Cassini ISS

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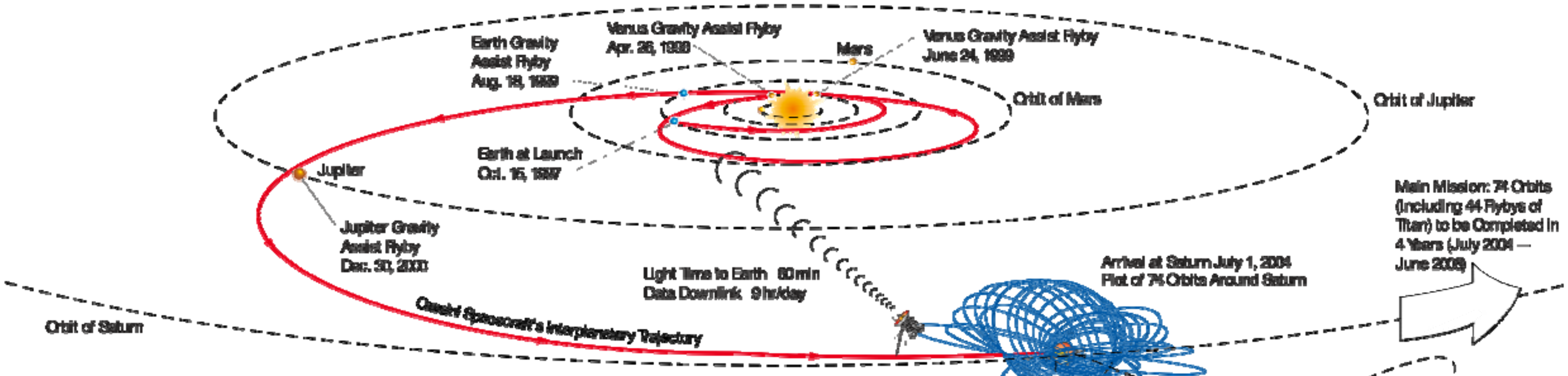
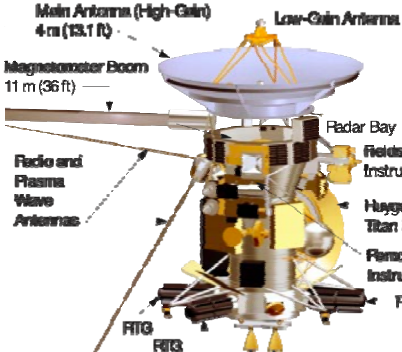
The Cassini Mission to Saturn



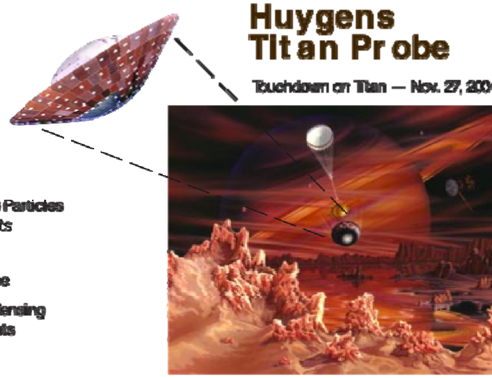
The Cassini Spacecraft



- Launch Mass
  Spacecraft — 2,442 kg (5,384 lb)
  Propellant — 3,132 kg (6,905 lb)
  Total Mass — 5,574 kg (12,288 lb)
- Propulsion: Two engines, 445 Newton (100 lb) thrust each
- Electrical Power Source: Three radioisotope thermoelectric generators (RTGs)
- Optical Remote-Sensing Instruments: Will determine temperatures, chemical composition, structure, and chemistry of Saturn, its rings, moons, and their atmospheres; will measure the mass and internal structure of Saturn and its moons; will photograph Saturn, its rings, and moons in visible, near-infrared, and ultraviolet wavelengths.
- Radar: Will map Titan and measure heights of surface features.
- Field and Particles Instruments: Will map the magnetic field of Saturn; detect charged particles and plasmas; study interactions between solid bodies and the solar wind; investigate ice and dust, plasma waves, and radio waves.

Huygens Titan Probe

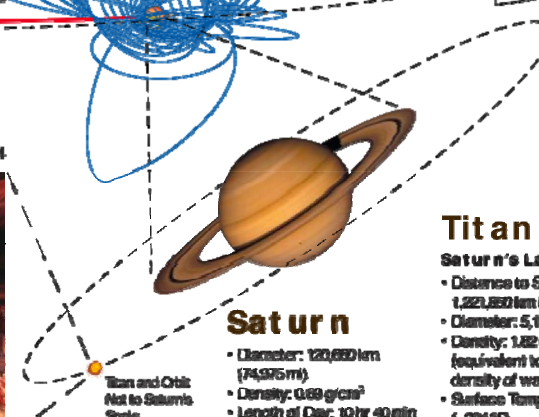
Touchdown on Titan — Nov. 27, 2004



During 3 hours of science observation and measurements, the Huygens Probe instruments will:
- Collect aerosols for chemical analysis.
- Make spectral measurements and take pictures of Titan's surface and atmosphere.
- Measure wind speeds using the Doppler effect.
- Identify constituents in atmosphere.
- Measure physical and electrical properties of the atmosphere.
- Measure physical properties of the solid or liquid surface of Titan.

Cassini Partners

The Cassini mission is a joint effort of the National Aeronautics and Space Administration (NASA), European Space Agency (ESA), and Italian Space Agency (ASI). The mission is managed for NASA by the Jet Propulsion Laboratory, California Institute of Technology. Partners include the U.S. Air Force (USAF), Department of Energy (DOE), and academic and industrial participants from 19 countries.



Saturn

- Diameter: 120,660 km (74,975 mi)
- Density: 0.69 g/cm^3
- Length of Day: 10 hr 40 min
- Length of Saturn Year: 29.42 Earth Years
- Rings: 7
- Moons: 18
- Composition of Atmosphere:
  Hydrogen (H_2)
  Helium (He)
  Methane (CH_4)
  Ammonia (NH_3)
  — and numerous other hydrocarbons

Titan

Saturn's Largest Moon

- Distance to Saturn: 1,221,850 km (759,200 mi)
- Diameter: 5,150 km (3,199 mi)
- Density: 1.82 g/cm^3 (equivalent to 1.82 times the density of water)
- Surface Temperature: –181 °C (–294 °F)
- Surface Pressure: 1.5 bars (approximately 1.5 times surface pressure at sea level on Earth)
- Composition of Atmosphere:
  Nitrogen (N_2)
  Methane (CH_4)
  — and other hydrocarbons and nitriles

World Wide Web (WWW): http://www.jpl.nasa.gov/cassini

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

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Spacecraft Issues

- To point the camera you must turn the spacecraft
- Normally done with reaction (momentum) wheels but sometimes done with hydrazine thrusters
- Reaction Wheels are degrading and are being managed (implies restrictions on turns)
- Many instruments compete for pointing

Spacecraft Issues, continued

- Now in the Equinox mission, but soon to enter the Solstice mission to carry us to end of mission by spacecraft suicide in 2017
- Periapses are typically > 5 R_S but will decrease to 1.01 R_S at the end of mission. Apoapses are 20-60 R_S
- Use Titan for gravity assist (one Titan pass every few revs, 16 days and multiples).

Science Decision Making Process

- The Traceability Matrix (NASA Mission Review)
- Project Science Group (PSG) is the highest level and the Project Scientist Linda Spilker is in charge of this group. PSG consists of instrument PIs and facility Team Leaders plus 6 Interdisciplinary Scientists
- There are two Orbital Science Teams (OSTs)
  - Titan and Icy Satellites
- There are four Target Working Teams (TWTs)
  - Saturn
  - Rings
  - Magnetosphere
  - Cross Discipline

Science Planning, continued

- The tour (shape of the orbits) planning process is finished except for some small tweaks
- We are now deciding where to point.
- A high-level plan for trajectory correction maneuvers is already in place (typically twice per rev). These time periods are not accessible to science
- Each of the OSTs and TWTs meet, set priorities and negotiate for revs.
- Understanding of the issues is lagging (probably the current science requests cannot be met)

Negotiations for Pointing, Data

- The first step is to identify the highest-priority observations – each TWT and OST does this independently and then meet over a series of months to hash out conflicts. Decisions have already been made for about 2/3 or the remaining tour. Only about 2000 hours are allocated this way but they have priority.
- The second step is to assign revs to TWTs and OSTs to add lower priority observations and for those groups to produce a detailed timeline of observations. These decisions are made typically 9 months before the observations are executed and then the plan goes to the integration and implementation teams. This process saturates the available resources.

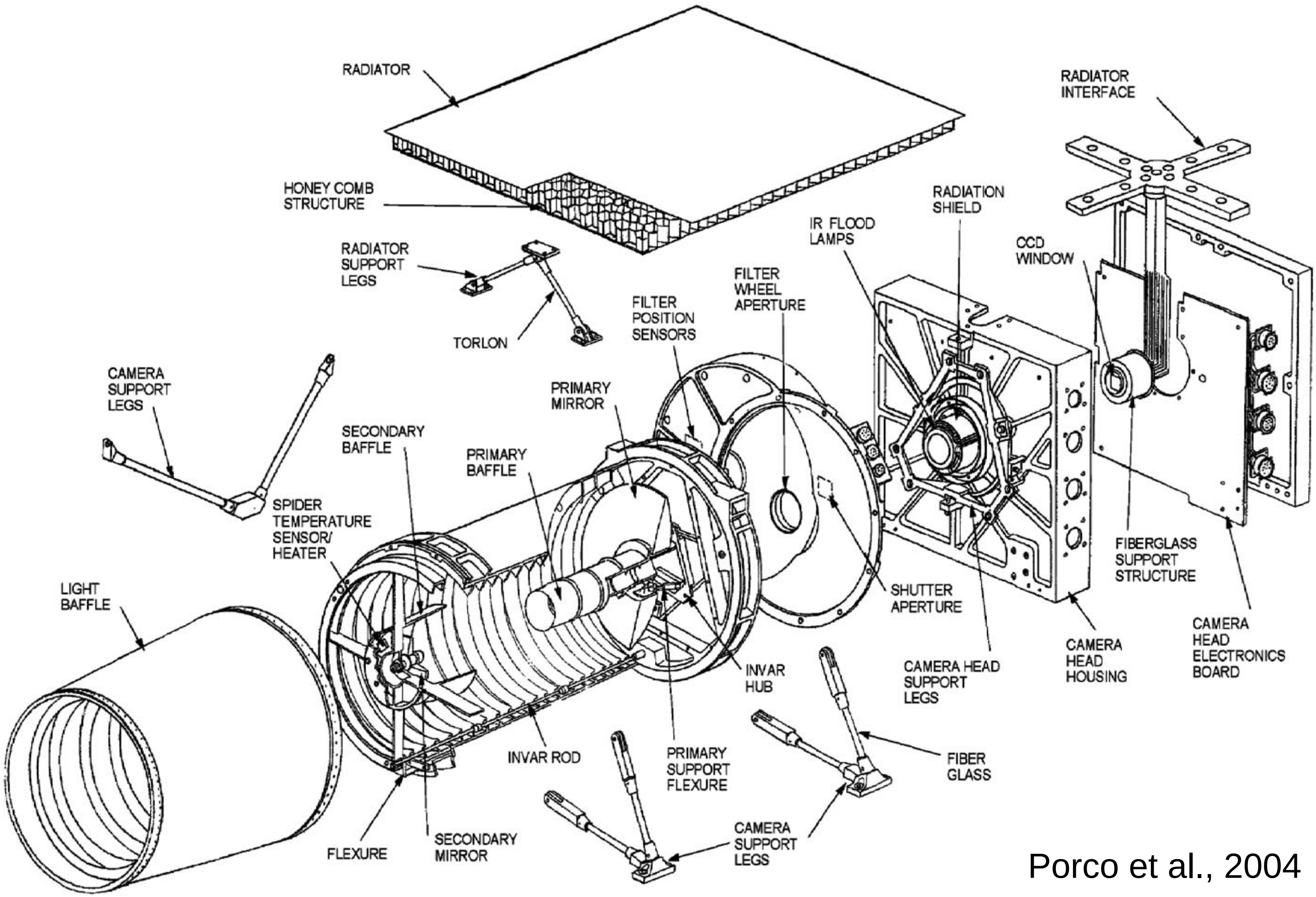
Constraints on Planning

- Spacecraft must turn to earth to downlink data accumulated on the solid state recorder. A typical downlink is 8 hours, plus turn time and an hour or so for biasing the reaction wheels. Time between downlinks is typically 1-2 days. The optical instruments cannot point at this time.
- Some kinds of turns are bad for the reaction wheels and the problem and its solution are poorly understood. Therefore the project is being conservative with turning. Recently the project imposed a 2-out-of-3 rule (turns for downlinks, optical remote sensing, or calibrations and magnetospheres science). No turns for out-of-discipline science except for a few high priority items.
- In the Solstice Mission beginning in September, funding for operations is dropping to 60% of FY 2008 levels. We need to find a way to do the mission on less and this will mean cutting back in addition to finding greater efficiency. I don’t think the science community has come to grips.

ISS

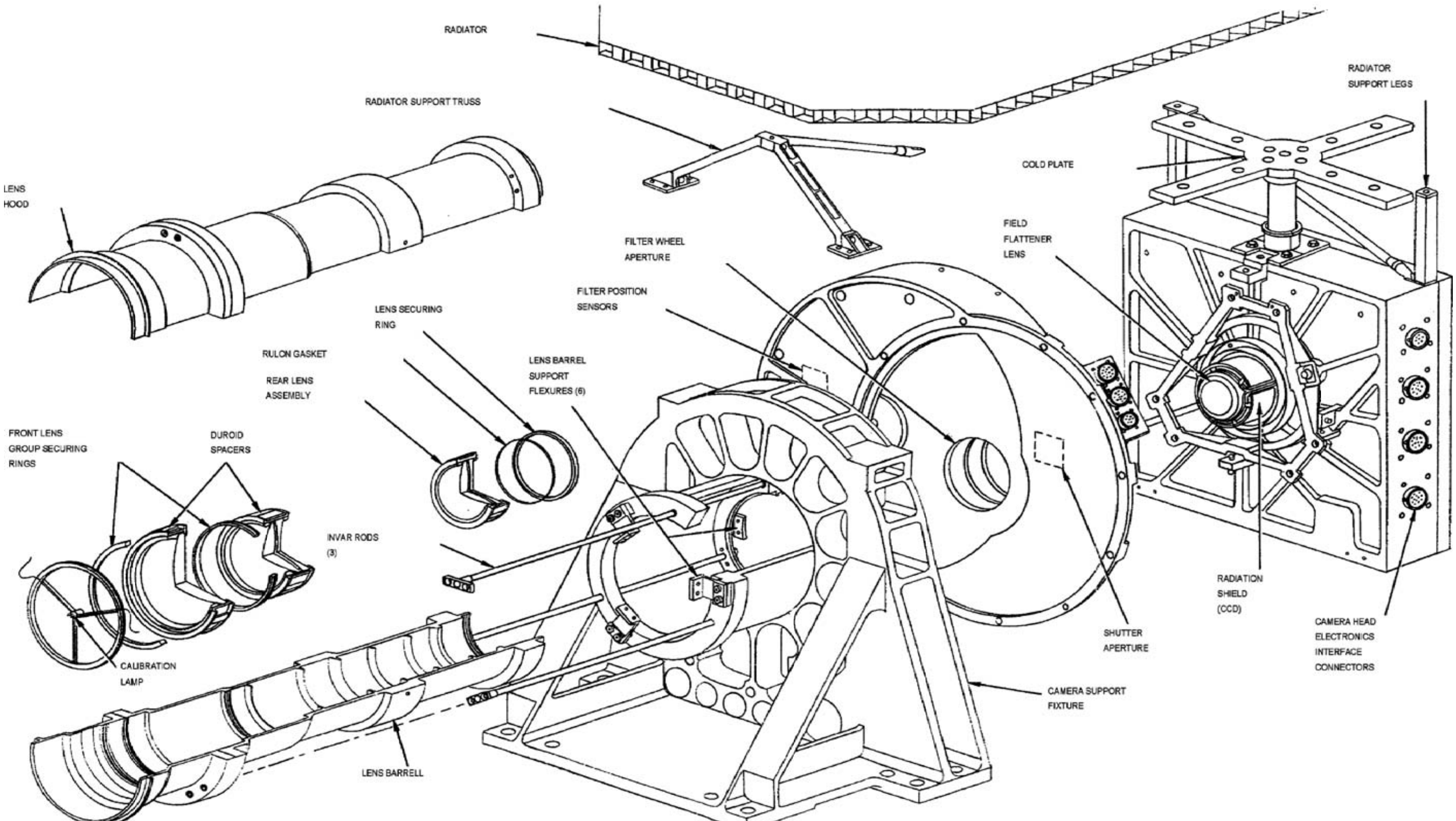
- Two cameras, Narrow Angle Camera and Wide Angle Camera (NAC and WAC)
- NAC is a Ritchey-Chretien design, 2000 mm focal length, f 10.5, CCD
  - 200 – 1100 nm
  - 6 micro-radian/pixel, 1024X1024
- WAC is a refractor (a spare from Voyager), 200 mm focal length f 3.5, CCD
  - 350-1100 nm
  - 60 micro-radian/pixel 1024X1024

Narrow Angle Camera



Porco et al., 2004

Wide Angle Camera



Porco et al., 2004

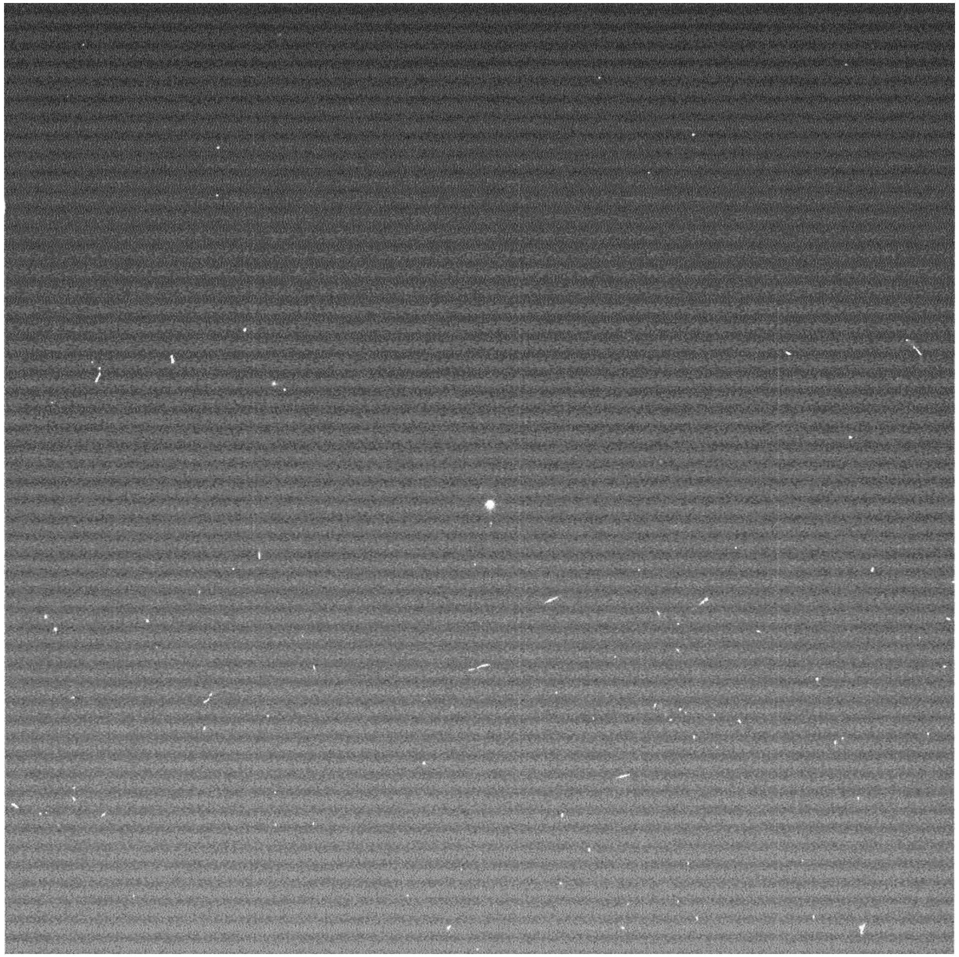
Camera Characteristics, continued

- Two filter wheels on each camera, in tandem; some broad-band and some narrow-band and polarizing filters
- Exposure times from 5 ms to 1200 s but smear is evident in the NAC for t > 48 s.
- Four gain states from 12 e-/DN to 233 e-/DN
- Detector held at -90 C
- Light flood prior to each exposure (Residual Bulk Image is the largest contributor to dark frame)
- 12 and 8-bit encoding, lossless and lossy compression and no compression are available

Calibration Procedure

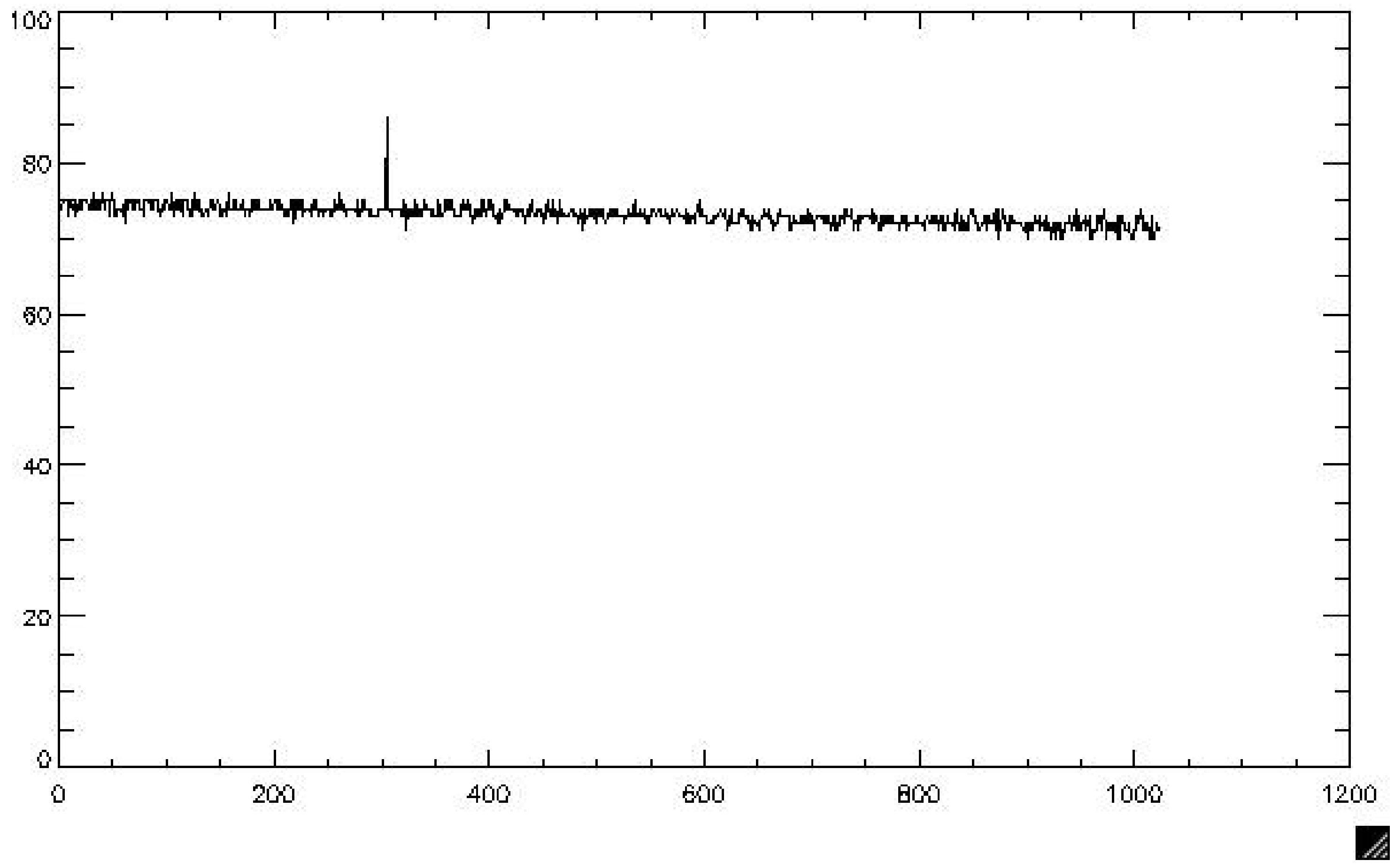
- Reverse 12->8 Lookup Table, if needed
- Subtract Bias from over-clocked pixels
- Remove 2-Hz signal from over-clocked pixels or sky
- Subtract dark field – a complicated procedure
- Remove non-linear terms (small correction)
- Apply Flat Field
- Apply individual filter corrections
- Convert DN to flux or I/F

WAC photo of Vega

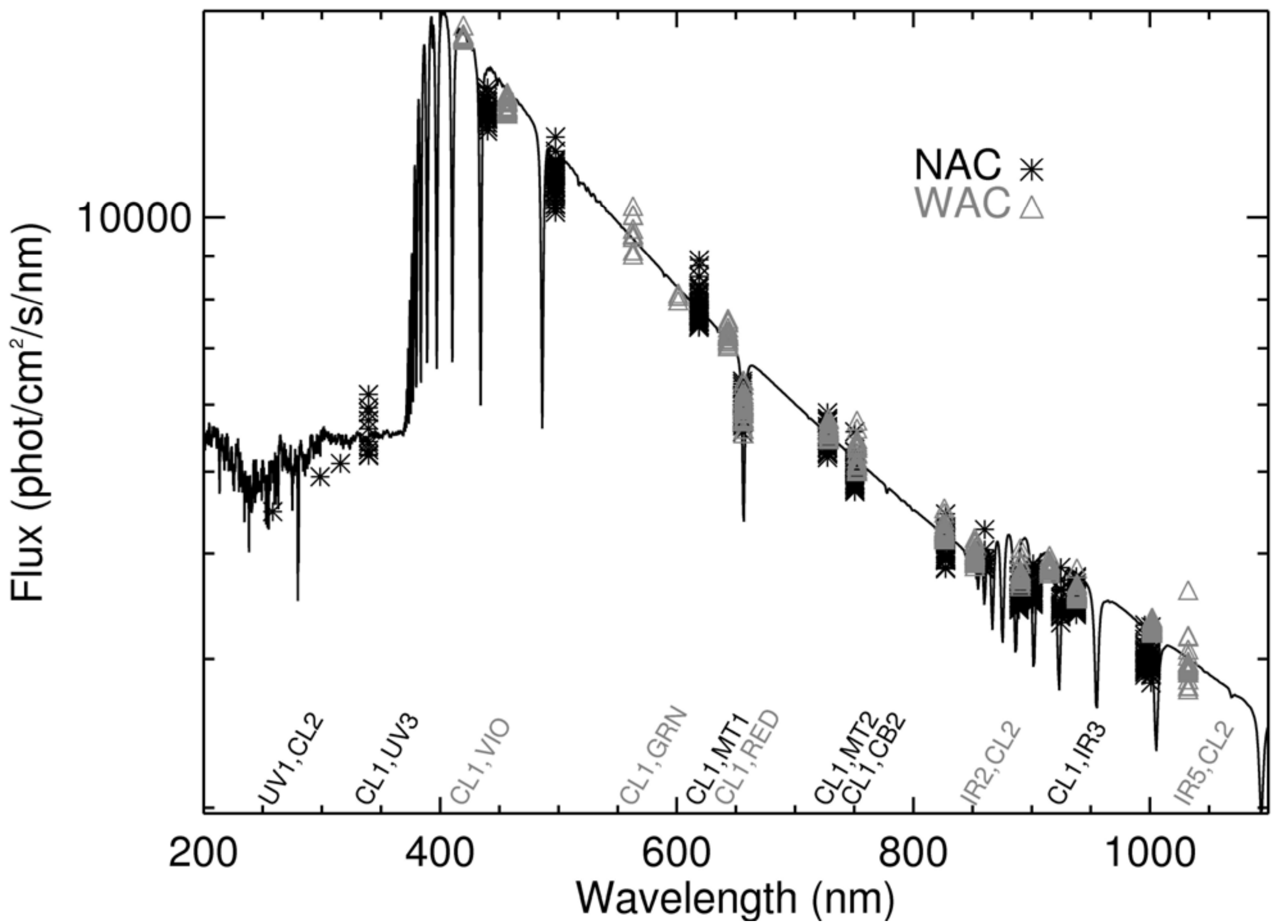


Stretch to show low DN values

DN Values on Line 500



Absolute Calibration: Vega

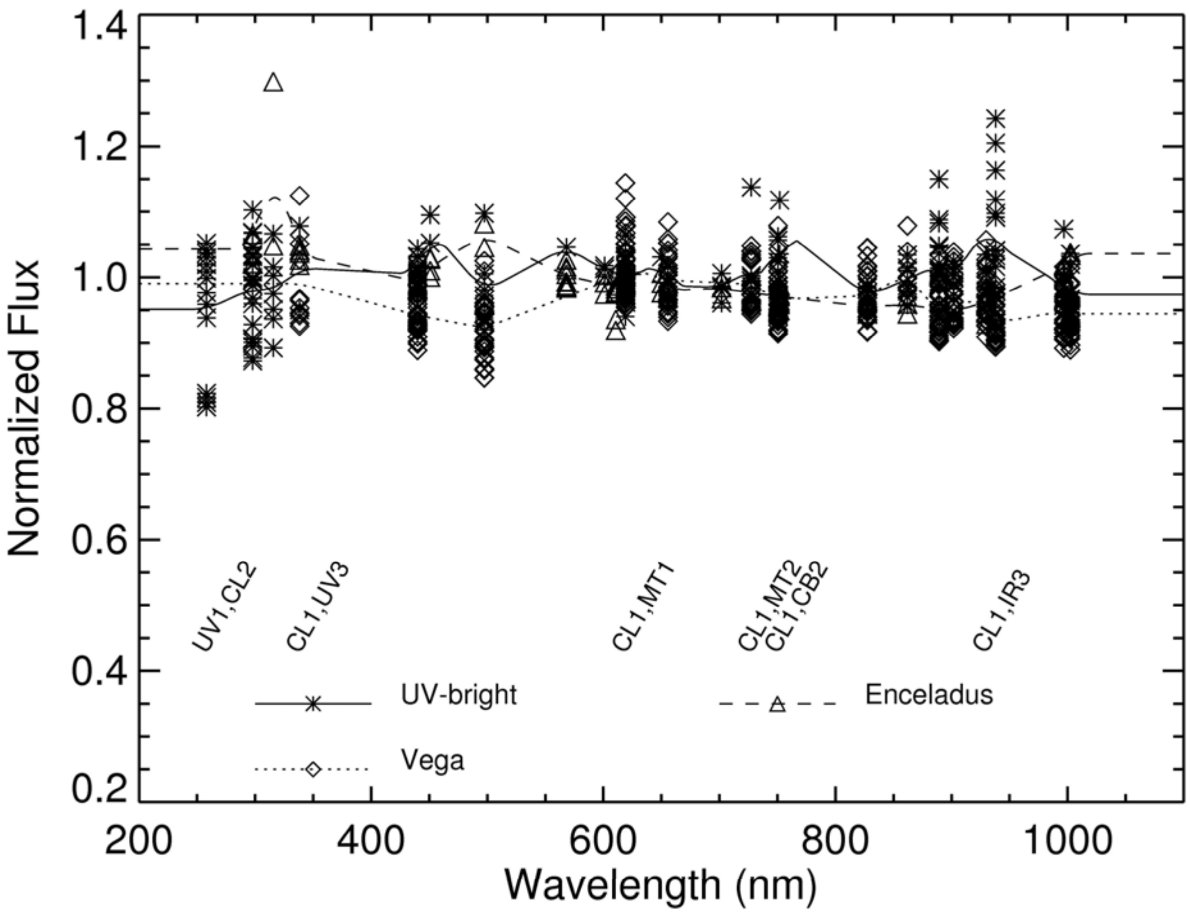


Bohlin, R.C. and Gilliland, R.L.. 2004. Hubble Space Telescope absolute spectrophotometry of Vega from the far-ultraviolet to the infrared. Astron. J. 127, 3508–3515.

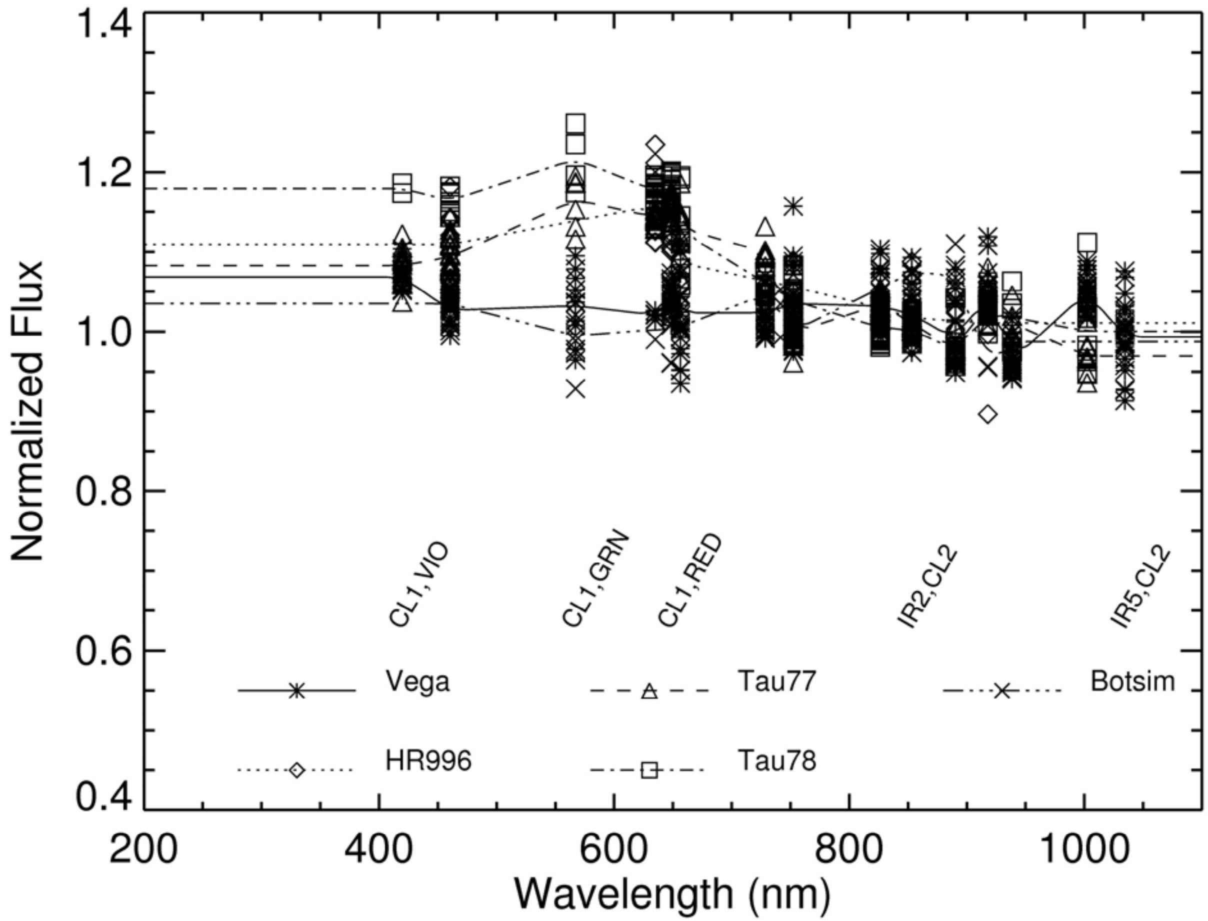
Camera Sensitivity Examples

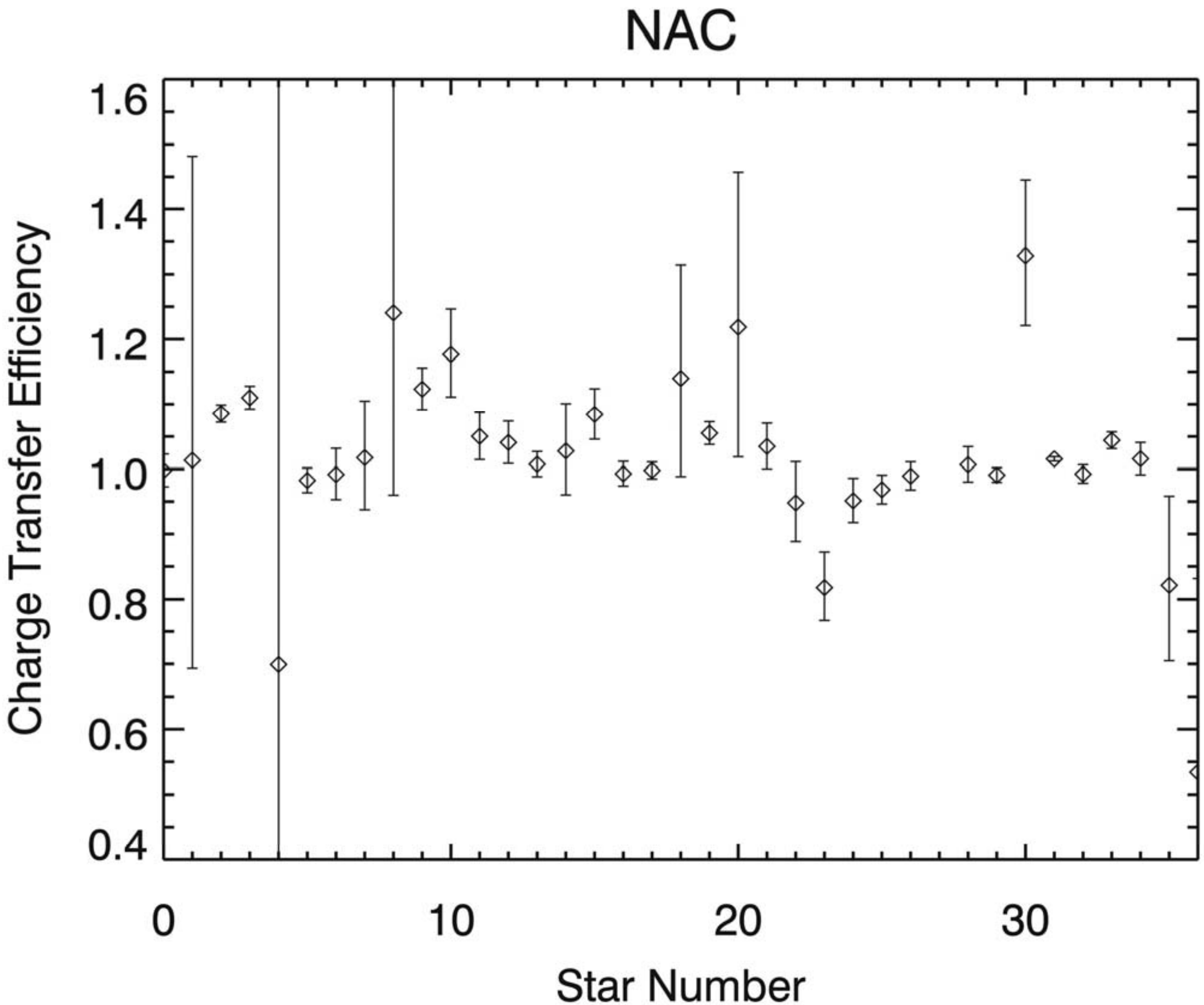
- NAC [CL1,CL2] filter combination
  - Maximum DN is about 1500 (out of 4096) for 100 ms exposure on a GV star Kap Cet, V mag = 4.83
  - Total DN is about 7100 = 210000 electrons
- WAC [CL1,CL2] Filter combination
  - Maximum DN is about 1200 (out of 4096) for 15 ms exposure on Vega (A0, V mag 0.1)
  - Total DN is about 6950 = 206000 electrons

Absolute Calibration: NAC

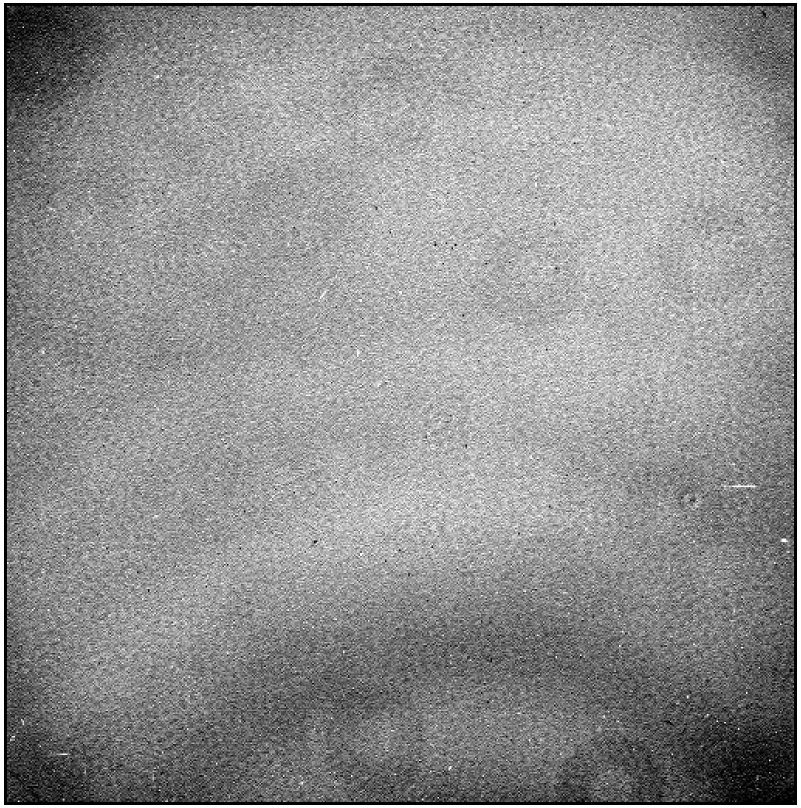


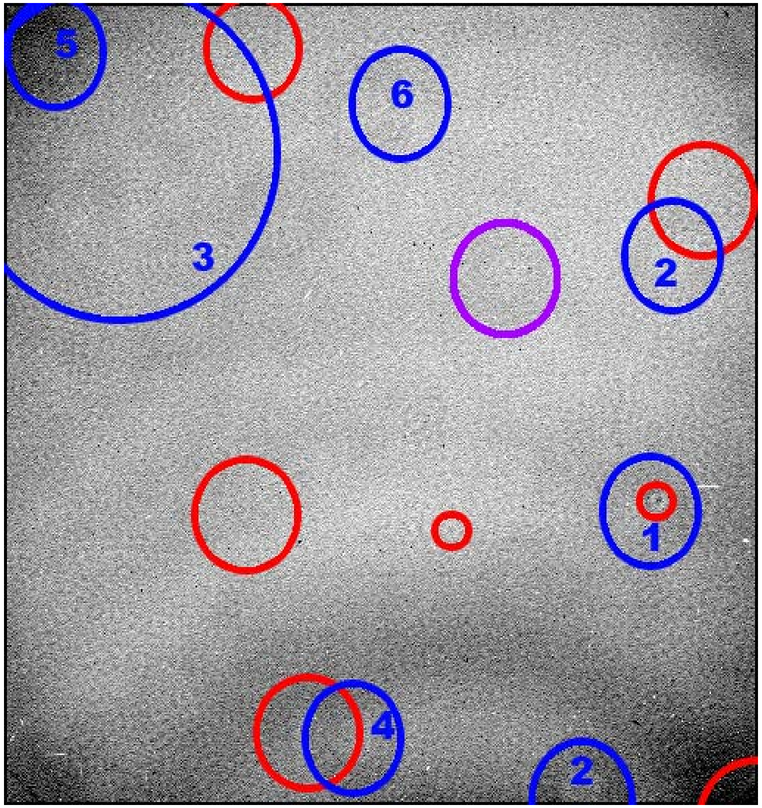
Absolute Calibration: WAC



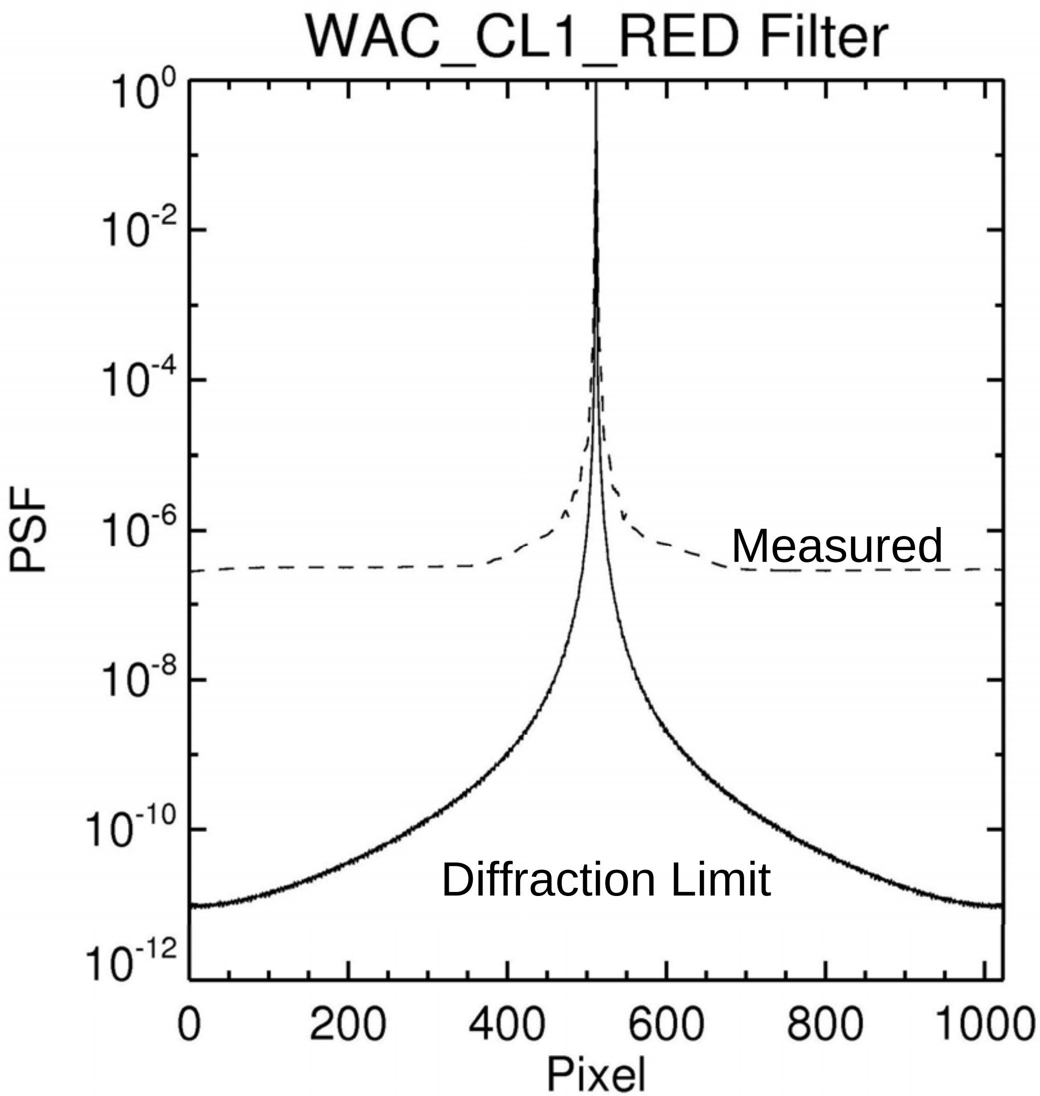

NAC
Charge Transfer Efficiency
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0
10
20
30
Star Number

NAC 'Flats' from Titan

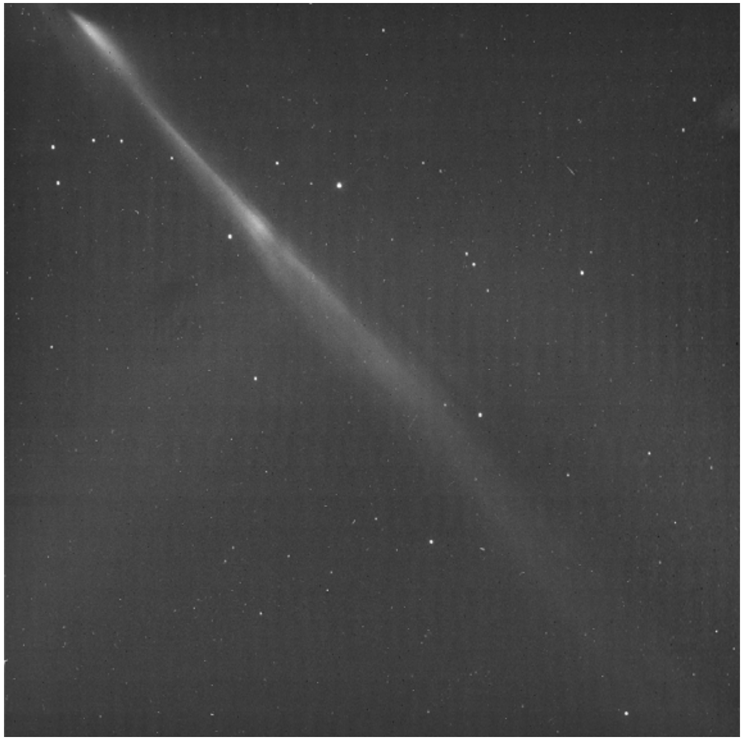


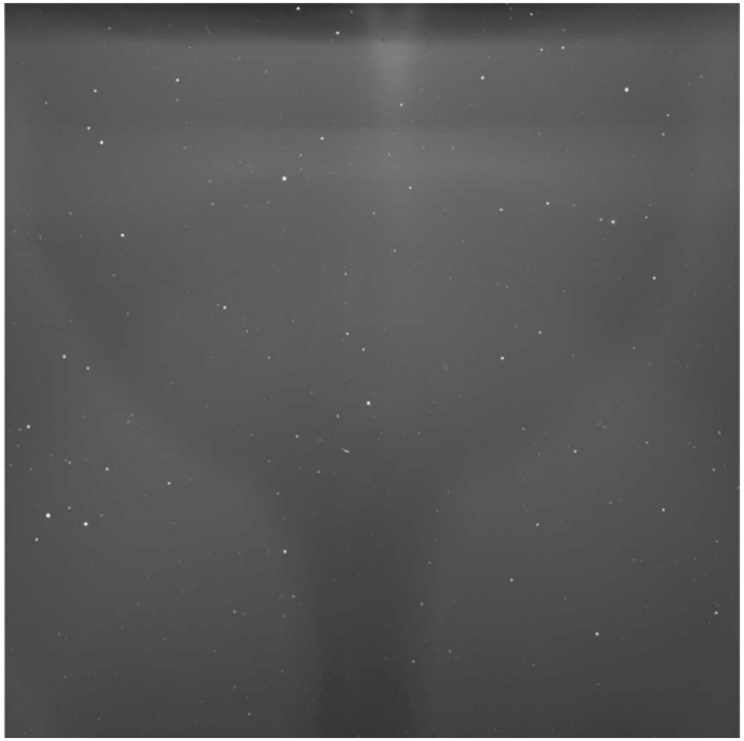


The numbered dust rings can be traced to epoch

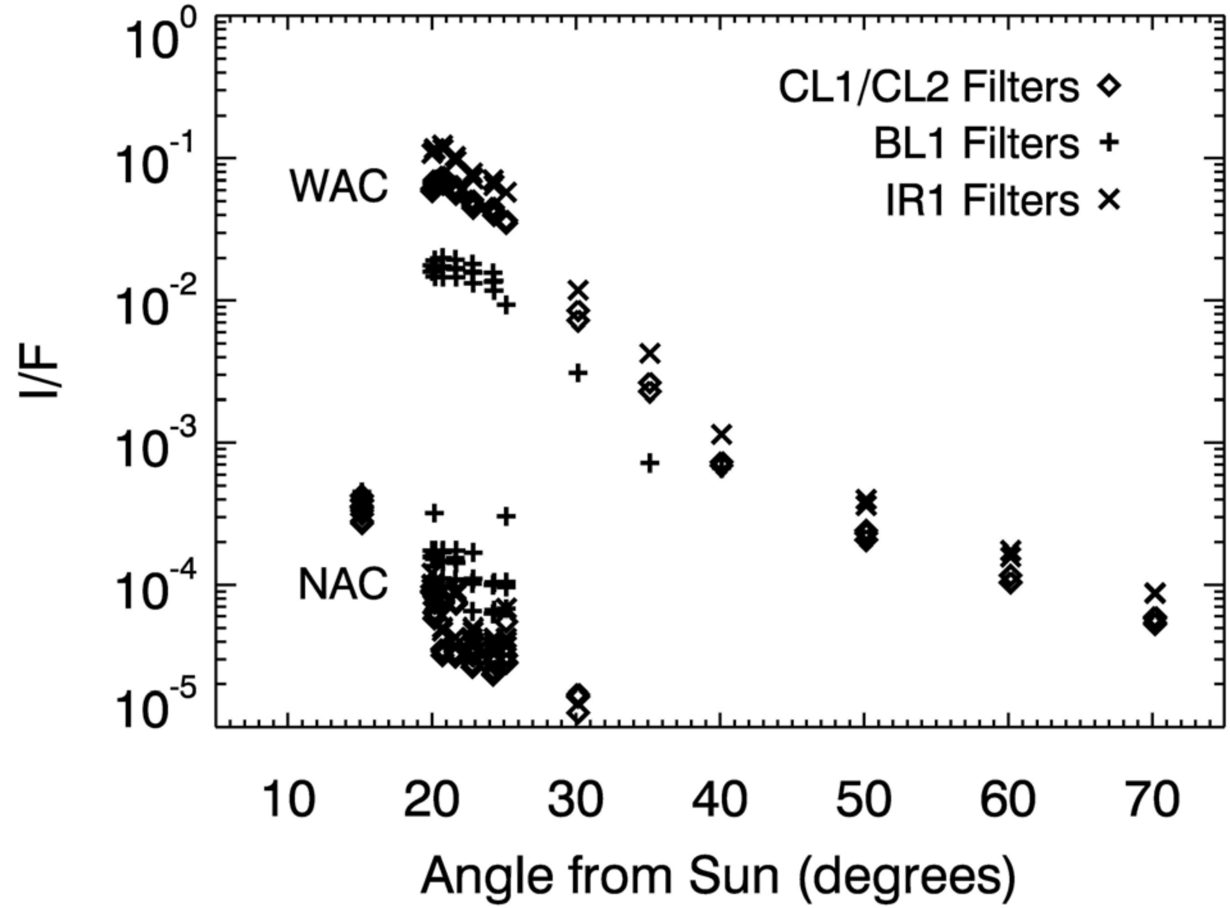

WAC_CL1_RED Filter
PSF
Pixel
Measured
Diffraction Limit
10^0
10^-2
10^-4
10^-6
10^-8
10^-10
10^-12
0
200
400
600
800
1000

Stray Light Patterns: NAC





Stray Light



10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
I/F
WAC
NAC
CL1/CL2 Filters ◇
BL1 Filters +
IR1 Filters ×
10
20
30
40
50
60
70
Angle from Sun (degrees)

References

- Porco,C. et al., CASSINI IMAGING SCIENCE: INSTRUMENT CHARACTERISTICS AND ANTICIPATED SCIENTIFIC INVESTIGATIONS AT SATURN, Space Science Reviews 115: 363–497, 2004
- West, R. et al., In-flight Calibration of the Cassini Imaging Science Subsystem Cameras, Planetary and Space Sciences manuscript, 2010.