Hubble Science Briefing: 25 Years of Seeing Stars with the Hubble Space Telescope

March 5, 2015
Dr. Rachel Osten
Dr. Alex Fullerton
Dr. Jay Anderson
Hubble’s Insight into the Lives of Stars Comes From:

- Better image clarity: no atmosphere, no blurring means higher spatial resolution
- Access to ultraviolet wavelengths: not possible from the ground
Outline

• Rachel Osten - cool stars
• Alex Fullerton - massive stars
• Jay Anderson – globular clusters
The UV spectrum of a Sun-like star

Hot gas (>10,000 K) means that many elements are ionized. Hotter than the visible surface of the star (Sun=5800 K).

Linsky & Wood 1994
The UV spectrum of a Sun-like star

Alpha Cen A at higher spectral resolution than UV spectra from the Sun!

Pagano et al. 2004
The UV spectrum of a Sun-like star

Linsky & Wood 1994

Dynamics of the atmosphere
The UV spectrum of a Sun-like star

The changing of a star’s intensity with time on these short timescales is due to heating from flares occurring in the atmosphere of the star

Hawley et al. (2003)
Stars Blow Bubbles in Space
Stars Blow Bubbles in Space

Wood et al. 1995
Stars Blow Bubbles in Space

Wood et al. 2002
Stars Blow Bubbles in Space

Linsky et al. 2010
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Massive Stars

Massive stars are also luminous stars.

1 Solar Mass
1 Solar Radius
1 Solar Luminosity
T = 5,800 Kelvin

Massive stars can be luminous because they are
• hot and compact
• hot and large
• cool and very large

4 - 300 (?) Solar Masses
3,000,000 Solar Luminosities

Temperature: 10,000 – 50,000 Kelvin
Radius:

- 2 – 15 Solar Radii
- 30 Solar Radii “Blue” supergiants

T = 7,500 – 3,600 Kelvin
R = 80 = 8,000 Solar Radii “Red” supergiants

The Kelvin Temperature Scale: \[ K = \frac{5}{9}(F - 32) + 273.15 \]
The R136 star cluster hosts several stars whose individual masses greatly exceed the accepted $150M_\odot$ stellar mass limit

Paul A. Crowther,1* Olivier Schnurr,1,2 Raphael Hirschi,3,4 Norhasliza Yusof,5 Richard J. Parker,1 Simon P. Goodwin1 and Hasan Abu Kassim5

1Department of Physics and Astronomy, University of Sheffield, Sheffield S3 7RH
2Astrophysical Institute Potsdam, An der Sternwarte 16, D-14482 Potsdam, Germany
3Astrophysics Group, EPSAM, University of Keele, Leonard-Jones Labs, Keele ST5 5BG
4Institute for the Physics and Mathematics of the Universe, University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa 277-8583, Japan
5Department of Physics, University of Malaya, 50603 Kuala Lumpur, Malaysia

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"P Cygni Profiles" tell us about mass loss via a "stellar wind"
FIRST IMAGE OF THE SURFACE OF A STAR WITH THE HUBBLE SPACE TELESCOPE

RONALD L. GILLILAND
Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218

AND

A. K. DUPREE
Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138

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Atmosphere of Betelgeuse

Size of Star

Size of Earth’s Orbit

Size of Jupiter’s Orbit

HST · FOC

PRC96-04 · ST ScI OPO · January 15, 1995 · A. Dupree (CfA), NASA
The Carinae Region: A Cauldron of Hot, Massive Stars

This spectacular montage was created to celebrate the 17th anniversary of Hubble’s deployment. It is composed of many separate exposures with Hubble’s Advanced Camera for Surveys (ACS) and ground-based images from the Cerro Tololo Inter-American Observatory (CTIO). For a fuller appreciation of its information content, explore the “zoomable” version: [http://hubblesite.org/newscenter/archive/releases/2007/16/image/a/format/zoom/](http://hubblesite.org/newscenter/archive/releases/2007/16/image/a/format/zoom/)
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Eta Carinae
Hubble Space Telescope

WFPC2

He Ar FeFe Ni Ni Fe Ni Fe

STIS/CCD G750M

NASA, ESA, and the Hubble SM4 ERO Team
STScI-PRC09-25i
LATITUDE-DEPENDENT EFFECTS IN THE STELLAR WIND OF η CARINAE

NATHAN SMITH AND KRIS DAVIDSON
Astronomy Department, University of Minnesota, 116 Church Street SE, Minneapolis, MN 55455

THEODORE R. GULL
Laboratory for Astronomy and Space Science, NASA Goddard Space Flight Center, Greenbelt, MD 20771

KAZUNORI ISHIBASHI
Center for Space Research, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA 02139

AND

D. JOHN HILLIER
Department of Physics and Astronomy, University of Pittsburgh, 3941 O'Hara Street, Pittsburgh, PA 15260

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RESOLVING OB SYSTEMS IN THE CARINA NEBULA WITH THE HUBBLE SPACE TELESCOPE FINE GUIDANCE SENSOR

EDMUND P. NELAN AND NOLAN R. WALBORN
Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218; nelan@stsci.edu, walborn@stsci.edu

DEBRA J. WALLACE
Center for High Angular Resolution Astronomy, Department of Physics and Astronomy, Georgia State University, Atlanta, GA 30303;
wallace@chara.gsu.edu

ANTHONY F. J. MOFFAT
Département de Physique, Université de Montréal, C.P. 6128, Succursale Centre-Ville, Montréal, QC HC3 3J7, Canada;
moffat@astro.umontreal.ca

RUSSELL B. MAKIDON
Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218; makidon@stsci.edu

DOUGLAS R. GIES
Center for High Angular Resolution Astronomy, Department of Physics and Astronomy,
Georgia State University, Atlanta, GA 30303; gies@chara.gsu.edu

AND

NINO PANAGIA
Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218;
panagia@stsci.edu

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“S-Curve” from an FGS scan of a point source.

Actual WFPC2 and simulated FGS Observations of a 168 mas binary system.

Although the binary in this example is clearly resolved by the WFPC2 Planetary Camera (PC) (Niemela et al. 1999), the FGS could measure the component separation and relative brightness with greater accuracy (± 1 mas v. ± 30 mas).

Simulated WFPC2 and FGS Observations of a 70 mas binary system.

Although a PC detection would be questionable at 70 mas, the FGS clearly isn’t challenged in detecting duplicity and measuring separations. Detections of duplicity down to 7 mas are possible with the FGS.
Component A is also a binary!
NGC 3603
HST/ACS
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Plan

(1) Globular Clusters before HST
(2) Globular Clusters with HST
(3) Globular Clusters with 25 years of HST
Globular Clusters

• “Textbook” simple stellar populations
  – Formed stars early
  – Single cloud, single metallicity, single age
  – Not large enough to self-enrich
  – Continue orbiting in spheroid of Galaxy

• Perfect fossil laboratories to evaluate stellar evolution
$\omega$ Centauri

Early Release Field
What Astronomers see…

http://hubblesite.org/newscenter/archive/releases/2010/28/
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What Astronomers see…

1) Main Sequence
2) SubGiant Branch
3) Red Giant Branch
4) Horizontal Branch
5) White Dwarf Sequence

http://hubblesite.org/newscenter/archive/releases/2010/28/
Easy to identify stars…
Stellar Populations

One line means:
- same age
- same metallicity
- same distance

→ same small cloud

“test of good photometry”
Plan

(1) Globular Clusters before HST
(2) Globular Clusters with HST
(3) Globular Clusters with 25 years of HST
Globular Cluster or Dwarf Spheroidal?
Stellar Populations

- More metals
- More helium
- Age

Red Giant Branch

Similar to galaxies...

metal poor

metal rich
Is Omega Cen a GC?

Could the textbook globular cluster not be one?

M54  

47Tuc

NGC 6388  

N6388


N2808

N6656
Is Omega Cen a globular?

Are there any globular clusters?

Questions to answer:
1) How does the enrichment happen?
2) Why are they all so different?
3) What connection is there between clusters and galaxies?
4) Any relevance for star formation going on today?
Plan

(1) Globular Clusters before HST
(2) Globular Clusters with HST
(3) Globular Clusters with 25 years of HST
GCs with Hubble Over Time

• Set up new experiments
  – Probe deeper
  – Probe more broadly

• Use new detectors
  – Better sensitivity, resolution
  – Better filter sets

• Things move!
Anderson et al 2002
Initial 2-seq Discovery on Main Sequence (WF/PC2)

Bellini 2014 (WFC3/UVIS)
Latest results all over the diagram! 10 Seqs!

ω Centauri
D’Antona 2005 (ACS) Initial Discovery

Bellini et al in prep (WFC3/UVIS)
Motions in ω Centauri
Motions in ω Centauri
Motions in ω Centauri

2015 WFC3/UVIS F606W
Proper Motions

Important Qs

• Formation hints
• Are GCs just little galaxies?
• Do they have medium-sized BHs?
• How did the big BHs form in big galaxies?
Plan

(1) Globular Clusters before HST
(2) Globular Clusters with HST
(3) Globular Clusters with 25 years of HST
(4) Globular Clusters in the next 25 years...
View to the Future: the James Webb Space Telescope
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