Sizing Up the Universe

Robert J. Vanderbei

2023 September 5
Some Things to Discuss…
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▶ Textbook
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- Textbook
- Course Expectations
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- Grading
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- Student Background
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- Nighttime imaging?
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- Nighttime imaging? Moon and Saturn on Sept 26
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- Projects?
- Nighttime imaging?  Moon and Saturn on Sept 26
- Software
How I Got Interested
How I Got Interested
Camera on a Tripod
Telescope Images

3.5” Questar
10” Reflector, 4” Refractor, and Finder

1. Mount

2. Camera
   Computer
   Software

3. Telescope
Move equipment outside.
Ready To Go...
Our Solar System
SuperMoon...

Minimoon
Distance = 399,686 km = 1.333 ls
22:09 EST, Feb 3, 2015

Supermoon
Distance = 353,615 km = 1.180 ls
23:30 EDT, Aug 9, 2014
APOLLO at Apache Point Observatory

2.3 watt laser
2 km diameter Moon patch
10^-10 sec pulse
3.5m aperture
Quantum Efficiency (QE) = 1

Vanderbei:
5mW laser
200 km diameter
10 sec pulse
0.25m aperture
QE = 0.5

V

2 photons

10^-3
10^-4
10^-11
5.1 x 10^-3
0.5

-----> 11.2 x 10^1 = 112 photons
Lunar Eclipse (2010 Dec. 21)
Jupiter and Saturn
Crescent Venus (Daytime!)
Venus Transit 2012

Distance to Sun = 8.3 light-min.,  Distance to Venus = 2.4 light-min.
Venus Transit Weather
Mercury Transit 2019

Next Mercury transit: 2032 Nov. 13

Next Venus transit: 2117 Dec. 10
Jupiter in the Daytime
Disclaimer:
The Pictures Are Better Than The "Visual" View

Distance to Jupiter 41 light-minutes
Comets Come and Go...
Comet Lulin

Click to see video
Comet 17P-Holmes
Comet Garradd
Comet 103p Hartley and the Double Cluster
Venturing Beyond the Solar System
Barnard’s Star
Barnard’s Star
Barnard’s Star
Barnard’s Star
Barnard’s Star Closeup

The measured parallax is 0.5478 arcsecs. Corresponds to a distance of 5.97 lightyears.
Nebulae In Our Home Galaxy (the Milky Way)

Diameter: 180,000 light-years
Lagoon Nebula
Orion Nebula
Orion Nebula—Close Up
Orion Nebula—Hubble
Orion in the Daytime

Starlight Express SXV-H9 on 10” RC at f/9
Hα (13 nm bandwidth)

06:20–06:22 EDT
6 × 5 seconds

SUNRISE at 06:23 EDT local time
Orion in the Daytime

Starlight Express SXV-H9 on 10″ RC at f/9
Hα (13 nm bandwidth)

06:22–06:36 EDT
33 × 1 seconds

SUNRISE at 06:23 EDT local time
Orion in the Daytime

Sept. 9, 2007

Starlight Express SXV-H9 on 10″ RC at f/9

Hα (13 nm bandwidth)

06:36–06:47 EDT
118 × 0.2 seconds

SUNRISE at 06:23 EDT local time
Orion in the Daytime

Sept. 9, 2007

Starlight Express SXV-H9 on 10” RC at f/9
Hα (13 nm bandwidth)

06:47–06:55 EDT
110 × 0.2 seconds

SUNRISE at 06:23 EDT local time
Orion in the Daytime

Sept. 9, 2007

Starlight Express SXV-H9 on 10” RC at f/9
Hα (13 nm bandwidth)

06:55–07:03 EDT
110 × 0.1 seconds

SUNRISE at 06:23 EDT local time
Back to Nighttime
Running Man Nebula
Rosette Nebula
Rosette Nebula—New Camera
Rosette Nebula—Widefield
Comparison

Driveway

Mt. Palomar (48-inch)
Denoised

Driveway

Mt. Palomar (48-inch)
Pleiades
Ring Nebula
Little Dumbbell Nebula
Eskimo Nebula
Crescent Nebula
Crescent Nebula
Soap Bubble Nebula
Veil Nebula
Veil Nebula
Bubble Nebula
Horsehead Nebula
Clusters Clustered Around the Milky Way
Hercules Globular Cluster
Galaxies Beyond Our Milky Way
M82 and M81

Distance: 11.7 million light-years
Whirlpool Galaxy

May 9, 2005
Sombrero Galaxy
Deerlick Galaxy Cluster
Why Astrophotography?

Long Exposures, Permanent Record, Digital Enhancement, Light Pollution!

Visual Experience

Long Exposure

Light Pollution Subtracted
Old Astronomical CCD camera

- StarlightXpress SXV-H9
- Pixel size: $6.45 \times 6.45$ microns
- Pixels: $1392 \times 1040$
- Quant. Eff.: $\sim 65\%$
- Readout Noise: $\sim 7$ electrons
- Cooling: $\sim 30^\circ$C below ambient
- Download: 3.5 seconds
- Weight: 350g
New Astronomical CMOS camera

- **ZWO ASI2400MC-Pro**
- **Pixel size:** $5.94 \times 5.94$ microns
- **Pixels:** $6072 \times 4042$
- **Quant. Eff.:** $\sim 80\%$
- **Readout Noise:** $\sim 1.1$ electrons
- **Cooling:** $\sim 35^\circ C$ below ambient
- **Download:** 0.125 seconds
- **Weight:** 1360g
Example

“Telescope”: 200mm f/3.5 Vivitar lens ($30)
Mount: Questar
Camera: Starlight Express SXV-H9
Filter: Dichroic Hα

Fundamental Principles
▶ Focal length determines field of view
▶ F-ratio determines exposure time

Total exposure time = 156 mins.
Field of view = 1.9° × 2.5°.
Combatting Light Pollution

Narrow-Band Filters
L-Extreme Filter  7nm

Transmittance %

Wavelength (nm)

Hg  Hβ OIII  Hg  Na  Na  Hα  SII

Optolong L-eXtreme Filter

Optolong