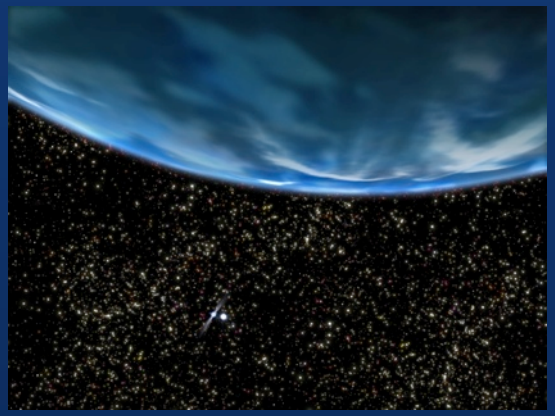
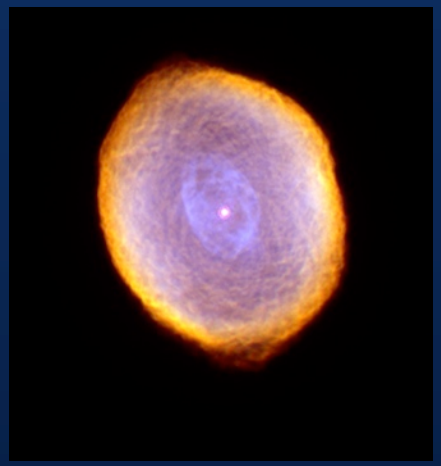
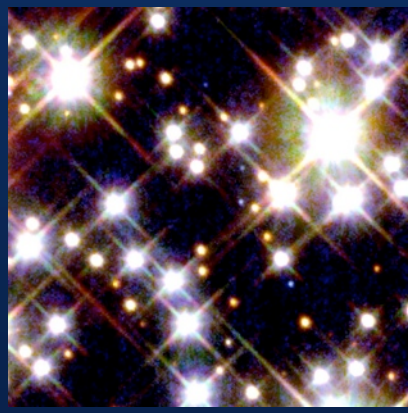
Watcher of the Sky: The Highs and Lows of Being an Observational Astronomer





Harvey B. Richer: Pacific Institute of Theoretical Physics: October 20 2010

Plan for this evening's talk

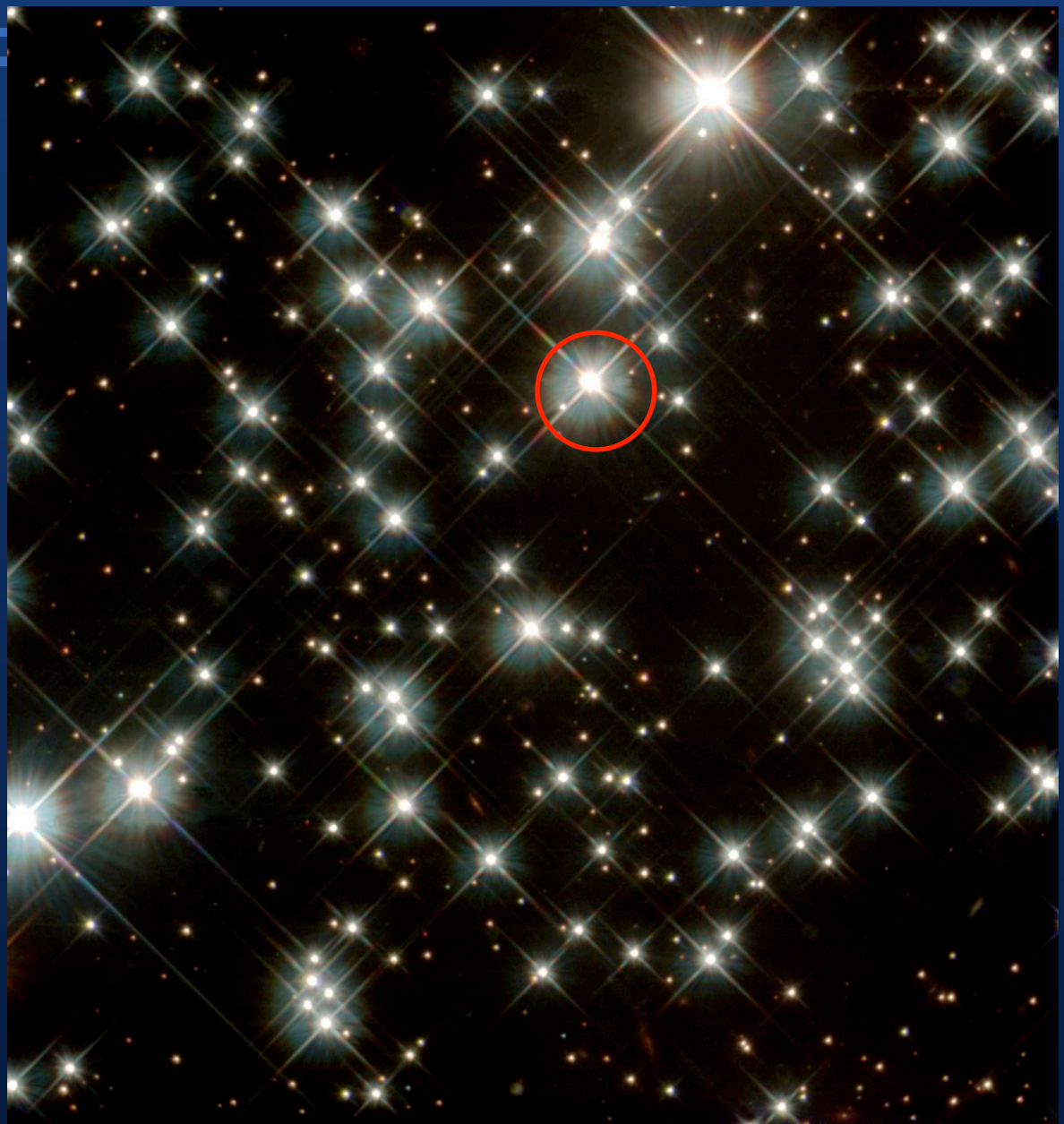
- Early trials of a graduate student
- Why do astronomy from space?
- How to get time on the Hubble Space Telescope
- A current project
- A recent project - fluffy clusters
- A peek at the future

The Start - First Observing Run -

Chile and Observatories

Santiago - 1968

Finding Chart



Checking the Engine

Things Do Not Look Good

Problem is Very Serious!

In the End - No Hope….

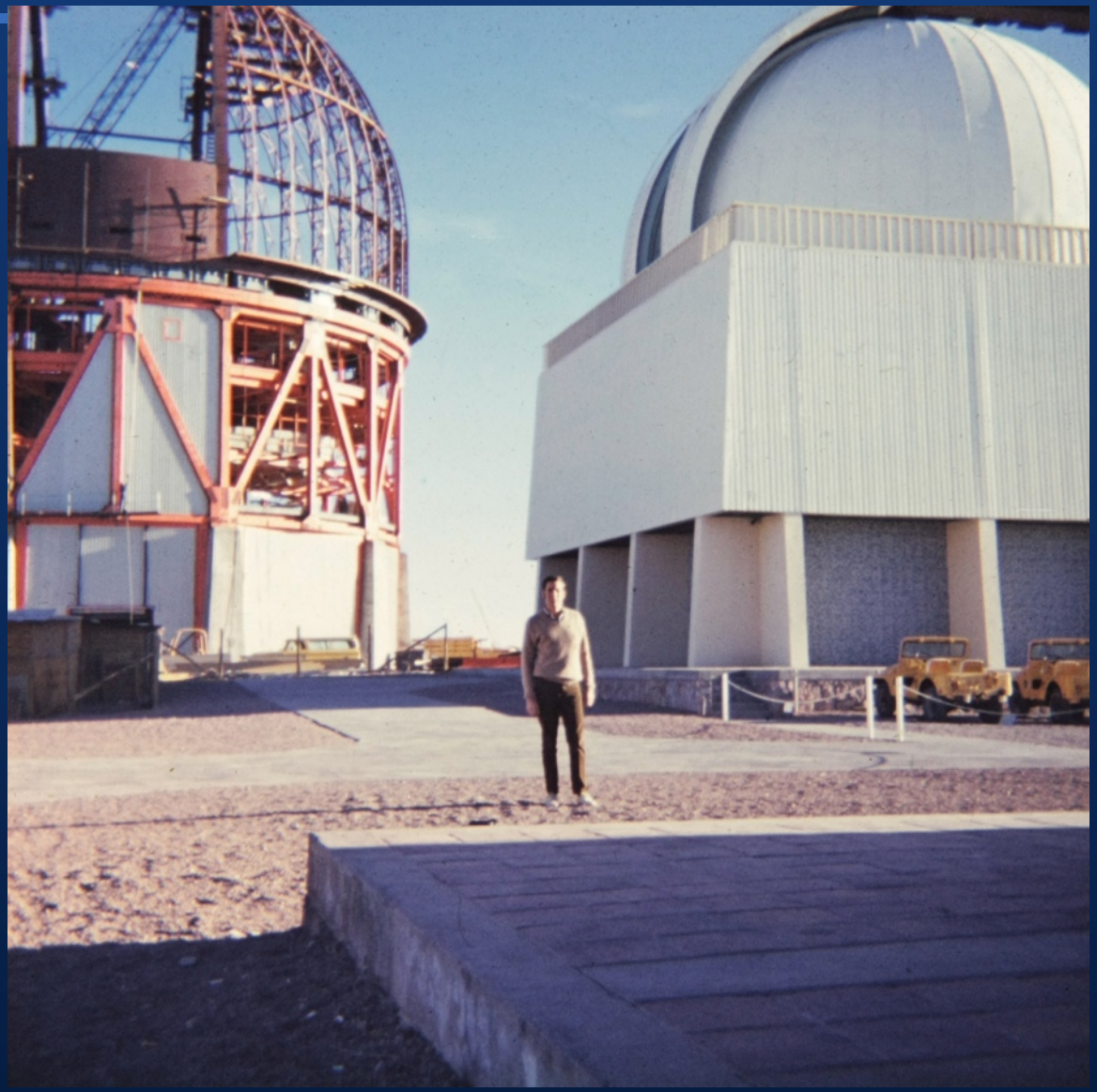
Waiting for Help

Looking for Food

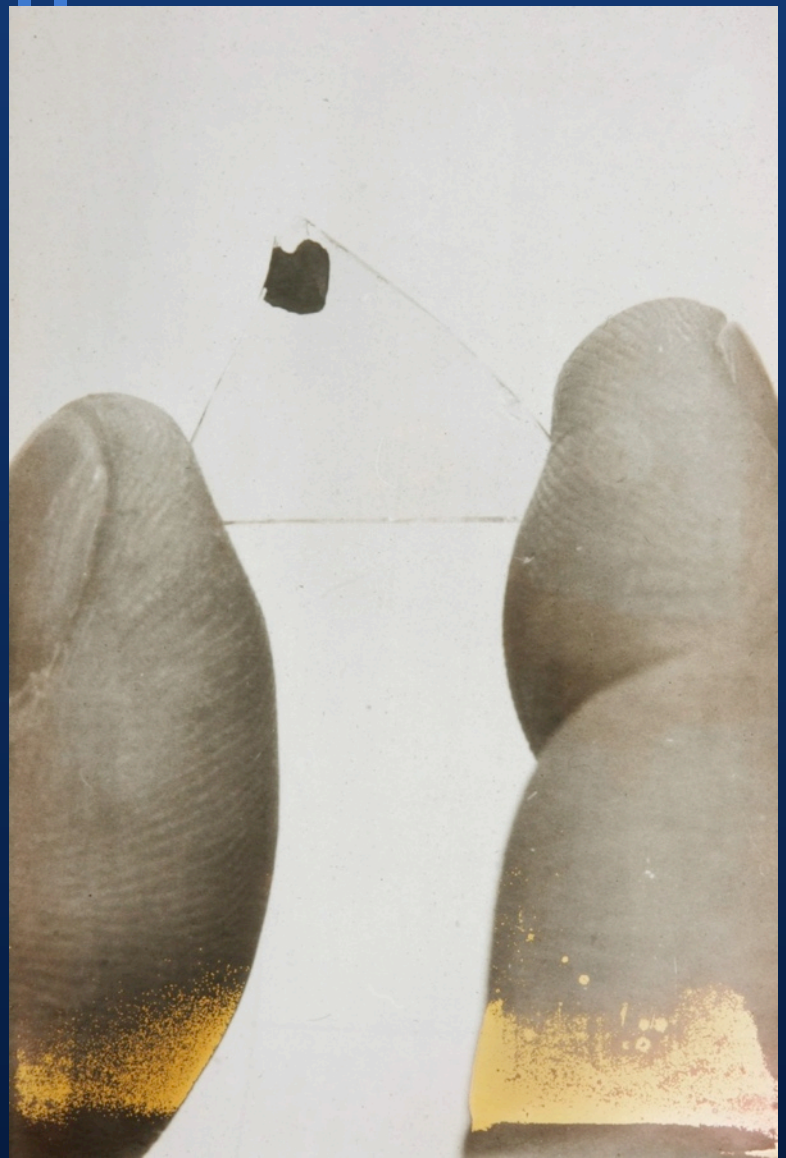
Ageing … in a Few Hours

Ageing … in a Few Hours

At Cerro Tololo



Spectra - Old Fashioned Way



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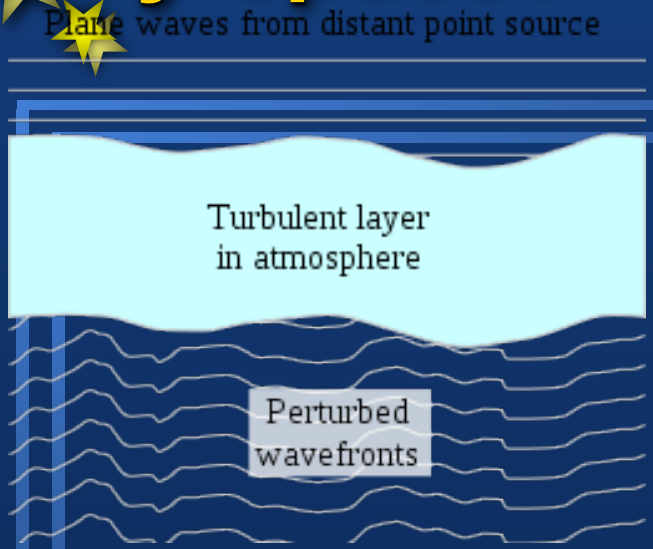
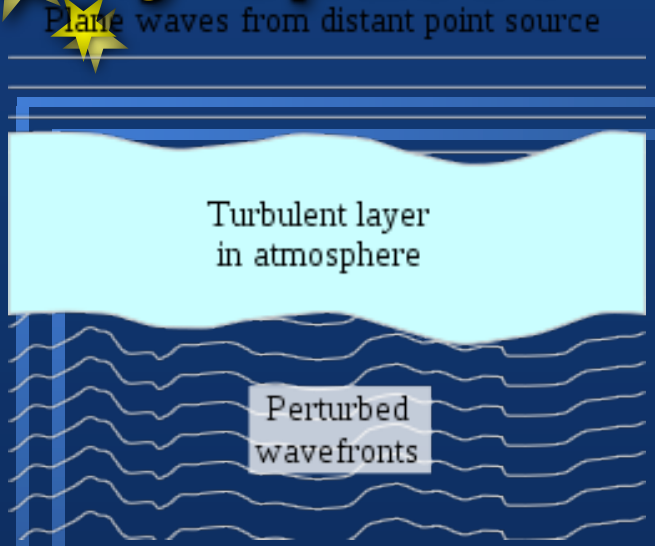
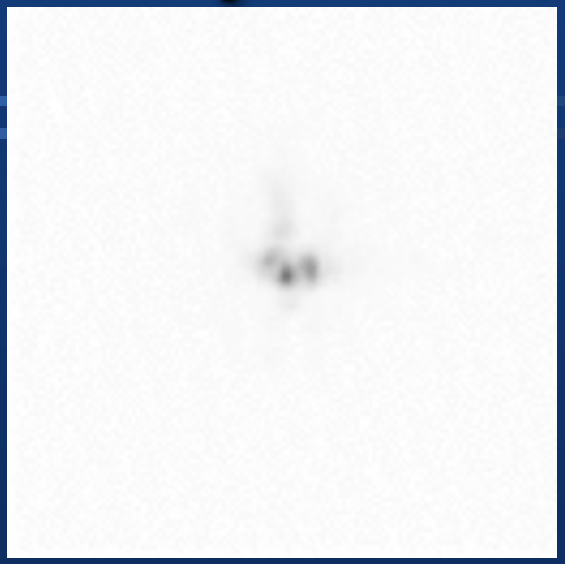
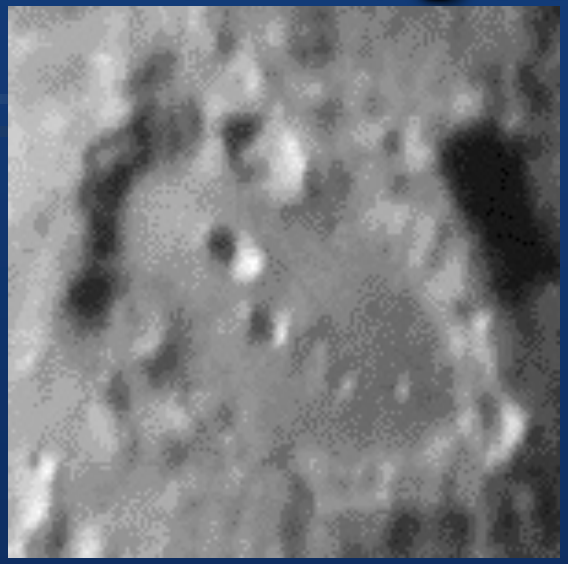
Why Space? - Sharp and Stable Images



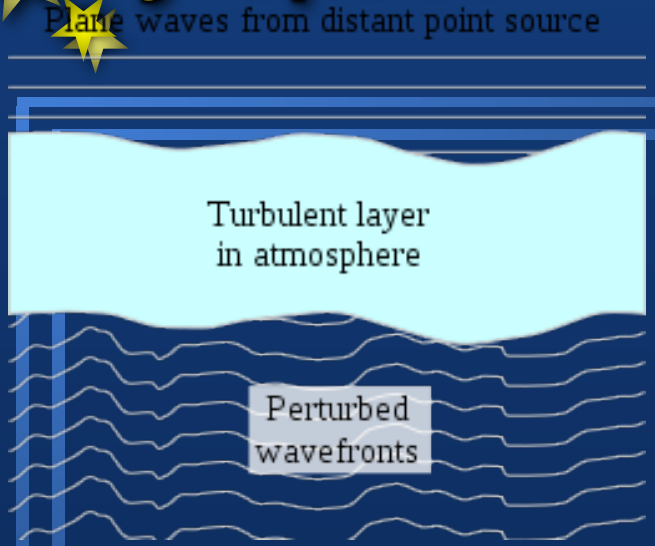
Why Space? - Sharp and Stable Images

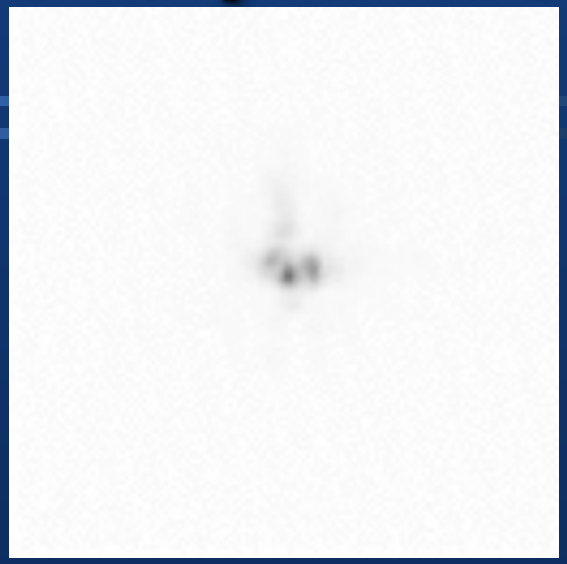


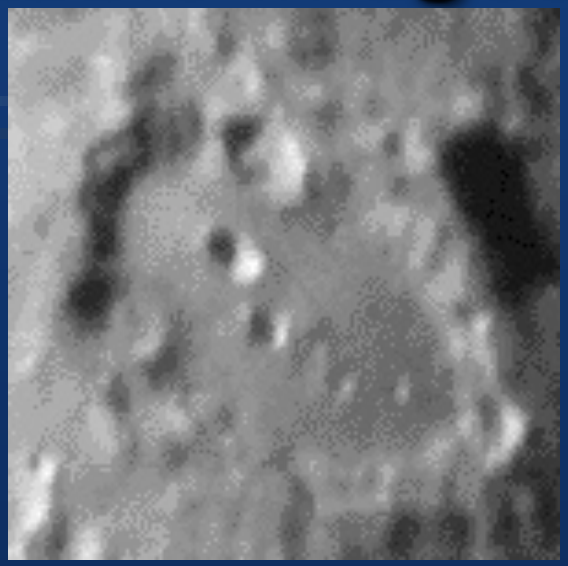




Why Space? - Sharp and Stable Images

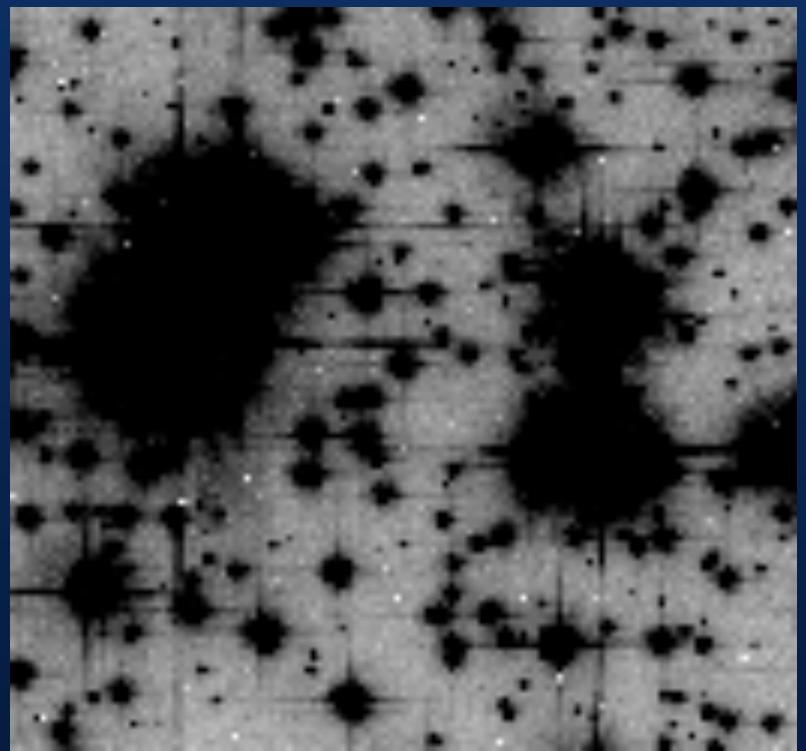


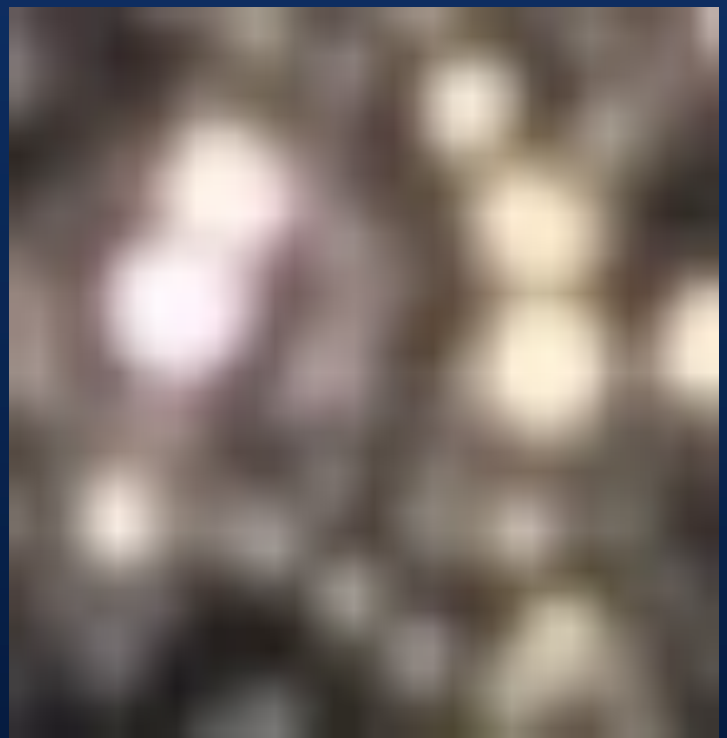




Left:
Space

Right:
Ground





Hubble Space Telescope (HST)

Hubble Against Earth's Horizon

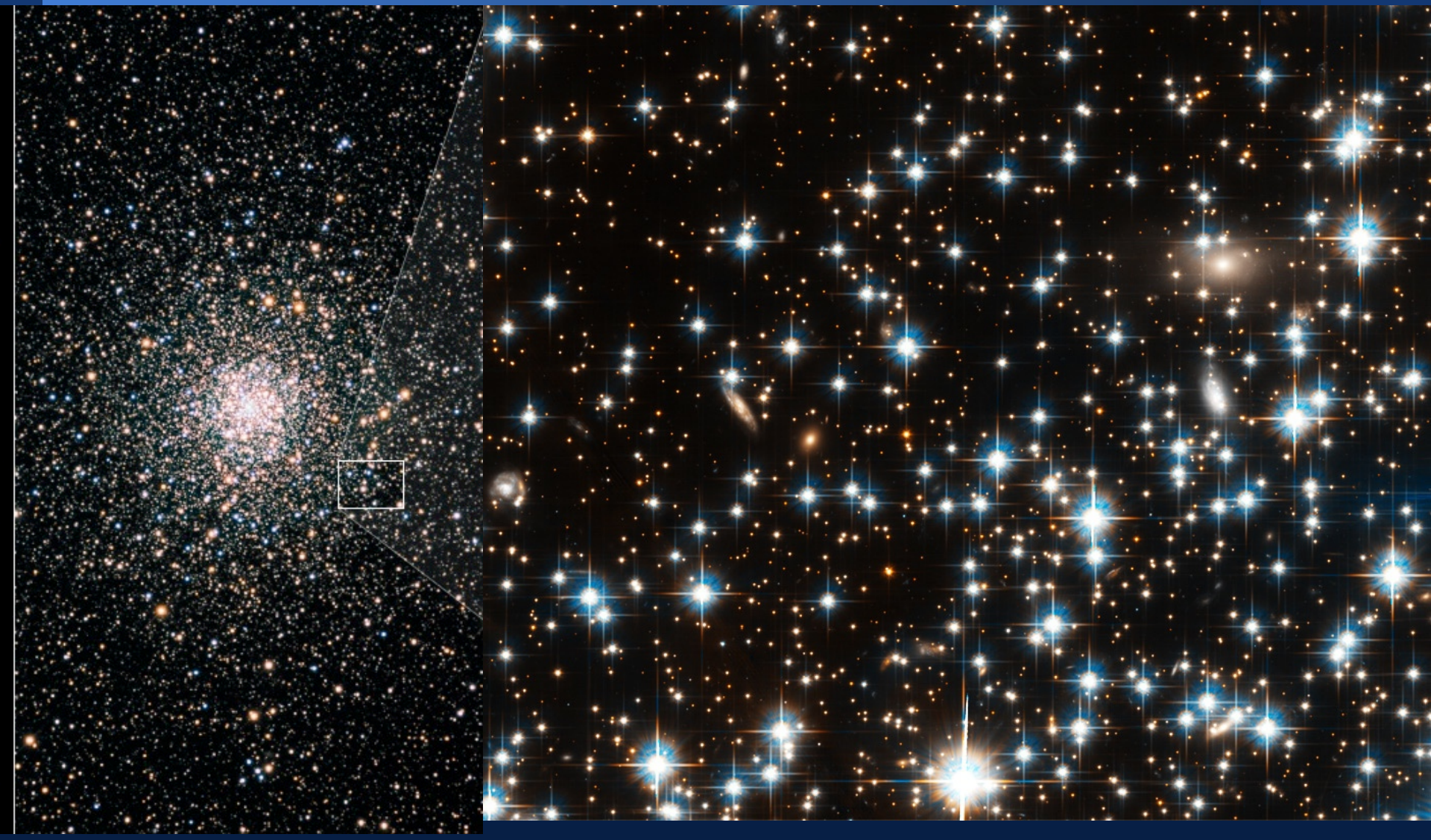
Image Credit: NASA, 1997

- 2.4m Reflector
- Launched 1990
- Orbits at 575 km
- Period 97 min
- UV to IR

Hubble Space Telescope (HST)

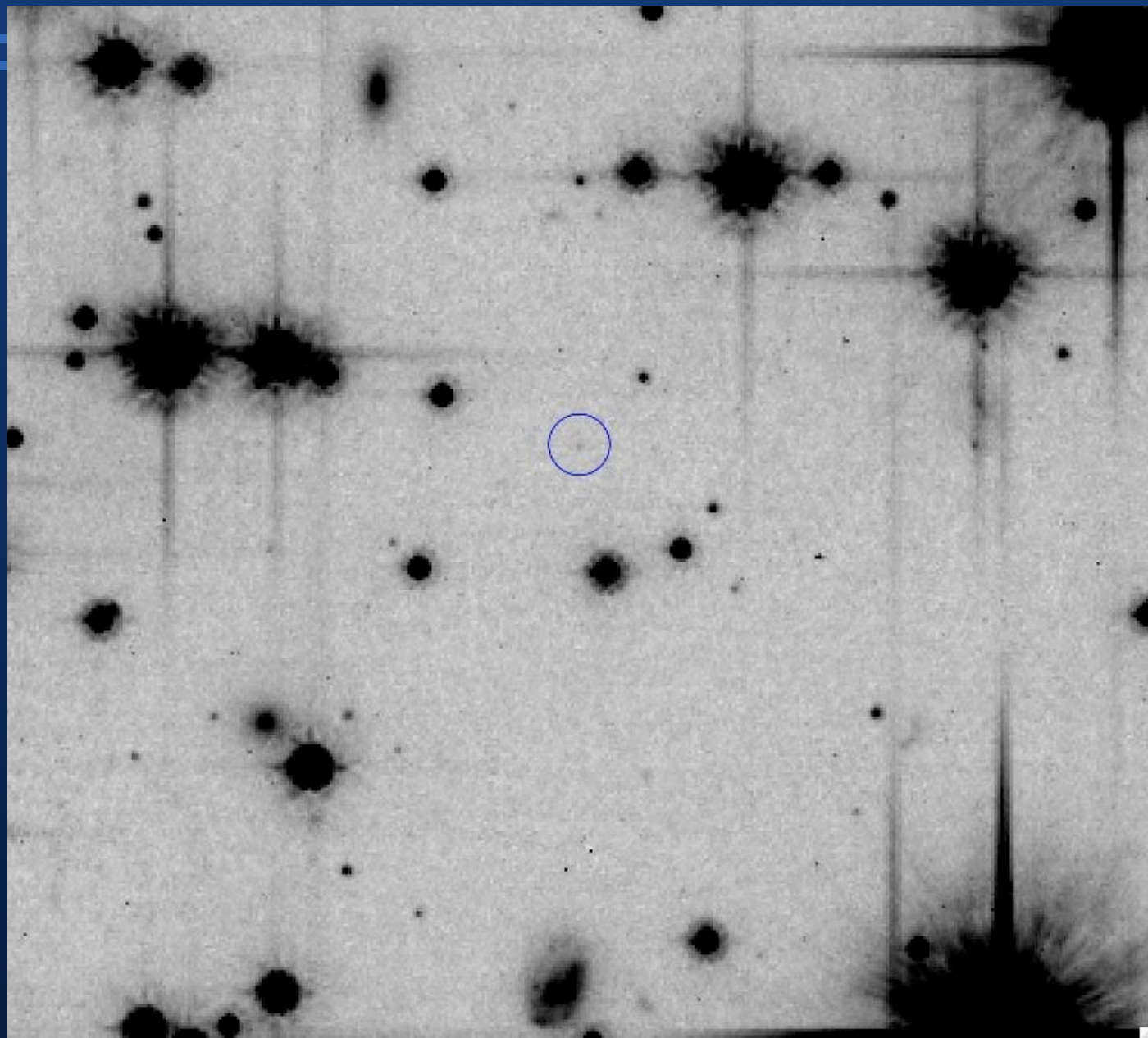
- 2.4m Reflector
- Launched 1990
- Orbits at 575 km
- Period 97 min
- UV to IR

A Superb Image from HST



Recent HST image obtained to measure age cluster

Proper-Motion Cleaning



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Getting Time on Hubble

- Write a proposal

Getting Time on Hubble

- Write a proposal

Hubble Space Telescope

Cycle 16 GO Proposal

Is 47 Tuc Young? Measuring its White Dwarf Cooling Age

Principal Investigator: Dr. Harvey B. Richer

Institution: University of British Columbia

Electronic Mail: richer@astro.ubc.ca

Scientific Category: RESOLVED STELLAR POPULATIONS

Scientific Keywords: ASTROMETRY, GALACTIC BULGE, GALACTIC HALO, GLOBULAR CLUSTERS, WHITE DWARFS

Instruments: WFPC2, NICMOS

Proprietary Period: 12

Orbit Request	Prime	Parallel
Cycle 16	194	194

Abstract

Several recent analyses have suggested that 47 Tuc is more than 2 Gyr younger than the Galactic halo. Others have suggested an age similar to that of the most metal-poor globular clusters. The current situation is clearly uncertain and obviously a new approach to age dating this important cluster is required. With this proposal we will firmly establish the age of 47 Tuc from its cooling white dwarfs. 47 Tuc is the nearest and least reddened of the metal-rich disk globular clusters. It is also the template used for studying the giant branches of nearby resolved galaxies. In addition, the age sensitive magnitude spread between the main sequence turnoff and horizontal branch is identical for 47 Tuc, two bulge globular clusters and the bulge field population. A precise relative age constraint for 47 Tuc, compared to the halo clusters M4 and NGC 6397, both of which we recently dated via white dwarf cooling, would therefore constrain when the bulge formed relative to the old halo globular clusters. With our high quality ACS data in NGC 6397, we were capable, with the technique of dating via white dwarf cooling, of determining ages to an accuracy of +/-0.5 Gyr at the 95% confidence level. With the current WFPC2 proposal we will not be able to reach this level of precision for ages as old as 11.5 Gyr, but will achieve this if the cluster turns out to be younger. Ages determined from the cluster turnoff are not currently capable of reaching this level of precision. The important role that 47 Tuc plays in galactic formation studies, and as the metal-rich template for the globular clusters, makes the case for a white dwarf cooling age for this metal-rich cluster compelling.

Getting Time on Hubble

- Write a proposal
- It gets peer reviewed

Getting Time on Hubble

- **Write a proposal**
- **It gets peer reviewed**
- **It gets rejected**

March 30, 2007
Dear Dr. Richer,

We regret to inform you that following the peer review process your proposal:
Title: Is 47 Tuc Young? Measuring its White Dwarf Cooling Age
for Hubble Space Telescope Cycle 16 General Observer time has not been approved.

Your proposal received detailed consideration by the the Cycle 16 Peer Review Panels and final review by the STScI Director. Your proposal was graded in the third quartile of proposals in your Panel, with the first quartile being the top proposals before the panel.

Getting Time on Hubble

- Write a proposal
- It gets peer reviewed
- It gets rejected
- Edit, submit again

Hubble Space Telescope Cycle 17 GO Proposal <ID>

Is 47 Tuc Young? Measuring its White Dwarf Cooling Age and Completing a Hubble Legacy

Principal Investigator: Dr. Harvey B. Richer
Institution: University of British Columbia
Electronic Mail: richer@astro.ubc.ca

Scientific Category: RESOLVED STELLAR POPULATIONS
Scientific Keywords: Astrometry, Galactic Bulge, Galactic Halo, Globular Clusters, White Dwarfs
Instruments: ACS, WFC3
Proprietary Period: 12

Orbit Request	Prime	Parallel
Cycle 17	121	121

Abstract

With this proposal we will firmly establish the age of 47 Tuc from its cooling white dwarfs. 47 Tuc is the nearest and least reddened of the metal-rich disk globular clusters. It is also the template used for studying the giant branches of nearby resolved galaxies. In addition, the age sensitive magnitude spread between the main sequence turnoff and horizontal branch is identical for 47 Tuc, two bulge globular clusters and the bulge field population. A precise relative age constraint for 47 Tuc, compared to the halo clusters M4 and NGC 6397, both of which we recently dated via white dwarf cooling, would therefore constrain when the bulge formed relative to the old halo globular clusters. Of particular interest is that with the higher quality ACS data on NGC 6397, we are now capable with the technique of white dwarf cooling of determining ages to an accuracy of +/- 0.4 Gyrs at the 95% confidence level. Ages derived from the cluster turnoff are not currently capable of reaching this precision.The important role that 47 Tuc plays in galaxy formation studies, and as the metal-rich template for the globular clusters, makes the case for a white dwarf cooling age for this metal-rich cluster compelling.

Several recent analyses have suggested that 47 Tuc is more than 2 Gyrs younger than the Galactic halo. Others have suggested an age similar to that of the most metal poor globular clusters. The current situation is clearly uncertain and obviously a new approach to age dating this important cluster is required.

With the observations of 47 Tuc, this project will complete a legacy for HST. It will be the third globular cluster observed for white dwarf cooling; the three covering almost the full metallicity range of the cluster system. Unless JWST has its proposed bluer filters (700 and 900 nm) this science will not be possible perhaps for decades until a large optical telescope is again in space. Ages for globular clusters from the main sequence turnoff are less precise than those from white dwarf cooling making the science with the current proposal truly urgent.

Getting Time on Hubble

- Write a proposal
- It gets peer reviewed
- It gets rejected
- Edit, submit again
- It gets accepted!!

May 29, 2008
Dear Dr. Richer,

We are pleased to inform you that your Hubble Space Telescope Cycle 17 proposal Title: Is 47 Tuc Young? Measuring its White Dwarf Cooling Age and Completing a Hubble Legacy has been approved for Hubble Space Telescope Cycle 17 General Observer time, following detailed consideration by the Cycle 17 Peer Review Panels and final review by the STScI Director.

Your proposal was graded in the first quartile of proposals in your Panel, with the first quartile being the top proposals before the panel.

Getting Time on Hubble

- **Write a proposal**
- **It gets peer reviewed**
- **It gets rejected**
- **Edit, submit again**
- **It gets accepted!!**
- **It gets delayed**

As Cycle 17 PIs, you are no doubt as disappointed in the delay of Hubble Servicing Mission 4(SM4) as we at STScI are. We were eagerly anticipating the installation of two new instruments, the repair of two old instruments, and the exciting discoveries these actions will enable. The purpose of this note is to inform you, as best we can in this fluid situation, of our expectations and plans for SM4 and Cycle 17.

Getting Time on Hubble

- **Write a proposal**
- **It gets peer reviewed**
- **It gets rejected**
- **Edit, submit again**
- **It gets accepted!!**
- **It gets delayed**
- **And finally you get data**

One or more observations from the following HST proposal have been scheduled for execution on SMS 100187C2. The SMS begins 18-JAN-2010 00:00:00 (UT) and ends 25-JAN-2010 00:00:00(UT). No action is required on your part unless you have a Real Time Contact. Please contact your Program Coordinator if you have any questions. Proposal Id:11677 Title: Is 47 Tuc Young? Measuring its White Dwarf Cooling Age and Completing a Hubble Legacy

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Short History of White Dwarfs

1844: ‘Sirius Wobbles’ as it moves through space - invisible companion

1862: Sirius B discovered & photographed - blue not red

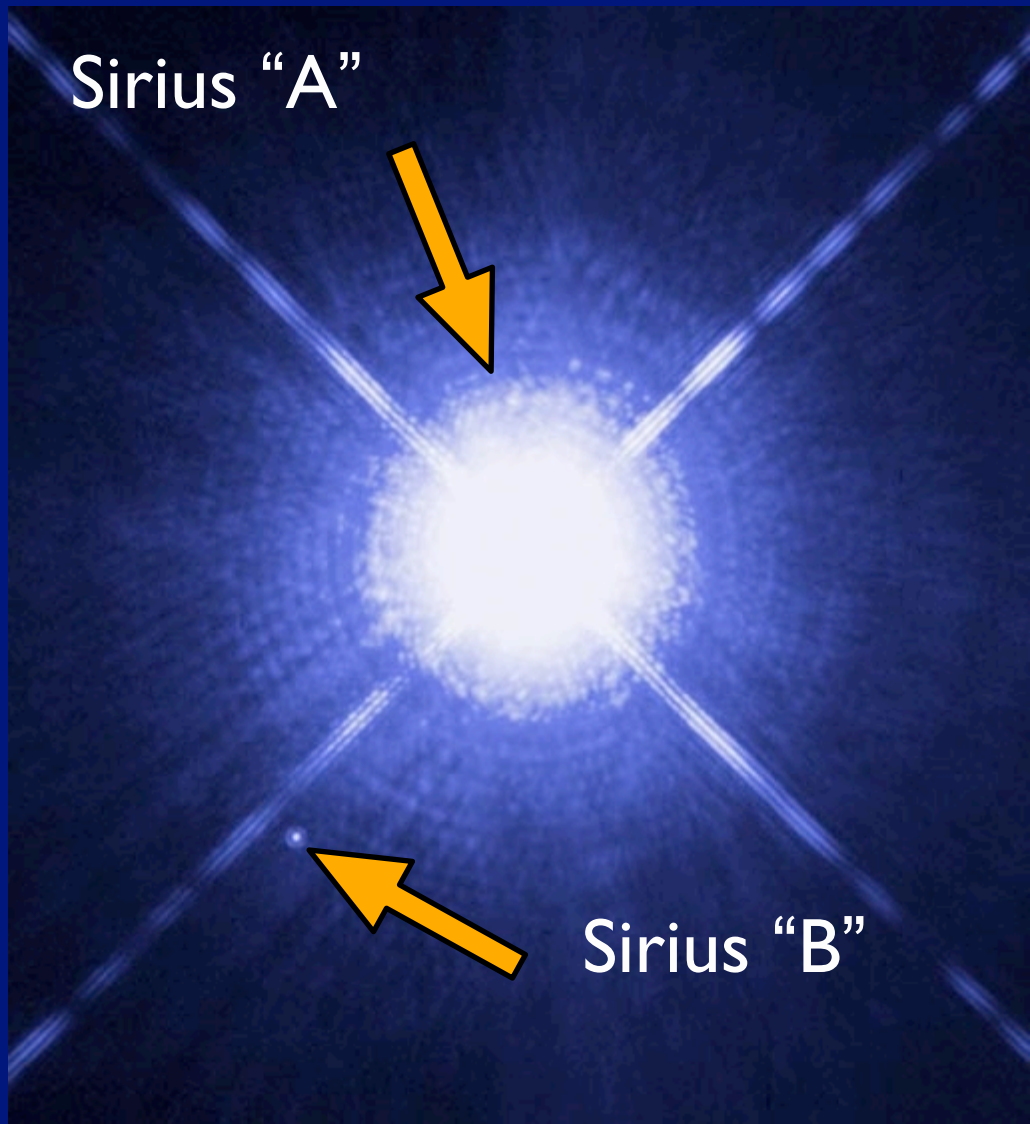
1930’s: Structure explained with quantum mechanics

This is how this talk fits in with those in a series on

Measuring Ages using White Dwarfs

White Dwarfs are small, hot, compact stars.

The name comes from the companion to Sirius, which is hotter (hence "white" as in "white hot") but also fainter, implying that it is also much smaller (hence "dwarf")

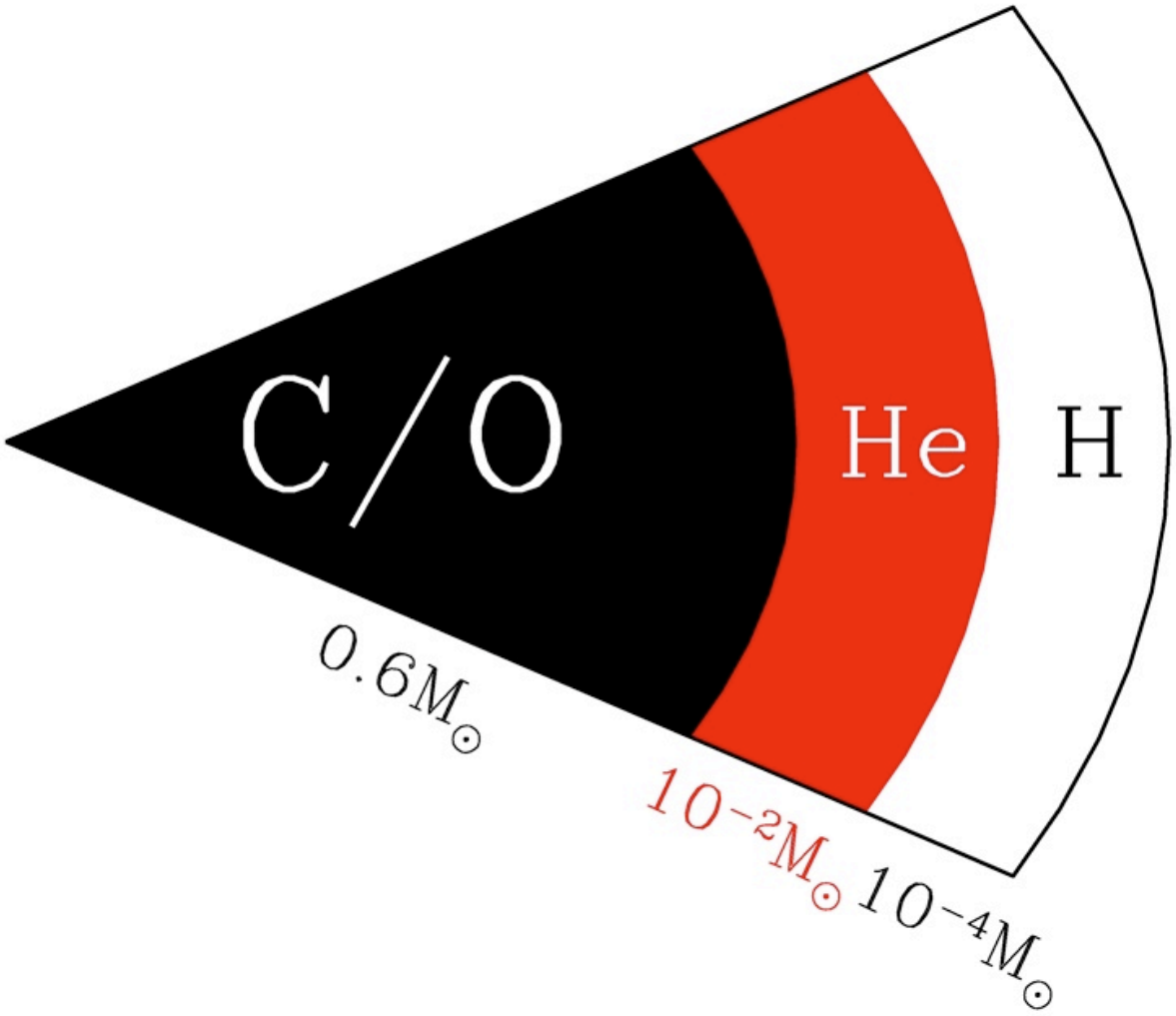


White Dwarfs are the End Product of Stellar Evolution

Stars like the sun will eventually run out of fuel for their nuclear reactions

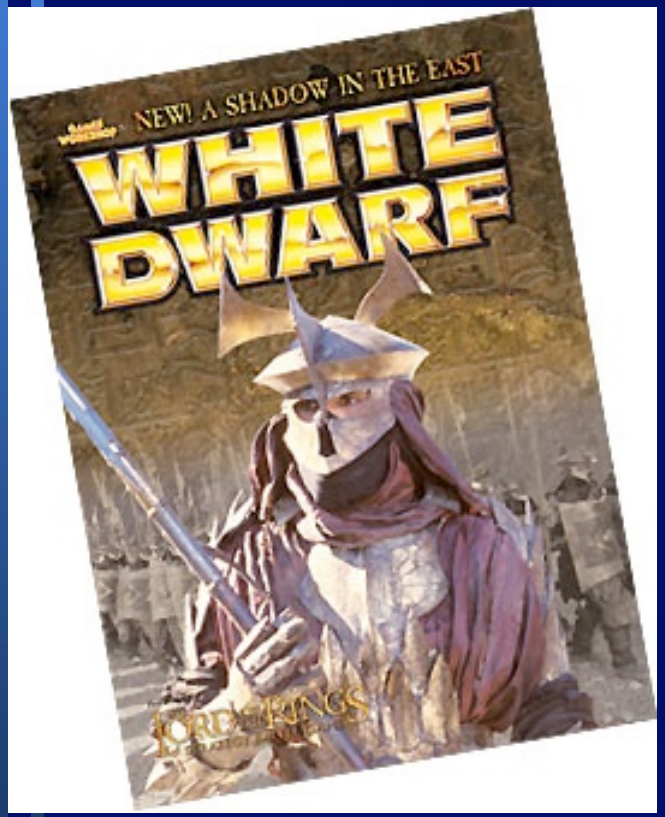
What remains is the burnt out core - the white dwarf

White Dwarfs are Essentially Giant Diamonds



Before the star became a white dwarf, it "burned" hydrogen into helium, carbon, and oxygen in nuclear reactions

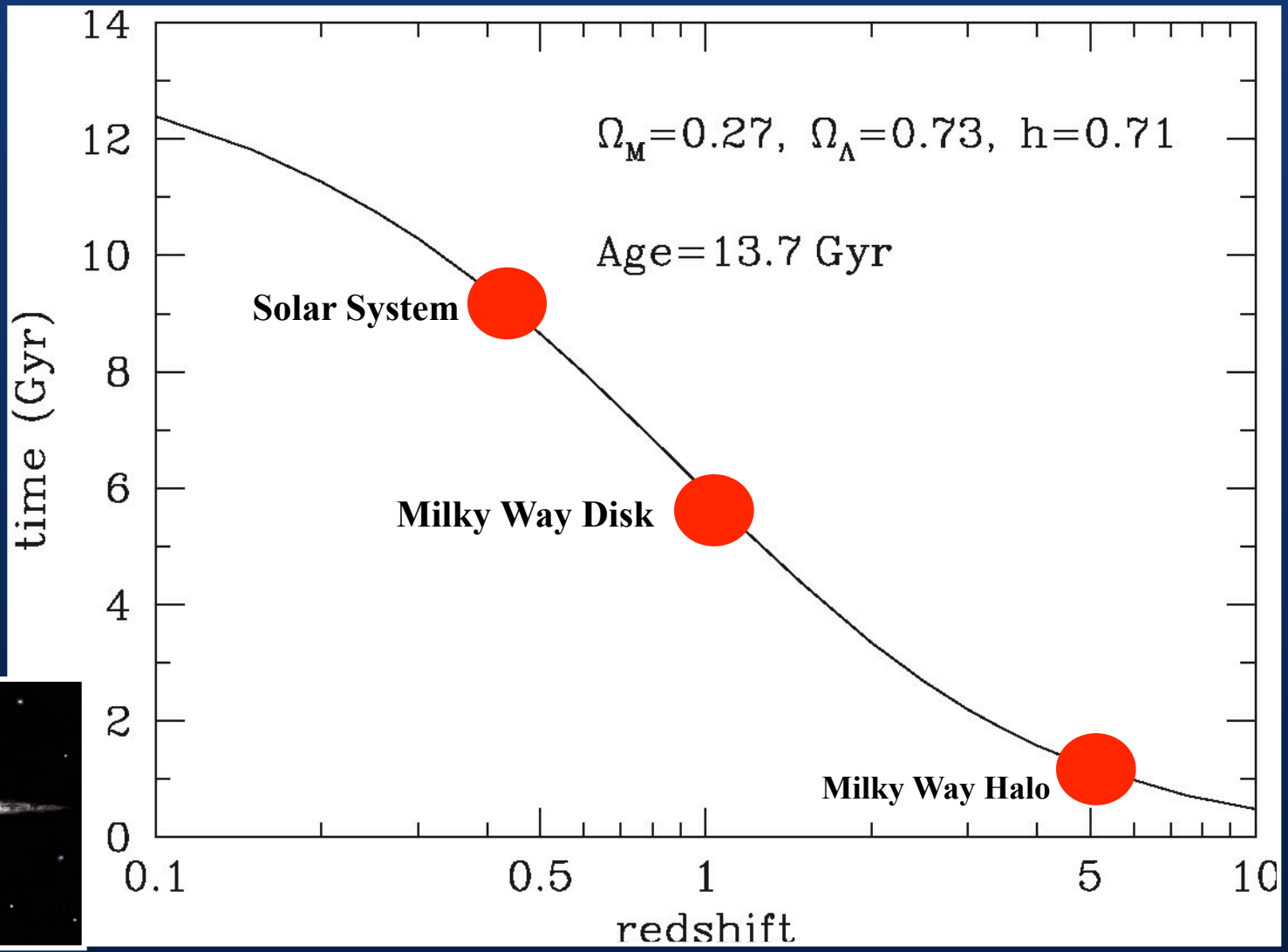
Modeling the White Dwarf Evolution



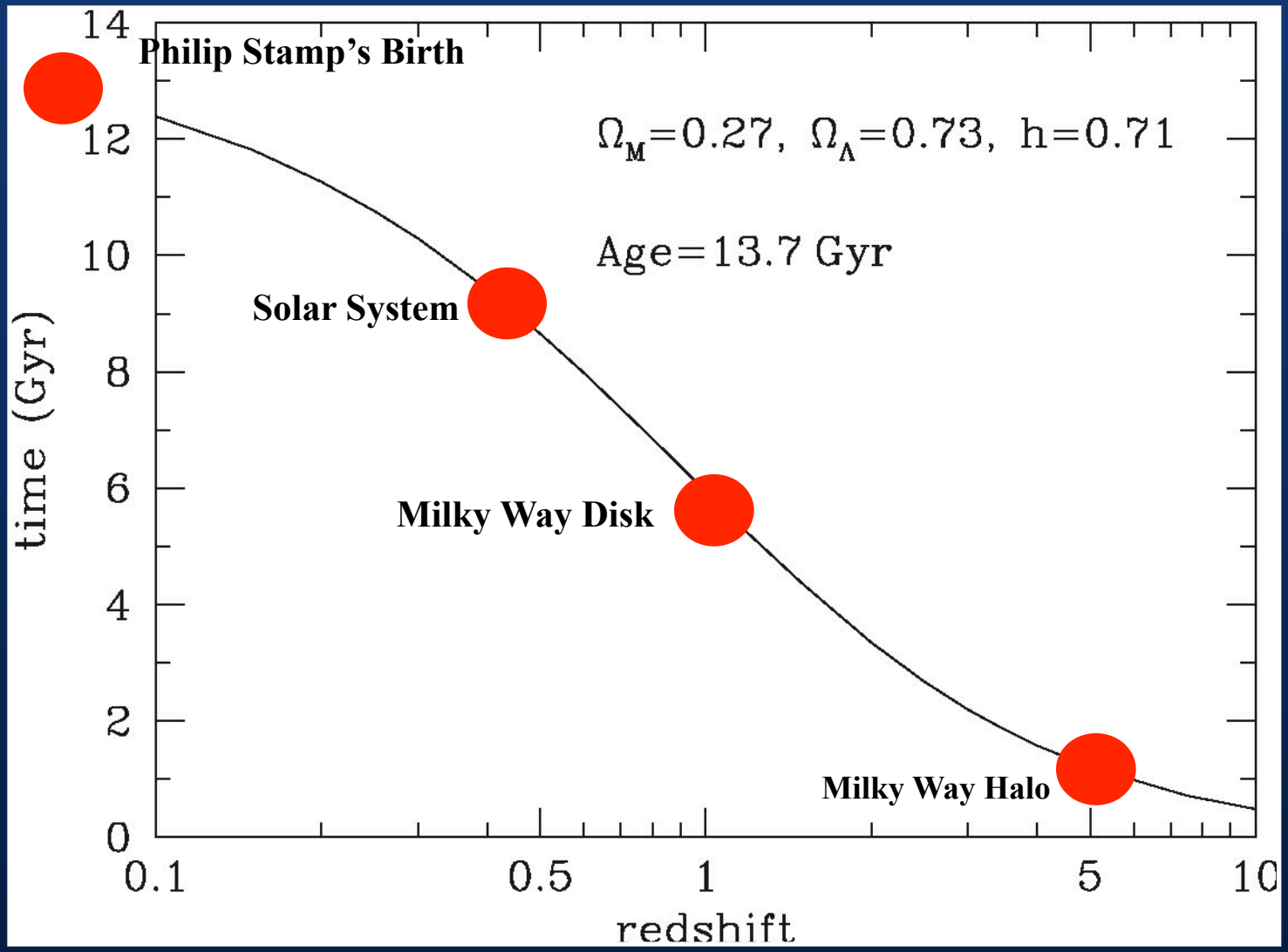
White dwarfs are born hot and then cool slowly over time.

We model this cooling process in order to determine how long it takes for a star to reach the observed temperature. This gives us an estimate of the age.

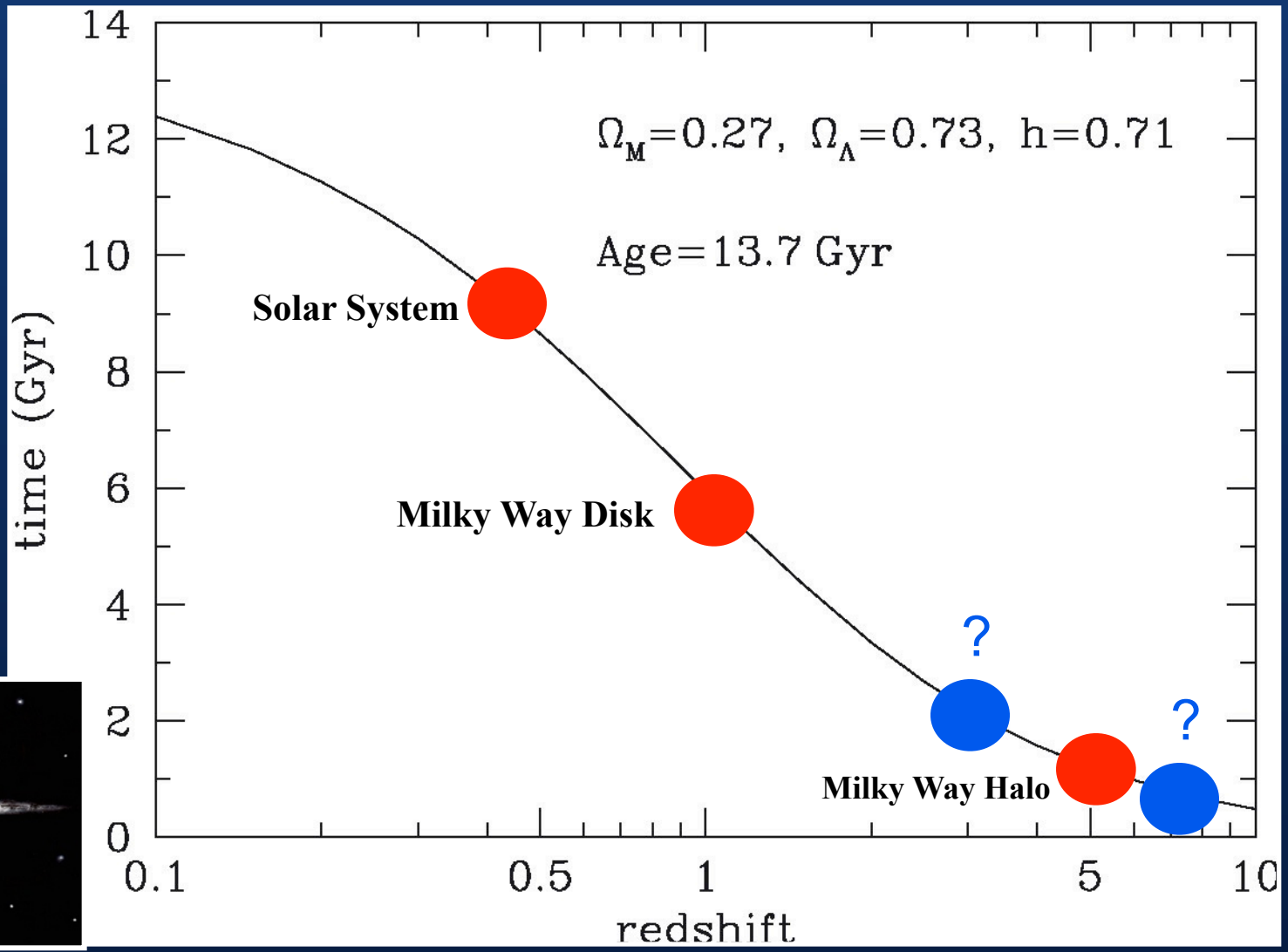
Major Events in the Universe



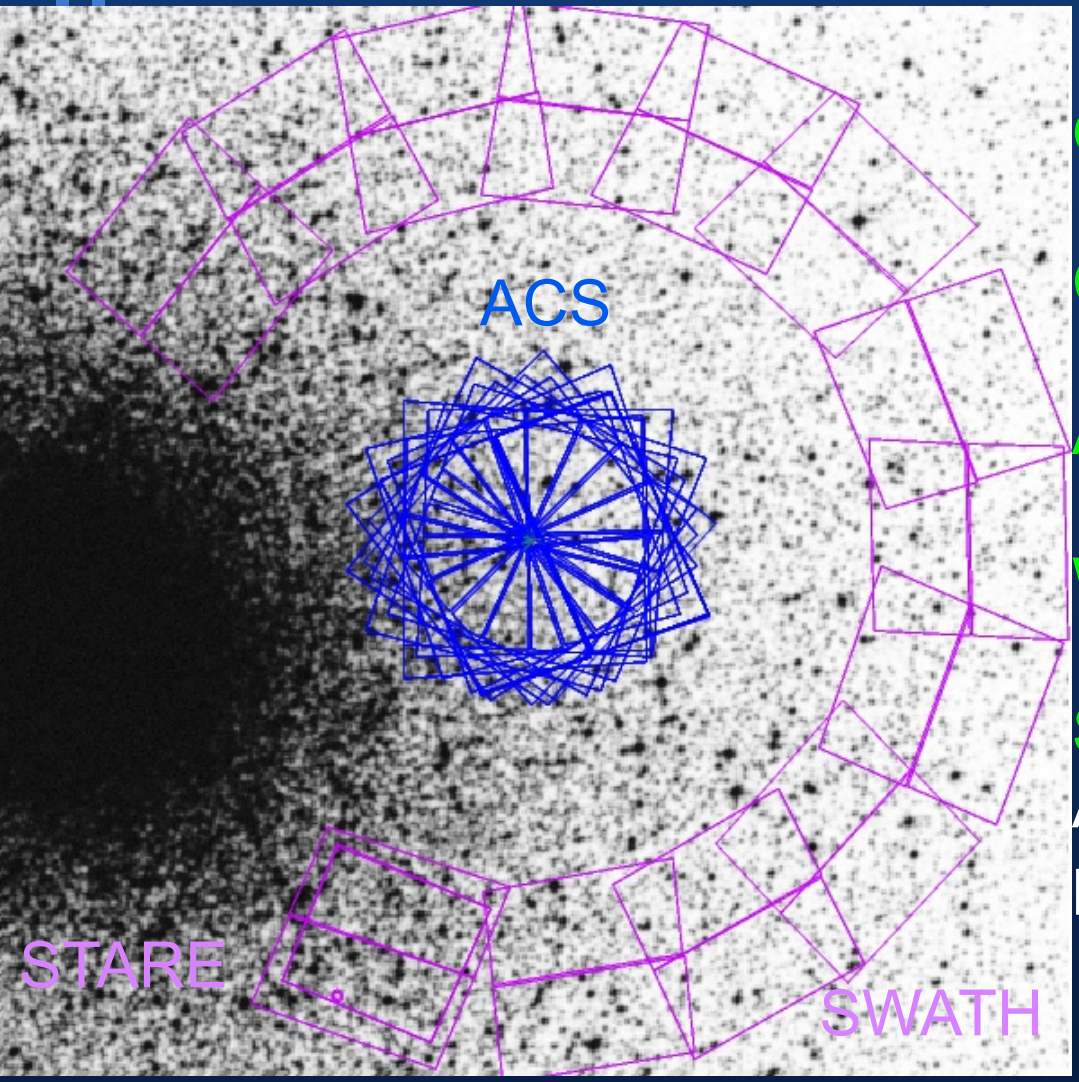
Major Events in the Universe



Major Events in the Universe



Ancient Cluster 47 Tuc



Orbits 121 (4% all time 2010)

Cameras 2 simultaneously

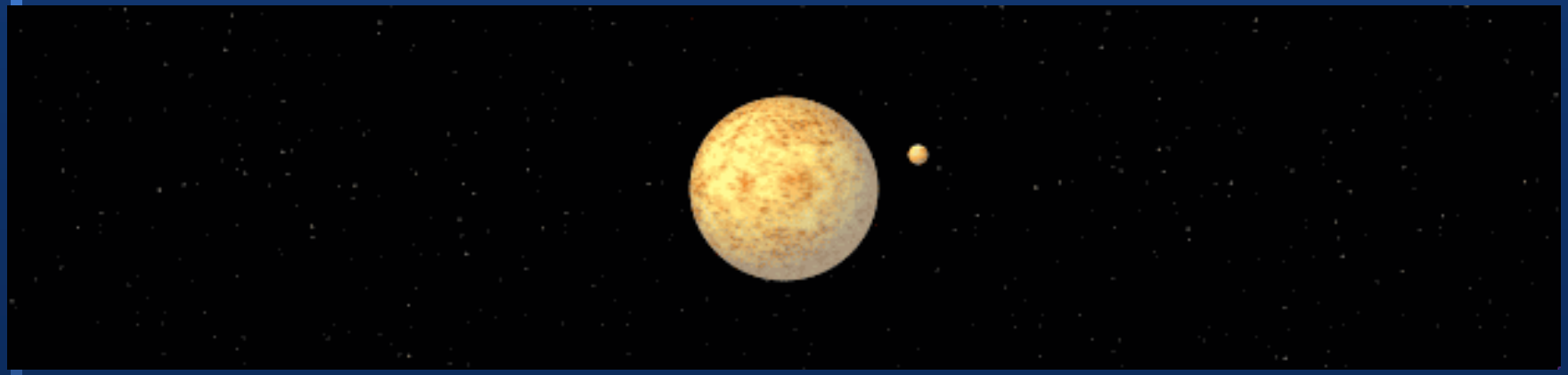
ACS Optical

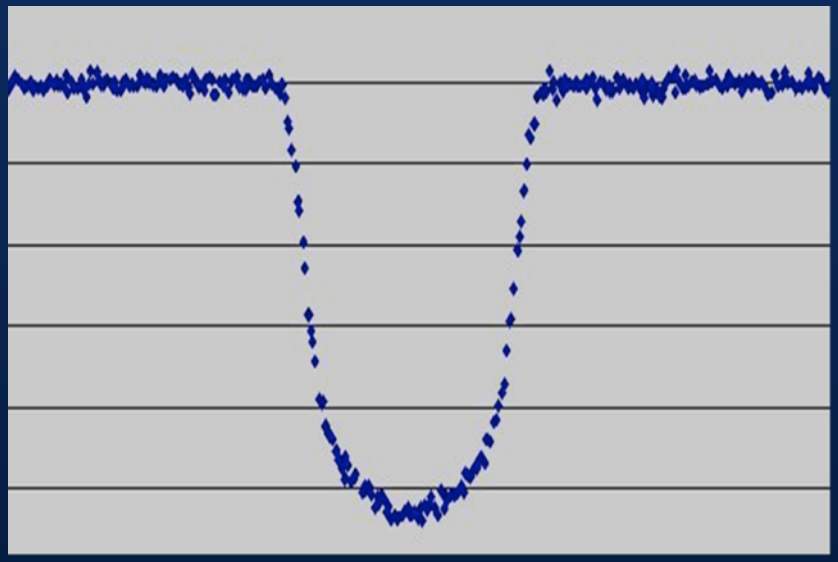
WFC3 UV and IR

Science
Age, binary, variables, planets, coolest stars,

Other Science

Search for planets





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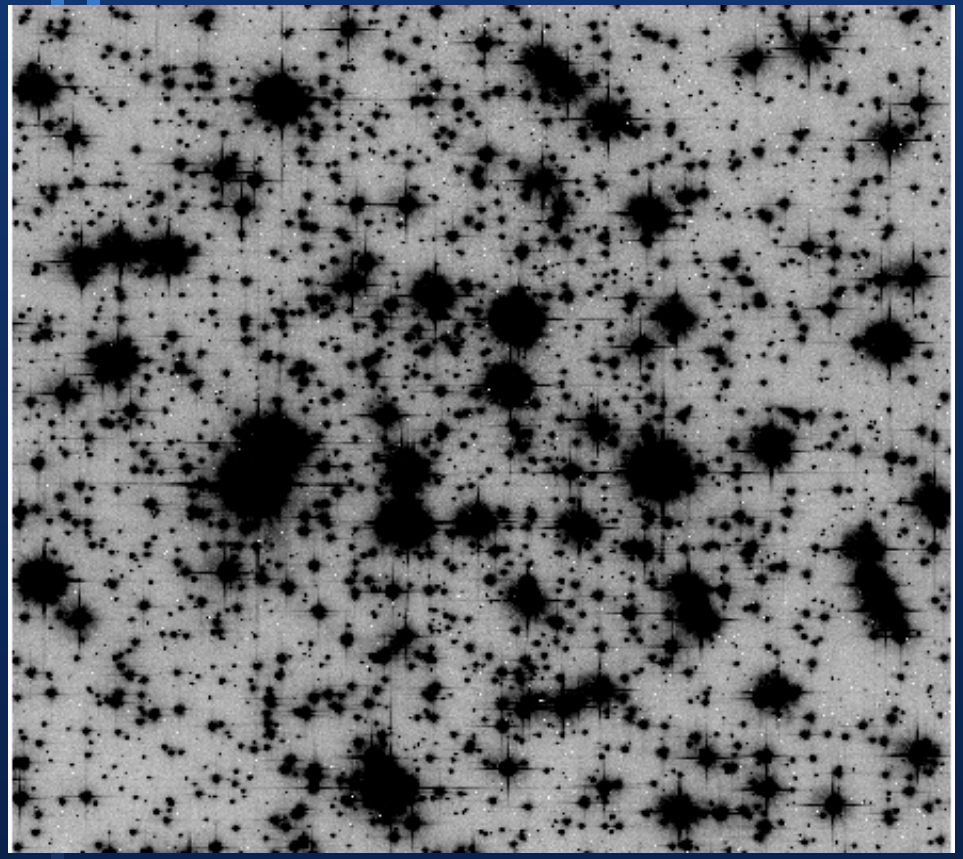
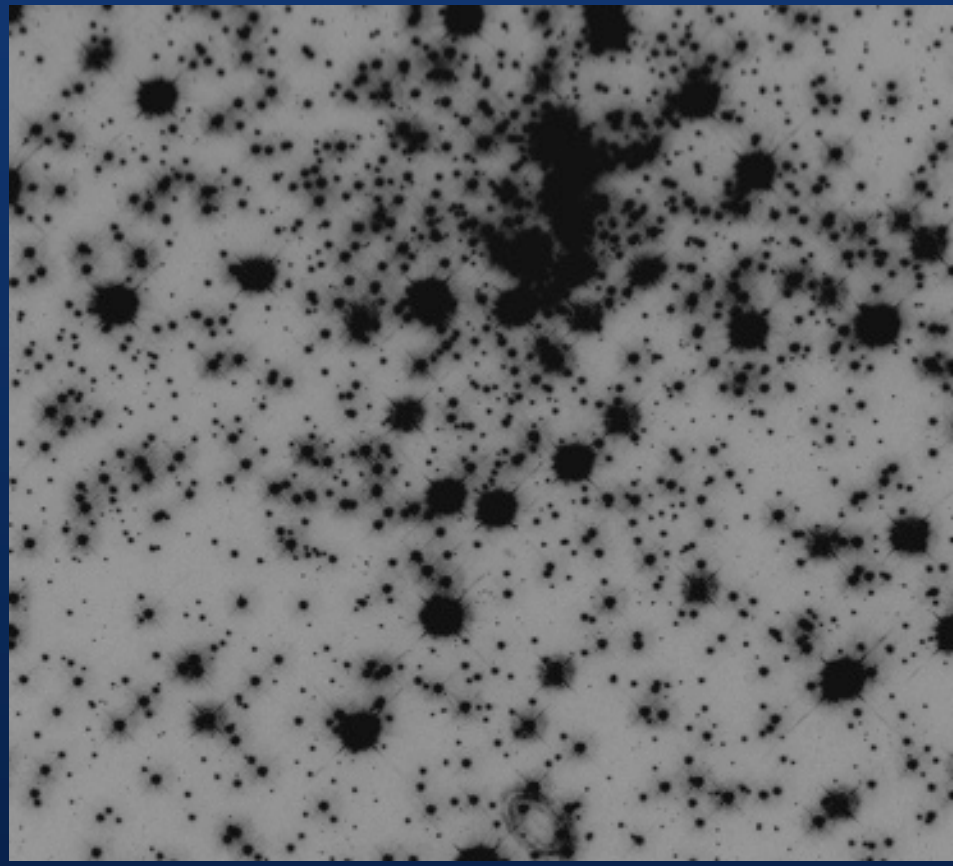
Cores Two Globular Clusters



M71 - Fluffy Core
(The Norm)



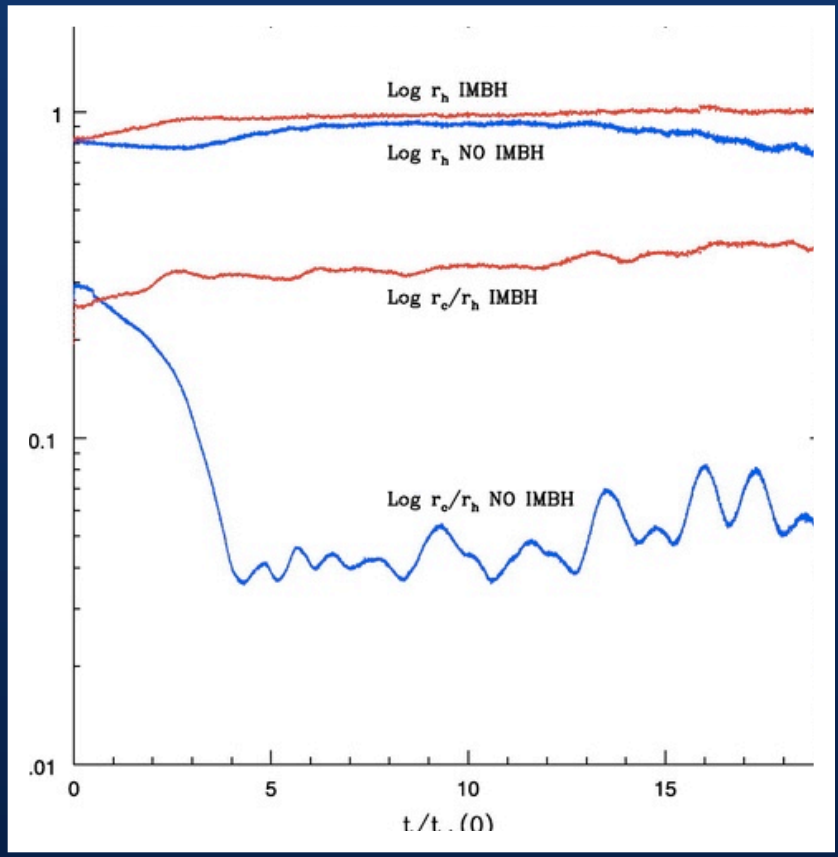
NGC 6397 - Collapsed Core
(Unusual)

Claim: Occurrence of Black Holes in Globular Clusters is High

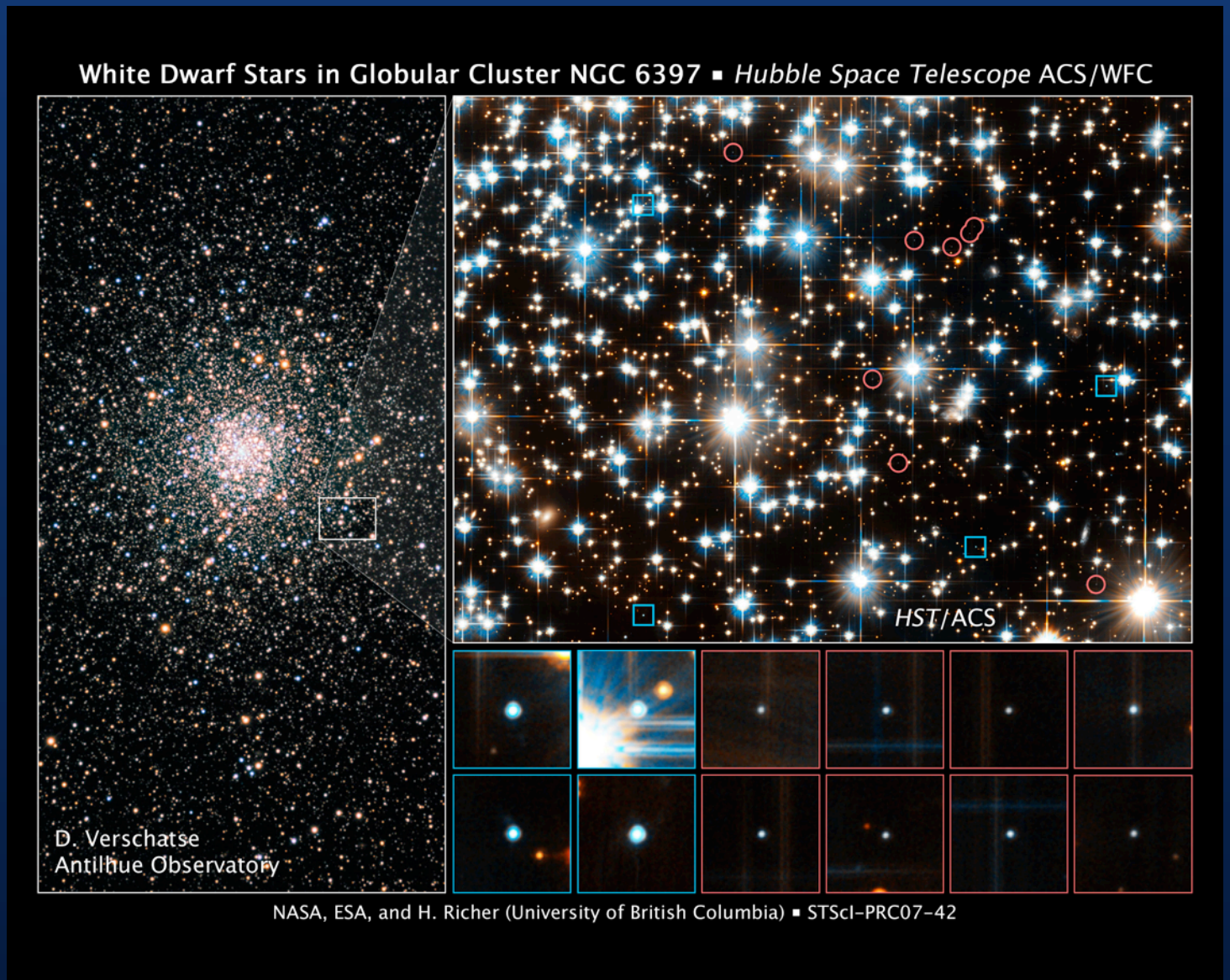
Why? Needed to understand why so many are "FLUFFY"

"Only presence of a Black Hole appears to be consistent with such large core radius values" Trenti (2006)

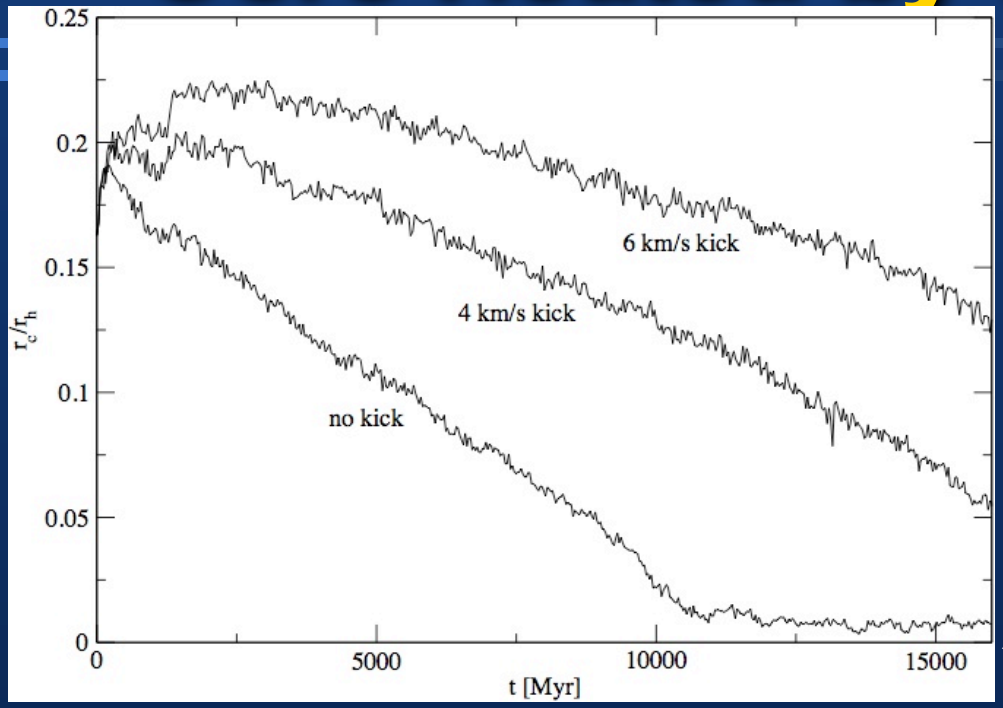
"presence of a Black Hole prevents core collapse" Gill et al. (2008)



Black Holes suggested as another heat source ignored - “kicked” white dwarfs



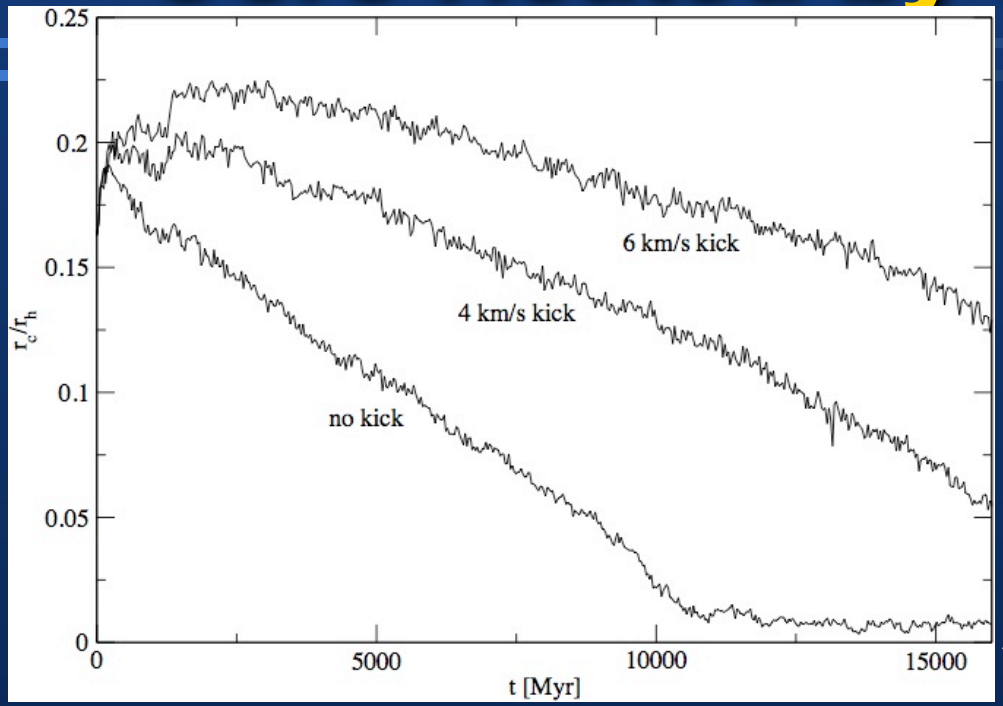
Core Heated by Kicked WDs



No need for Black Hole

Fregeau & Richer 2009

Core Heated by Kicked WDs



No need for Black Hole

Fregeau & Richer 2009

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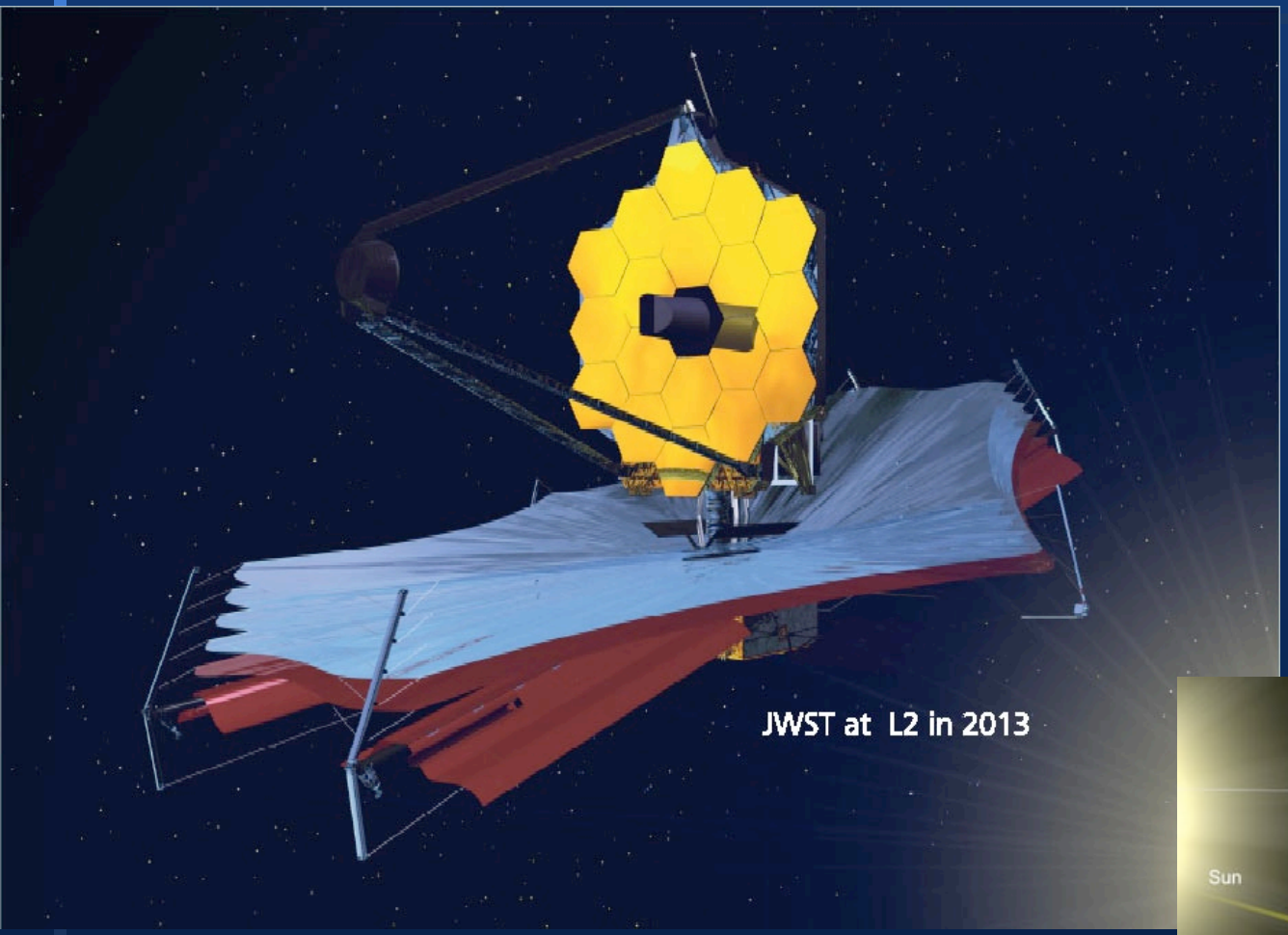
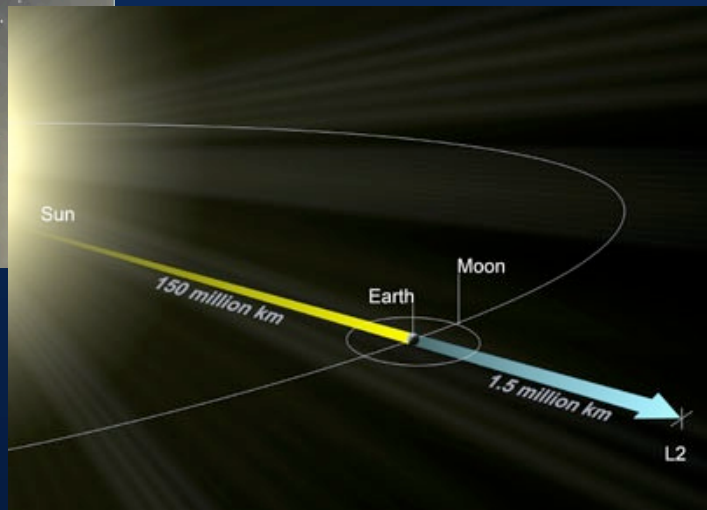
The Future - No HST!!

- Space - No HST?
- Space - JWST
- Ground ELTs

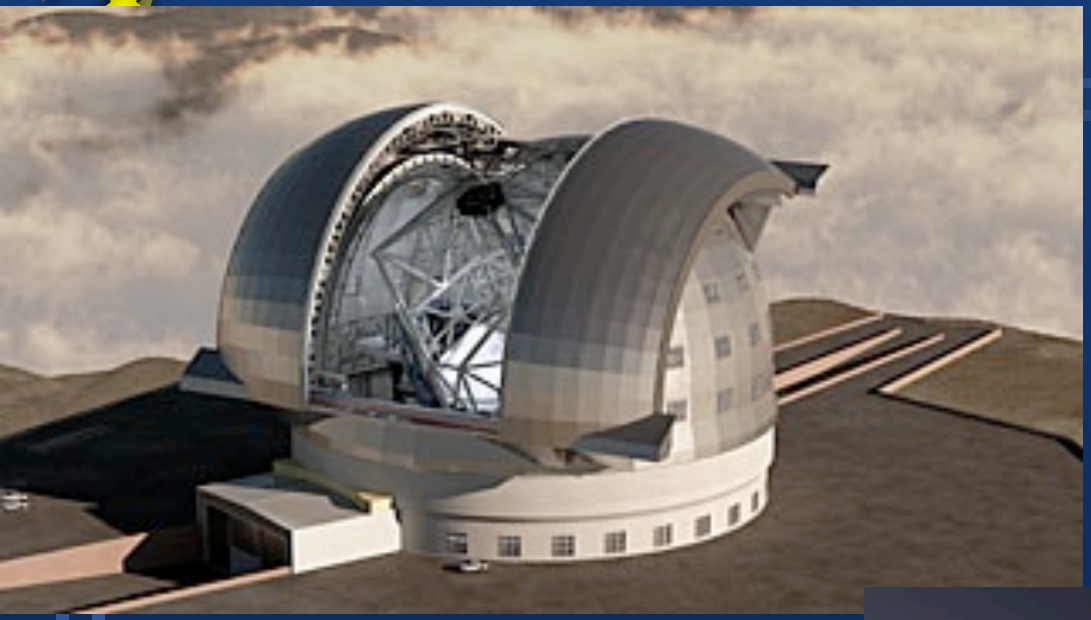
James Webb Space Telescope (JWST)



- 6.5m Reflector
- Launch 2015?
- Orbits at L2
- Period 1 year
- IR

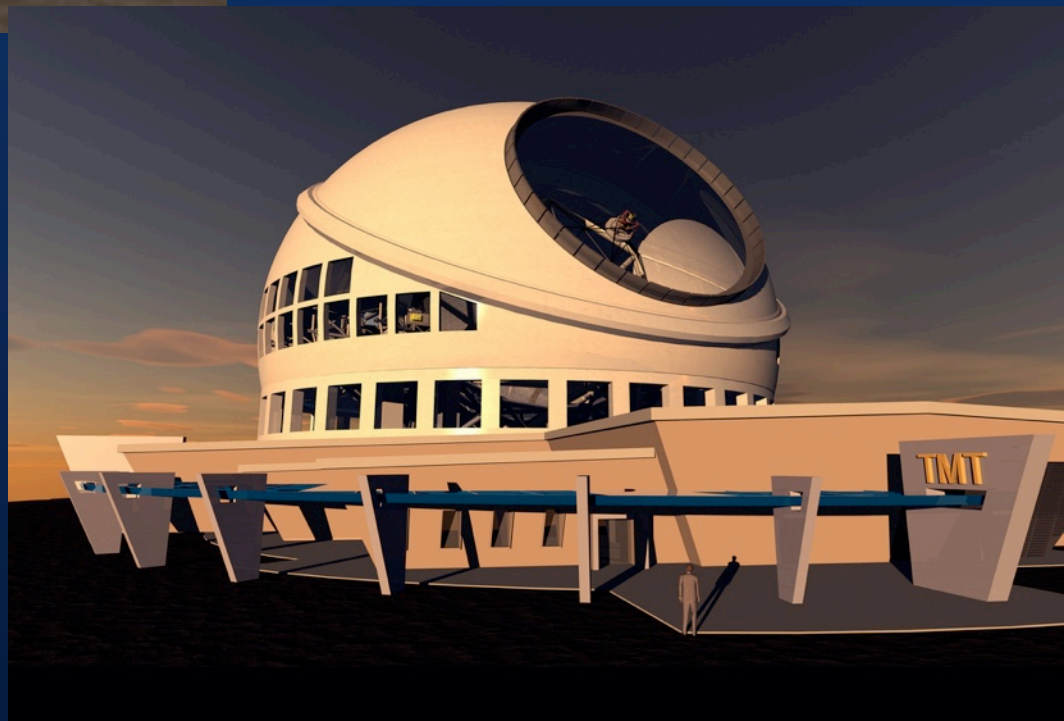


Large Ground-Based Telescopes



E-ELT 42m Chile

TMT 30m Hawaii



Thanks