Long-Focus Astrometric Observations of the Planetary Satellites at USNO: 1967 - 2003

Synopsis

- Long-focus astrometric photographic and/or CCD observations of the moons of Mars, and those of the outer planets taken at USNO from 1967 to 2003.
- Observations used in many international programs.
- The 2000 plate archive sent to IMCCE for digitizing with the ROB scanner. IMCCE interested in CCD archive.
- GAIA star positions will significantly improve astrometry of these plates; especially for the ~5000 CCD frames!

Photographic Observations: Martian Satellites

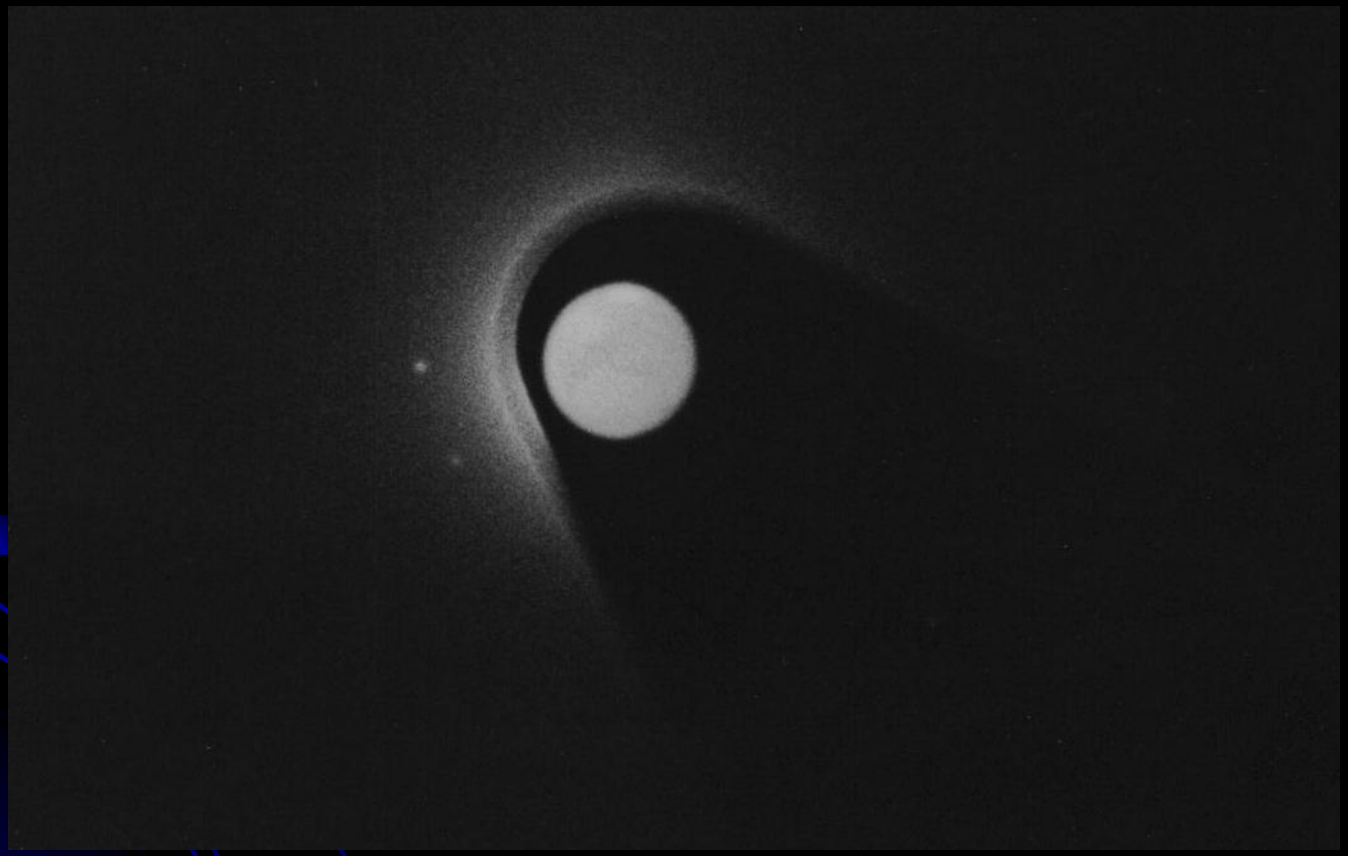
- Wilkins challenges secular acceleration of Phobos, requests new observations.
- Observations begun in1967 amid claims of large ephemeris errors.
- Continued in support of space reconnaissance missions.
- Photographic observations ended after 1997 opposition with Kodak's termination of scientific plate production.
- 684 multi-exposure plates, 88 nights, 31 years, 14 opps.

Martian Satellites: Photographic Techniques

- Fast motions → short exposures → 61-inch, 26-inch. Full aperture exposures.
- Kodak 103aJ emulsion for shortest exposures and to reduce Mars' red halo. 103aG with 26-inch.
- Schott GG14 + Neutral Nichrome filter for image of Mars.
- Observations at small (< 0.1 arcsec) phase angle.
- Manual measurements for planet and satellites.

Martian Satellites: USNO 61-inch Reflector Flagstaff, AZ 1969

Mars Satellites: USNO 26-inch Refractor Washington, DC 1971



Mars Satellites: USNO 26-inch Refractor Washington, DC 1988

Photographic Observations: Galilean Satellites of Jupiter

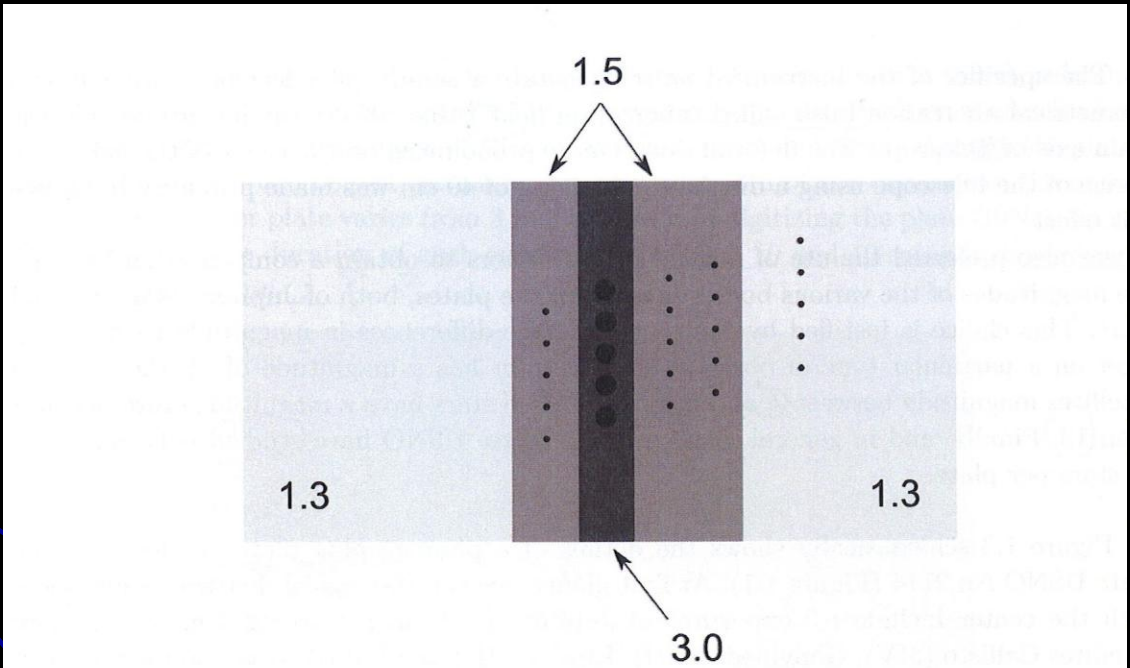
- Begun at apparition of 1967/68 by request of Jean Kovalevsky, Director, BdL, for ephemeris improvement.
- First set taken with McCormick refractor.
- Continued with USNO 26-inch from 1973 by request from NASA to support Voyager space reconnaissance.
- Concluded in 1998 when Kodak ended production of scientific plates. 605 multi-exp. plates, 272 nights, 25 oppositions, 31 years.

Galilean Satellites of Jupiter: Photographic Techniques

- Long-focus visual refractors ideal for astrometry.
- Fast emulsions (Kodak 103aG) for short exposures.
- Filter methods (made with HRP plates) ➔ magnitude compensation with 9/10 th mag. stars
- Diaphragm aperture to increase coma-free field.
- Trails for orientation, cluster scale plates

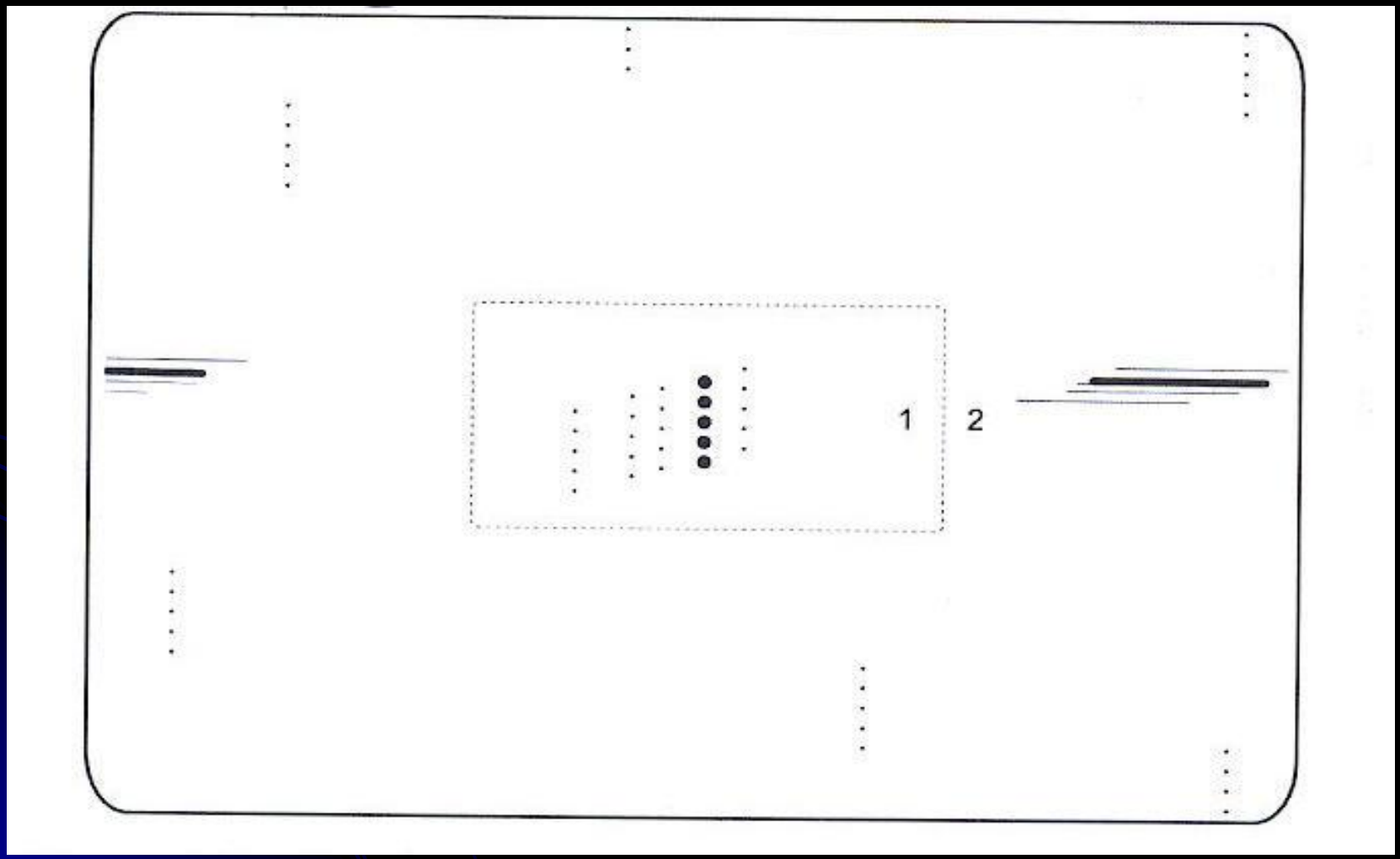
Schematic of Galilean Satellites Filter

(V. Robert Dissertation)

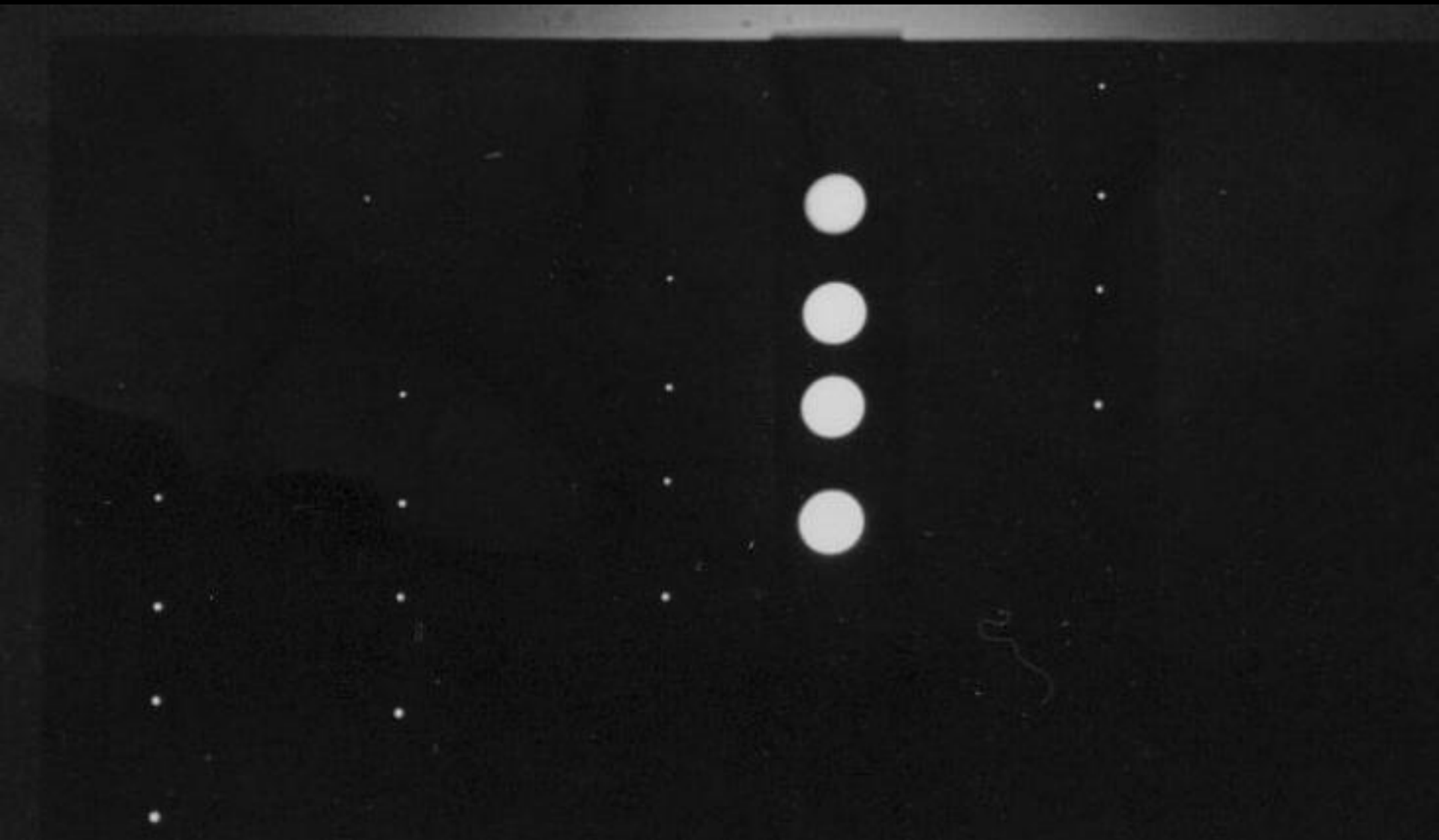


Schematic of Plate 21-14

(V. Robert Dissertation)



Galilean Satellites: USNO 26-inch Refractor, Washington, DC 1974



Photographic Observations: Satellites of Saturn

- Begun in 1974 by request from NASA for support of the Voyager mission.
- Emphasis on inner moons with poor observational histories: Mimas, Enceladus, Hyperion
- Recovered Janus (1980S1) and revised period.
- Photo observations ended Jan 20, 1999 –last plates!
- 676 multi-exp plates, 177 nights, 25 years, 24 opps..

Satellites of Saturn: Photographic Techniques

- USNO 26-inch, fast emulsion – 103aG
- Nichrome filter for measurable image of Saturn, rings.
- 26-inch aperture for mimas, 16-inch for Saturn positions.
- Determined RA, Dec for Saturn on AGK3 from measures on rings and from satellites: 1974-1980.

Saturnian Satellites: USNO 26-inch Refractor Washington, DC 1974

Saturnian Satellites: USNO 26-inch Refractor Washington, DC 1977

Saturnian Satellites: USNO 26-inch Refractor Washington, DC 1986

CCD Observations

- Begun in 1980 to test potential of HST WFPC CCD detectors for solar system research. Observed with Seidelmann, Rohde & IMCCE interns on occasion.

- Saturn's 1980 ring-plane crossing to study E - ring. 61-inch + WFPC ground system + Lyot Coronagraph (to reduce bright planetary halos).

- Concluded that configuration favorable for observation of inner satellites -- Applied to all satellite systems.

- Because of small field and faint stars, Gaia catalogue needed for best reduction.

CCD Observations: Martian satellites

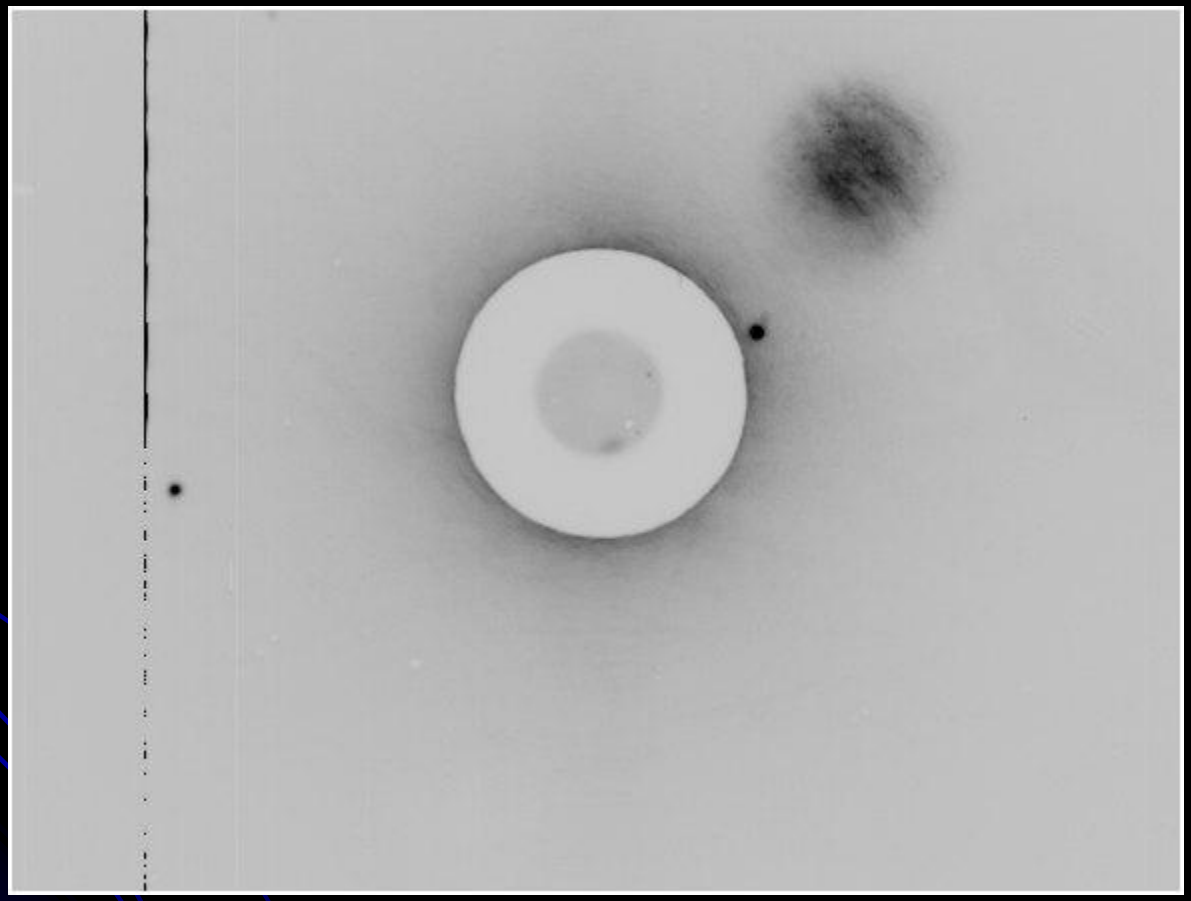
- On occasion, CCD observations with 61-inch supplemented the photographic made with 26-inch.
  Good set at very favorable 2003 opposition by J. Rohde.

- Only black film filters used with CCD and mainly to prevent blooming of the planetary image.

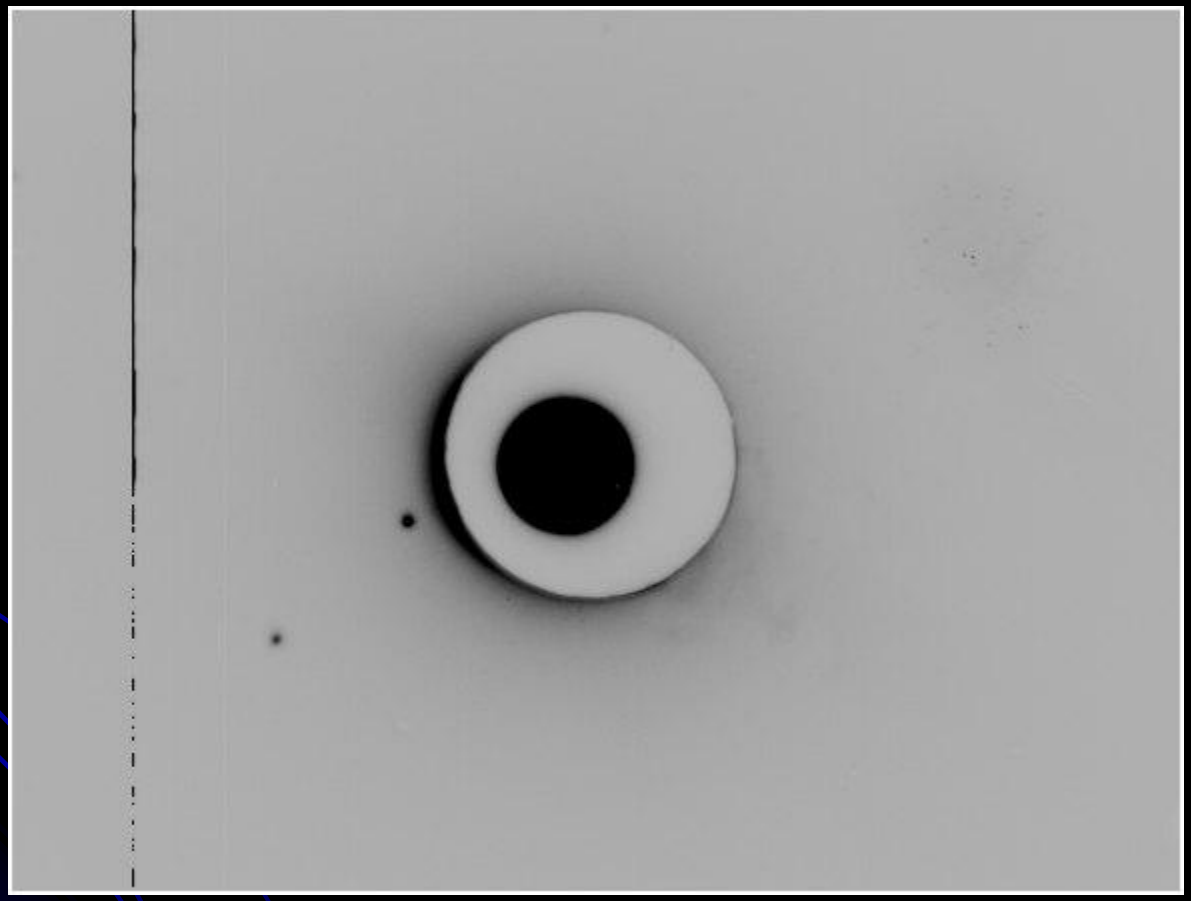
- Only intersatellite observations made.

- Blue filter observations minimize halo: halo light modelled ➔ +/- 0.06 arcsec residuals for 2003 set.

CCD *B* image of Martian satellites
USNO 61-inch Astrometric Reflector, Flagstaff, 2003



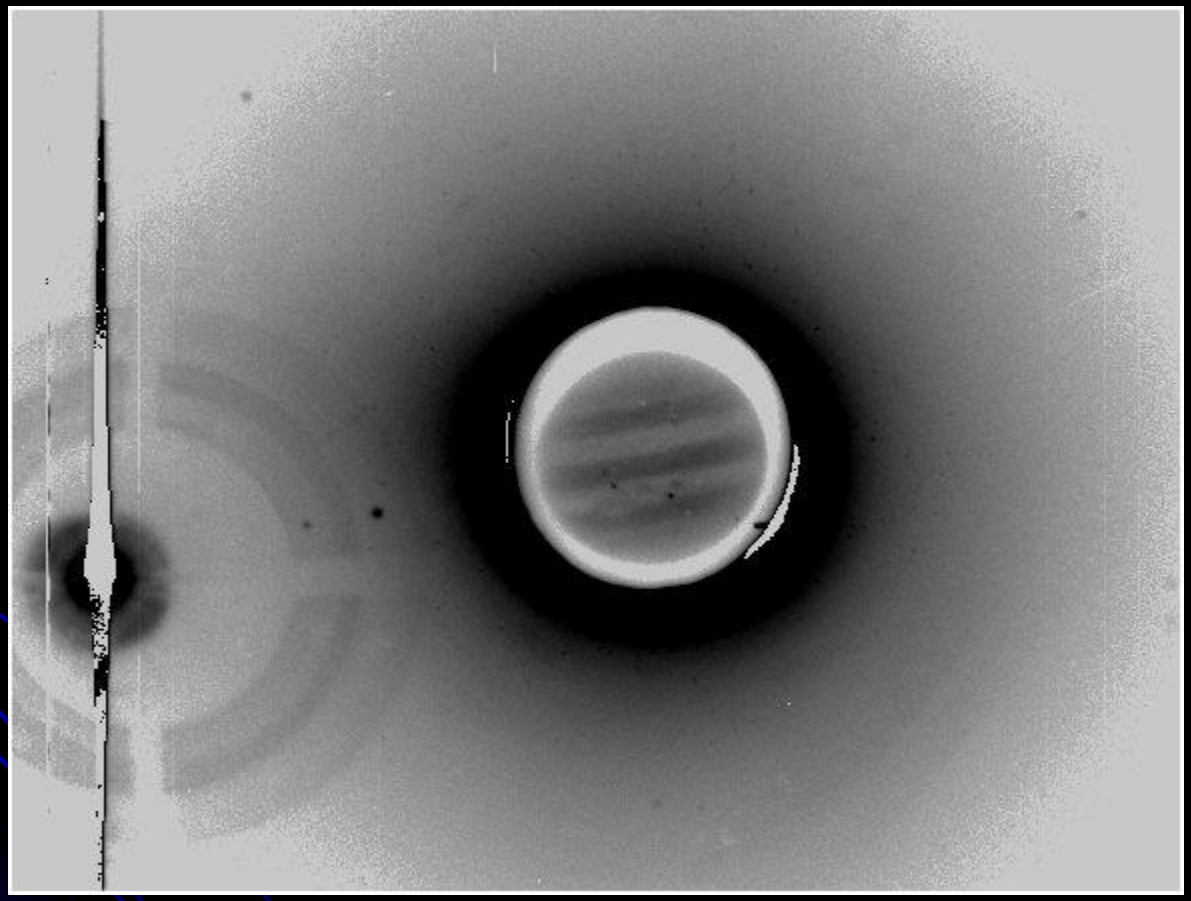
CCD *V* image of Martian Satellites
USNO 61-inch Astrometric Reflector, Flagstaff, 2003



CCD Observations: Inner Jovians Thebe (JXIV) and Amalthea (JV)

- Thebe detected in 1981 – first ground-based detection.
- Observations planned when both satellites near elongation within 2 hours of meridian.
- Intersatellite measures, trail/scale reduction.
- Calibration using short exposures of Galileans

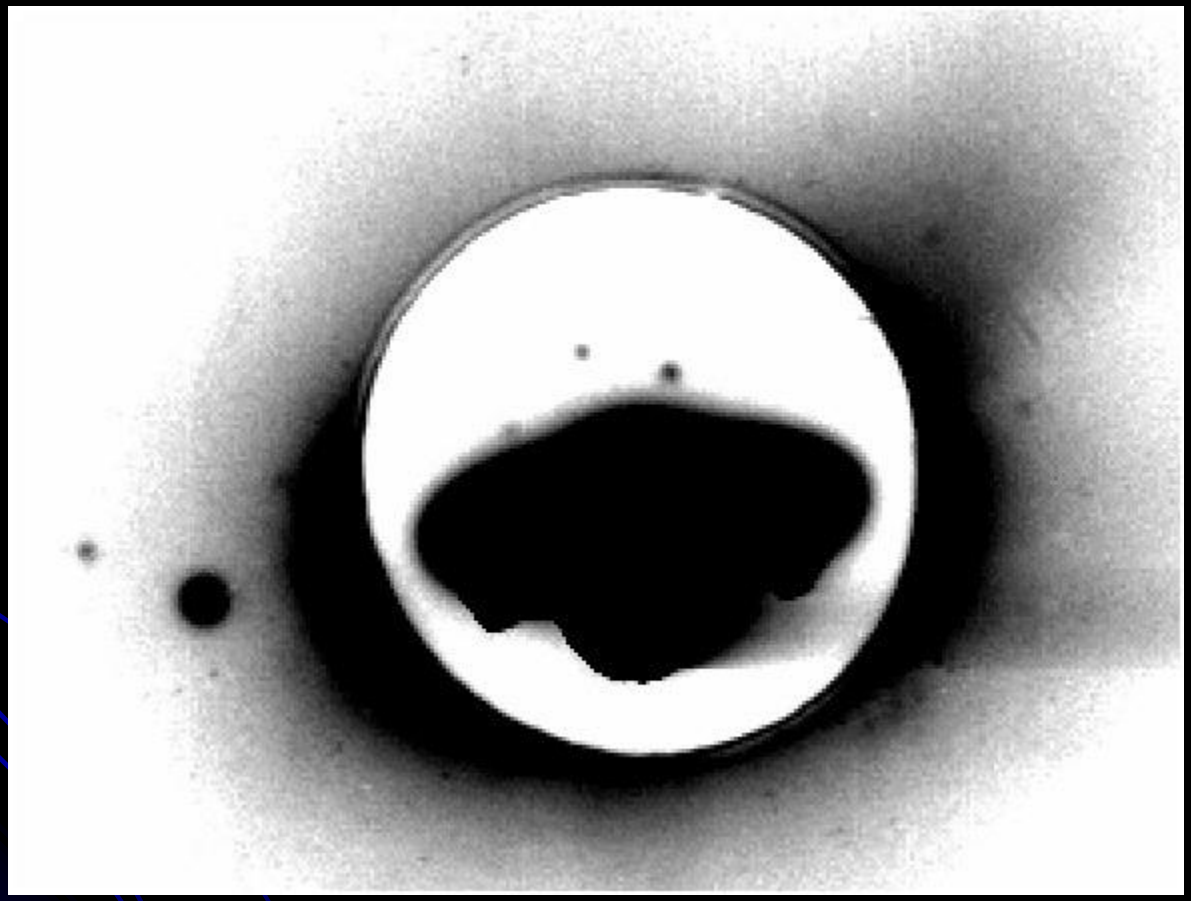
CCD *B* image of JV (Amalthea) and JXIV (Thebe)
USNO 61-inch Astrometric Reflector: Flagstaff, AZ, 1988



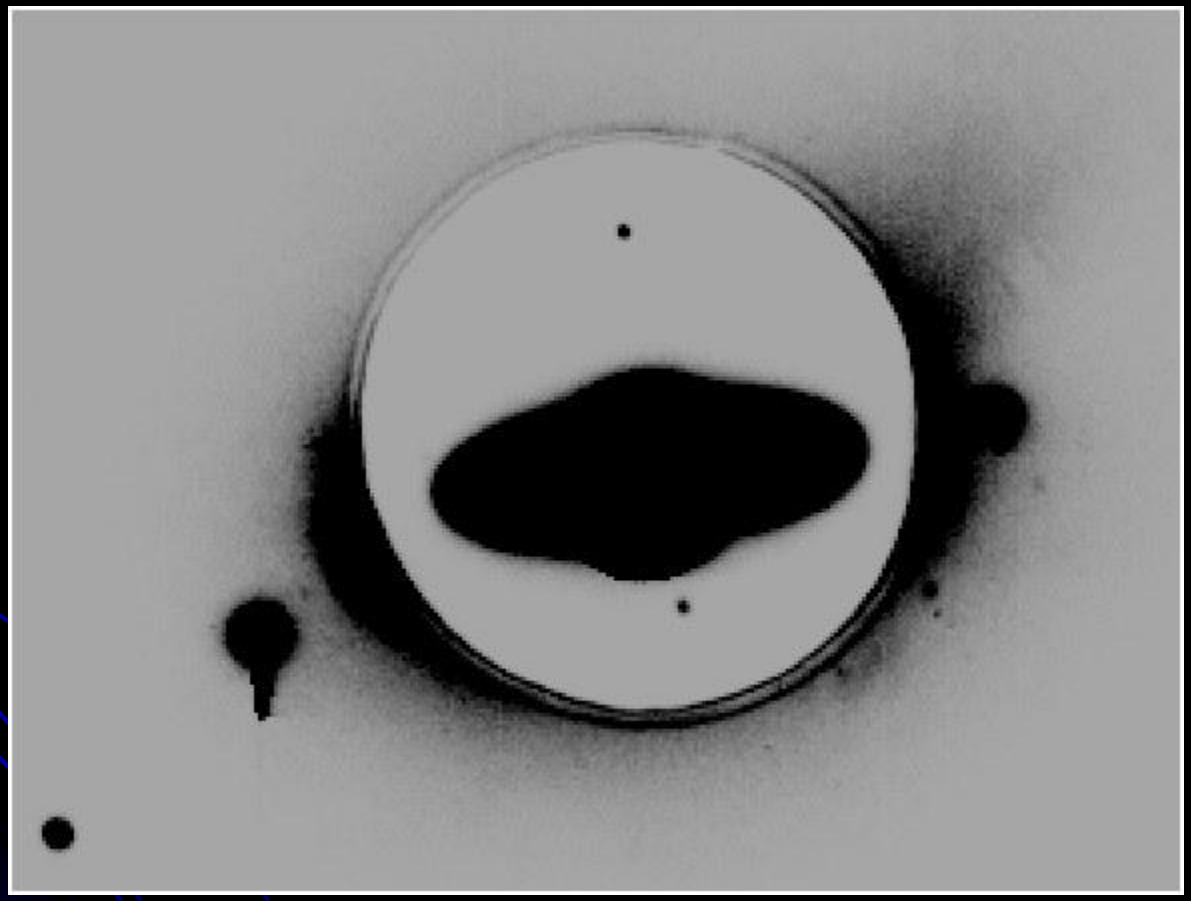
CCD Observations of Saturn's faint co-orbitals

- Janus & Epimetheus co-orbitals detected.
- Calypso, Tethys L5 librator discovered
- Dione and Tethys librators observed at all oppositions.
- Positions of faint moons referred to bright moons; filtered if possible, or by use of alternating exposure technique.
- Trail/scale reduction

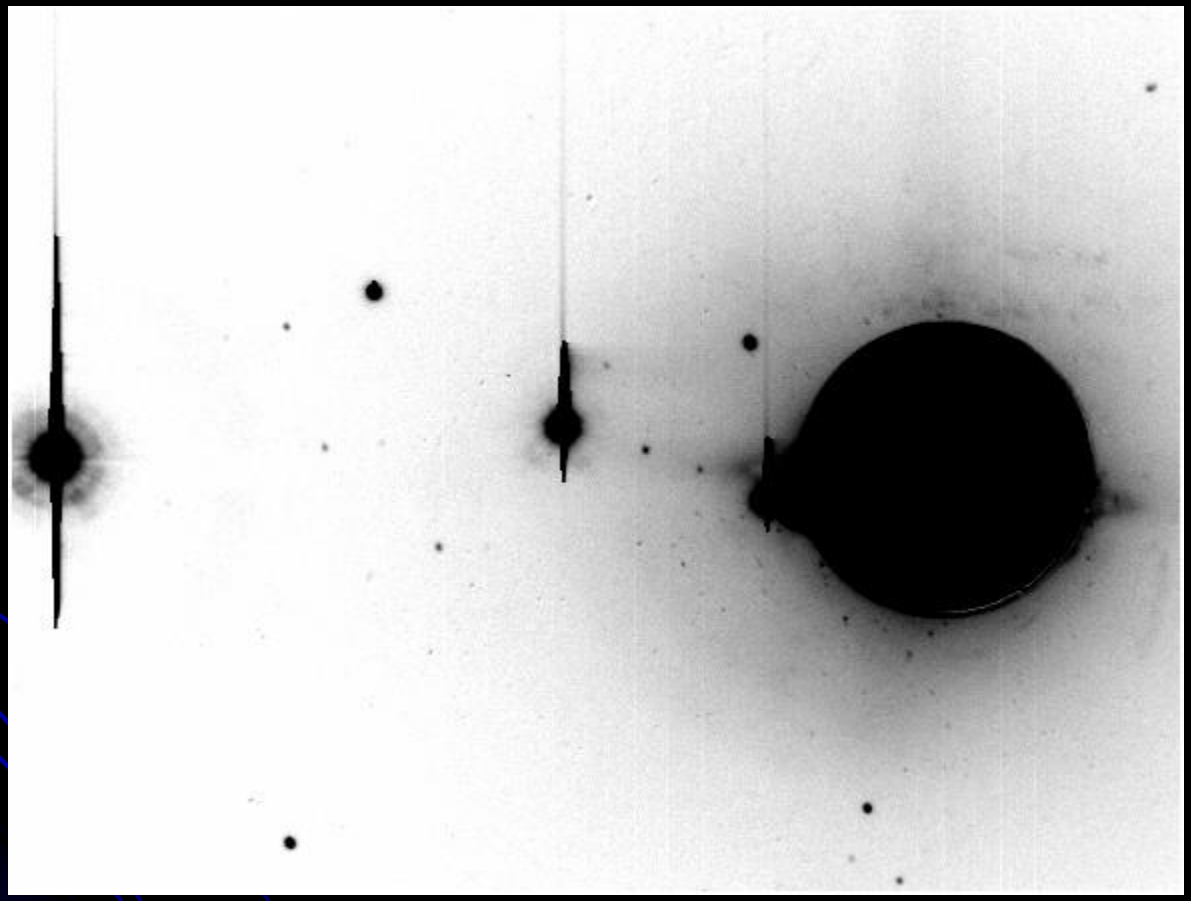
CCD *V* image of Saturn's Dione & Tethys Lagrange librating satellites. USNO 61-inch: September 26, 1992, Flagstaff, AZ



CCD *V* image of Saturn's Dione & Tethys librating satellites September 27, 1992: USNO 61-inch, Flagstaff, AZ



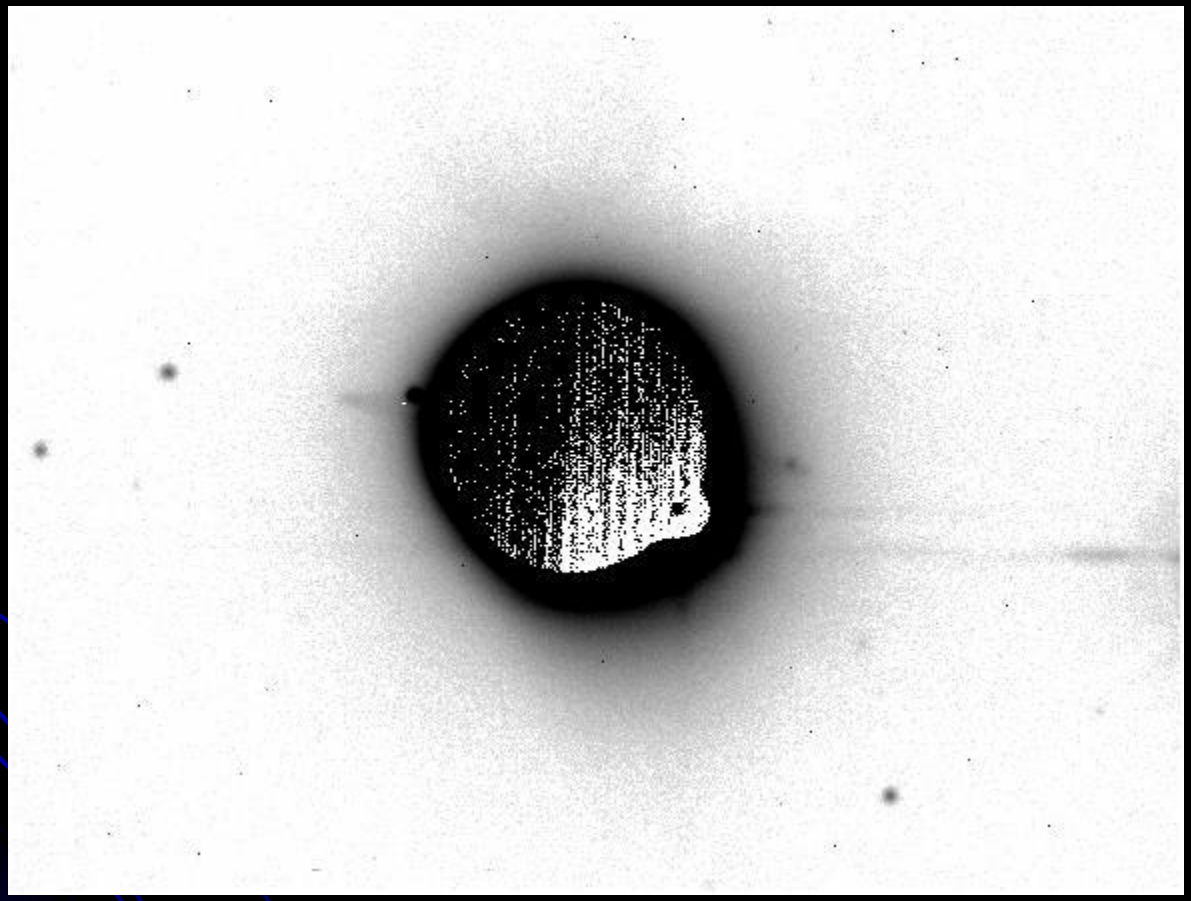
CCD wide-*R* image of Saturn Dione and Tethys Lagrange L4 librators Helene and Telesto USNO 61-inch Reflector, Flagstaff, AZ, 1994



Infrared Observations (2.2 microns)

- Methane in atmospheres of Jovian planets absorb strongly in the 2.2micron band → fainter planets → detect innermost moons.
- Does not work for Saturn because of bright rings.
- Best for inner satellites of Jupiter, Uranus and Neptune.
- Trying for Metis, Adrastea, Puck and Proteus.

Jupiter at 2.2 microns
Amalthea, Thebe, Metis and Ring



Uranians at 2.2 microns
Miranda and Ring system