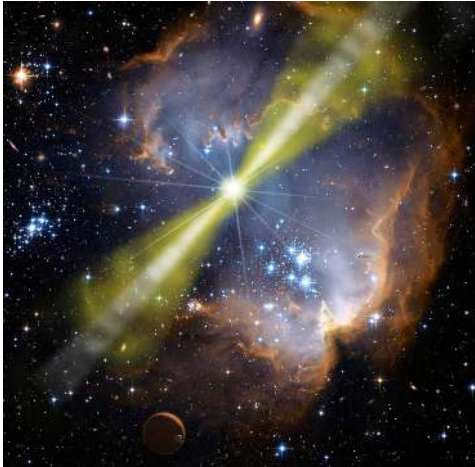


# Sterren, sterrenstelsels en gravitatiegolven



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[hemel.waarnemen.com](http://hemel.waarnemen.com)

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## Sterrenstelsels

- De Melkweg
- Sterrenstelsels en clusters
- Botsende sterrenstelsels
- Supermassieve zwarte gaten en LISA

2

## Sterren

- Zon en sterren
- Witte dwergen en LISA
- Supernovae
- Neutronensterren, zwarte gaten en LIGO
- Gammaflitsen

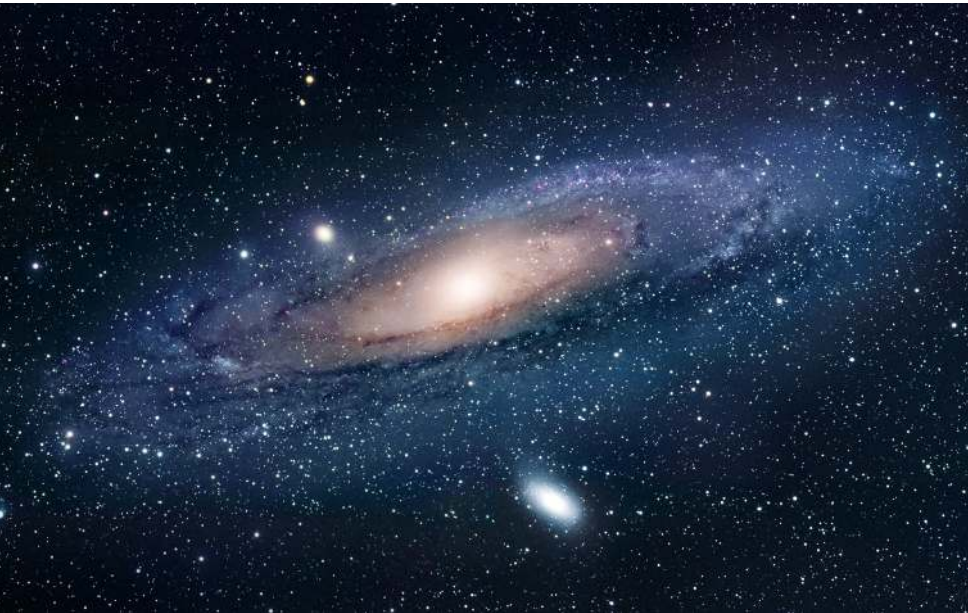


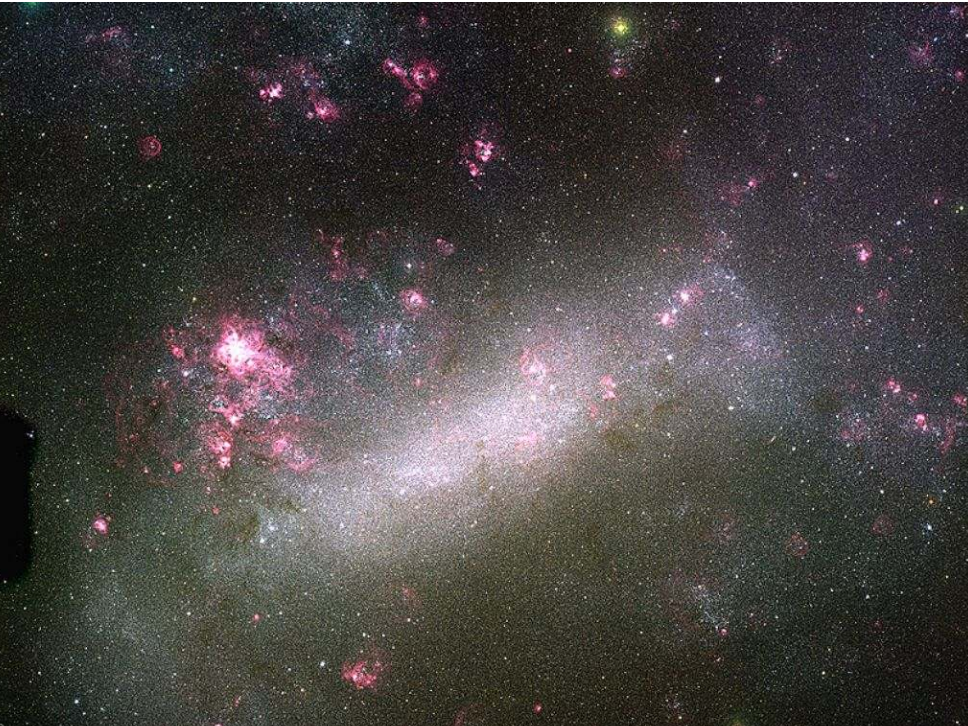
# De Melkweg en NGC 891





# De Andromedanevel



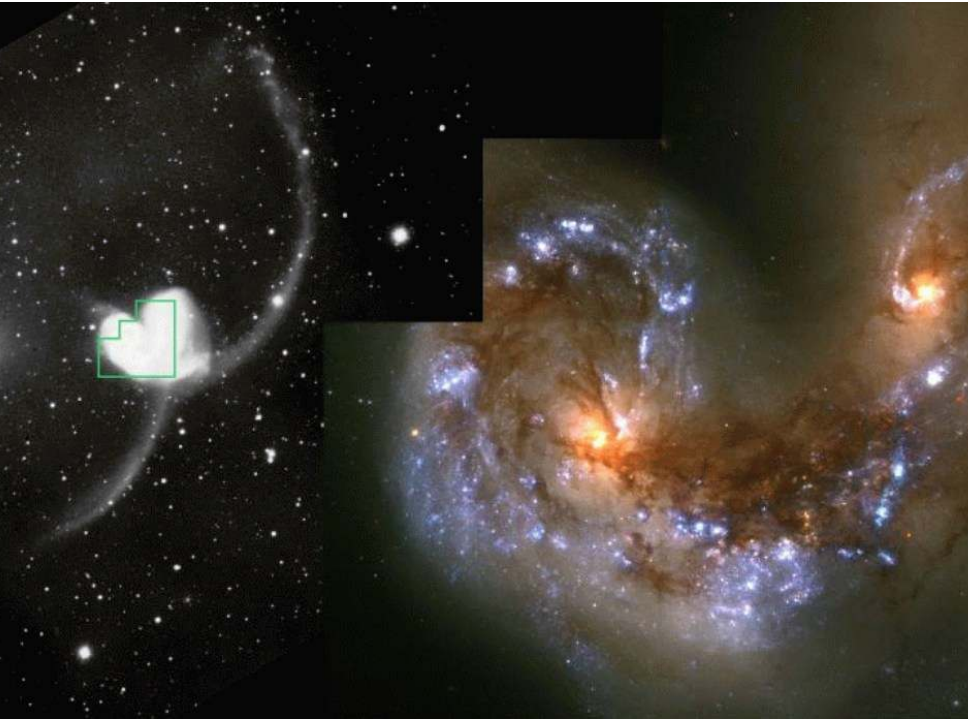


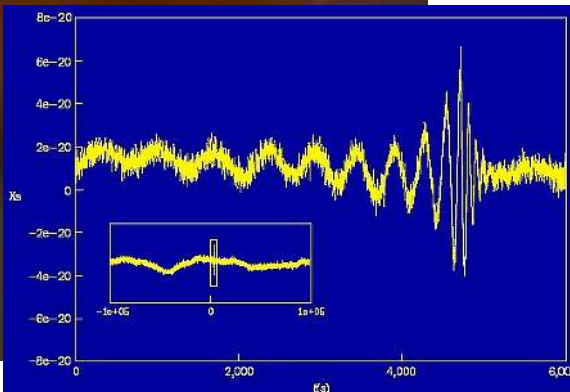
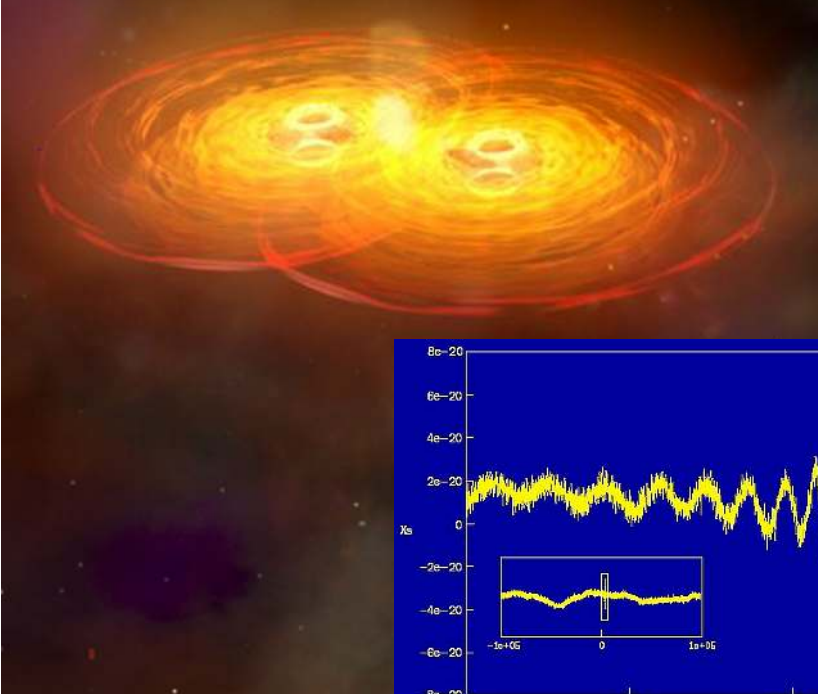
# M 87 en de Virgocluster

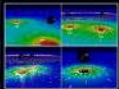












Supermassive  
Black Hole Binaries



Compact Object  
Captures



Galactic White  
Dwarf Binaries



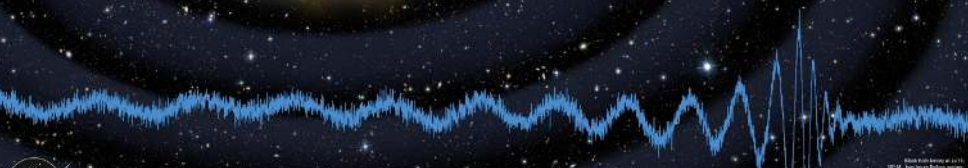
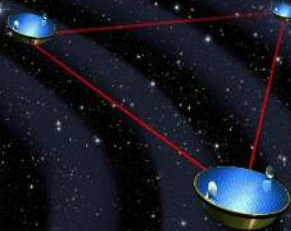
Cosmic Strings and  
Phase Transitions

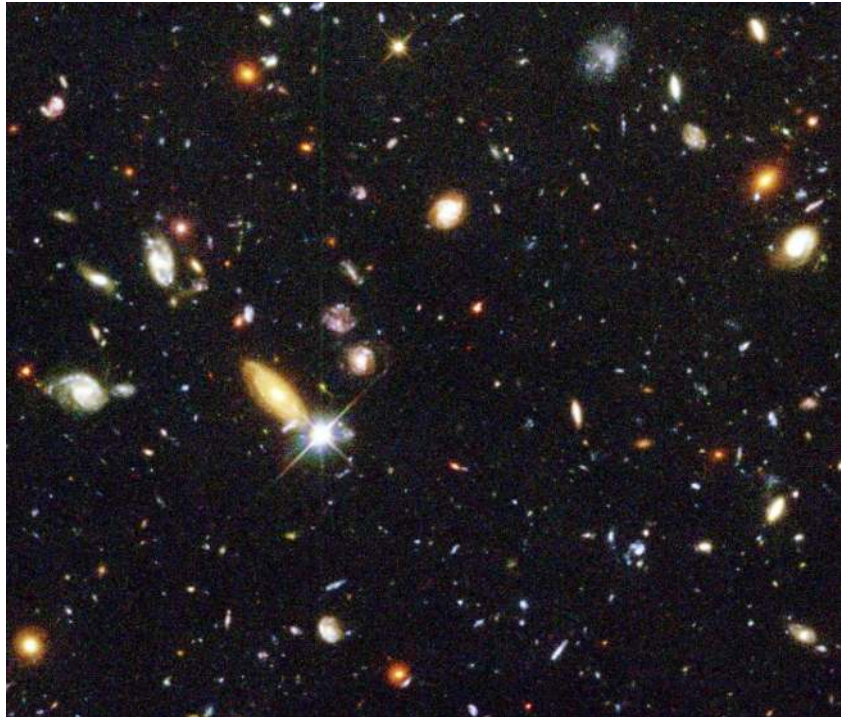
# LISA

Laser Interferometer Space Antenna

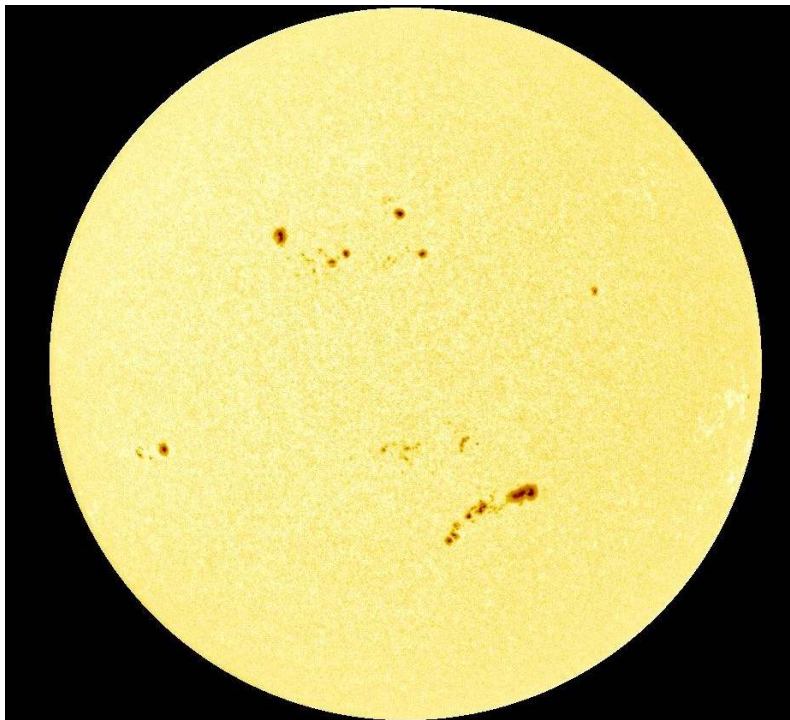


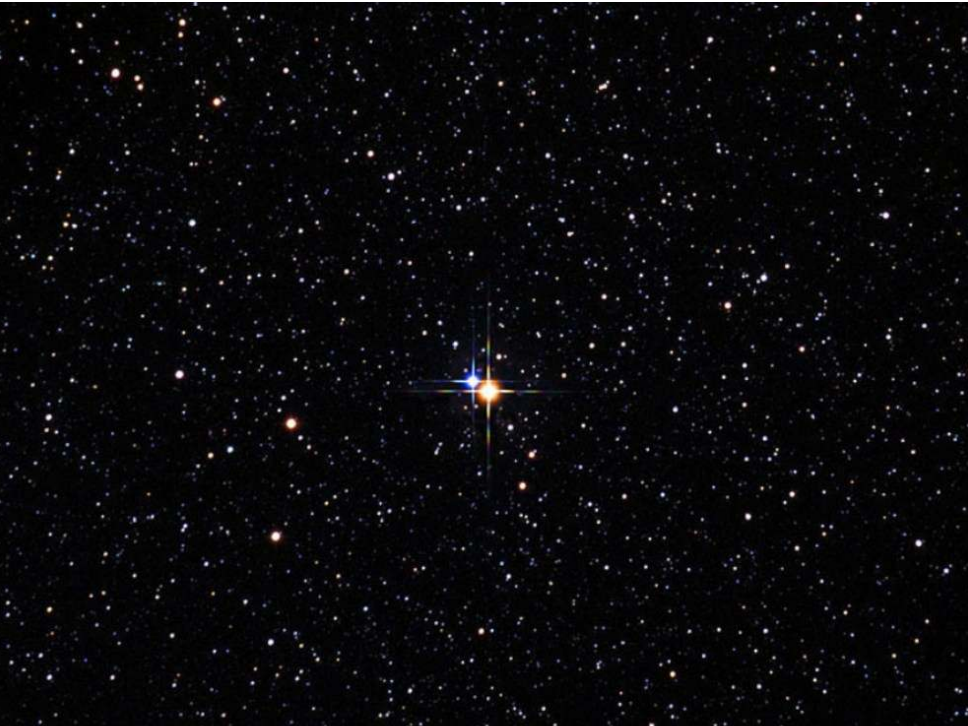
*Gravity is talking. LISA will listen.*





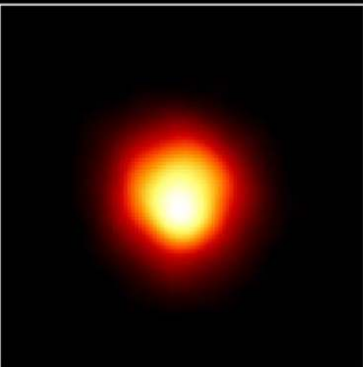








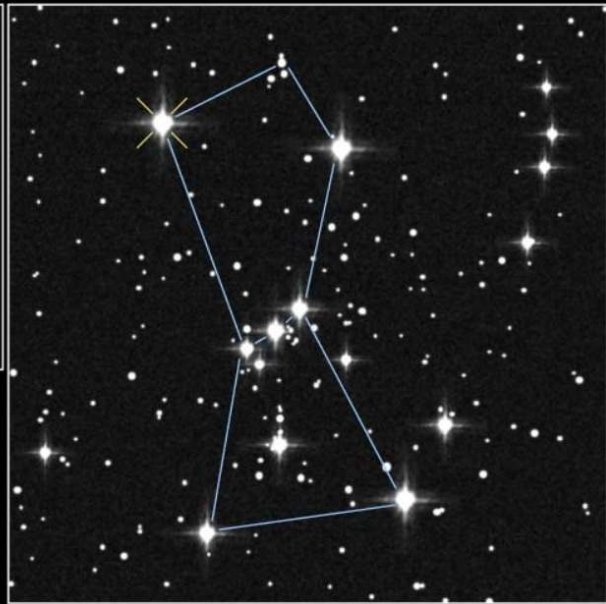
# Betelgeuze



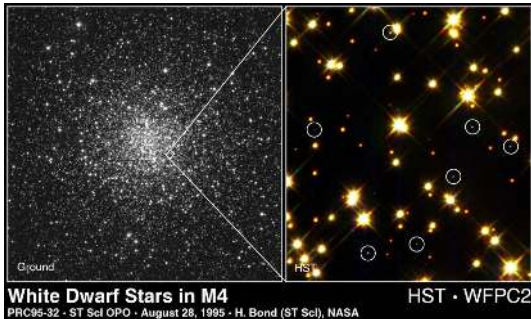
Size of Star

Size of Earth's Orbit

Size of Jupiter's Orbit

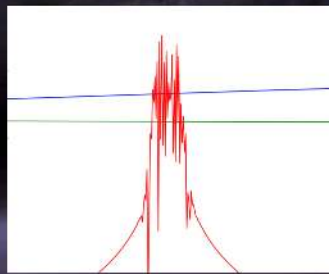
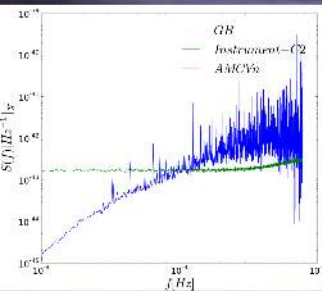




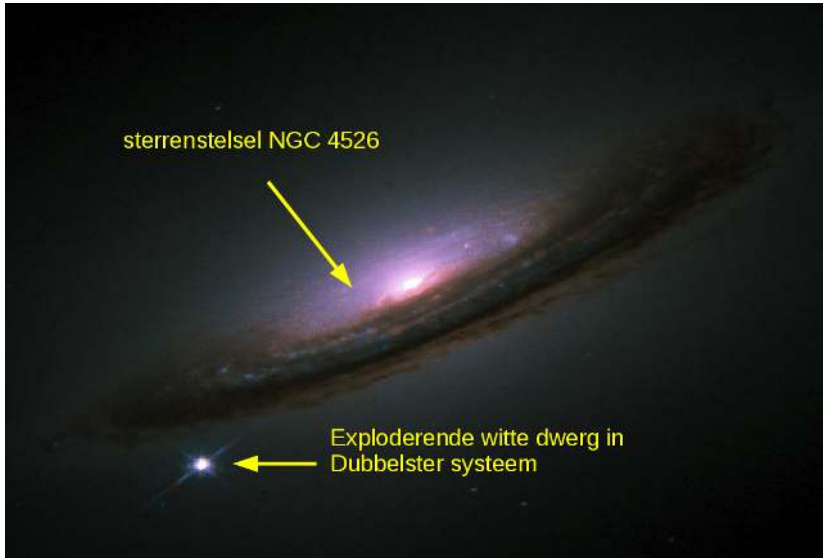


- Sterren met  $M \lesssim 8 - 10 M_{\odot}$ ,  $> 90\%$  van alle sterren, worden WDs
- WDs bestaan meestal uit He of C+O
- Dichtheid van een WD  $\sim 1$  miljoen keer die van water
- $M_{wd} \lesssim 1.4 M_{\odot}$ ;  $\langle M_{wd} \rangle \approx 0.6 M_{\odot}$
- $L_{wd} \lesssim 0.001 L_{\odot}$

- DWDs kunnen worden waargenomen door LISA
- Nauwe systemen zijn waarschijnlijk op te lossen, de rest is 'voorgroondruis'



# Type-Ia supernovae

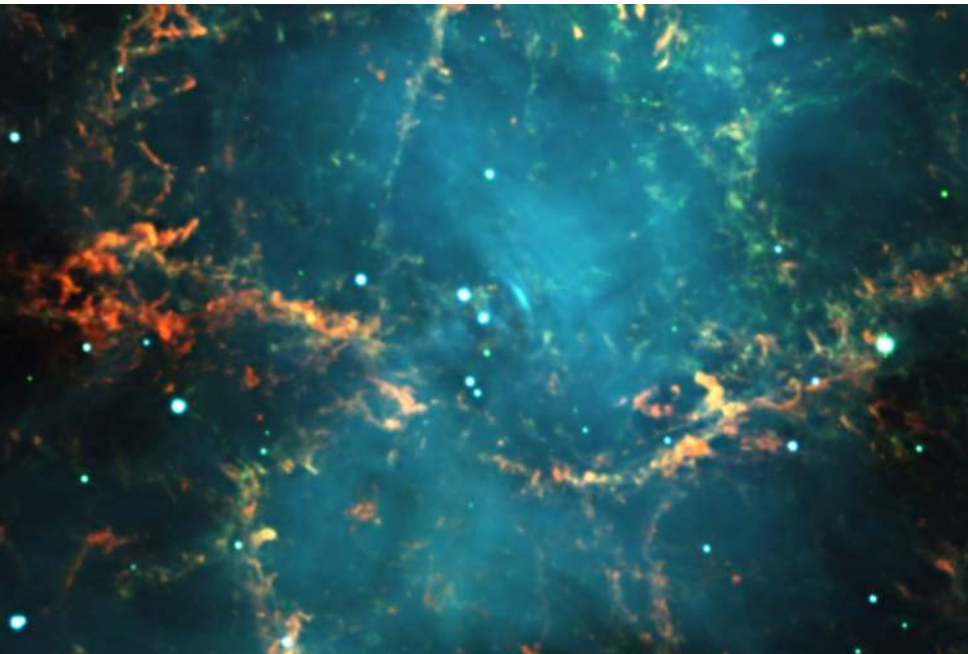


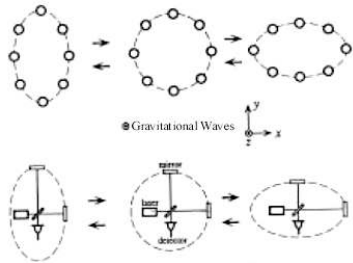
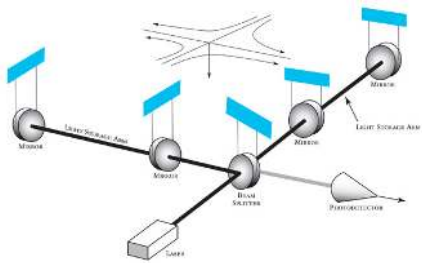
- Zeldzaam maar helder: zichtbaar van verre
- Te gebruiken voor afstandsmetingen

# Type-II supernovae



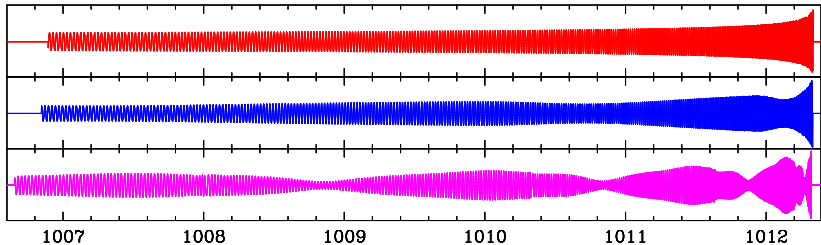
# De Krabpulsar







## LIGO en Virgo detecteren de laatste $\sim 10$ s van een zwart-gat–neutronenster:

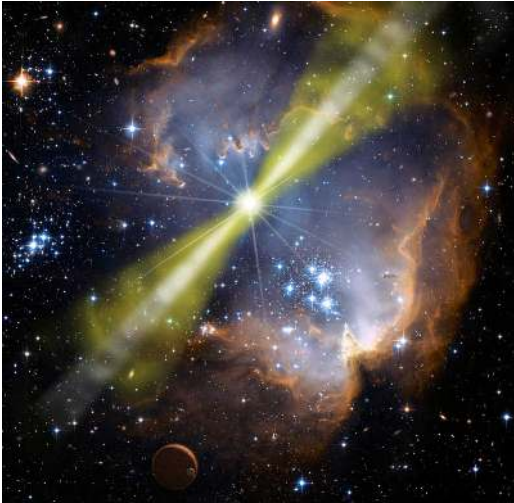


### Schatting van detectie-aantallen ( $\text{jr}^{-1}$ ):

	NS-NS	BH-NS	BH-BH
Initial LIGO/Virgo	$2 \times 10^{-4} - 0.2$	$7 \times 10^{-5} - 0.1$	$2 \times 10^{-4} - 0.5$
Advanced LIGO/Virgo	0.4 – 400	0.2 – 300	0.4 – 1000

Schattingen gaan uit van  $M_{\text{NS}} = 1.4 M_{\odot}$  en  $M_{\text{BH}} = 10 M_{\odot}$

# Gamma-ray bursts (GRBs)



Artist's impression van een GRB (bron: NASA)

## Gammaflitsen:

- $\sim 2$  per dag
- $\sim 25\%$  short GRB
- duur:  $\sim 10$  ms – 10 s
- $\sim 10^{44}$  W, circa 1 miljoen sterrenstelsels
- straling *gebeamed* door emissie in *jets*
- long GRBs gerelateerd aan supernovae
- short GRBs veroorzaakt door NS-NS en NS-BH mergers?
  - oude sterpopulaties
  - energie
  - frequentie