a Network for Observing White Dwarfs around the Globe

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Overview

- What *are* white dwarfs?
  - small, very dense objects
  - endpoints of evolution for about 98 % of all stars
- Why are they scientifically interesting?
  - Their ages allow us to date the Milky Way
  - We can study exotic physics
  - Some of them pulsate
- Large scale surveys
  - designed to find faint, blue quasars
    also find faint, blue white dwarfs
- Final thoughts + “Video Bonus”

Galaxy interactions can lead to star formation

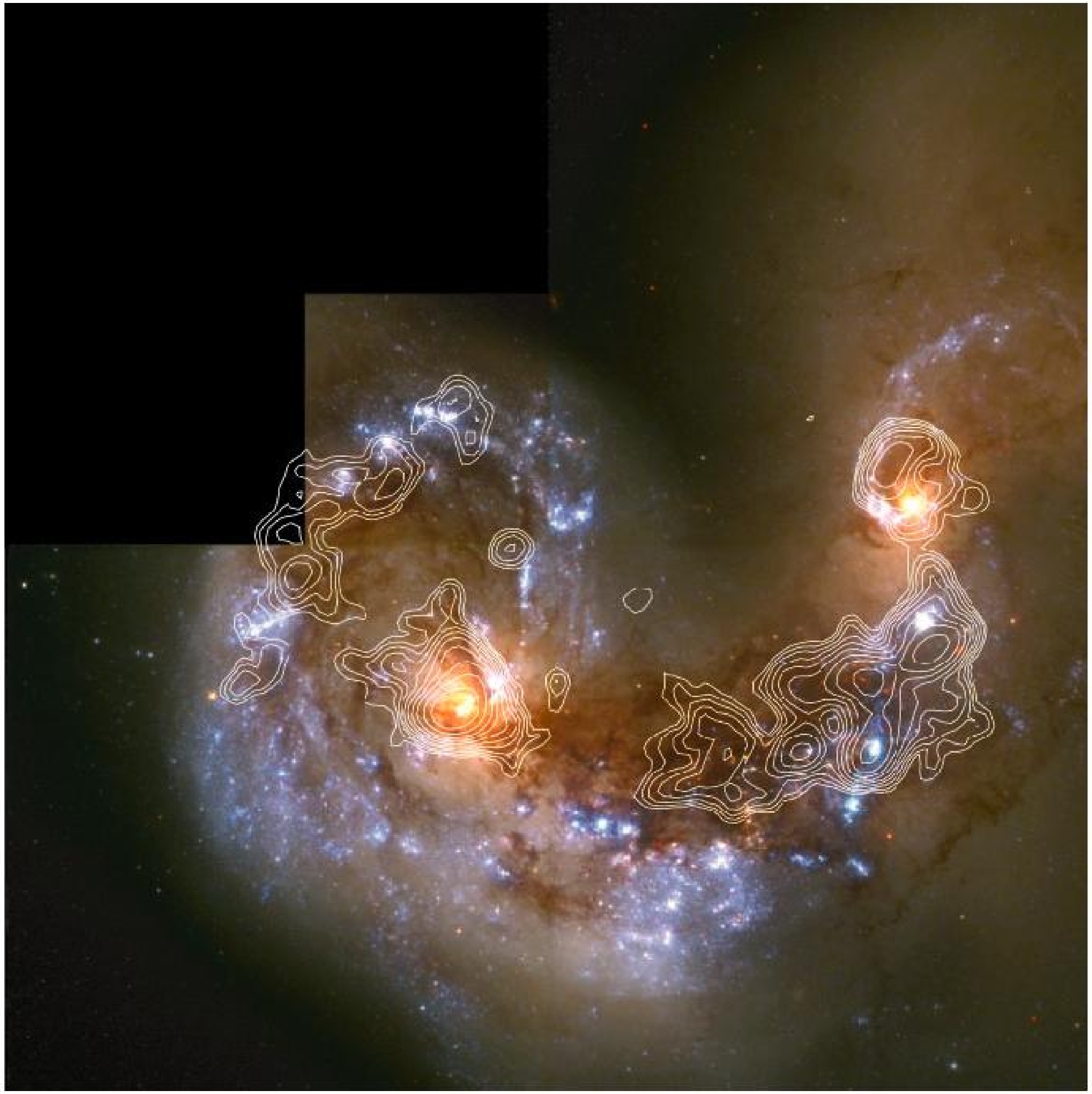
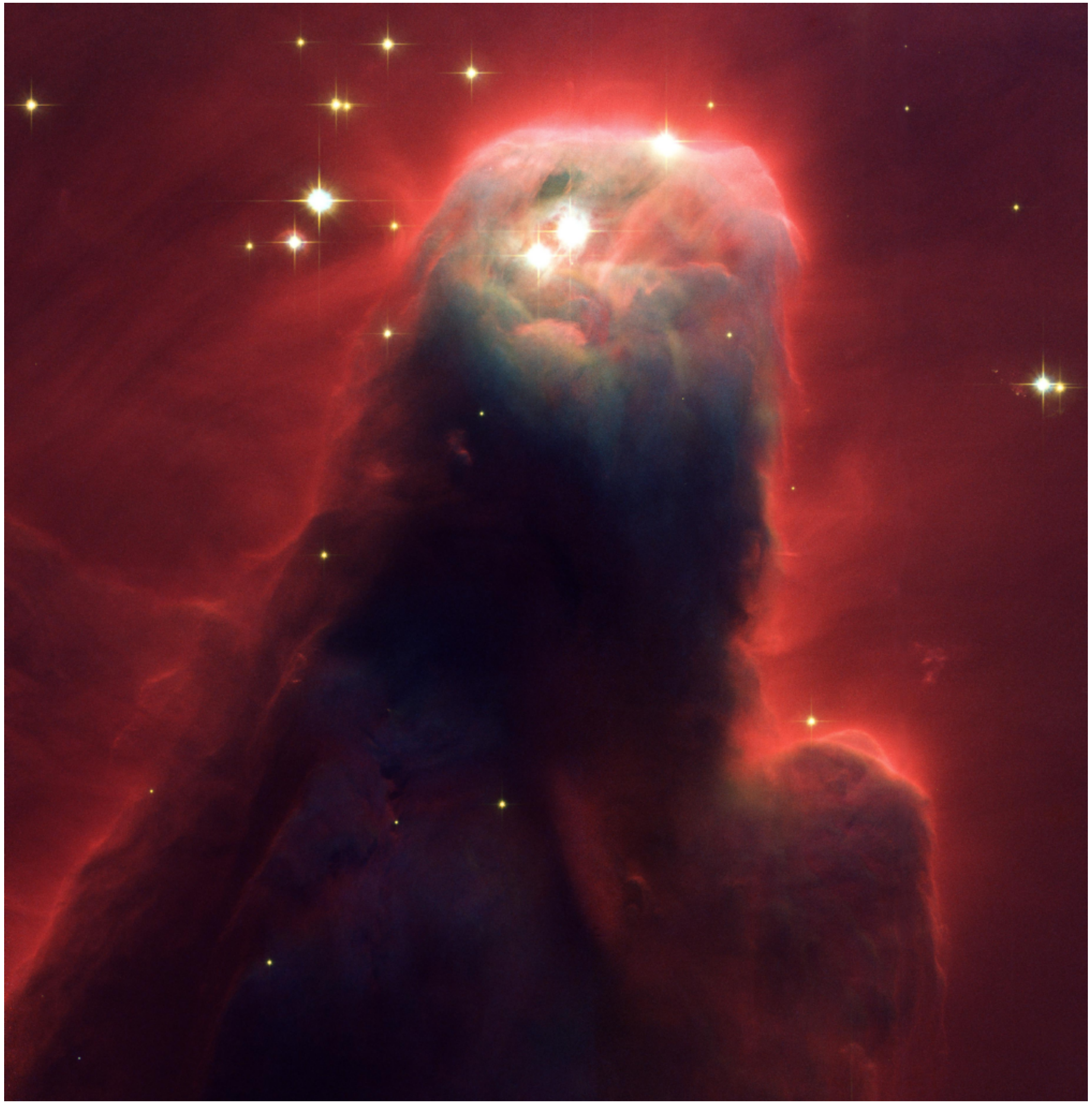


Fig. 2. A CO integrated intensity map (white contours) overlaid on a true color HST image of the Antennae galaxies (*95*) from (*21*). [Courtesy Christine Wilson] The young SSCs are the bright blue objects seen in this image.

The interaction between the Antennae galaxies has led to bursts of star formation (“star bursts”)

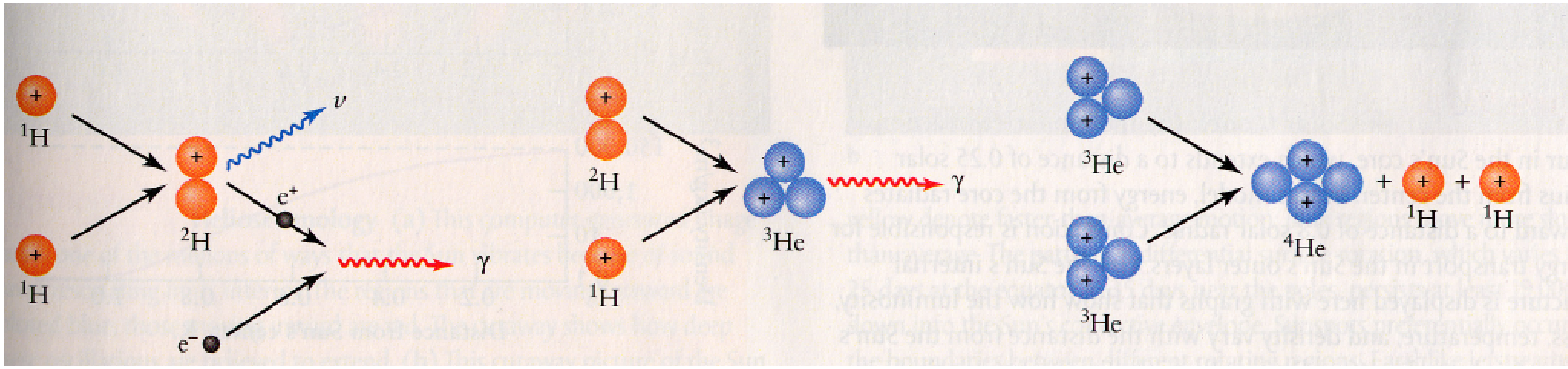
Star formation: "The Cone Nebula"



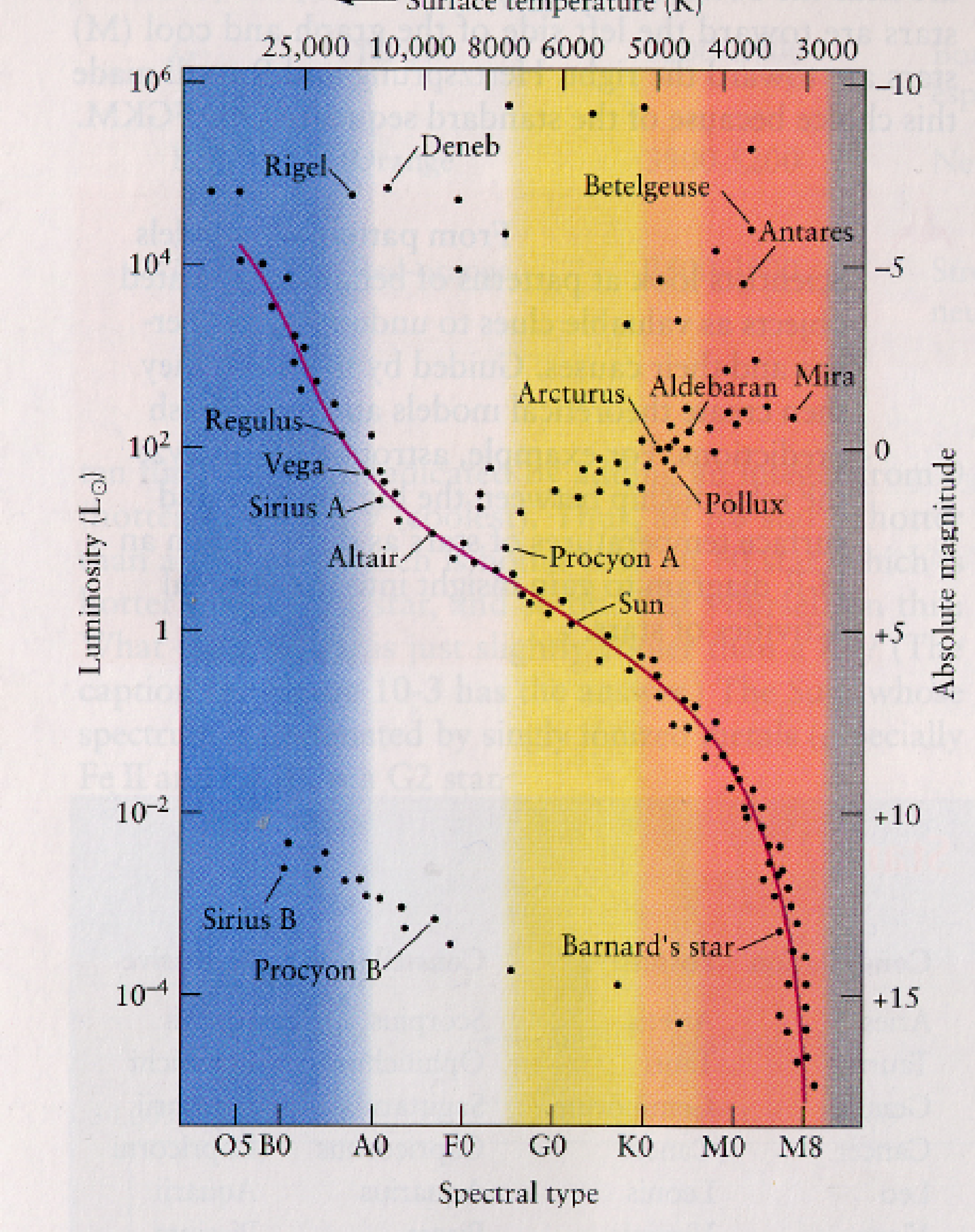
Molecular clouds, such as those found in the Cone Nebula, are the sites of star formation

Brief discussion of stellar evolution

- stars form – this takes on the order of a million years
- they begin life on the "Main Sequence"
  - steadily convert hydrogen to helium through nuclear reactions



  - spend most of their life in this phase (thousands of millions of years)
- as they exhaust their hydrogen reserves, they are said to evolve off of the Main Sequence



The Hertzsprung-Russell Diagram (H-R Diagram):

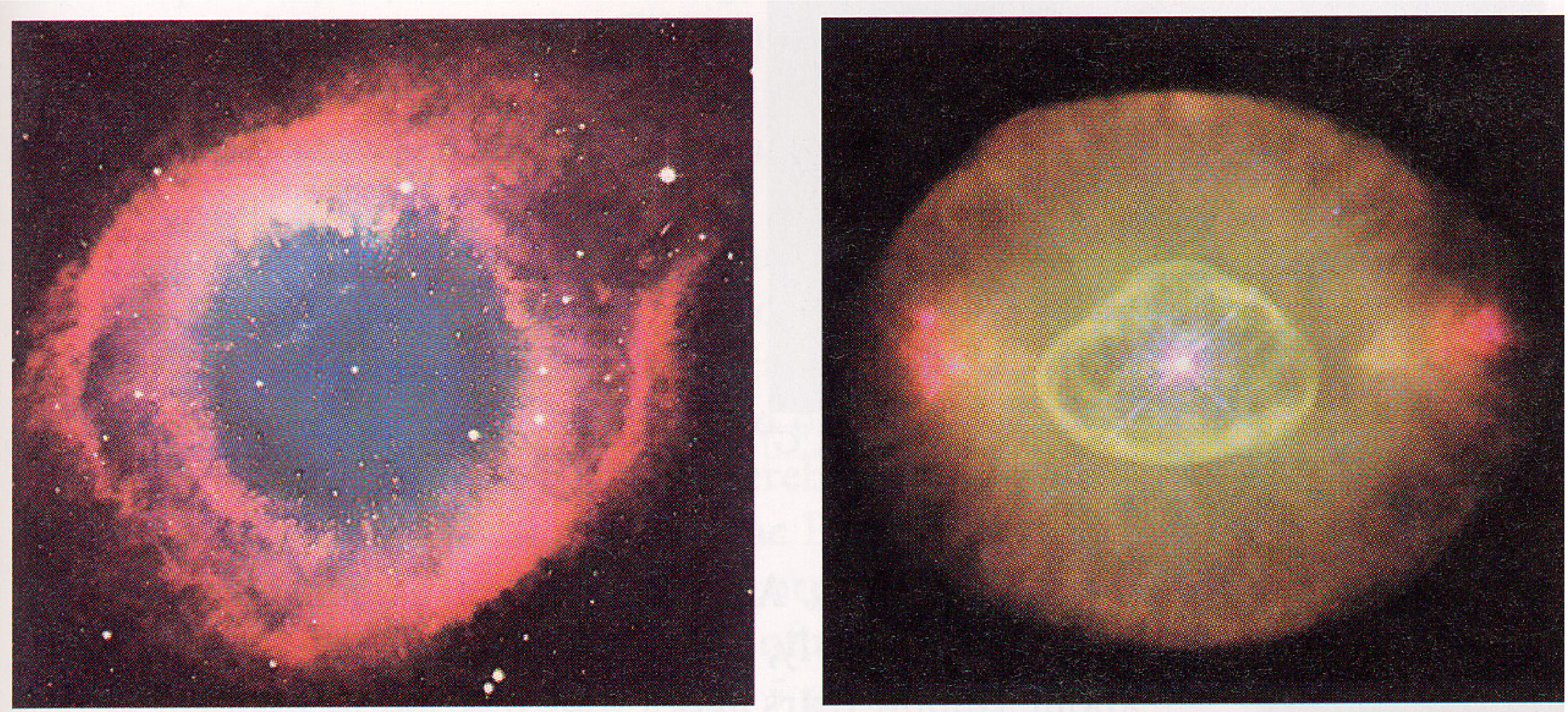
the absolute luminosity plotted versus the spectral type (temperature) of the star

The Main Sequence, on which stars begin their lives, is shown by the red curve

Stellar evolution (cont.)

- at first they burn helium to carbon
- if they are massive enough, even heavier elements will be produced

- they undergo mass loss, losing most of their mass



this can result in “planetary nebulae” being formed

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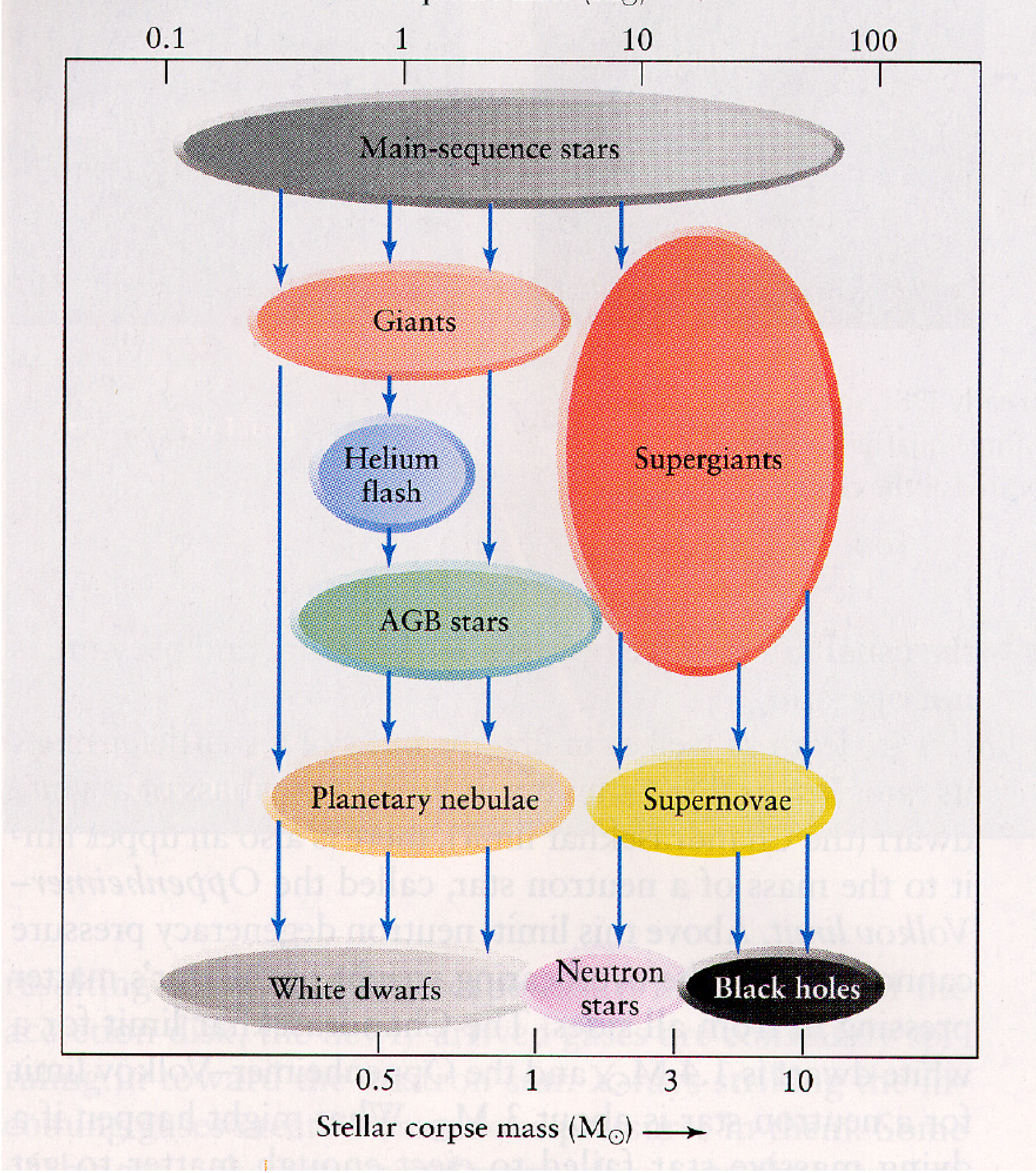
- finally, the stars with initial masses less than about 8 solar masses will become **white dwarfs**
- stars which are initially more massive than this can also become neutron stars or black holes
- *theoretically*, the post-Main Sequence evolution is very difficult to model
- *observationally*, we are able to observe different phases of this evolution

This can be graphically shown by the following:

initial mass →

evolution ↓

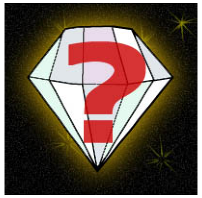
final mass →



The Importance of White Dwarfs

- endpoint of evolution of most (98%) stars
  - give us clues concerning stellar mass loss
- white dwarfs are born "hot" and then cool off steadily
  - their temperatures tell us how old they are
  - they can be used to determine the age of the Milky Way!
- are progenitors of Type Ia supernovae
- Some of them pulsate (change luminosity)
  - we can use their pulsations to study their interior structure
    this is called "asteroseismology"
  - they may be clues to exotic physics:

    crystallization (diamonds in the sky)
    carbon/oxygen burning rates
    neutrino rates, convection, diffusion, . . .



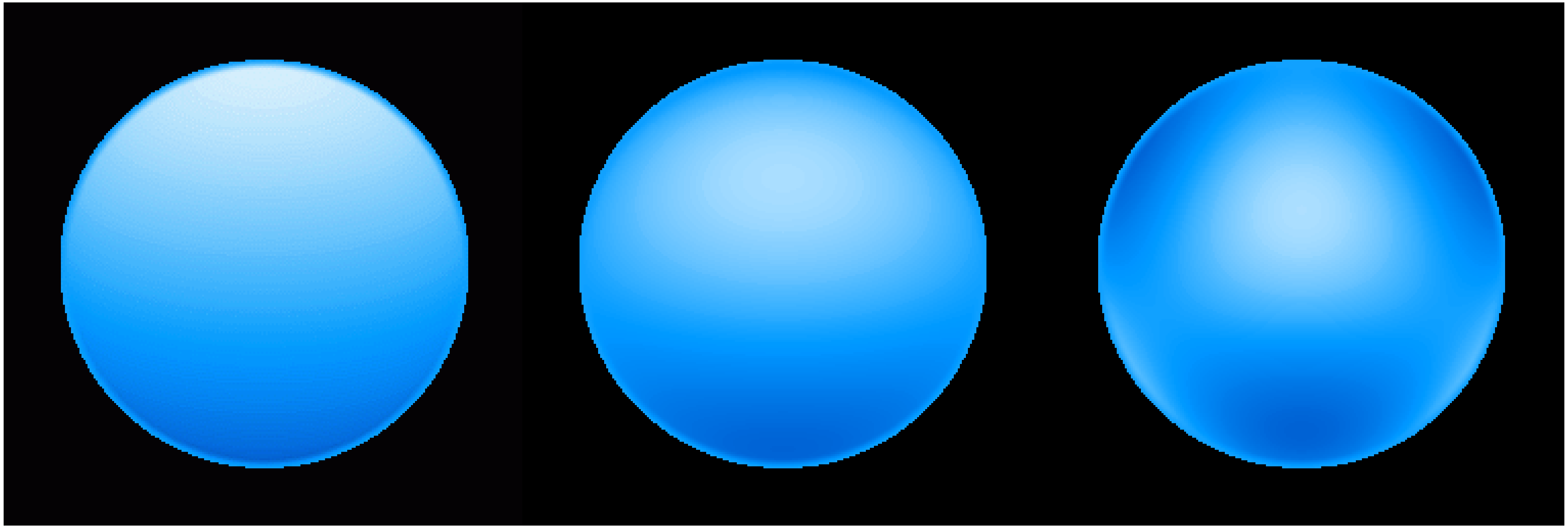
The pulsations of white dwarfs are like the vibrations of a violin:



different pitches (frequencies) correspond to different patterns (modes)

$\Rightarrow$ the patterns/frequencies tell us about the interior structure of the instrument

This is also true for pulsating stars



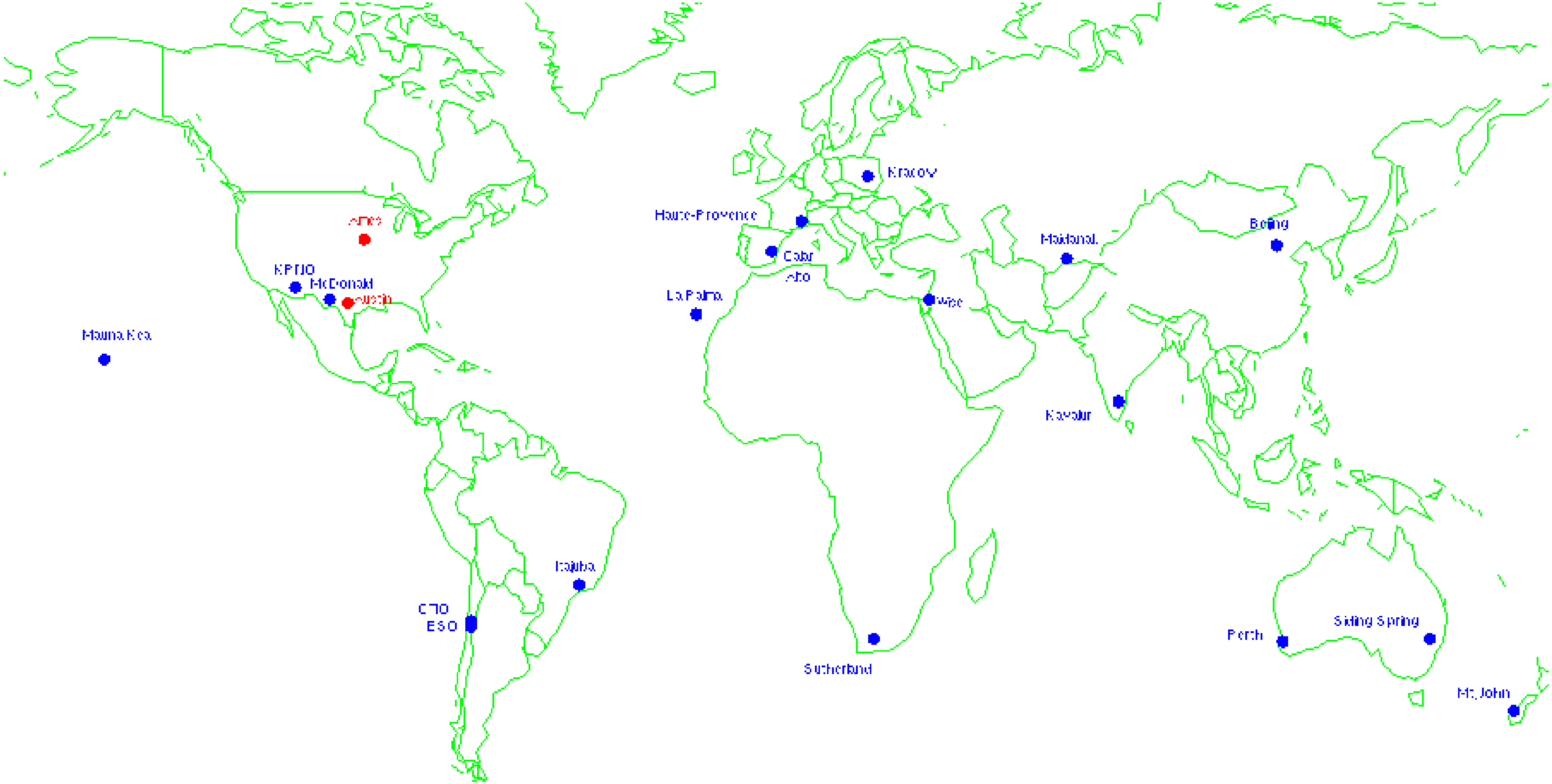
- These patterns of temperature are the spherical analogues of modes of vibration of a violin
  - each pattern (mode) corresponds to a particular frequency (pitch)
  - by observing a pulsating star, we find the frequencies with which it pulsates, which allows us to learn about its interior structure

However, there is a catch:

- the observations need to be continuous (or nearly continuous) in order for the frequencies to be correctly determined
- from the ground, it is not possible to observe a given astronomical object for much more than about 12 hours from a given site
- we could go to space, although that's no guarantee
- or we could come up with . . .

the Whole Earth Telescope

The Whole Earth Telescope (WET) (UT-Austin, circa 1995)

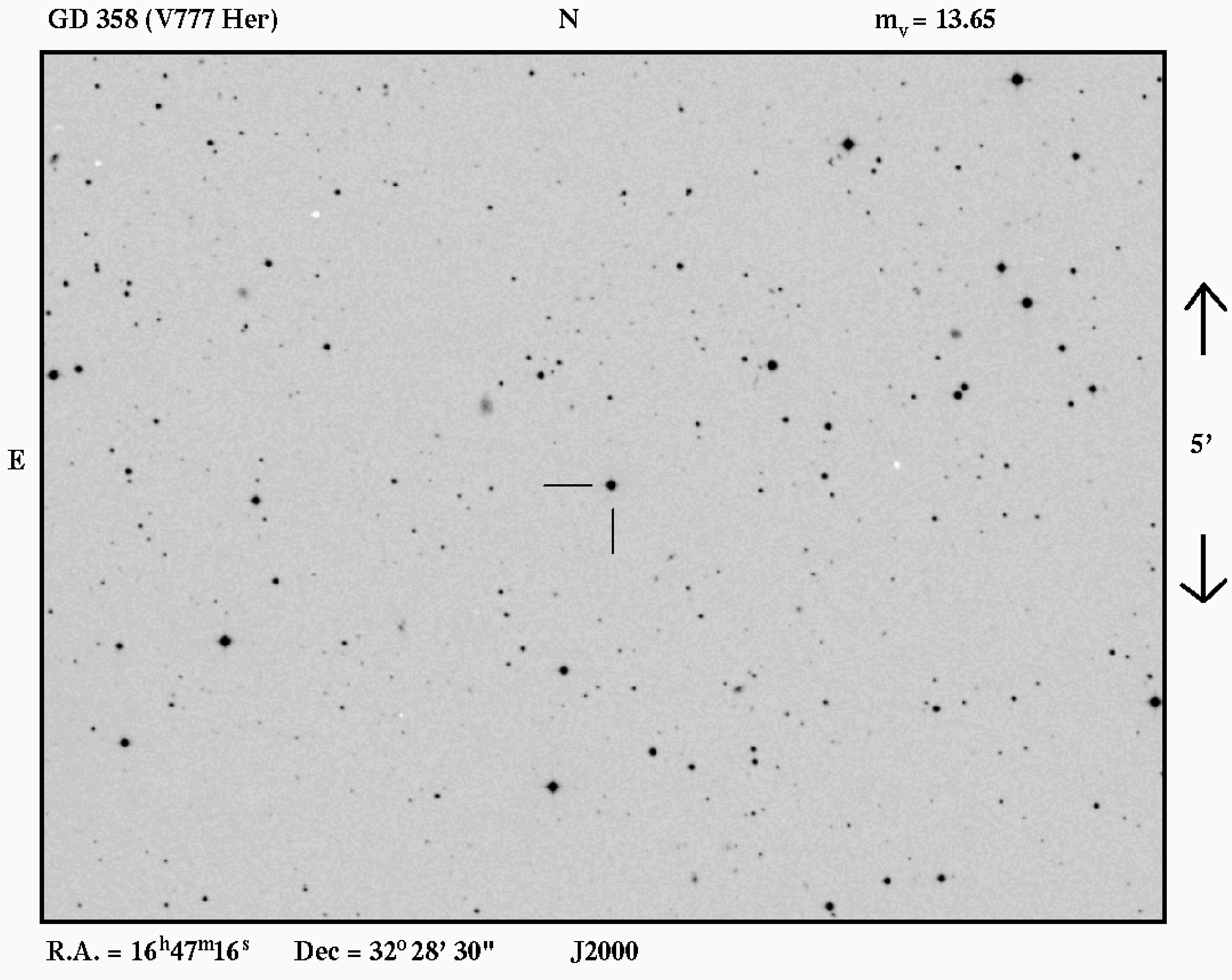

KPNO
McDonald
Mauna Kea
Haute-Provence
Kracow
La Palma
Maidanak
Beijing
Kavalur
Itajuba
CTIO
ESO
Sutherland
Siding Spring
Perth
Mt. John

More than anything it is a network of *people* around the globe who agree to observe the same object for the same period of time (1–2 weeks)

The Founders:

Ed Nather

Don Winget



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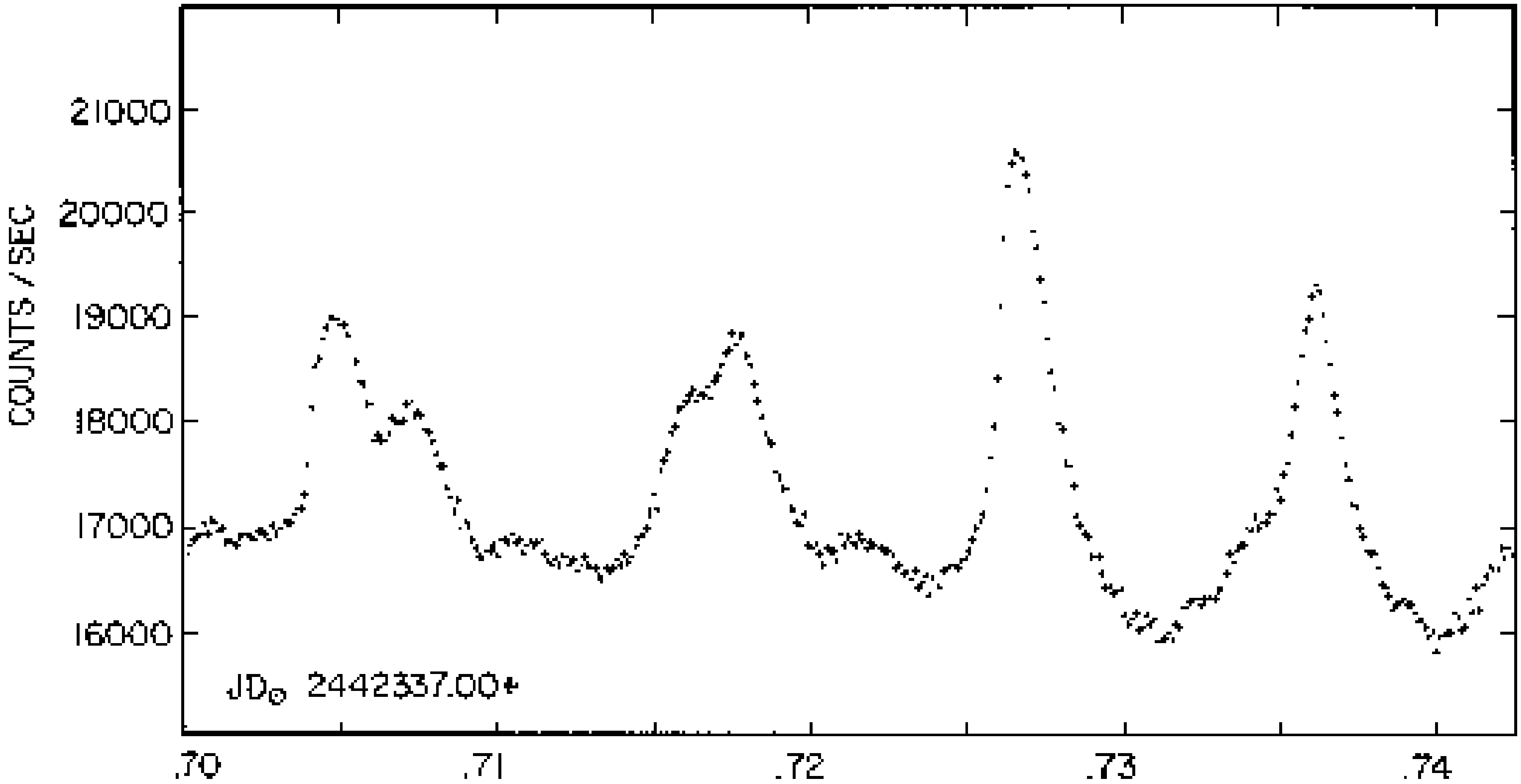
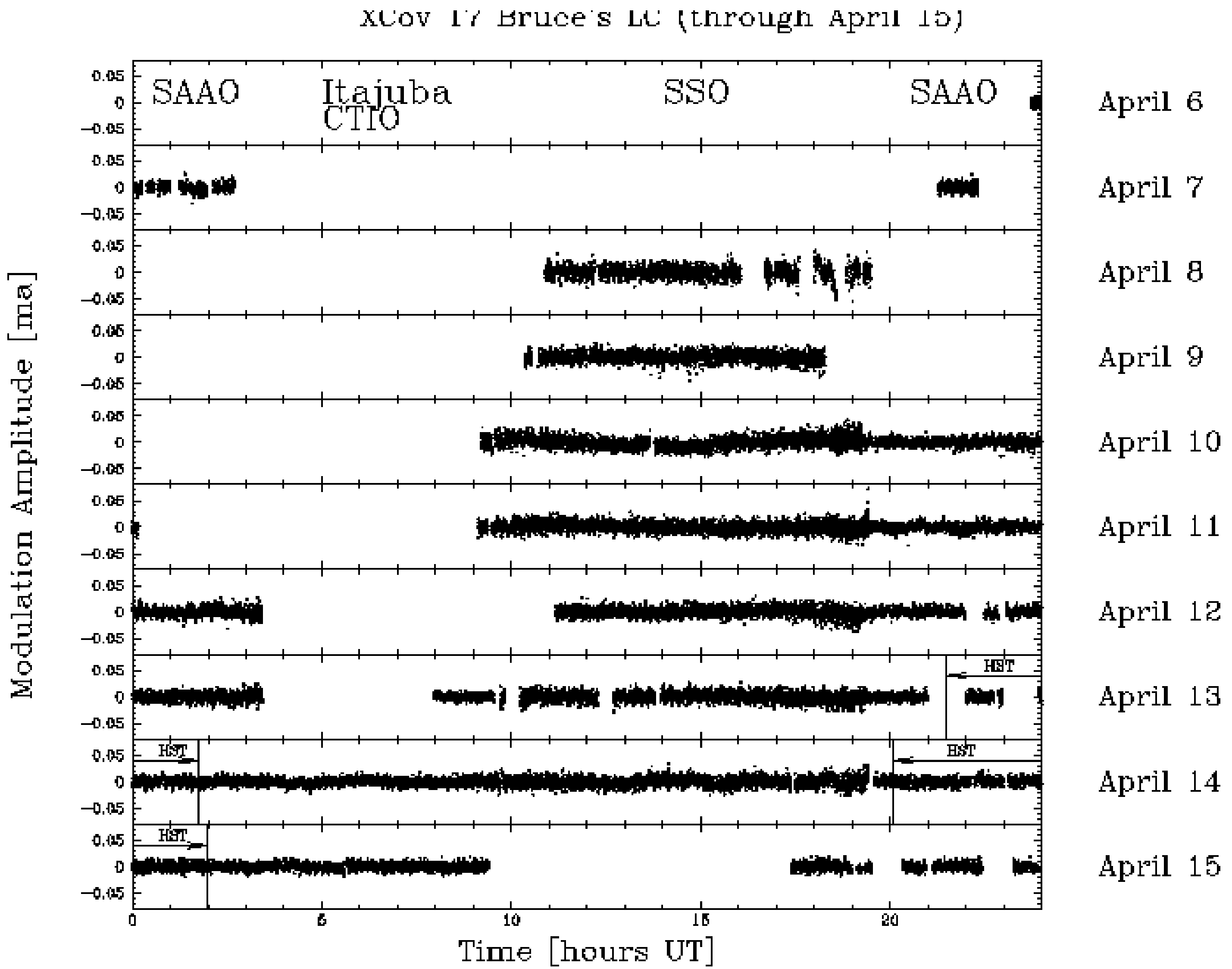


time →

This star, G29-38, is pulsating simultaneously at many different frequencies (284 sec, 615 sec, 820 sec, etc.)

One week of data from a WET run



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From such observations, we obtain a set of pulsation frequencies for each star. This allows us to constrain their:

- Mass
- Temperature
- *Age*
  - the age of the Milky Way is 9.5 ± 1 Gyr (thousand million years) this is completely independent of other techniques
- Internal composition
  - the carbon/oxygen ratio in the core
    $\Rightarrow$ important for Type Ia supernovae
    $\Rightarrow$ important for estimates of cosmological acceleration
  - whether crystallization occurs as they cool
  - neutrino rates
  - convection
  - magnetic fields

The Good News

- Many surveys are underway to detect quasars, which are faint and blue
- White dwarfs are faint and blue
- These surveys are finding lots of white dwarfs
- Surveys are finding a lot of white dwarfs:

The Sloan Digital Sky Survey
(Fort Apache, New Mexico)

- We'll be learning a lot more in the future!