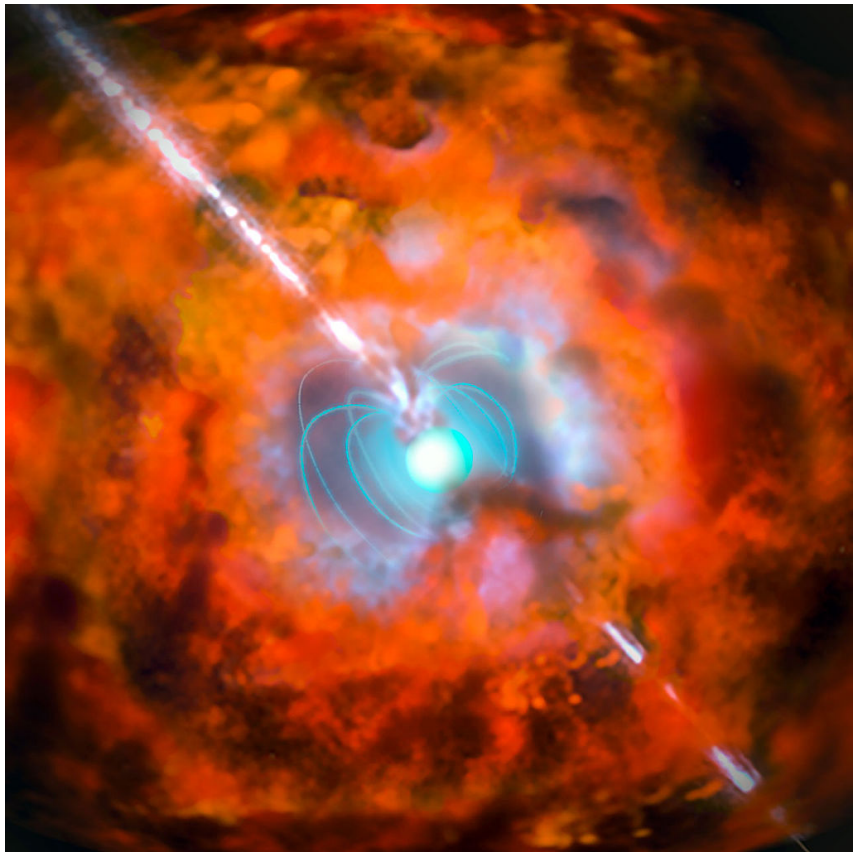

Figure: Artist's depiction of supernova remnant and magnetar [Cite here]

Supernova Remnant Associations

Basics:

- 8/23 magnetars
- 2 other possible associations
- provides additional evidence to youth requirement

Consequences:

- unexpected characteristics
- challenges dynamo model and fossil field theory
- no conclusive theory of formation as of yet

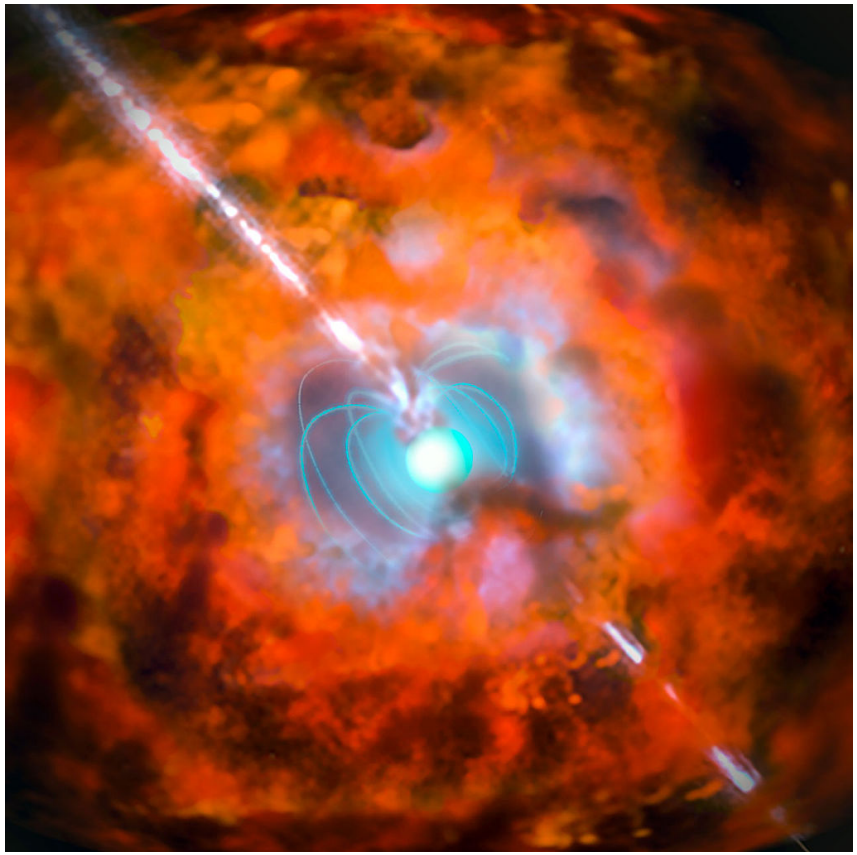

Figure: Artist's depiction of supernova remnant and magnetar [Cite here]

Formation

Theories

Common Conditions

Formation

Theories

- Neutron stars with $\sim$1 ms period at birth [1]

Common Conditions

Formation

Theories

- Neutron stars with $\sim$1 ms period at birth [1]

Common Conditions

- parasitic binary star systems ending in supernova

Formation

Theories

- Neutron stars with $\sim$1 ms period at birth [1]
- Leading Theory: divine entity

Common Conditions

- parasitic binary star systems ending in supernova

Formation

Theories

- Neutron stars with $\sim$1 ms period at birth [1]
- Leading Theory: divine entity

Common Conditions

- parasitic binary star systems ending in supernova
-

Kinds of Magnetars

Bi-modal

Cross-species

Kinds of Magnetars

Bi-modal

- Persistent Magnetars

Cross-species

Kinds of Magnetars

Bi-modal

- Persistent Magnetars
- Transient Magnetars

Cross-species

Kinds of Magnetars

Bi-modal

- Persistent Magnetars
- Transient Magnetars

Cross-species

- Magnetar Pulsar

Kinds of Magnetars

Bi-modal

- Persistent Magnetars
- Transient Magnetars

Cross-species

- Magnetar Pulsar
- Theoretically: neutron star switch between magnetar, pulsar, and magnetar pulsar

Magnetic Breaking

Materials

Magnetic Breaking

Materials

EM-Bursts

EM-Bursts

Summary and Conclusions

What we know

What we don't know

Summary and Conclusions

What we know

-

What we don't know

Summary and Conclusions

What we know

-

What we don't know

- A definitive model for the formation of magnetars

References

1. Duncan RC, Thompson C. 1992. ApJ 392:L9-L13