The 1.3-m RCT: Telescope Characteristics, Current Research and Education Programs

Ed Guinan & Richard Gelderman
and the RCT Consortium

Consortium Members

- **Western Kentucky University (WKU)**
  - ***Contact:*** **Richard Gelderman, Louis Strolger, Charles McGruder, Richard Carini, & Rachel Campbell**
  - ***Research:*** **Searches for extra-solar planets, active galactic nuclei, Gamma-Ray Bursts, studies of supernovae.**
- **Planetary Science Institute (PSI)**
  - ***Contact:*** **Don Davis and Edward Tedesco**
  - ***Research:*** **Searches for extra-solar planets, precision photometry, studies of small solar system objects.**
- **South Carolina State University (SCSU)**
  - ***Contact:*** **Don Walter**
  - ***Research:*** **Galactic and extragalactic emission line nebulae, starburst galaxies**
- **Villanova University (VU)**
  - ***Contact:*** **Ed Guinan , George McCook, Scott Engle**
  - ***Research:*** **Eclipsing Binary Stars, extrasolar planets and habitabilty, asteroseismolgy, cool stars, rapid stellar evolution, active galactic nuclei.**

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RCT POSTERS AT THIS CONFERENCE

☆ **Poster 14 Scott Engle et al. Villanova Univ.**

RCT Photometry of the Hubble's Cepheid V19 in M33: Evidence of Cessation of Pulsations- A Case for Stellar Evolution in Real Time?

☆ **Poster 16 Donald Walter et al. South Carolina State University (SCSU)**

Narrow-band Imagery with the 1.3-meter Robotically Controlled Telescope (RCT)

☆ **Poster 29 Richard Gelderman et al.**

Western Kentucky Univ. (WKU)

The Robotically Controlled Telescope (RCT): First Five Years of Fully Autonomous Operation

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RCT POSTERS (CONTINUED)

☆ **Poster 31 Richard Treffers (Starman Systems)**

Automation of the 1.3-meter Robotically Controlled Telescope (RCT)

☆ **Poster 32 Michael Carini et al. (WKU)**

Flexible Queue Scheduling Capabilities of the 1.3-m RCT: Application to Time Variable Sources

☆ **Poster 38 Louis Strolger et al. (WKU)**

Autonomous Scheduling of the 1.3-meter Robotically Controlled Telescope (RCT)

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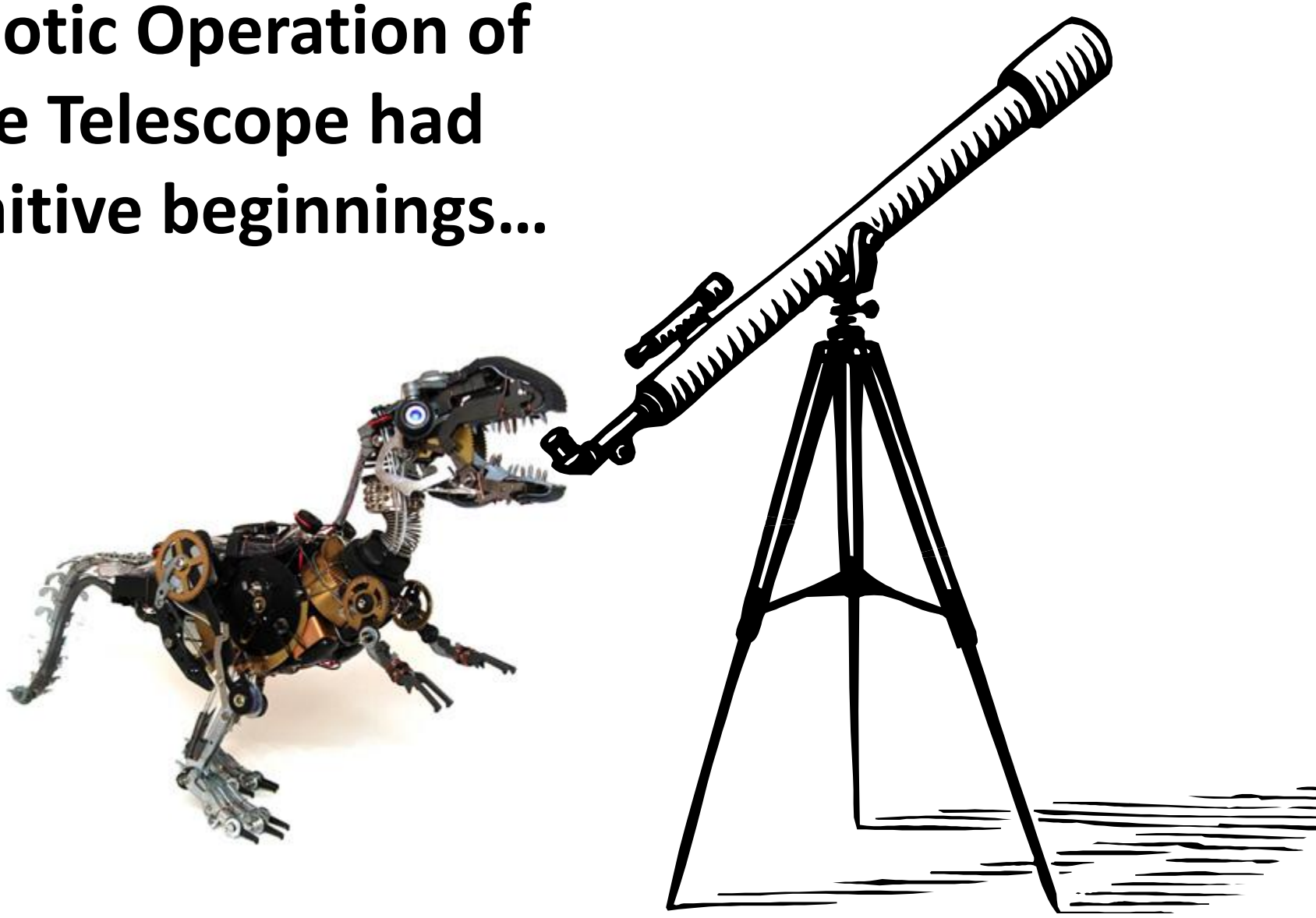
The 1.3-m RCT

The 1.3-m RCT is located at Kitt Peak National Obs. near Tucson, Arizona.

Telescope Properties

The Robotically-Controlled Telescope (RCT) is a 1.3-meter (50inch) f/14 Schmidt-Cassegrain telescope on a German equatorial mount. Located on Kitt Peak in southern Arizona at an elevation of 2070 meters (6790 feet), the RCT occupies the dome across from the Kitt Peak Visitors' Center and adjacent to the KPNO administration building. The RCT name originally stood for Remotely-Controlled Telescope, and served as a Kitt Peak instrument for almost 30 years prior to being closed in 1995 (read more on the RCT webpage and posters here).

Robotic Operation of the Telescope had primitive beginnings…



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A Brief History - Original RCT

- In 1964, with NASA funding, a new 1.3-meter telescope was commissioned on Kitt Peak and named the "**Remotely Controlled Telescope**".
- Originally intended to develop techniques for operating space based telescopes, the purpose shifted to an attempt to enhance the productivity of small telescopes, in response to the Whitford Committee's report (1964).
- 60's technology was not up to the demands of the dream, and the RCT was refurbished for classical, on-site, use.
- The 1.3-meter was a productive telescope, first with a photo-electric photometer and an IR photometer. RCT played a pivotal role in the development of infrared arrays for astronomical applications e.g. IR instrumentation (IRIM, CRSP, SQIID, COB) used on the Kitt Peak telescopes
- The 1.3-meter was decommissioned by KPNO in 1996.

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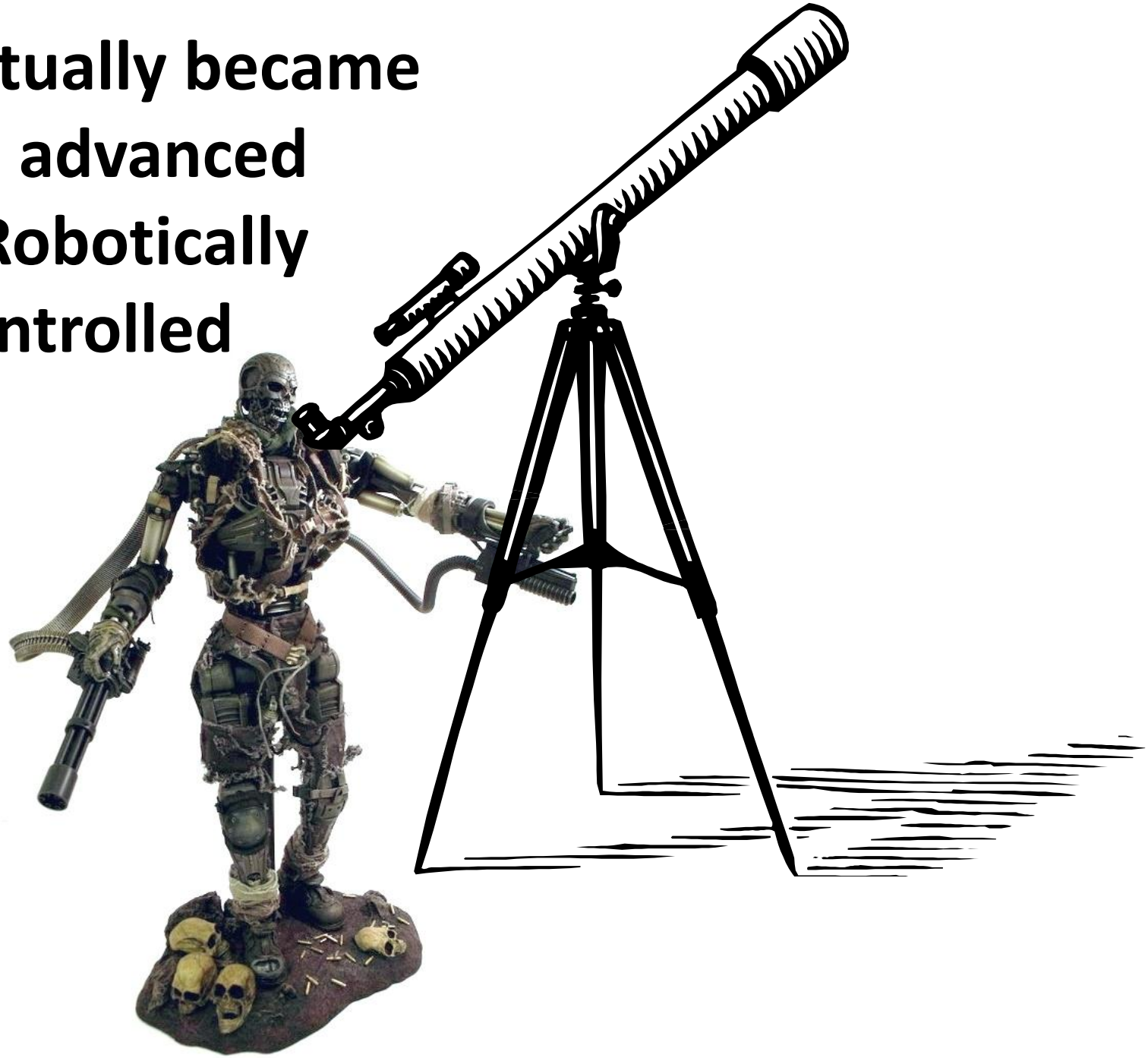
Robotic Dream realized

- In 1999, the US National Optical Astronomy Observatory announced an opportunity to “assume responsibility for operation of the Kitt Peak 1.3-meter telescope”
- A group of astronomers around the US successfully proposed to refurbish and automate the observatory an operate it as the “**Robotically Controlled Telescope” – Grant from NASA**

- **The RCT Consortium is comprised of four partners:**
  - **Western Kentucky University, Bowling Green, Kentucky**
  - **Villanova University, Villanova, Pennsylvania**
  - **South Carolina State University, South Carolina**
  - **Planetary Science Institute, Tucson, Arizona**
- **Starman Sytems, LLC was awarded the contract to automate the new RCT. (Richard Treffers)**

But eventually became more advanced and Robotically Controlled



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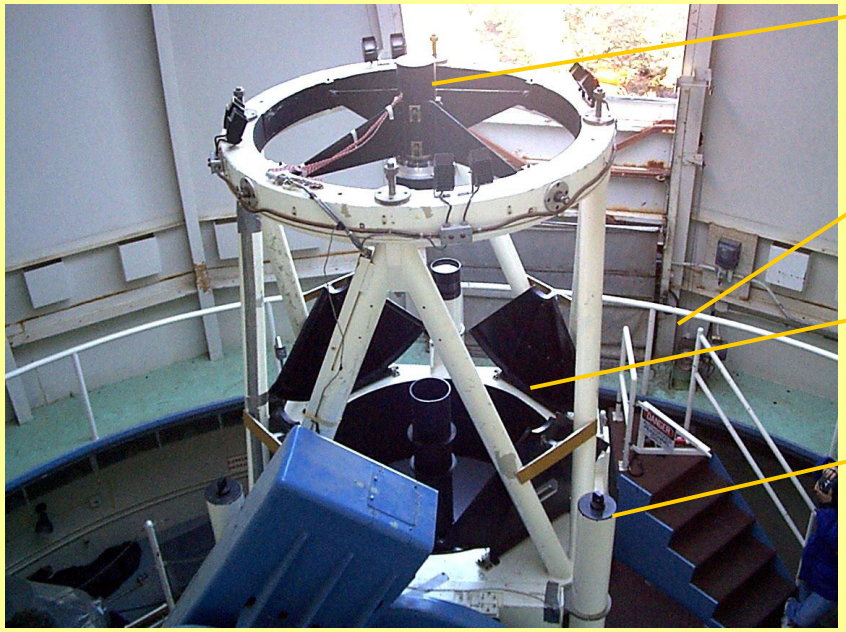
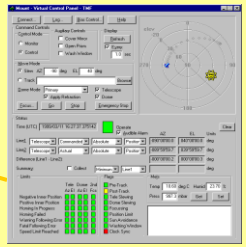
Refurbishing the RCT

- Install new encoders for computer control of existing motors
- Provide computer interfaces for previously manual functions
- Use the existing optics, mount, and drive motors
- Design custom software for fully autonomous observing
- New autoguider and double filter wheels





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Cryogenically cooled CCD

- Camera supplied by Astronomical Research Cameras
- SITe 2048 x 2048 CCD with 92% DQE in R band
- Four amplifiers available for fast readout (~20 sec)
- Low read noise, 4.5 to 7 e^- per amp
- Full well of 400,000 e^-
- CryoTiger closed cycle refrigerator operates at LN_2 temps
- Plate scale of 0”.3/pix
- 10 arcminute field of view

- See posters here

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Observatory WebCams and Remote Operation

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The refurbished 1.3-m RCT Today

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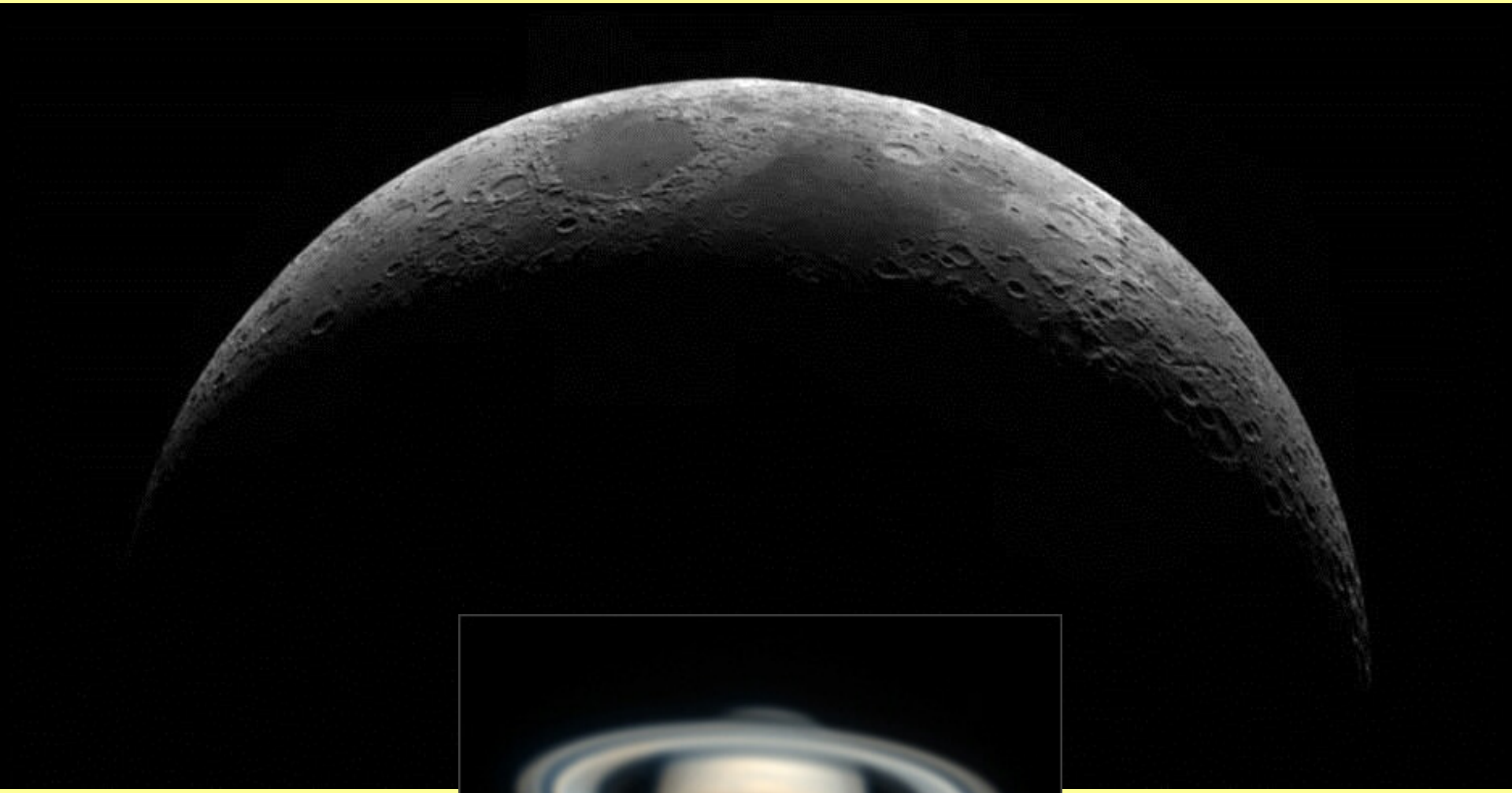
Recommisioning Images 5 April 2003



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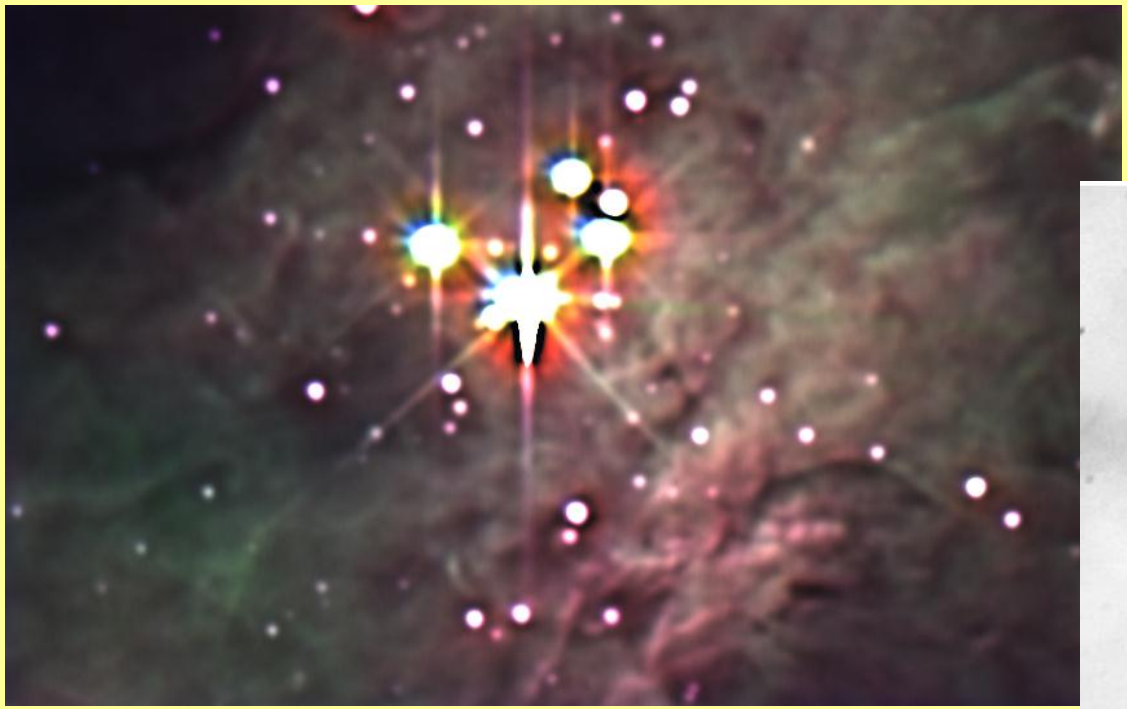
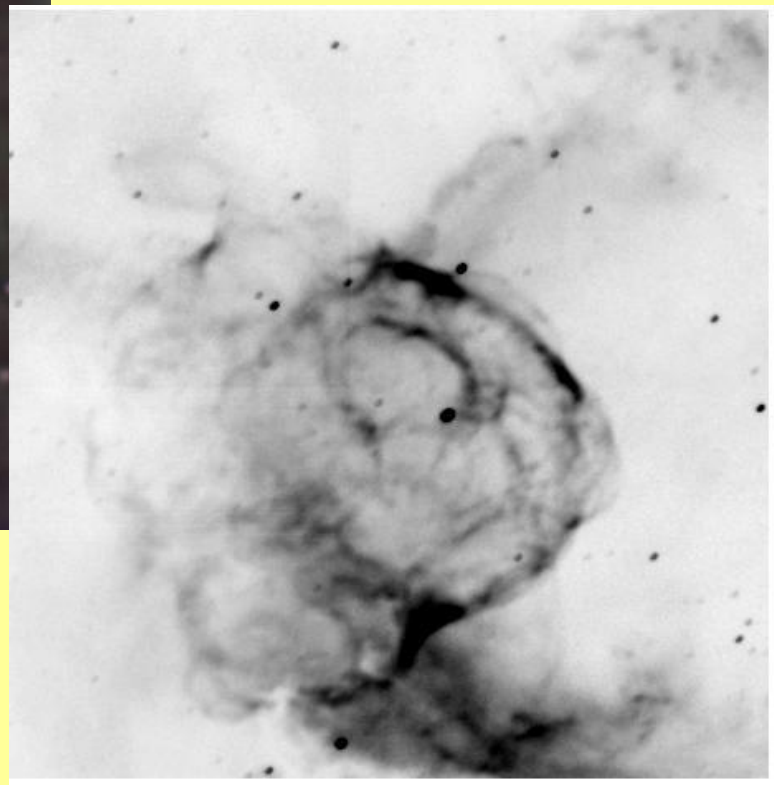
Images of Galactic & Extragalactic Nebulae



Orion Nebula and Trapezium cluster in broadband false color



Hα emission from NGC 2359

The

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Autonomous Operation (since 2009)

- Seamless integration of telescope, observatory and instruments
- Allow for remote, robotic, and fully autonomous operation
- Act as “best trained observer” in fully autonomous mode
- Start-up and shut-down according to weather conditions
- Automated acquisition of objects and auto-guiding
- Weighted scheduling algorithm
- Utilize standardized robotic telescope language (RTML)
- User expandable through Generic Instrument Interface

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medium sized collaboration - diverse, but not too diverse

- Consortium formed around complementary research interests
- Time allocation without proposals, limited TAC
- Obtained upfront funding through NASA OSS Education
- Decided to refurbish, rather than start new
- Chose to go with single instrument, minimal changes
- Operational support available for hire from KPNO
- Partners reconfirm support via sweat equity (vs. cash)
- Unique Features of the RCT is “Versatility” and an
- Autonomous “scheduler”

Examples of Current RCT Programs

AGN / Blazar monitoring – short and long term
Supernovae monitoring programs
Gamma Ray Bursts programs
Supporting observations for NASA Missions - Such as HST, Chandra and Kepler
Exoplanet transits
Near-Earth Crossing Asteroid programs
Narrow band photometry of comets and nebulae
Variable Stars- Stellar evolution in real time
Host stars of exoplanets (rotation-age-activity relations)/ Living with red dwarf programs-age and habitability of red dwarf stars…

Also interested in Research and Educational Collaborations…

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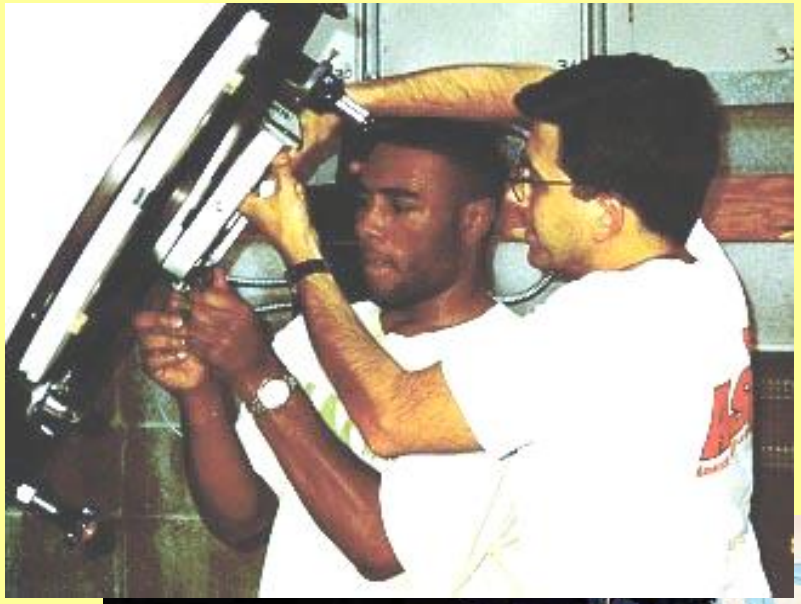
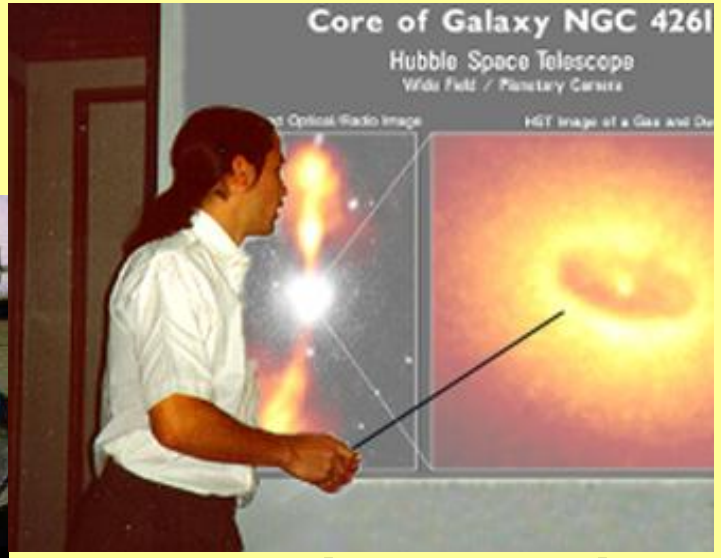
Providing experiences for undergraduate students



Engineering and science students work with the RCT to demonstrate their abilities with cutting-edge technology.



Science majors directly contribute to research projects.

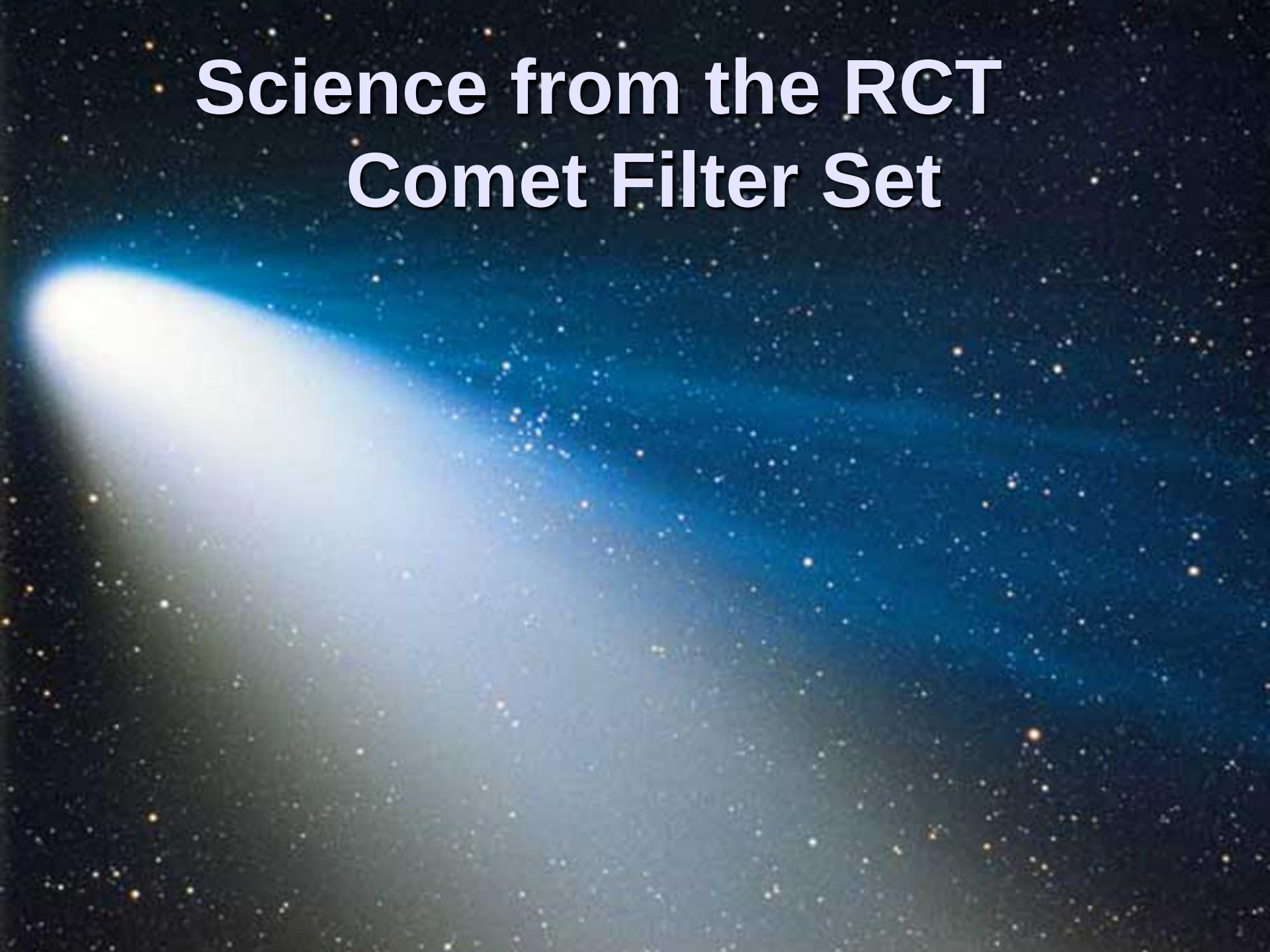
the RCT consortium

RCT Narrow-band Interference Filters

See poster 16 – Don Walter et al.

- 2 filter wheels – each hold 8 filters & one clear position
- Total of 16 filters at one time
- One wheel holds UBVRI and medium-band filters
- 2nd wheel holds narrow-band interference filters
- 2nd wheel filled with one of two sets
  - Nebular filters centered on diagnostic emission lines
  - Comet filters centered on emission lines of molecular species
- 1-hour turn around time to switch out narrow band sets

Science from the RCT Comet Filter Set



Science from the RCT Comet Filter Set

- Extensive coverage pre and post-perihelion to detect outbursts and fragmentation
- Early calculation of volatile production rates to support large telescope follow-on
- Evolution of the coma as a function of heliocentric distance for multiple species
- Cospatial with IR spectra to determine species parentage

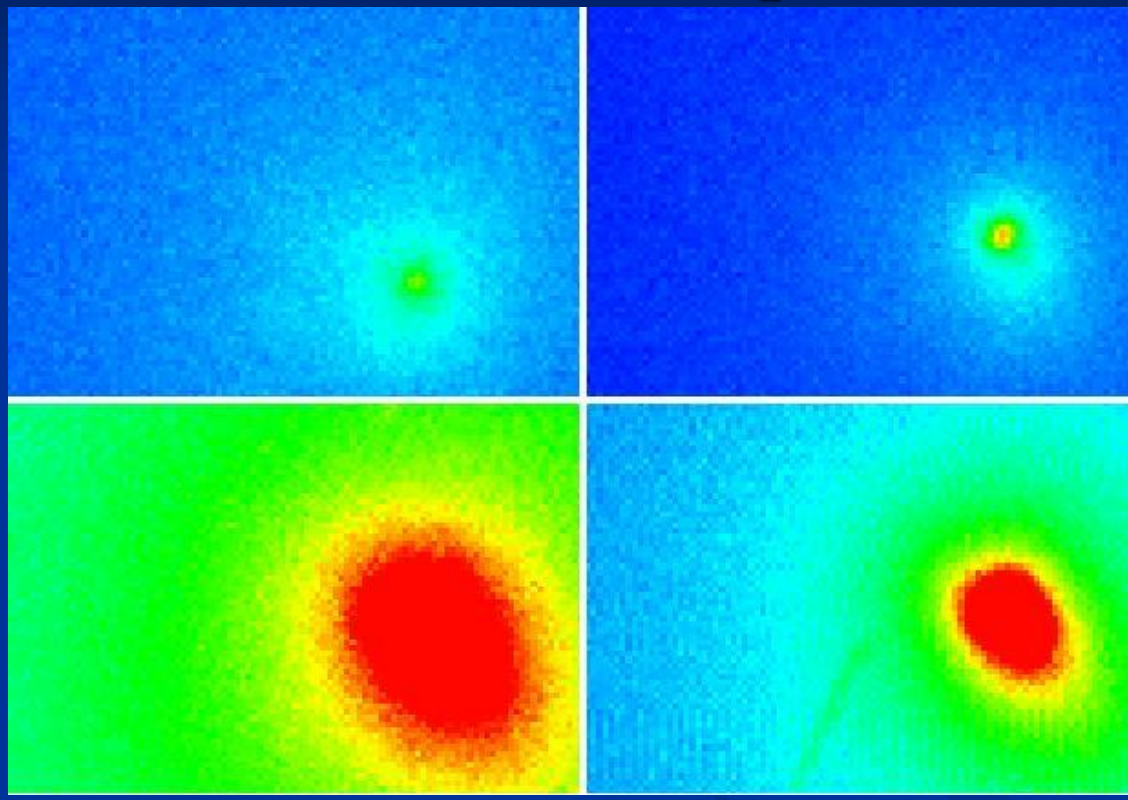
Species	Central λ (Å)	FWHM (Å)
OH (0-0)	3090	62
UV Continuum	3448	84
CN (Δv = 0)	3870	62
C_3 (Swings System)	4062	62
Blue Continuum	4450	67
C_2 (Δv = 0)	5141	118
Green Continuum	5260	56
NH_2 Continuum	5660	20
NH_2 (0,10,0)	5720	100

Narrow-band Comet Filters

Coma morphology as a function of volatile species

- Comet Hartley 2
- October 14, 2010

- RCT filters allow one to simultaneously examine the spatial distribution of multiple species
- RCT extensive temporal coverage will track all species during pre and post perihelion passage



CN, C_3, NH_2 and C_2

(Clockwise from upper left)

All exposures are 300 seconds

Intensity display ranges are identical

Streaks are star trails

Science from the RCT Nebular Filter Set

Spatially Resolved Diagnostic Ratio Maps

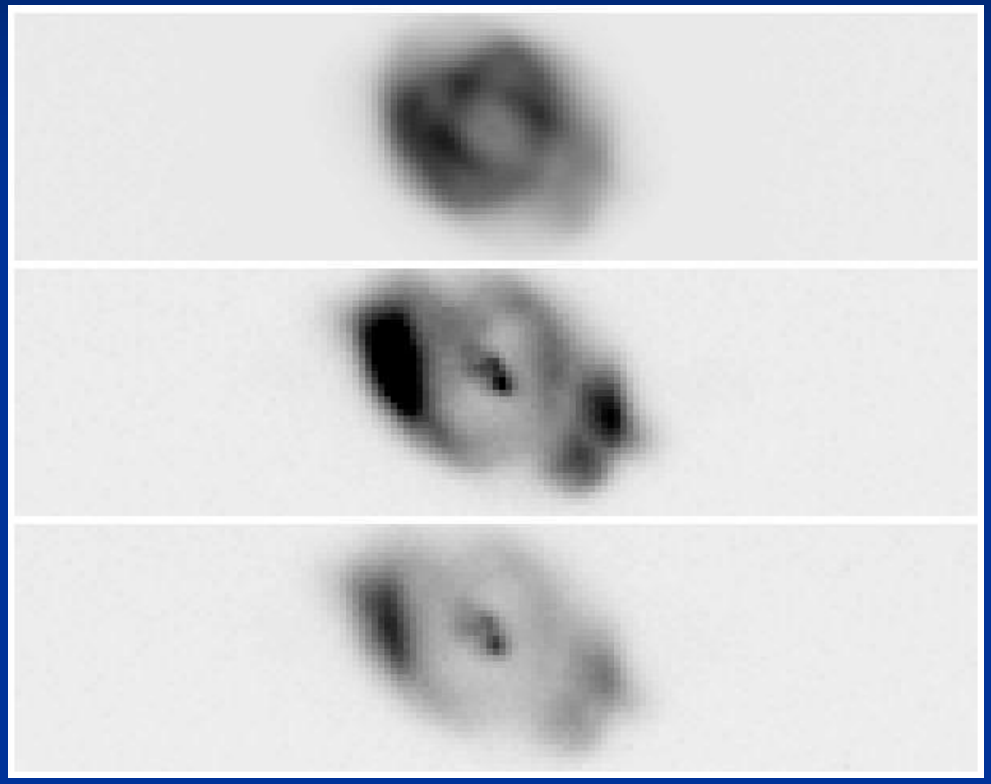
Science from the Nebular Filter Set

- 2-D spatially resolved maps
  - extinction (Hα/Hβ)
  - electron temperature (T_e)
  - electron density (N_e)
- Nebular ionization maps such as O^{++}/H^{+}, N^{+}/S^{+}
- Cospatial coverage with spectra for nebular abundance calculations
- Identify stars with atmospheric Hα emission

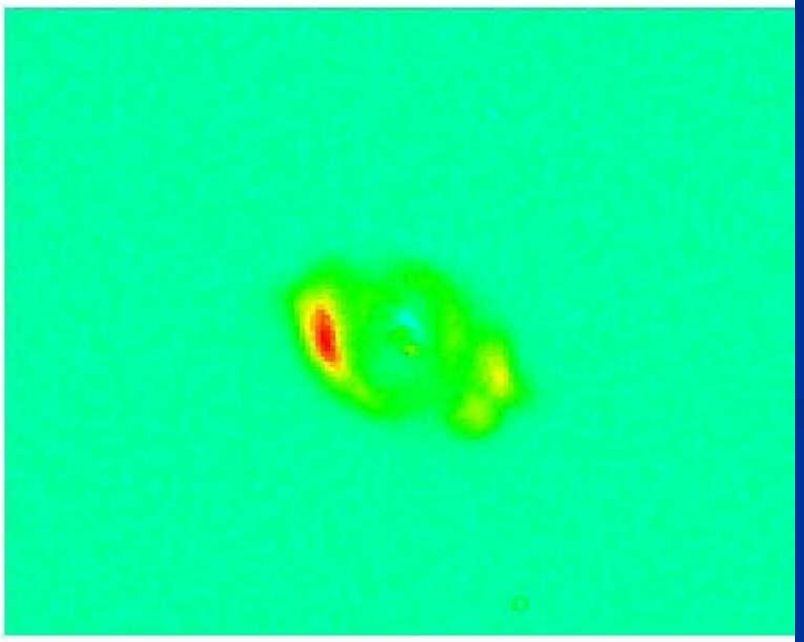
Filter	Central λ (Å)	FWHM (Å)	Ion
He I	4689	29	He+
Green Cont. I	4807	47	
Hβ	4865	29	H+
O III	5008	25	O++
Green Cont. II	5312	90	
N II	5759	29	N+
Red Cont.	6458	80	
Hα (narrow)	6565	9	H+
Hα (wide)	6564	17	H+
N II	6585	10	N+
S II	6716	9	S+
S II	6729	8	S+

Science from the Nebular Filter Set

Spatially Resolved Diagnostic Ratio Maps



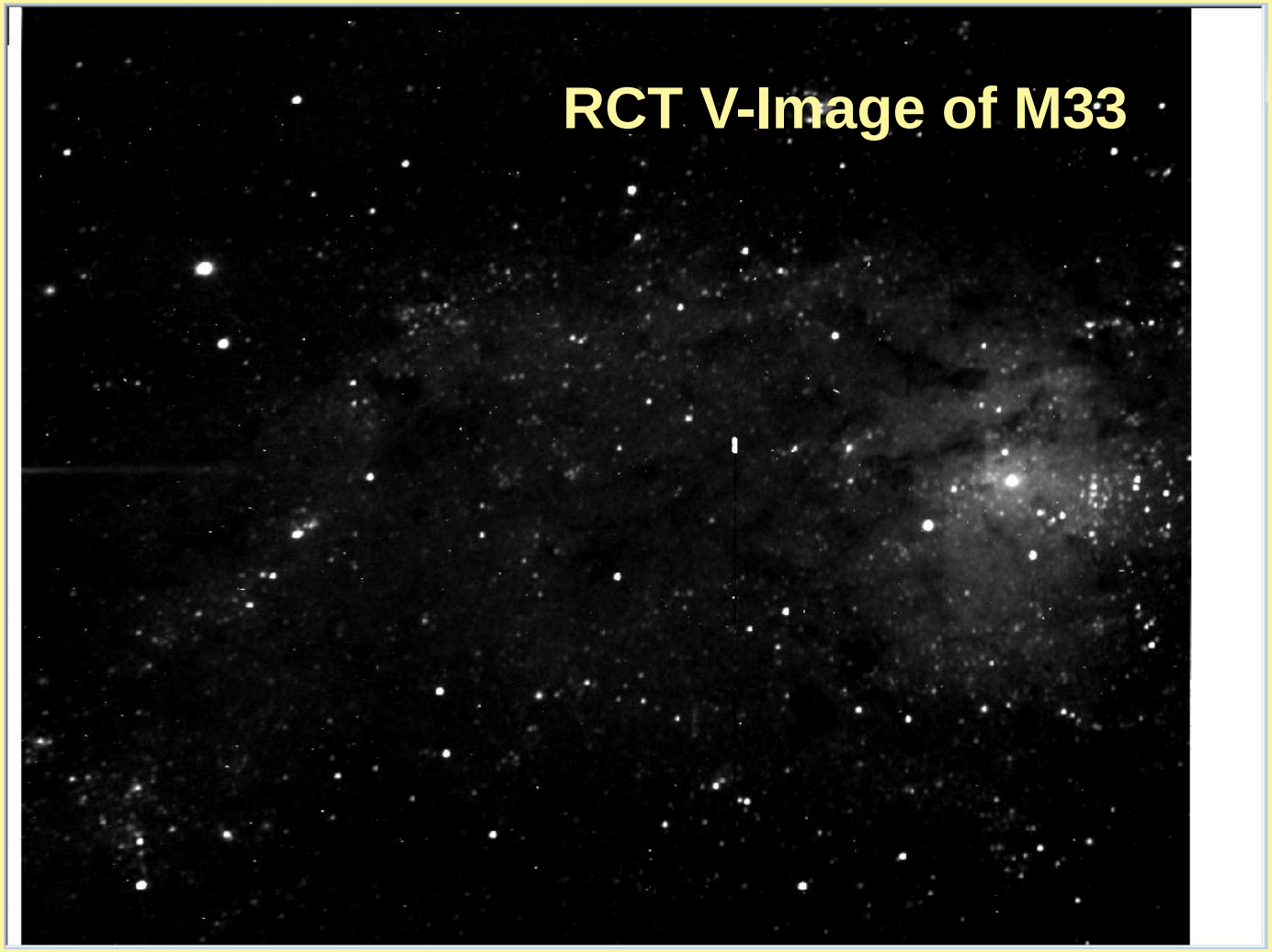
Top: 100s Hα - 6563 Å
Middle: 300s [SII] - 6731 Å
Bottom: 300s [SII] - 6717 Å



Electron Densities in NGC 6543
from Ratio Map of [SII] 6731/6717

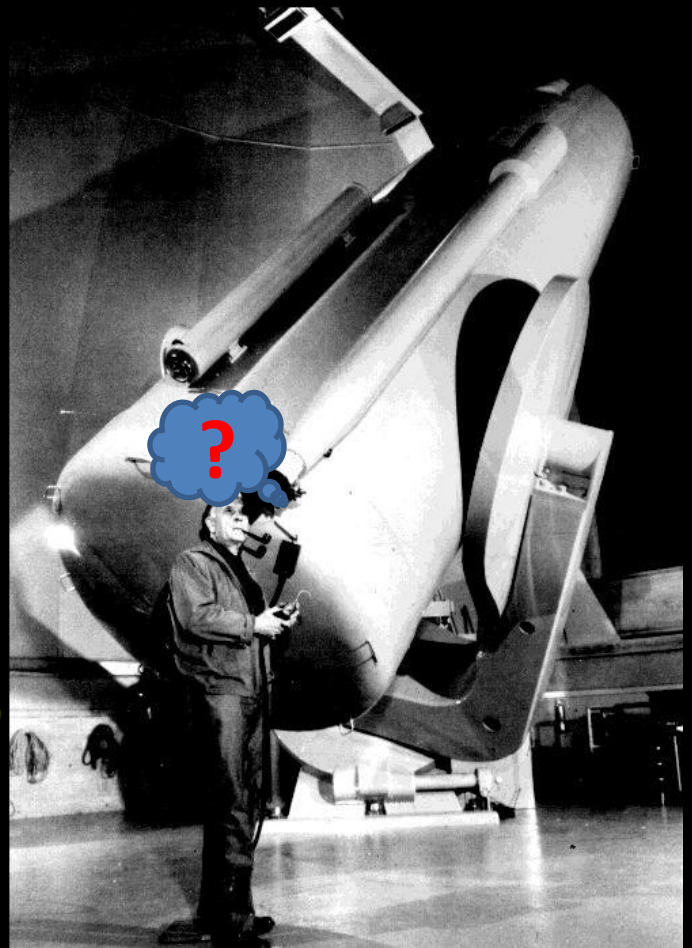
Dark Red - 2000 electrons/cm^3
Light Red - 1600 electrons/cm^3
Yellow - 1200 electrons/cm^3
Green - 800 electrons/cm^3

Example of RCT Photometry of Faint Variable Stars in Nearby Galaxies – the strange case of Hubble Variable V19 in M33

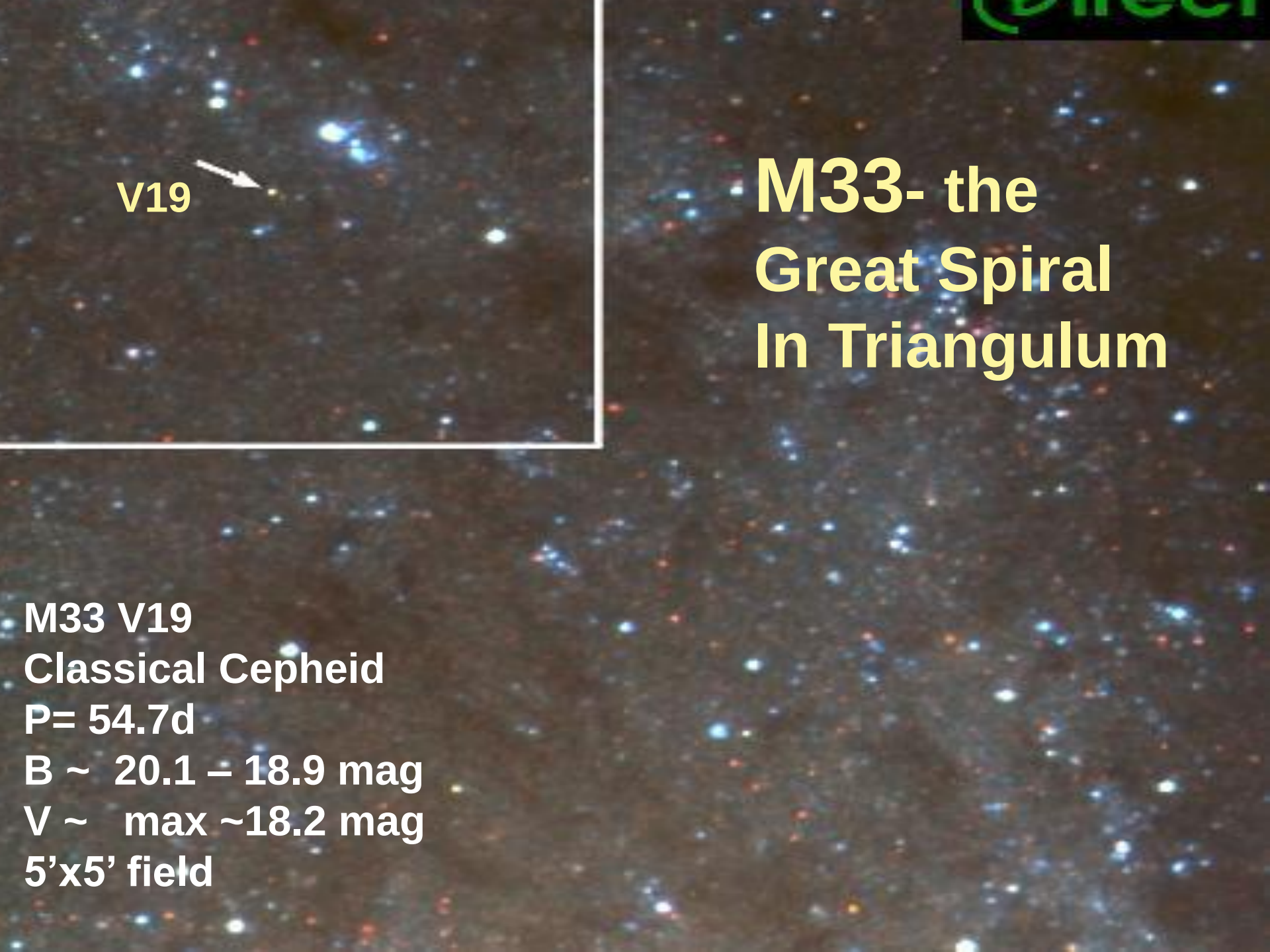


The Strange Case of Hubble's V19 in M33:

Monitoring the Remarkable Changes and Possible Real-Time Evolution of a Classical Cepheid



Scott G. Engle,
Edward Guinan
Villanova University
Lucas Macri Anne Pellerin Texas A&M


V19
M33- the
Great Spiral
In Triangulum
M33 V19
Classical Cepheid
P= 54.7d
B ~ 20.1 – 18.9 mag
V ~ max ~18.2 mag
5’x5’ field

A SPIRAL NEBULA AS A STELLAR SYSTEM MESSIER 33[1]

By EDWIN HUBBLE

ABSTRACT

The spiral nebula Messier 33.—This object is the fainter of the two naked-eye spirals. Its great angular diameter and high degree of resolution, suggesting that it is one of the nearest objects of its kind, offer exceptional opportunities for detailed investigation.

TABLE II

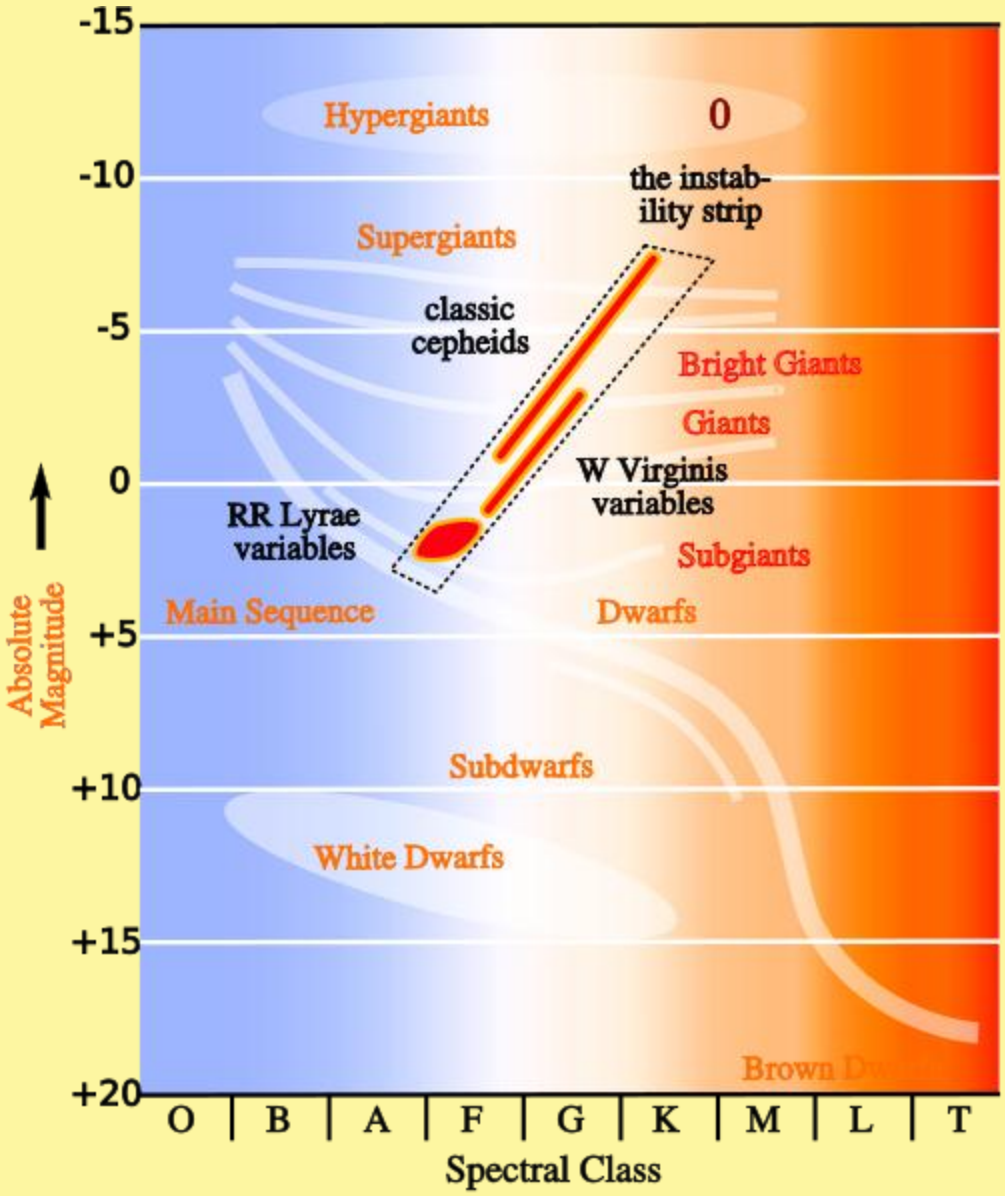
CEPHEIDS IN MESSIER 33

VAR. No.	PERIOD		PG. MAG.		EPOCH J.D.	DISTANCE FROM NUCLEUS	POSITION ANGLE‡	IDENTIFICATION PLATES
	Days	Log *P*	Maximum	Range*				
10† . . .	69.50	1.842	18.55	(0.6)	2424004.5	188″	105°	XIV, XV
19	54.706	1.738	18.0	.8	4018.0	346	15	XIV

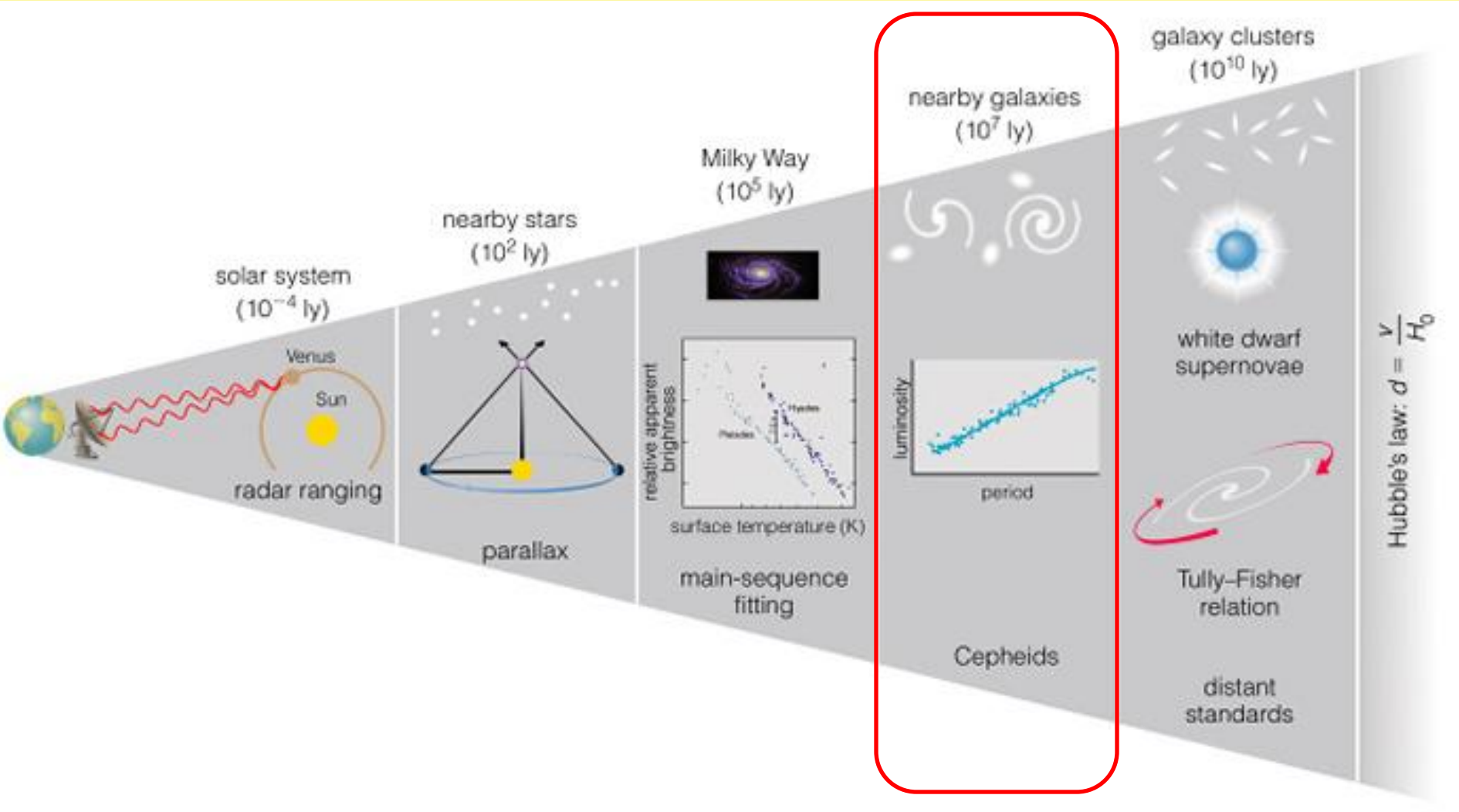
A Quick Primer on Cepheids

- F-G-K Supergiants
- Radial Pulsations
- Mass <4.0 →
- Radius <40 →
- Periods <2 – 45
- **Period-Luminosity Law**

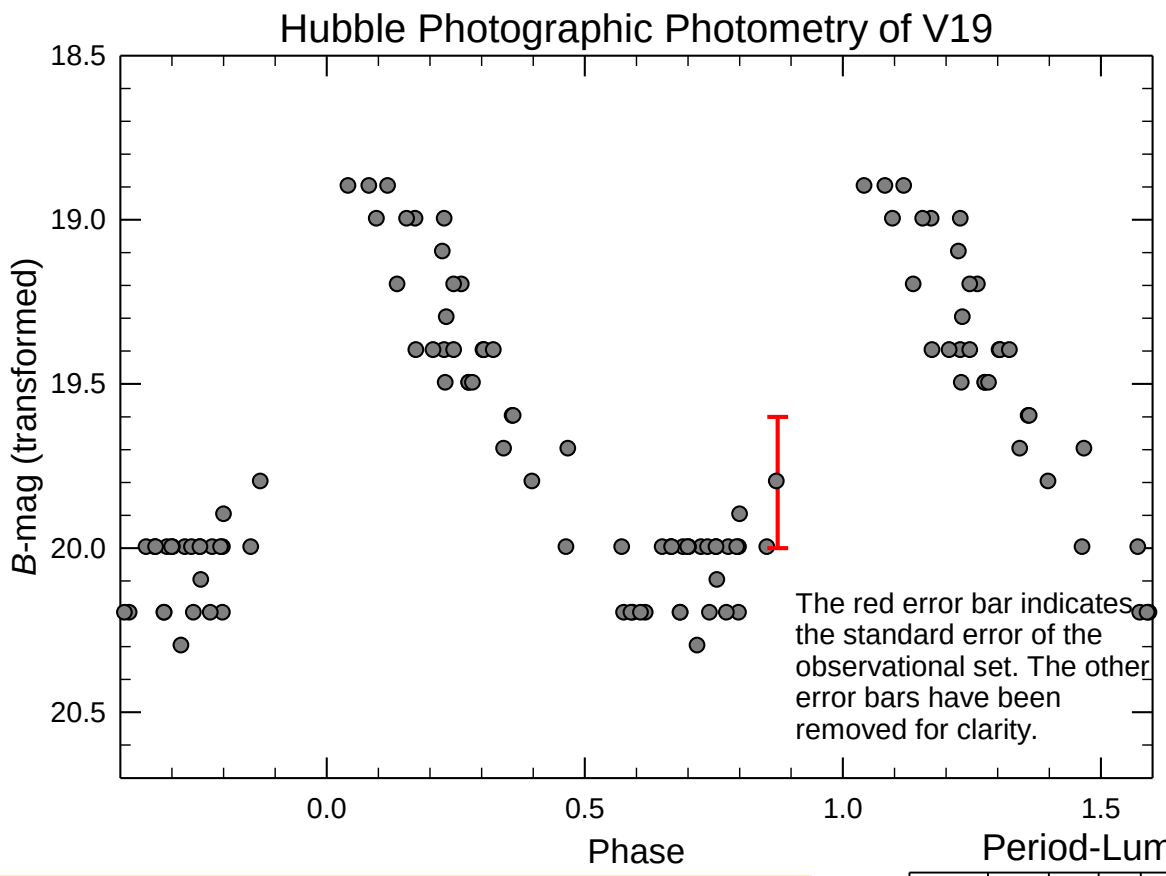
“Leavitt Law”



The Cosmic Distance Ladder

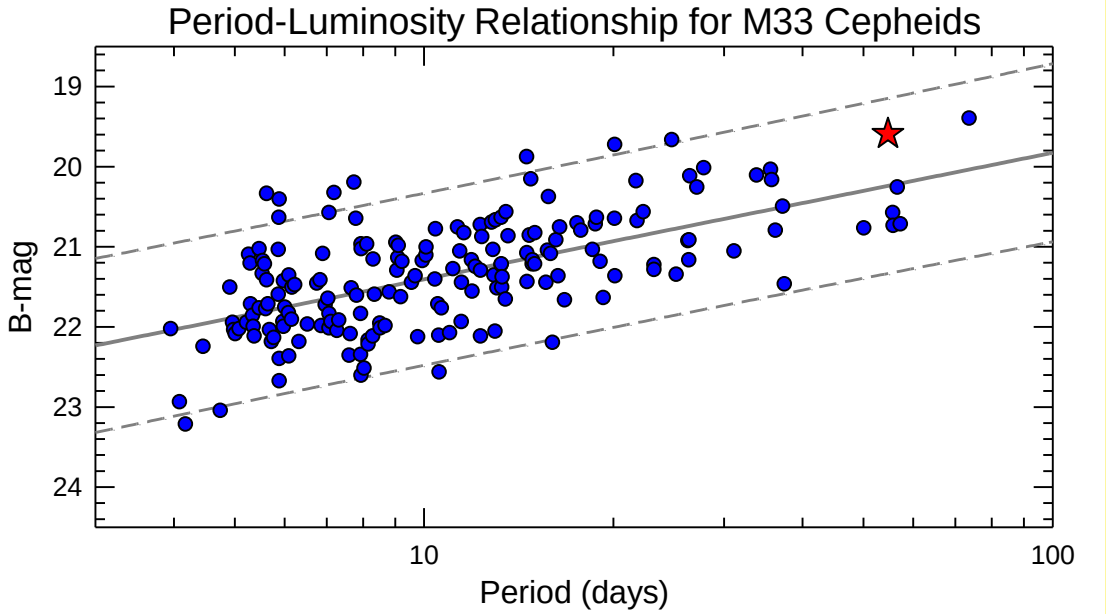


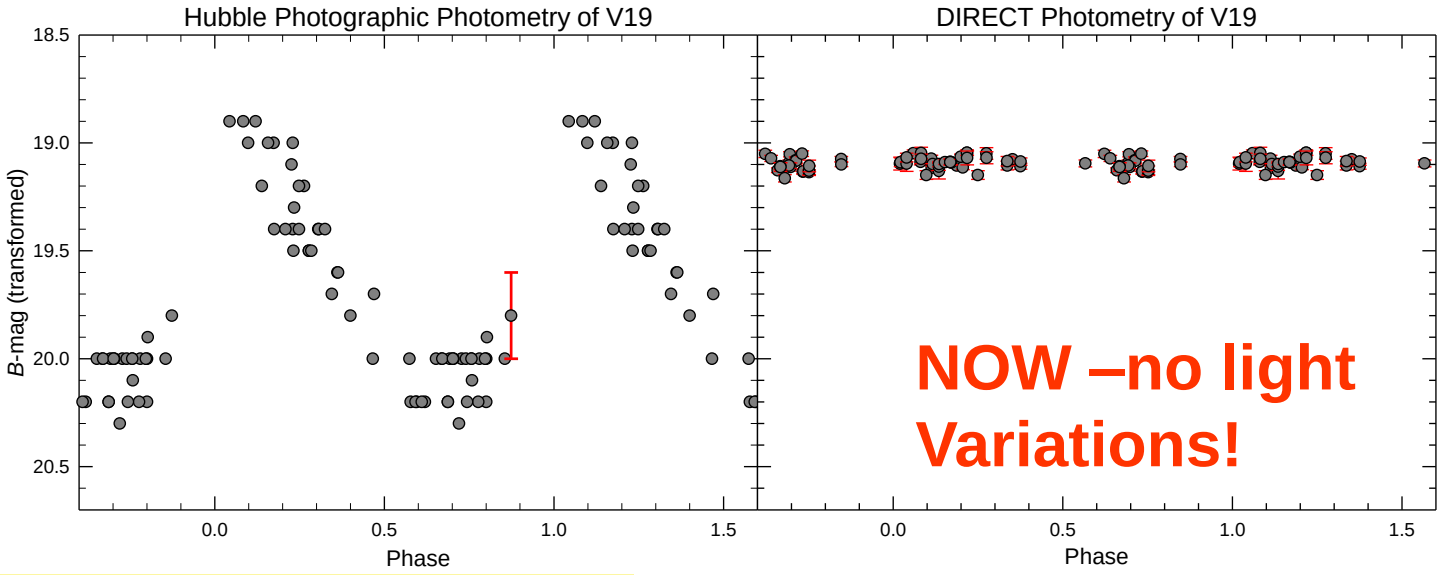
Taken from: The Internet Encyclopedia of Science



Hubble's Original data agreed well with other M33 Cepheids.

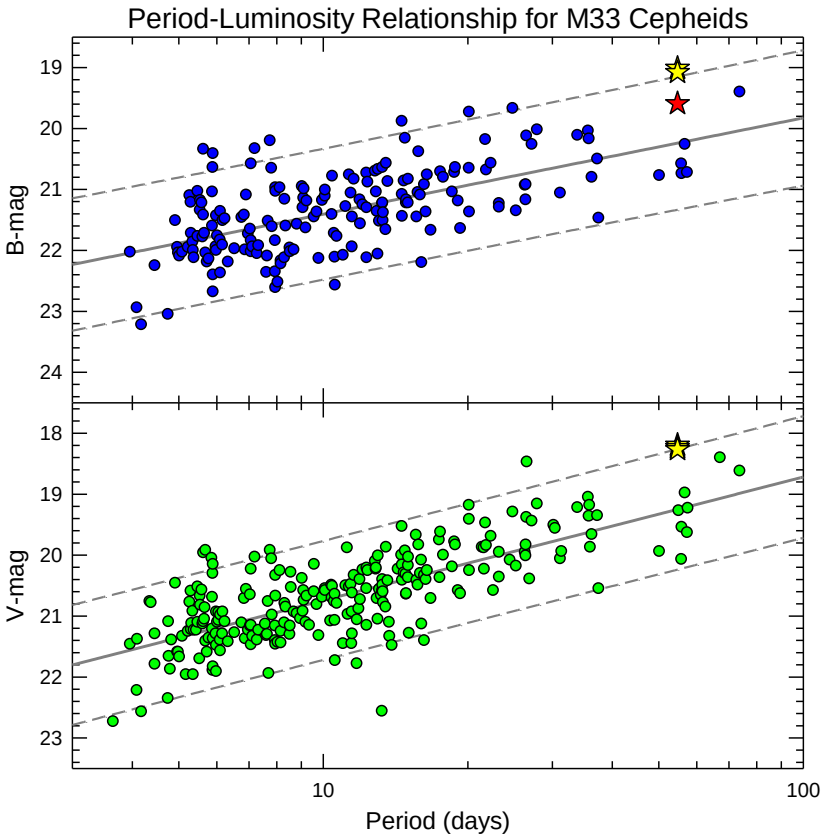
In Hubble's time
V19 was classified
as a classical Cepheid
With P = 54.8 days and
with an Amp (B) ~1.0 mag





The general picture of what V19 has been up to.

V19 stopped Pulsating!!! Why??



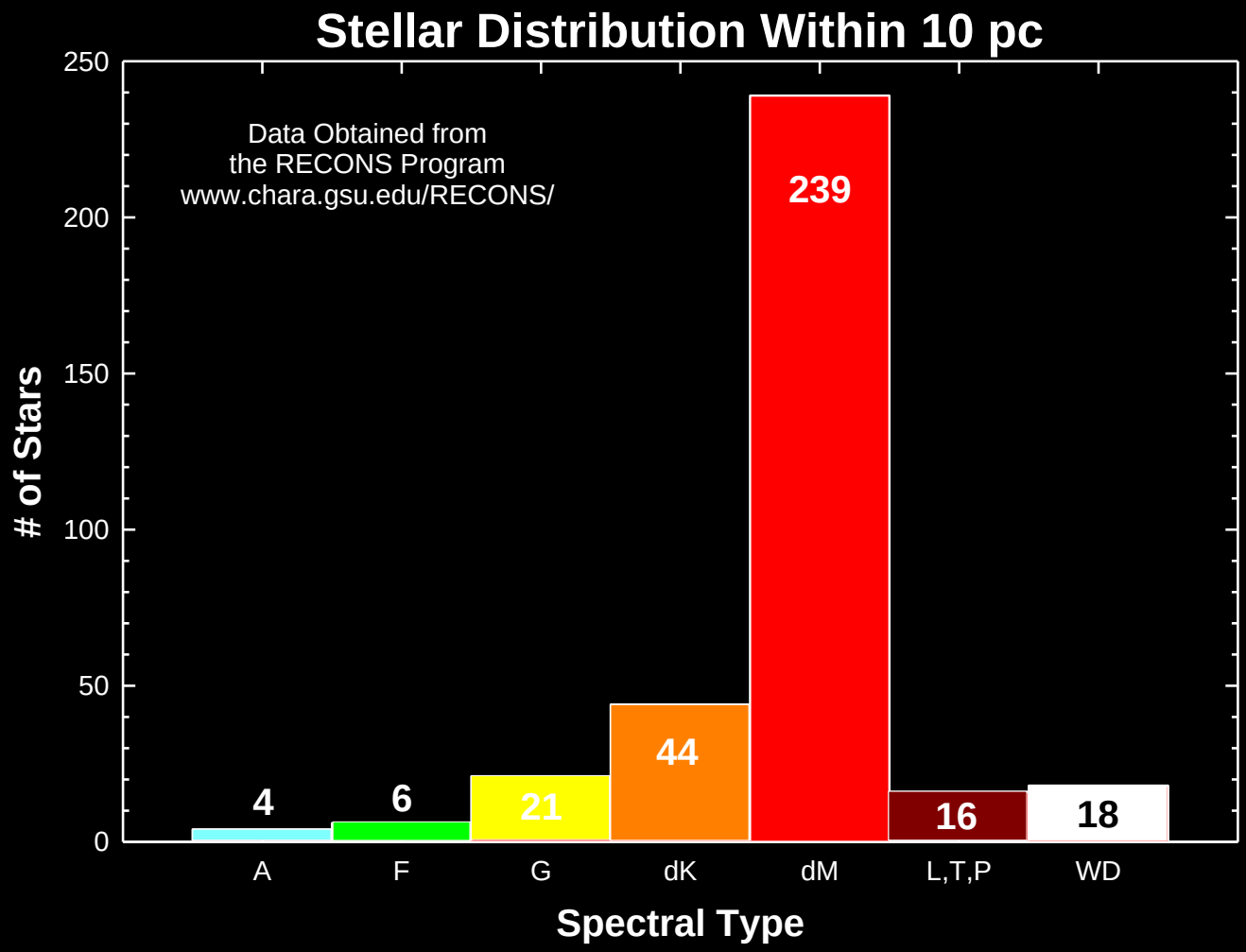
The Living With a Red Dwarf Program

Determining the Ages and Radiative Environments of Single dM Stars

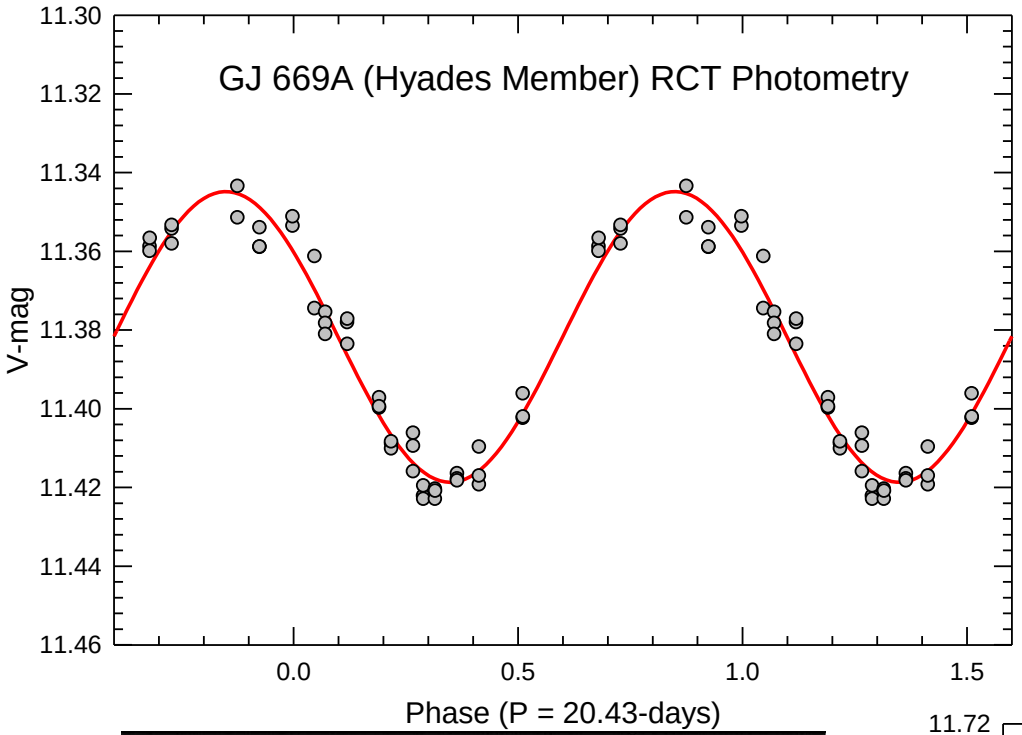
Scott G. Engle — Villanova U.
Ed Guinan — Villanova U.
George P. McCook — Villanova U
Undergrads

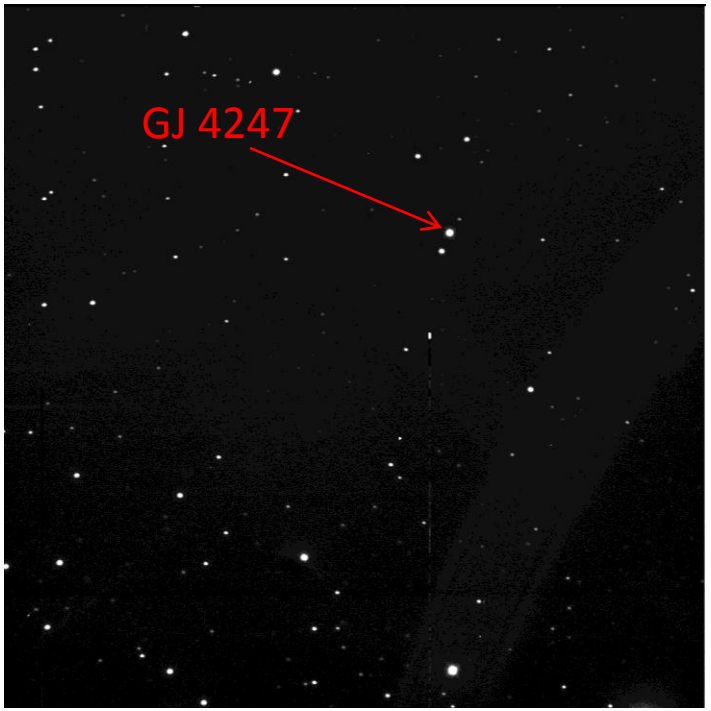
Dirk Schulze-Makuch — WSU
Ignasi Ribas — IEEC, Spain

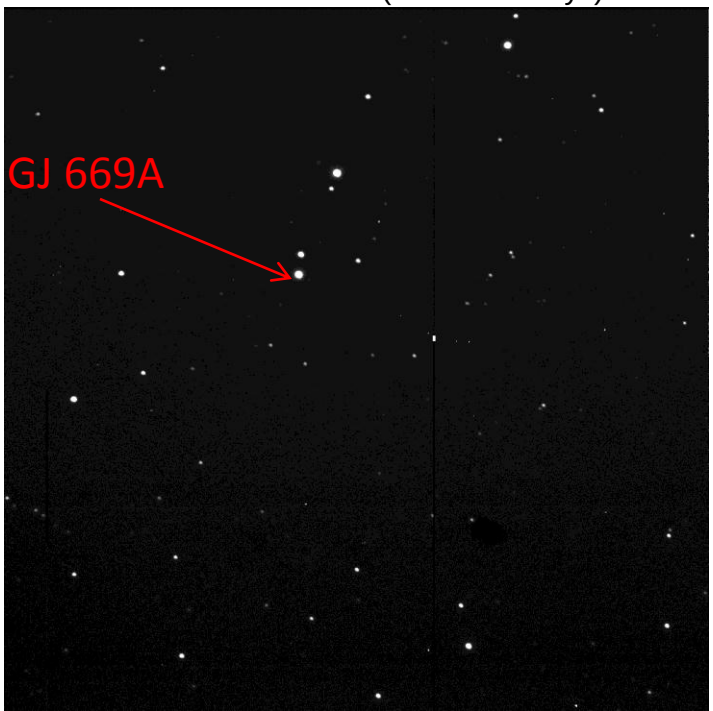
http://astronomy.villanova.edu/lward/

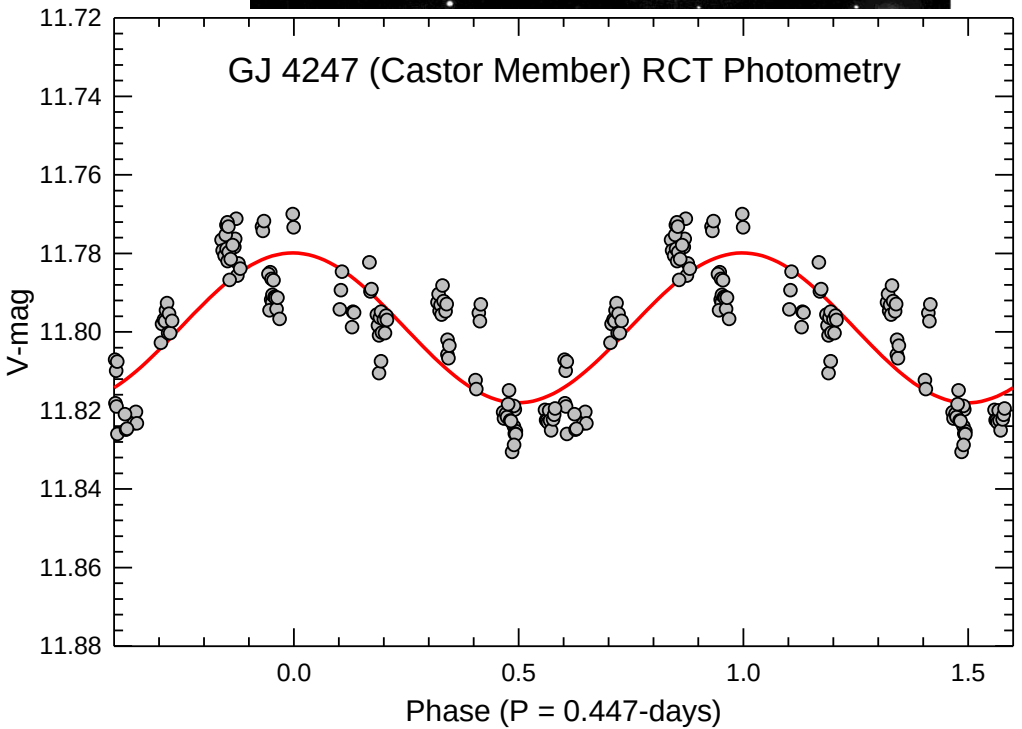


M-stars comprise ~75% of nearby stars

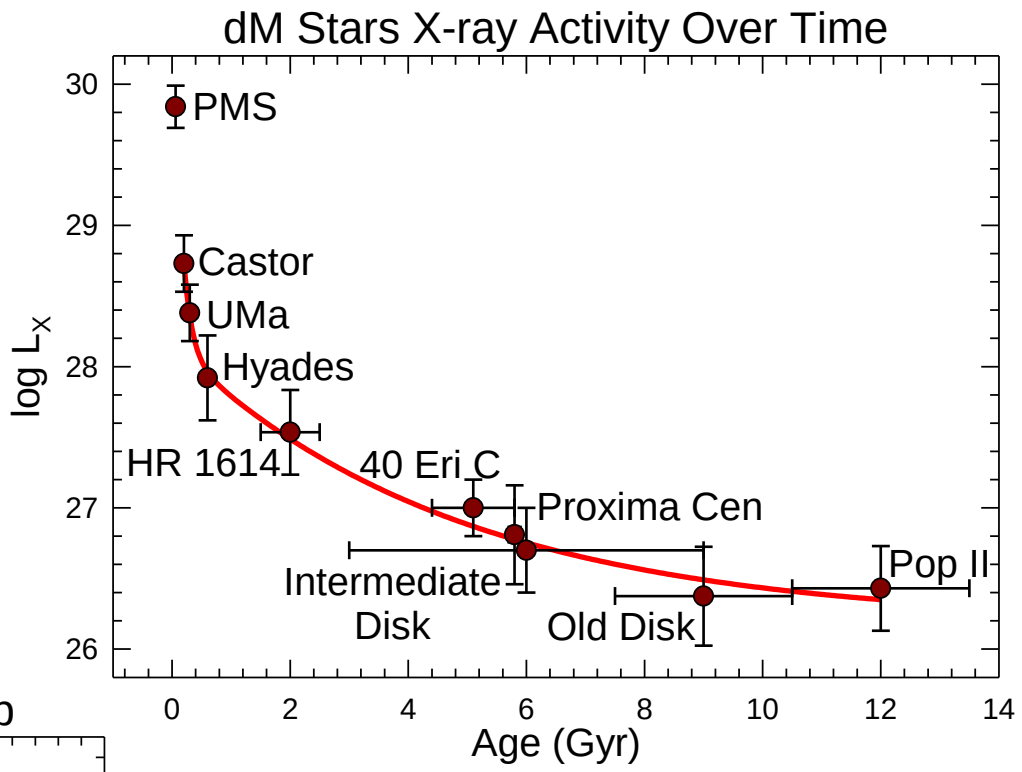

GJ 669A (Hyades Member) RCT Photometry
V-mag
11.30
11.32
11.34
11.36
11.38
11.40
11.42
11.44
11.46
0.0
0.5
1.0
1.5
Phase (P = 20.43-days)

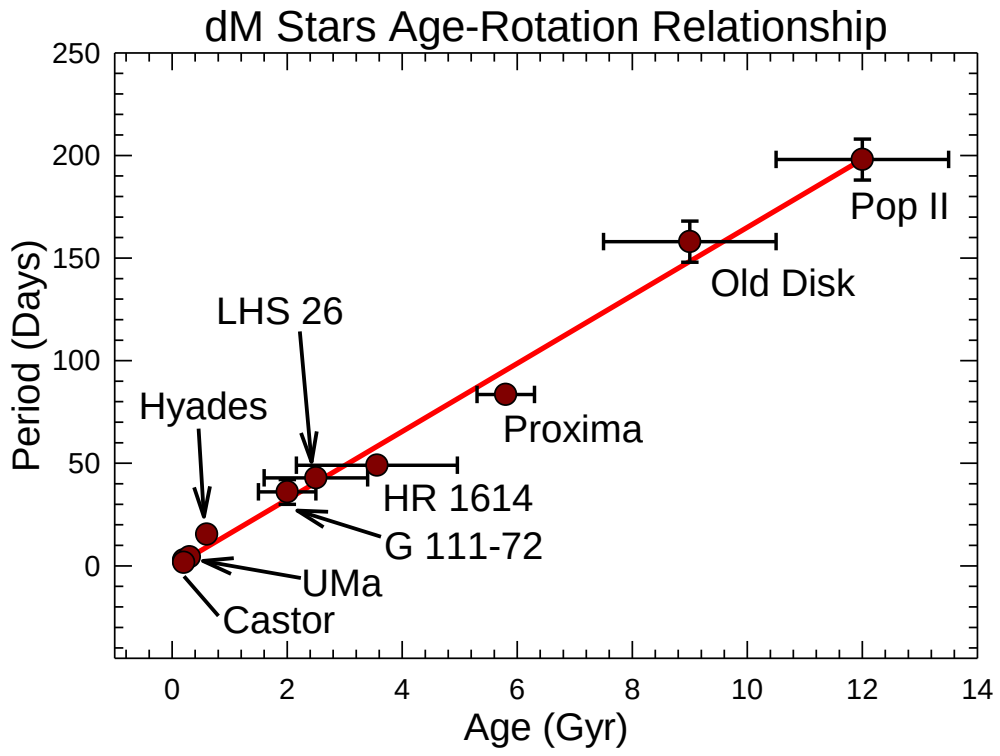

GJ 4247


GJ 669A


GJ 4247 (Castor Member) RCT Photometry
V-mag
11.72
11.74
11.76
11.78
11.80
11.82
11.84
11.86
11.88
0.0
0.5
1.0
1.5
Phase (P = 0.447-days)

Results from the Living with a Red Dwarf program - Decrease in Coronal X-ray Emission with Age





Rotation- Age Relation for Red Dwarf Stars— rotation Period of older from the RCT CCD photometry

Near-Earth Crossing Asteroids and Comets

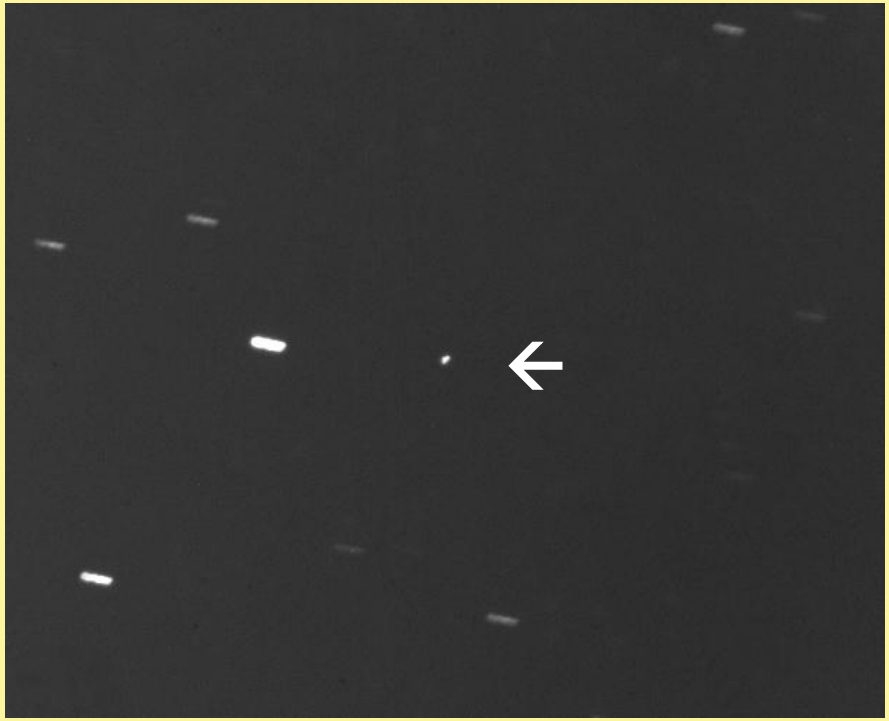
Don Davis and Ed Tedesco
Planetary Sci. Inst.

Some Examples:

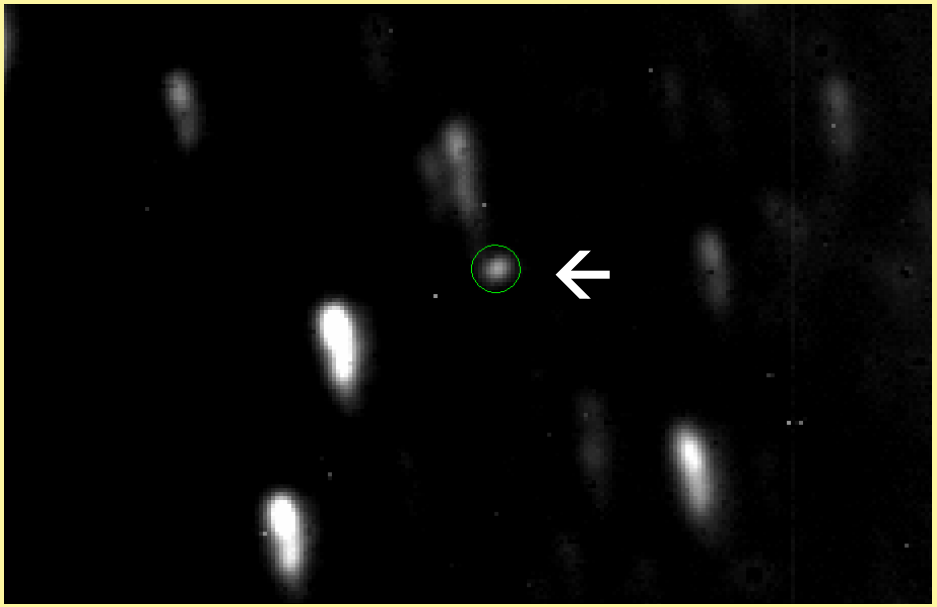
Non-sidereal tracking

Typical well-tracked images of rapidly-moving near-Earth asteroids

from PSU Davis and Tedesco



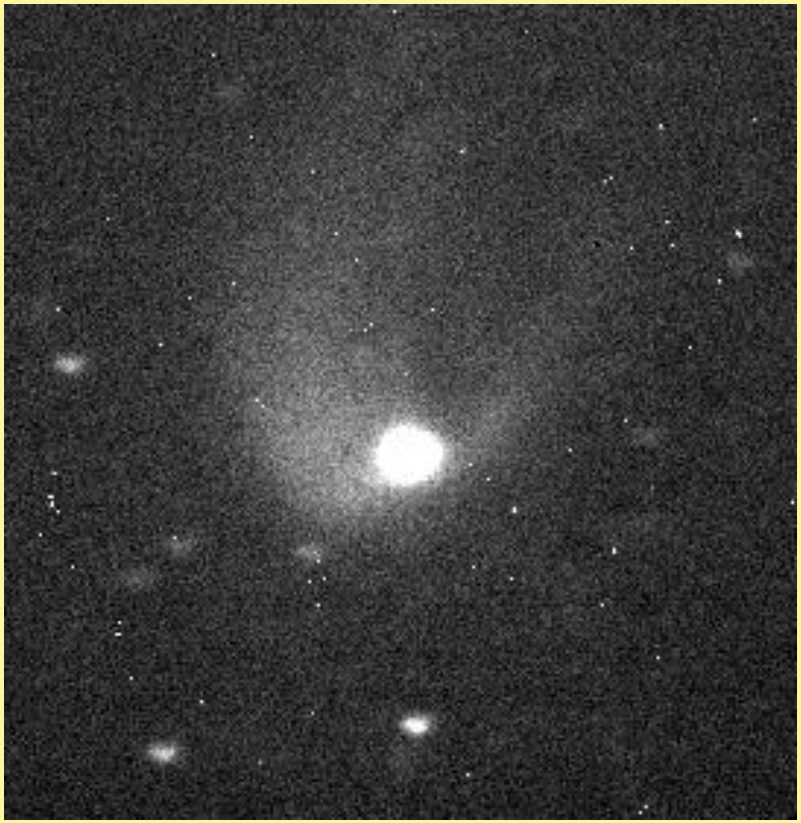
6239 Minos on 09 Sep 2010; B~16.1; 300 sec, rate 2.14 "/min)



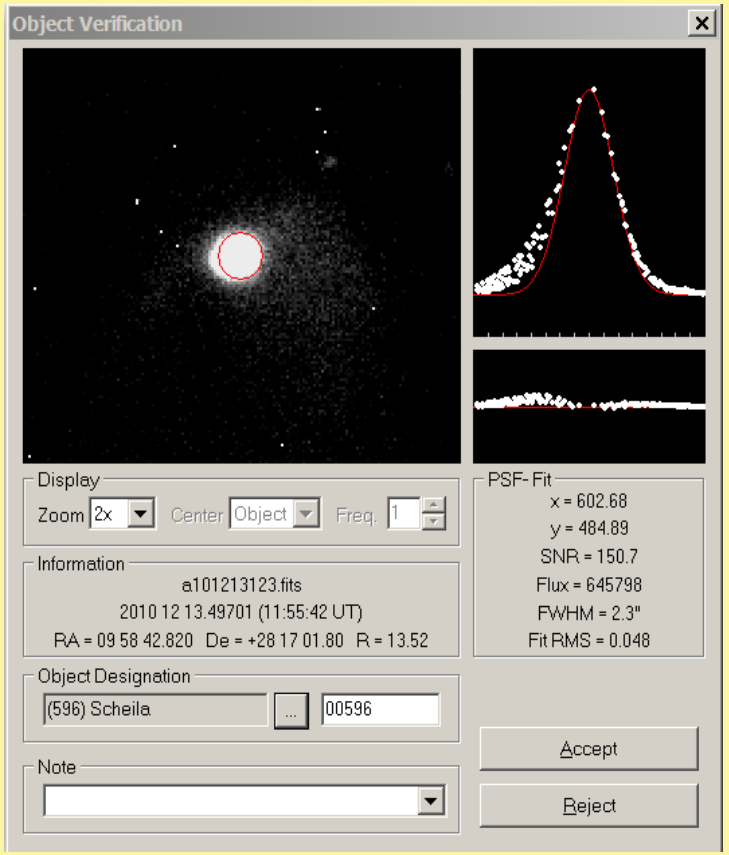
2002 AJ129 on 25 Feb 2010; V~16.5; 900 sec, rate 1.56 "/min)

RCT OBSERVATIONS OF MINOR PLANET 596 SCHEILA

200s exposures through an R filter. The image on 13 Dec clearly shows a coma while those on 18 and 29 Dec do not.



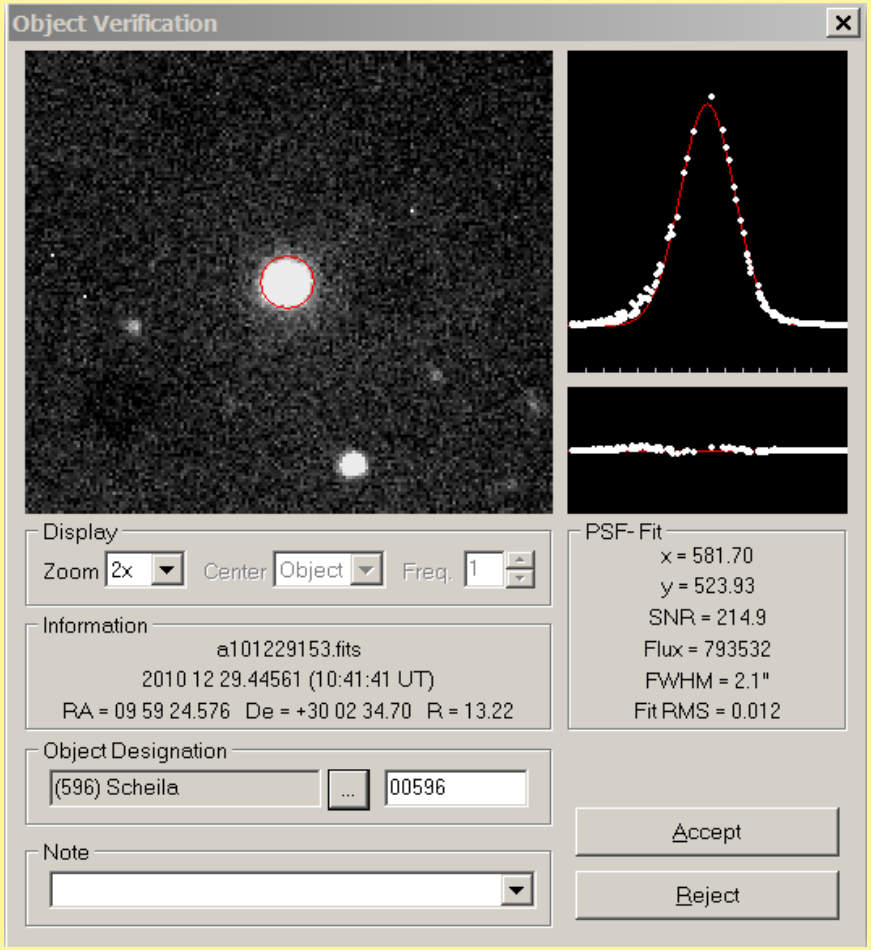
R-band Image of Scheila with Coma on 13 December 2010 UT . By 19 Dec, - coma is gone.



R-band Image PSF fit of Scheila on 13 Dec. 2010 UT

RCT OBSERVATIONS OF MINOR PLANET 596 SCHEILA
29 December 2010 – No Evidence of coma

R-band Image of Scheila (circled) with no Coma on 29 December 2010 UT



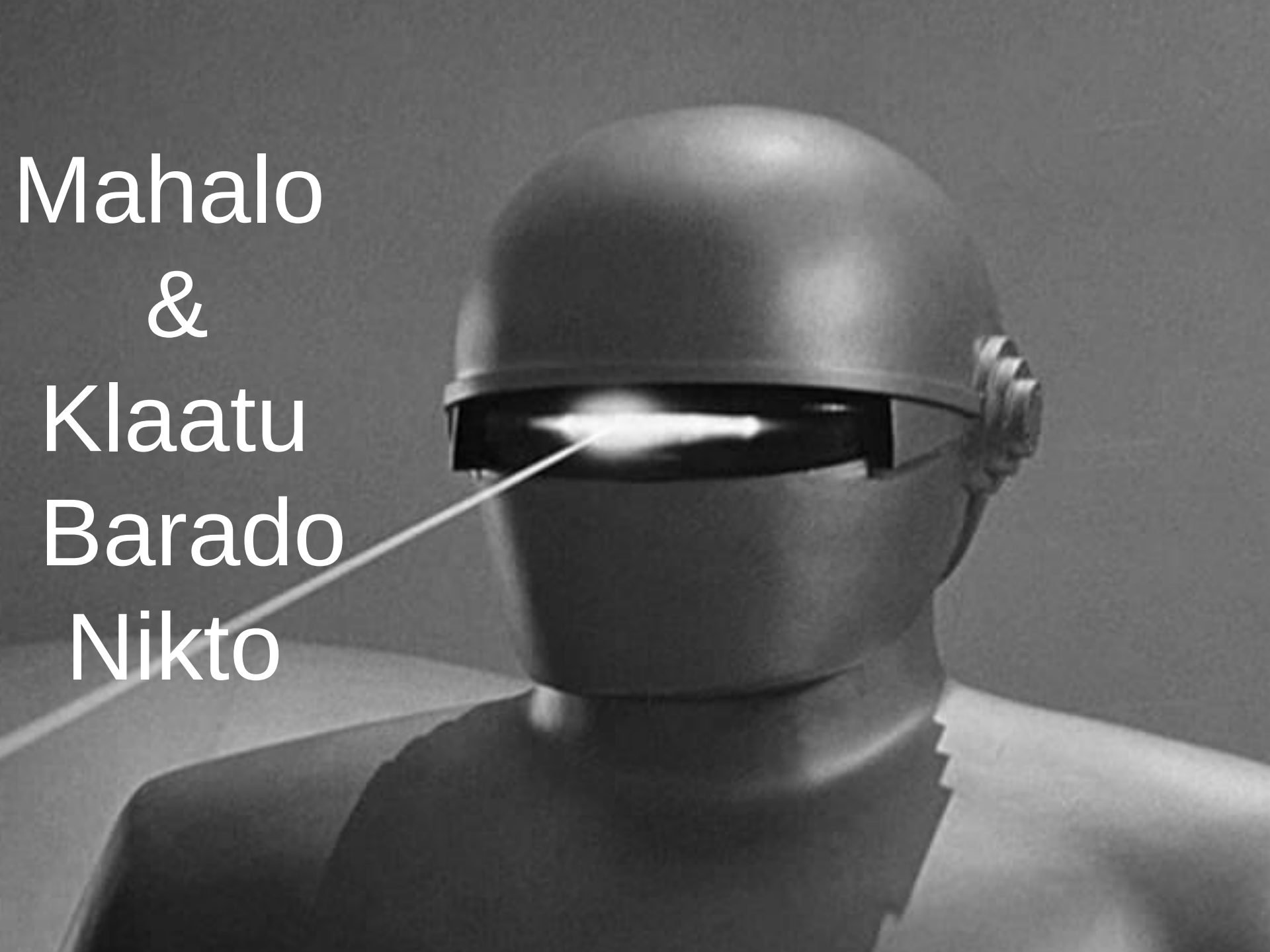
R-band Image PST fit of Scheila on 29 December 2010 UT

So after many years the original dream for the RCT at Kitt Peak is Realized!

- We welcome collaborations Contact us at:
- http:// RCT.wku.edu
- Richard.Gelderman @ wku.edu
- Louis.Strolger @ wku.edu

We are very grateful to NASA and NSF for their support of the RCT project. THANKS!!


Mahalo!


Mahalo
&
Klaatu
Barado
Nikto