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

Daryl Janzen
University of Saskatchewan

Emily Hoang
UC Davis

Yize Dong
UC Davis

Nicolas Retamal
UC Davis

Kuntal Misra
Aries Institute
WISTEMM fellow

David Sand
Univ. of Arizona

Griffin Hosseinzadeh
Univ. of Arizona

Jennifer Andrews
Gemini

Michael Lundquist
Keck

Azalee Bostroem
University of Arizona

Jacob Jencson
Johns Hopkins University

Jeniveve Person
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 ?

Supernova explosion in the frame of stellar evolution

Progenitor Initial Mass	Supernova	Remnant

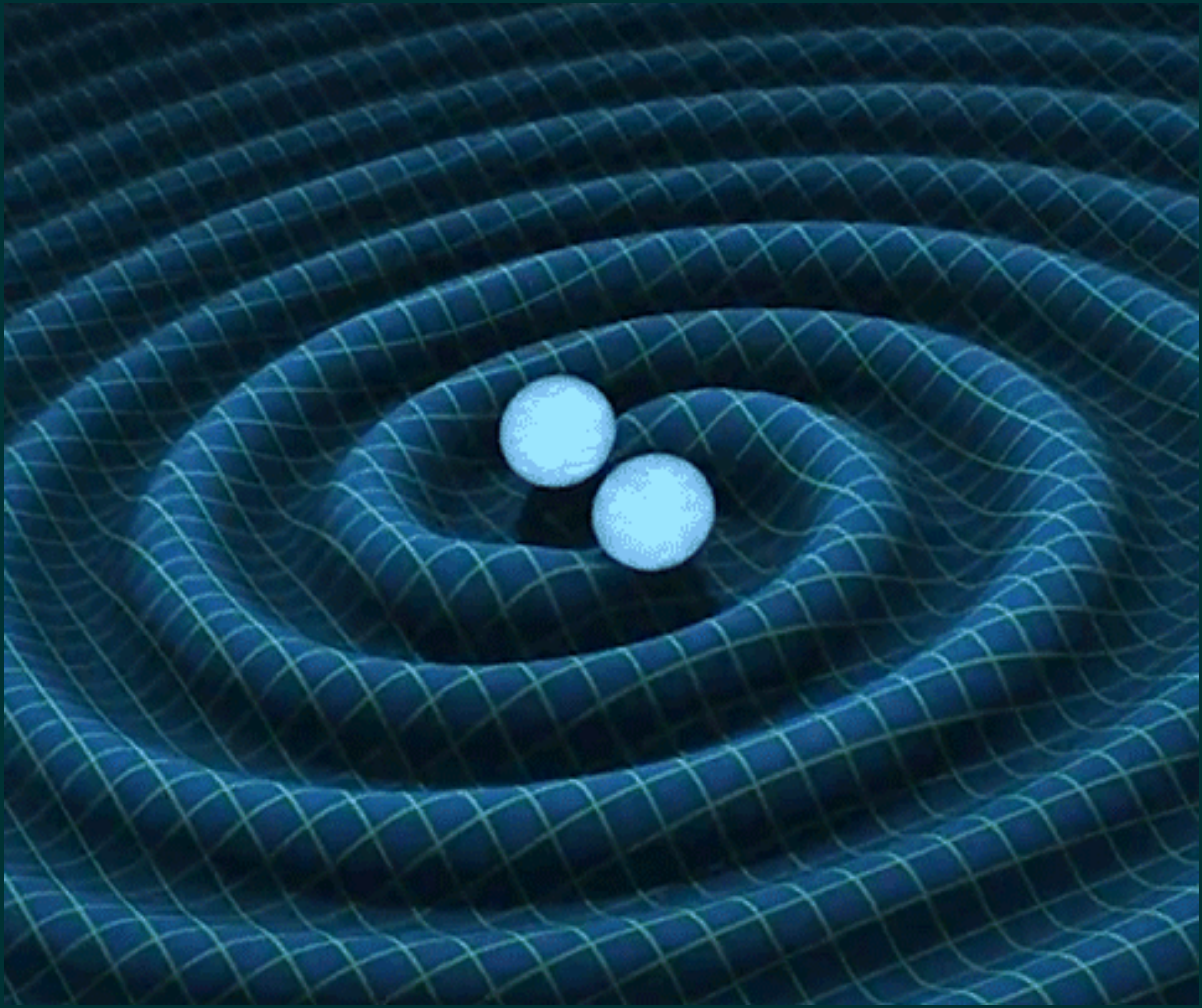
Time Domain Astronomy

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 ?

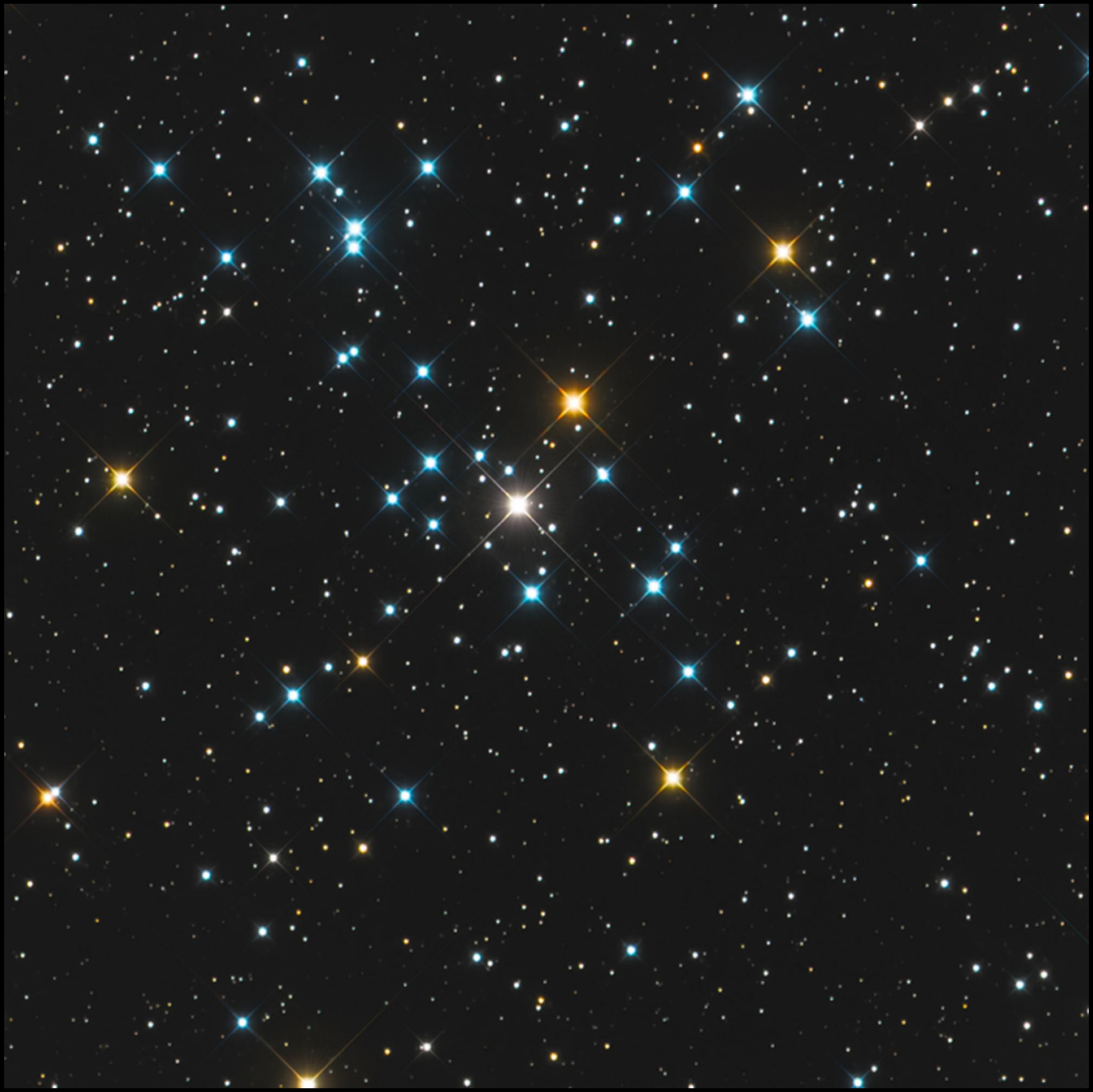
Gravitational waves



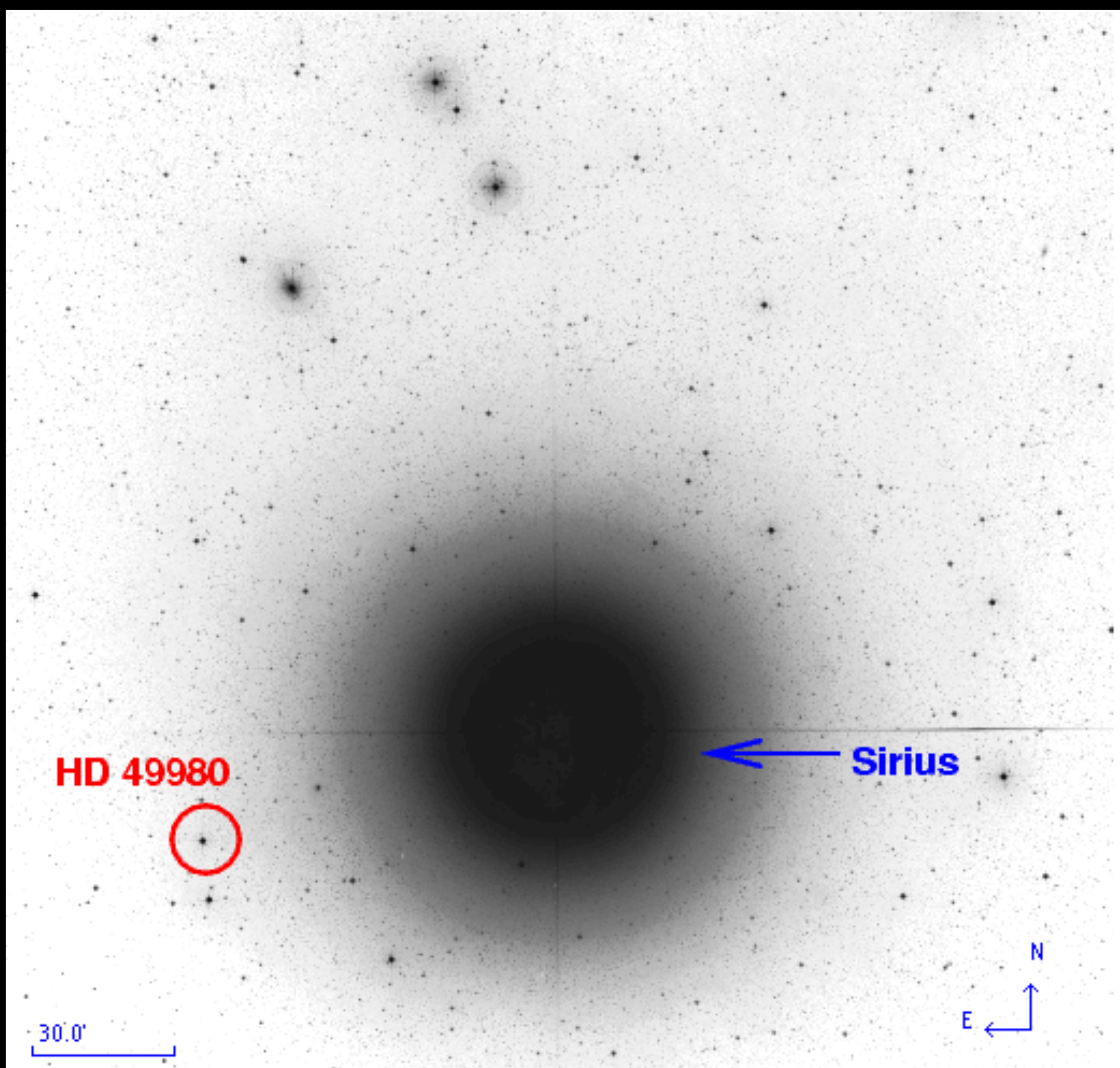
AST 296LB

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

Ok we got an image …… and now?

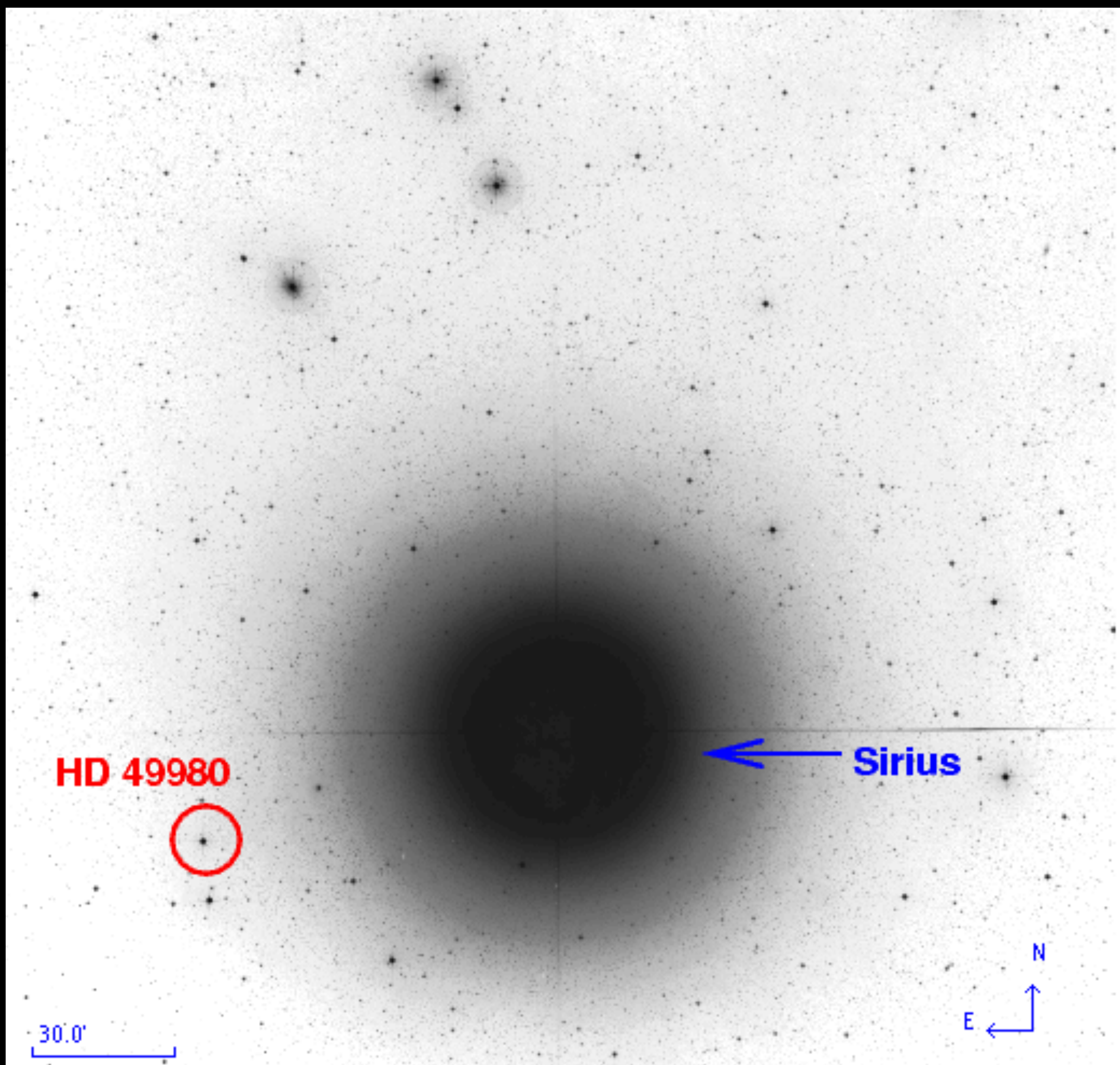


Ok we got an image …… and now?



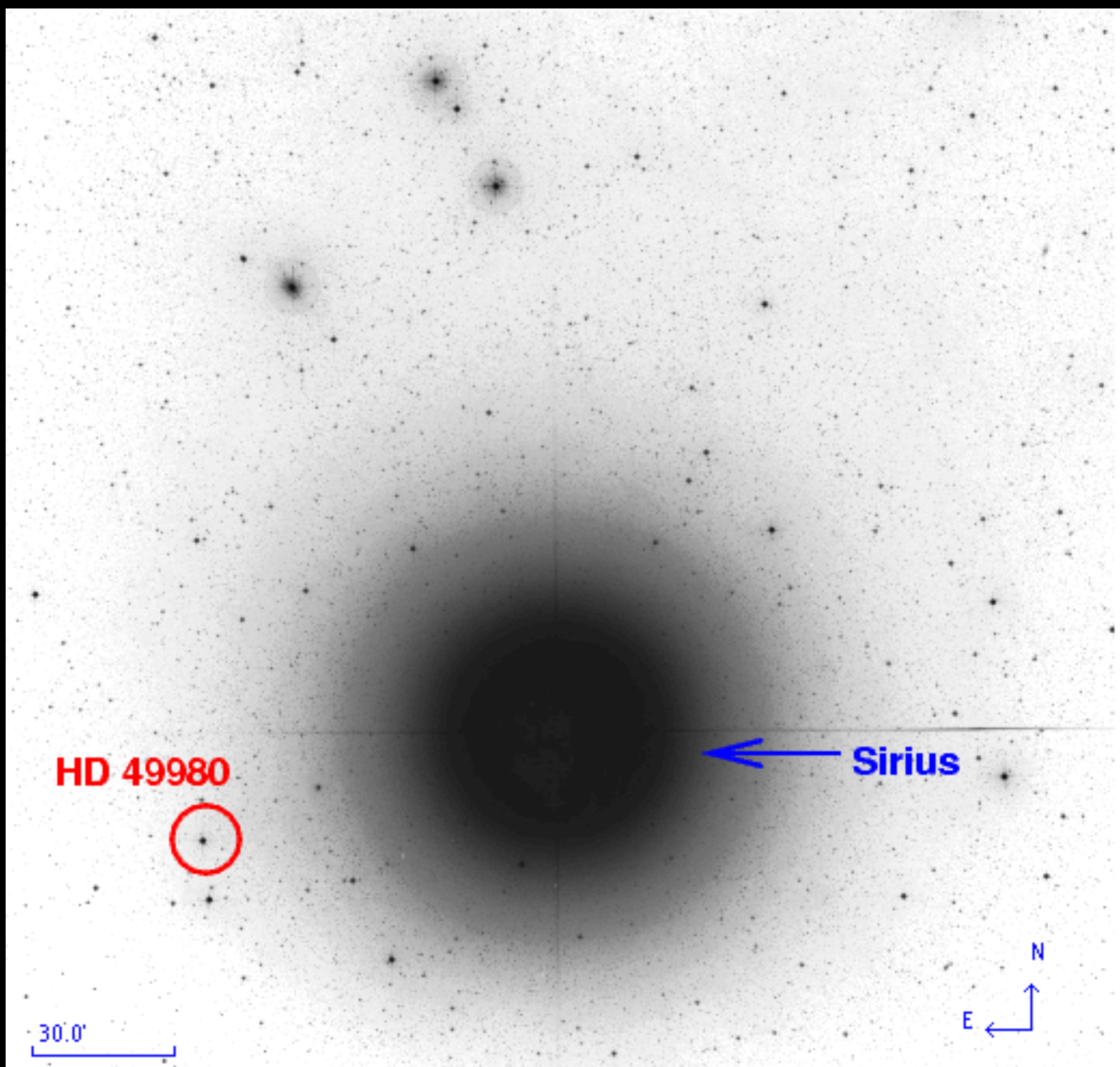
(in reality we get black and white images)

Ok we got an image …… and now?



we measure how bright an object is

Ok we got an image …… and now?

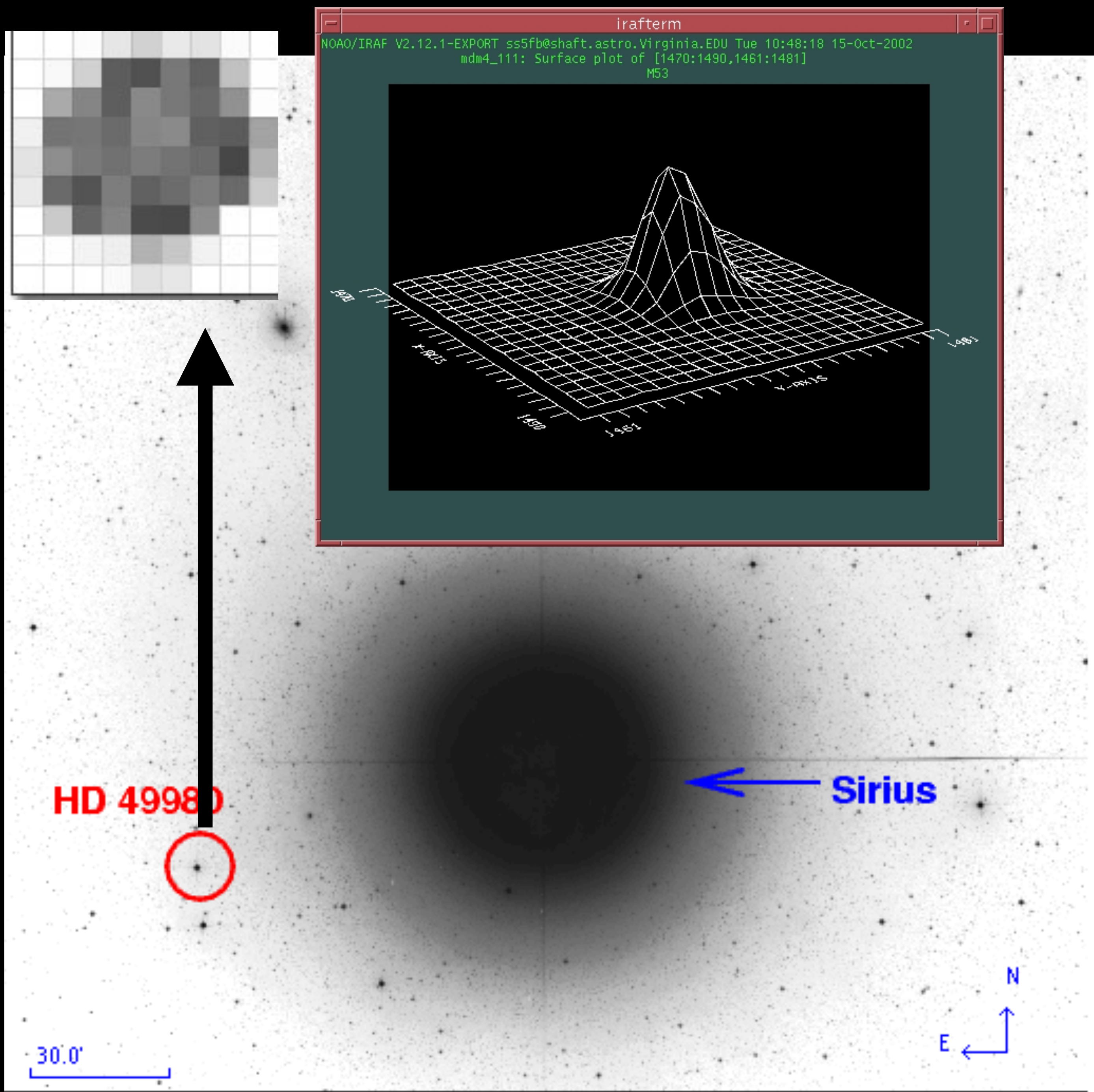


we measure how bright an object is

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

photons?
counts?
electrons?
potatoes?

Ok we got an image …… and now?



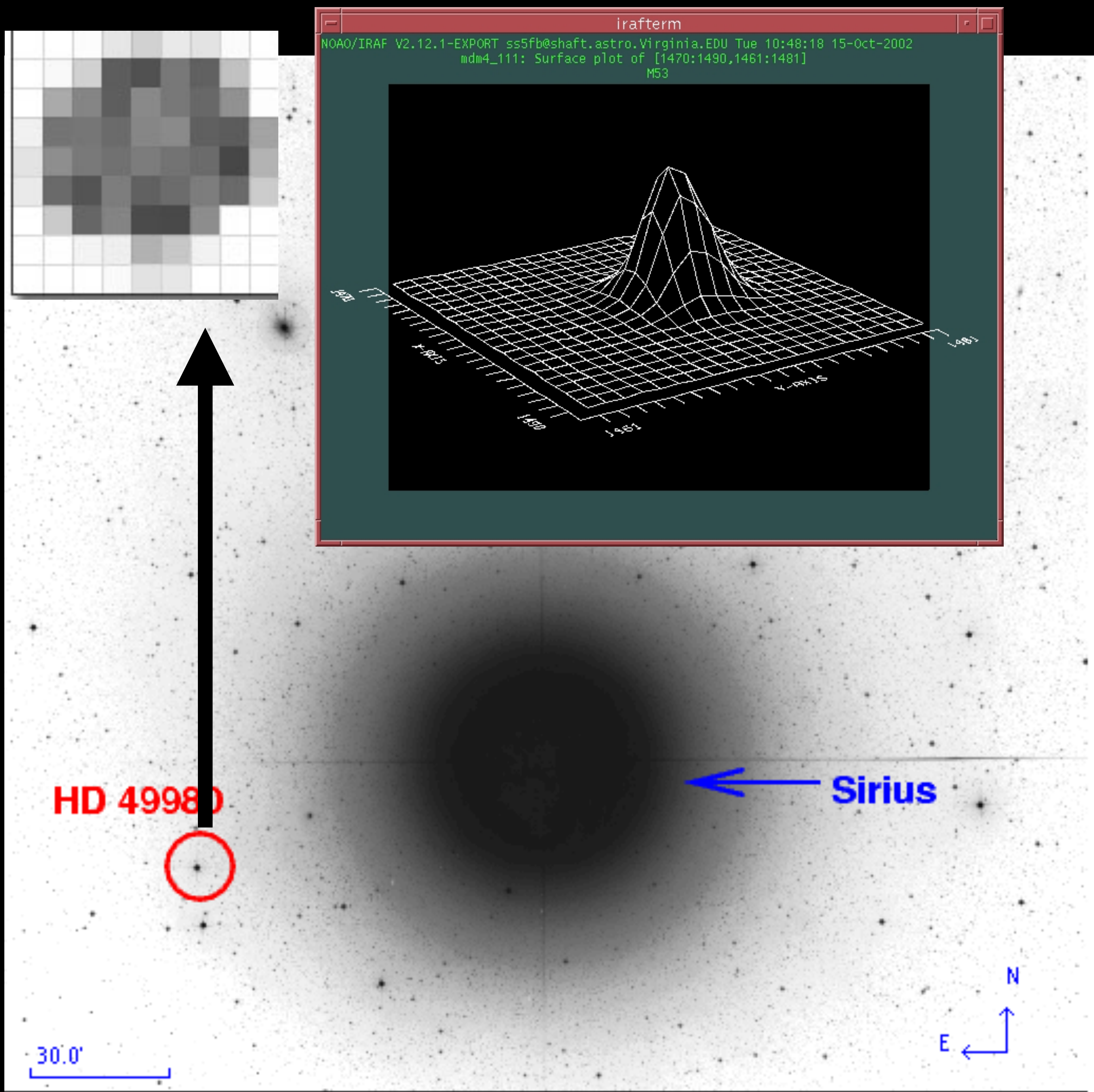
we measure how bright an object is

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

photons?
counts?
electrons?
potatoes?

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

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?

→ photons

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

How Does a CCD Work?

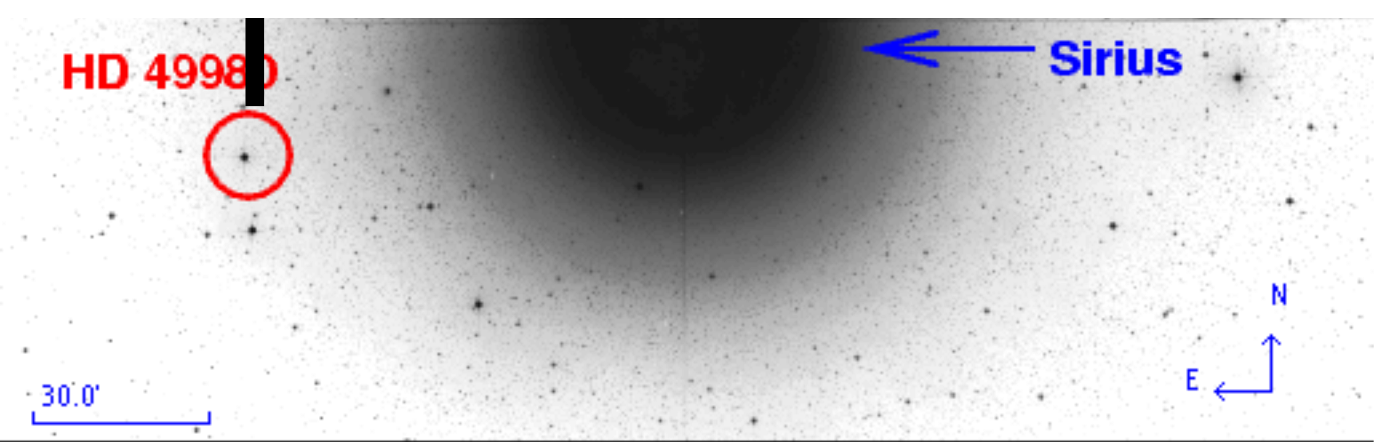
- Rain = Photons
- Water = Charge (photon strikes silicon semiconductor surface and knocks an electron loose by the photoelectric effect)
- Buckets = pixels (electrons accumulate in "potential wells;" depth represents how much charge each pixel can hold)
- The charge in each line of pixels is shifted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

www.assignmentpoint.com

nd now?

easure how bright
an object is

easure the number
? of the object we
re interested in

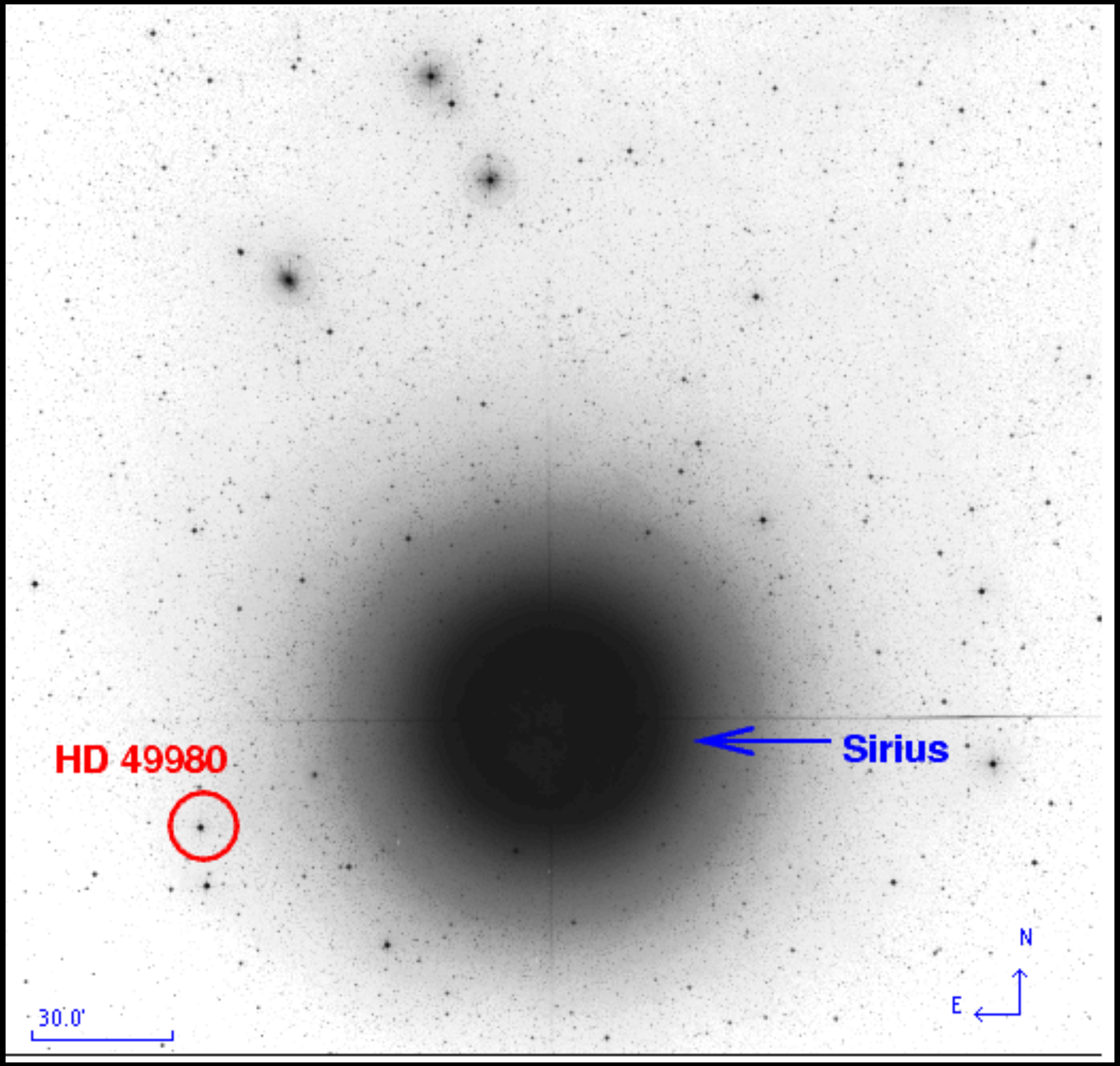


photons?
counts?
electrons?
potatoes?

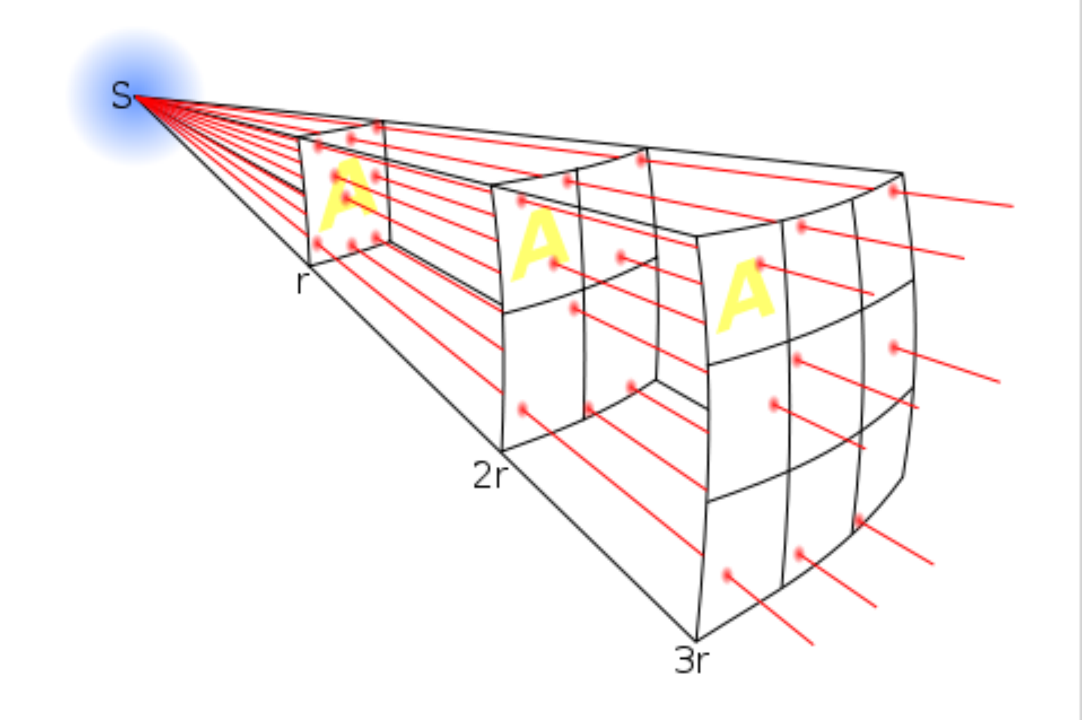
→ photons

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.

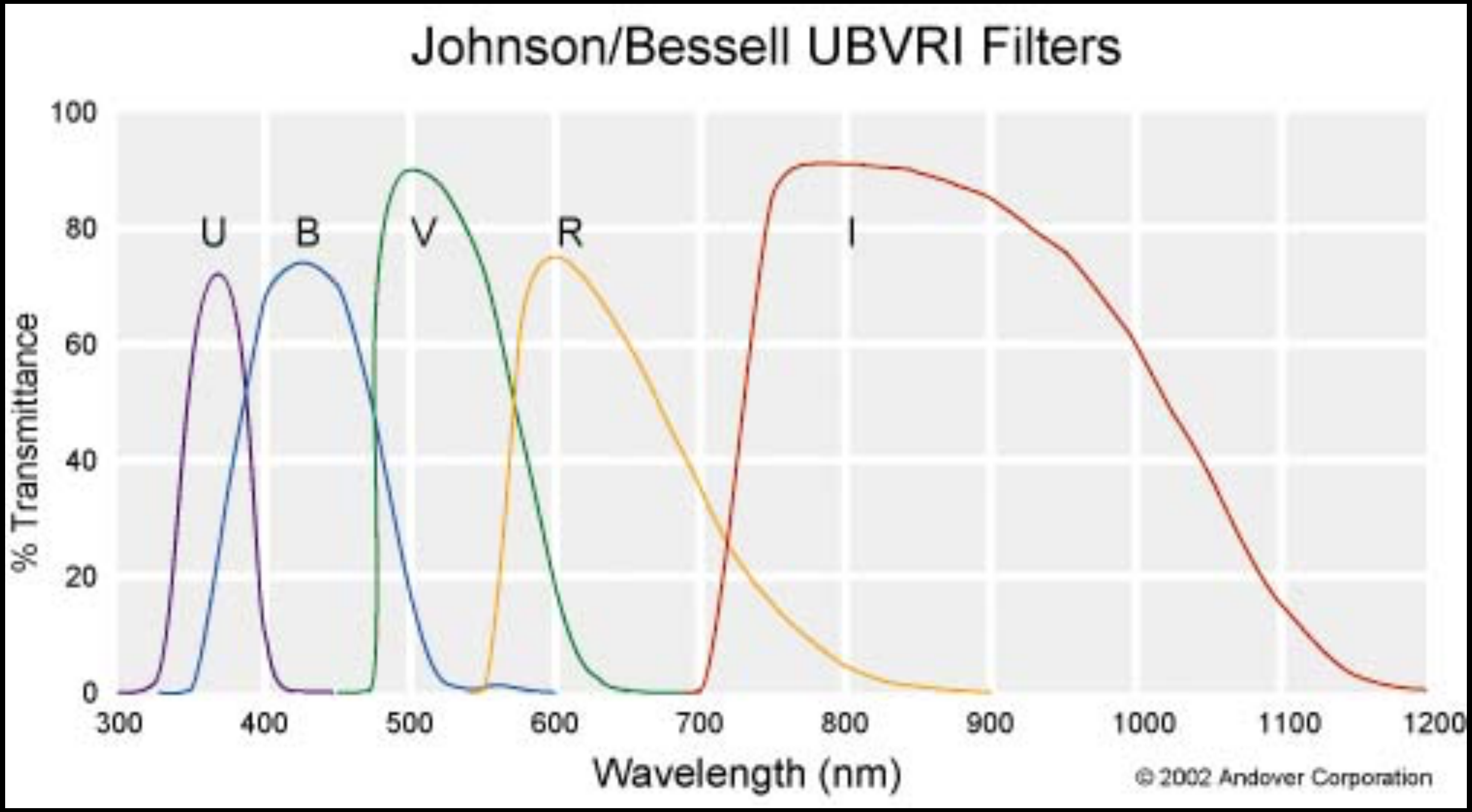
$$(m_1 - m_2) = -2.5 * log_{10}\frac{F_1}{F_2}$$

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

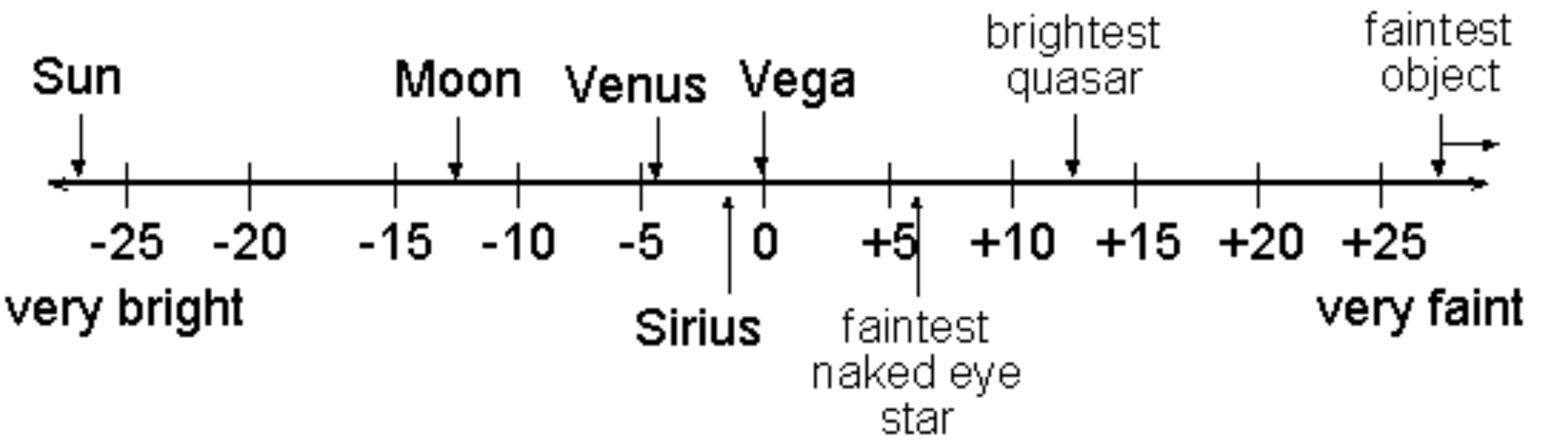
$$\frac{F_1}{F_2} = 10^{-0.4(m_1 - m_2)}$$

Magnitude in different filters

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

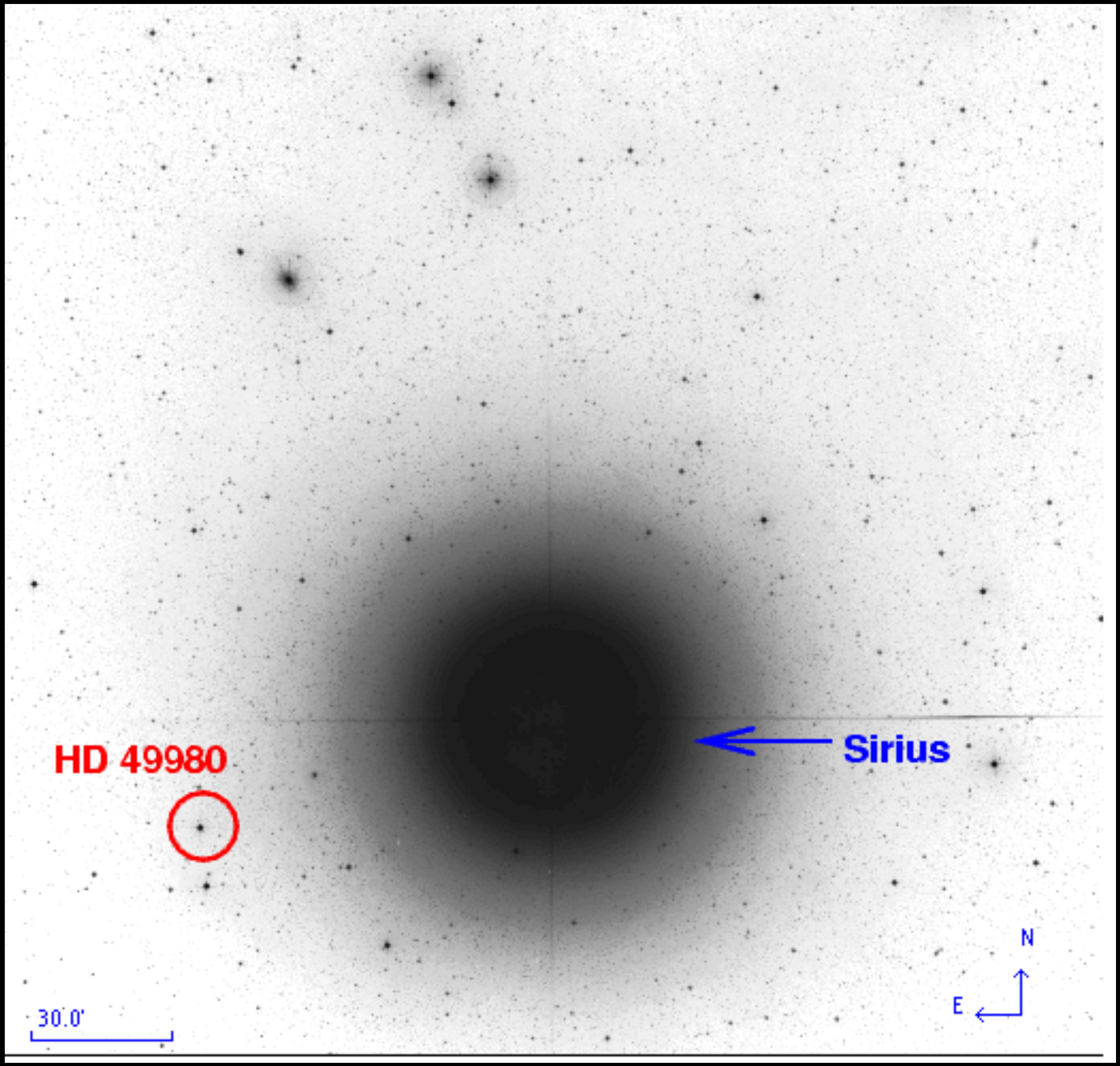


Magnitude in different filters



Apparent brightnesses of some objects in the magnitude system.

How many times brighter does Sirius appear?



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

m(Sirius) = -1.5

m(HD 49980) = 5.8

How many times brighter does Sirius appear?

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

```
 m(Sirius)    =  -1.5

 m(HD 49980) =   5.8


 I(Sirius)         -0.4*[ (-1.5) - 5.8 ]
------------   =  10
 I(HD 49980)
```

How many times brighter does Sirius appear?

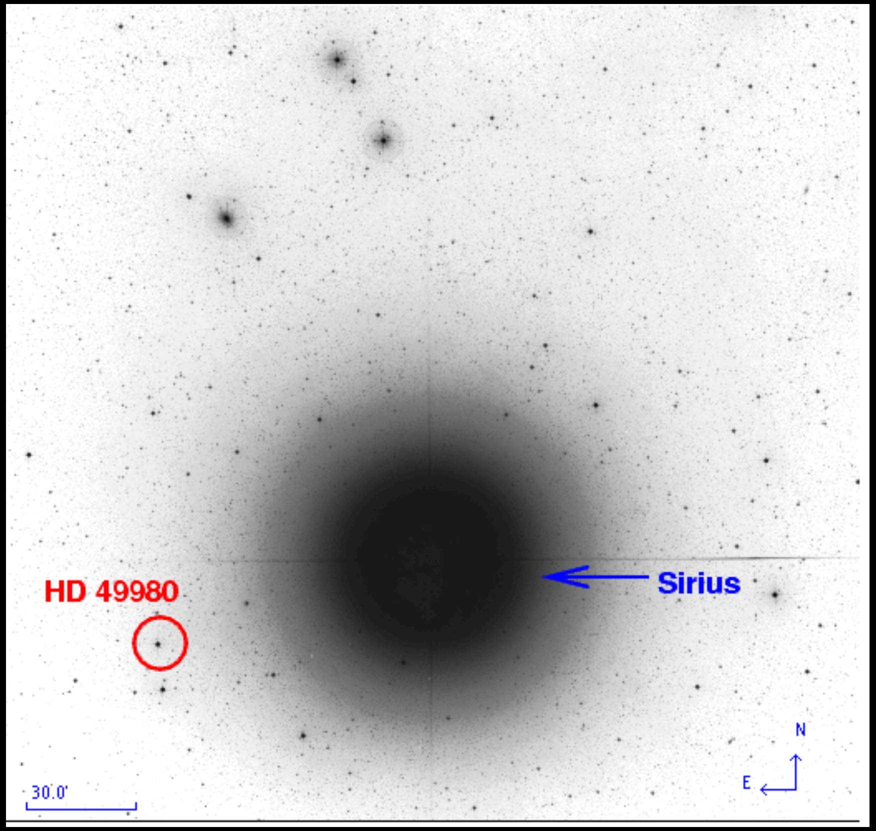
m(Sirius) = -1.5

m(HD 49980) = 5.8

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

$$= 10^{2.92}$$

$$= \mathbf{832}$$



How many times brighter does Sirius appear?

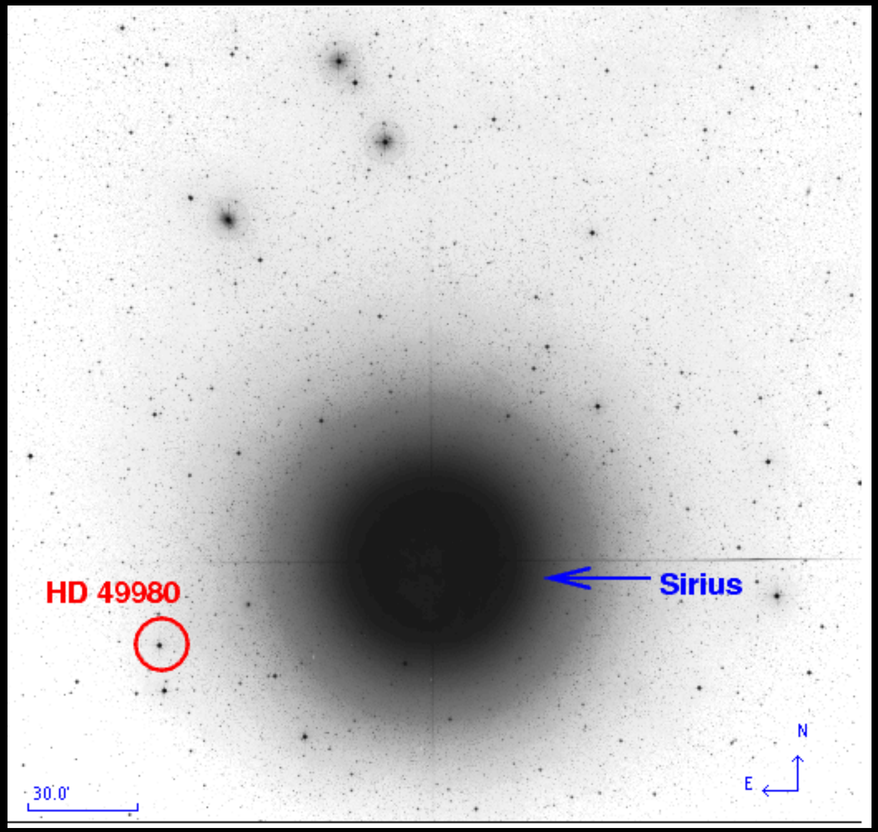
m(Sirius) = -1.5

m(HD 49980) = 5.8

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

$$= 10^{2.92}$$

$$= \mathbf{832}$$



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?

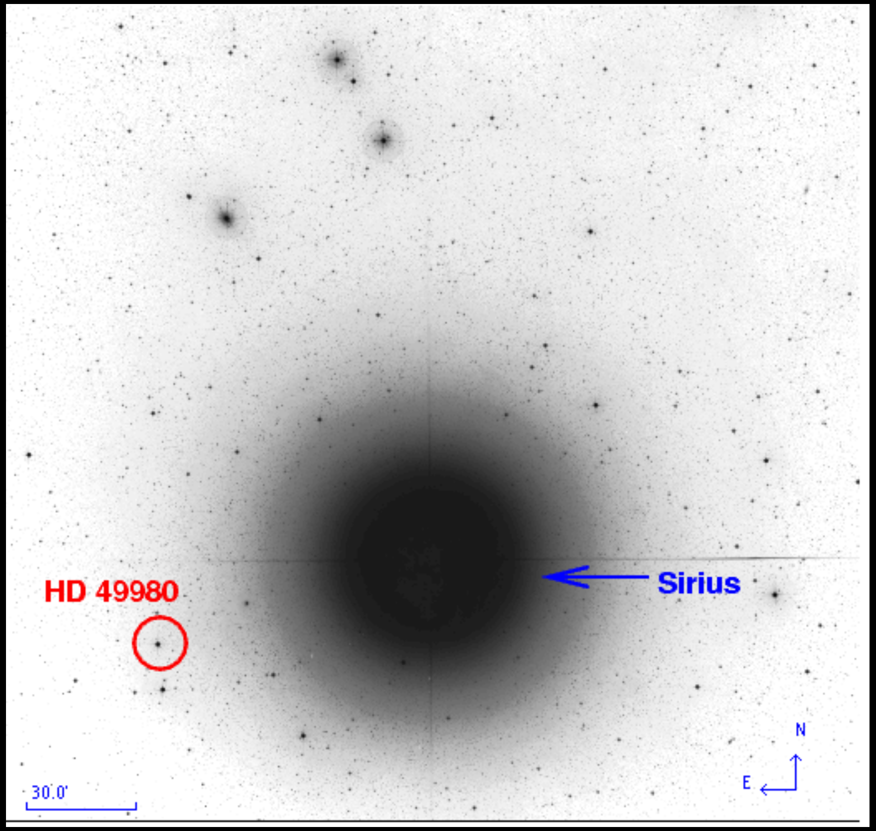
m(Sirius) = -1.5

m(HD 49980) = 5.8

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

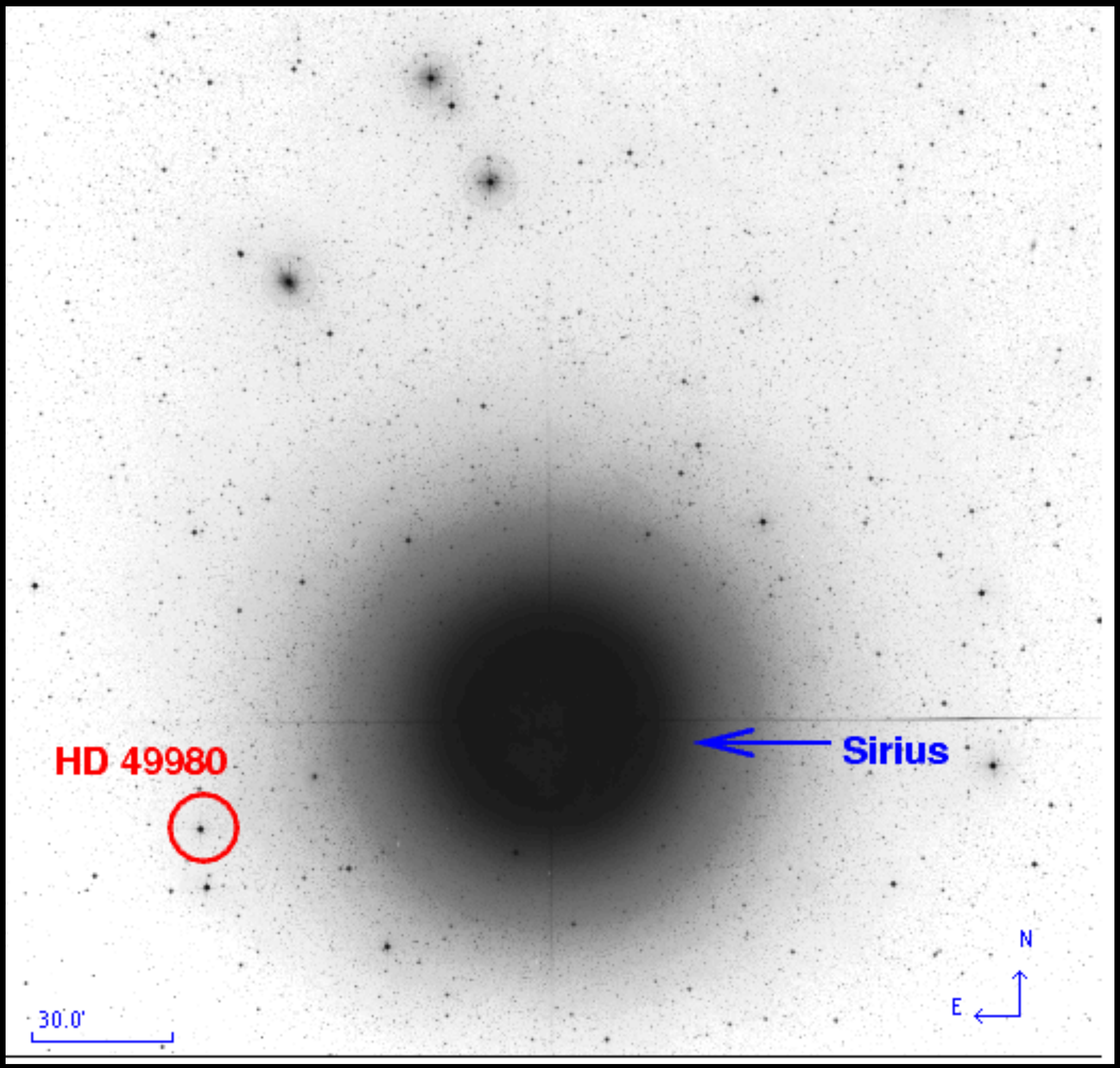
$$= 10^{2.92}$$

$$= \mathbf{832}$$



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



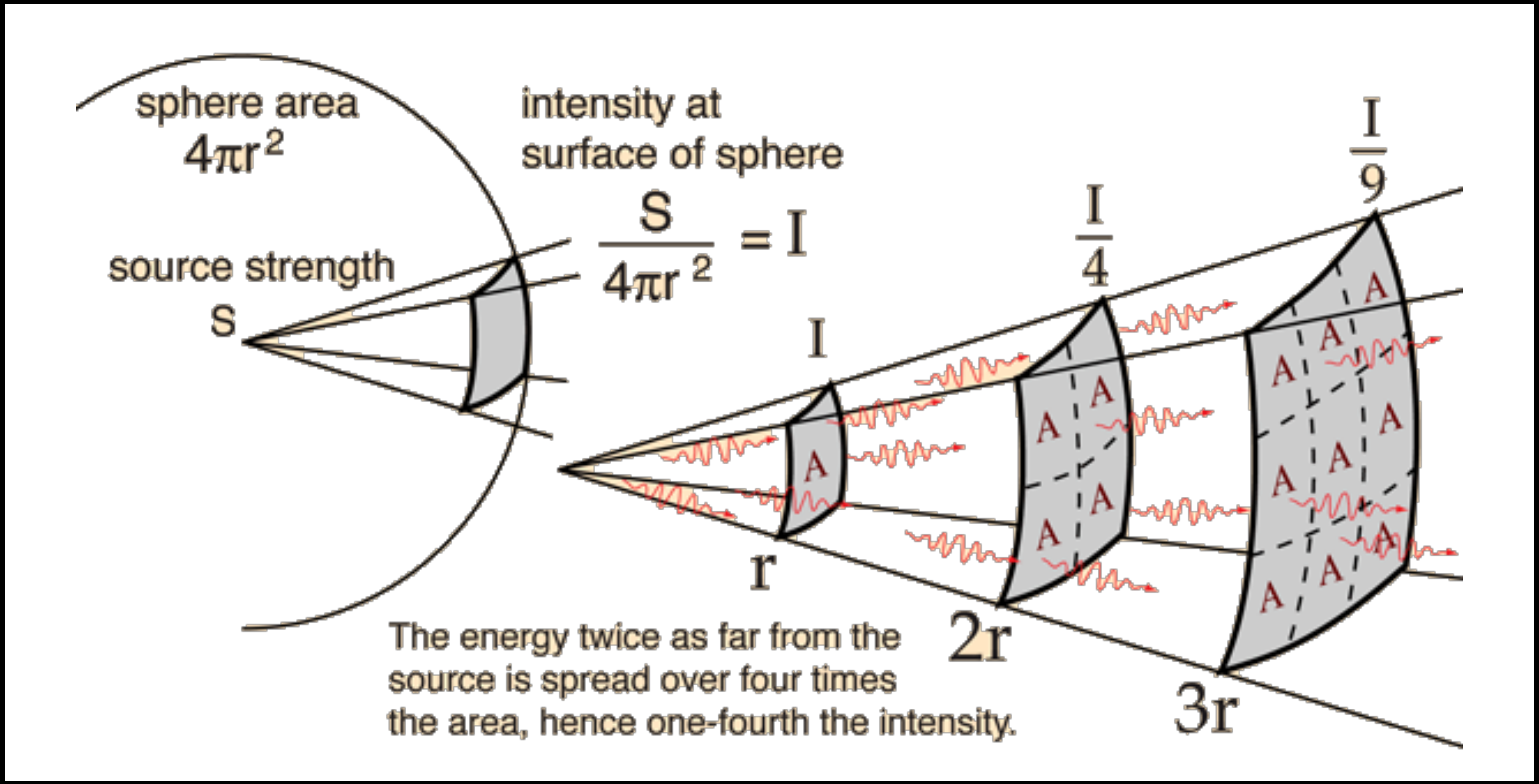
m(Sirius) = -1.5

m(HD 49980) = 5.8

d(Sirius) = 2.64 parsec

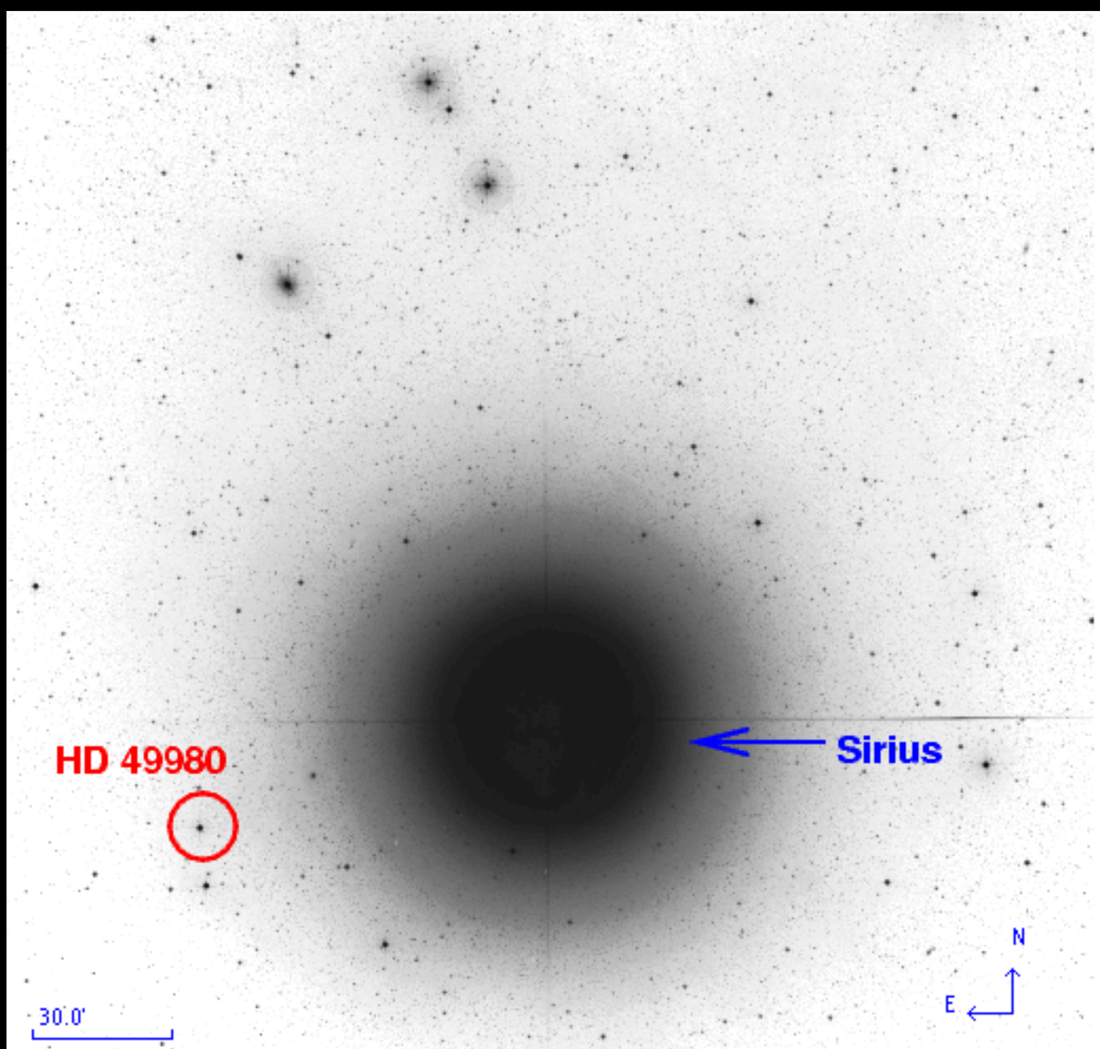
d(HD 49980) = ~500 parsec

Intensity (distance)



(apparent) magnitude

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



m(Sirius) = -1.5

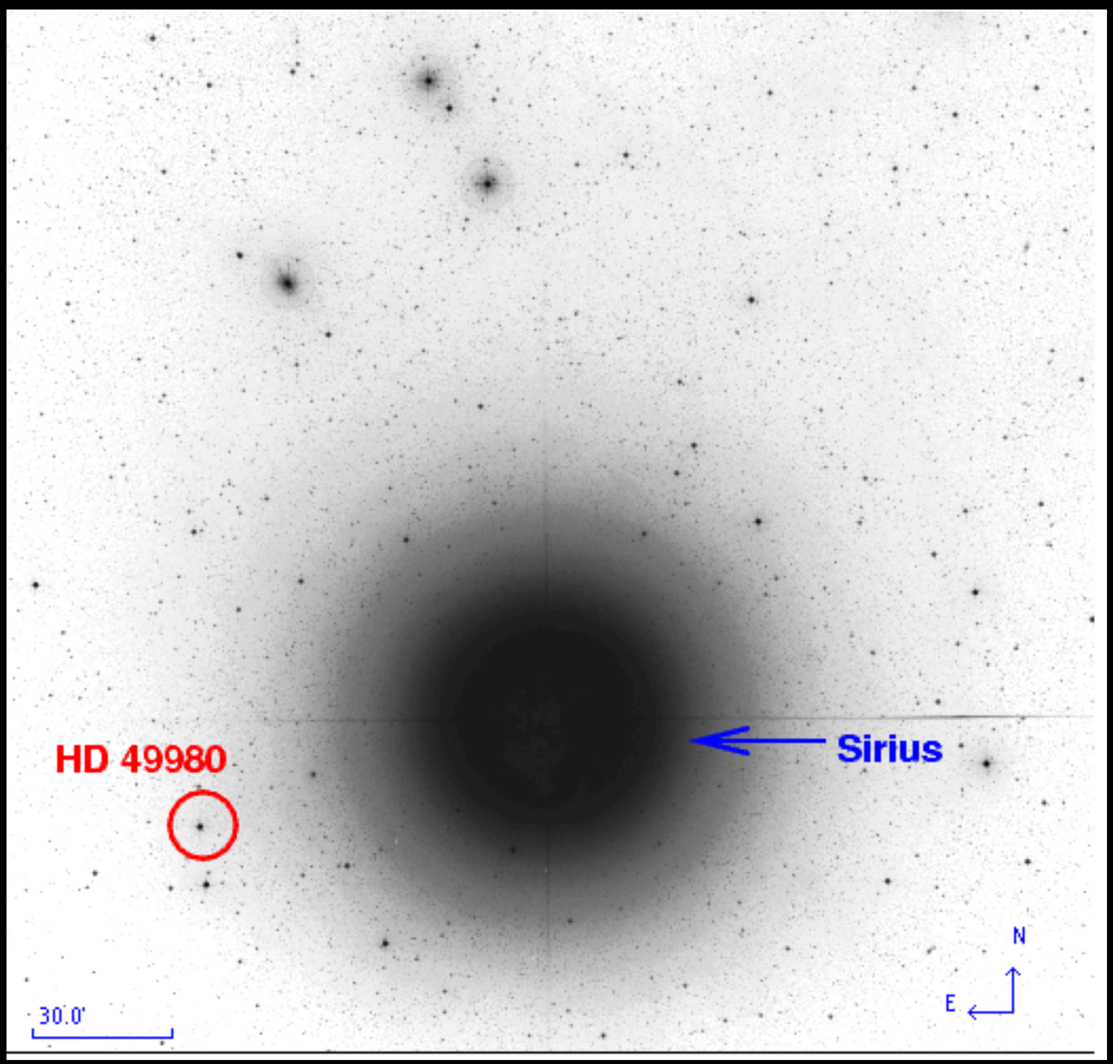
m(HD 49980) = 5.8

d(Sirius) = 2.64 parsec

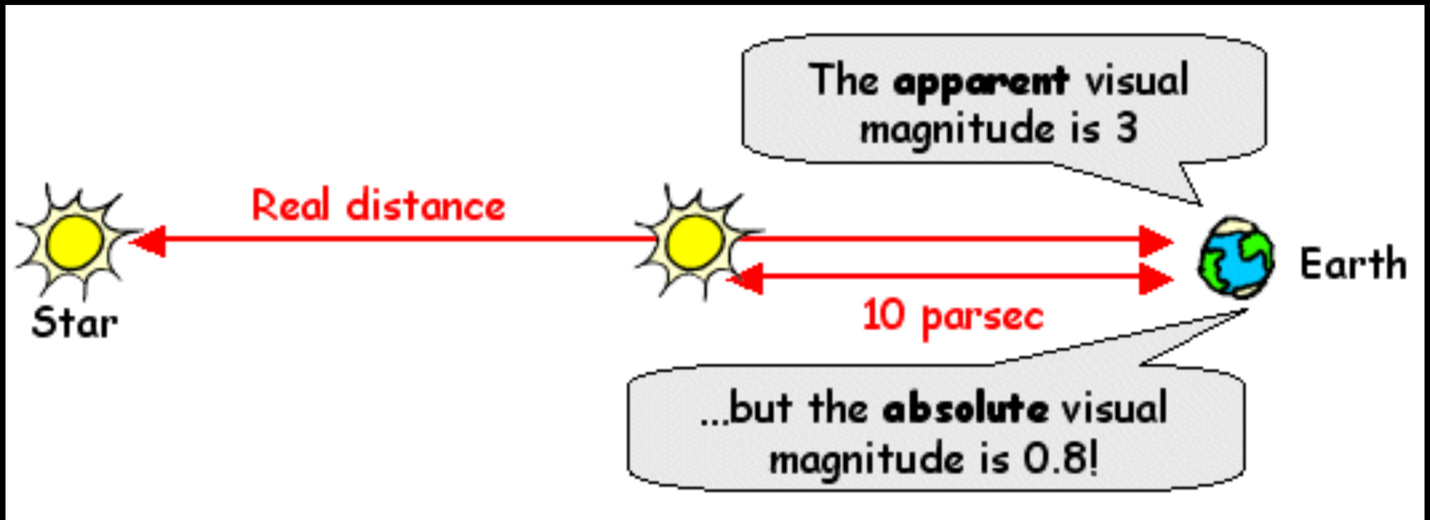
d(HD 49980) = ~500 parsec

(apparent) magnitude

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



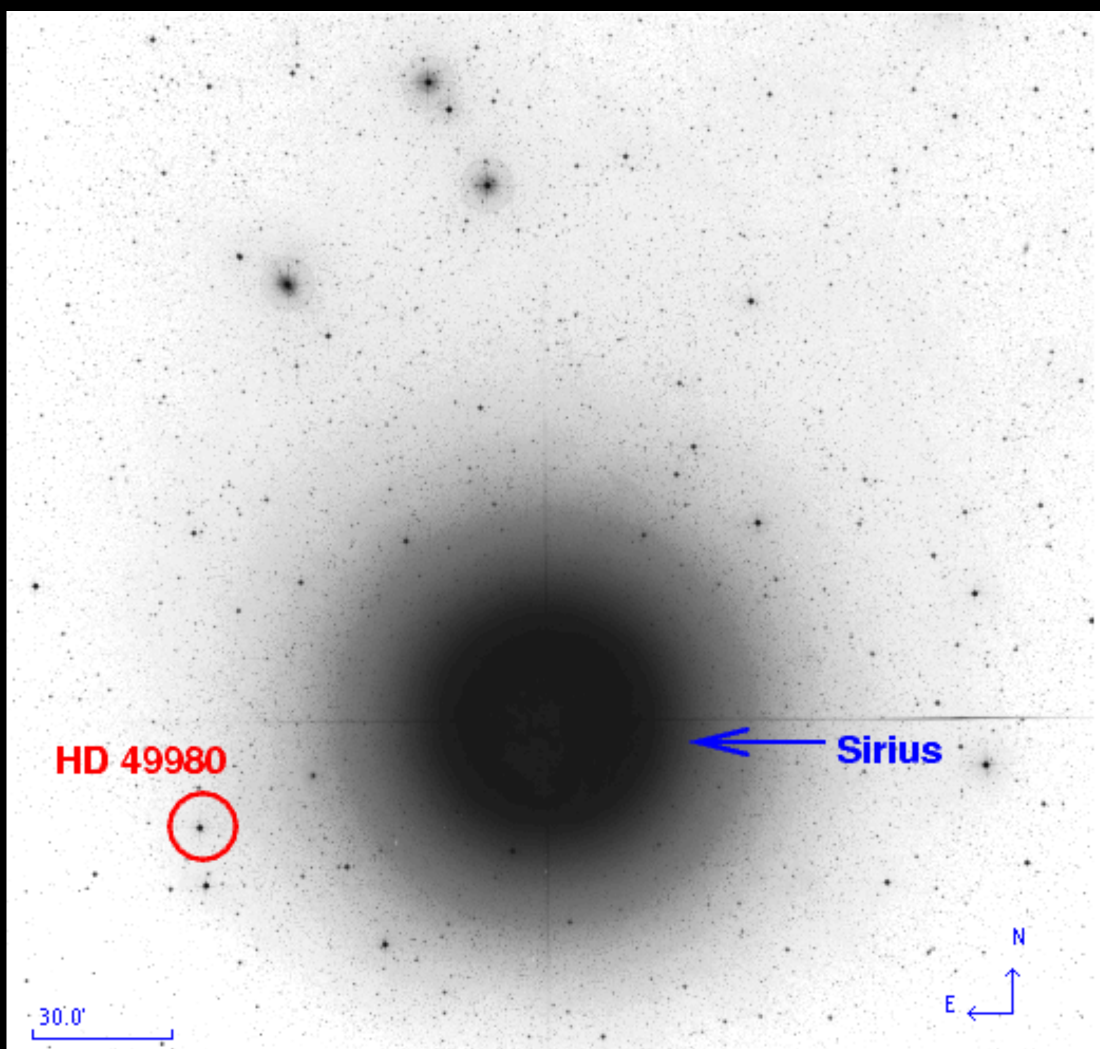
compare Sirius and HD49980
at the same distance




```
m(Sirius)    =  -1.5          d(Sirius)    =  2.64 parsec
m(HD 49980) =   5.8          d(HD 49980) =  ~500 parsec
```

Absolute magnitude

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



distance of the star (pc)

$$\overbrace{m - M}^{\text{distance modulus}} = 5log_{10}(\frac{d}{10})$$

apparent magnitude

absolute magnitude

m(Sirius) = -1.5

d(Sirius) = 2.64 parsec

m(HD 49980) = 5.8

d(HD 49980) = ~500 parsec

What is the absolute magnitude of Sirius and HD49980?

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

```
m(Sirius)   =  -1.5          d(Sirius)   =  2.64 parsec

m(HD 49980) =   5.8          d(HD 49980) =  ~500 parsec
```

What is the absolute magnitude of Sirius and HD49980?

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

M(Sirius) = m(Sirius) - (5log10 d(S) - 5) =

-1.5 - (5 * log10(2.64) - 5) = **1.39**

M(HD 49980) = m(HD49980) - (5log10 d(HD) - 5) =

5.8 - (5 * log10(500) - 5) = **-2.69**

m(Sirius)	=	-1.5	d(Sirius)	=	2.64 parsec
m(HD 49980)	=	5.8	d(HD 49980)	=	~500 parsec

Recap

apparent magnitude

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

Recap

apparent magnitude

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

absolute magnitude

$$\underbrace{m - M}_{\text{distance modulus}} = 5log_{10}(\frac{d}{10})$$

distance modulus

distance of the star (pc): d

m: **apparent magnitude**

M: **absolute magnitude**

Recap

apparent magnitude

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

absolute magnitude

distance of the star (pc)

$$\overbrace{m - M}^{\text{distance modulus}} = 5log_{10}(\frac{d}{10})$$

apparent magnitude

absolute magnitude

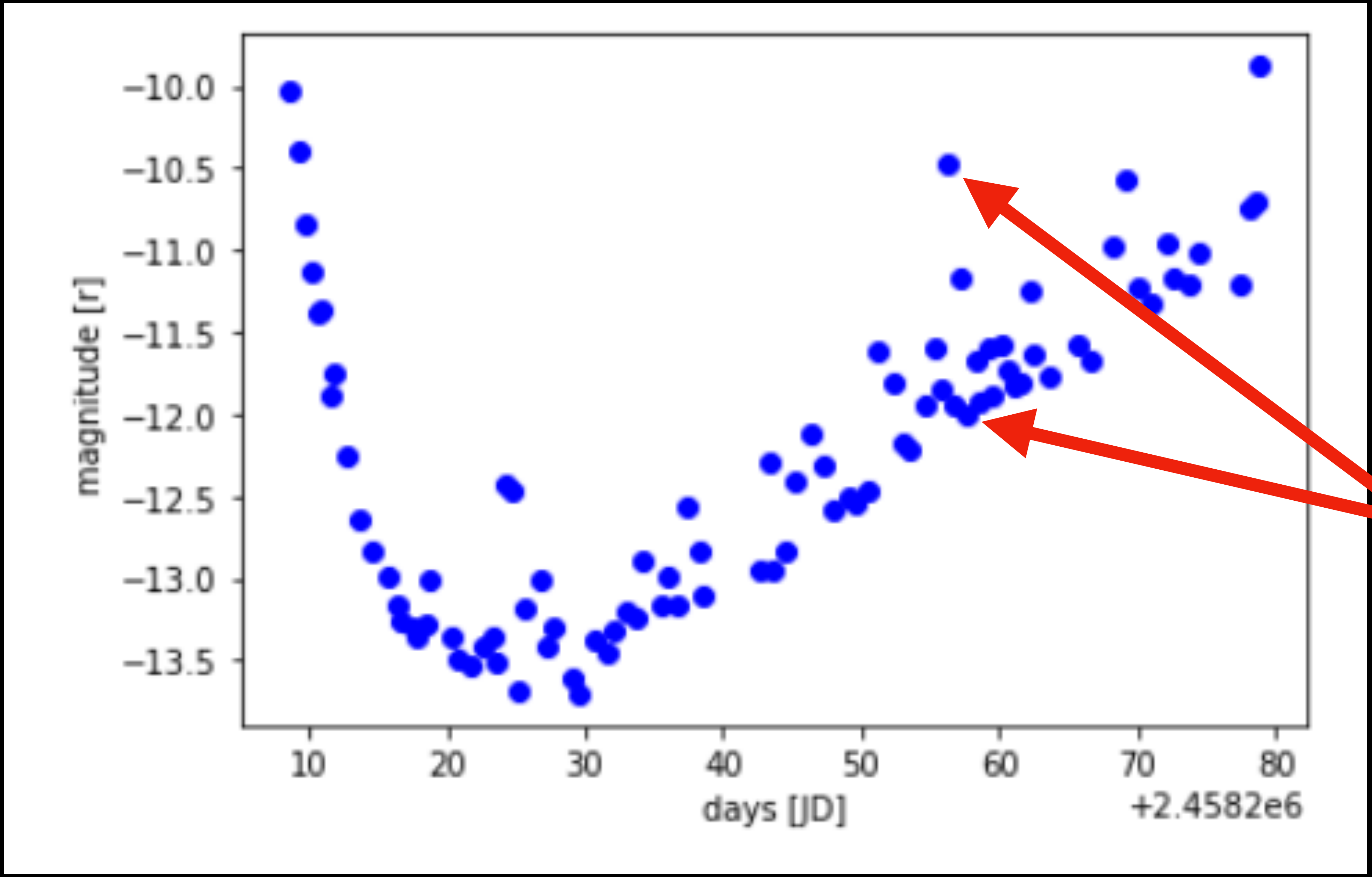
instrumental magnitude

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

what you actually measure on your image: I = counts

instrumental magnitude

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



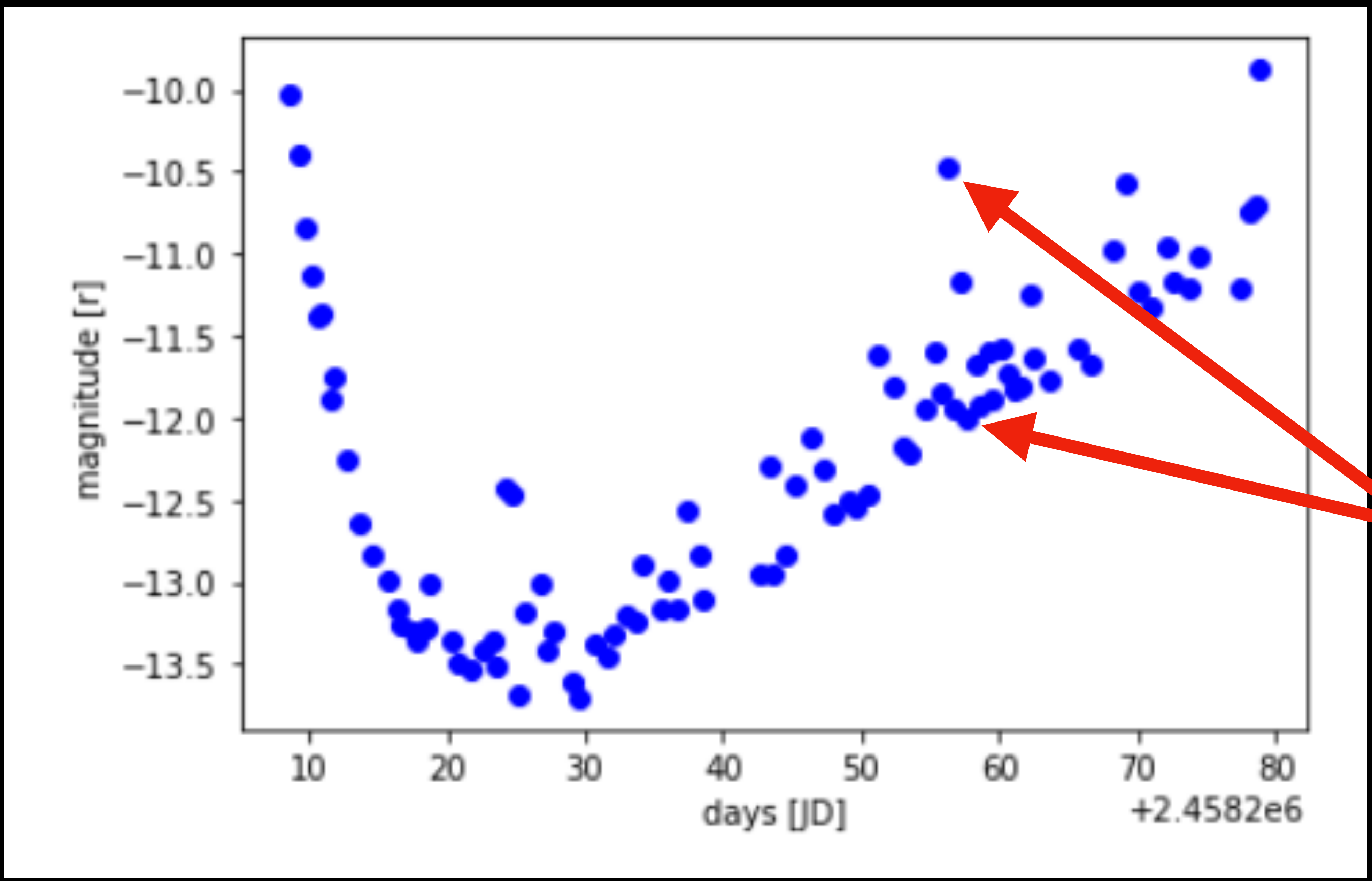
a lot of scatter from night to night

why?

instrumental magnitude

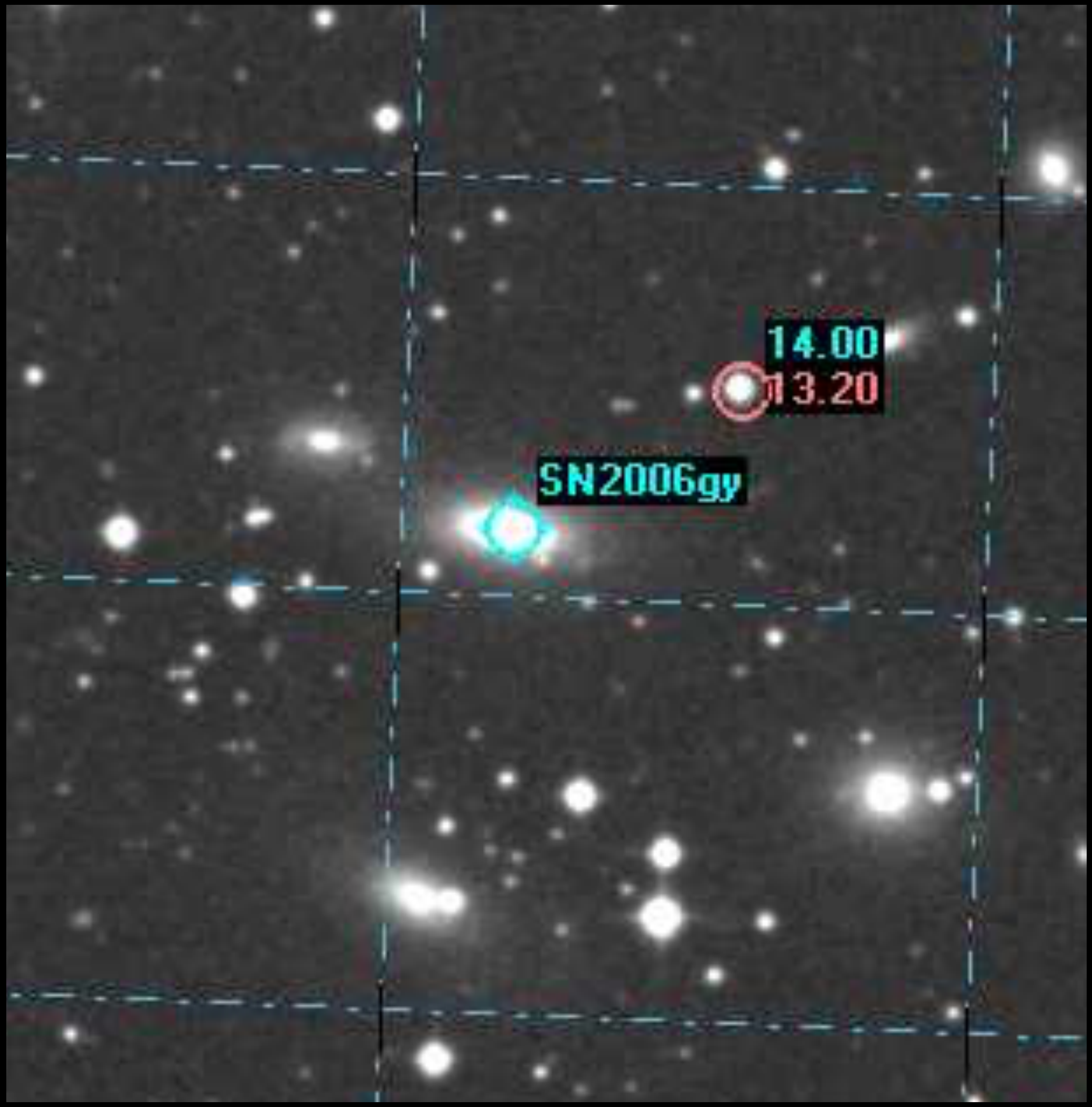
Bad weather!!!!!

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



a lot of scatter from night to night

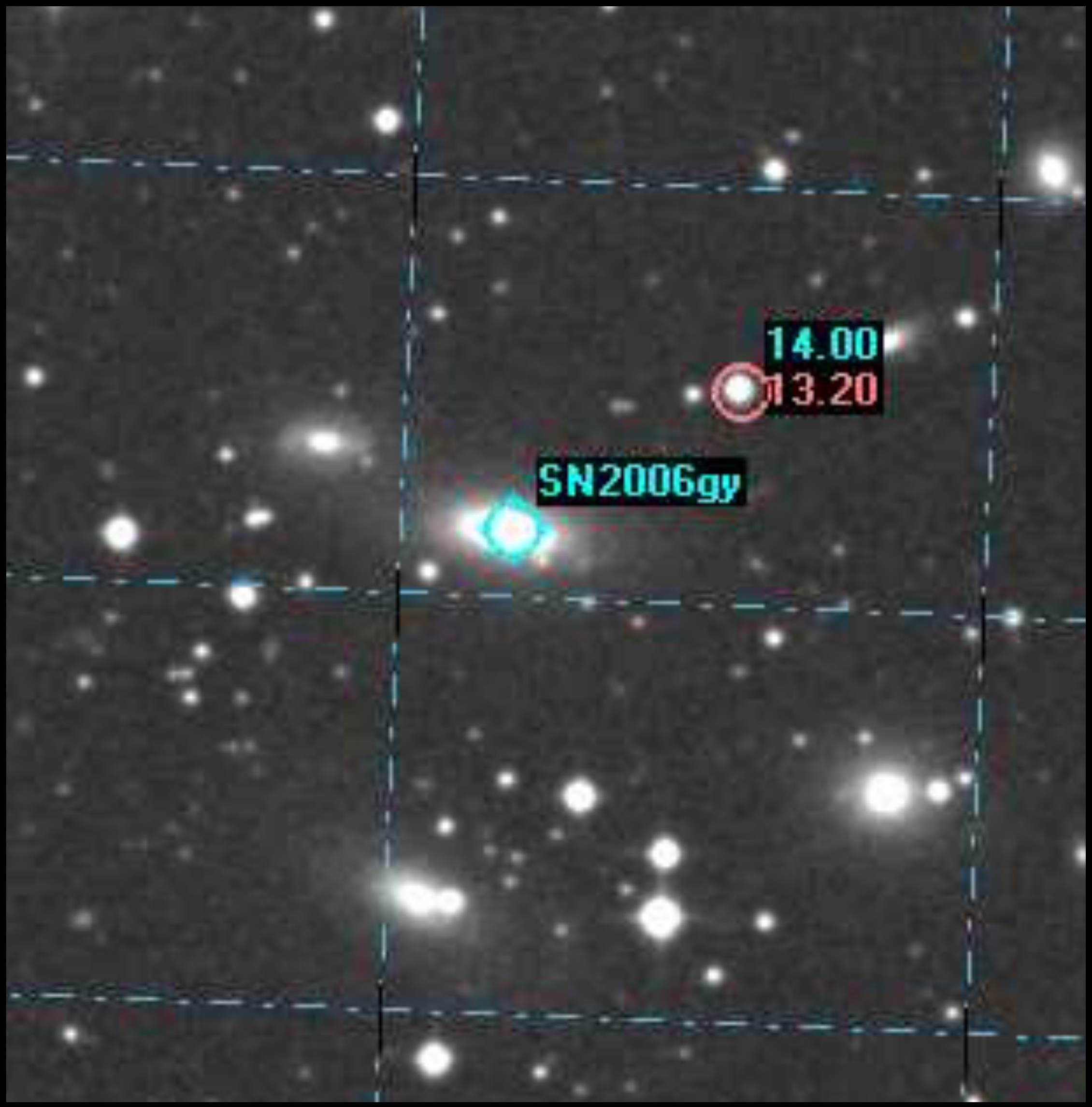
Typical SN image



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

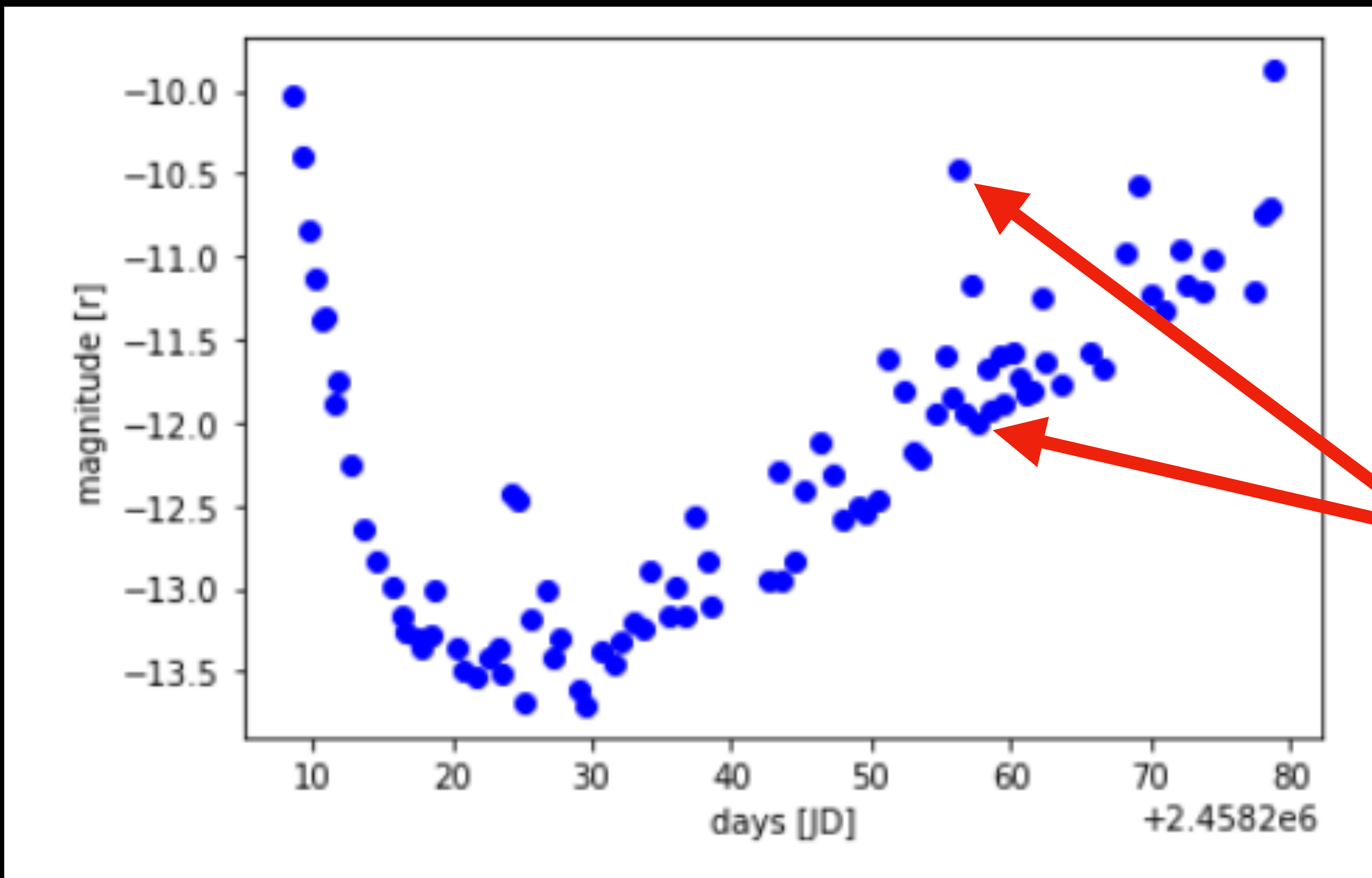
$$ZP = m_{app} - m_{inst}$$ from the reference star

$$m_{app} = ZP + m_{inst}$$ for your Supernova

instrumental magnitude

Bad weather!!!!!

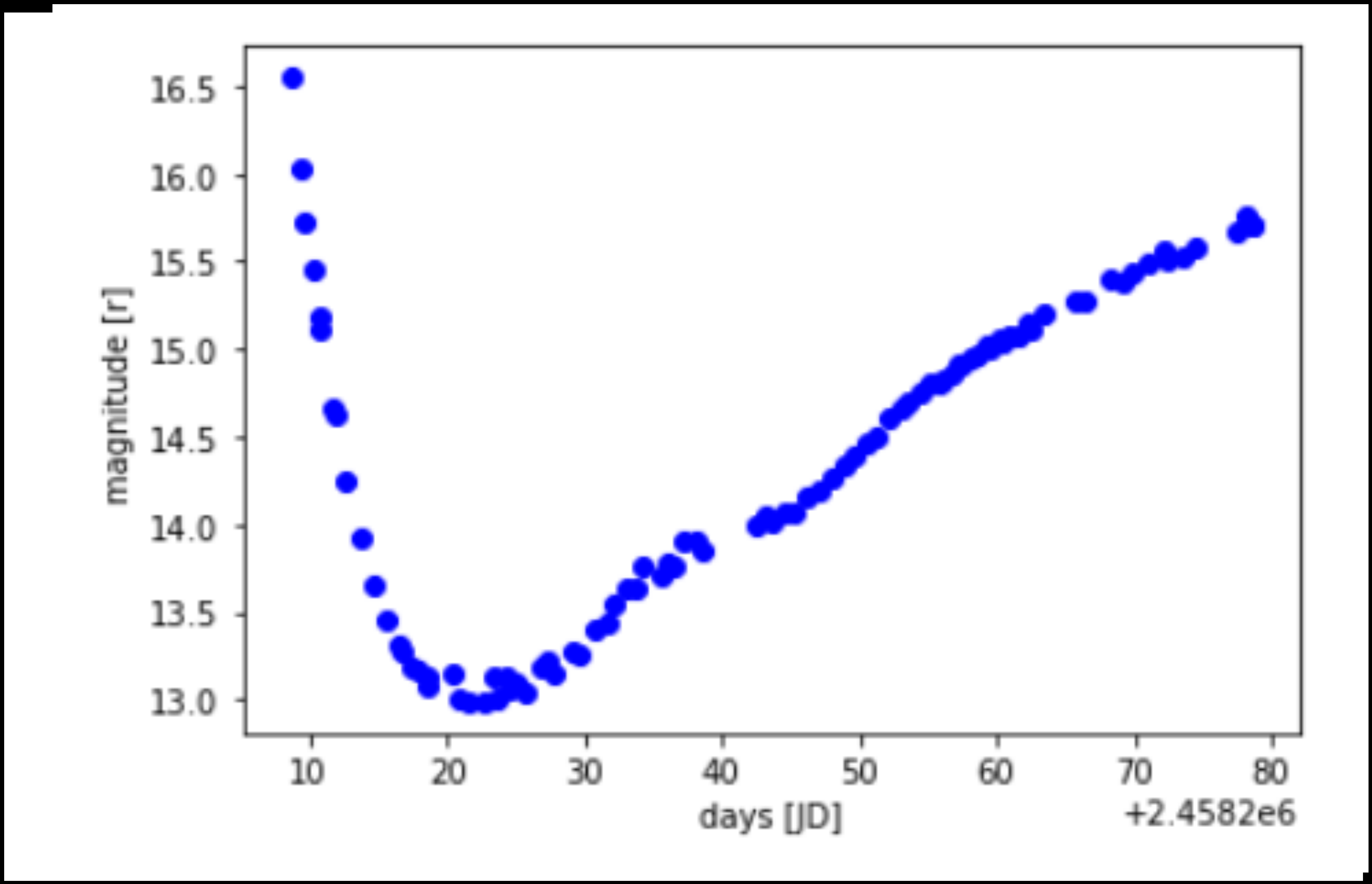
$$m_{inst} = -2.5 \times log_{10} I$$



a lot of scatter from night to night

apparent magnitude

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



Recap

apparent magnitude

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

absolute magnitude

distance of the star (pc)

$$\underbrace{m}_{\text{apparent magnitude}} - \underbrace{M}_{\text{absolute magnitude}} = 5log_{10}(\frac{d}{10})$$

where $m - M$ is the distance modulus.

instrumental magnitude

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

Zero Point

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

Tough Question

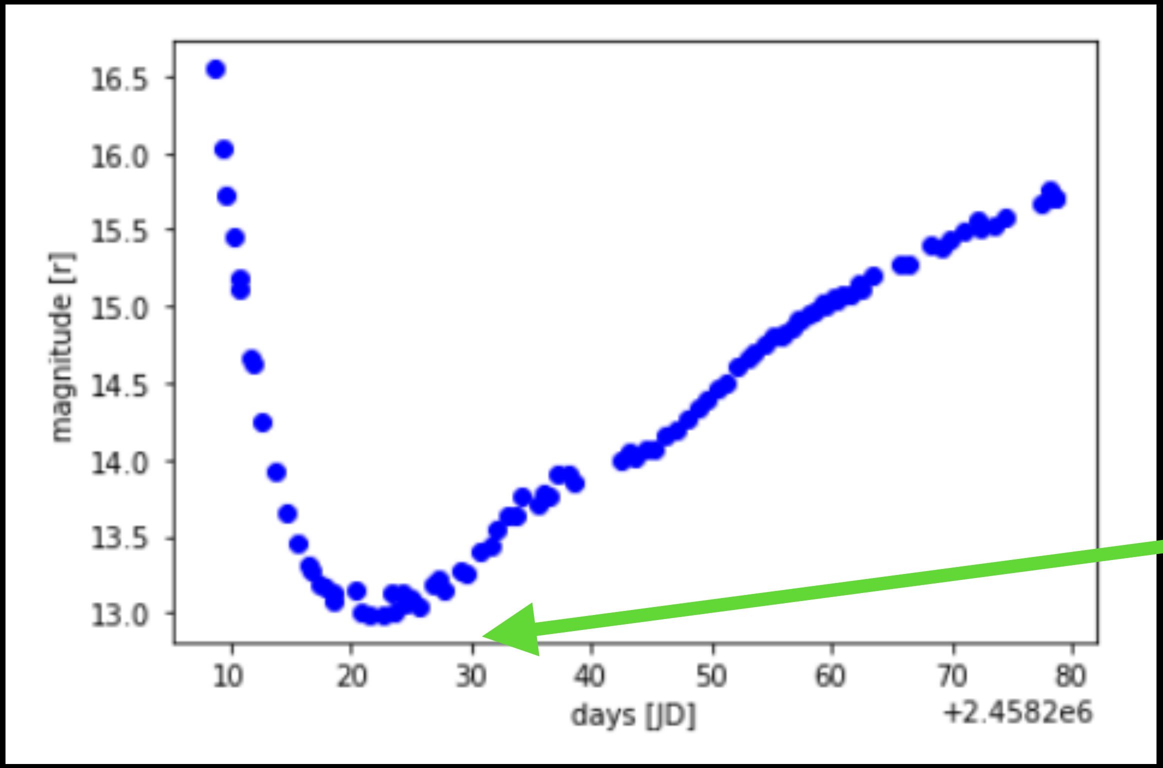
Suppose that you know the absolute magnitude of an object in the sky, for example you know that all SNe Ia have an absolute magnitude of -19.5

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

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

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



you measure the apparent magnitude of the SN

what you can say about the distance of the SN?