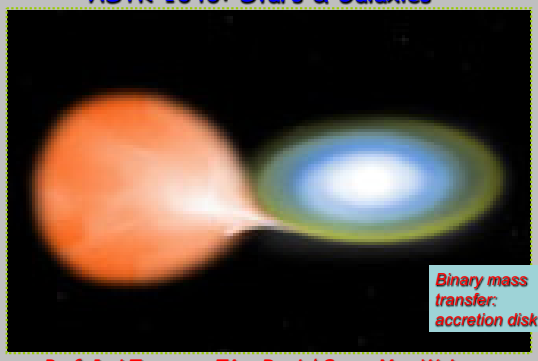
## ASTR 1040: Stars & Galaxies

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Lecture 18 Thur 12 Mar 2020
zeus.colorado.edu/astr1040-toomre

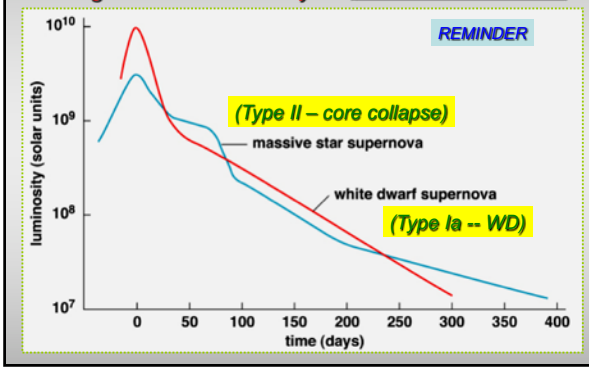
## Today and Tues

- Famous supernovae: *SN1987A + earlier*
- *Black holes*, their general properties, and their "care and feeding" – and *Mr. Einstein's work* S.2 (special relativity), S.3 (general relativity)
- Overview read *Chap 19: `Our Galaxy'*
- *New HW # 9 (involves supernova energies), HW #8 due today*
- *Second Mid-Term Exam* in class today

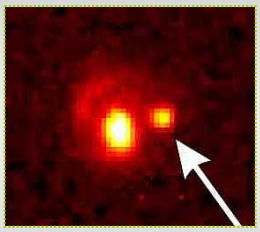
## White dwarf SN as distance estimators

- *"Standard explosion" = fusion of 1.4 solar masses of material*
- *Nearly the same amount of energy released*

## SUPERNOVA Light Curves
## Bright Candles in Sky to Measure Distance

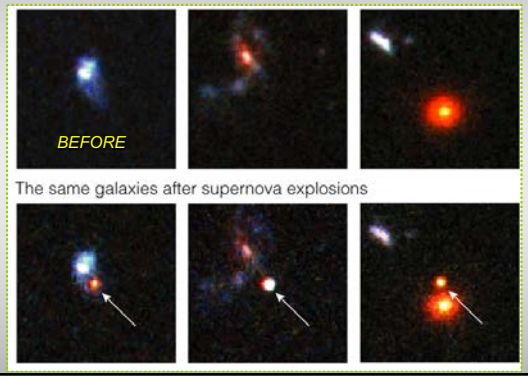



## Bright enough to be seen halfway across observable universe



*Useful for mapping the universe to the largest distances*

## Supernovae in very distant galaxies

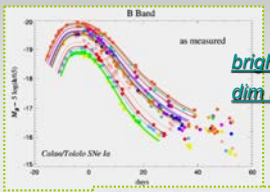


## Clicker: What happens in a "white dwarf supernova" ?

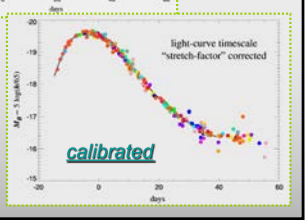
- A. Carbon fuses throughout the white dwarf
- B. Hydrogen fuses on the surface of the white dwarf
- C. The white dwarf collapse into a neutron star
- D. Helium fuses throughout the white dwarf

## White dwarf supernovae

- Carbon fusion explosion: mass transfer in binary takes white dwarf `over the edge'
- Roughly same amount of energy released (calibrate)



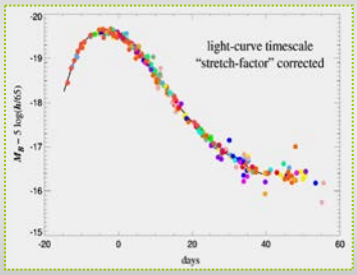

brighter SN
dim more slowly!




calibrated

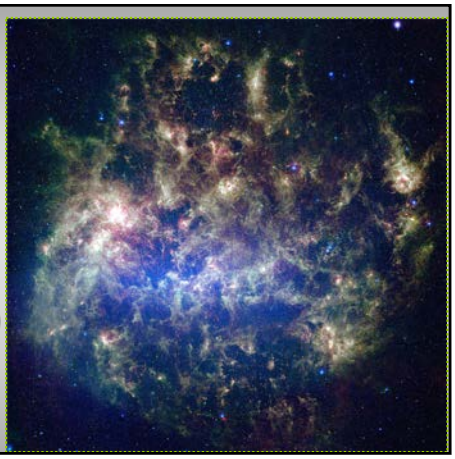
## Practical difficulty: White dwarf SN

- Need to catch them within a day or two of the explosion
- About 1 per galaxy per century
- Need to monitor thousands of galaxies to catch a few per year → galaxy clusters are useful




Nearest: Story of SN 1987A in LMC

Large Magellanic Cloud (LMC) (10,000 tiles with Spitzer composite IR)



## 24 Feb 1987: SN in LMC (160,000 ly away)

BEFORE blue supergiant

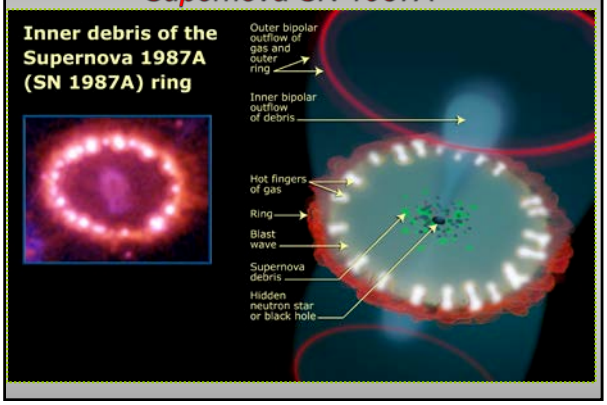
AFTER (SN 1987A)

## Mysterious triple rings in SN 1987A

20 year birthday picture (Chandra + HST)

## SN 1987A: Brightening knots 1994 > 2006

## Supernova SN 1987A



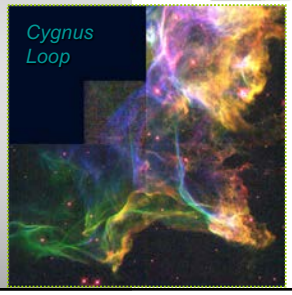

## SNR "numbers game"

SUPERNOVA REMNANTS (SNR)

... EXPANDING DEBRIS OF EXPLOSION

DO NOT LAST VERY LONG BEFORE DISPERSING

- FOR ABOUT 1000 YEARS, SEEN IN X-RAY, VISIBLE, RADIO
- AFTER ~ 10,000 YRS, SHOCK WAVE SNOWPLOWS MATERIAL AHEAD, BUT GAS HAS COOLED ⇒ RADIO EMISSION ALONE
- PROBABLY INVISIBLE AFTER ~ MILLION YEARS




BUT... SUPERSHELLS CAUSED BY SUCCESSIVE SN IN OB ASSOCIATIONS MAY LAST MUCH LONGER!

THE NUMBERS GAME:

~120 SNR DETECTED IN OUR GALAXY (MOSTLY IN RADIO)
5 HAVE IDENTIFIABLE PULSARS

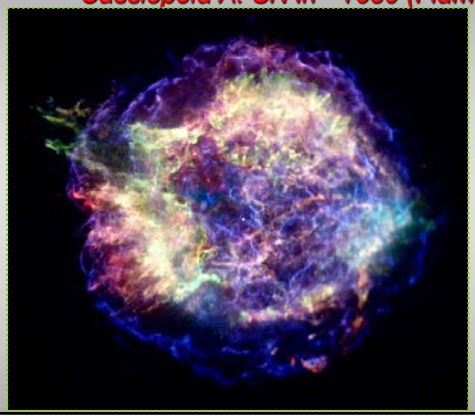
~ 50 SNR IN LMC

~ 10 SNR IN SMC

BUT ~ 400 PULSARS FOUND IN OUR GALAXY, 1 IN LMC

ANSWER: PULSARS VISIBLE LONGER (~ 4 MY), PROPER MOTION OF PULSAR MAY CARRY IT AWAY FROM SNR

## Cassiopeia A: SN in ~1680 (Flamsteed)



Youngest SNR in MW (Chandra X-ray image) synchrotron emission

Neutron star at center

## Cass A: Viewed with Spitzer IR

## Second Mid-Term Exam