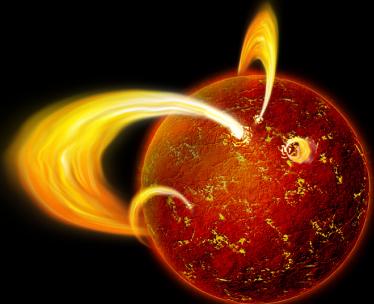


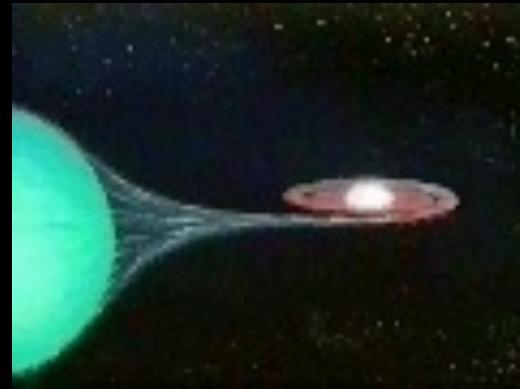
# ASTRONOMIA DE RAIOS X e $\gamma$

João Braga

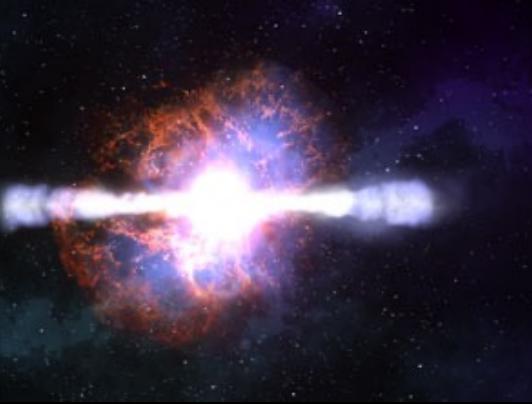
joao.braga@inpe.br



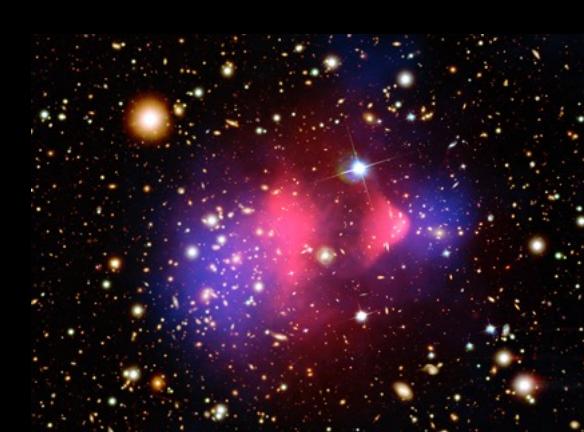
estrelas



sistemas binários



“bursts” de raios gama



Gás quente em aglomerados



M1: Caranguejo  
supernovas



buraco negro  
em M87:AGNs

# UNIVERSO

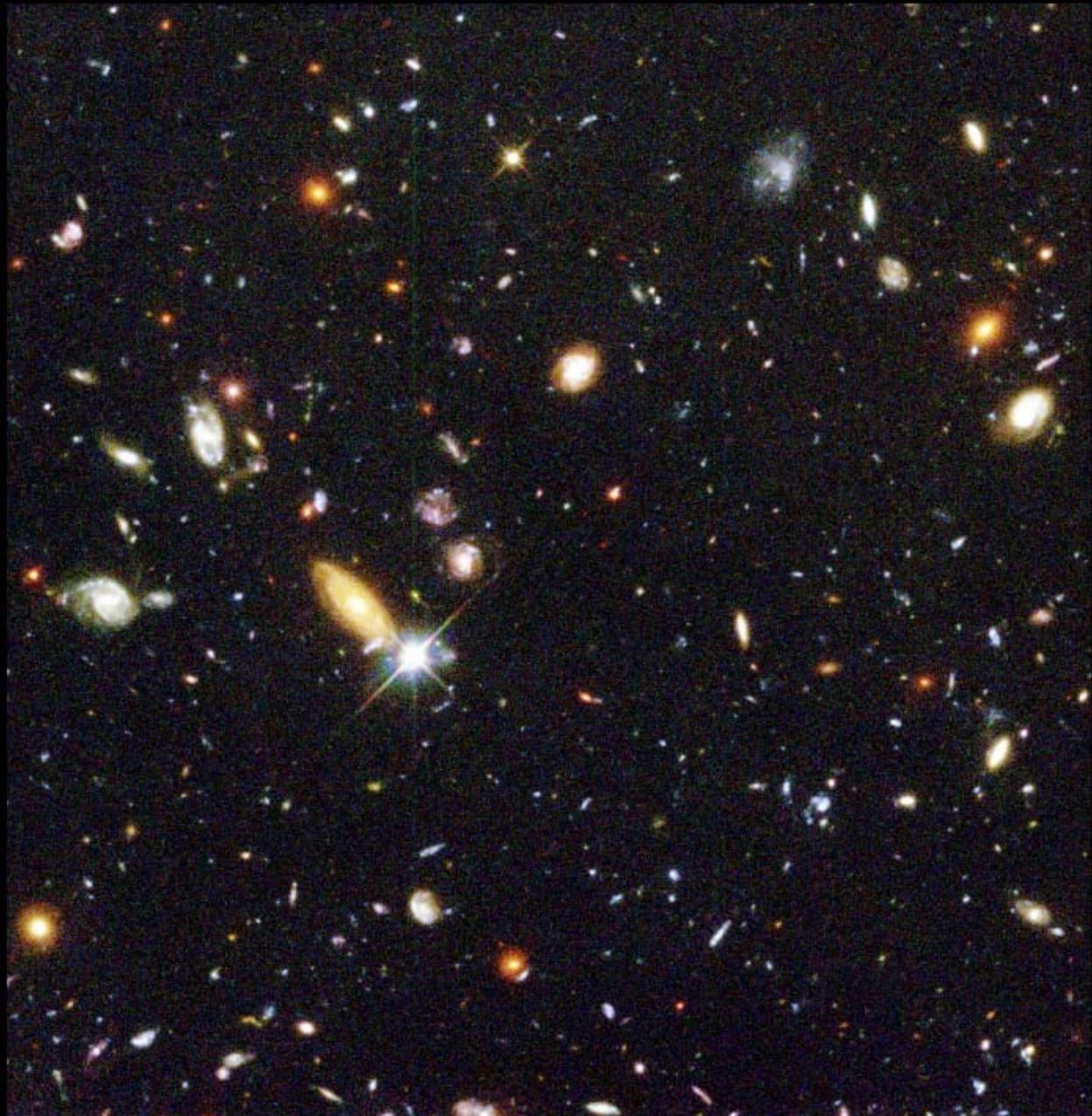
Imagen de uma  
região “vazia”

Telescópio  
Espacial Hubble

# Universo

Imagen de uma  
região “vazia”

Telescópio  
Espacial Hubble



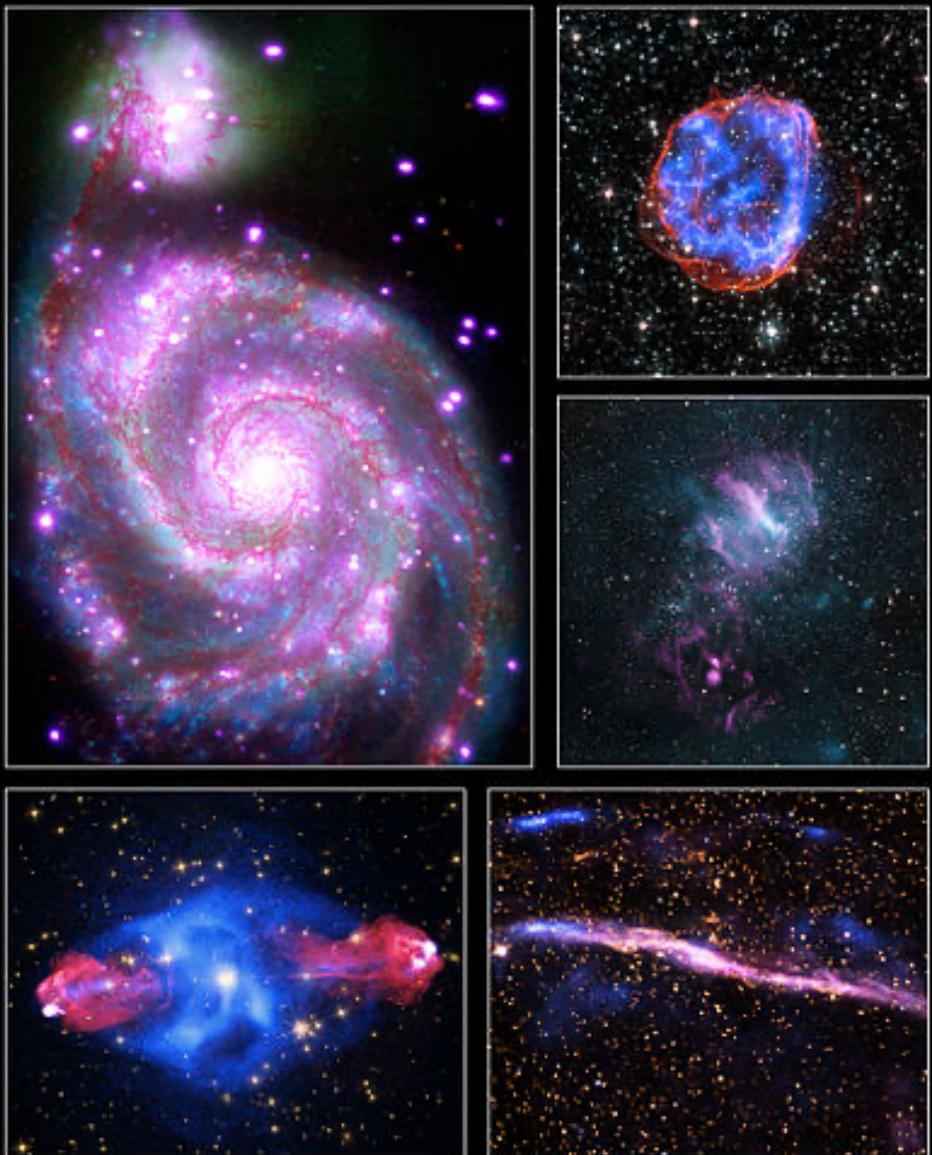
Hubble Deep Field

PRC96-01a · ST Scl OPO · January 15, 1996 · R. Williams (ST Scl), NASA

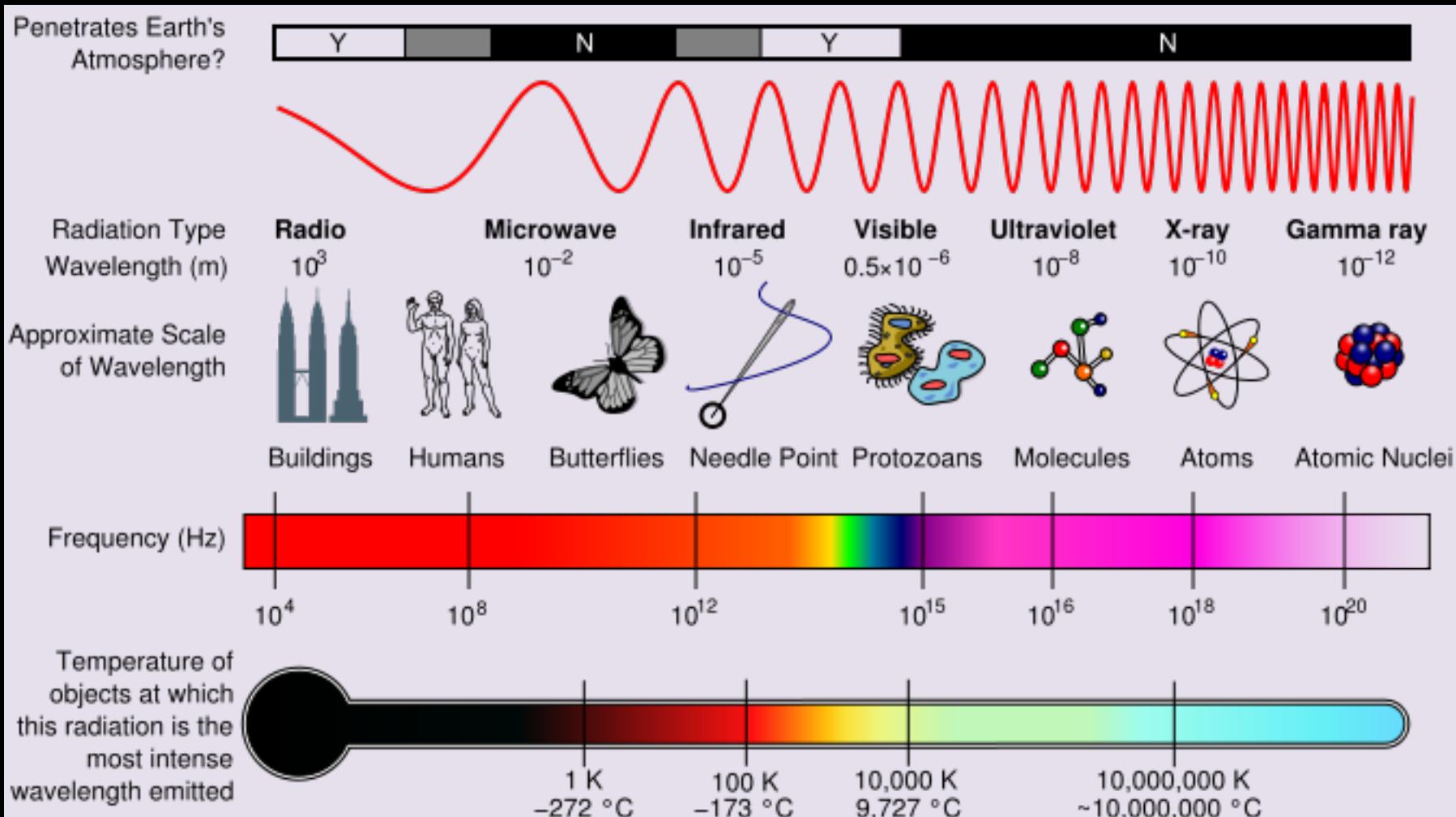
HST · WFPC2

# Mensageiros cósmicos:

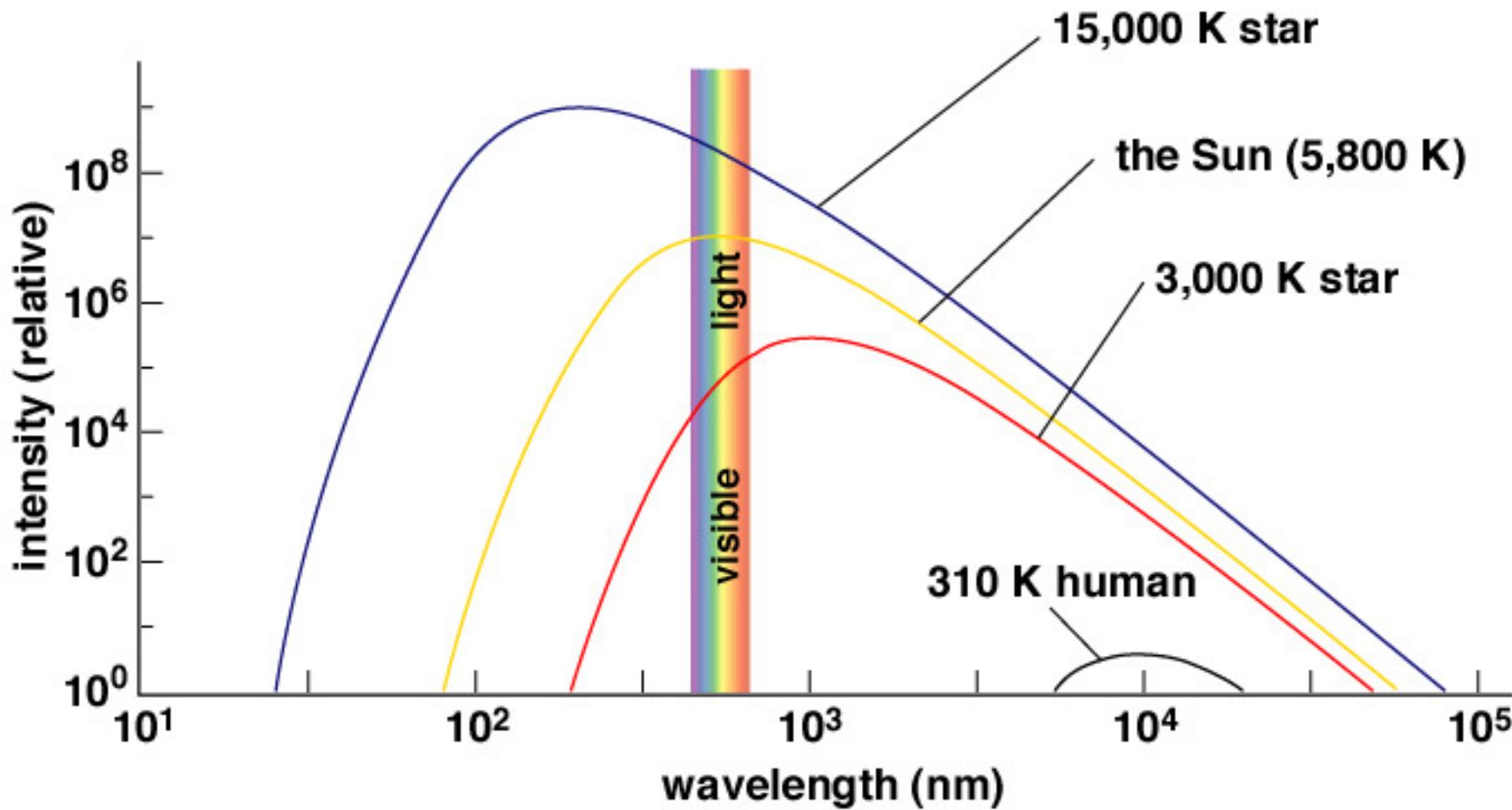
Luz :  
radiação  
eletromagnética

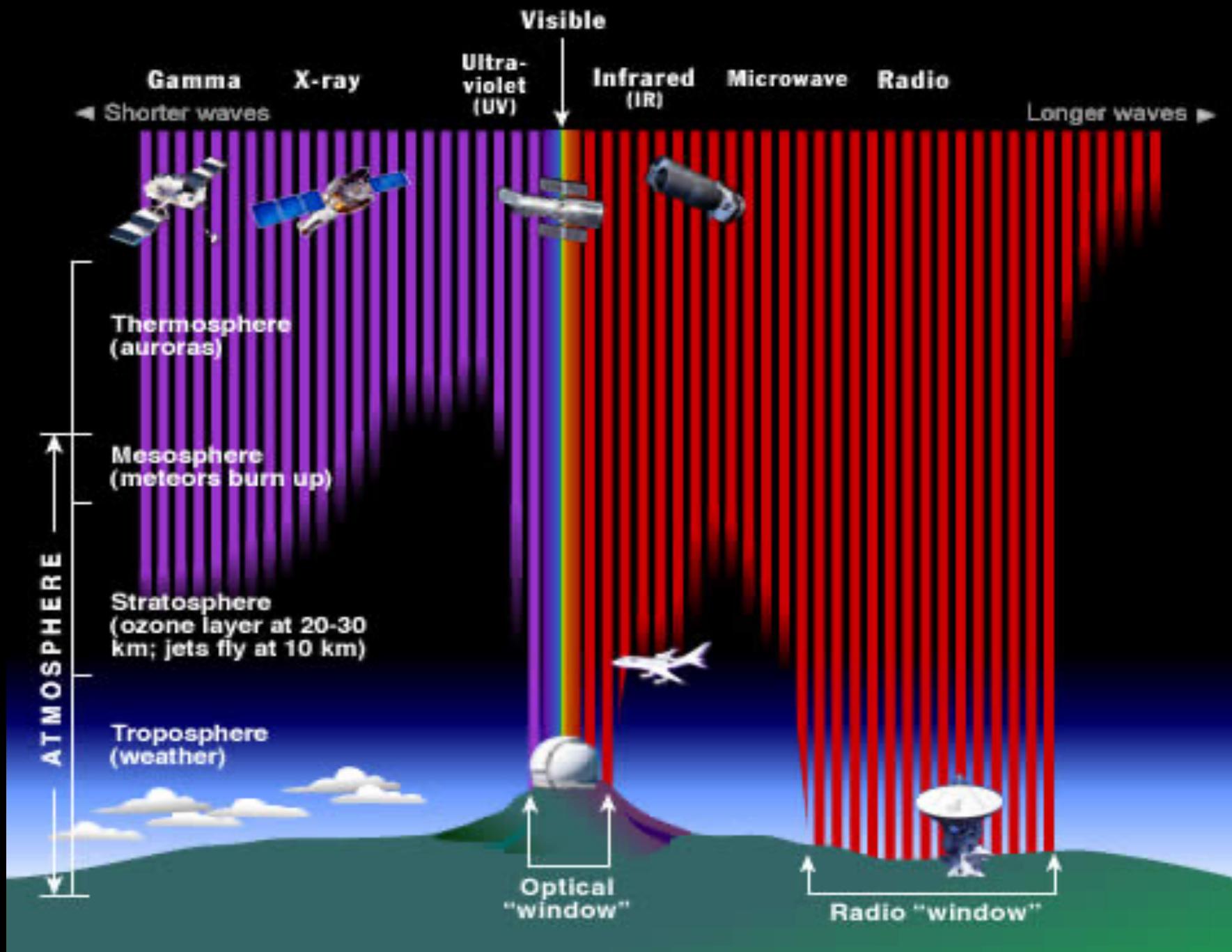


# Espectro eletromagnético



# Espectro da luz de uma fonte térmica

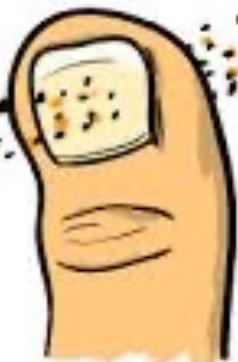




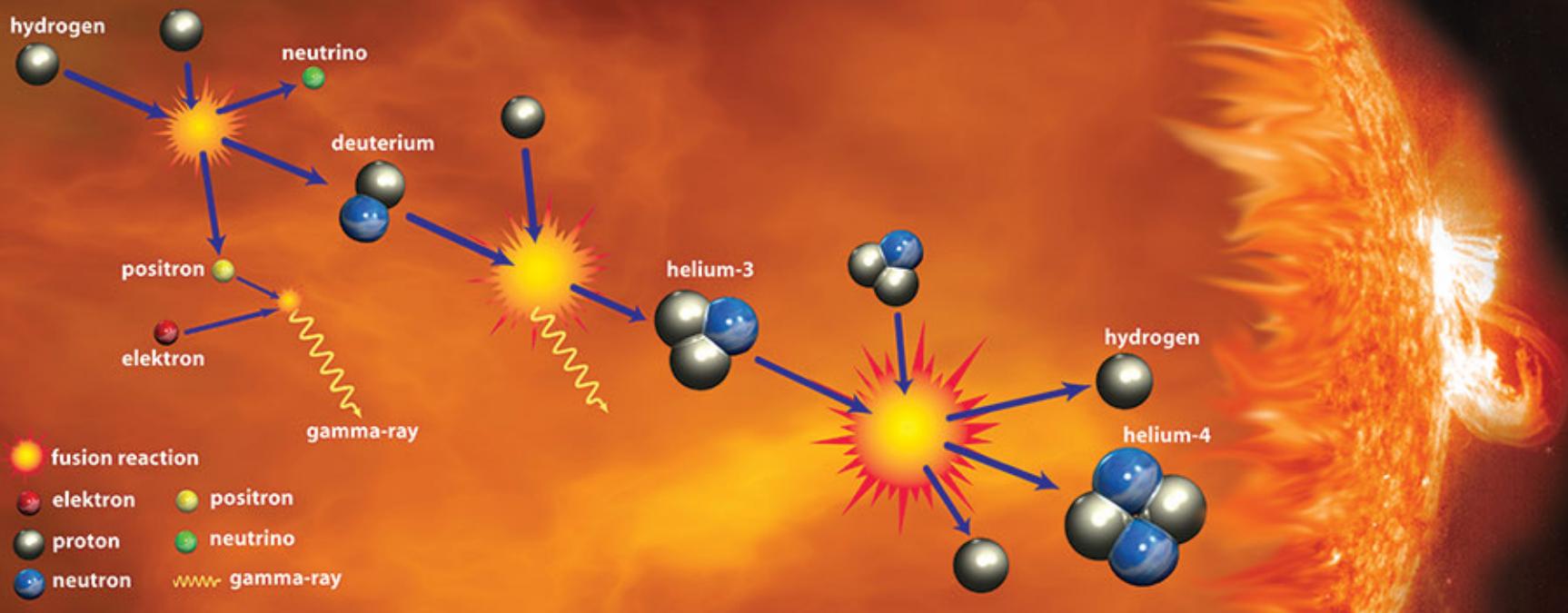
# Raios cósmicos



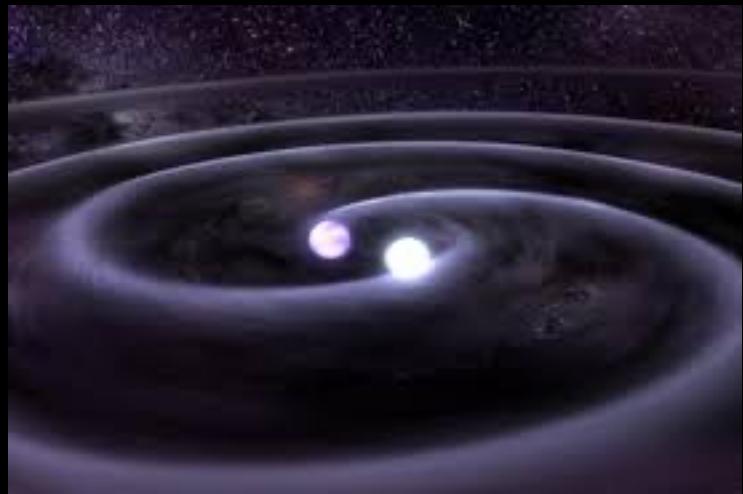
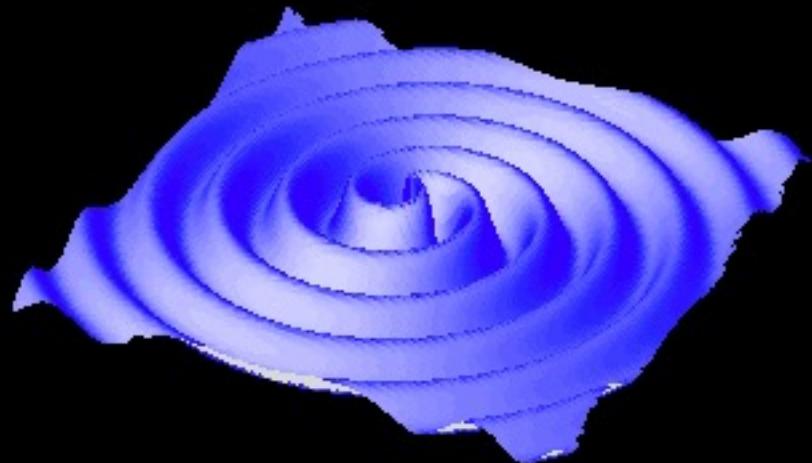
# neutrinos



**FACT:** about 65 million neutrinos pass through your thumbnail every second.



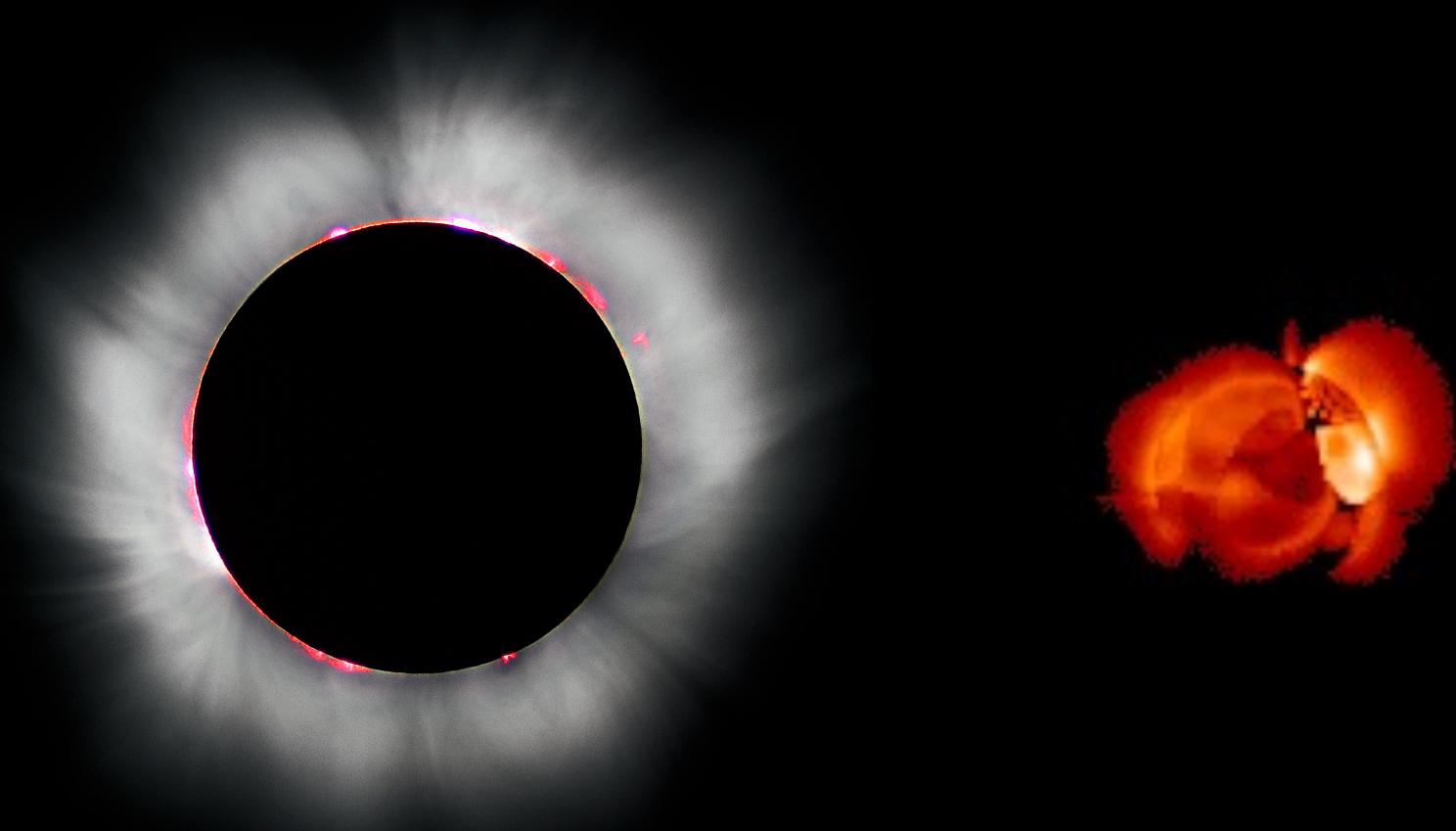
# ondas gravitacionais



# Fontes cósmicas de raios X e $\gamma$

- Coroas e explosões estelares
- Supernovas
- Sistemas binários com um objeto compacto
- Pulsares
- Galáxias
- Núcleos ativos de galáxias
- Bursts de raios gama
- Ruído de fundo difuso de raios X

# Coroas estelares



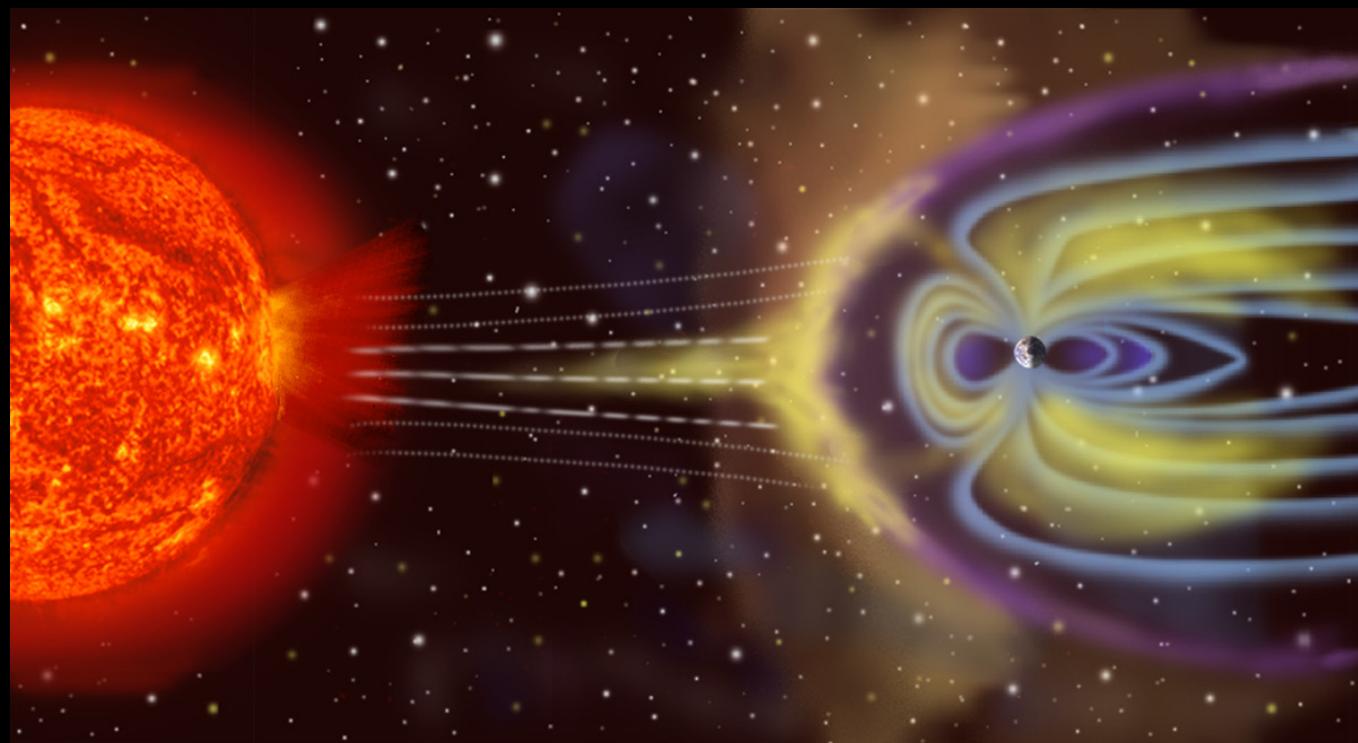
# Explosões em estrelas



SOL



Proxima Centauri



# PRODUTOS FINAIS DA EVOLUÇÃO DAS ESTRELAS: OBJETOS COMPACTOS

- estrelas com  $M < 8 M_{\odot}$



anãs brancas (tamanho da Terra)

- estrelas com  $M > 8 M_{\odot}$



explodem: supernovas

$\Rightarrow$  estrelas de nêutrons (

$\Rightarrow$  buracos negros (horiz



# Objetos compactos

Uma colher de chá de:

anã branca: **20**



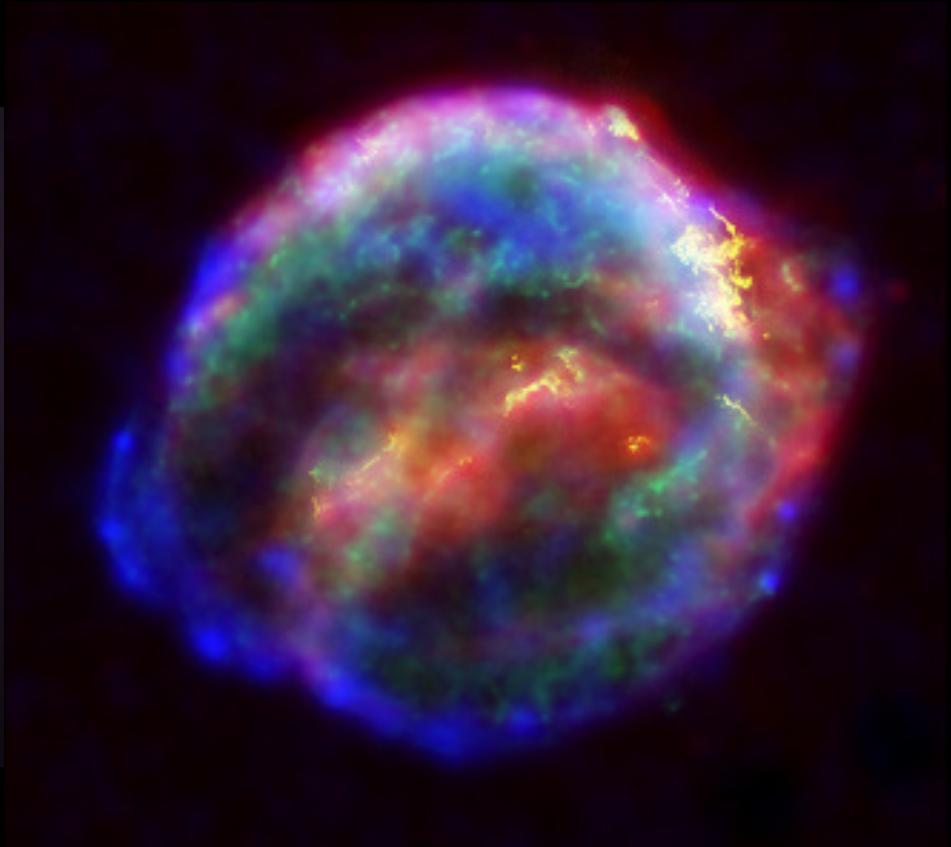
s

estrela de nêutrons:  
**população da Terra, ou 800**



s

# Supernovas !

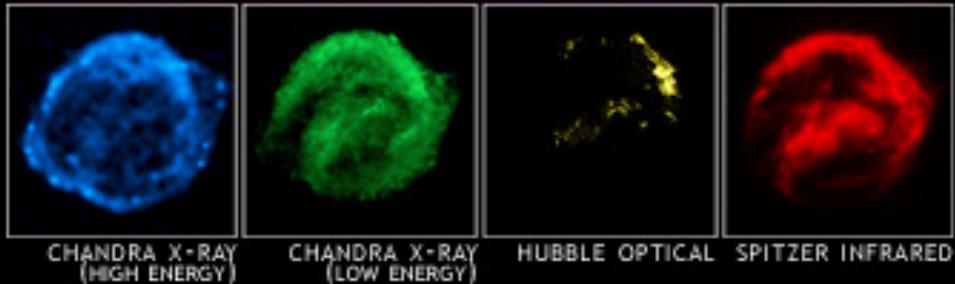


Uma a cada século por galáxia

A olho nu:

- supernova de Kepler (1604)
- SN 1987A (fev. de 1987) na LMC

Brilha como uma galáxia inteira!



# Queima de combustível nuclear nas estrelas

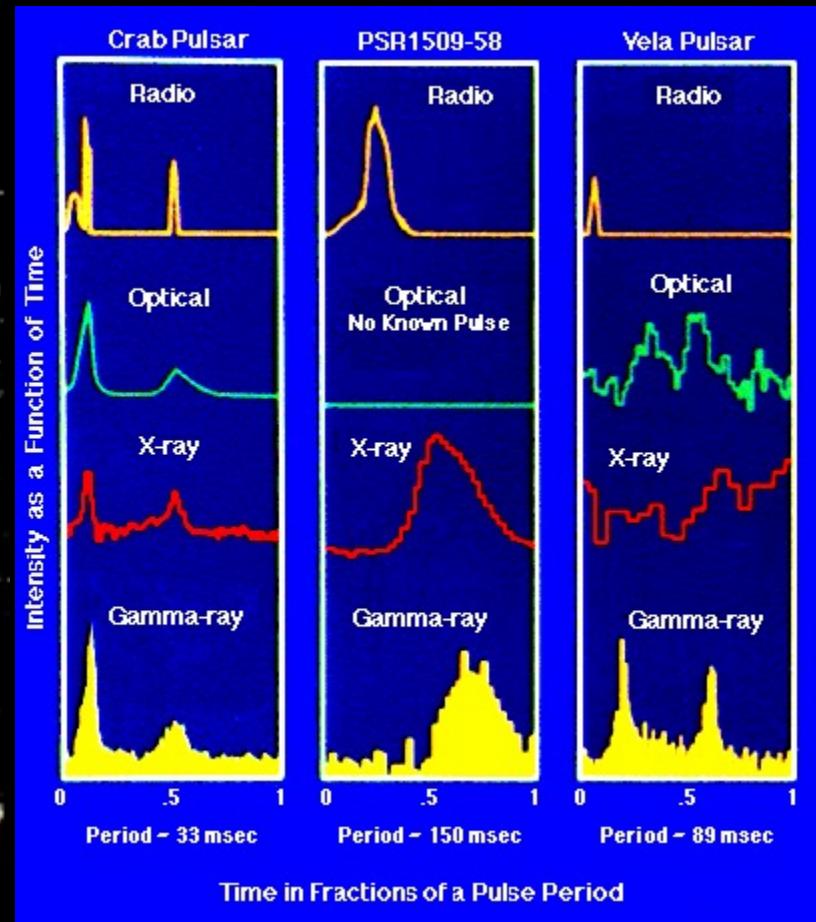
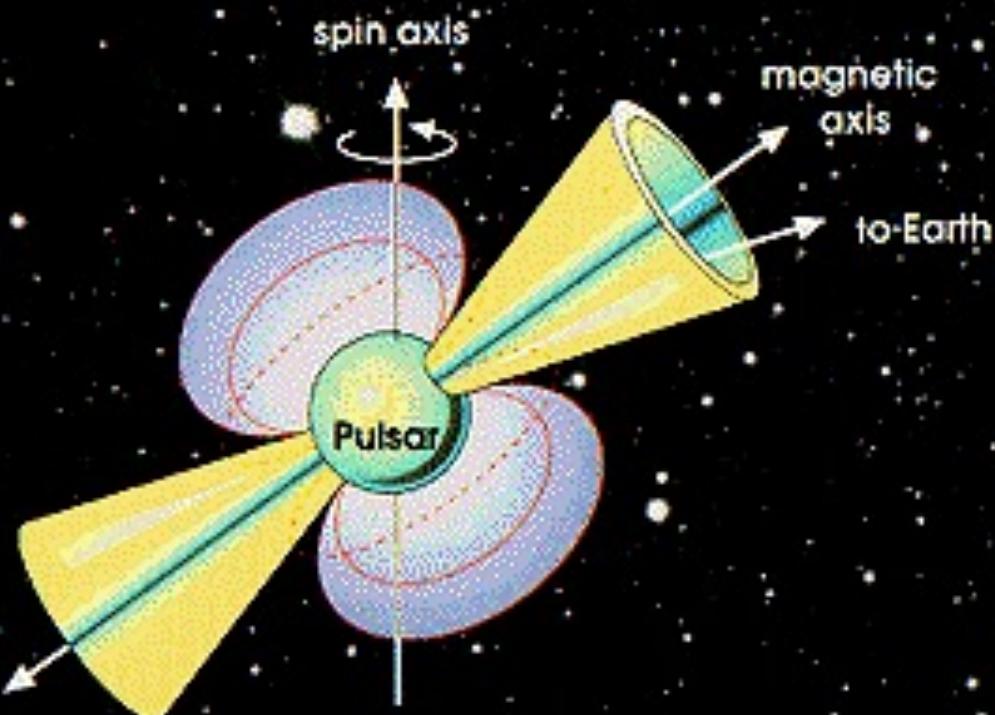


# EXPLOSÃO DE UMA SUPERNOVA



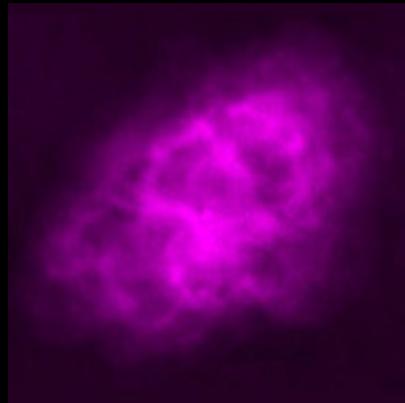
# Estrelas de nêutrons isoladas: pulsares

pulsar



# A nebulosa e o pulsar do Caranguejo

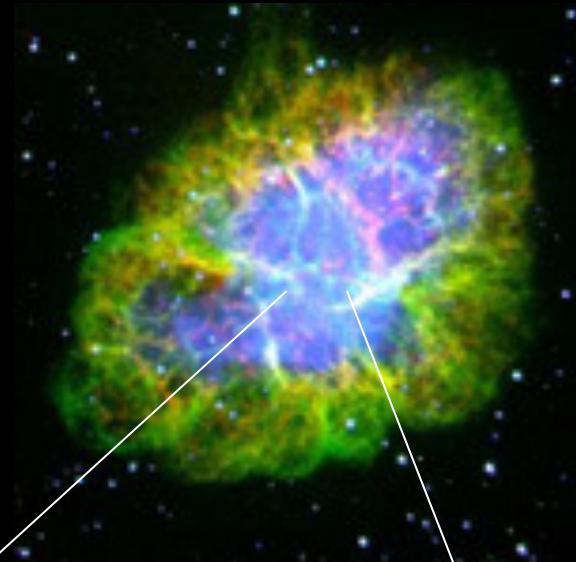
Supernova observada pelos chineses no ano 1054



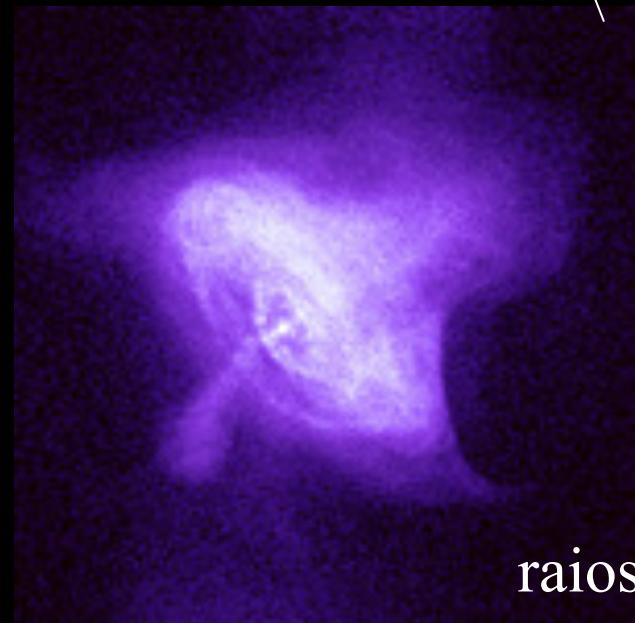
rádio



infravermelho



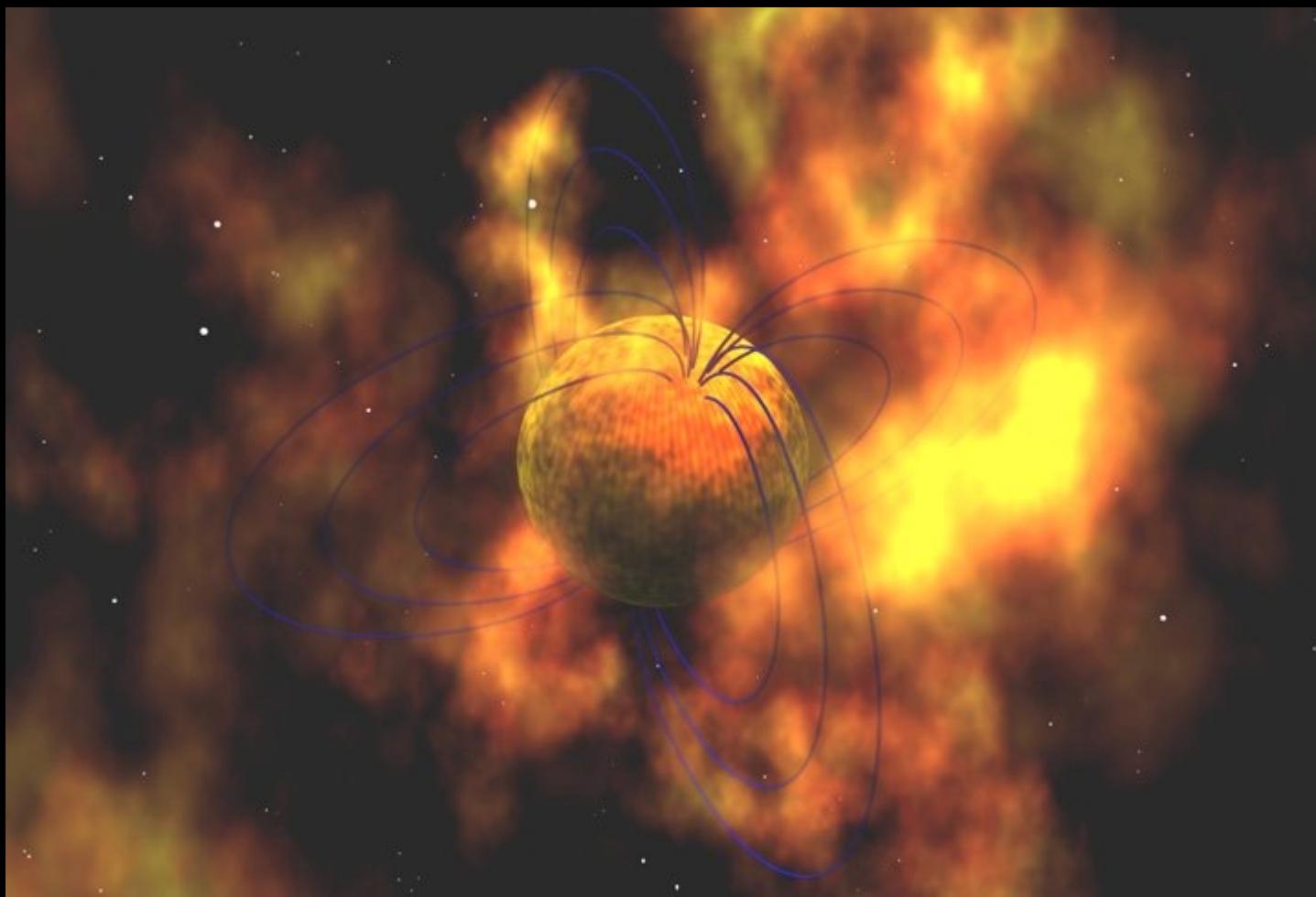
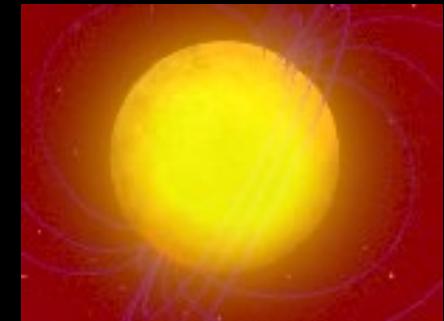
óptico



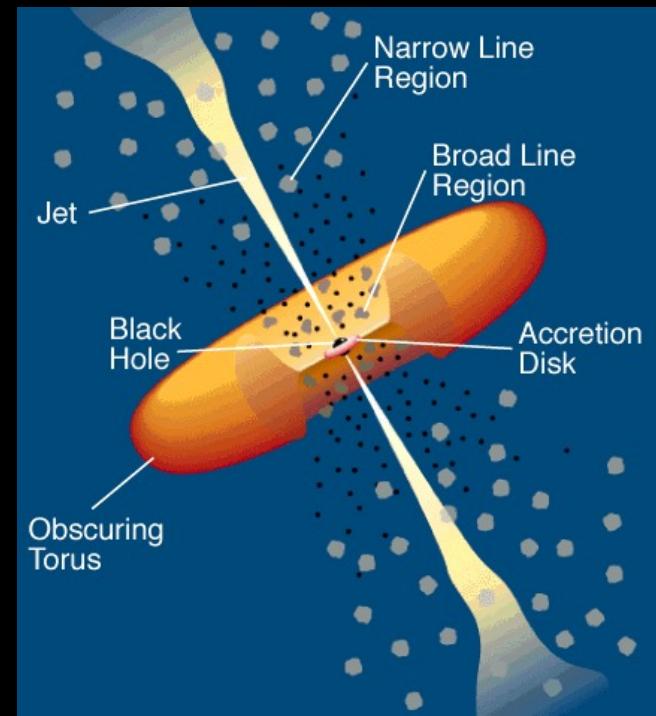
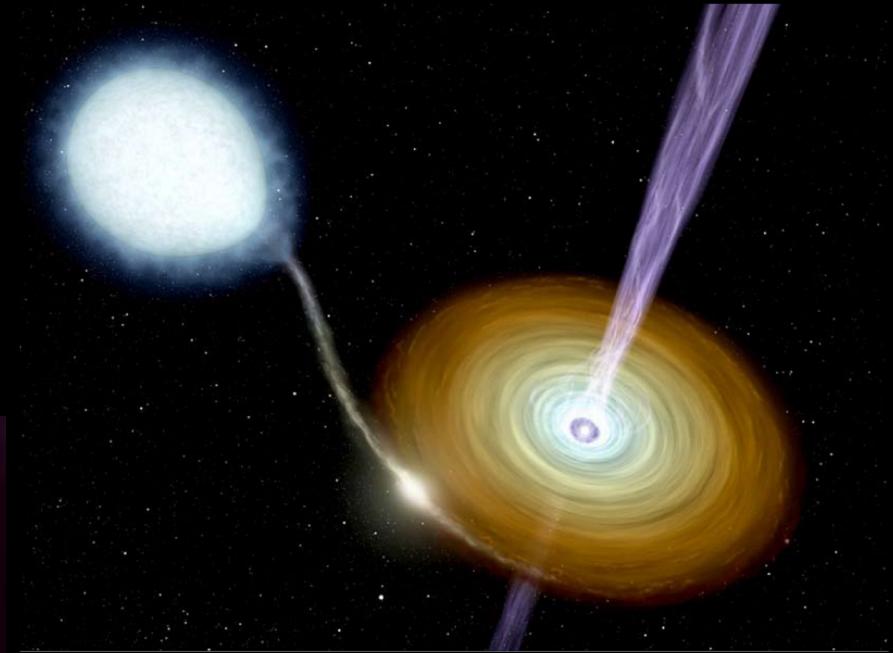
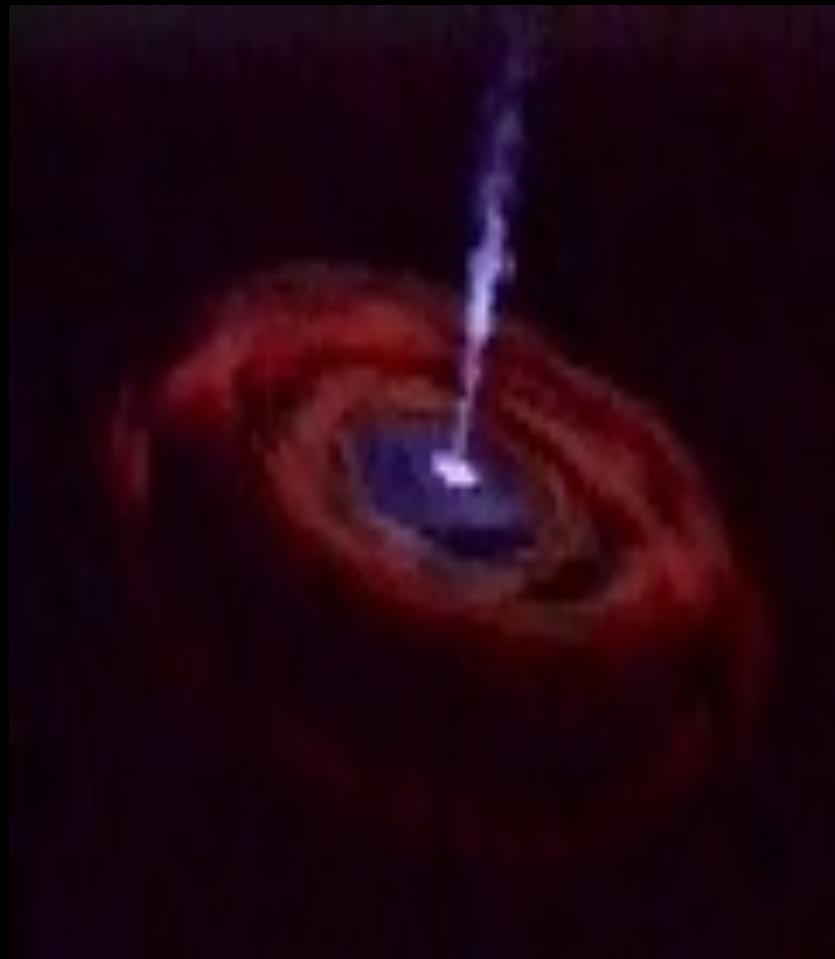
raios X



# Magnetars



# buracos negros



# Buracos Negros nos centros das galáxias





Jatos observados em rádio

M87

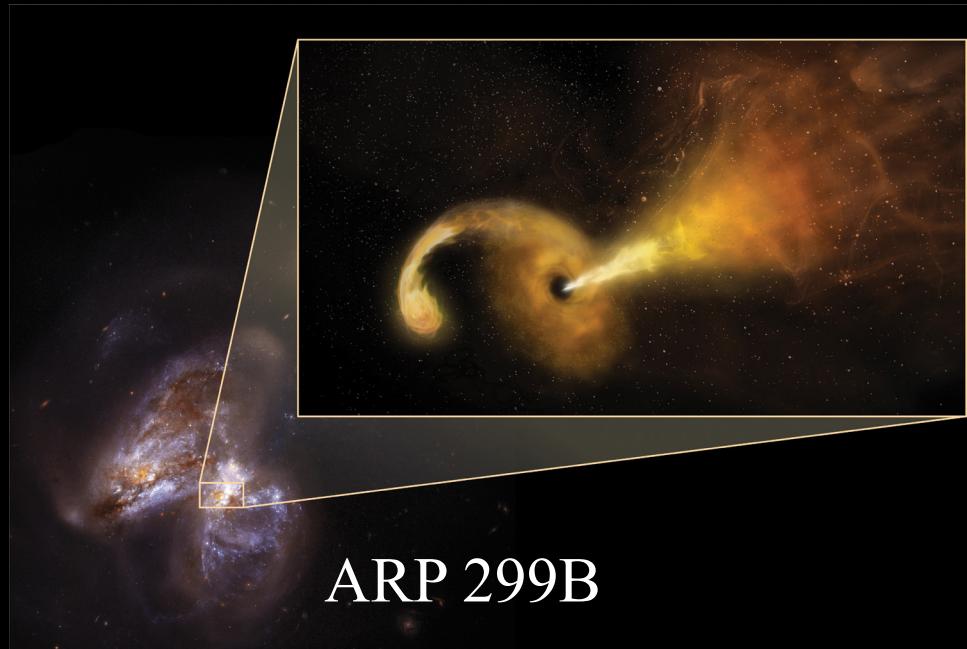
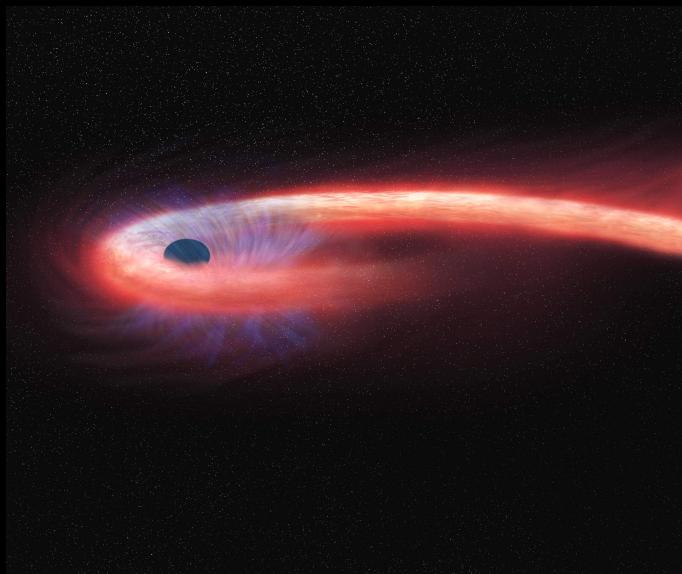
53 milhões de anos-luz da Terra

## Imagens de buracos negros: The Event Horizon Telescope

Buraco negro de  
6,5 bilhões de  $M_{\odot}$

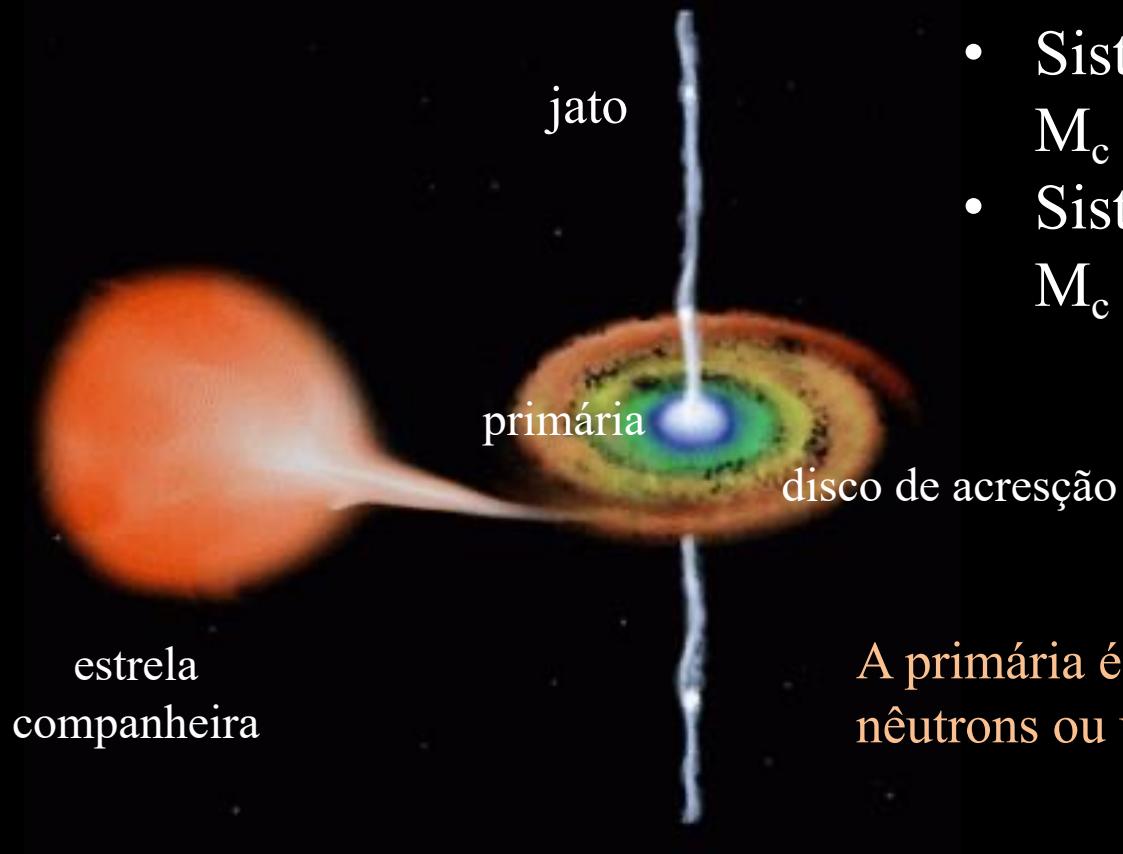


# Tidal Disruption Events (TDEs)



ARP 299B

# Sistemas binários de raios X

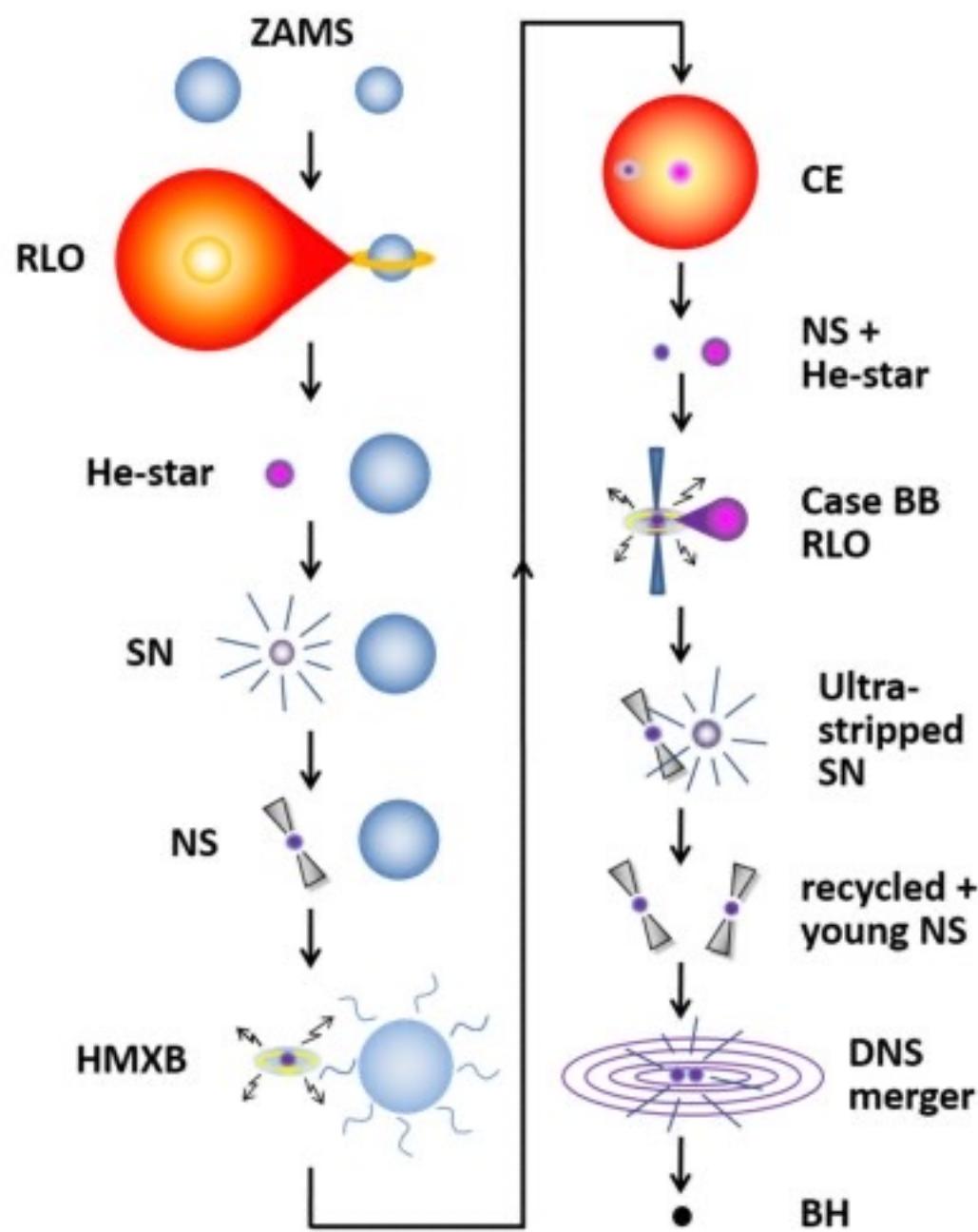


- Sistemas de alta massa:  
 $M_c > 10 M_\odot$
- Sistemas de baixa massa:  
 $M_c < 1 M_\odot$

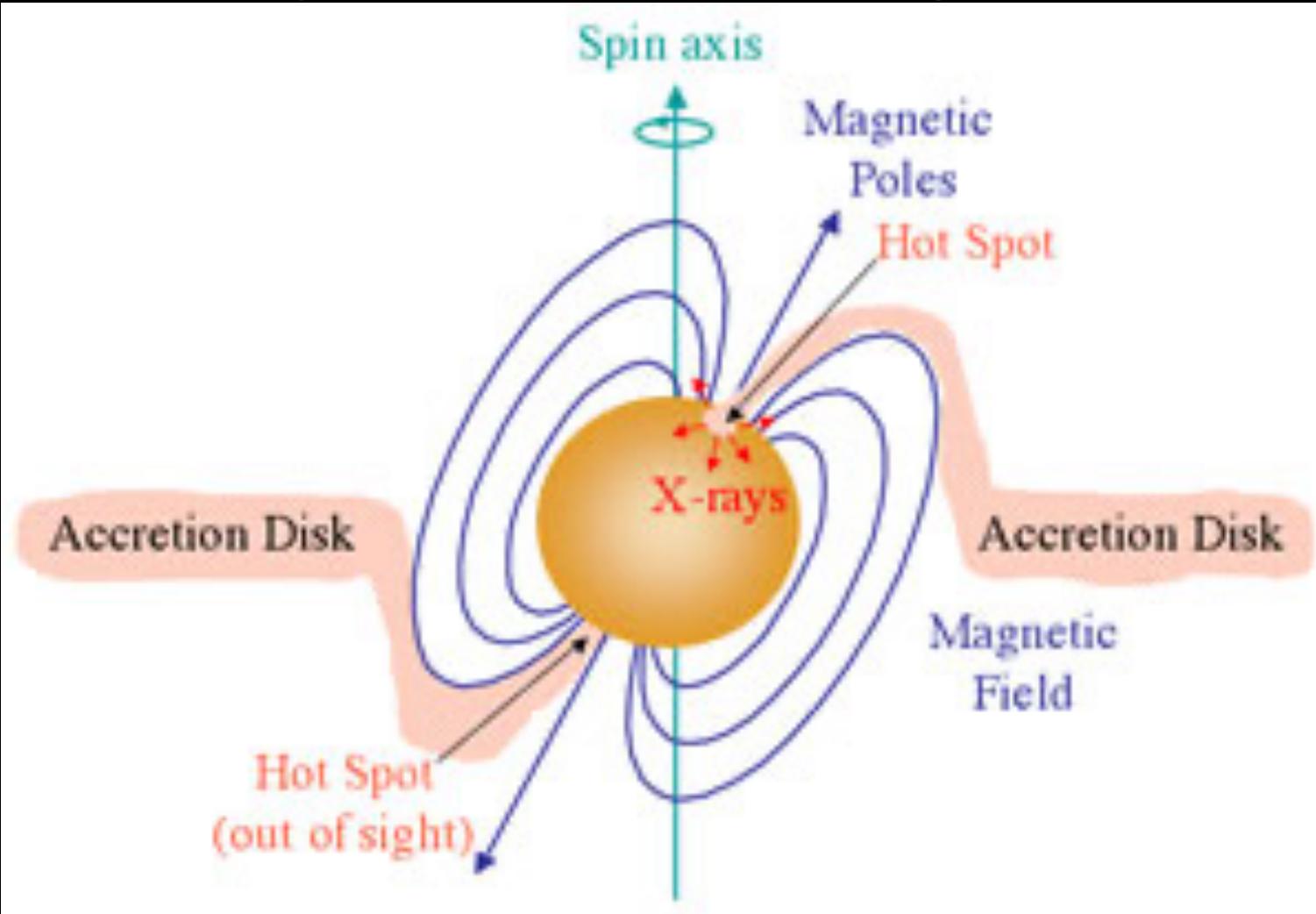
A primária é uma estrela de  
nêutrons ou um buraco negro

Às vezes a distância entre a primária e a secundária pode chegar a  $1 R_\odot$  e a secundária pode ser uma anã branca

# possível evolução



# Pulsar de raios X, ou pulsar de acreção

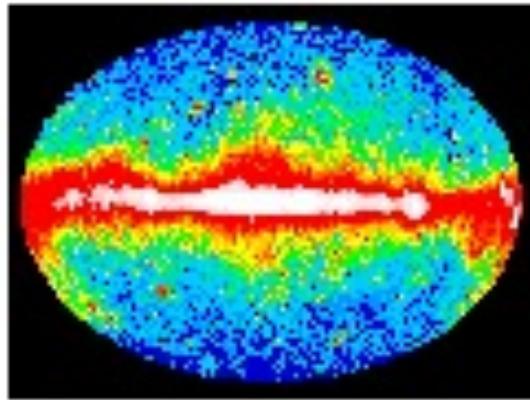


# bursts de raios $\gamma$

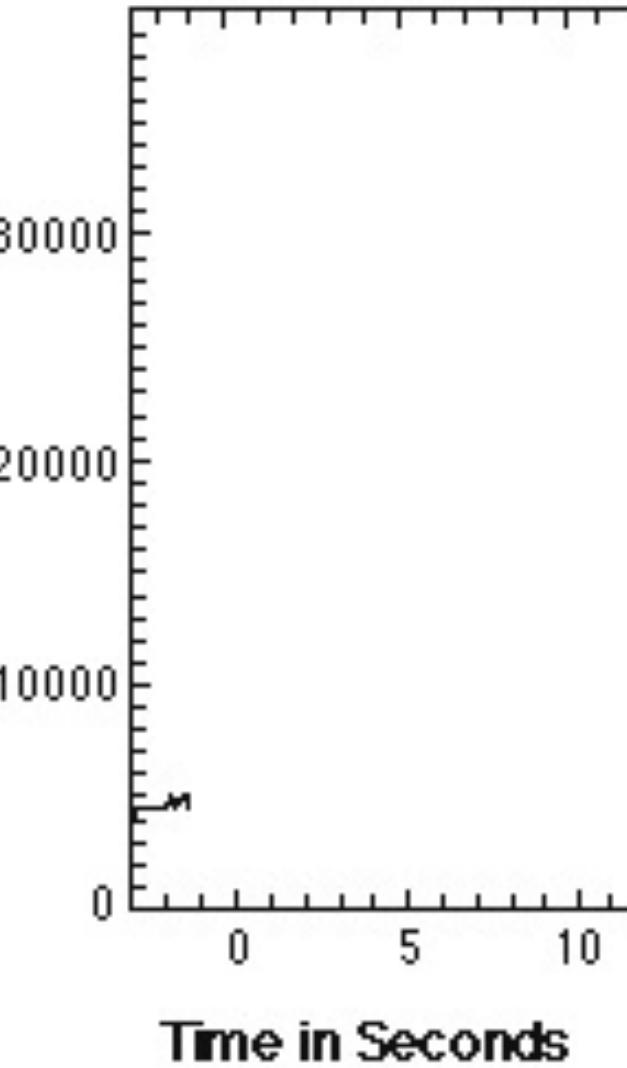
Explorando

- maiores
- emitem
- são

Algumas

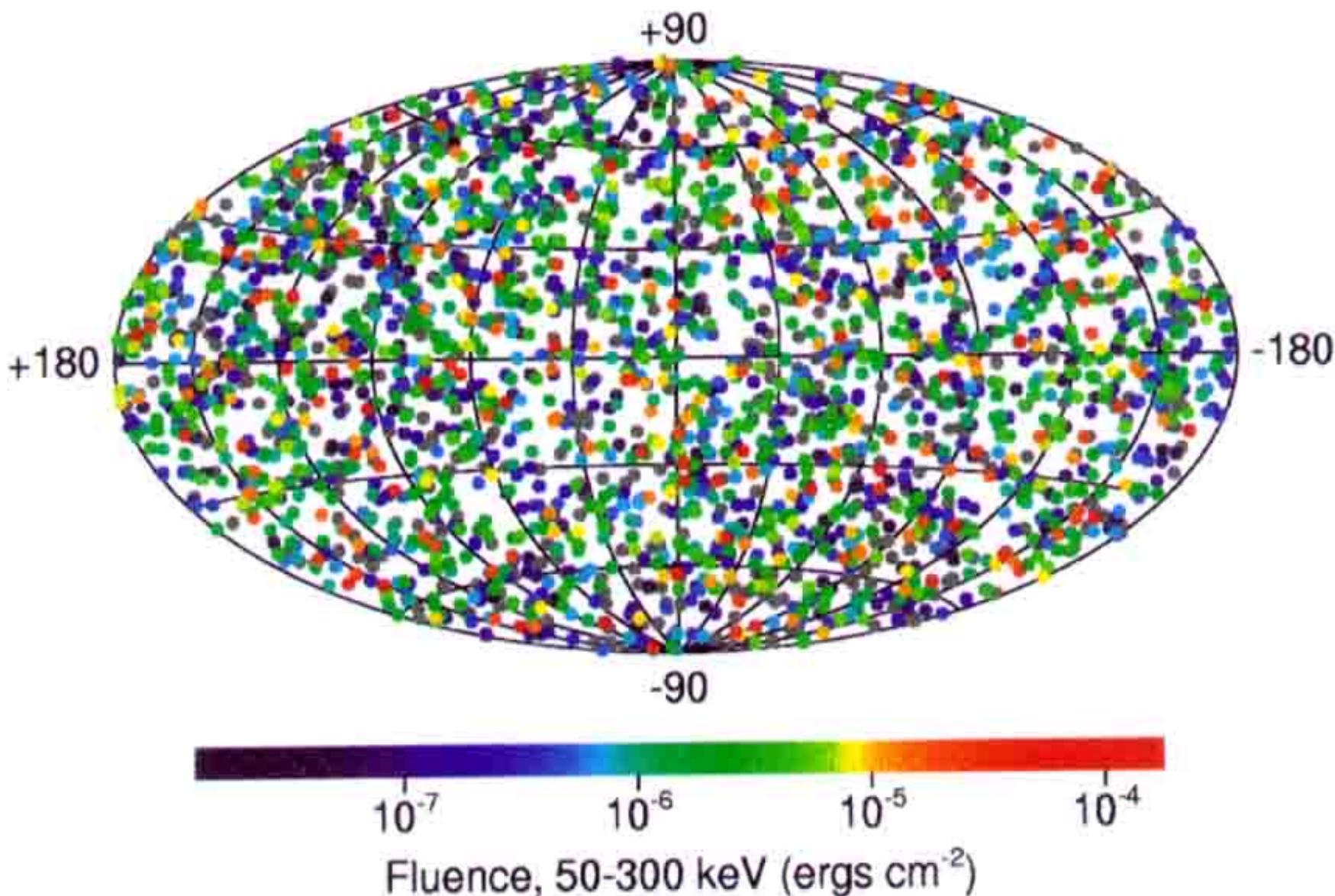


Counts per Second



rama)  
ol  
 $I_{\odot}$

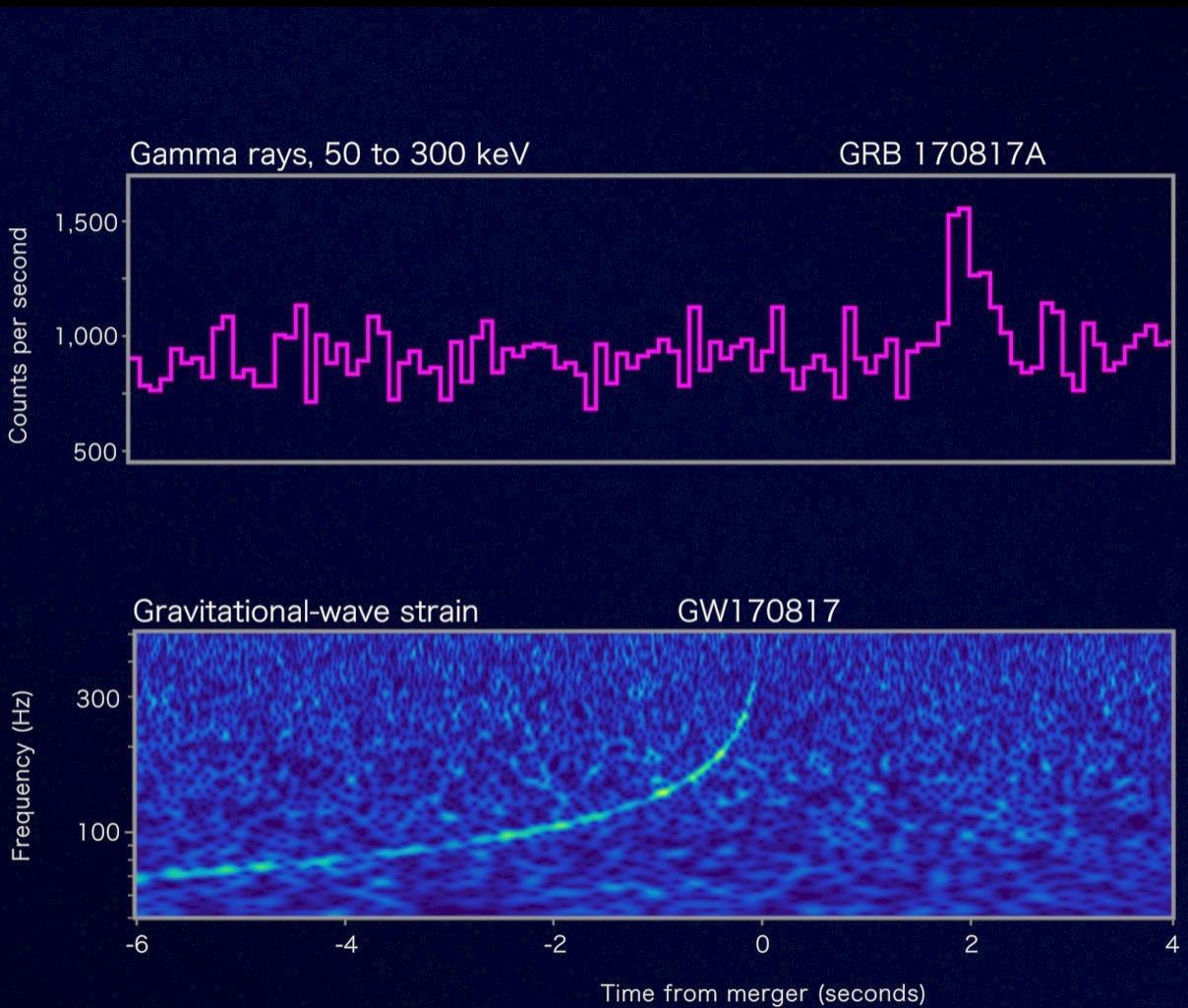
# 2704 BATSE Gamma-Ray Bursts

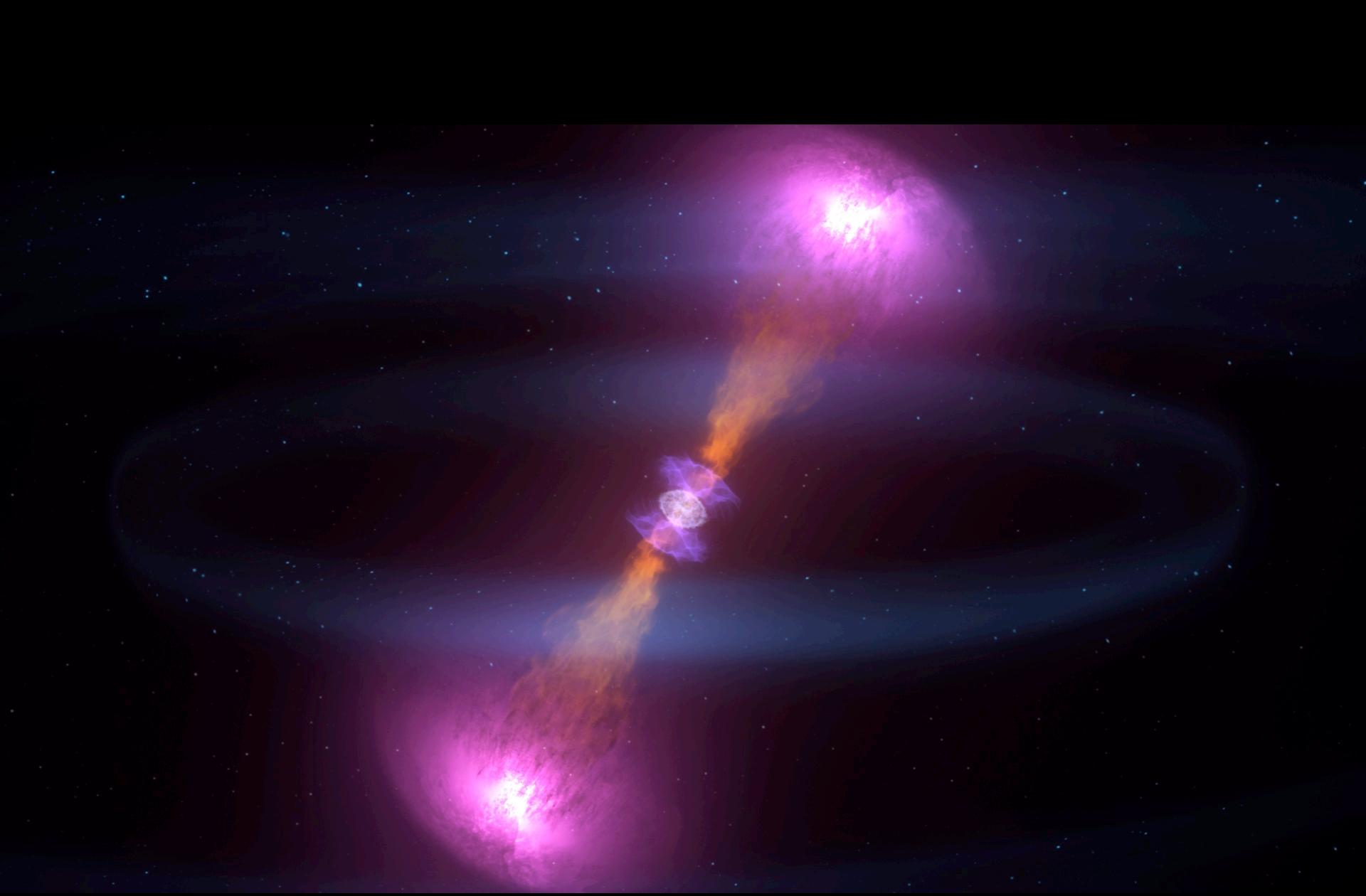


# GW 170817/GRB 170817A

Fermi

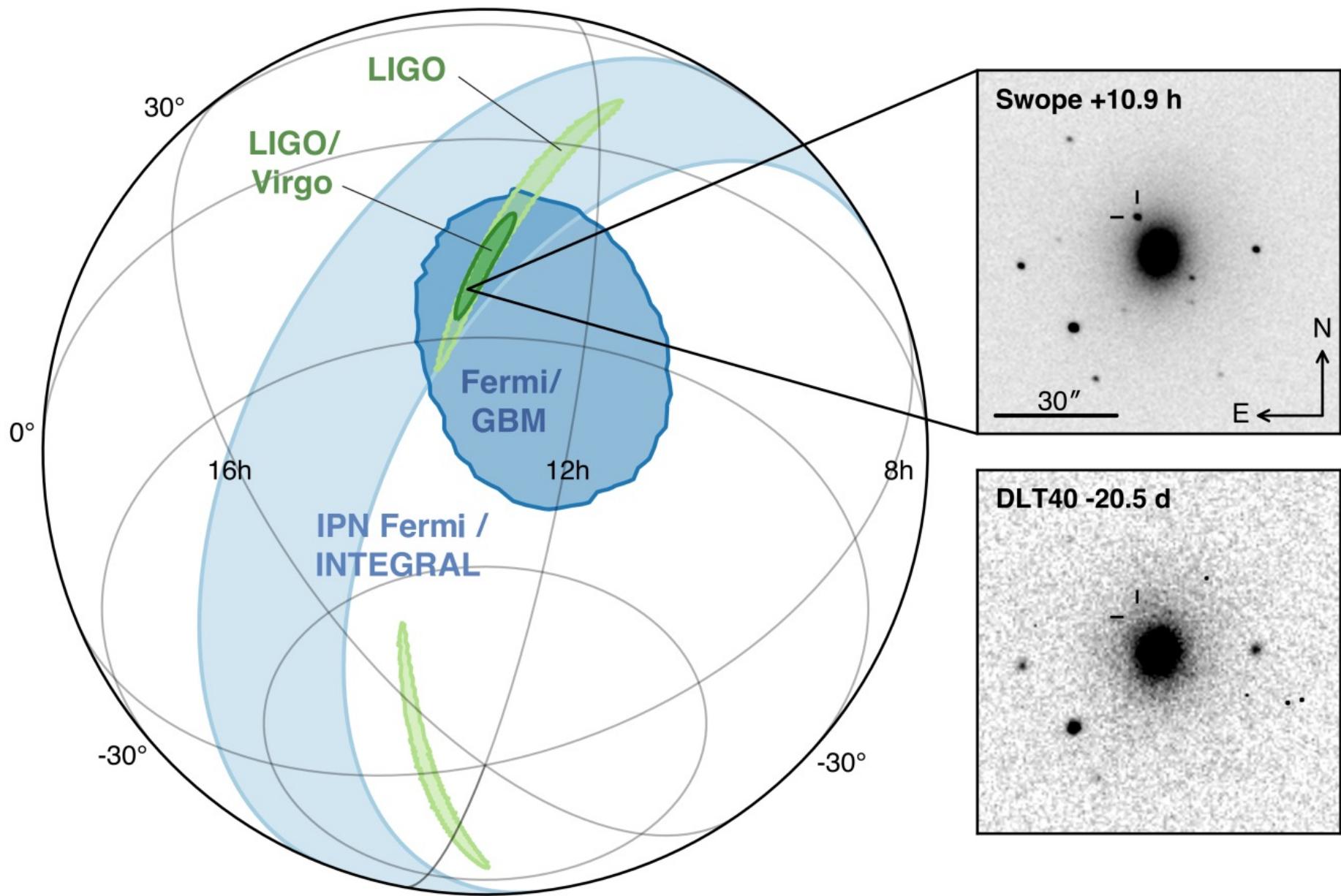
LIGO





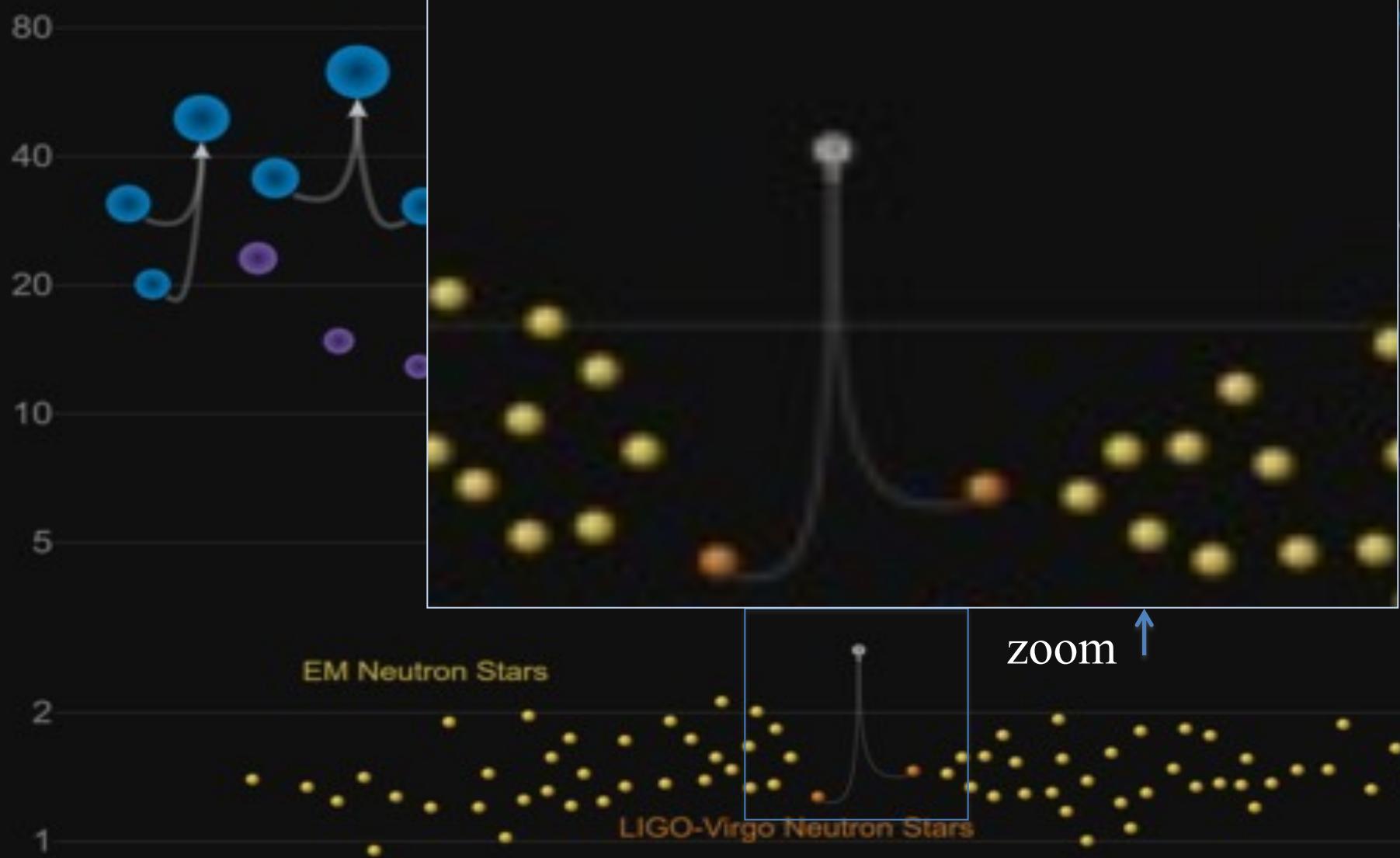
Distância: 120 milhões de anos-luz

# Localização no céu



# Masses in the Stellar Graveyard

*in Solar Masses*



# Grandes contribuições da astronomia de raios X

- Descoberta dos sistemas binários estelares com um objeto compacto: *Scorpius X-1*
- Descoberta dos buracos negros estelares: *Cygnus X-1* e mais ~30
- Descobertas dos pulsares de acresção: *Centaurus X-3* e mais dezenas
- Descoberta dos gases quentes em aglomerados de galáxias
- Em geral: gases extremamente quentes e fenômenos extremamente energéticos e rápidos são estudados em raios X ! Objetos compactos são vistos em raios X

# Desafios atuais da astrofísica

- Usar diferentes mensageiros cósmicos:  
Astronomia multimensageira
- Encontrar planetas como a Terra:  
Vida no universo
- Entender o que são a matéria escura e a energia escura
- Descobrir se o “nosso universo” é o único ou se existem outros “universos”
- Encontrar uma “teoria de tudo” que explique o Big Bang e os buracos negros