GUVI Calibration and Characterization

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Calibration Goals for GUVI

- In order to produce valid science products the calibration of GUVI must be done to better than about 10%
  - must understand the instrument before flight
  - must be able to convert measured counts/pixel on-orbit into accurate radiances
  - must be able to understand on-orbit stellar calibrations

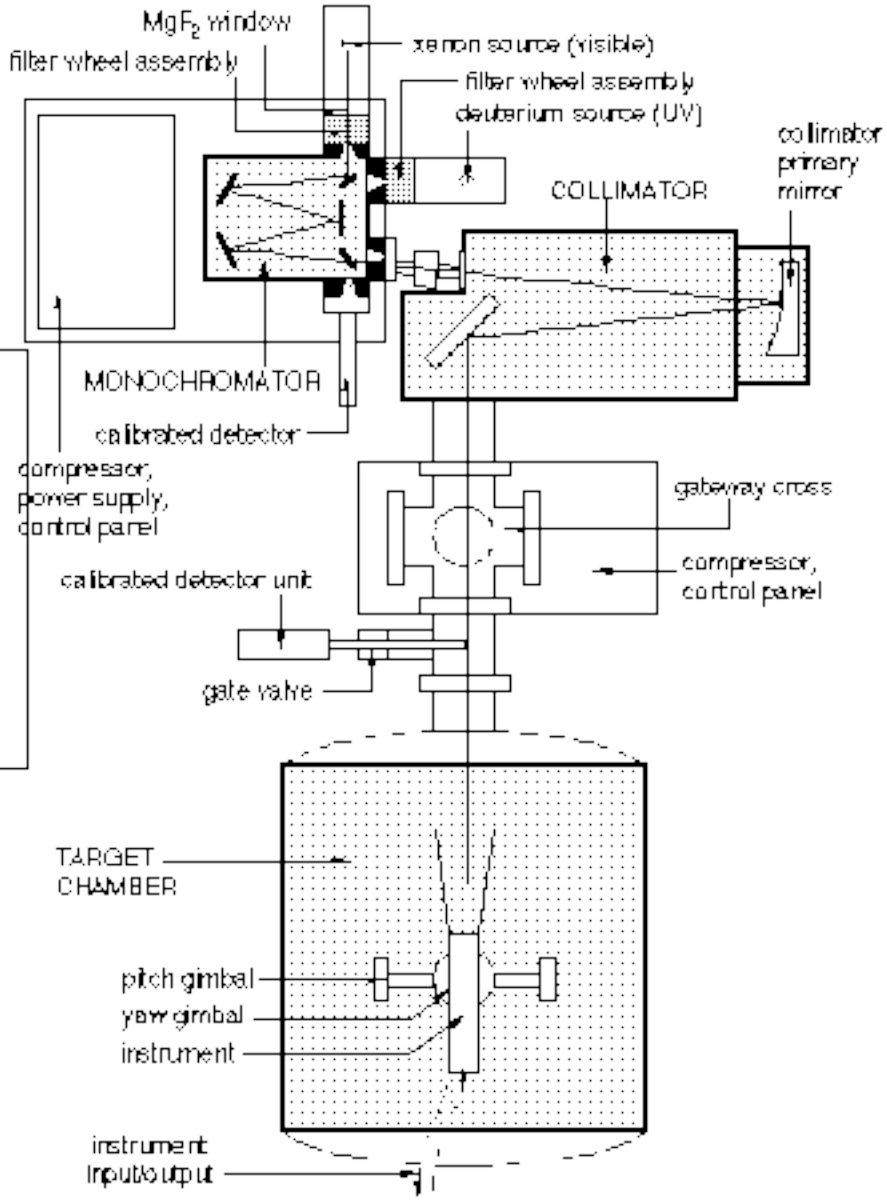
SSUSI Heritage

- All of the procedures have been worked out with the five SSUSIs
  - provide information about actual performance
- Problems have been identified in the Optical Calibration Facility
  - procedures have been developed to overcome these difficulties
  - changes to the OCF will be implemented before GUVI is to be calibrated
    - changes reduce the level of effort required to complete the calibration
- On-orbit procedures for SSUSI were tested by MSX
  - SSUSI and GUVI can be calibrated on orbit

OCF OVERVIEW
Facility

Schematic diagram of the Optical Calibration Facility

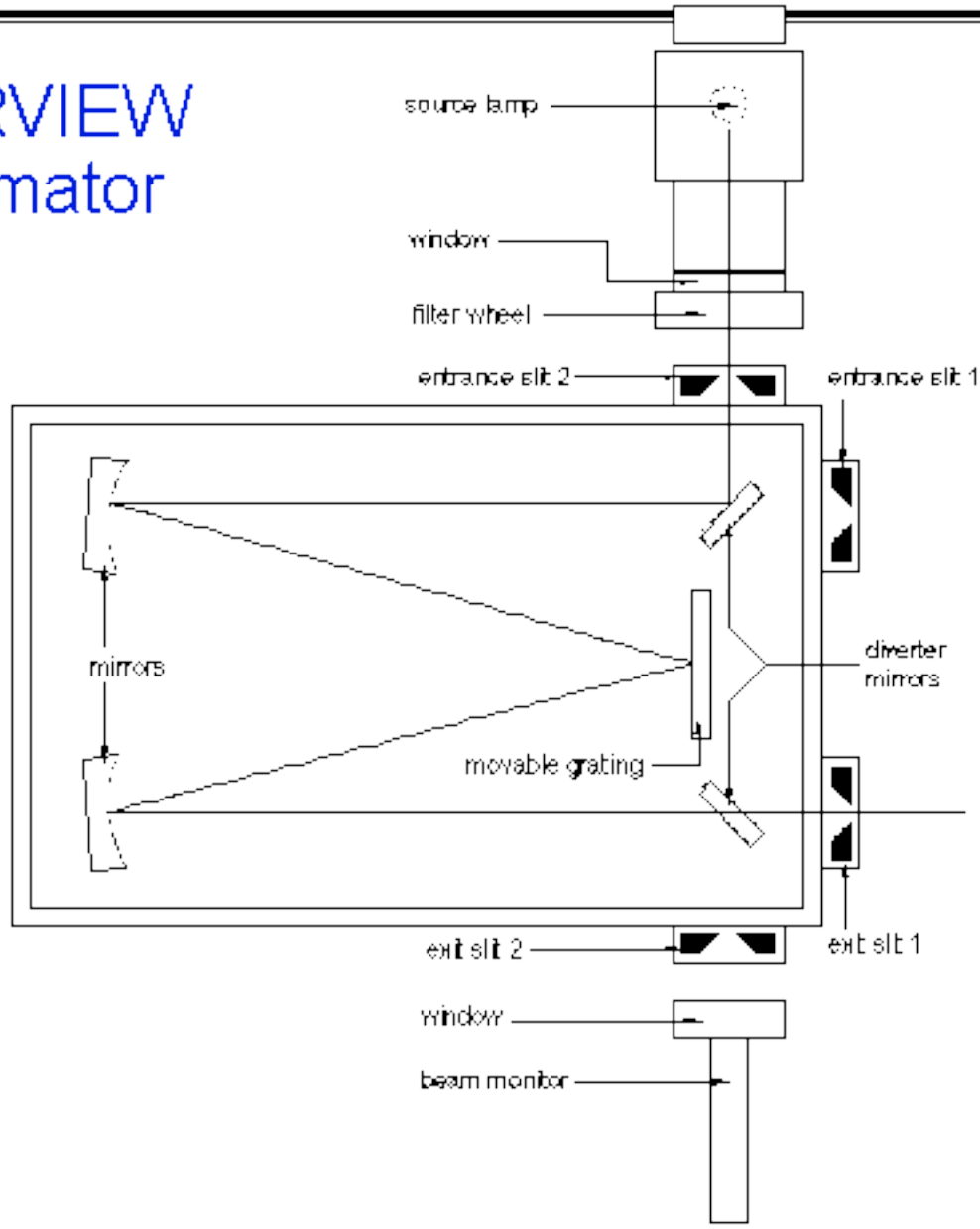
- **shaded blocks indicate detachable modules**
- **calibration beam is indicated by dashed line**



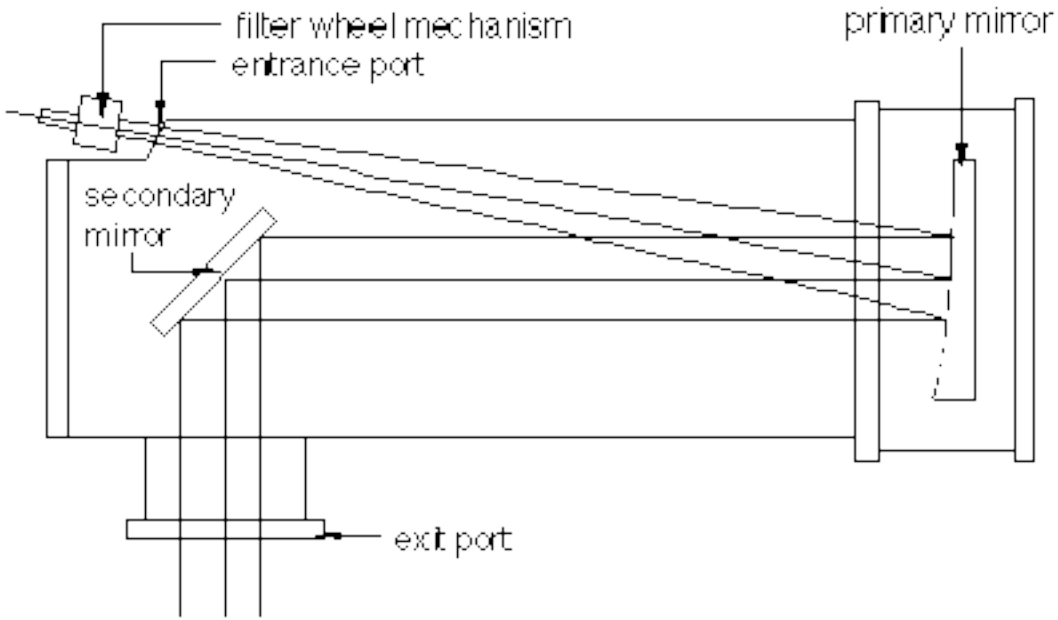
OCF OVERVIEW
Monochromator

The OCF monochromator

- **a source lamp provides input**
- **a beam monitor checks the output**

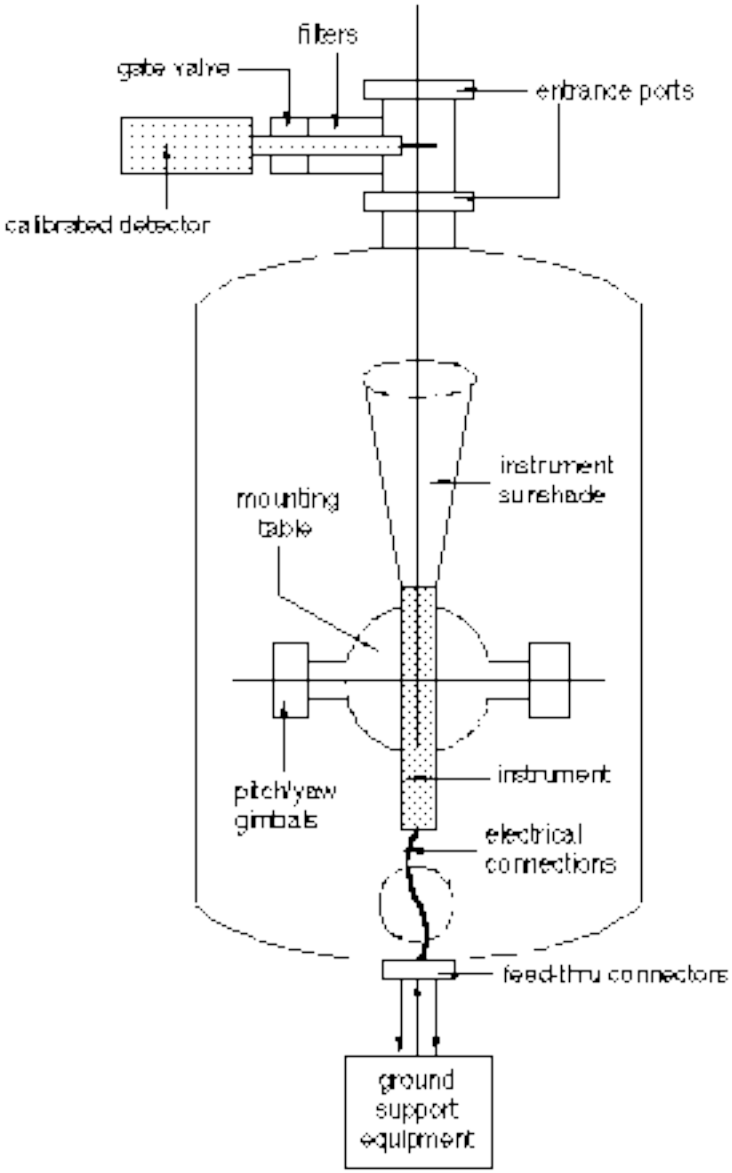


OCF OVERVIEW - Collimator



The collimator employs two mirrors to parallelize the light and direct it through the exit port. Light first strikes a parabolic primary mirror, which has a diameter of 8 inches (20.32 cm) and a focal length of 56.35 inches (143.13 cm). The parallel rays strike a flat secondary mirror oriented at 45° to the parallel beam. Micrometer mounts secure both mirrors and allow the precise alignment of the input and output beams. (Because of the precision required, these adjustments consume most of the time required to set up the complete OCF for calibrations.) Both mirrors have a coating of Al/MgF_2. This coating has an average reflectivity of 0.95% from ~250 nm to 750 nm. A stainless steel housing encloses the entire collimator and permits vacuum operation. The internal surfaces are coated with black Chemglaze to reduce stray reflections.

OCF
Target Chamber



- lines indicate motion axes of the gimbals
- SSUSI calibration required the use of a mounting fixture
  - 4-axis stage will be added for GUVI
- all problems have been worked out and while a larger chamber is desirable it does not appear to be required

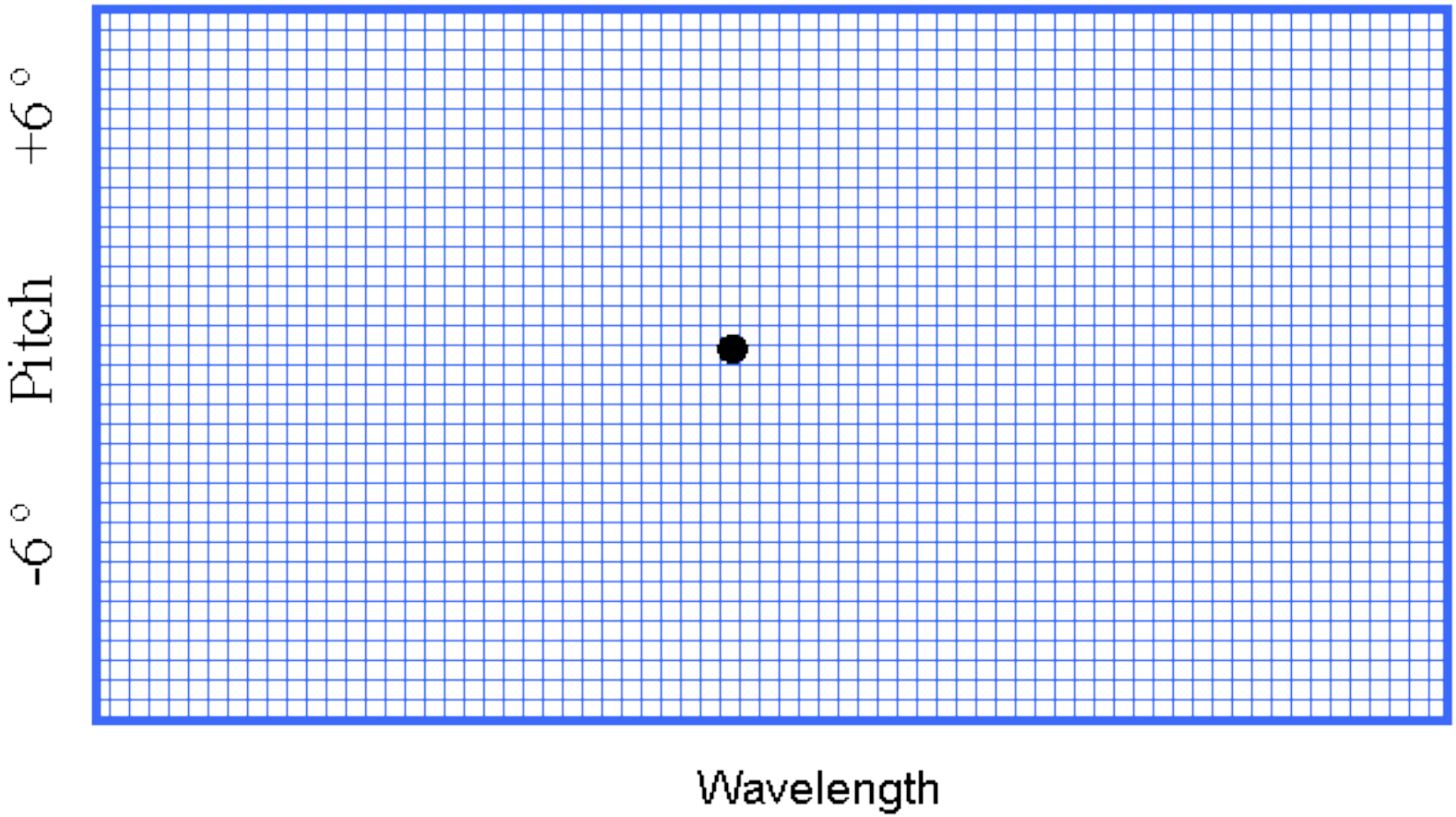
Calibration Matrix

Calibration Test	Bench	OCF	Pre-env	Post-env
SIS Detector				
Noise Level	X	X		
Flat Fielding/Distortion	X	X		
Quantum Efficiency		X		
Pulse Height Distribution	X	X		
Dynamic Range	X	X		
Linearity	X	X		
Ouf of Band Response	X	X		
SIS				
Sensitivity vs Wavelength			X	X
Intrascene Dynamic Range			X	X
Field of View			X	X
Spectral Resolution			X	X
Wavelength Scale			X	X
Off-axis Rejection			X	X
Out of Band Response			X	X

Point Source Calibration

- Calibration is performed by simulating a point source of known wavelength with a measured intensity
- This is directly transferable to the type of measurement carried out during calibration on orbit
  - stellar calibration on orbit
- Difficulty is in translating from irradiance to radiance calibration

Image of the Beam

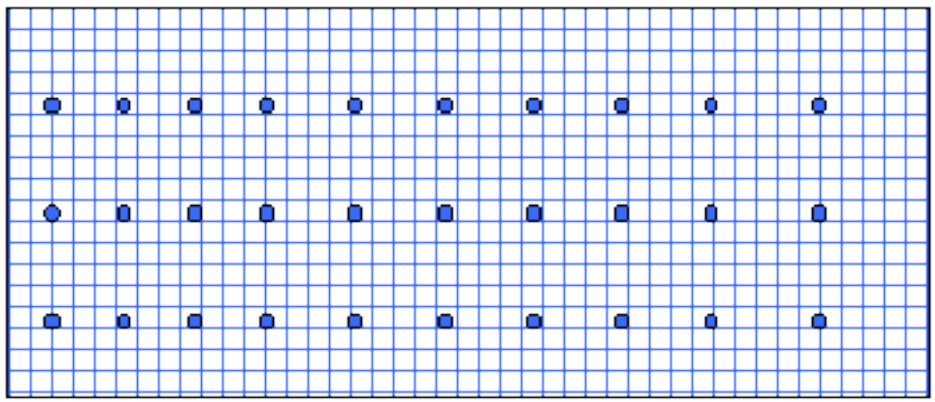


Scattered Light

- Initial grating scatter measurements
  - Grating scatter should be < 0.08% of Ly α in LBH wavelengths
- Determine the shape of the scattered light
- Detection of out-of-band light
  - "red leak" or sensitivity to light from wavelengths greater than 180nm has been observed in some SSUSI detectors
  - characteristics will be determined by direct measurement

PSF

- **Point Spread Function (PSF) of the SIS has been measured at 30 locations. The instrument optical performance for SSUSI is within design limits.**



Sensitivity (responsivity)

- Primary and secondary detector sensitivities at all wavelengths, wide slit, nadir position of scan mirror
- Sensitivity at other mirror scan positions.

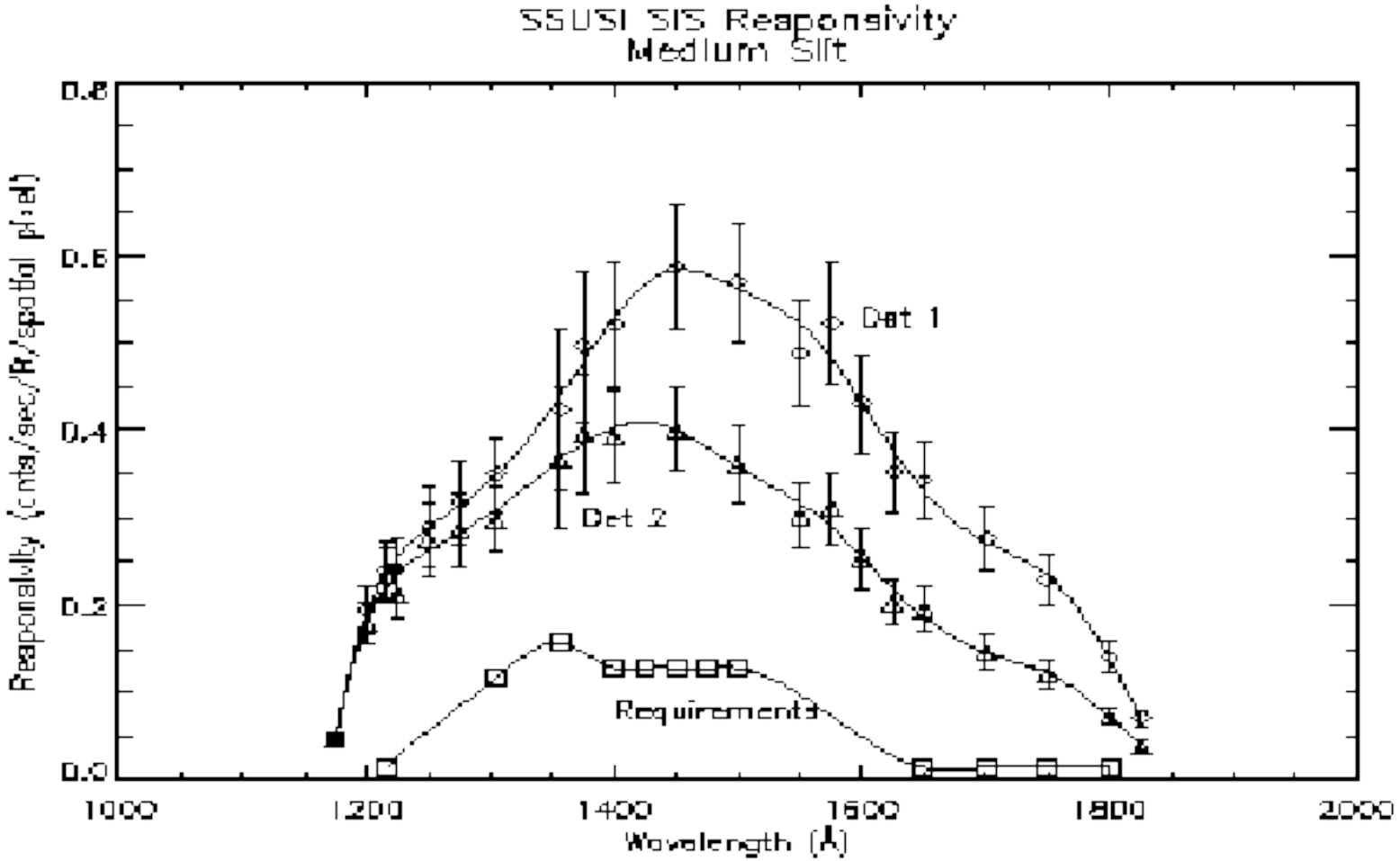
Slit Function

- Slit function (height and width) for
  - wide
  - medium
  - narrow slits
- The slit function is convolved with the PSF to get the instrument function

GUVI Sensitivity Measurements

- **Sensitivity at the following wavelengths**
  - **1175, 1200, 1216, 1250, 1275, 1304, 1325, 1356, 1375 Å,**
  - **1400, 1450, 1500, 1550, 1600, 1650, 1700, 1750, 1800, 1850 Å**
- **Measurements are made for the primary and secondary detector**

Responsivity



Measurement Plan

- The response for each spatial pixel will be determined.
- Measurements for pitch angles of
  - 5.46, 4.62, … -4.62, -5.46
- Also must make the measurements for each slit width
  - wide, medium, narrow

Measurement Plan

- The response of the total system depends on the mirror scan angle.
- Measurements are made for scan angles
  - -76.8, -73.6, -70.4, -60, -45, -30, -15
  - 0, +20, +40, +60°
    - only the primary detector need be used
    - must make the measurements as a function of wavelength

Measurement Plan

- The response of the system depends on the spatial pixel.
  - each spatial pixel samples a different portion of the scan mirror
  - The scan angle measurements will be repeated at along slit angles of
    - -5°, -2.5°, 0°, + 2.5 °, + 5 °

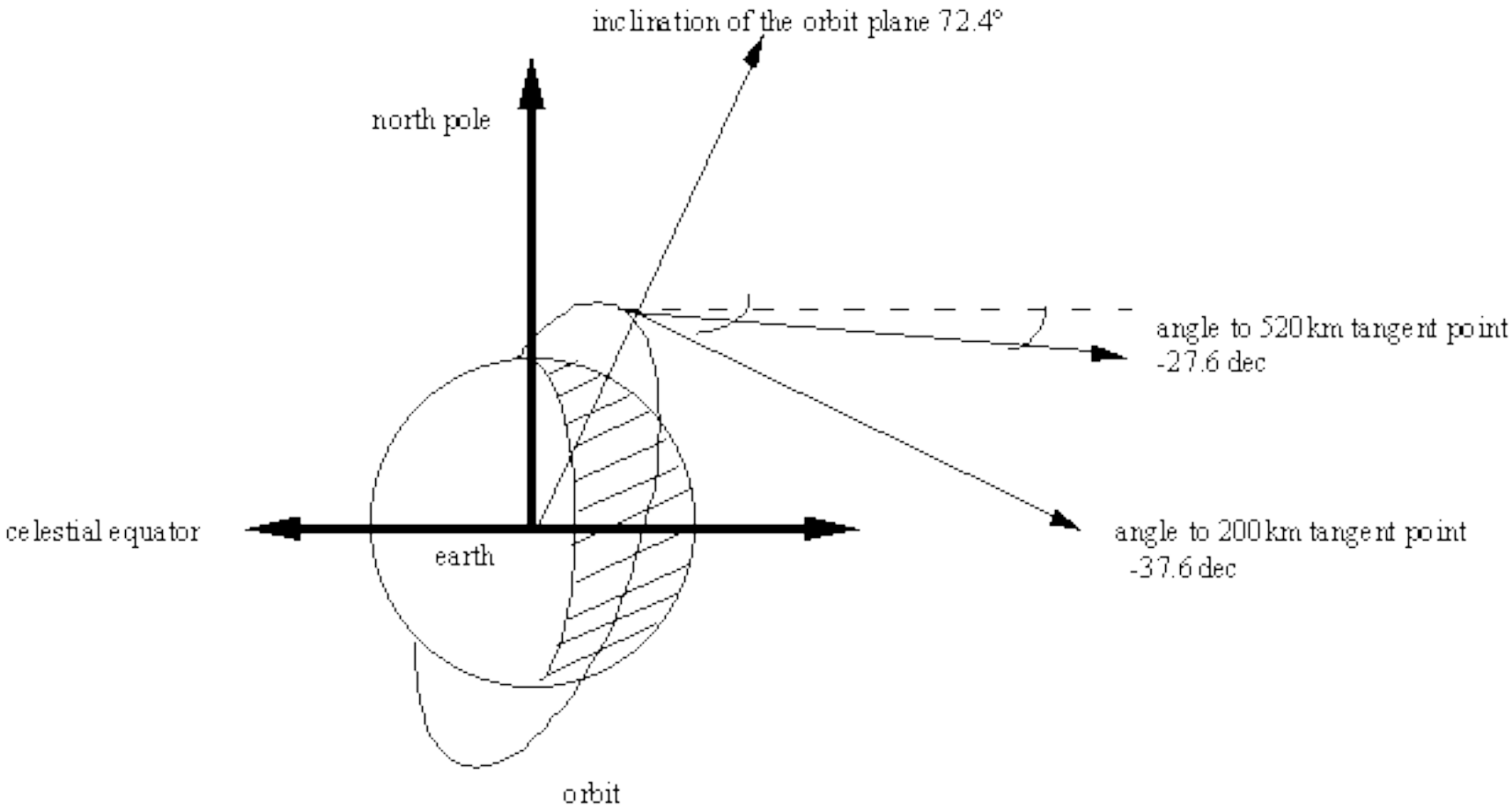
Calibration Measurements

- **Scan mirror relative reflectivity**
  - **is to be measured at the same wavelengths every 9.6° for disk portion of the scan**
  - **is to be measured every 2.5° for the limb portion of the scan range**

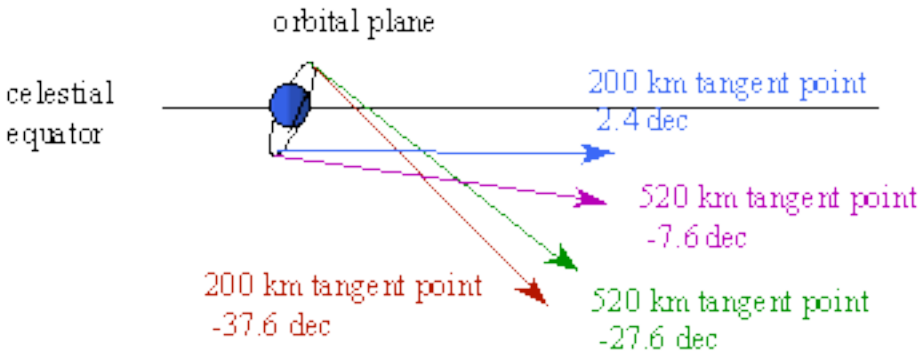
CALIBRATION REQUIREMENTS (IN FLIGHT)

- In-flight calibrations of GUVI must be performed.
- Operation of the detectors causes changes in the pulse-height distribution.
- The optical design can not accommodate a calibration source.
- GUVI's limb scan capability is used to observe HST and other standard stars for calibration.

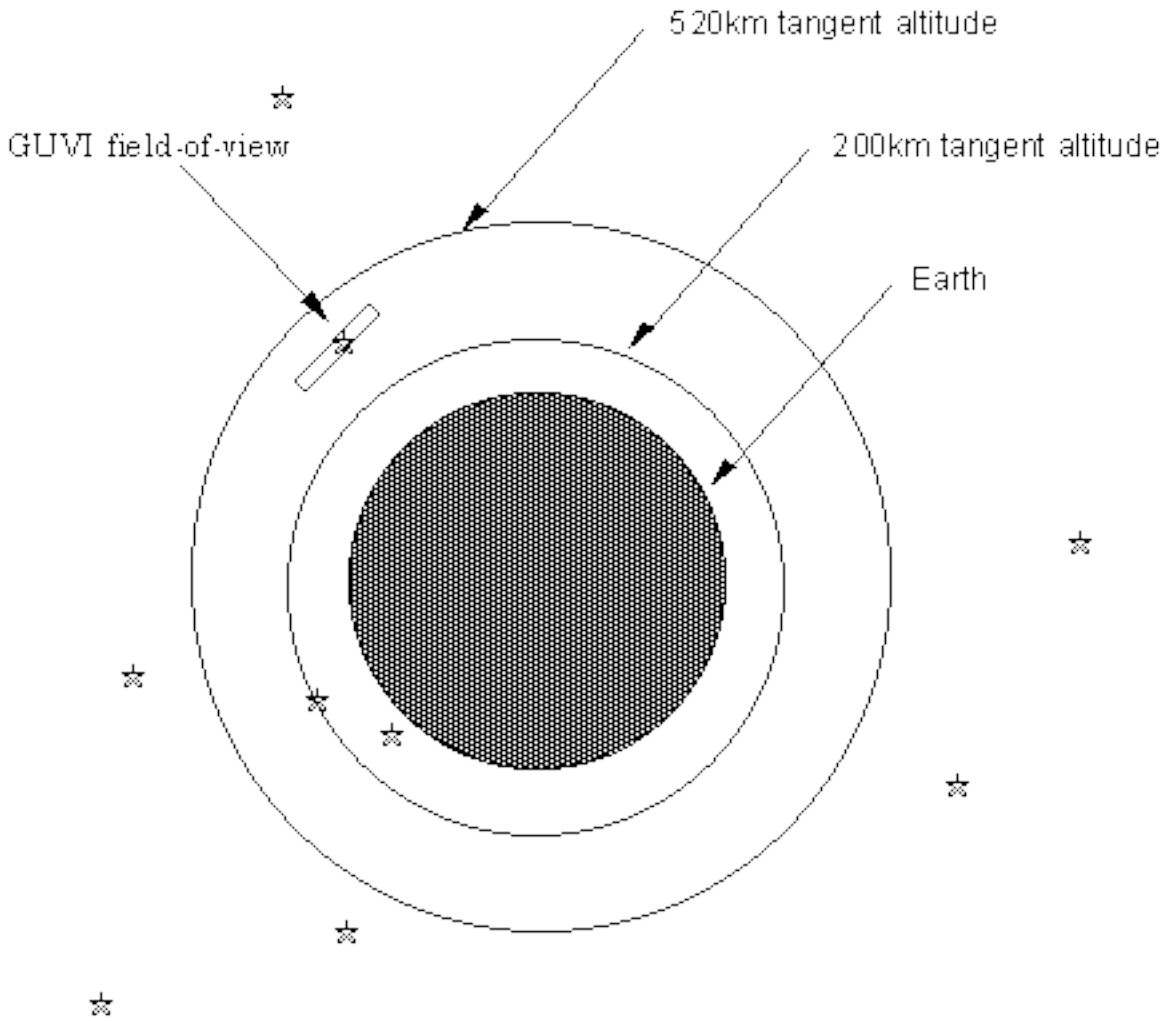
Line of Sight on the Celestial Sphere



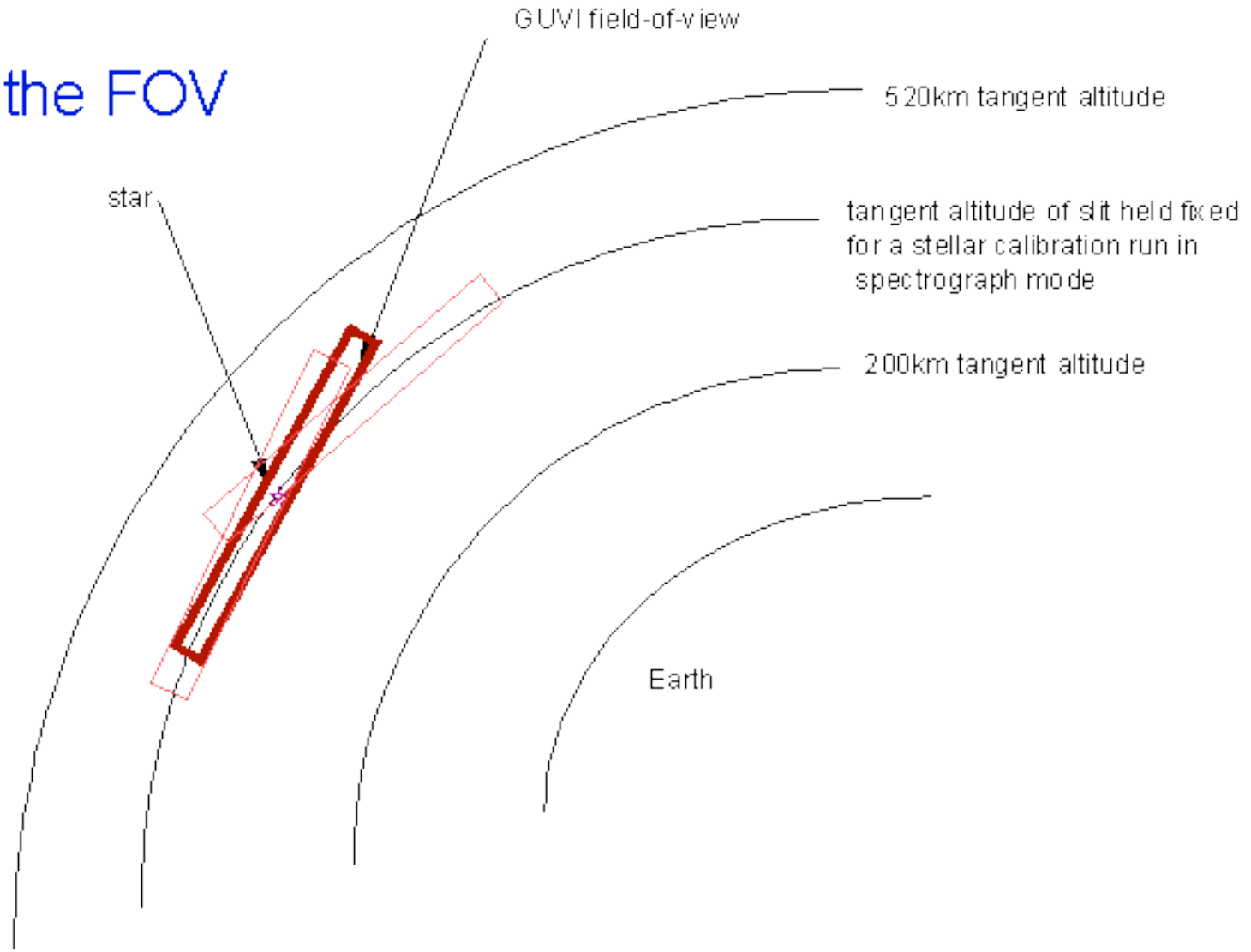
LOS at North and South Poles



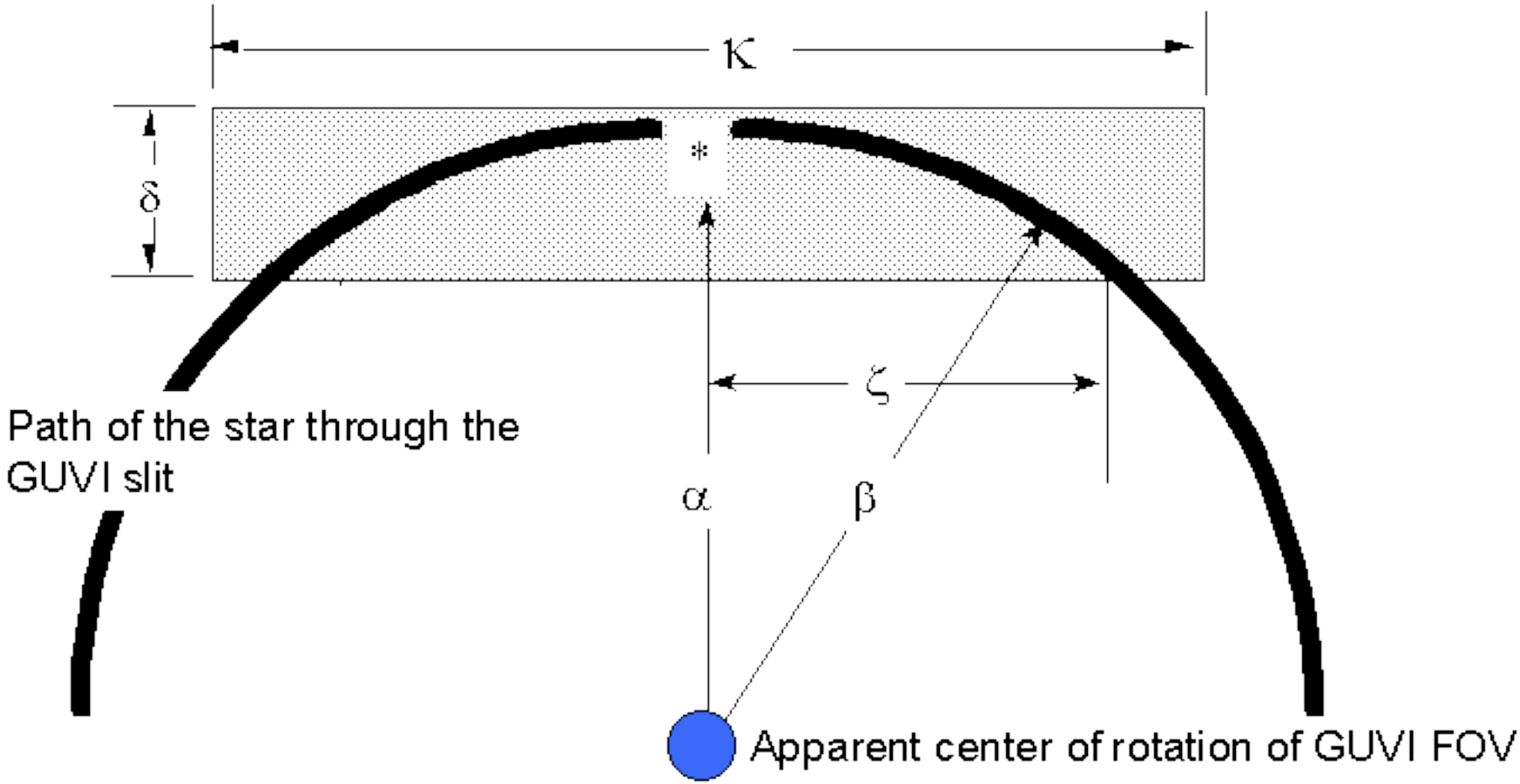
Star Calibration Sequence



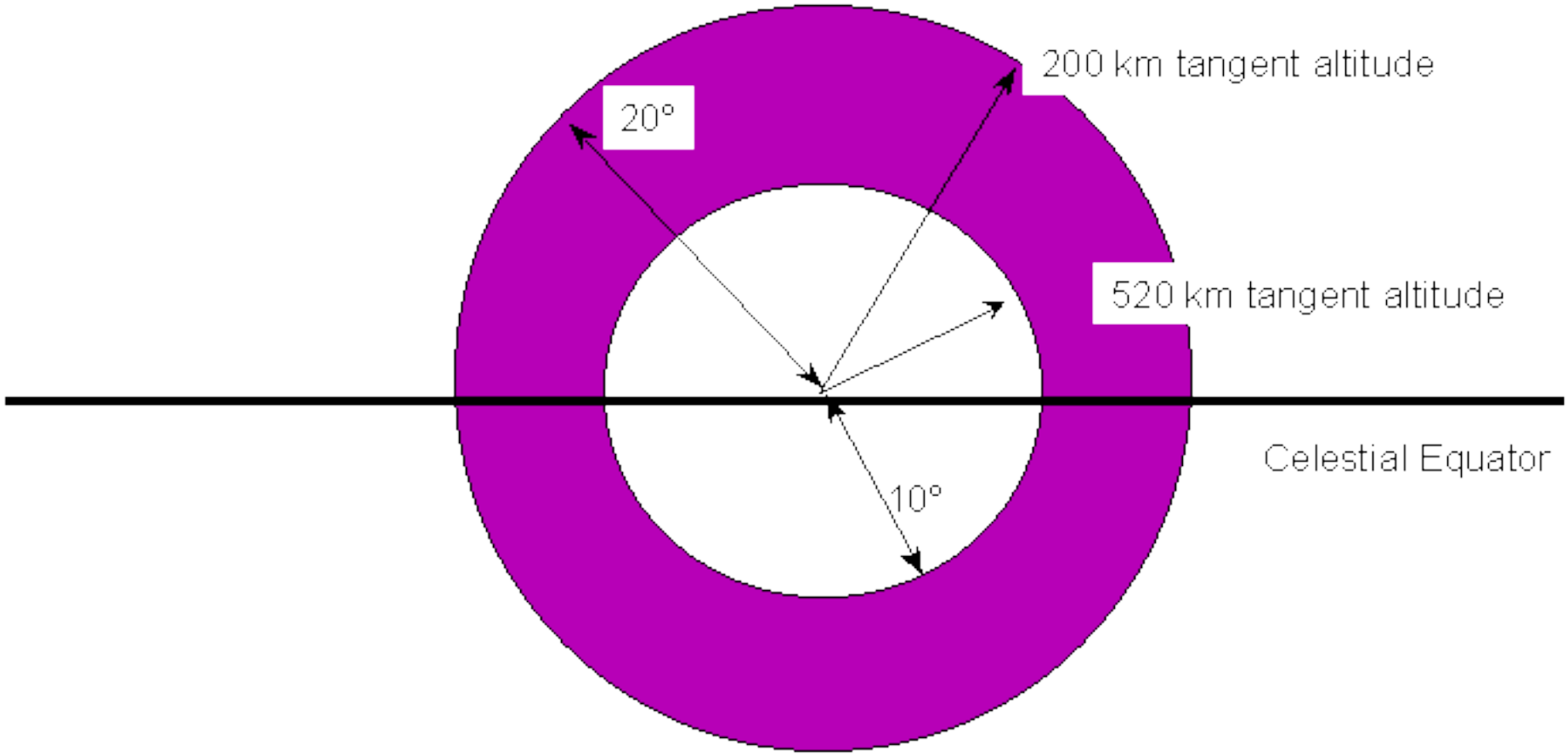
A Star in the FOV

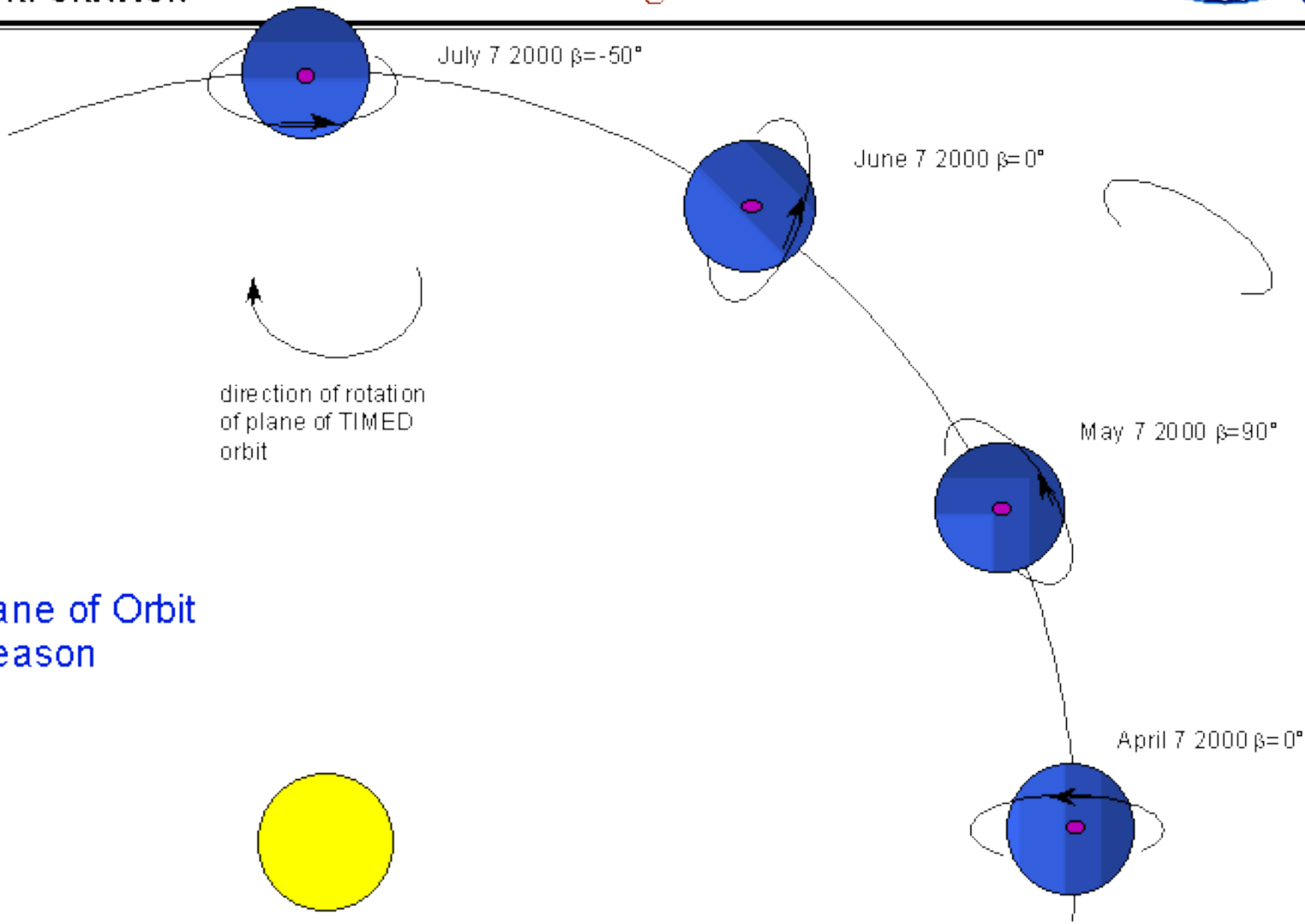


Star Motion through FOV

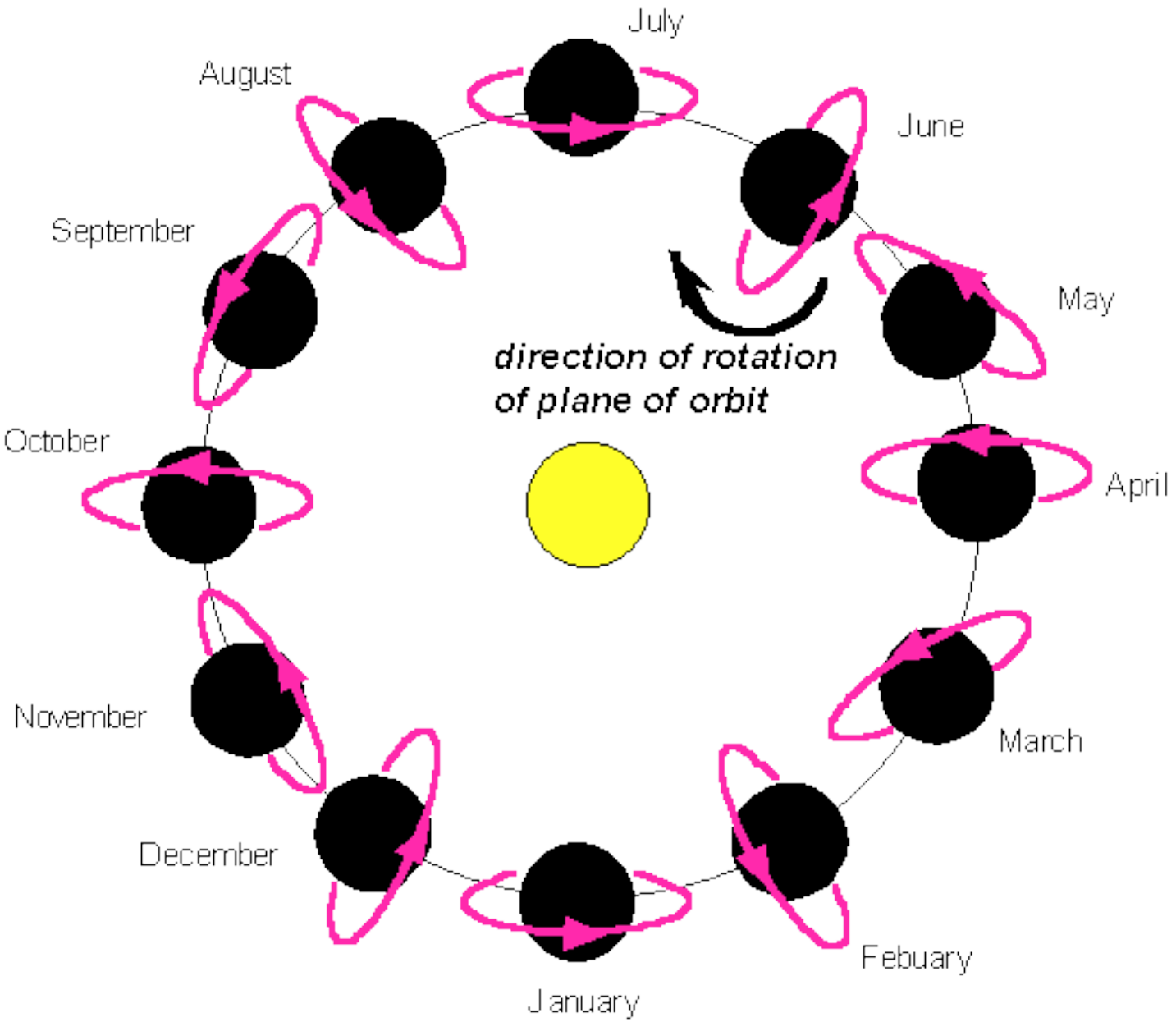


Area of Accessible Sky

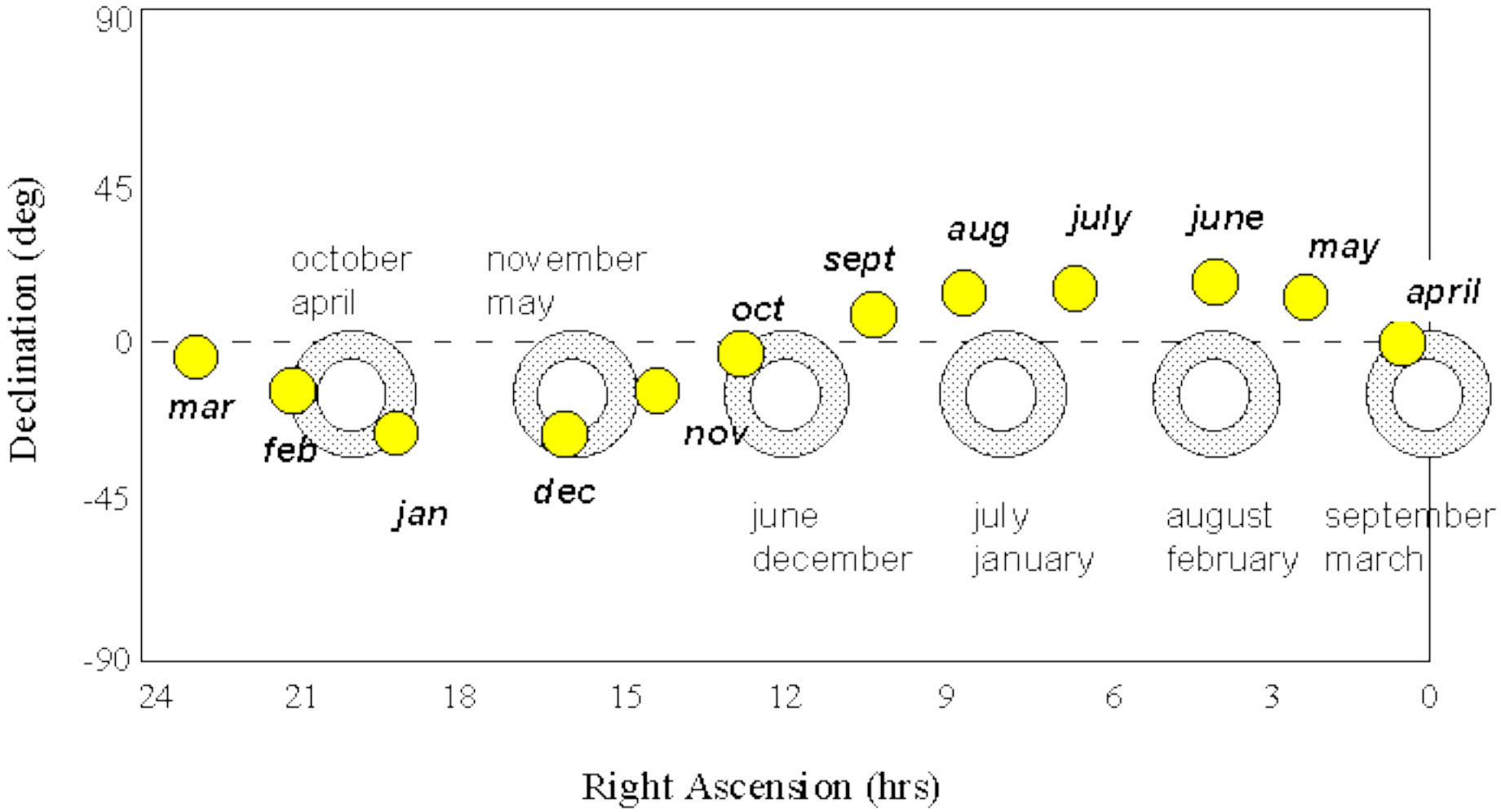




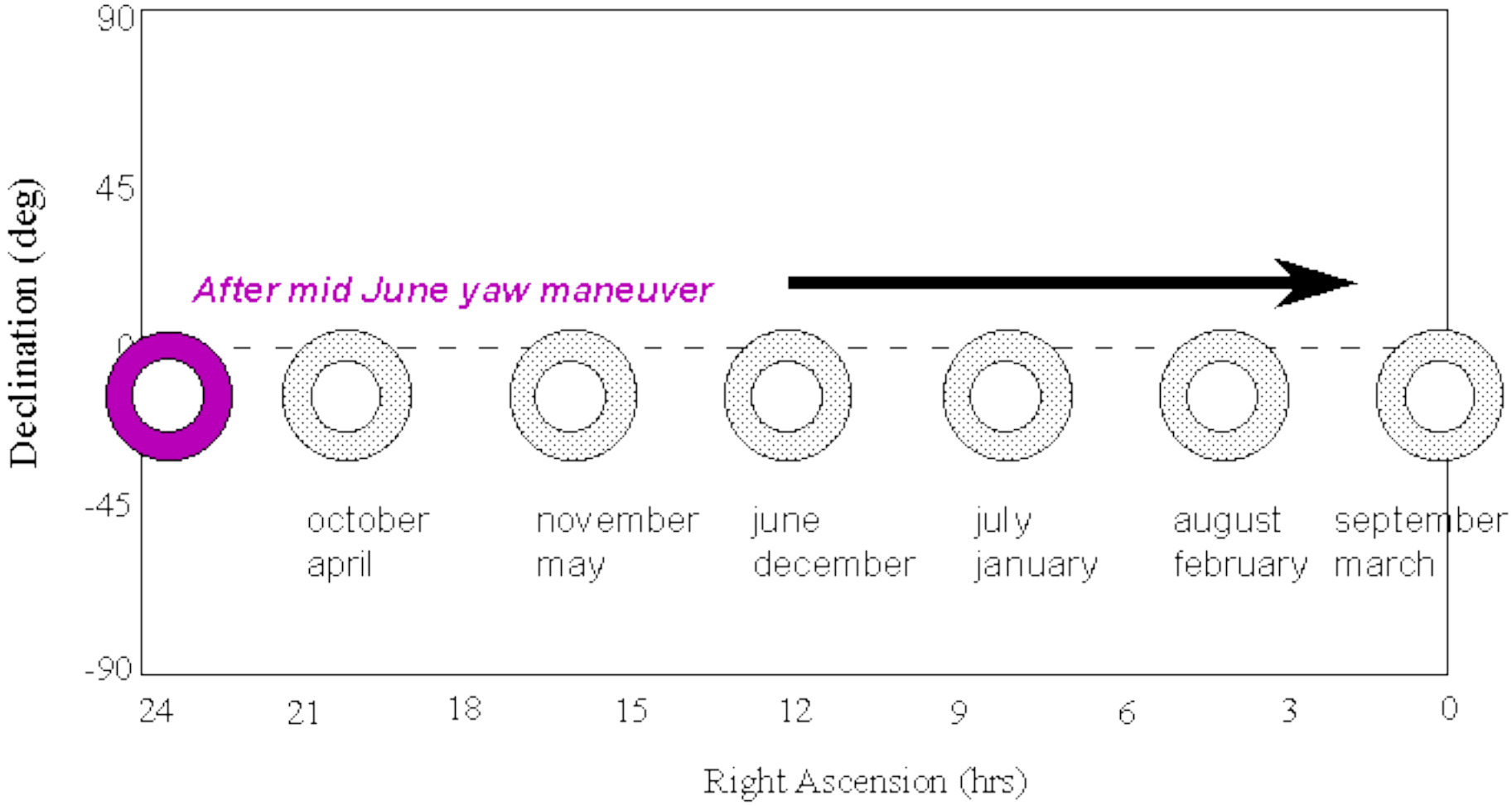
Motion of Plane of Orbit with Season


July
August
June
September
May
direction of rotation
of plane of orbit
October
April
November
March
December
Febuary
January

Celestial Sphere Coverage



Celestial Sphere Coverage
(no) yaw maneuver



Limiting Spectral Magnitude (V) (unreddened)

Spectral Type	110	120	130	140	150	160	170	180
O5	6.1	10.1	12.0	12.1	11.5	10.5	9.3	7.6
O6	5.9	9.9	11.9	12.0	11.4	10.3	9.2	7.5
O7	5.6	9.7	11.7	11.8	11.2	10.2	9.1	7.4
O8	5.4	9.5	11.5	11.6	11.1	10.1	8.9	7.3
O9	5.1	9.3	11.3	11.4	10.9	9.9	8.8	7.1
B0	4.8	9.0	11.0	11.2	10.7	9.7	8.6	7.0
B1	4.5	8.7	10.8	11.0	10.5	9.5	8.5	6.8
B2	4.1	8.4	10.5	10.7	10.2	9.3	8.3	6.7
B3	3.7	8.0	10.1	10.4	10.0	9.1	8.0	6.5
B4	3.2	7.6	9.8	10.1	9.7	8.8	7.8	6.3
B5	2.8	7.2	9.4	9.8	9.4	8.6	7.6	6.0
B6	2.3	6.7	9.0	9.4	9.1	8.3	7.3	5.8
B7	1.7	6.3	8.6	9.1	8.7	8.0	7.0	5.6
B8	1.2	5.8	8.2	8.7	8.4	7.6	6.7	5.3
B9	0.6	5.3	7.7	8.2	8.0	7.3	6.4	5.0
A0	0.0	4.7	7.2	7.8	7.6	7.0	6.1	4.7

for 4% counting statistics in 1nm bin

Limiting Sensitivity

Title:
Graphics produced by IDL
Creator:
IDL Version 5.0.3 (hp-ux hp_pa)
Preview:
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with a preview included in it.
Comment:
This EPS picture will print to a
PostScript printer, but not to
other types of printers.

Limiting Magnitude

Title:
Graphics produced by IDL
Creator:
IDL Version 5.0.3 (hp-ux hp_pa)
Preview:
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with a preview included in it.
Comment:
This EPS picture will print to a
PostScript printer, but not to
other types of printers.

Partial List of UV Calibration Stars

HD	Name	RA (hr min)	DEC (° ')	Spec. Type	V	B-V	E(B-V)
15318	ξ^2 Cet	2 28 .2	8 27	B9III	4.28	-0.06	0.02
34816	λ Lep	5 19.6	-13 11	B0.5V	4.28	-0.27	0.01
38666	μ Col	5 46	-32 18	O9V	5.17	-0.28	0.03
87901	α Leo	10 8.4	11 58	B7V	1.35	-0.11	0.02
149757	ζ Oph	16 37.2	-10 34	O9.5V	2.56	0.02	0.32
214923	ζ Peg	22 41.5	10 50	B8V	3.4	-0.09	0.02

see GUVI Characterization Plan for more stars

FUV Calibration Accuracy

- FUV calibration must be performed in vacuum
  - makes the procedures more difficult to carry out
  - limited number of suitable lamps and standards
- Fundamental NIST standard is accurate to only 5% (1σ)

OCF Upgrades and Procedure Changes

- OCF upgrades are performed under Space Dept. funds
  - Reference detector
    - Calibrate against our own NIST standard
  - Beam nonuniformity
    - Correct OCF astigmatism with toroidal mirror
- The revised calibration procedure will reduce the systematic errors
  - Source variation
    - Operate reference detector concurrently

Optical Calibration Schedule

- Three weeks are required for the initial optical calibration
  - includes focusing both detectors and calibration checks
- Six (6) weeks final calibration
  - including changes to procedures required to attain ±8% calibration accuracy

Calibration Errors

	SSUSI current	GUVI planned
Reference detector[1]	9%	6%
Source variation[2]	6%	1%
Beam nonuniformity[1]	12%	2%
Other errors	5%	5%
Total error	17%	8%

[1]A systematic error in that the error thus induced is consistent across a series of measurements

[2]A random error in that the source will fluctuate in brightness after restrike and positioning errors are not repeatable.

Conclusion

- Current demonstrated accuracy ±16%.
- We will improve our calibration process to reach the ±8% requirement.
- Plans and funding are in place to perform this accurate calibration and the schedule has the required time allocation.
  - on-orbit calibration is expected to be able to achieve this goal using HST reference and other standard stars