

# **AST 296LB**

**Life as an Astronomer II**  
**What we actually measure on the**  
**images and how we do that?**

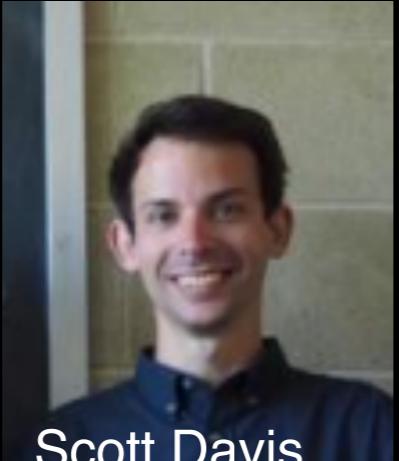
# Who am I ?

- PhD (2006-2008):
  - Ferrara (Italy)
  - Munich (Germany)
- PostDoc (2008-2015):
  - Queens University, Belfast (UK)
  - National Institute of Astrophysics, Padova (Italy)
  - University of California, Santa Barbara
- Researcher (2015-2016):
  - University of California, Davis
- A professor (2017-present):
  - University of California, Davis

# UC Davis and Univ.Arizona



Stefano Valenti  
UC Davis



Scott Davis  
UC Davis



Azalee Bostroem  
UC Davis



Yize Dong  
UC Davis



Kuntal Misra  
Aries Institute  
WISTEMM fellow



David Sand  
Univ. of Arizona



Rachael Amaro  
Univ. of Arizona



Jennifer Andrews  
Gemini



Michael Lundquist  
Keck



Sam Wyatt  
Univ. of Arizona



Jacob Jencson  
Univ. of Arizona

# Time Domain Astronomy

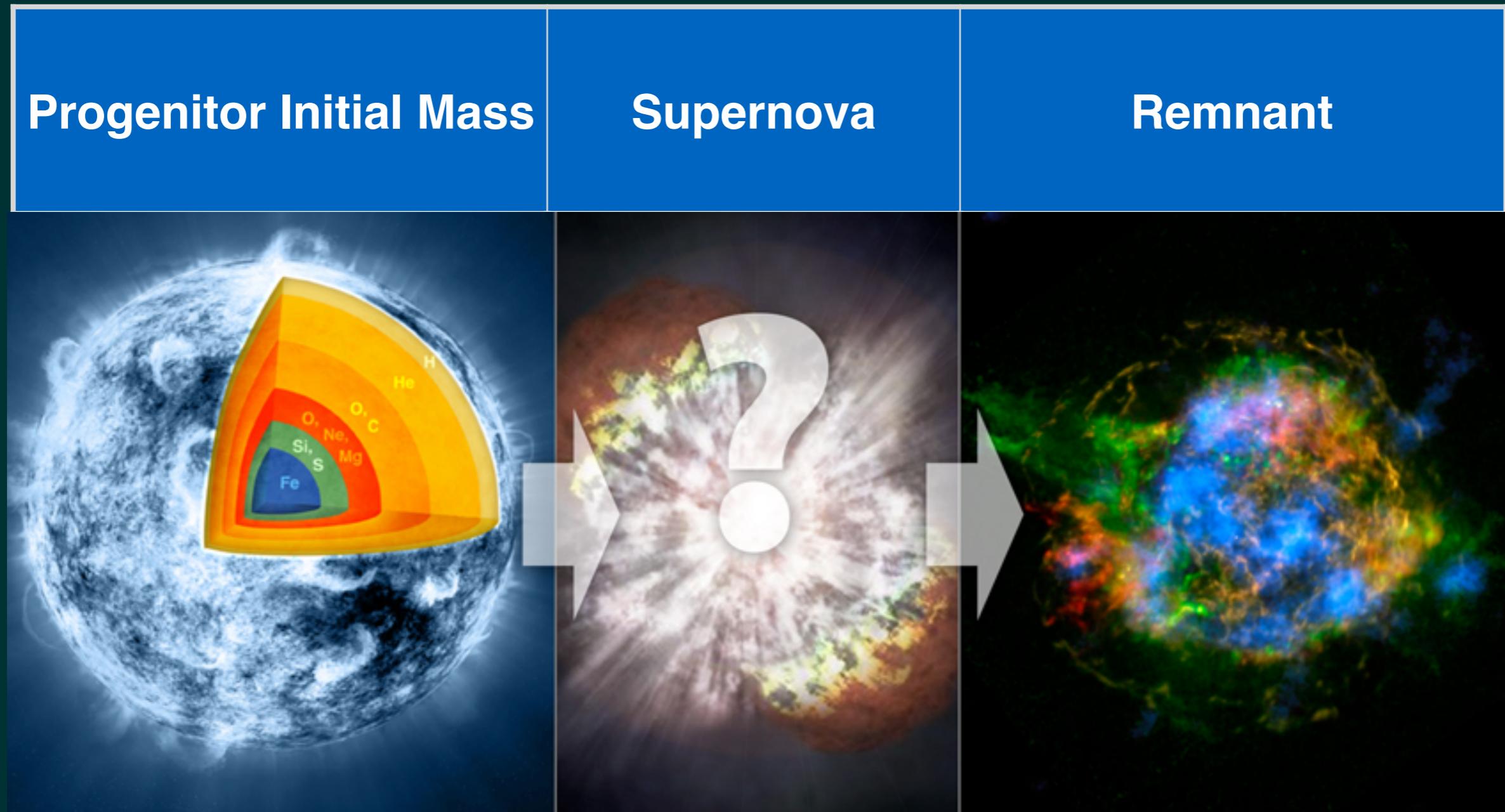
What is the link between stellar evolutionary paths and the different ways Supernovae explode ?

**Jennifer Andrews will talk about it**

What are we missing to complete the parameter space of explosive transients ? Optical counterpart of Gravitational waves ?

**I will talk about it another time**

# Supernova explosion in the frame of stellar evolution



# Time Domain Astronomy

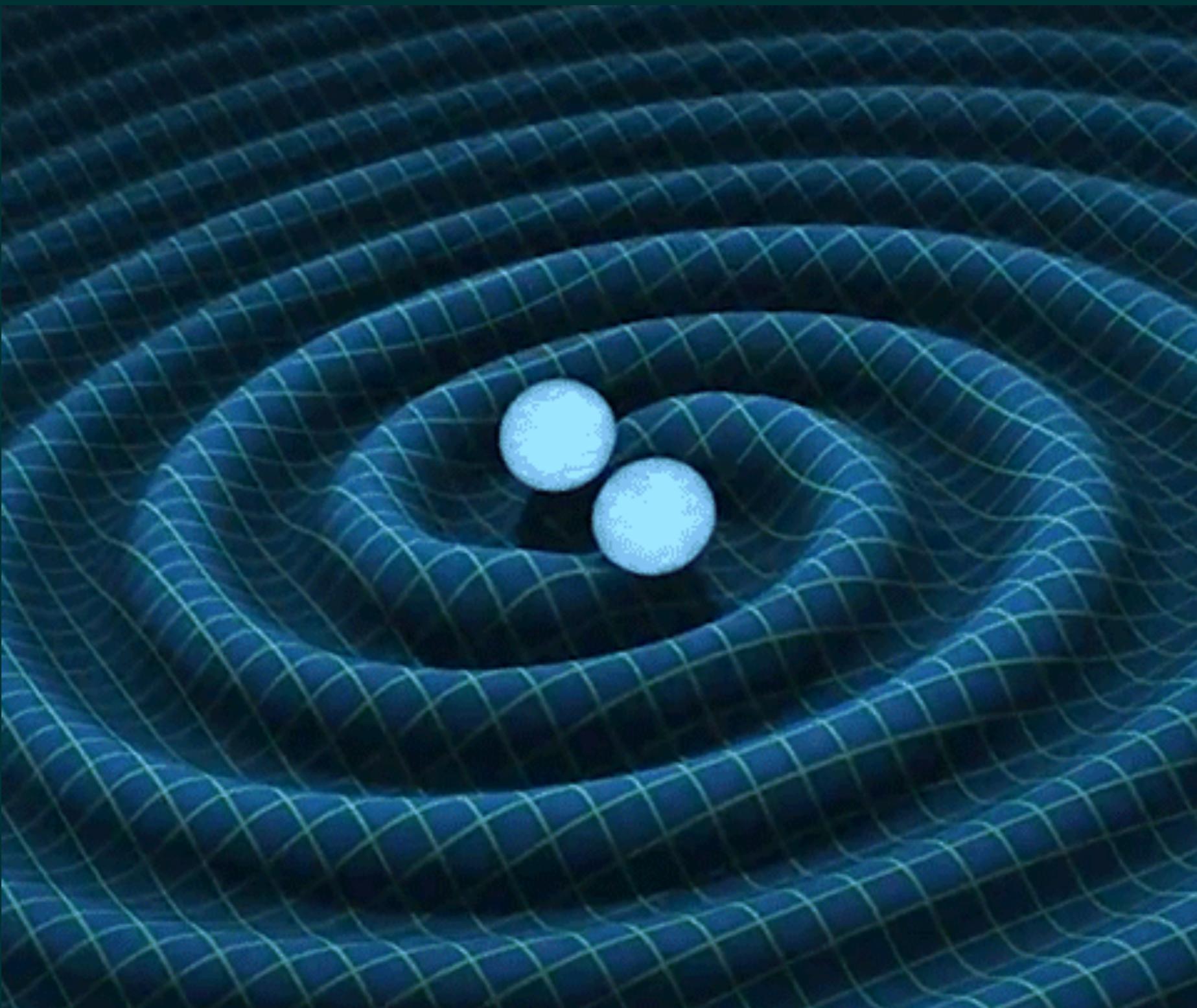
What is the link between stellar evolutionary paths and the different ways Supernovae explode ?

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What are we missing to complete the parameter space of explosive transients ? Optical counterpart of Gravitational waves ?

**I will talk about it another time**

# Gravitational waves



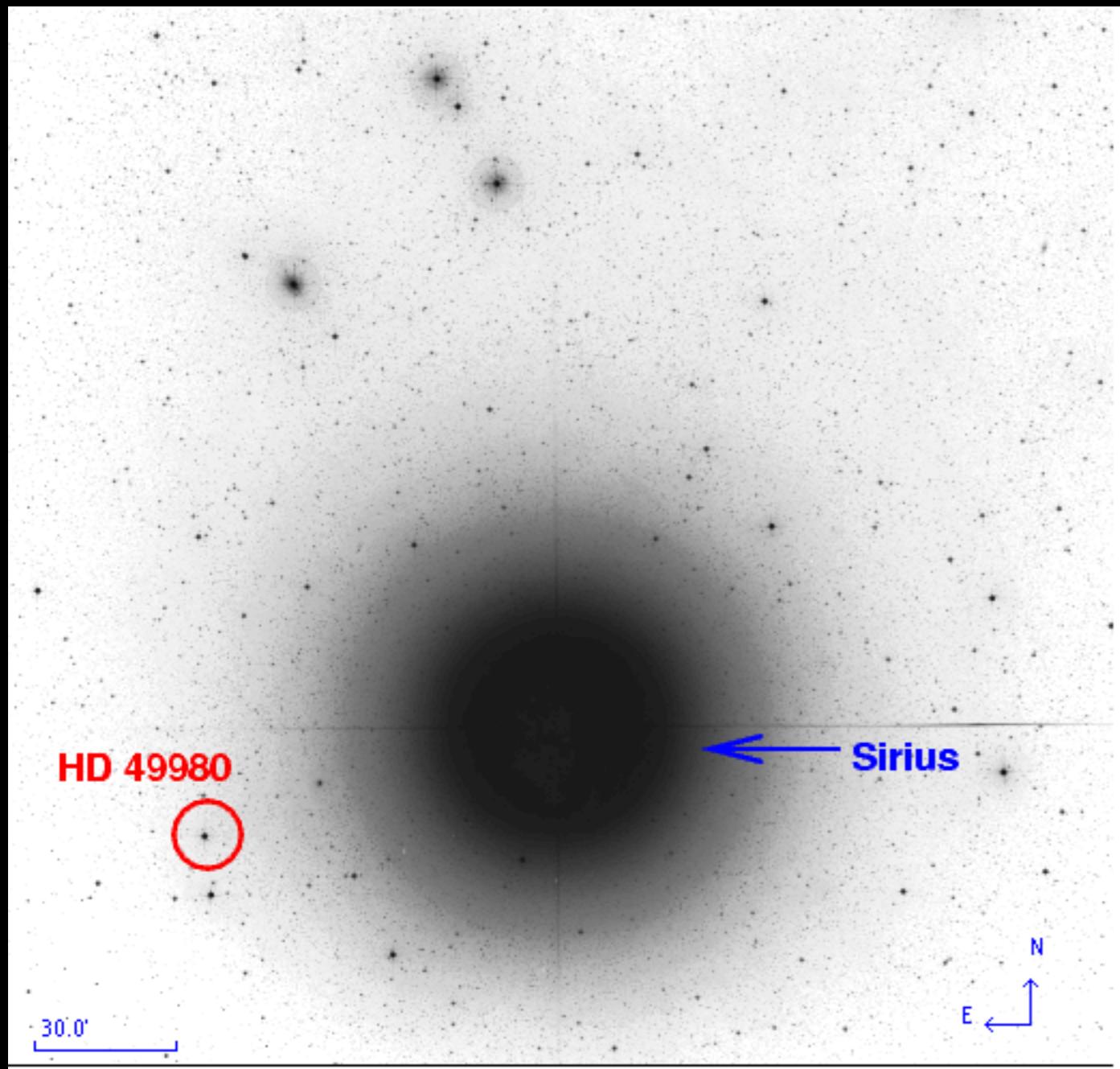
# **AST 296LB**

**Life as an Astronomer II**  
**What we actually measure on the**  
**images and how we do that?**

**Ok we got an image ..... and now?**

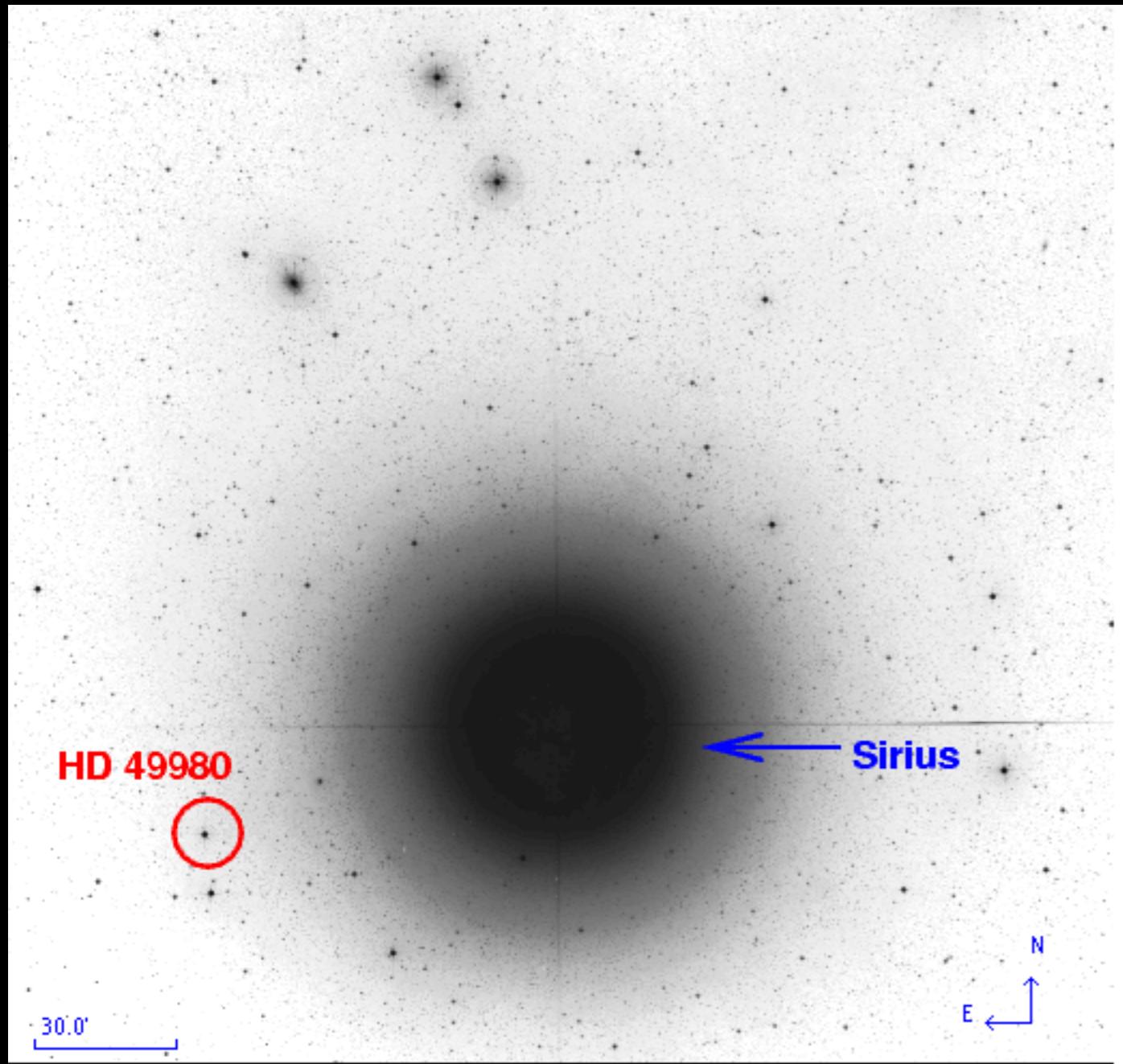


# Ok we got an image ..... and now?



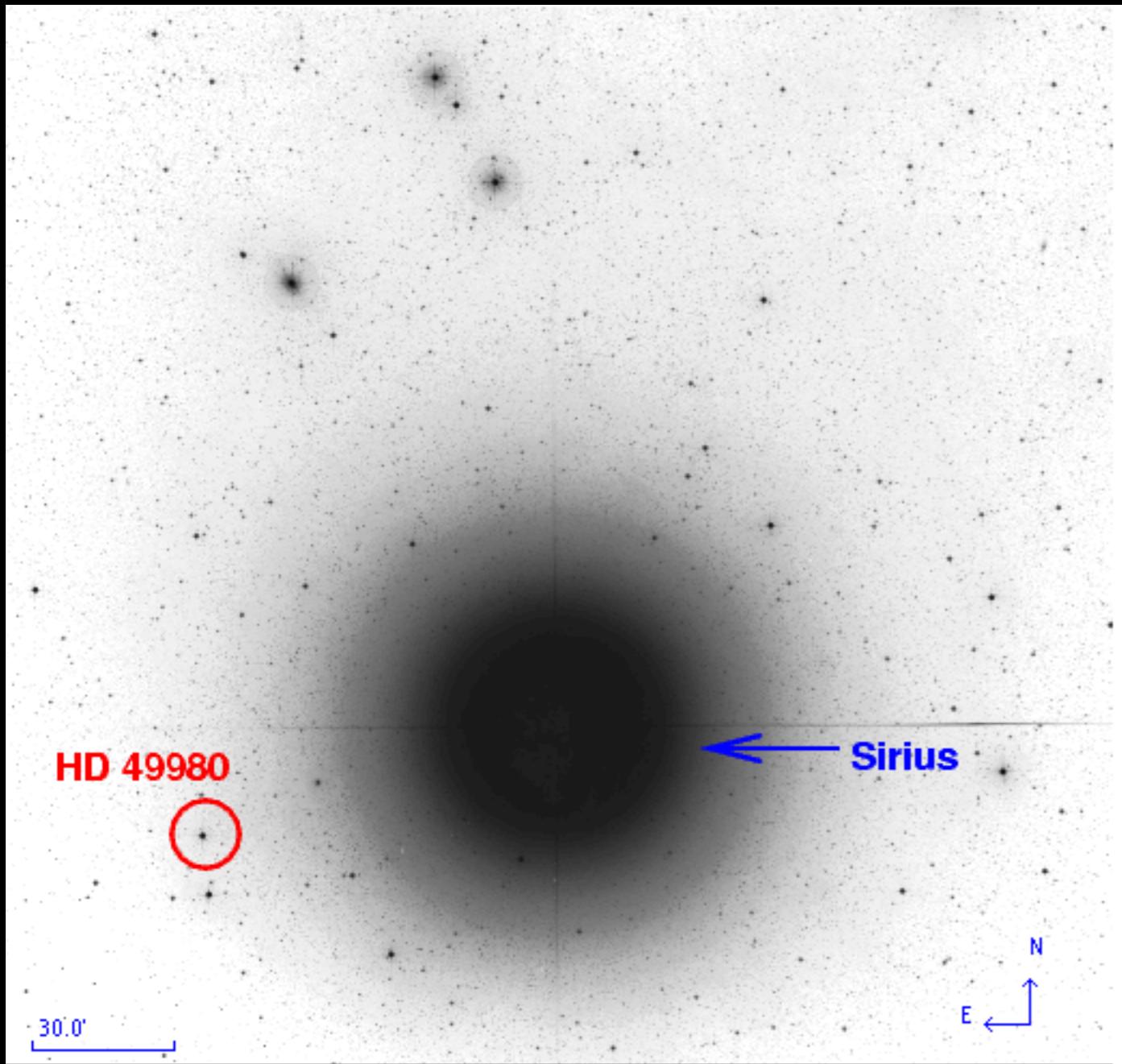
(in reality we get black  
and white images)

# Ok we got an image ..... and now?



**we measure how bright  
an object is**

# Ok we got an image ..... and now?

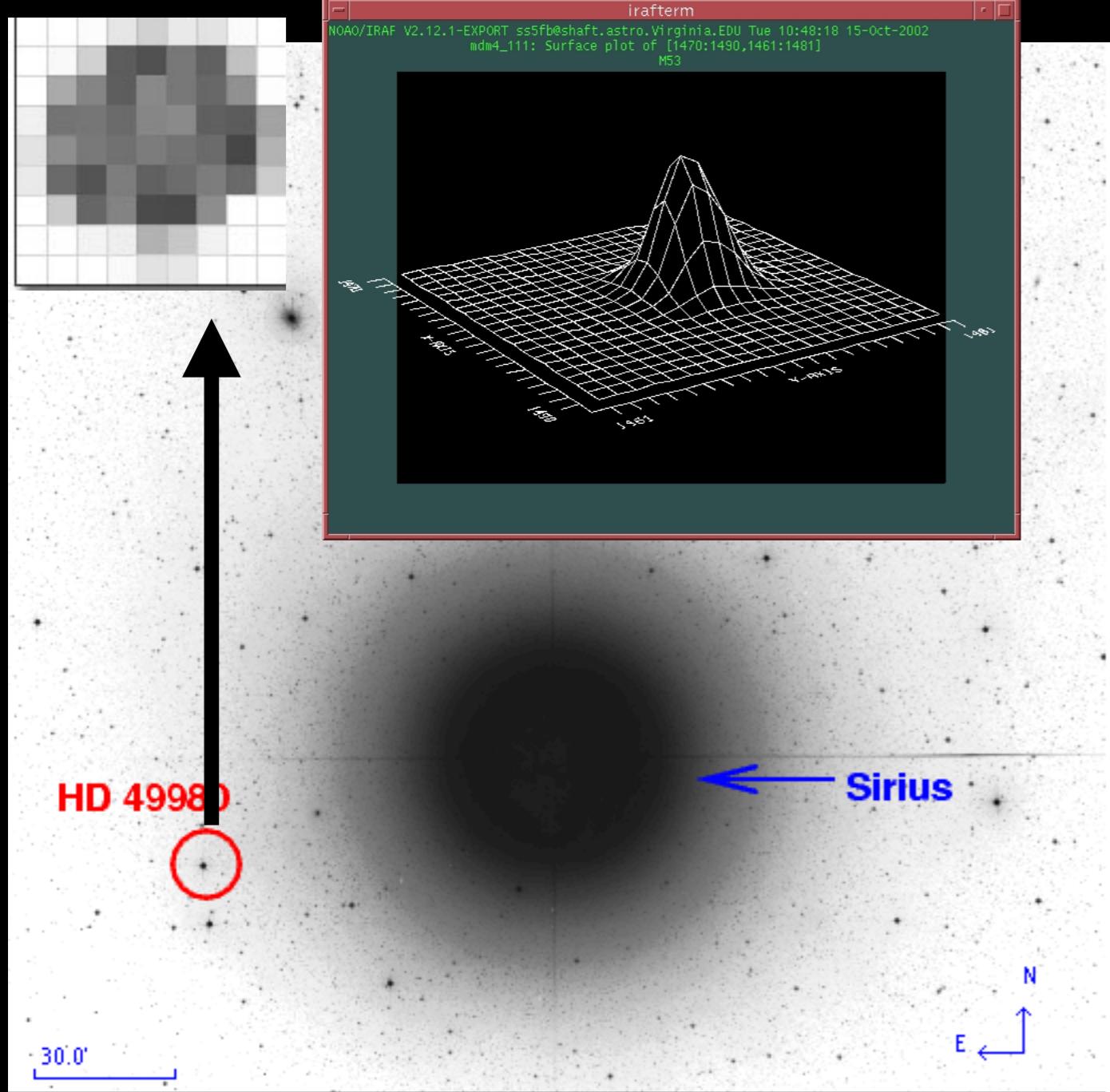


**we measure how bright  
an object is**

**we measure the number  
of ?? of the object we  
are interested in**

**photons?  
counts?  
electrons?  
potatoes?**

# Ok we got an image ..... and now?



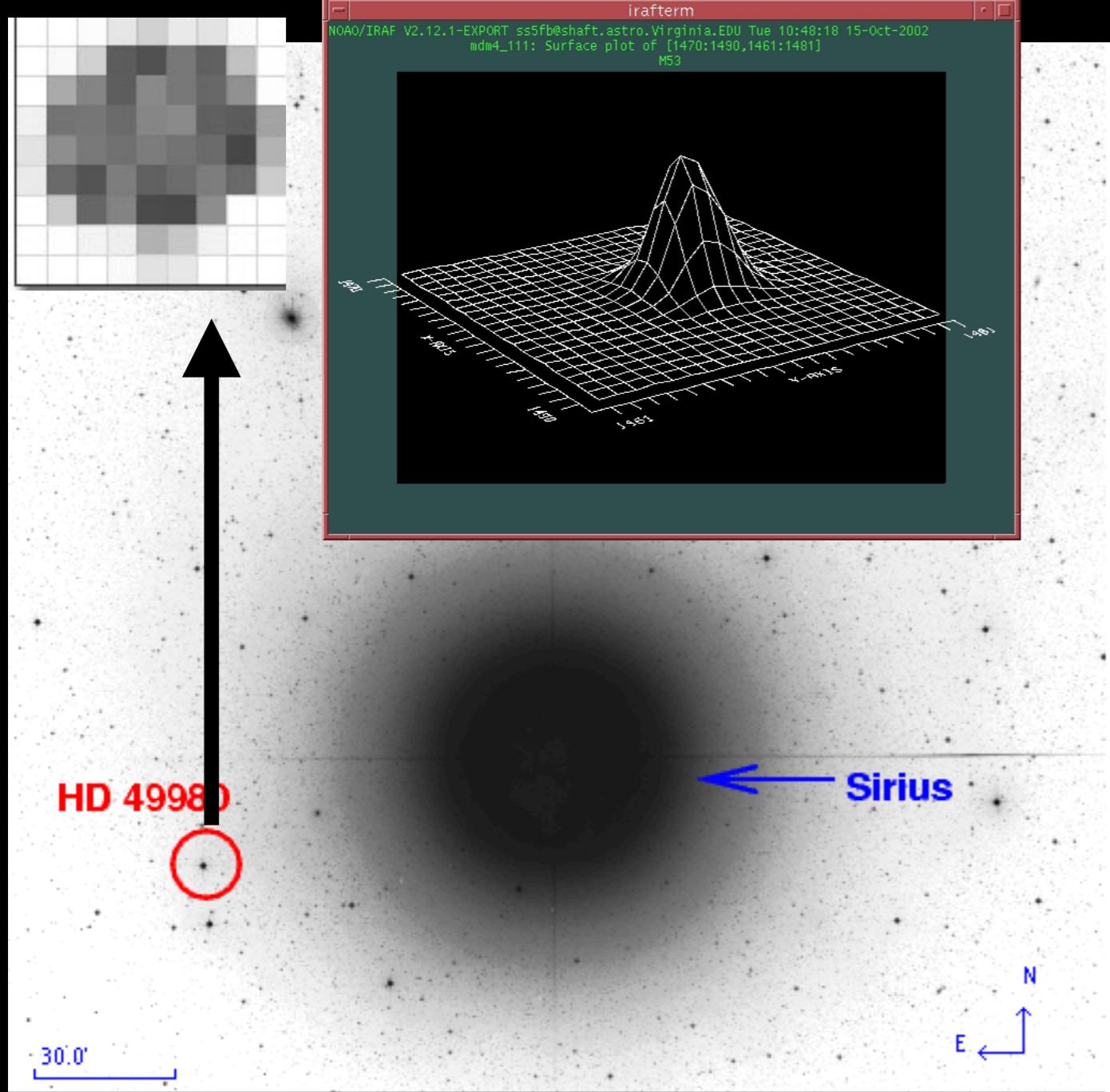
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**astronomical images (see next week python activity)  
are large matrices (2D arrays, see today python activity)**

# Ok we got an image ..... and now?



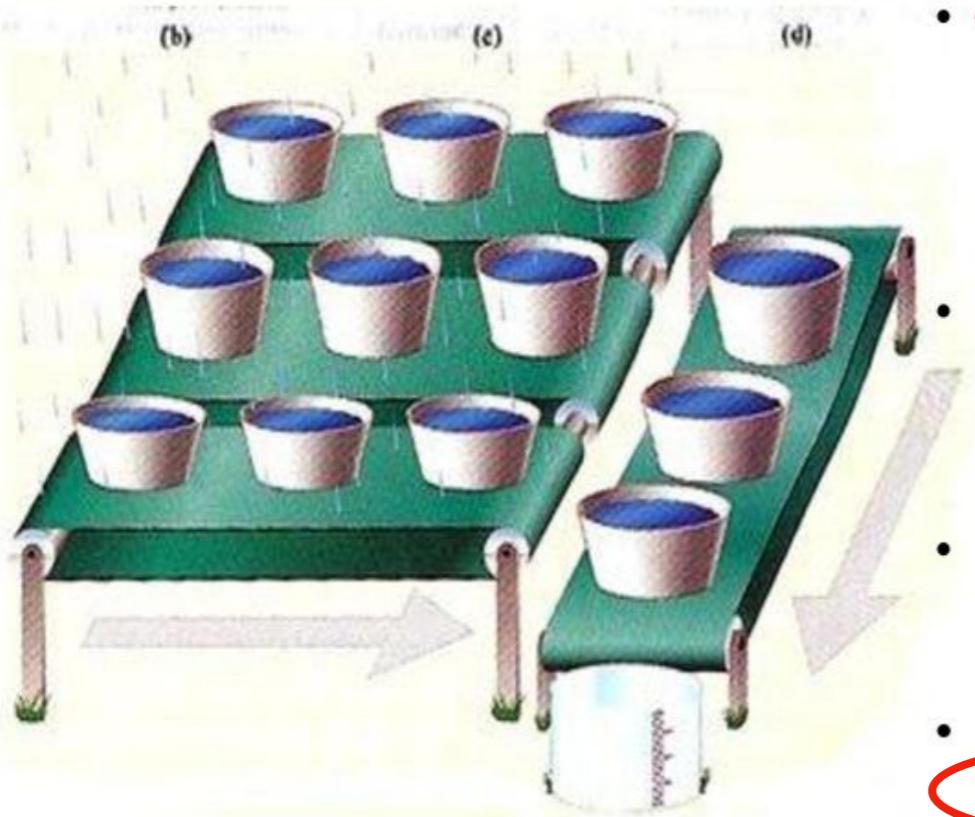
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**photons?  
counts?  
electrons?  
potatoes?** → **photons**

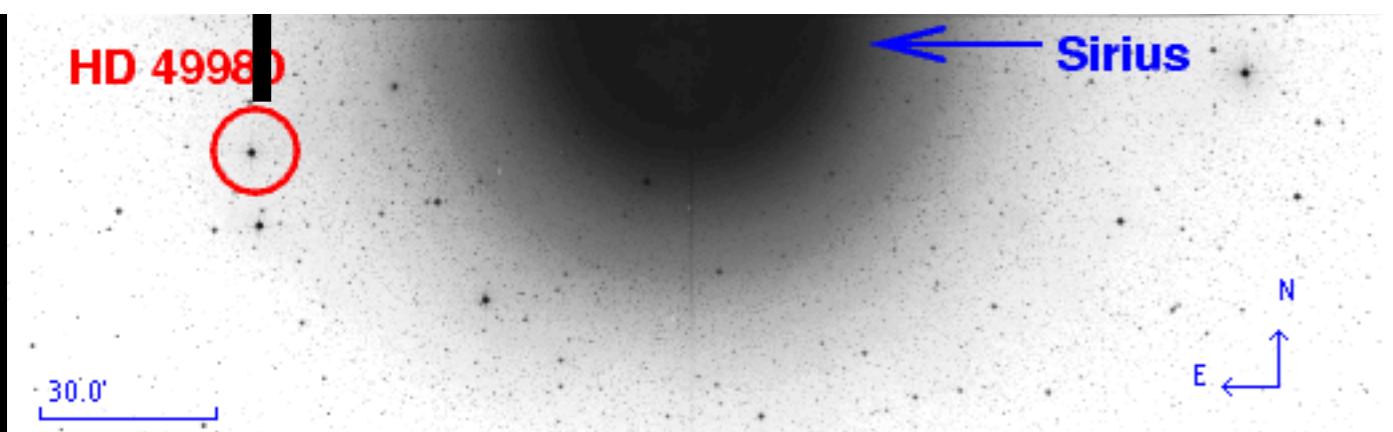
**astronomical images (see next week python activity)  
are large matrices (2D arrays, see today python activity)**

# How Does a CCD Work?



- Rain = **Photons**
- Water = **Charge** (photon strikes silicon semiconductor surface and knocks an electron loose by the photoelectric effect)
- Buckets = **pixels** (electrons accumulate in “potential wells;” depth represents how much charge each pixel can hold)
- The charge in each line of pixels is shifted to the **readout register**
- The charge in each pixel is **counted**

[www.assignmentpoint.com](http://www.assignmentpoint.com)



nd now?

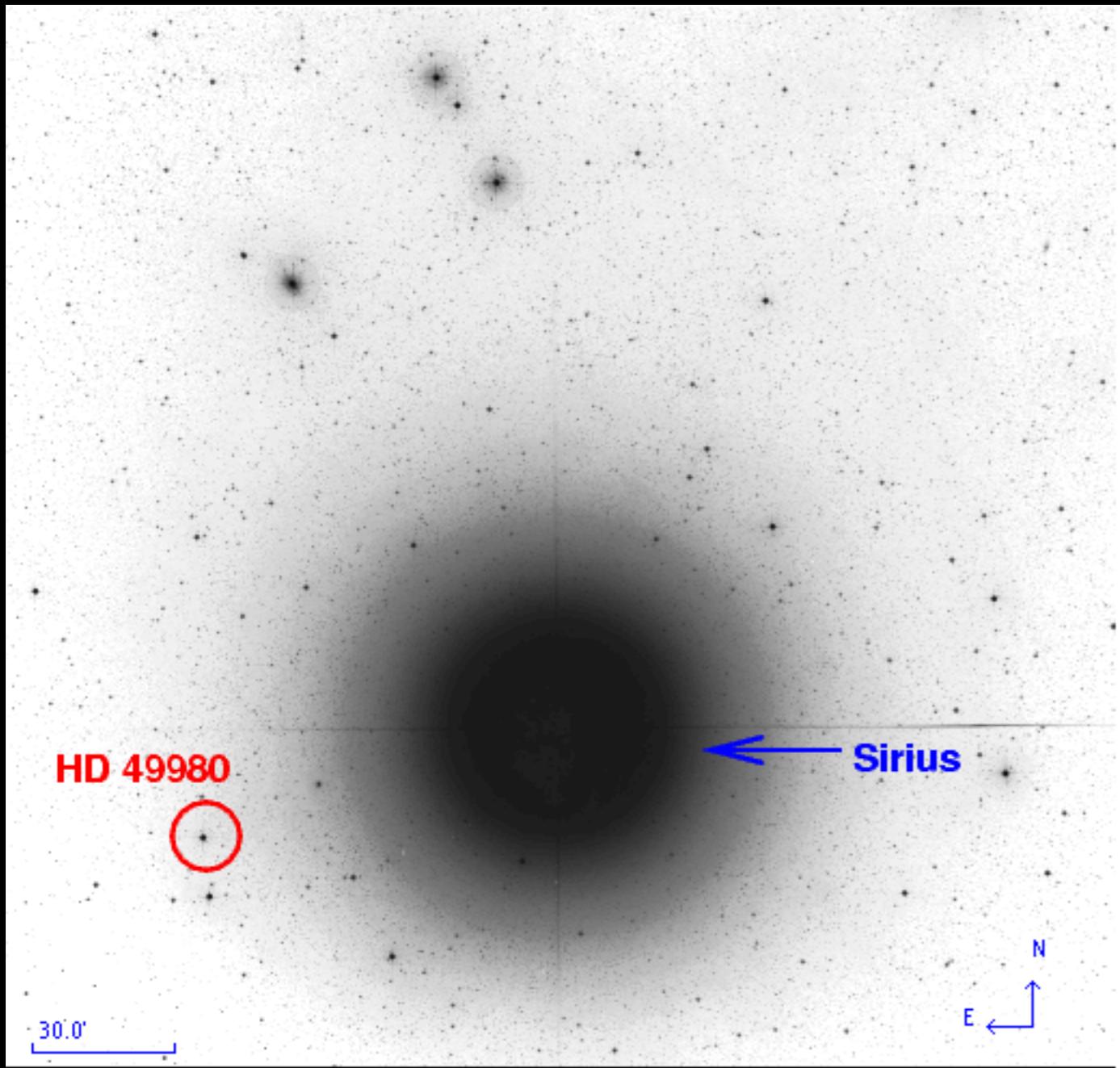
measure how bright  
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re interested in

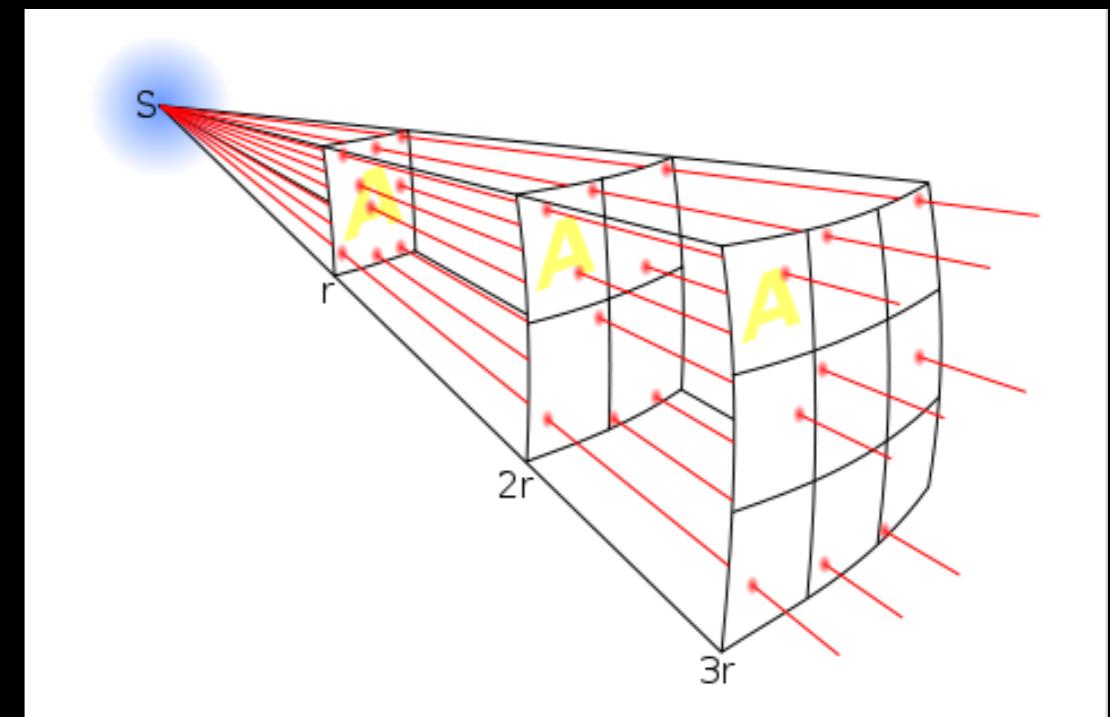
photons?  
counts?  
electrons?  
potatoes?

astronomical images (see next week python activity)  
are large matrices (2D arrays, see today python activity)

# Flux



**the flux is the total amount of energy that crosses a unit area per unit time.**



# Magnitude system

Astronomers are stuck with the historical artifact known as the magnitude scale. We describe the brightness of stars not in a linear sense -- "this one sends 1200 photons per second into our detector, that one sends only 492 photons per second" -- but in a logarithmic sense.

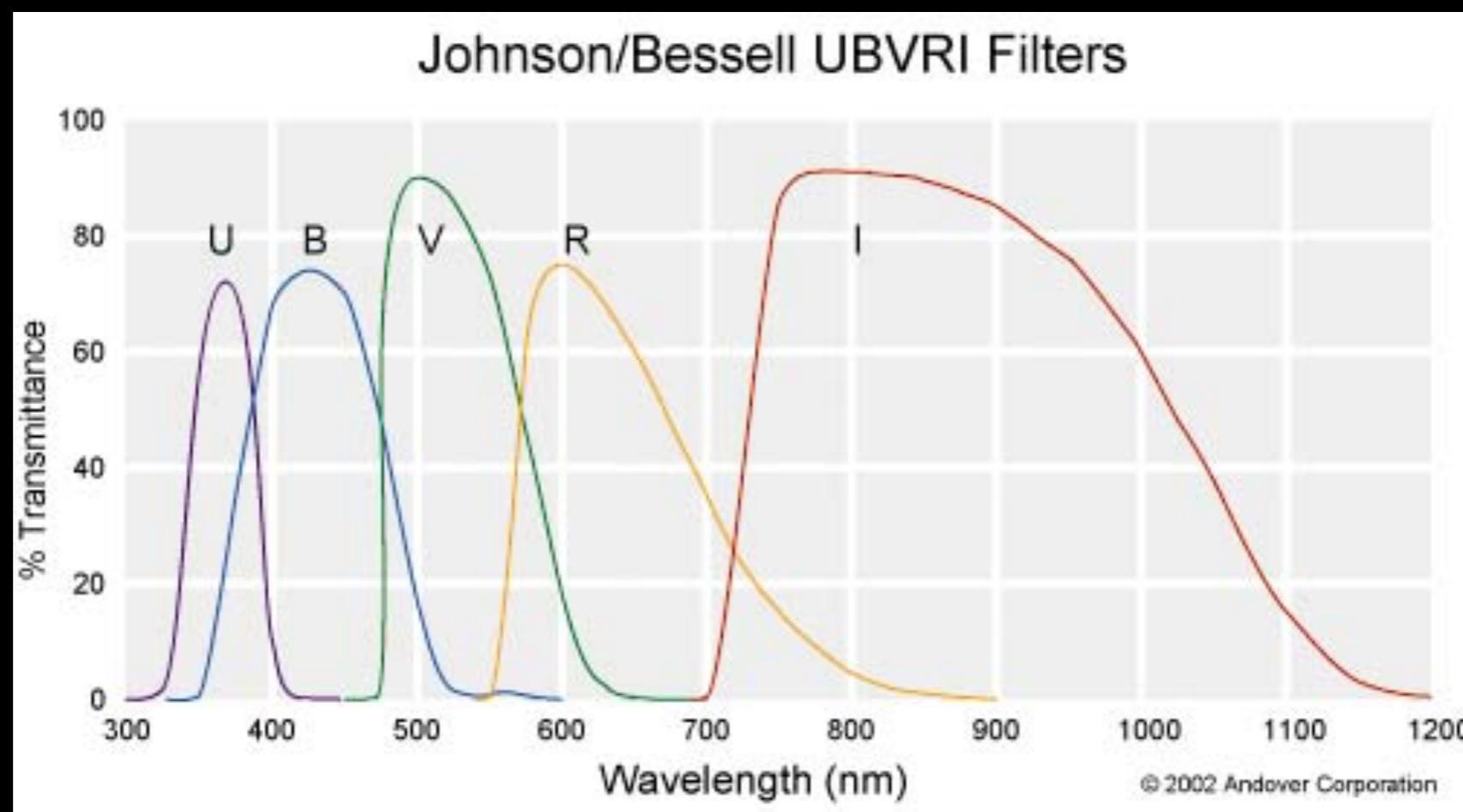
$$(m_1 - m_2) = -2.5 * \log_{10} \frac{F_1}{F_2}$$

Note that this definition says nothing about the zero-point (reference) of a magnitude: it provides only the DIFFERENCE between two stars

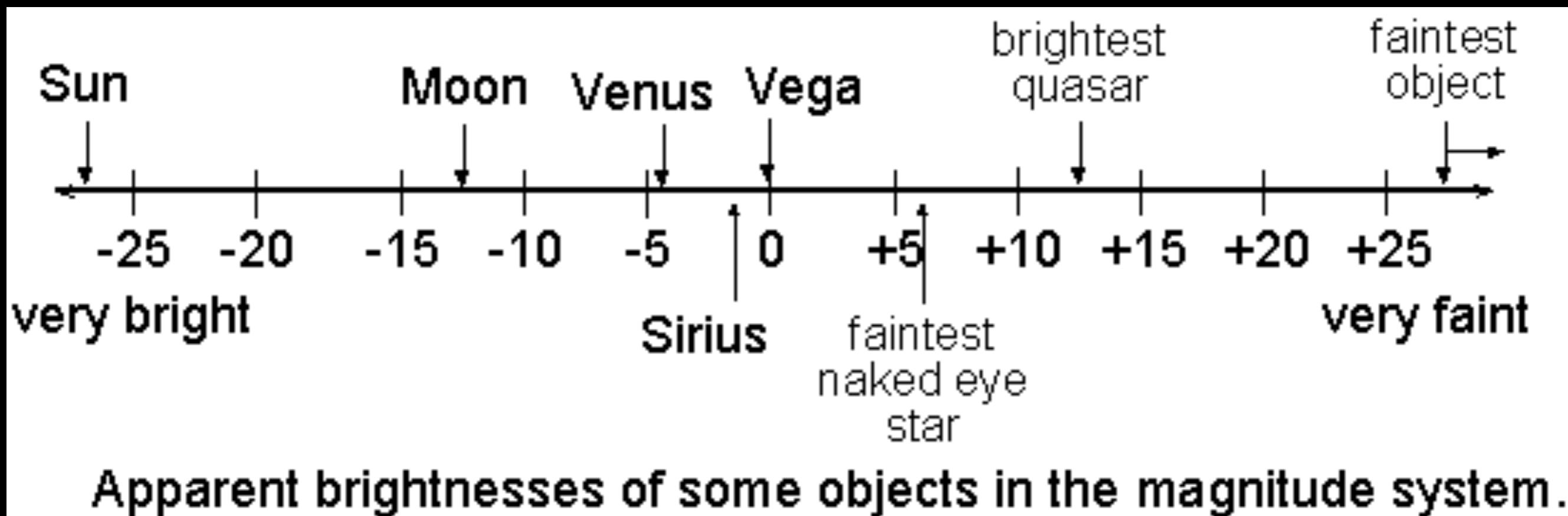
$$\frac{F_1}{F_2} = 10^{-0.4(m_1 - m_2)}$$

# Magnitude in different filters

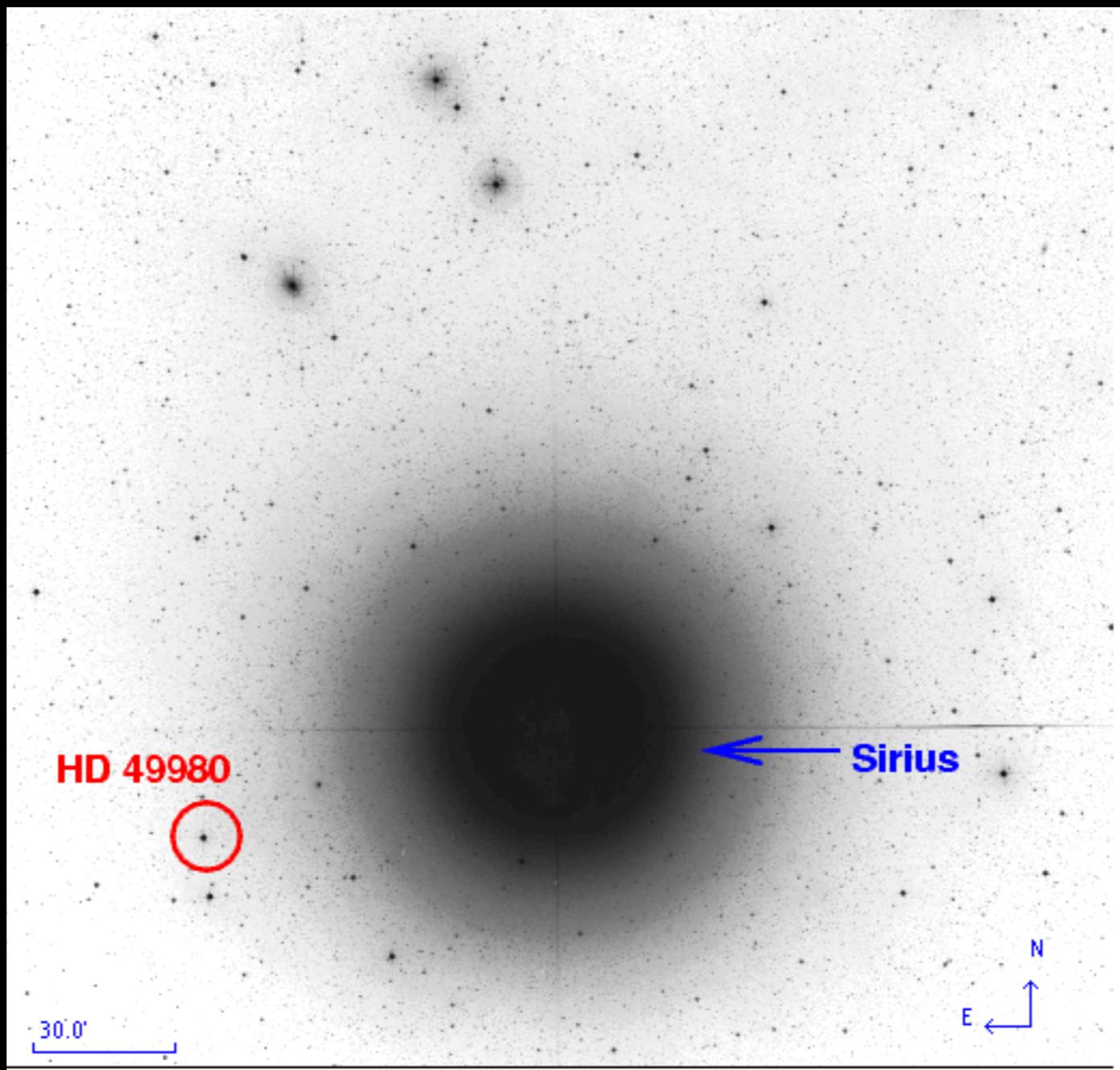
	B	V	(B-V)
<b>Vega</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>
<b>Antares</b>	<b>2.96</b>	<b>1.09</b>	<b>+1.87</b>
<b>Meissia</b>	<b>3.20</b>	<b>3.39</b>	<b>-0.19</b>



# Magnitude in different filters



# How many times brighter does Sirius appear?



$$\frac{F_1}{F_2} = 10^{-0.4(m_1 - m_2)}$$

$$m(\text{Sirius}) = -1.5$$

$$m(\text{HD 49980}) = 5.8$$

# How many times brighter does Sirius appear?

$$m(\text{Sirius}) = -1.5$$

$$m(\text{HD 49980}) = 5.8$$

$$\frac{F_1}{F_2} = 10^{-0.4(m_1 - m_2)}$$

$$\frac{I(\text{Sirius})}{I(\text{HD 49980})} = 10^{-0.4 * [ (-1.5) - 5.8 ]}$$

# How many times brighter does Sirius appear?

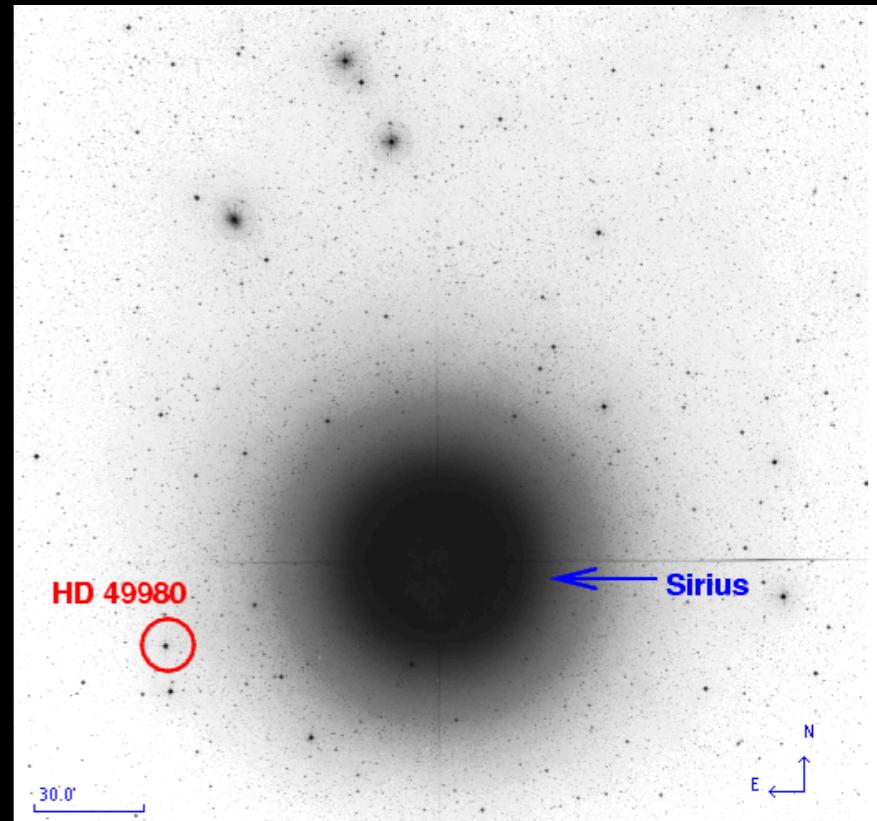
$$m(\text{Sirius}) = -1.5$$

$$m(\text{HD } 49980) = 5.8$$

$$\frac{I(\text{Sirius})}{I(\text{HD } 49980)} = 10^{-0.4 * [ (-1.5) - 5.8 ]}$$

$$= 10^{2.92}$$

$$= 832$$



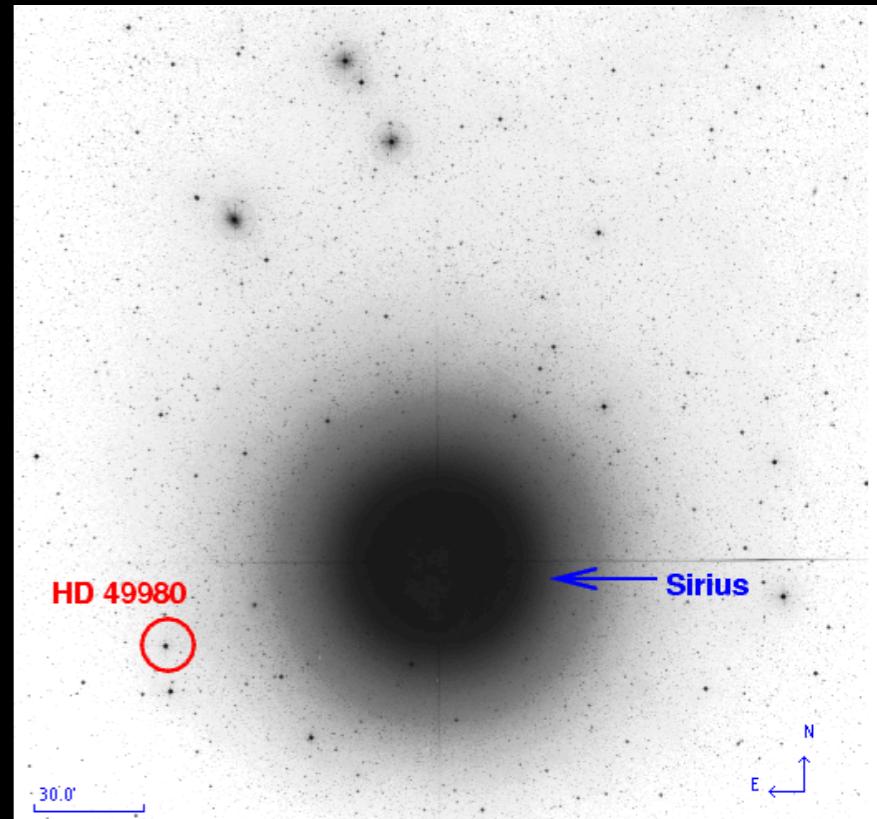
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$$\begin{aligned} &= 10^{2.92} \\ &= 832 \end{aligned}$$



Does this mean that Sirius is a much more powerful star, one which emits hundreds of times as much energy as HD 49980?

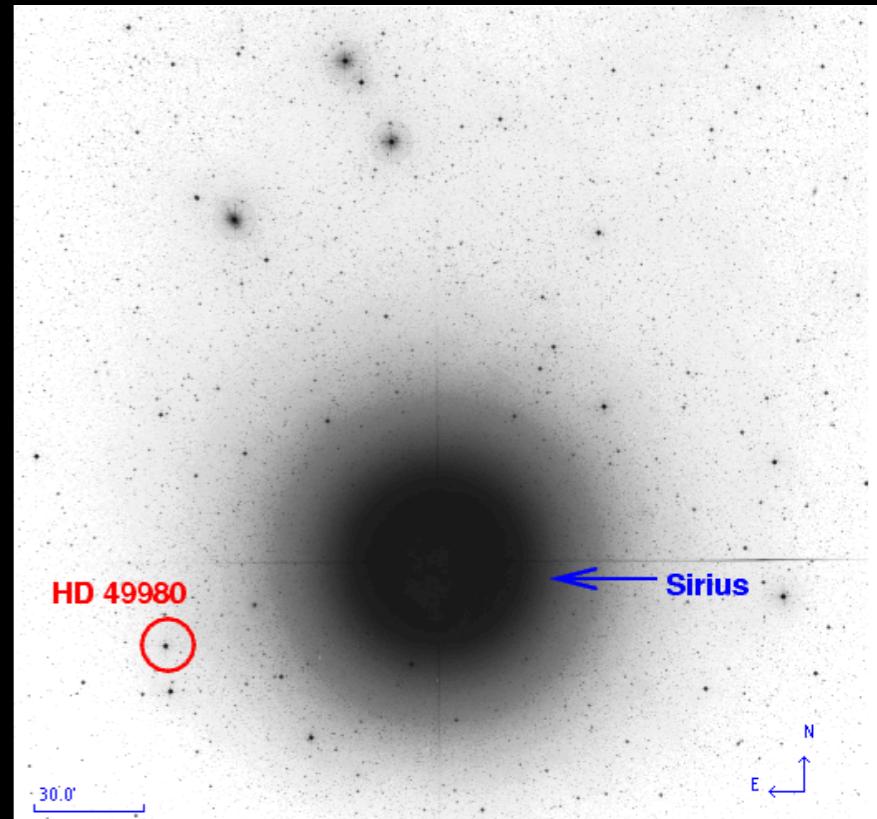
# How many times brighter does Sirius appear?

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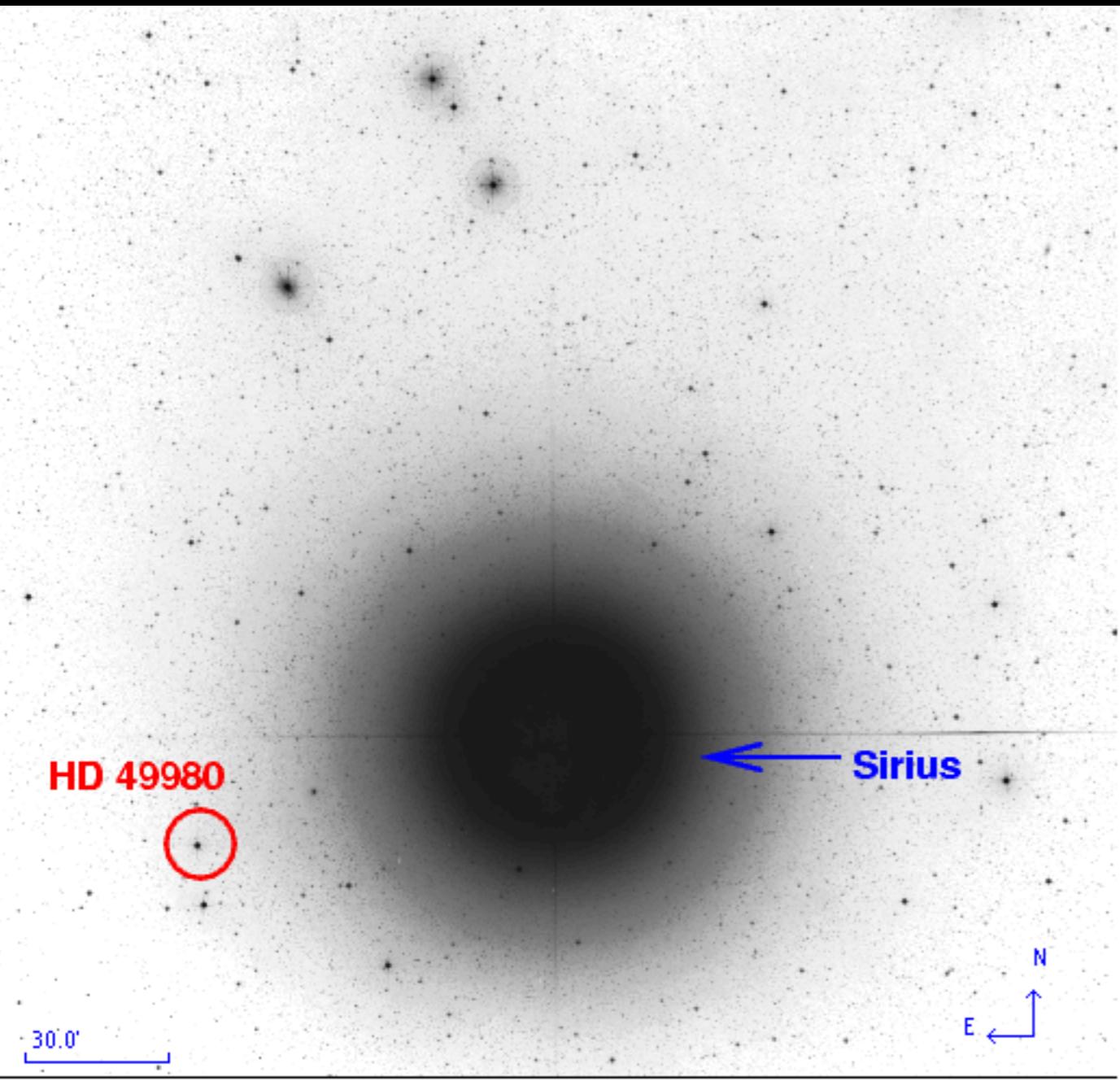
$$\frac{I(\text{Sirius})}{I(\text{HD } 49980)} = 10^{-0.4 * [ (-1.5) - 5.8 ]}$$

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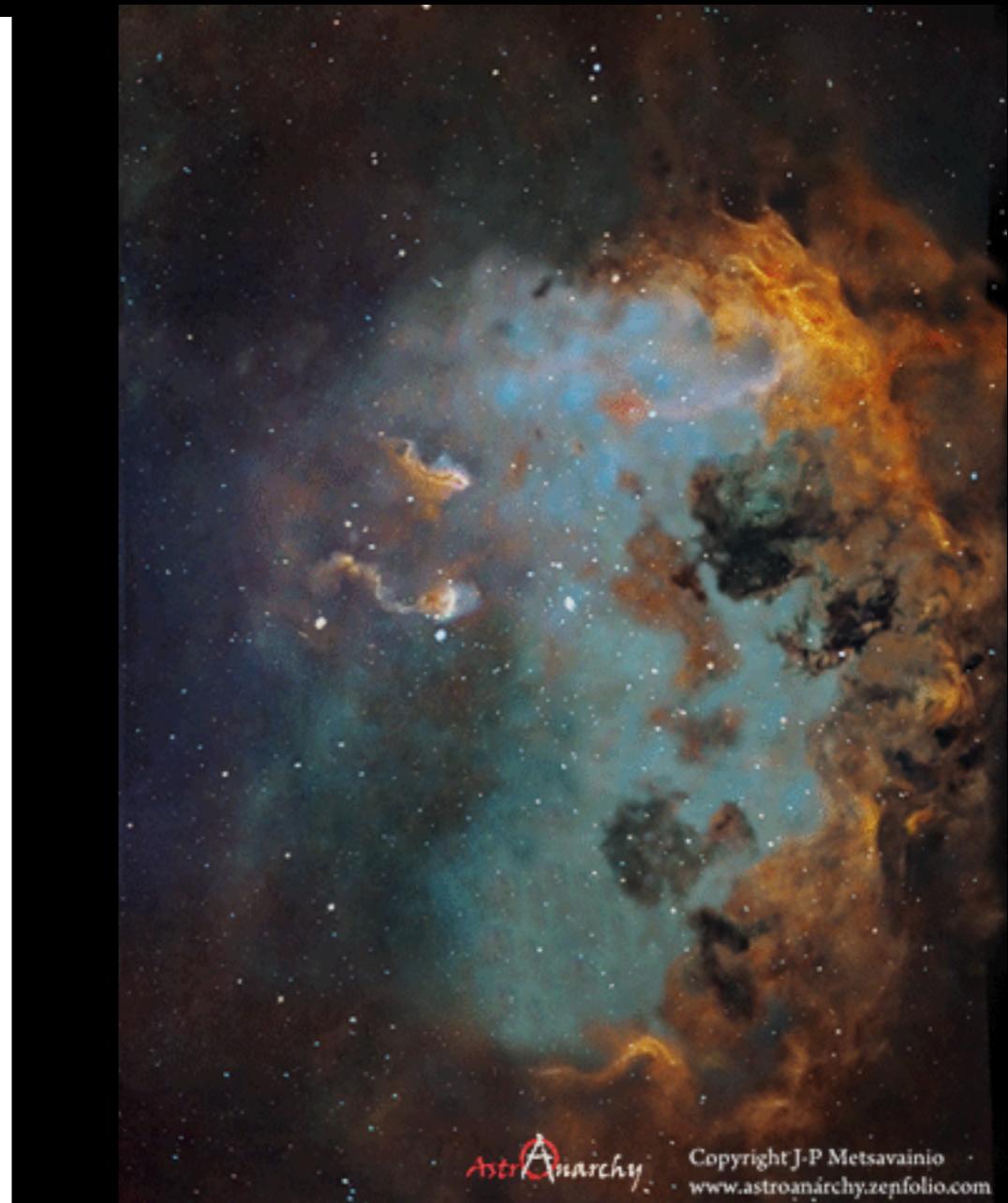
Does this mean that Sirius is a much more powerful star, one which emits hundreds of times as much energy as HD 49980? **NO**

# Distance



$$m(\text{Sirius}) = -1.5$$

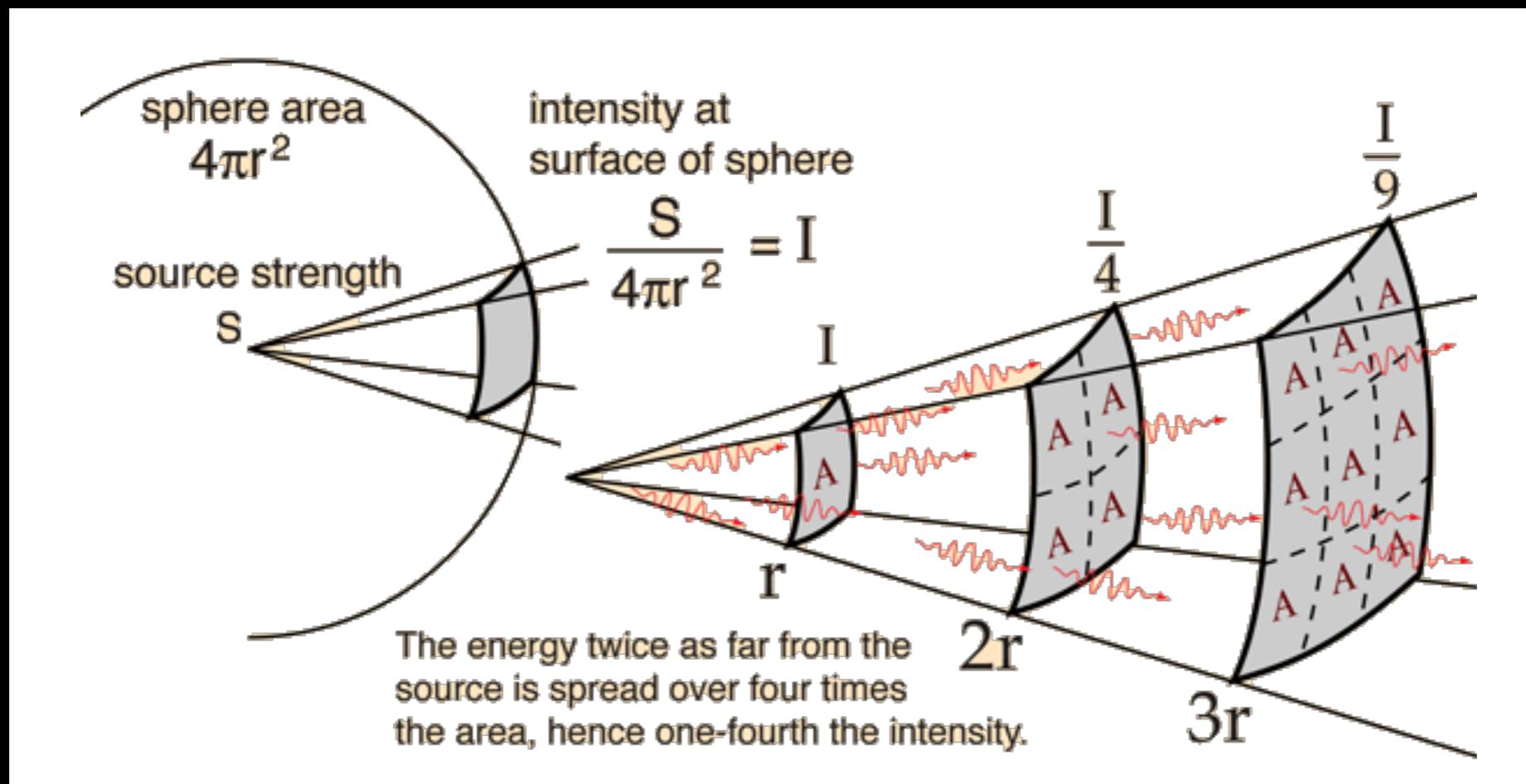
$$m(\text{HD 49980}) = 5.8$$



$$d(\text{Sirius}) = 2.64 \text{ parsec}$$

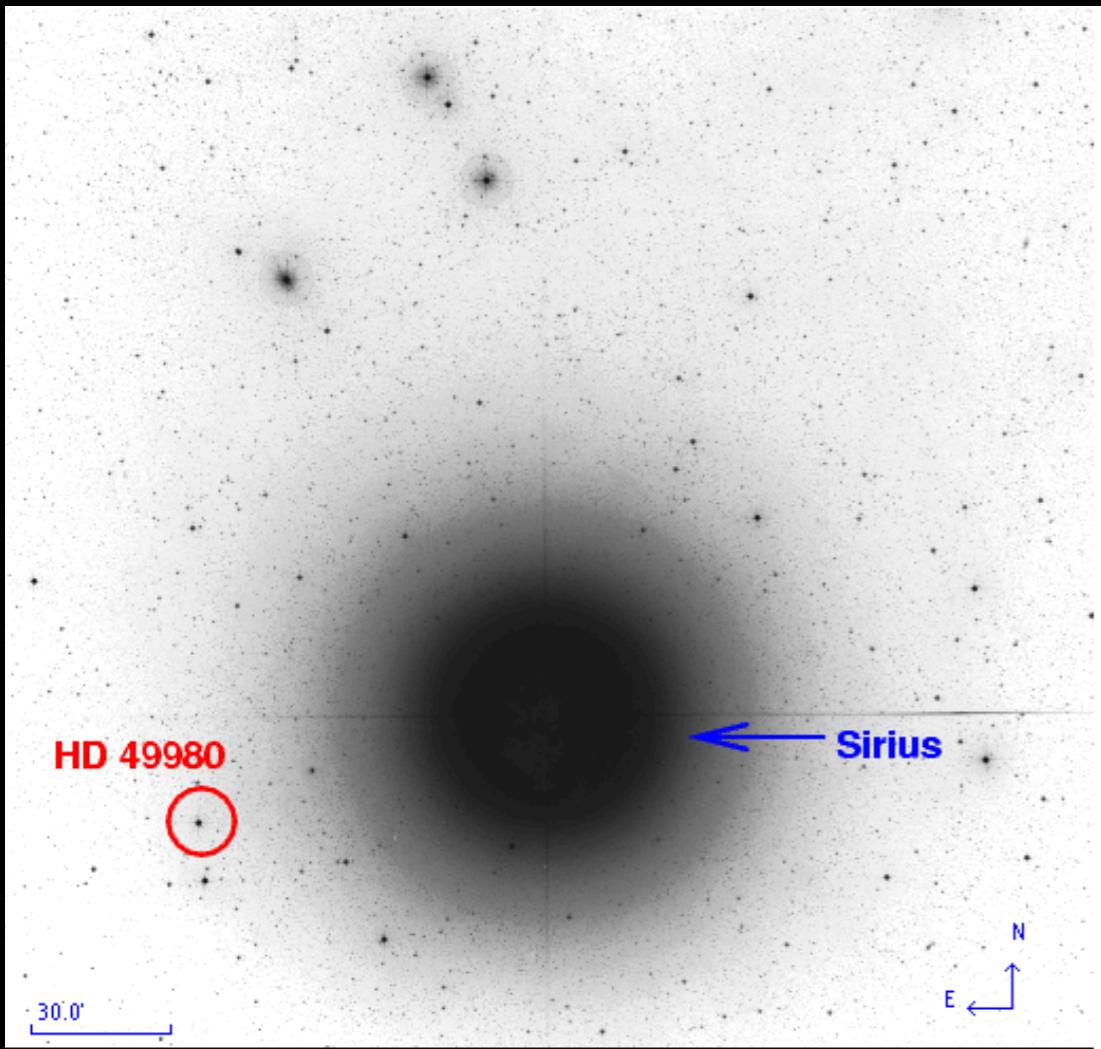
$$d(\text{HD 49980}) = \sim 500 \text{ parsec}$$

# Intensity (distance)



# (apparent) magnitude

$$(m_1 - m_2) = -2.5 * \log_{10} \frac{F_1}{F_2}$$



HD 49980

← Sirius

30.0'

N  
E ←

$$m(\text{Sirius}) = -1.5$$

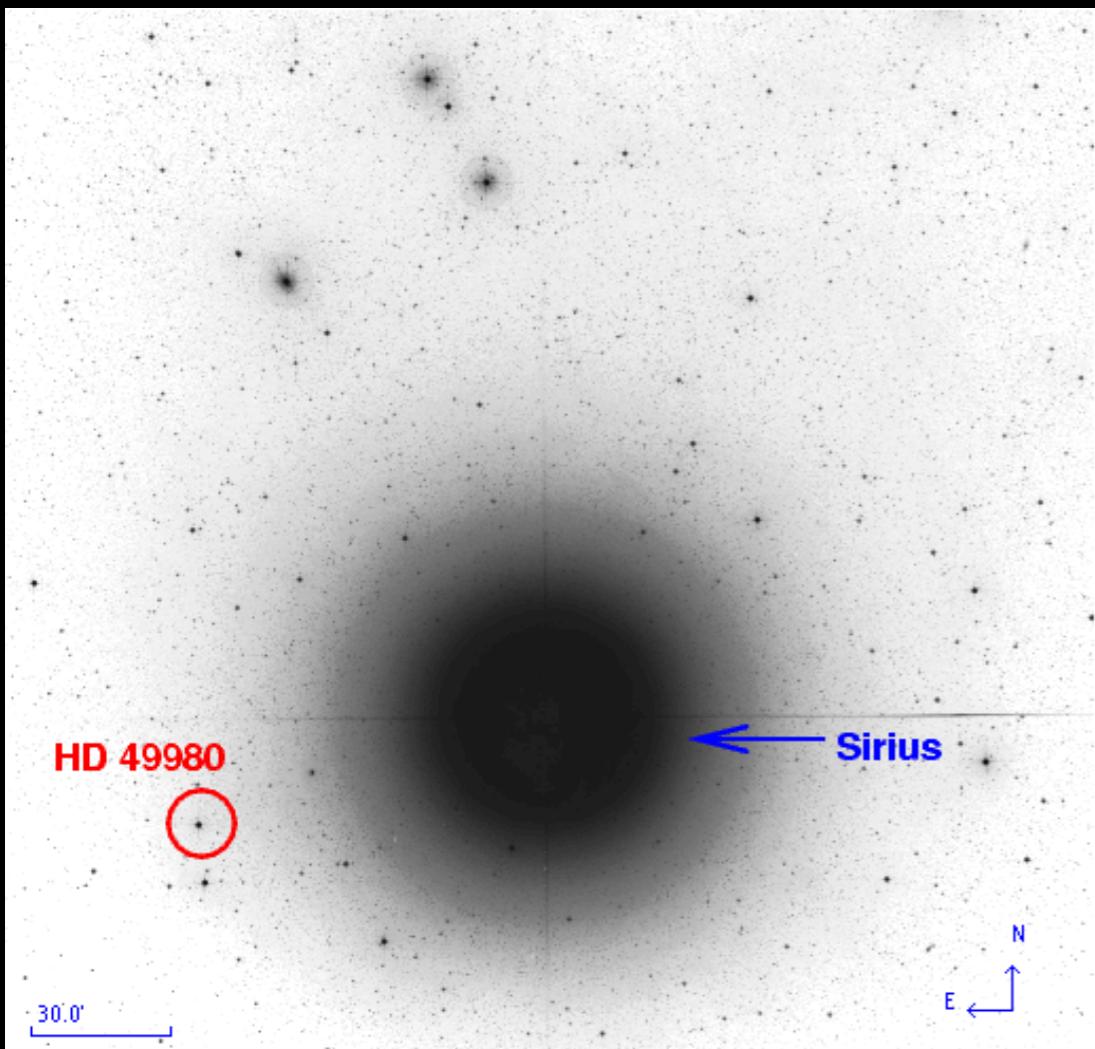
$$d(\text{Sirius}) = 2.64 \text{ parsec}$$

$$m(\text{HD 49980}) = 5.8$$

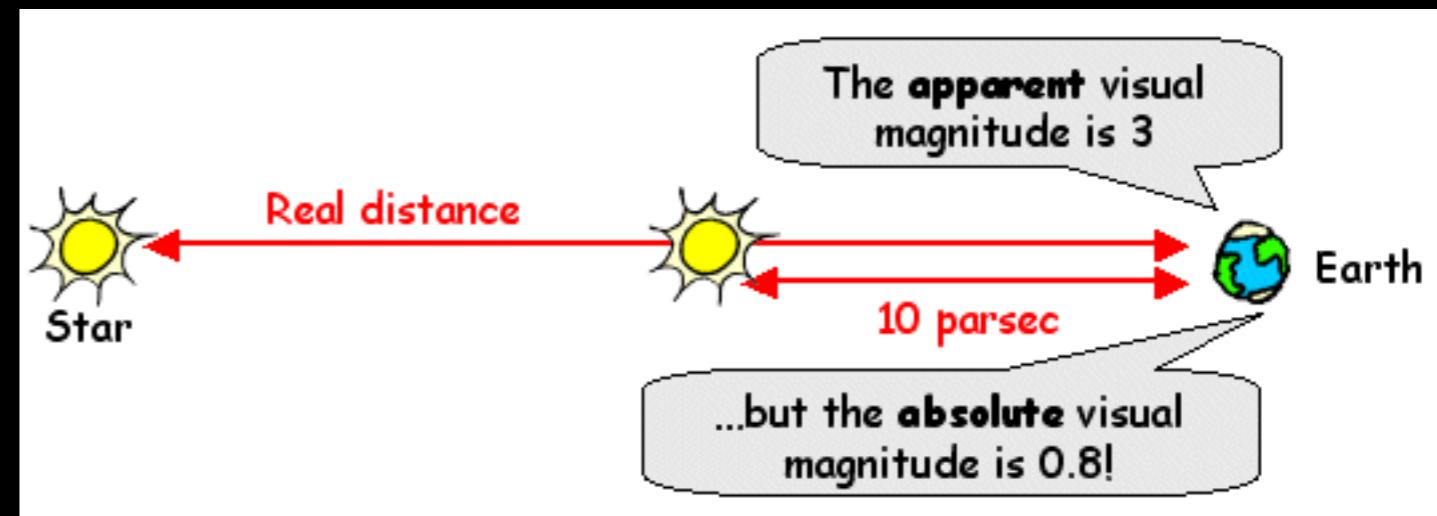
$$d(\text{HD 49980}) = \sim 500 \text{ parsec}$$

# (apparent) magnitude

$$(m_1 - m_2) = -2.5 * \log_{10} \frac{F_1}{F_2}$$



compare Sirius and HD49980  
at the same distance



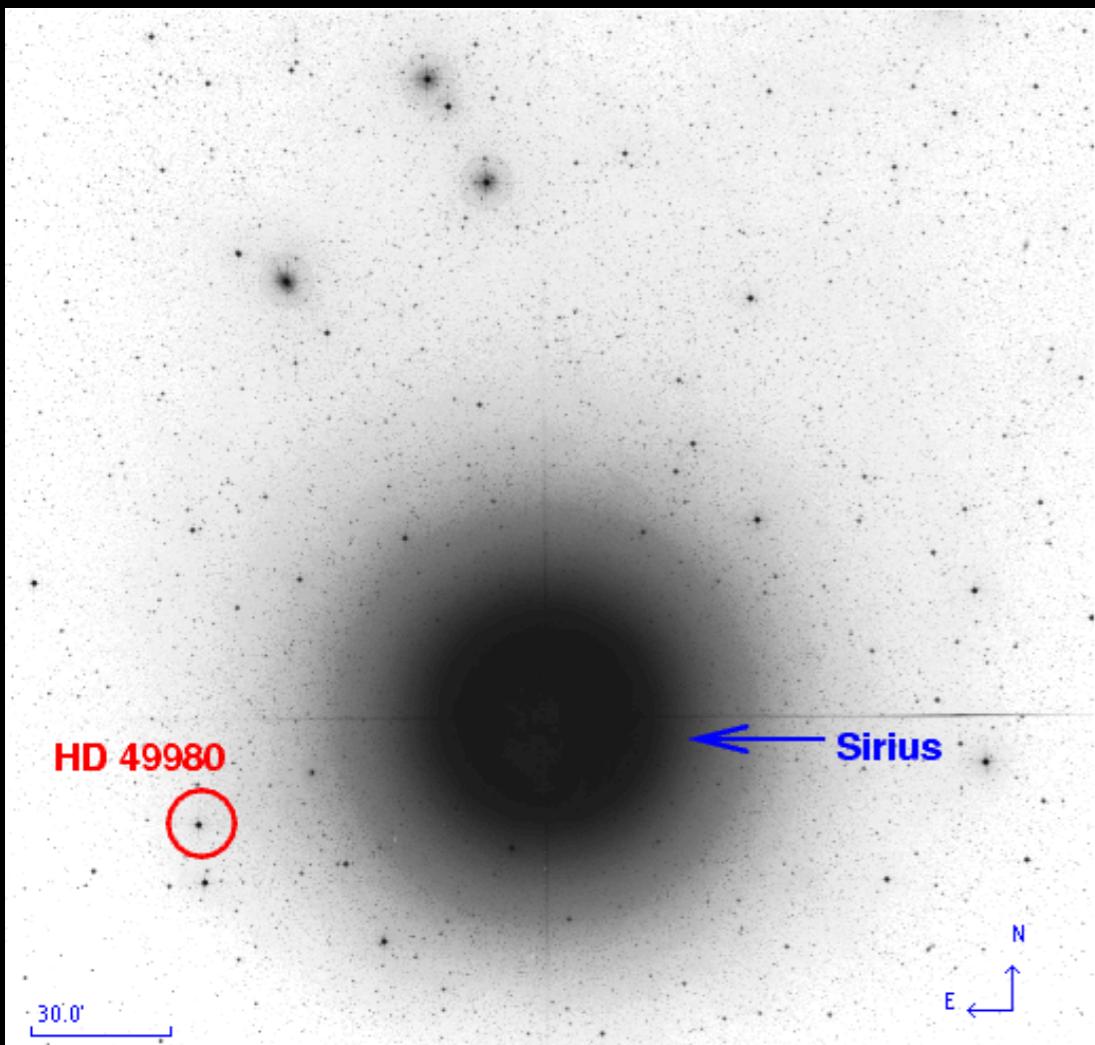
$$m(\text{Sirius}) = -1.5$$

$$d(\text{Sirius}) = 2.64 \text{ parsec}$$

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$$d(\text{HD 49980}) = \sim 500 \text{ parsec}$$

# Absolute magnitude



HD 49980



30.0'

Sirius



$$m(\text{Sirius}) = -1.5$$

$$m(\text{HD } 49980) = 5.8$$

$$(m_1 - m_2) = -2.5 * \log_{10} \frac{F_1}{F_2}$$

distance of  
the star (pc)

distance  
modulus

$$m - M = 5 \log_{10} \left( \frac{d}{10} \right)$$

apparent  
magnitude

absolute  
magnitude

$$d(\text{Sirius}) = 2.64 \text{ parsec}$$

$$d(\text{HD } 49980) = \sim 500 \text{ parsec}$$

# What is the absolute magnitude of Sirius and HD49980?

$$m - M = 5 \log_{10} \left( \frac{d}{10} \right) \quad (m_1 - m_2) = -2.5 * \log_{10} \frac{F_1}{F_2}$$

$$m(\text{Sirius}) = -1.5$$

$$d(\text{Sirius}) = 2.64 \text{ parsec}$$

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$$d(\text{HD 49980}) = \sim 500 \text{ parsec}$$

# What is the absolute magnitude of Sirius and HD49980?

$$m - M = 5 \log_{10} \left( \frac{d}{10} \right) \quad (m_1 - m_2) = -2.5 * \log_{10} \frac{F_1}{F_2}$$

$$\begin{aligned} M(\text{Sirius}) &= m(\text{Sirius}) - (5 \log_{10} d(\text{S}) - 5) = \\ -1.5 - (5 * \log_{10}(2.64) - 5) &= 1.39 \end{aligned}$$

$$\begin{aligned} M(\text{HD 49980}) &= m(\text{HD49980}) - (5 \log_{10} d(\text{HD}) - 5) = \\ 5.8 - (5 * \log_{10}(500) - 5) &= -2.69 \end{aligned}$$

$$\begin{aligned} m(\text{Sirius}) &= -1.5 & d(\text{Sirius}) &= 2.64 \text{ parsec} \\ m(\text{HD 49980}) &= 5.8 & d(\text{HD 49980}) &= \sim 500 \text{ parsec} \end{aligned}$$

# Recap

**apparent magnitude**

$$(m_1 - m_2) = -2.5 * \log_{10} \frac{F_1}{F_2}$$

# Recap

**apparent magnitude**

**absolute magnitude**

**distance modulus**

**apparent  
magnitude**

**absolute  
magnitude**

$$(m_1 - m_2) = -2.5 * \log_{10} \frac{F_1}{F_2}$$

**distance of  
the star (pc)**

$$m - M = 5 \log_{10} \left( \frac{d}{10} \right)$$

# Recap

**apparent magnitude**

**absolute magnitude**

**instrumental magnitude**

$$(m_1 - m_2) = -2.5 * \log_{10} \frac{F_1}{F_2}$$

**distance modulus**

apparent  
magnitude

absolute  
magnitude

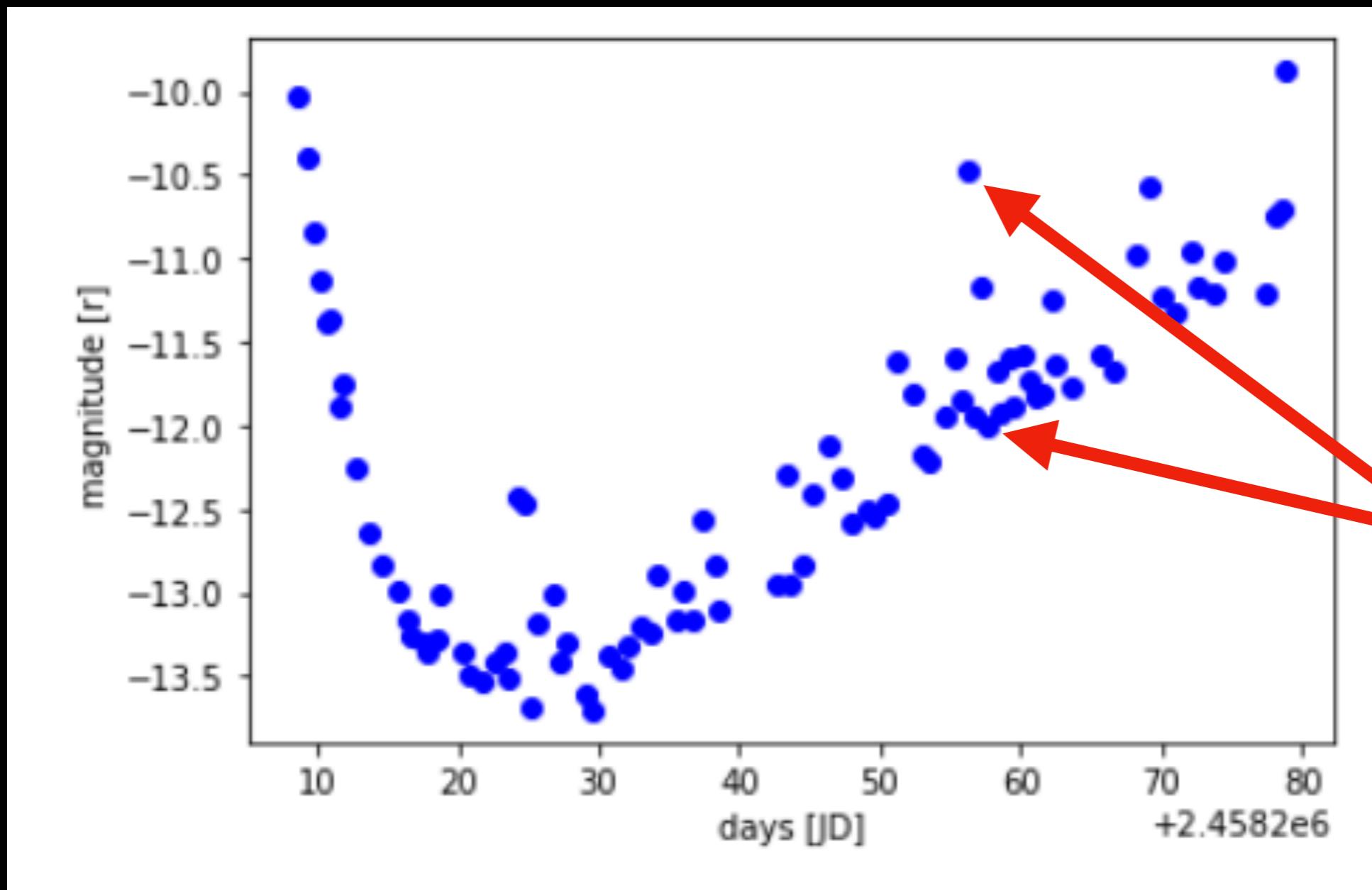
$$m - M = 5 \log_{10} \left( \frac{d}{10} \right)$$

what you actually measure on your image: **I = counts**

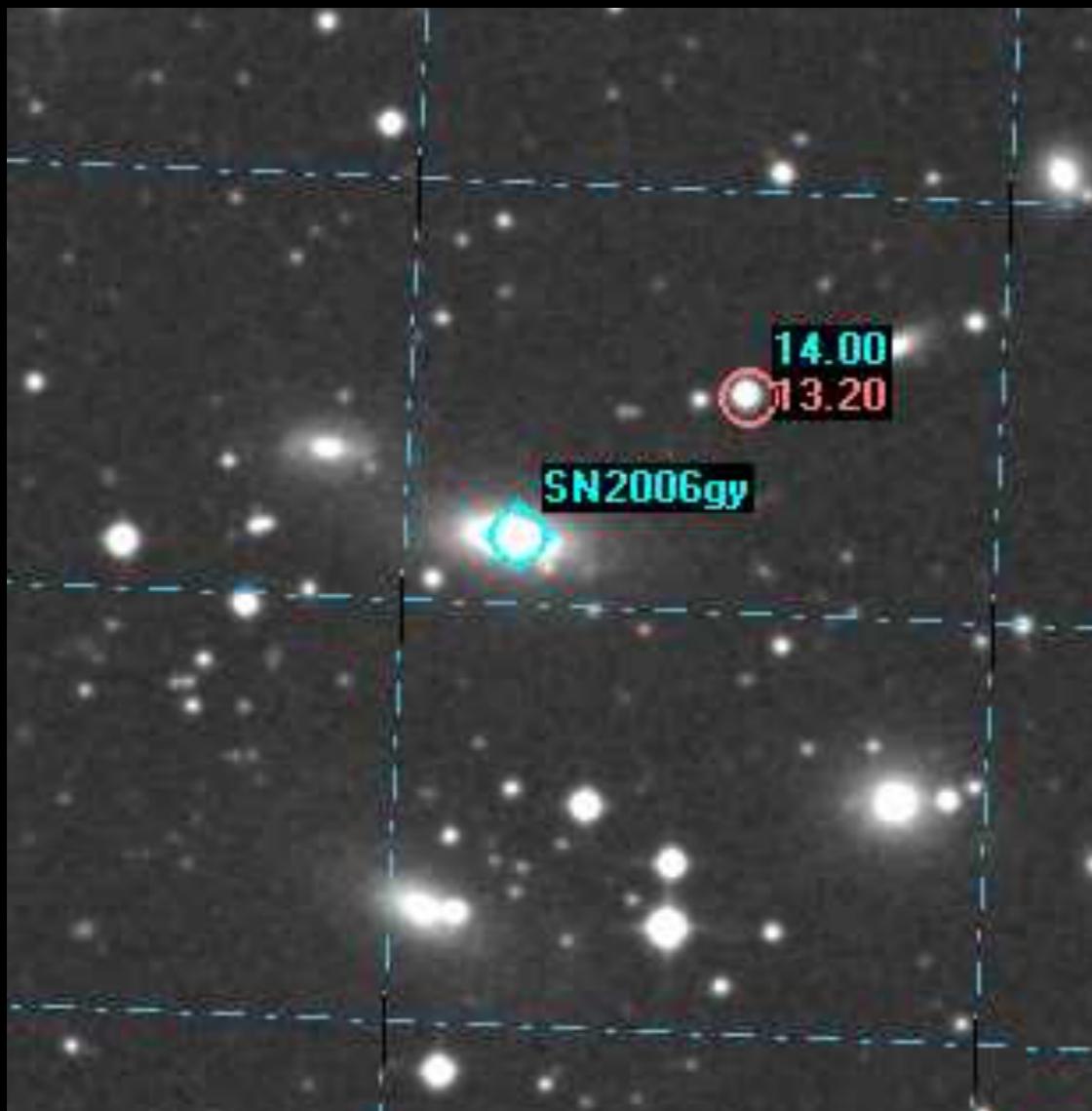
$$m_{inst} = -2.5 \times \log_{10} I$$

# instrumental magnitude

$$m_{inst} = - 2.5 \times \log_{10} I$$



# Typical SN image

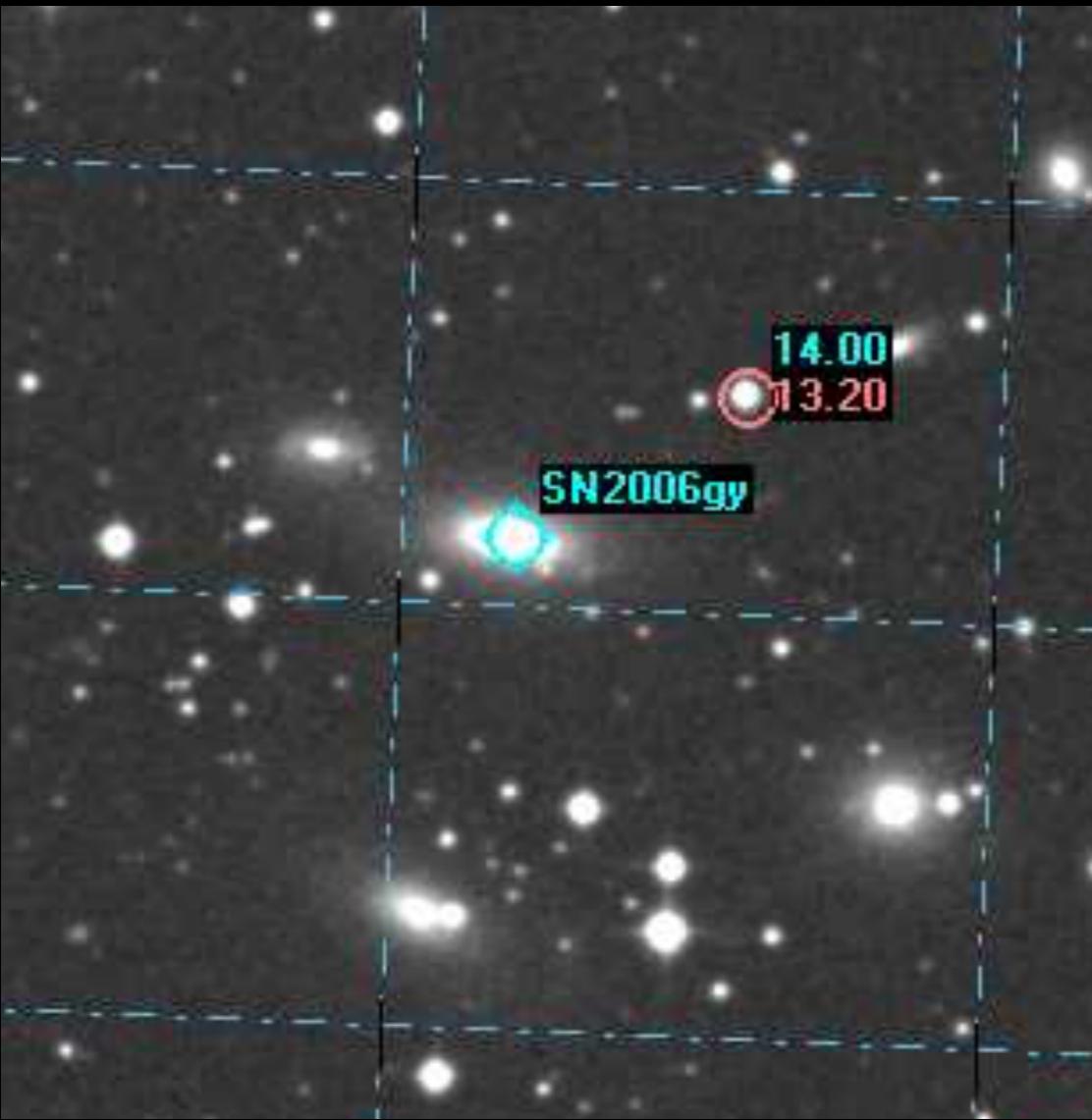


**SN**

$$m_{inst} = -2.5 \times \log_{10} I$$

**How to take into account the bad weather?**

# Typical SN image



**SN**       $m_{inst} = -2.5 \times \log_{10} I$

**Reference**       $m_{inst} = -2.5 \times \log_{10} I$

**How to take into account the bad weather?**

**measure the instrumental magnitude for a second object close to the SN for which you know the apparent magnitude and compute the zero point of each image**

$$ZP = m_{app} - m_{inst}$$

**from the reference star**

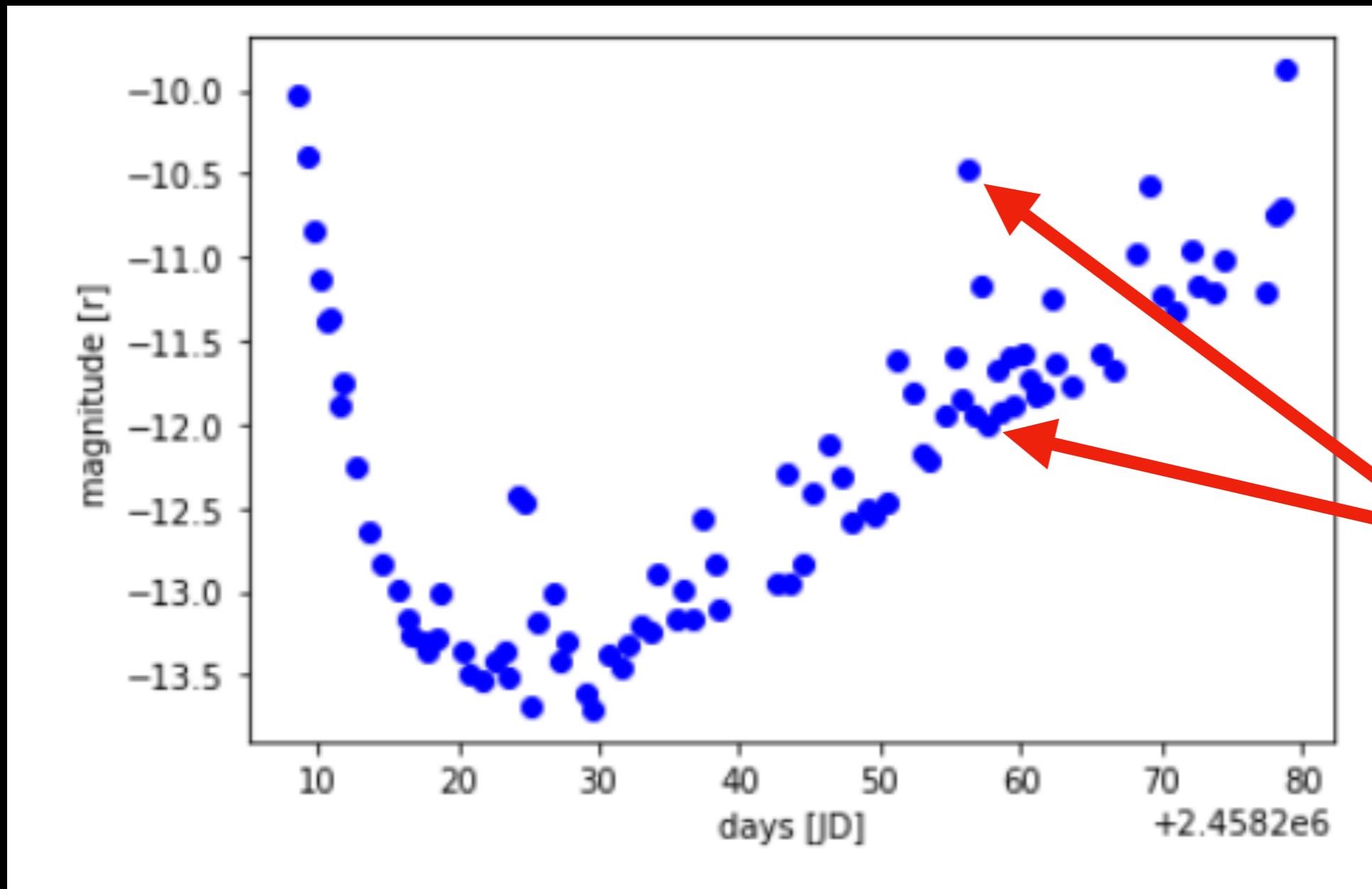
$$m_{app} = ZP + m_{inst}$$

**for your Supernova**

# instrumental magnitude

Bad weather!!!!

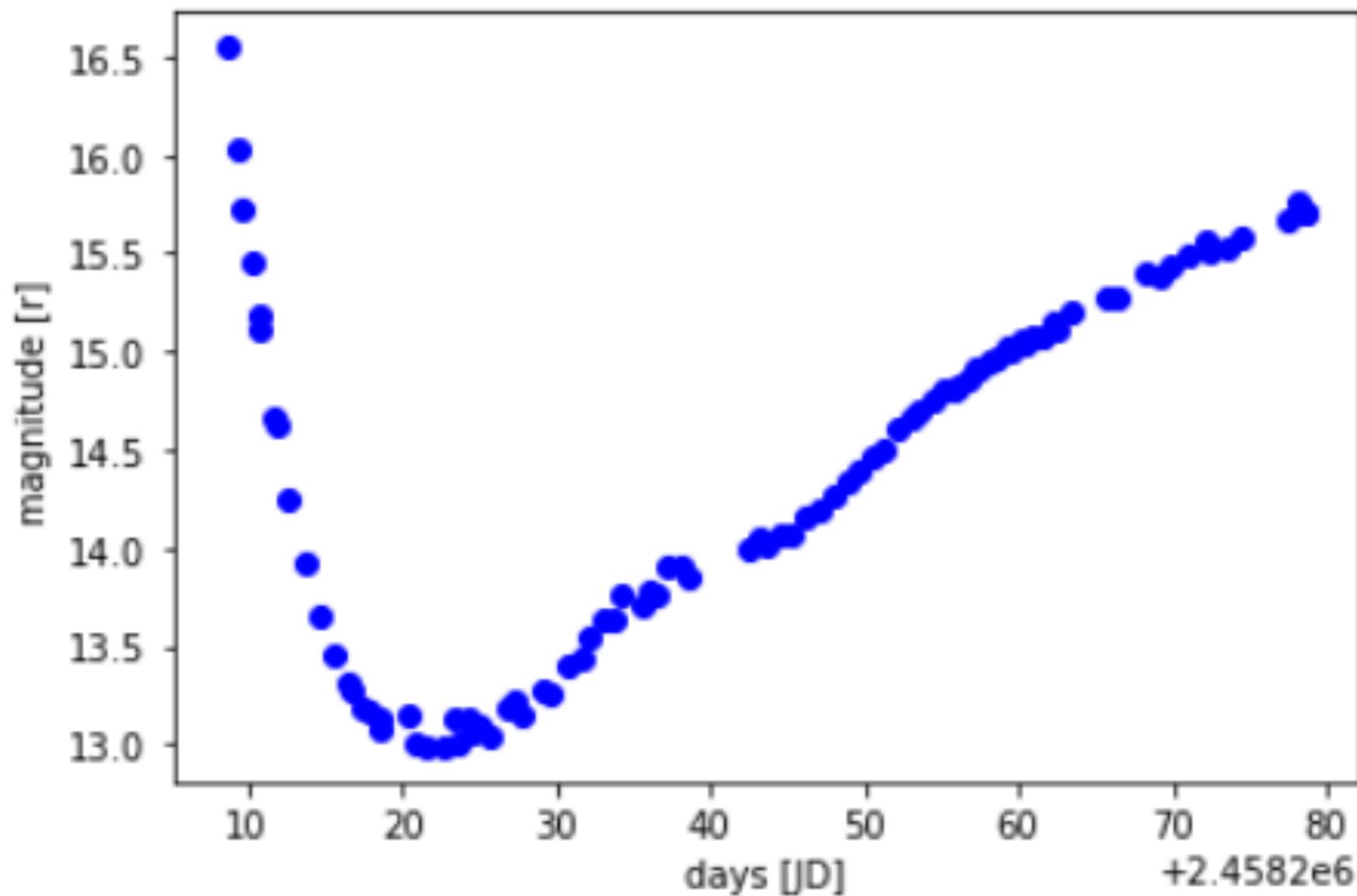
$$m_{inst} = -2.5 \times \log_{10} I$$



why?

# apparent magnitude

$$m_{app} = ZP + m_{inst}$$



# Recap

**apparent magnitude**

**absolute magnitude**

**instrumental magnitude**

**Zero Point**

$$(m_1 - m_2) = -2.5 * \log_{10} \frac{F_1}{F_2}$$

**distance modulus**

$$m - M = 5 \log_{10} \left( \frac{d}{10} \right)$$

**apparent magnitude**

**absolute magnitude**

$$m_{inst} = -2.5 \times \log_{10} I$$

$$ZP = m_{app} - m_{inst}$$

# Tough Question

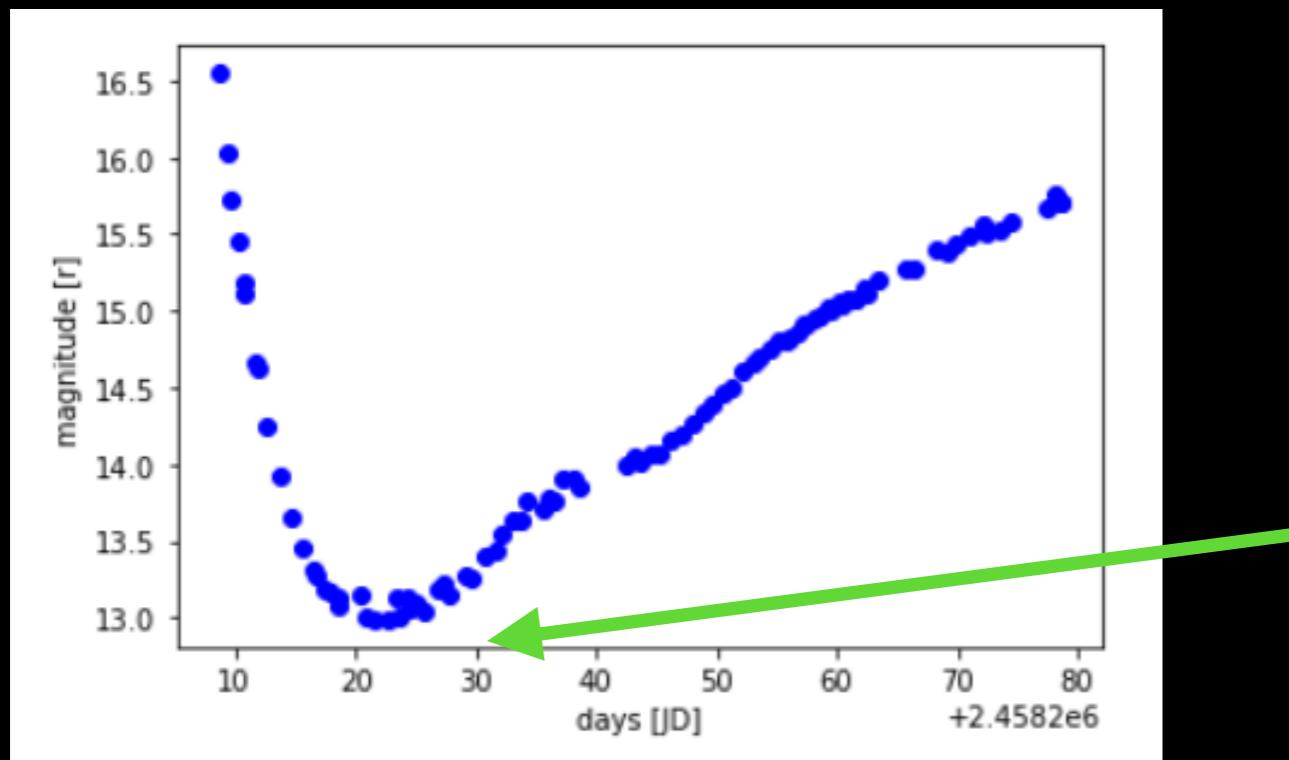
Suppose that you know the absolute magnitude of an object in the sky, for example you know that all SNe Ia have an absolute magnitude of -19.5

$$m - M = 5 \log_{10} \left( \frac{d}{10} \right)$$

# Tough Question

Suppose that you know the absolute magnitude of an object in the sky, for example you know that all SNe Ia have an absolute magnitude of -19.5

$$m - M = 5 \log_{10} \left( \frac{d}{10} \right)$$



you measure the apparent magnitude of the SN

what you can say about the distance of the SN?

