Exposure Time Calculator for IFOSC and Sky Background Estimaton

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Exposure time calculator (ETC) is an extremely necessary tool for the preparation of any observations. It provides us *a priori* with a reasonably good idea about the observations we wish to undertake and assists us greatly in proposal preparation. In this talk, we present the ETC, developed for spectroscopic observation using the "IUCAA Faint Object Spectrograph" (IFOSC). The technique to estimate and model the background sky brightness for different phases and angular distance from the Moon will be discussed.

The ETC code is written in ANSI C and thus portable to any system. A graphically interactive interface using HTML-cgi script has also developed so that the ETC is used over the internet (*http://meghnad.iucaa.ernet.in/~pavan/ETC/ETC.html*). If possible a live demo connecting the ETC on IUCAA website through the internet will be presented.

Resent observation of Comet 73P/Schwassmann-Wachmann 3 using IFOSC imager on IUCAA 2m Telescope at IUCAA Giravali Observatory (IGO) will also be discussed.

Exposure Time Calculator for IFOSC and Sky Background Estimaton

Exposure time calculator (ETC) is an extremely necessary tool for the preparation of any observations.

It provides us *a priori* with a reasonably good idea about the observations we wish to undertake and assists us greatly in proposal preparation.

Most instruments on major telescopes have such a calculator to aid its observers to plan their observations.

In this Talk we describe a spectroscopic ETC for IFOSC on IUCAA 2m telescope.

It is intended to provide reasonable estimates of the signal-to-noise (***S/N***) ratio for an observation with a given exposure time.

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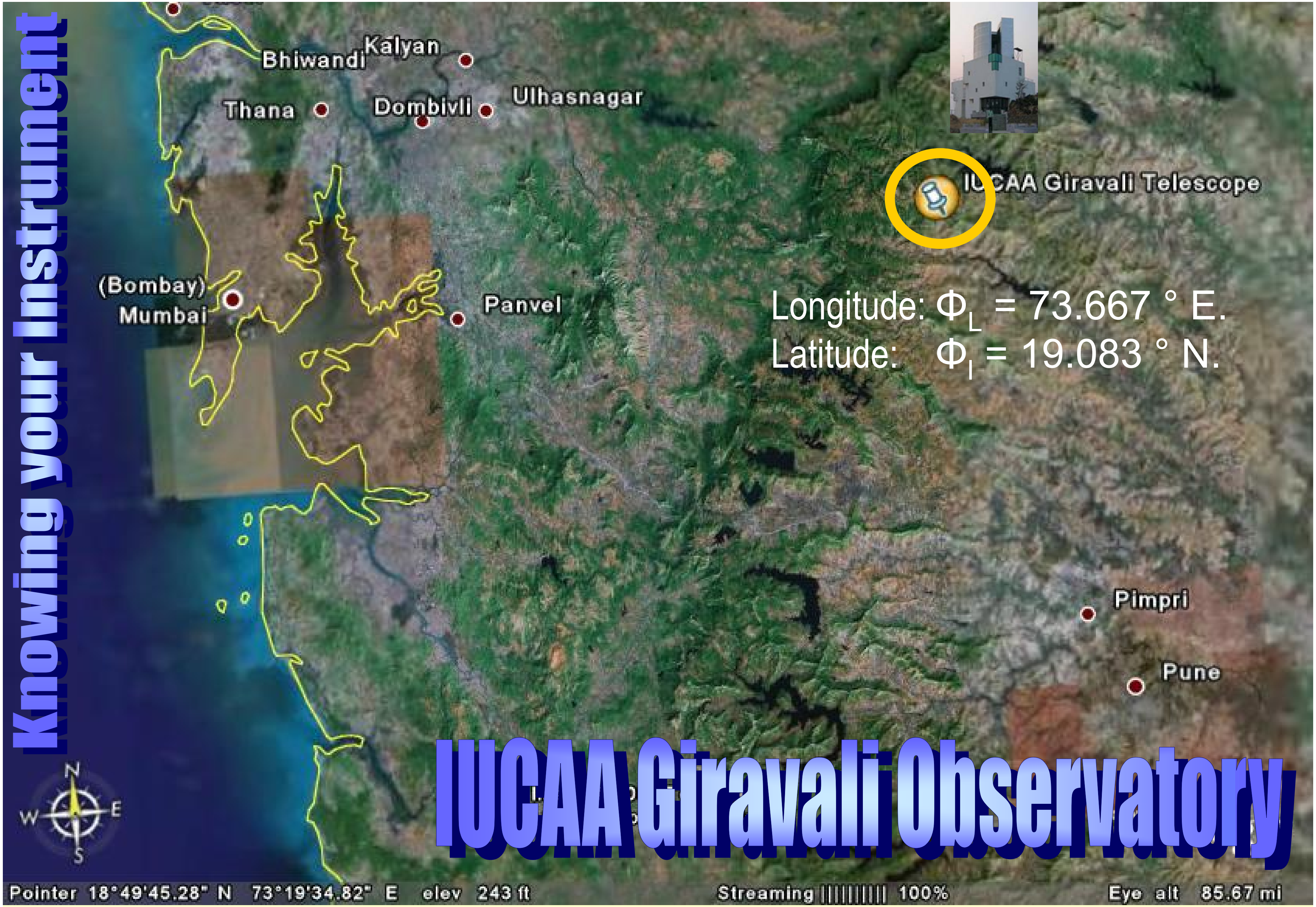
R. Srianand, Ranjan Gupta, Vijay Mohan, Ramprakash, Sonu Engineer, Sudhanshu Barway, Abhishek Rawat and Ramakant Yadav.

6 Commandments of ETC

1. Knowing your Instrument
2. Transmittivity Calculations
3. Sky Background Estimation
4. Model Object Flux
5. Signal-to-Noise Calculation
6. User Friendly Implimentation

Knowing your instrument

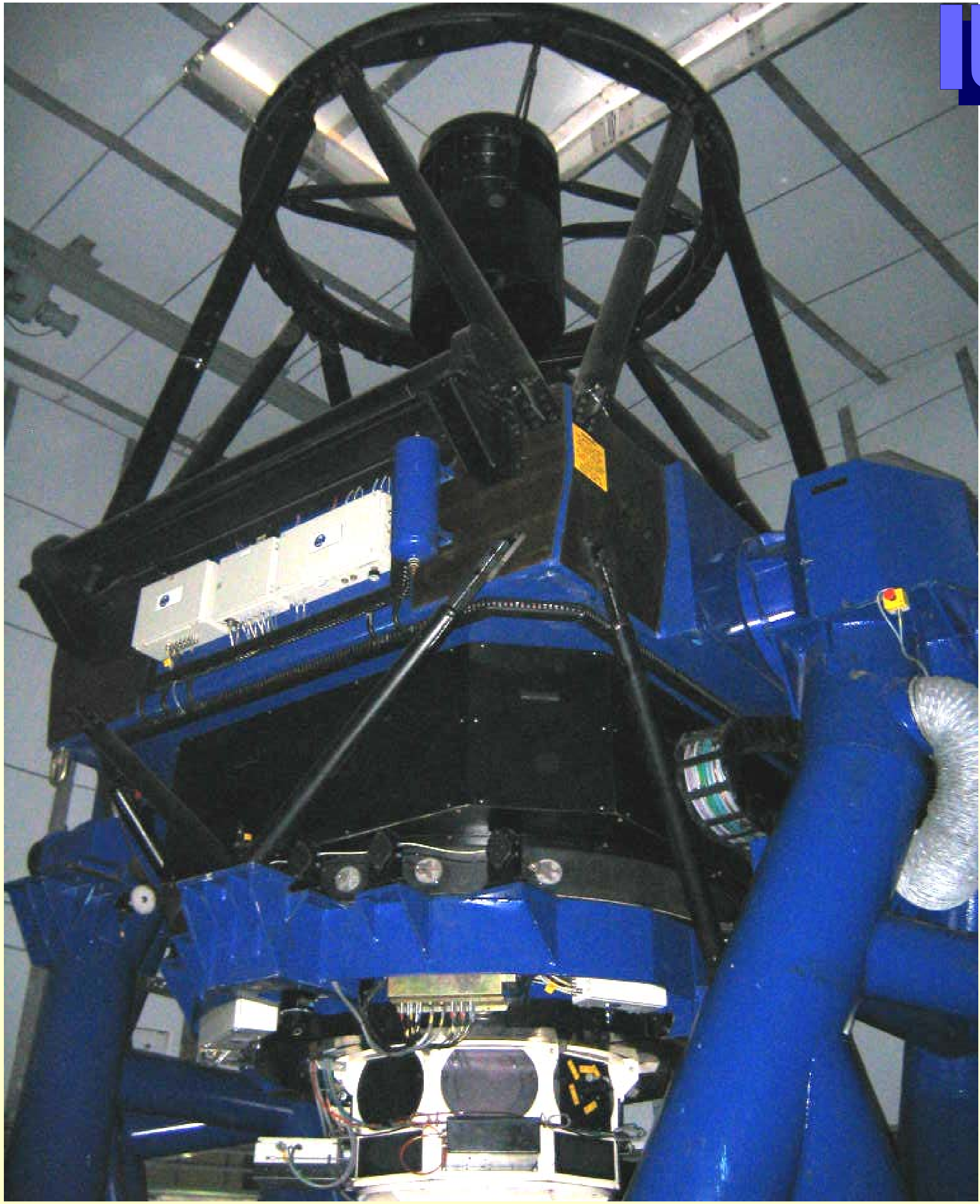
IUCAA Giravali Observatory



Longitude: Φ_L = 73.667 ° E.

Latitude: Φ_l = 19.083 ° N.

IUCAA Telescope



Aperture = 2m

Cassegrain ***f/10*** focus

Primary = *f/3*

Primary + Secondary = *f/10*

Primary of Astro-Sital ceramic glass

A Ritchey-Chrétien Cassegrain.

Alt-azimuth Mount.

Telescope Plate-Scale = 10.0 arcsec/mm

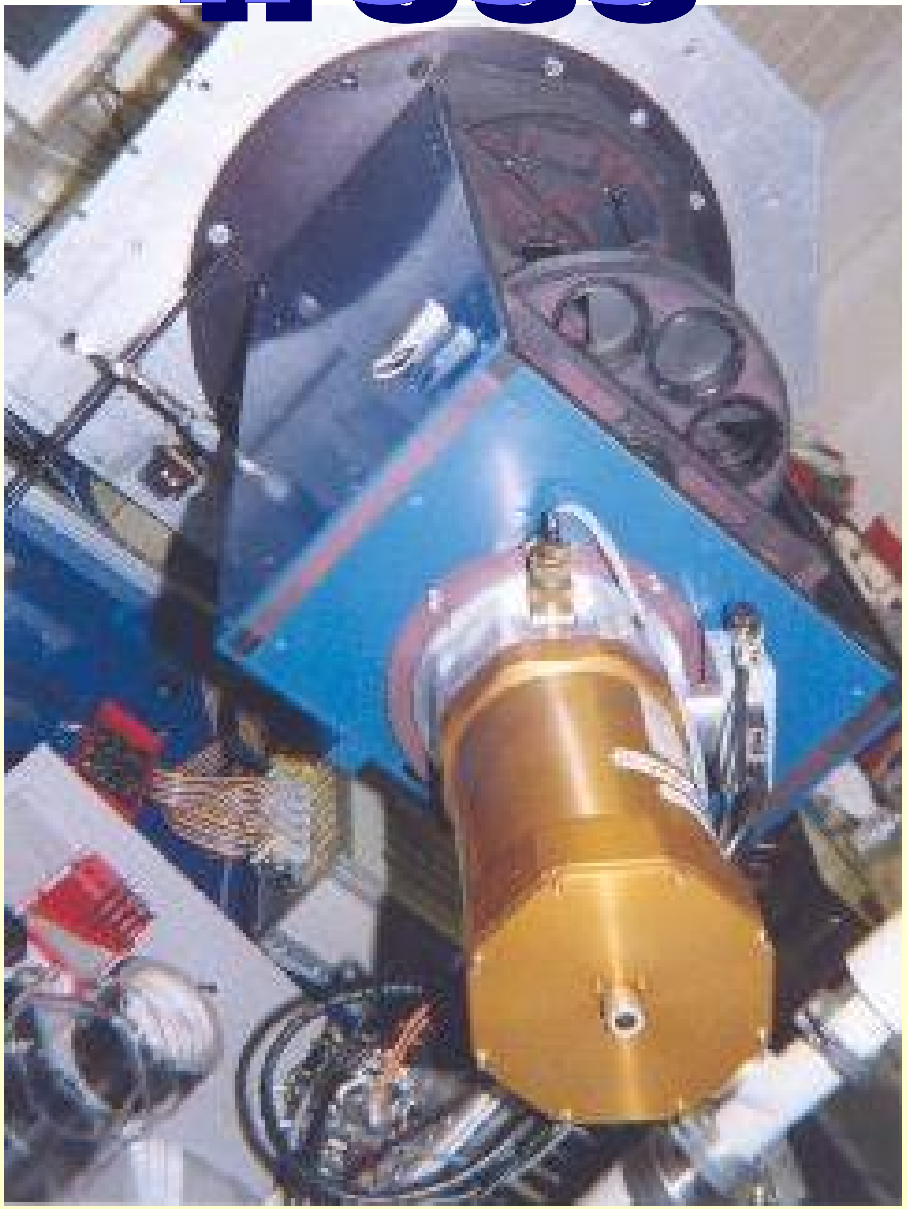
Built by:

Telescope Technologies Ltd. (TTL),

a unit of the Liverpool John Moores University

IUCAA Faint Object Spectrometer & Camera

IFOSC



The main features of IFOSC are :

Large field of view : (*f-ratio reduced to* ***f/4.5***)

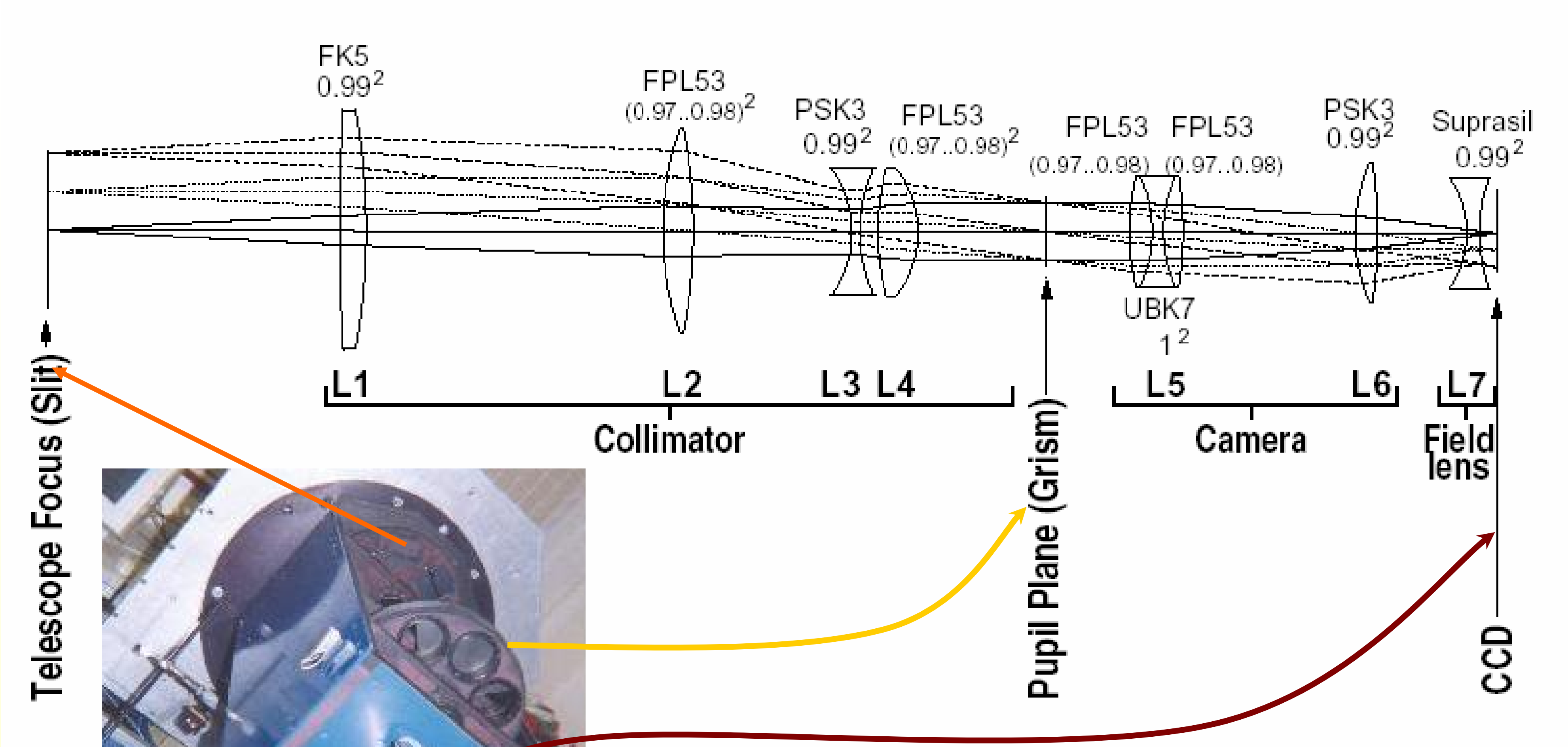
Wide wavelength coverage:
possibility of low and medium resolution spectroscopy with a large selection of grisms and filters etc.

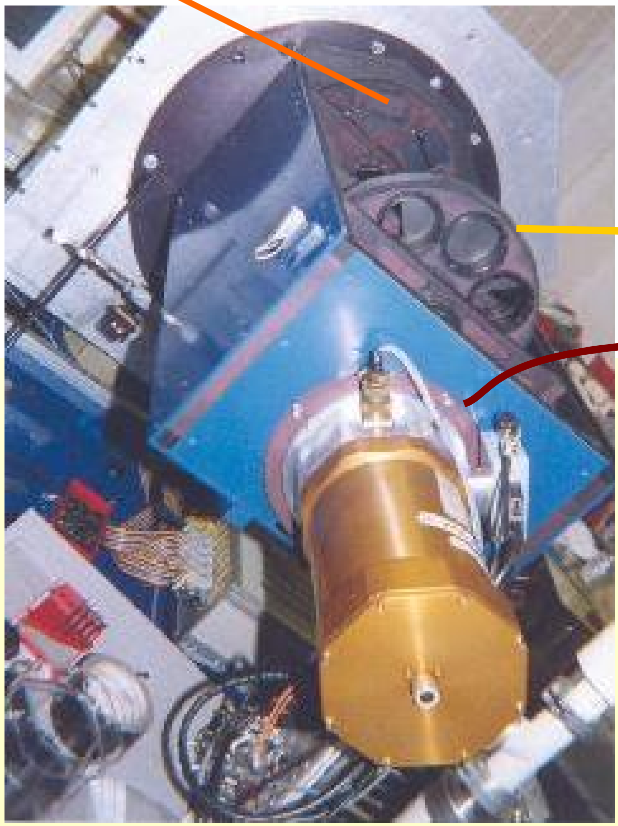
The instrument is a modified version of EFOSC made at ESO, and it was designed and fabricated at the Copenhagen University Observatory.

The collimation-camera combination was first designed at ESO and subsequently the design was modified at IUCAA to suit the constraints of manufacturing.

The front end of IFOSC consists of a calibration unit containing the spectral lamps, integrating sphere etc. and has been designed and developed at IUCAA.

For more details on IUCAA 2 meter Telescope and IFOSC, see Gupta et al., 2002, *BASI*, 30, 785.





- IFOSC reduces the beam to ***f /4.5***
- Results in a plate scale of ***22.7arcsec/mm*** = ***44 μm /arcsec***
- Detector is a 2k x 2k Thinned EEV CCD chip (Liquid N_2 Cooled)
- The pixel size is 13.5 μm
- Each CCD pixel corresponds to 0.3"
- Resulting field at Cassegrain focus is 10.5'

Folding Mirror difference between IFOSC & HFOSC

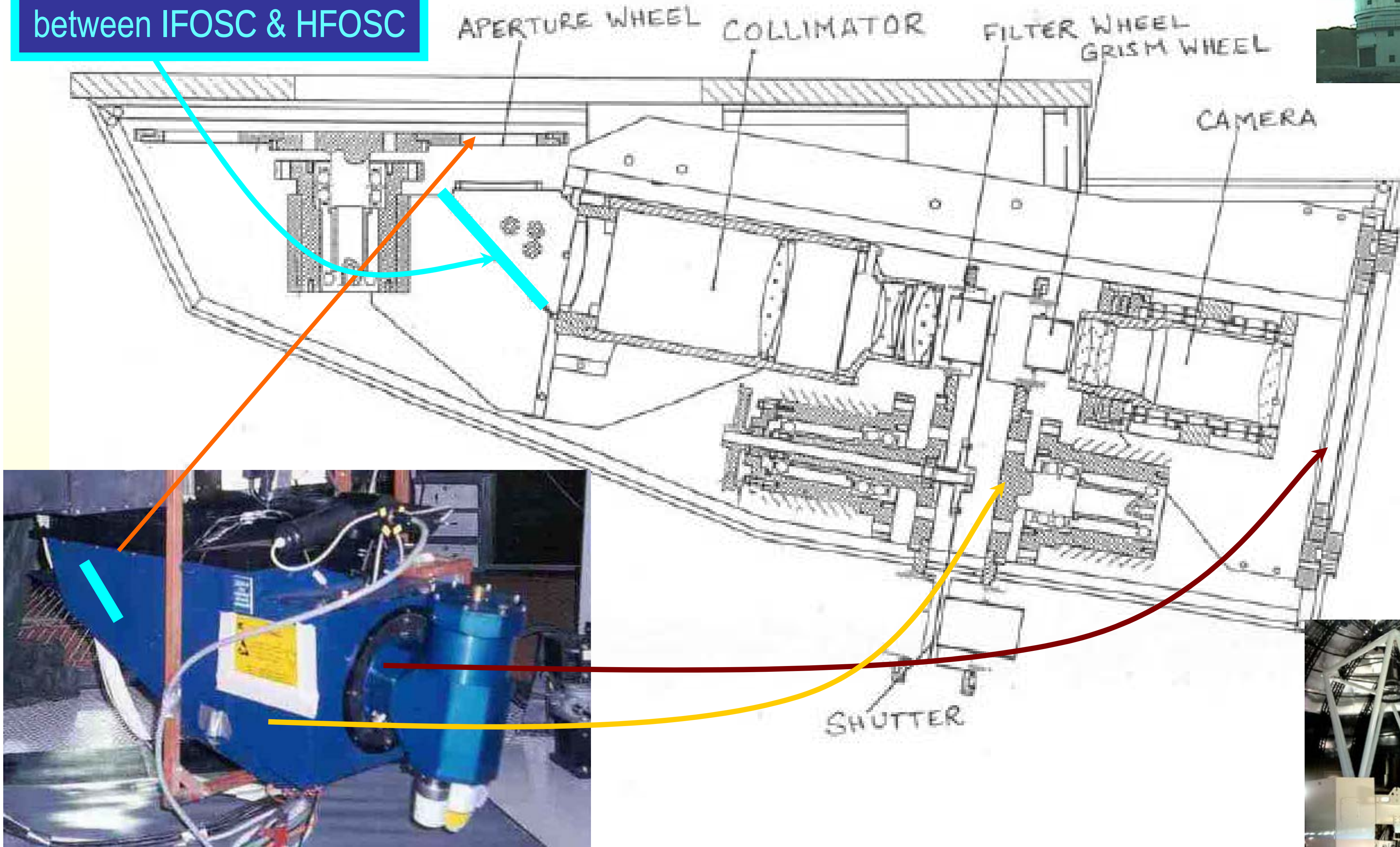


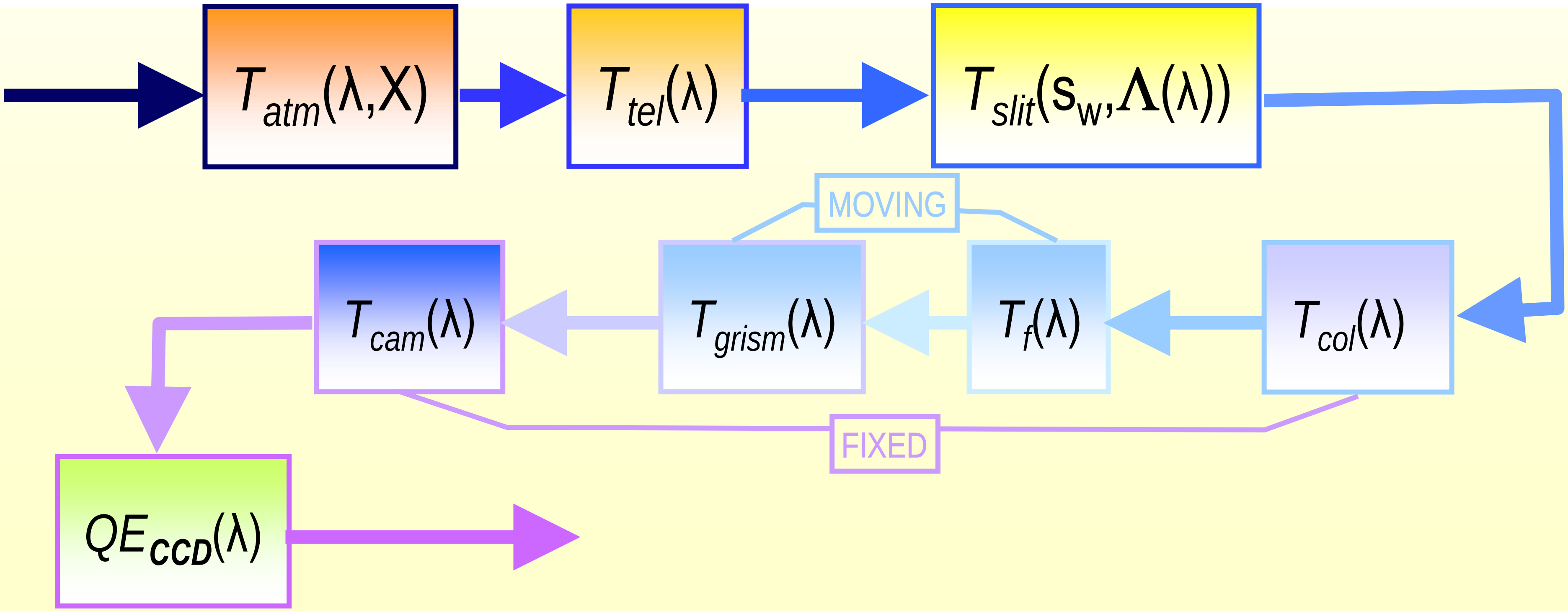
Figure 1.1: Schematic diagram of the HFOSC main instrument.

Curtsy: *http://www.iiap.res.in/iao/hfosc.html*

Transmittivity Calculations

The total transmittance $T_0(\lambda)$ can be separated out as the product of different transmittances due to different components in the path of the incoming light.

$$T_0(\lambda) = T_{atm}(\lambda, X) \cdot T_{tel}(\lambda) \cdot T_{slit}(s, \Lambda(\lambda)) \cdot T_{col}(\lambda) \cdot T_f(\lambda) \cdot T_{grism}(\lambda) \cdot T_{cam}(\lambda) \cdot QE_{CCD}(\lambda).$$



Transmittivity Calculations

The atmospheric transmittance is given by

$$T_{atm}(\lambda, X) = \exp\{-k(\lambda)\, X\}$$

$T_{atm}(\lambda, X)$

where $k(\lambda)$ is the extinction at zenith and X is the airmass

$$\text{Ozone}: \quad k_O(\lambda) = 1.11 \cdot 0.25 \cdot 2.5 \cdot \{1210 \cdot exp[-0.0131(\lambda - 2600) + 5.5 \times 10^{-2} \cdot exp[-1.88 \times 10^{-6}(\lambda - 5900)^2]\}$$

$$\text{Rayleigh}: \quad k_R(\lambda) = 9.5 \times 10^{-3} \cdot exp(-h_o/8) \cdot (10^4/\lambda)^4 \cdot \{0.23465 + 107.6/[146 - (10^4/\lambda)^2] + 0.93161/[41 - (10^4/\lambda)^2]\}^2$$

$$\text{Aerosol}: \quad k_A(\lambda) = 0.087 \cdot exp(-h_o/1.5) \cdot (10^4/\lambda)^{0.8}$$

Bessell, M.S., 1990, *PASP* 102, 1181.

$$X = \sec Z - 0{:}0018167(\sec Z - 1) - 0{:}002875(\sec Z - 1)^2 - 0{:}0008083(\sec Z - 1)^3$$

$$\sec Z = (\sin \phi_l \sin \delta_0 + \cos \phi_l \cos \delta_0 \cos H)^{-1}$$

Longitude: ϕ_L = 73.667 ° E.

Latitude: ϕ_l = 19.083 ° N.

Find X as a function of: ϕ_L, ϕ_l, α_0, δ_0 and U_T

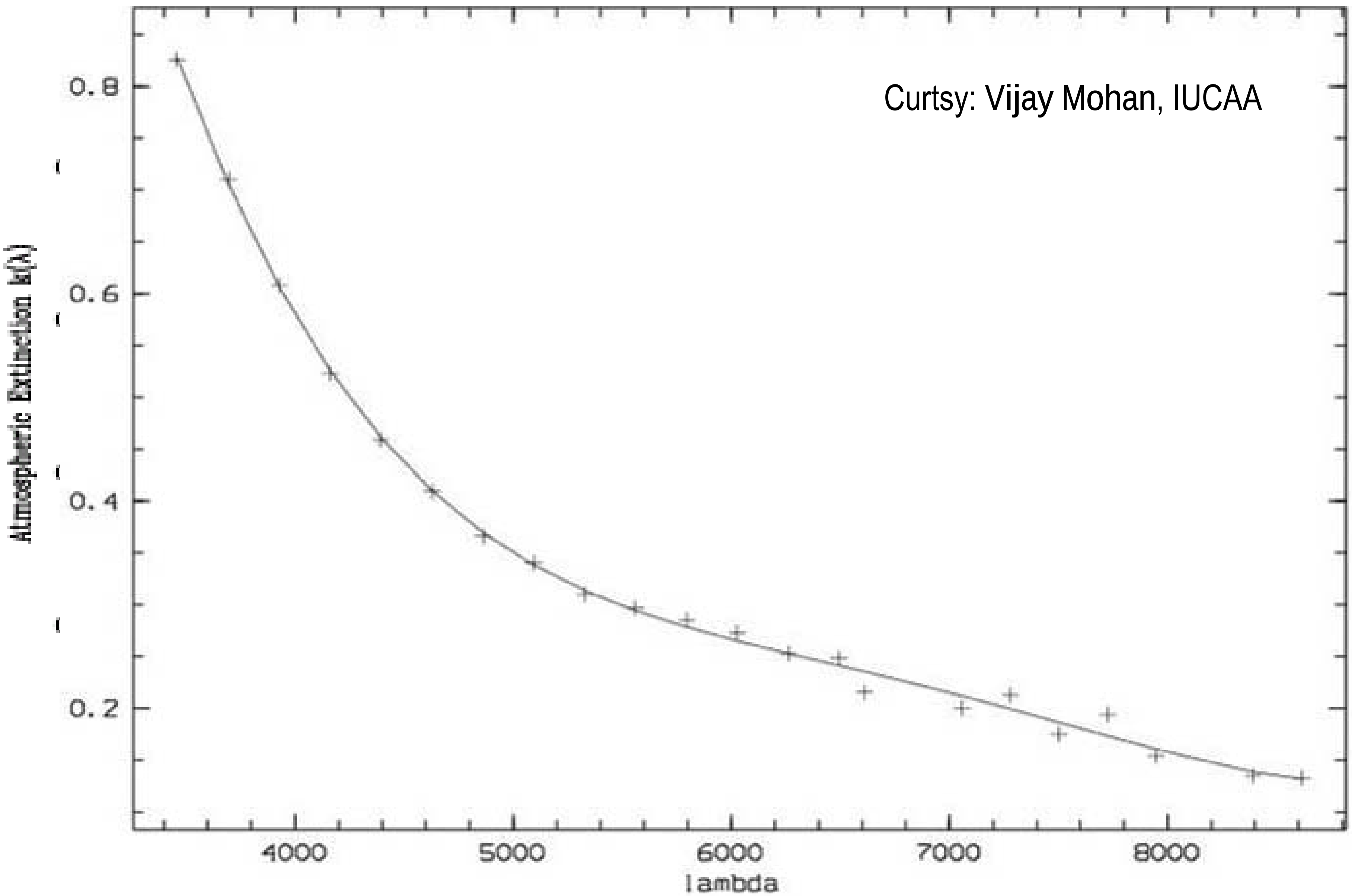
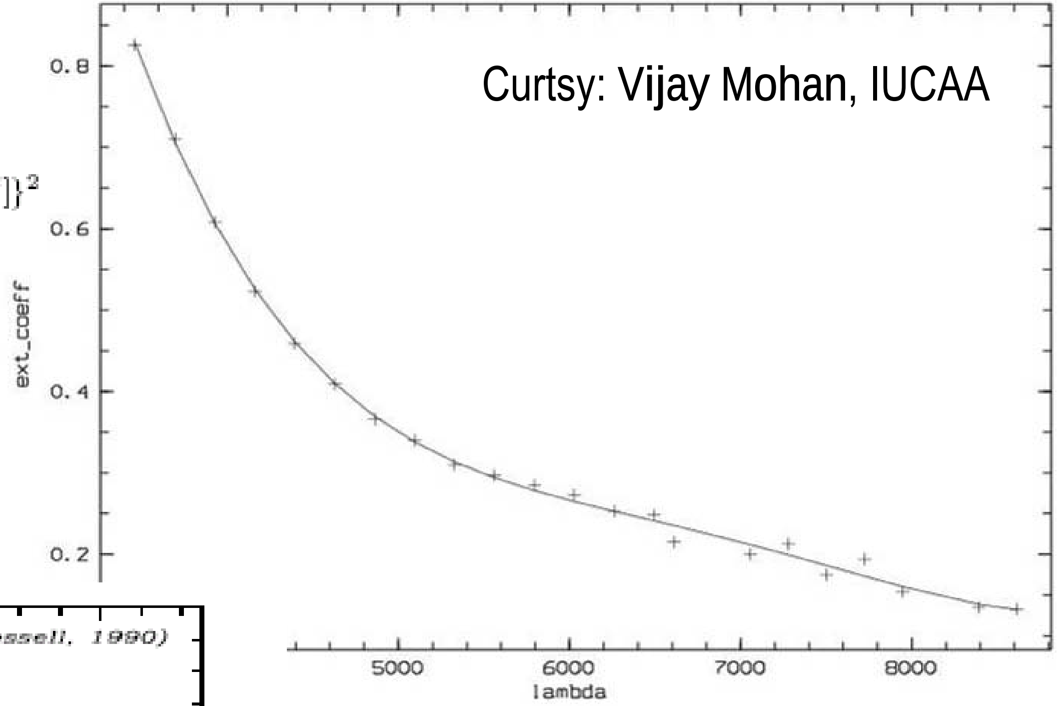


Figure 1. Atmospheric extinction. Fit using the extinction formulation given in Bessell (1990) and a simple two component model.

$$
\begin{aligned}
\text{Ozone}: \quad k_O(\lambda) &= 1.11 \cdot 0.25 \cdot 2.5 \cdot \{1210 \cdot exp[-0.0131(\lambda - 2600) \\
&\quad +5.5 \times 10^{-2} \cdot exp[-1.88 \times 10^{-6}(\lambda - 5900)^2]\} \\
\text{Rayleigh}: \quad k_R(\lambda) &= 9.5 \times 10^{-3} \cdot exp(-h_o/8) \cdot (10^4/\lambda)^4 \cdot \{0.23465 + \\
&\quad 107.6/[146 - (10^4/\lambda)^2] + 0.93161/[41 - (10^4/\lambda)^2]\}^2 \\
\text{Aerosol}: \quad k_A(\lambda) &= 0.087 \cdot exp(-h_o/1.5) \cdot (10^4/\lambda)^{0.8}
\end{aligned}
$$

$$k(\lambda) = k_O(\lambda) + k_R(\lambda) + k_A(\lambda)$$



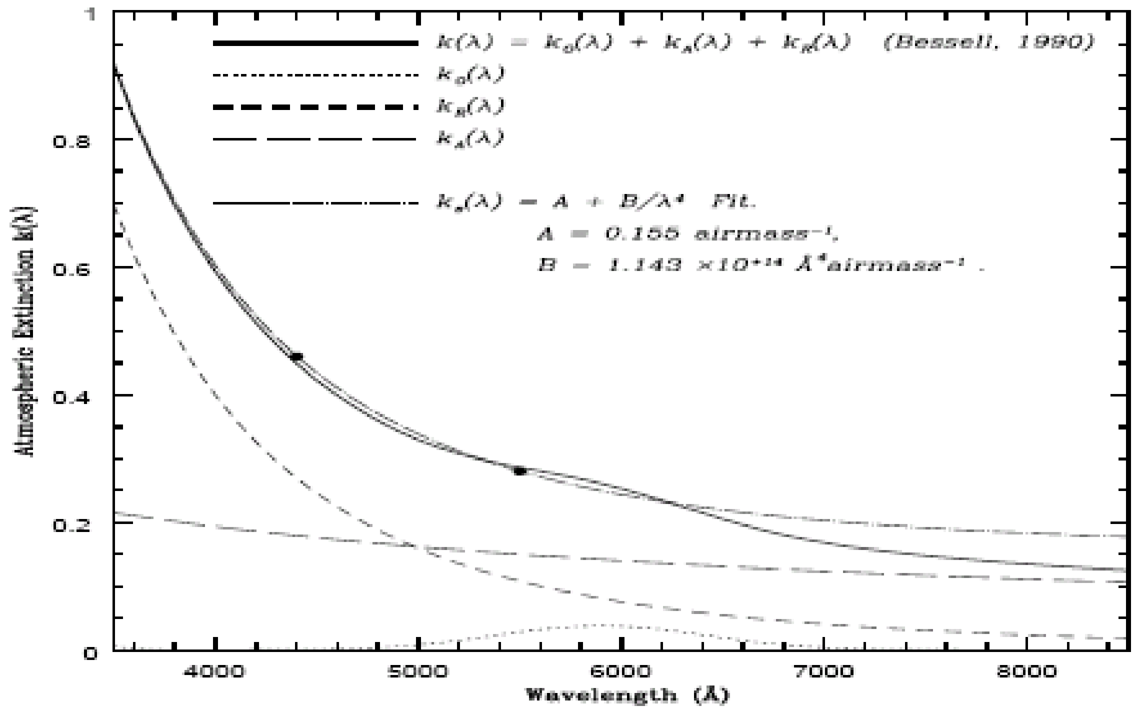


Figure 1. Atmospheric extinction. Fit using the extinction formulation given in Bessell (1990) and a simple two component model.

$$k_s(\lambda) = A + B/\lambda^4$$

Aerosol (large)

Rayleigh

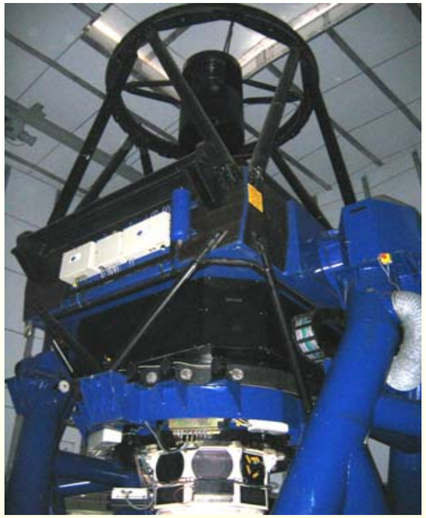
$A = 0.155$ airmass^{-1}

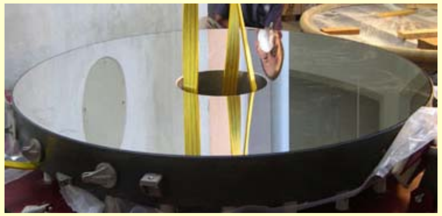
$B = 1.143 \times 10^{14}$ Å^4 airmass^{-1}

Transmittivity Calculations

Transmittivity of the telescope

$T_{tel}(\lambda)$





$T_{tel}(\lambda)$ will essentially depend on both primary and secondary mirrors and the telescope obscuration.

*{For the IUCAA telescope the total obscuration is about **18.5%** (TTL Manual for IUCAA Telescope)}.*

-- Varies from date of Aluminization.

For our calculations we take $T_{tel}(\lambda) = 0.7$ (*i.e.* 70%) a constant with wavelength.

This value is inclusive of the telescope obscuration correction.

A better estimation of $T_{tel}(\lambda)$ can now be made after the commissioning of the telescope.

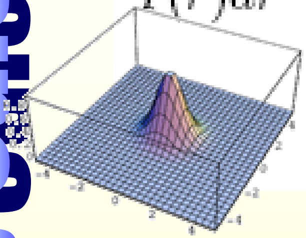
Transmitivity Calculations

The spectrograph slit

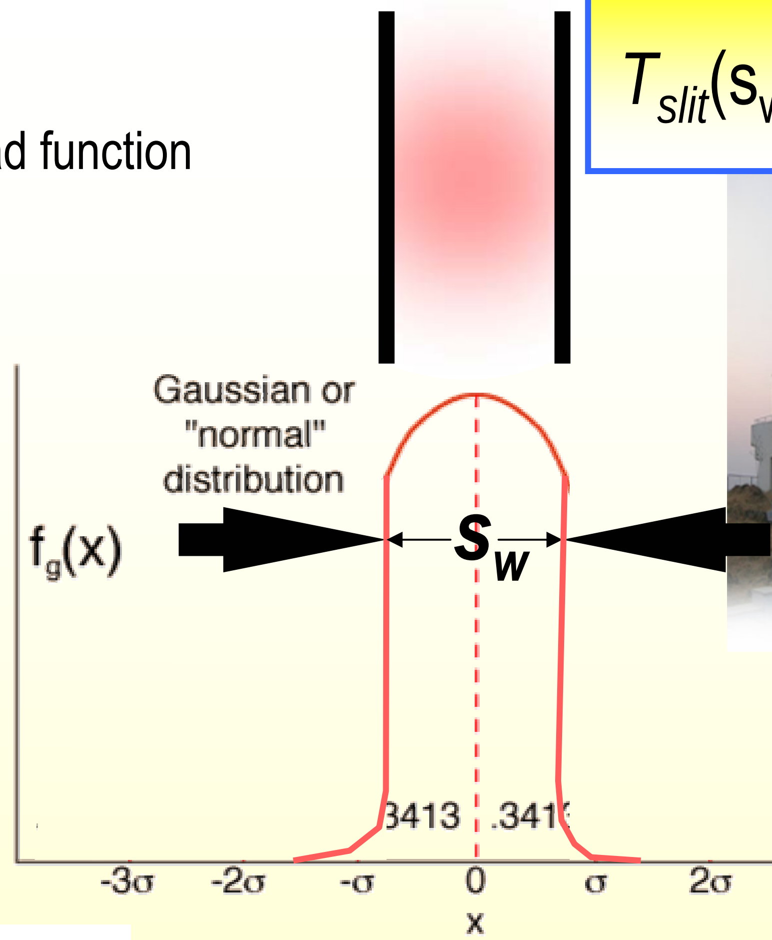
$T_{slit}(s_w, \Lambda(\lambda))$

We assume the star to have a Gaussian point spread function due to seeing

$$\Lambda(\lambda) = FWHM = 2\sqrt{2\ln(2)}\cdot\sigma(\lambda))$$



$$\begin{aligned} I(r)dr &= \frac{I_0}{2\pi\sigma^2}\cdot e^{-r^2/2\sigma^2}\cdot r\,d\theta\,dr \\ &= \frac{I_0}{2\pi\sigma^2}\cdot e^{-(x^2+y^2)/2\sigma^2}\cdot dx\,dy, \end{aligned}$$



The slit with slit-width s_w blocks some of the star light in the *x*-direction, the light passing through the slit will be:

$$\begin{aligned} I_0' &= \frac{I_0}{2\pi\sigma^2}\cdot\int_{-\infty}^{+\infty} e^{-y^2/2\sigma^2}dy\cdot\int_{-s_w/2}^{+s_w/2} e^{-x^2/2\sigma^2}dx. \\ &= \frac{I_0}{2\pi\sigma^2}\cdot\sqrt{2\pi}\sigma\cdot\sqrt{2\pi}\sigma Erf\left(\frac{s_w}{2\sqrt{2}\sigma}\right) = I_0\cdot Erf\left(\frac{s_w}{2\sqrt{2}\sigma}\right). \end{aligned}$$

$$T_{slit}(s_w, \Lambda(\lambda)) = \frac{I_0'}{I_0} = Erf\left(\frac{\sqrt{\ln(2)}s_w}{\Lambda(\lambda)}\right).$$

Transmitivity Calculations

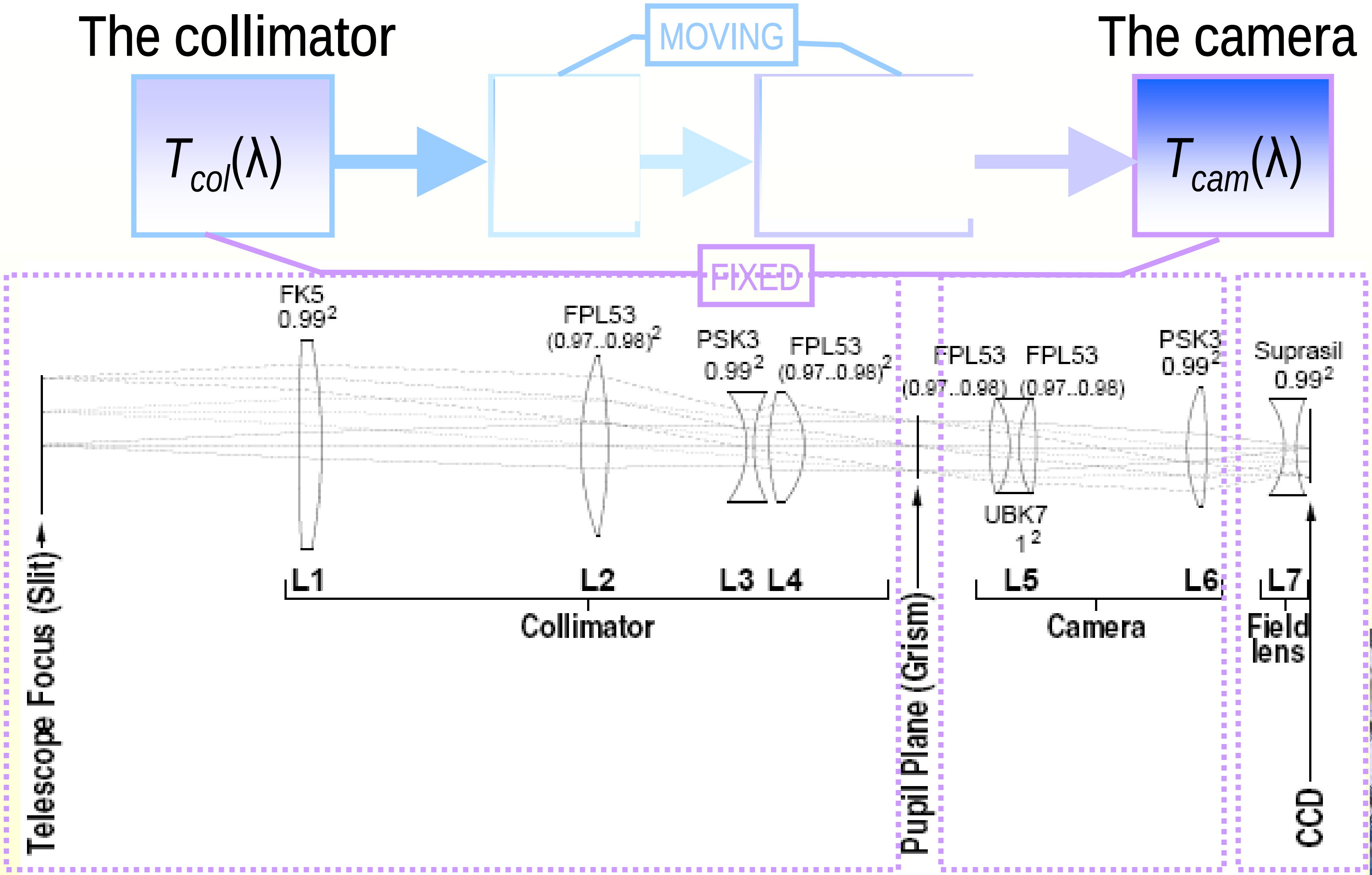
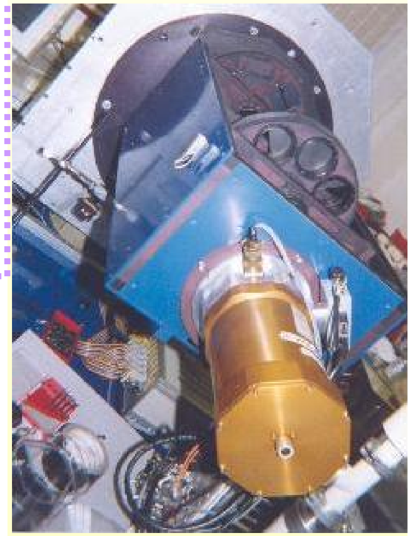
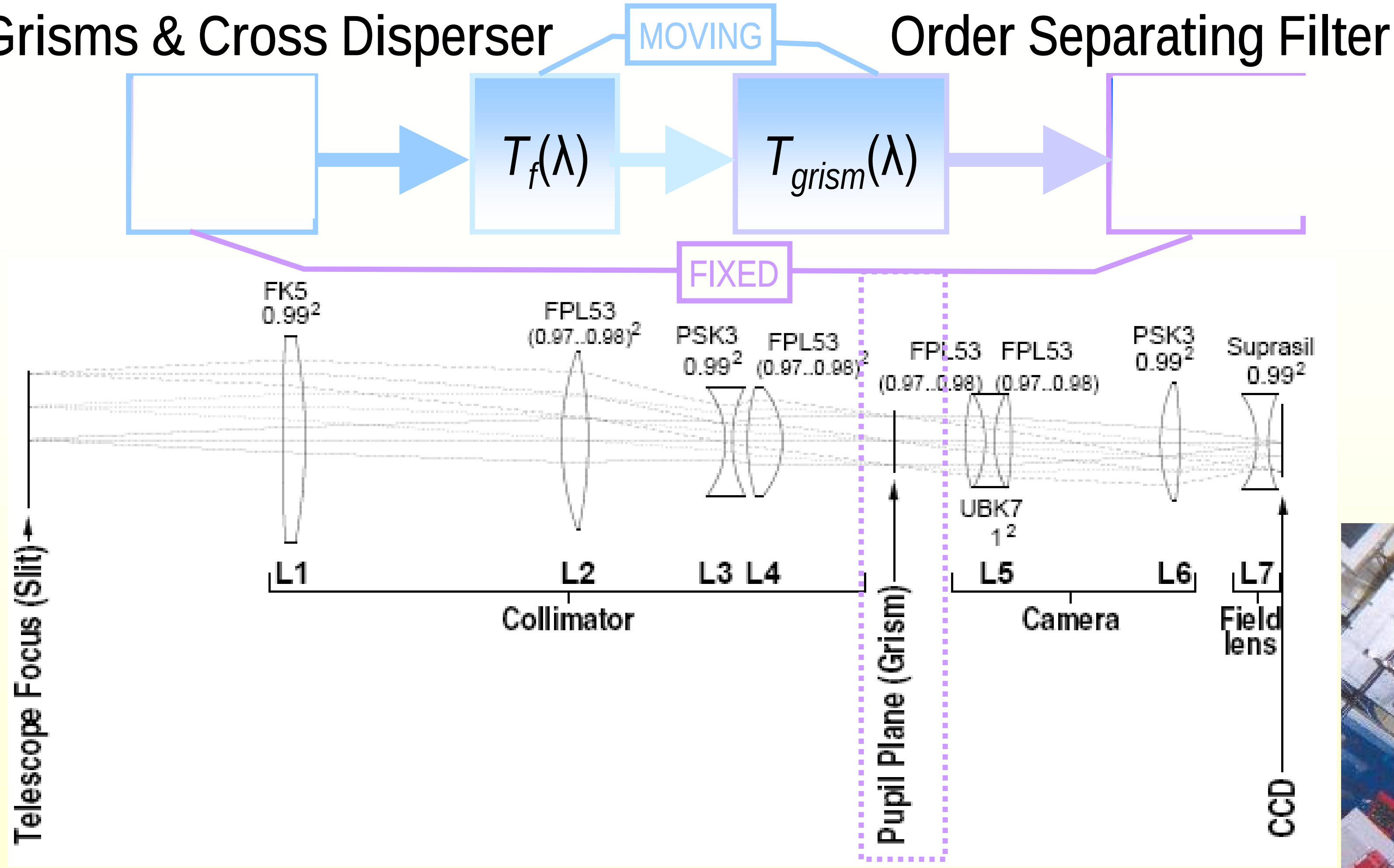


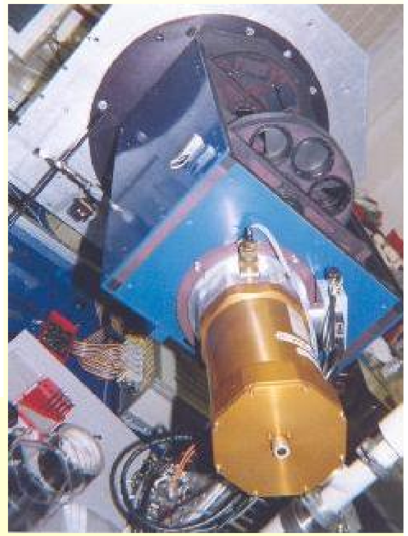
Figure 2. The optical layout of IFOSC. The caption along with each of the lenses in the collimator, the camera and the field lens, indicates the coated glass material used and its average transmittance. The optical ray drawing shows the telescope focus, the pupil plane and the instrument focus on the CCD plane. Collimator focus $f_{col} = 315.7$ mm and camera + field lens focus $f_{cam} = 141.8$ mm.



The transmittance through the collimator and the camera ($T_{col}(\lambda)$ and $T_{cam}(\lambda)$) depends on the number of lenses and the transmittance of the different coated glasses used for the lenses.

Transmittivity Calculations





The transmittance through the grisms $\boldsymbol{T_{grism}}(\lambda)$ are taken from the wavelength Dependent transmittance graphs available at the Danish 1.54-m telescope DFOSC website:

http://www.ls.eso.org/lasilla/Telescopes/2p2T/D1p5M/misc/dfosc grisms.html

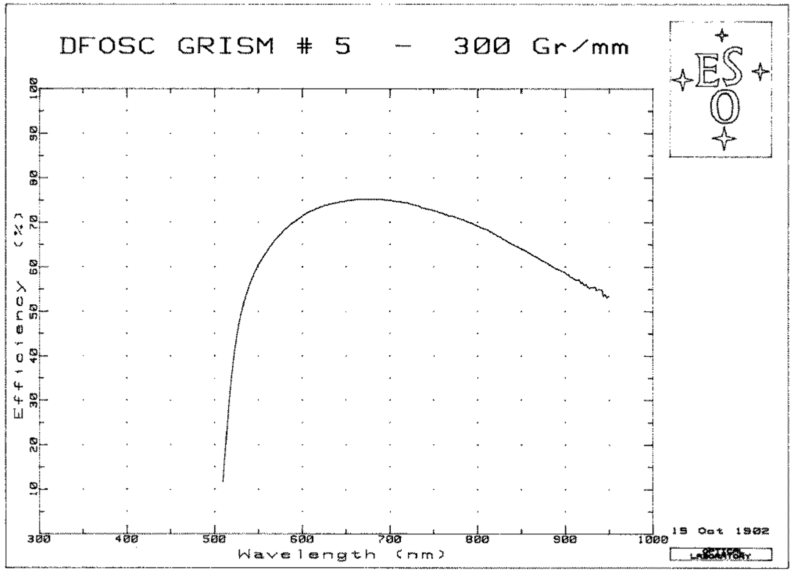
Grism Name	Peak Wavelength (Å)	Wavelength Range w1(Å) w2(Å)	Resolution (Å)
IFORS5	4000	3300 - 6300	8.8
IFOSC5	6000	5200 - 10300	9.2
IFORS1	4000	3300 - 5400	4.2
IFOSC7	5000	3800 - 6840	4.4
IFOSC8	6000	5800 - 8300	3.7
IFOSC13	5100	4800 - 5800	1.5 (3rd order)
Echelle			
IFOSC9 a b	5000	3300 - 11500	1.4 (13th order)
Cross Dispersers			
IFOSC10	4000	3300 - 6500	19.1
IFOSC11	5000	3700 - 7420	13.6
IFOSC12	6000	5200 - 10400	38.6

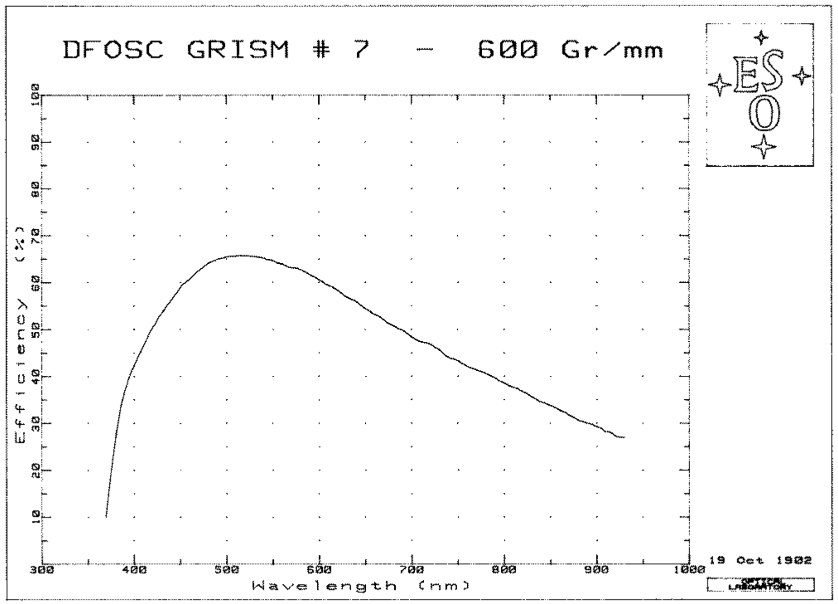
Resolution is for a 1Arcsec slit (100micron on telescope image plane).

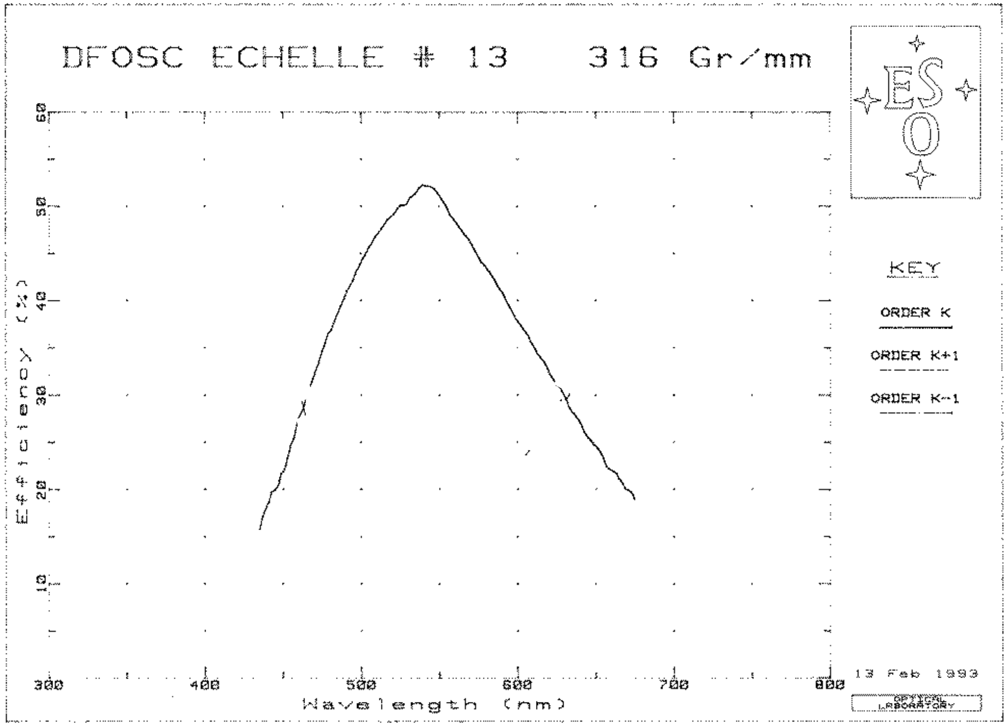
elp.htn

Grism Response

Transmittivity Calculations



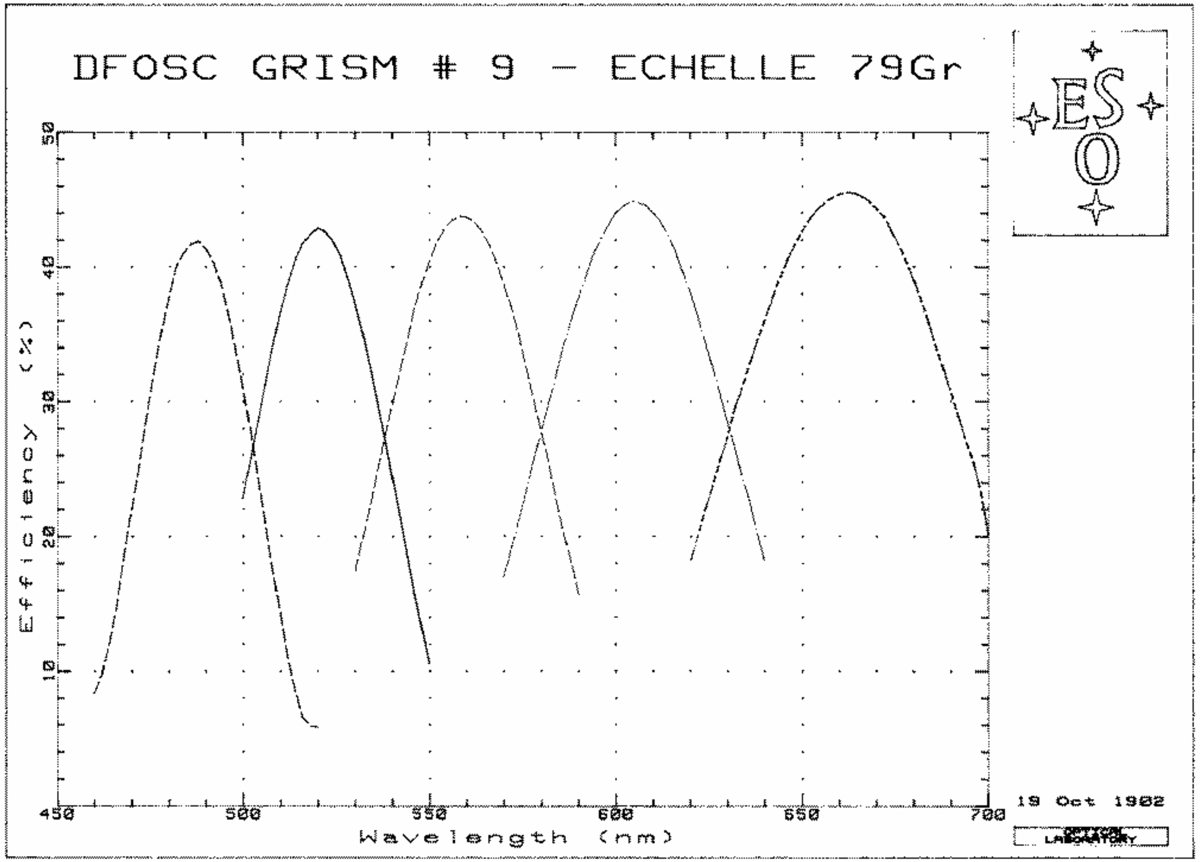


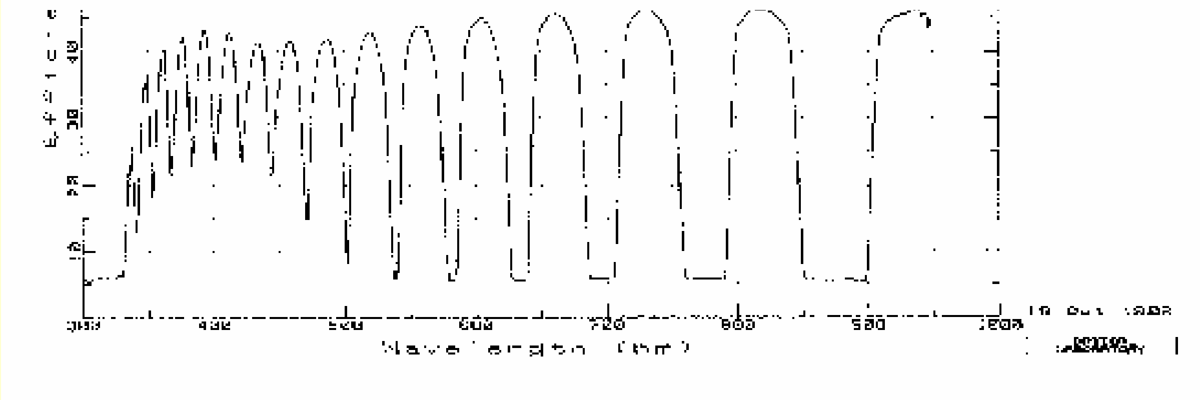


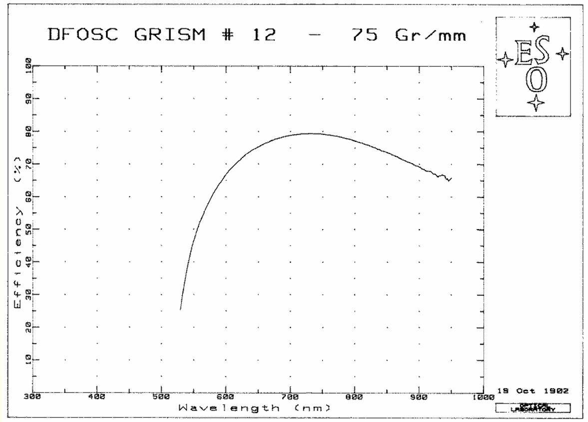
Transmittivity Calculations

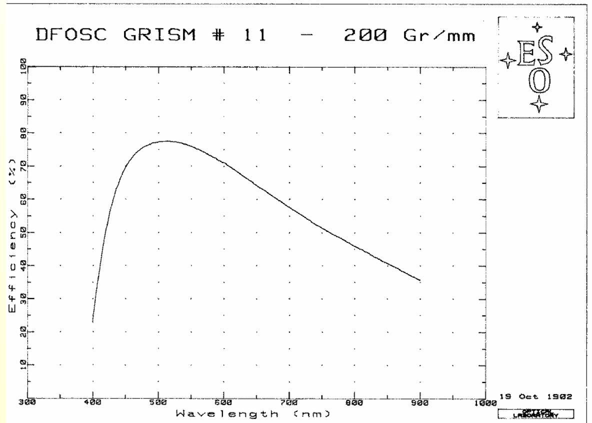
Grism Resp. for ECHELLE

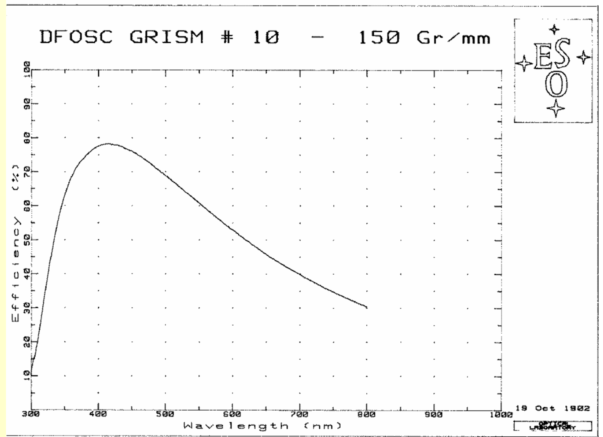
Cross-Dispersers



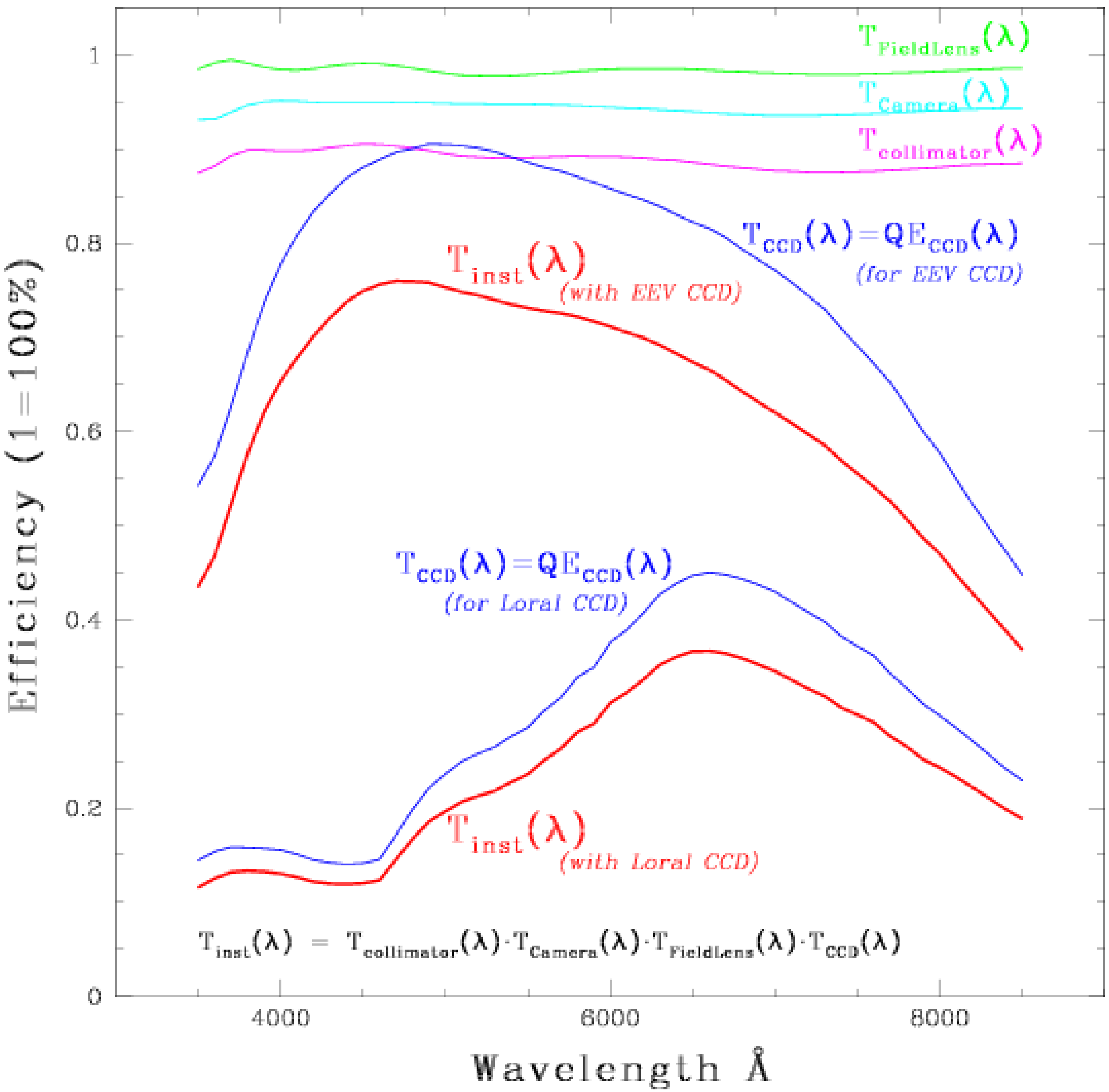






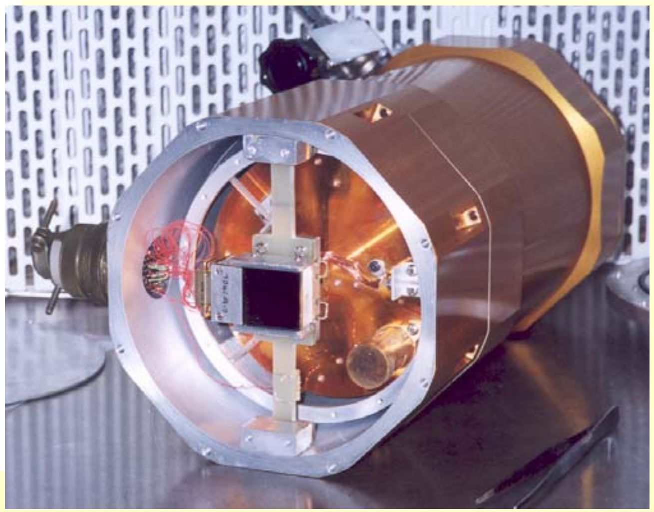


Transmittivity Calculations



CCD

EEV CCD:
(2048 X 2048 pixels)
13.5 micron Square Pixel size
3.26 *pixel/arcsec* Camera Plate-Scale
1.8 e^- /ADU CCD gain
6.3 e^- CCD read out Noise (3.5 ADU)
3.6 e^- /pixel/hour Dark Current at 153K (Typical)
65536.0 ADU CCD Saturation Level (16 bits data)



Sky Background Estimation

The sky background can contribute significant Poisson noise and must be taken into account during noise calculations.

The source for the background sky radiation ***B***(λ,***t***) can be separated into :

1. The faint unresolved stars and galaxies on the line of sight of the observation contributes to this background.

2. Star/Sun light is scattered by interstellar, interplanetary, and atmospheric dust (The zodiacal background light is part of it). This scattered light along with the air glow, that enters the telescope beam, also contributes to this background.

3. Moon light essentially scatters from our atmospheric dust and molecules.

4. Light pollution from city/villages around the observatory.

The sky background may vary due to clouds which can either decrease the background by blocking the sky or increase the background by scattering more moon light and artificial light from ground sources.

Sky Background Estimation

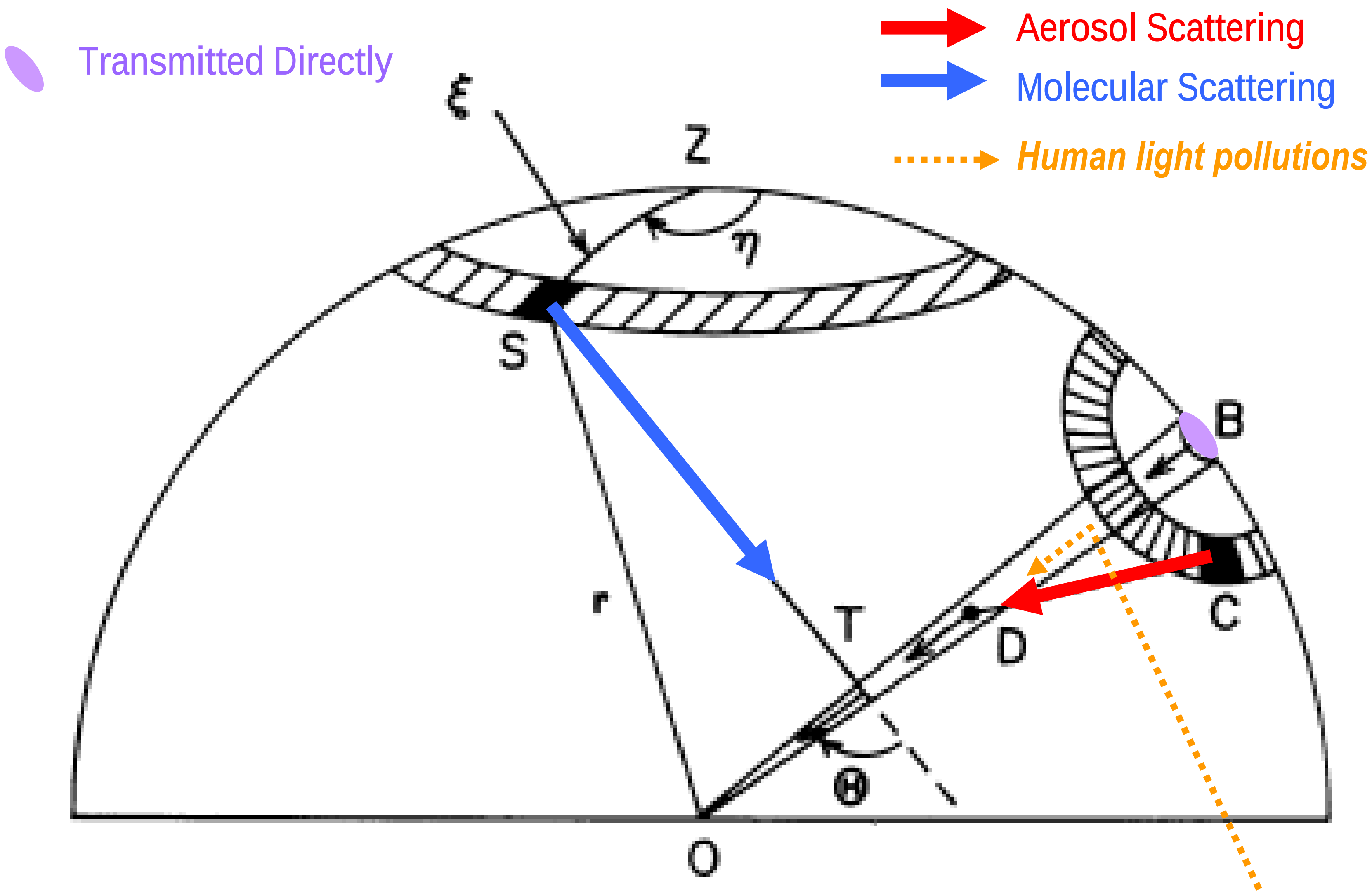


FIG. 3–Calculation of the night-sky background intensity. The observer at O sees light from the sky at B transmitted directly along BO, light from C scattered at D, and light from S scattered at T. For mathematical convenience we treat molecular scattering (at T) and aerosol scattering (at D) as if they were separate. (Note that the letters B, C, D, S, and T have different meanings than those letters have in Figs. 1 and 2.) r, ξ, and η are spherical polar coordinates for S. θ is the scattering angle at T.

Garstang, R. H., 1989, *PASP*, 101, 306.

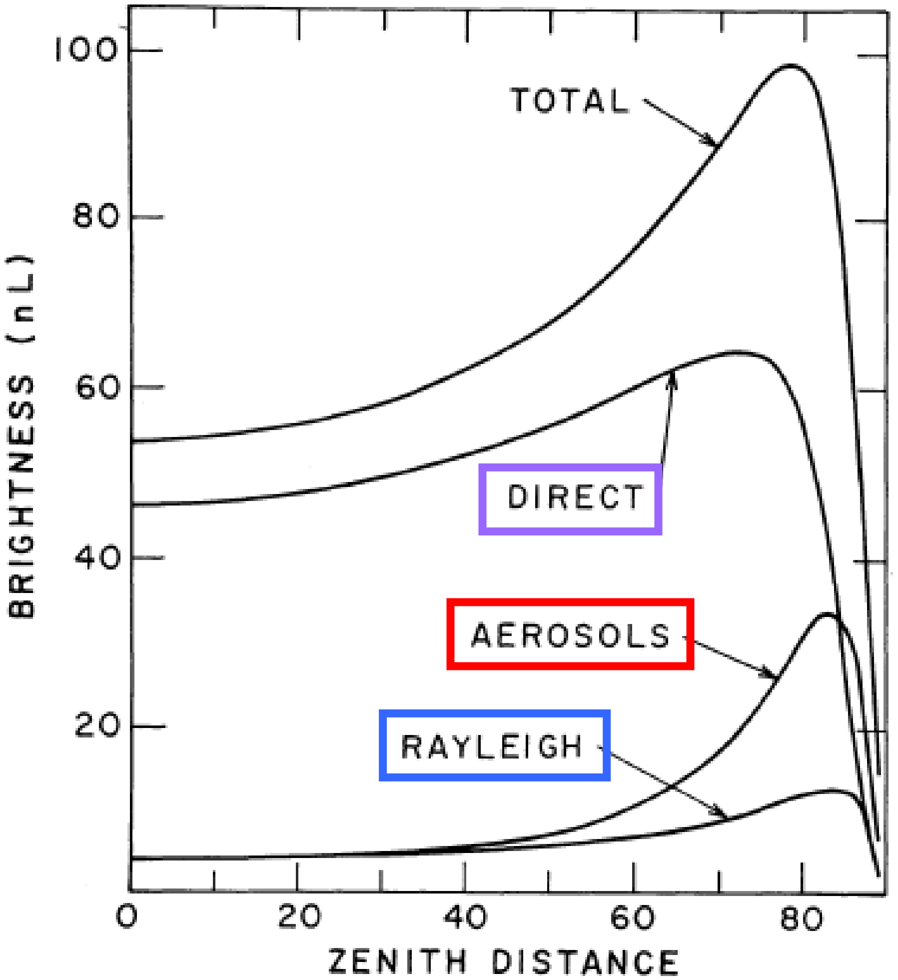


FIG. 4–Contributions to the night-sky brightness by directly transmitted light, by Rayleigh scattering, and by aerosol scattering, calculated for Mount Graham.

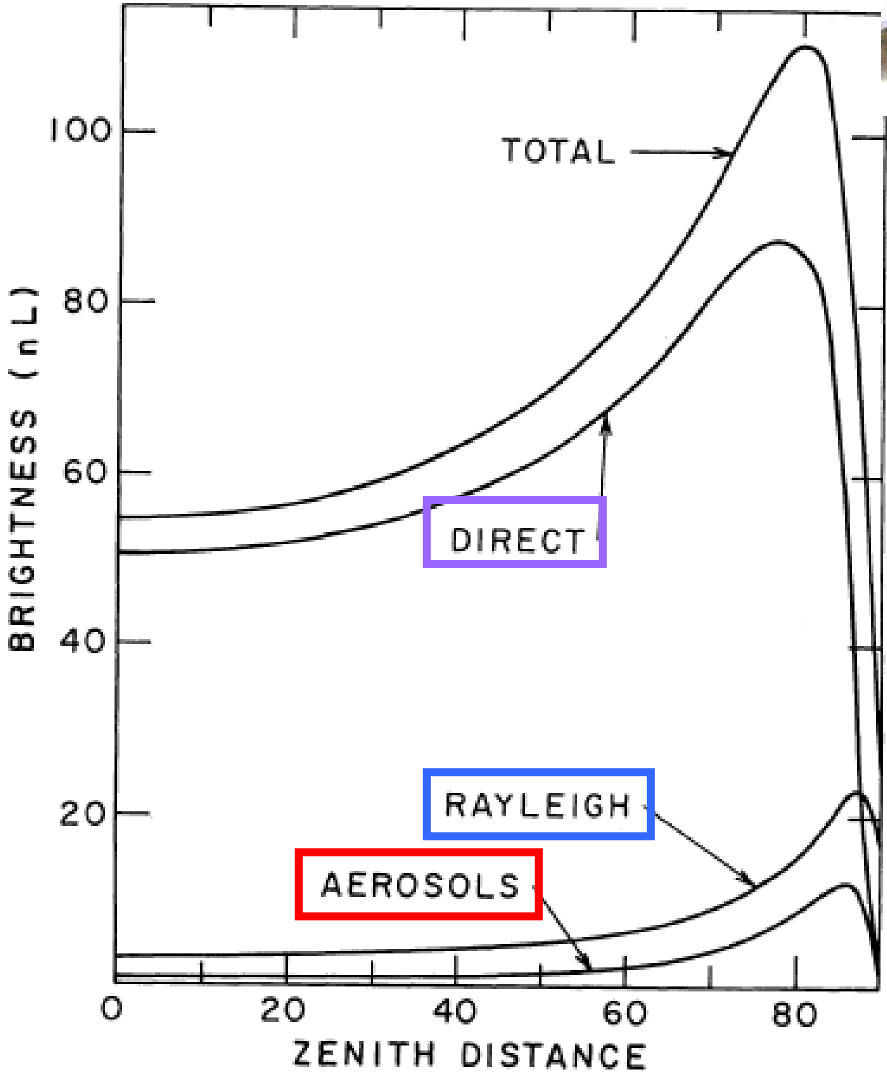
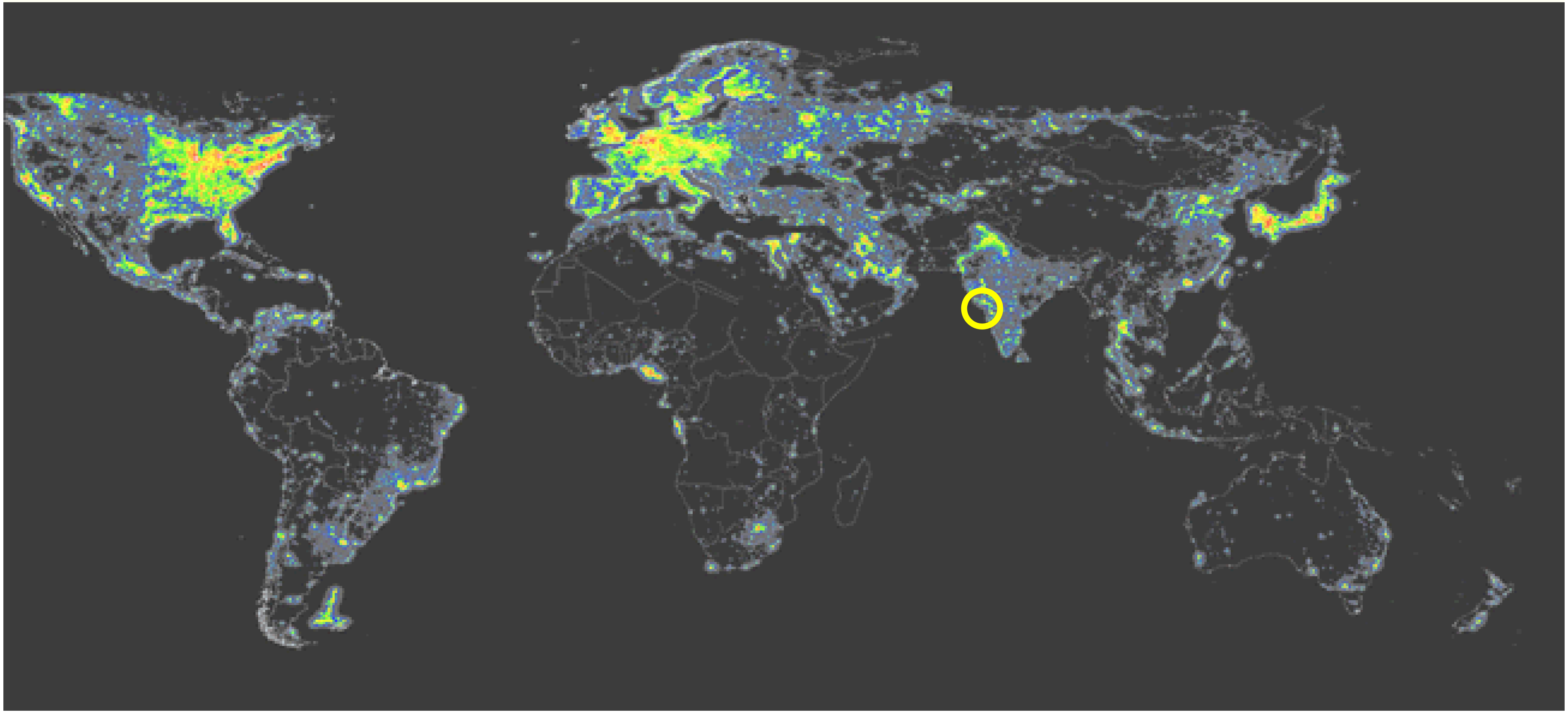


FIG. 5–Contributions to the night-sky background brightness by directly transmitted light, by Rayleigh scattering, and by aerosol scattering, calculated for Boulder.

Garstang, R. H., 1989, *PASP*, 101, 306.

Sky Background Estimation

Light Pollution



Human light pollutions

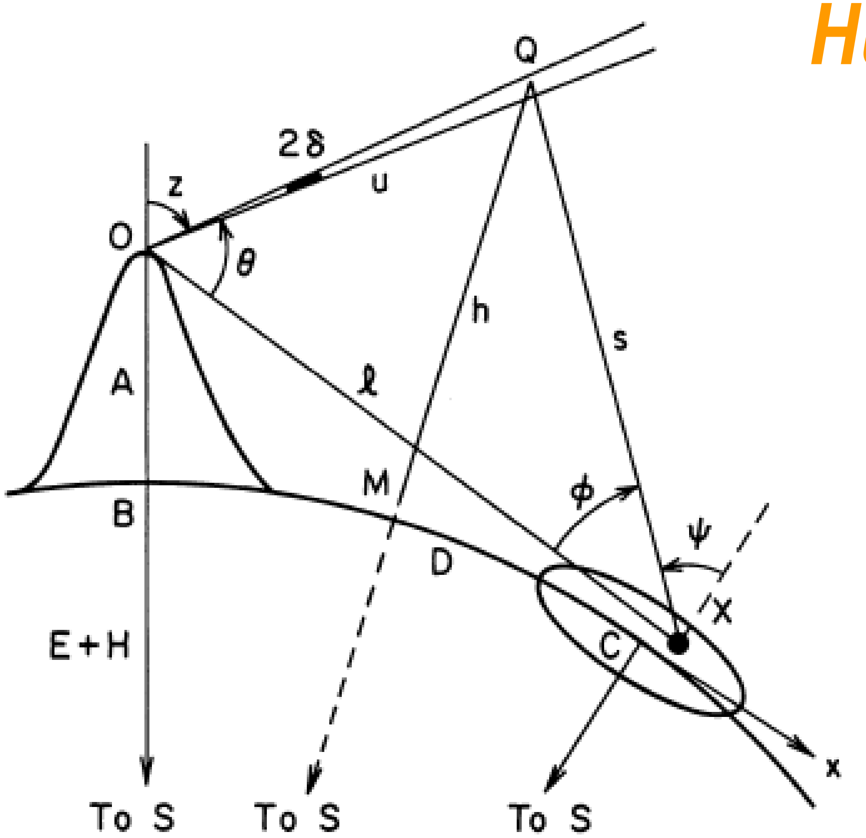


FIG. 1– Scattering of light by a city, with a curved Earth. The city has center C and lies in the tangent plane to the Earth at C. BC is the curved surface of the Earth, assumed spherical. The observer O is at a height A above B. Light from a small area X is scattered at Q and received by the observer O. Q is at a height h above the spherical surface through C. z is the zenith distance of observation. The observer receives light from a cone of semiangle δ around QO. The center of the Earth is at S (off the diagram).

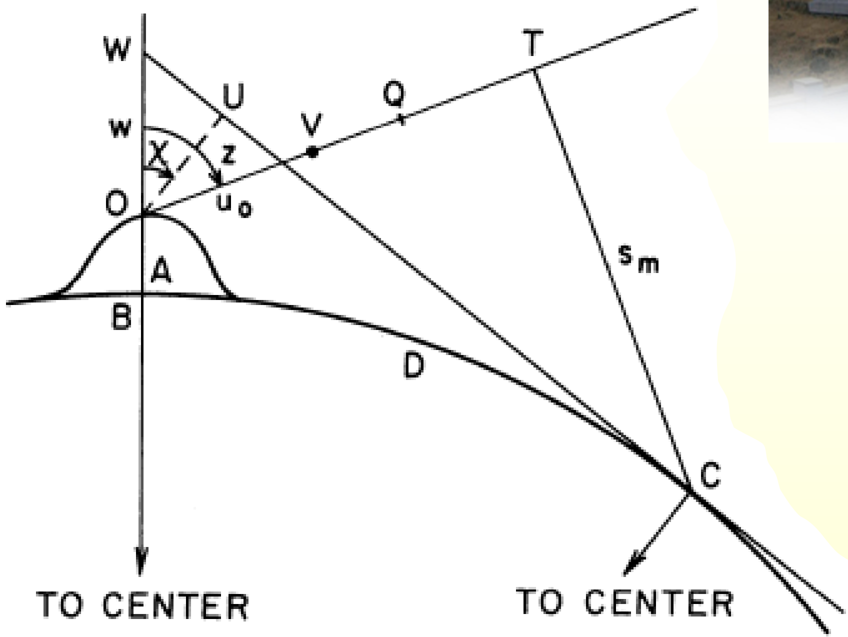


FIG. 2–Geometry associated with the line of sight. The tangent plane at C to the spherical surface BC meets the vertical BO through the observer O at W. The line of sight OVQT meets the tangent plane at C at a point V at a distancse u_0 from O along OQ (the line of sight is in general not in the plane WBC, so that V is not on the line WC). CT is the perpendicular from C to OQ.

Garstang, R. H., 1989, *PASP*, 101, 306.

Human light pollutions

Night-sky Brightness at Mount Graham.

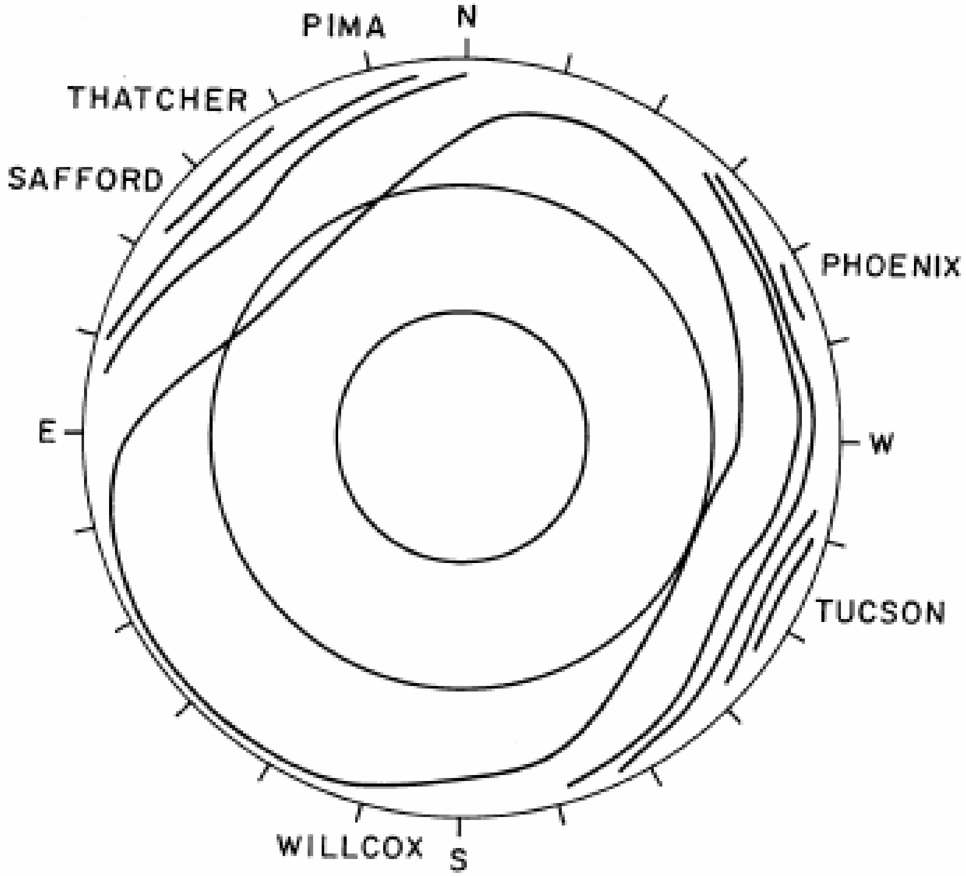


FIG. 8–Artificial contribution to night-sky brightness at Mount Graham. The radial coordinate is zenith distance, with 30°, 60°, and horizon circles drawn. Contours of Δm are shown, where Δm is the artificial contribution to the brightness of the sky expressed in magnitudes per square second above the natural background. The contours are drawn for Δm = 0.1, 0.2, 0.3, 0.5, and 1.0 mag sec^{-2}. The zenith (center of the diagram) has Δm = 0.045.

Garstang, R. H., 1989, *PASP*, 101, 306.

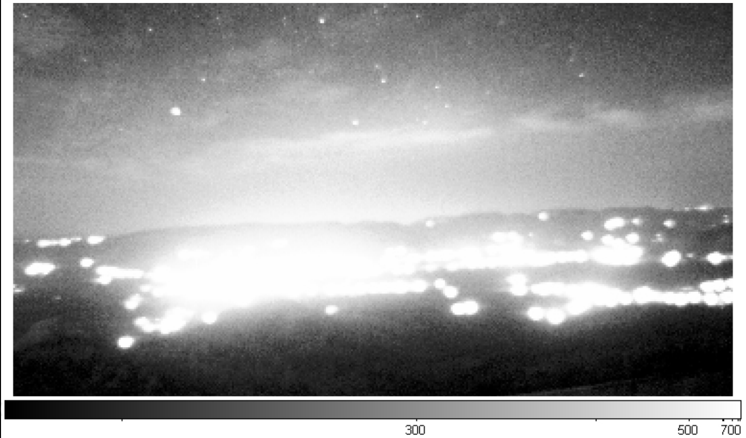

IUCAA Giravali Observatory
Longitude: Φ_L = 73.667 ° E.
Latitude: Φ_l = 19.083 ° N.
IUCAA Giravali Telescope
Image © 2006 TerraMetrics
© 2006 Europa Technologies
© 2005 Google
N
W
E
S
Pointer 19°05'03.89" N 73°40'20.70" E elev 2969 ft
Streaming .||||||| 85%
Eye alt 50164 ft

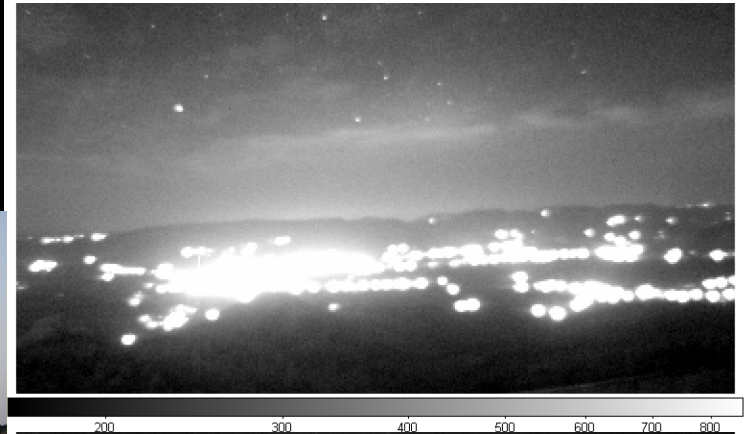
Sky Background Estimation

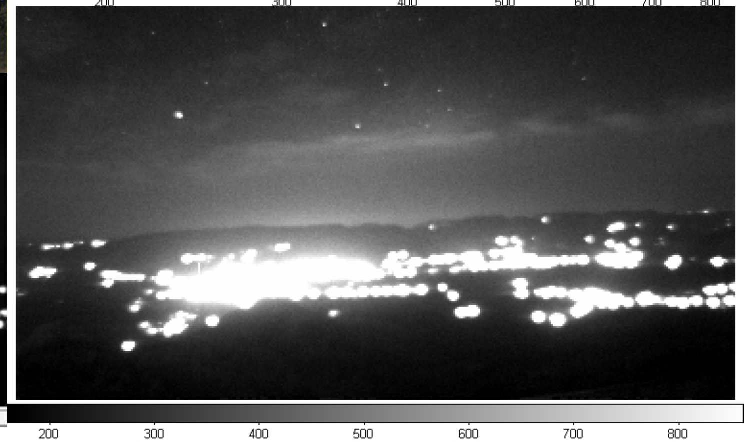
LIGHT PULLUTION

Animation of different display scales

Goregaon from IGO







Sky Background Estimation

To estimate the night sky background, we make use of a model constructed by Krisciunas, K., Schaefer, B. E., 1991. *PASP*, 103, 1033.

The sky background $B(Z, Z_m, \varphi, \rho, \lambda)$ is modeled by two parts,

$$B(Z, Z_m, \varphi, \rho, \lambda) = B_0(Z, \lambda) + B_{moon}(Z, Z_m, \varphi, \rho, \lambda)$$

The sky background $B_0(Z, \lambda)$ relevant for man-made light scattered by the atmosphere is of the form

$$B_0(Z, \lambda) \;=\; B_{zen}(\lambda) \cdot \left(\frac{1 - e^{-k(\lambda) \cdot X}}{1 - e^{-k(\lambda)}} \right). \qquad (16)$$

Krisciunas and Schaefer (1991) in their model of the brightness of moonlight have used

$$B_0(Z, \lambda) = B_{zen}(\lambda)\, X_s(Z)\, 10^{-0.4\, k(\lambda)\, (Xs - 1)}. \qquad (17)$$

$$X_s \;=\; (1 - 0.96 \sin^2 Z)^{-0.5}, \qquad (18)$$

X_s in Eq. 18 as the "scattering airmass" and X as the "extinction airmass".

$$B_{moon}(Z, Z_m, \varphi, \rho, \lambda) = f(\rho)\; I^*(\varphi)\; 10^{-0.4k(\lambda)\, Xs(Zm)}\; [\, 1 - 10^{-0.4k(\lambda)\, Xs(Z)}\,]$$

Lunar Zenith angle Z_m

Object Zenith angle Z

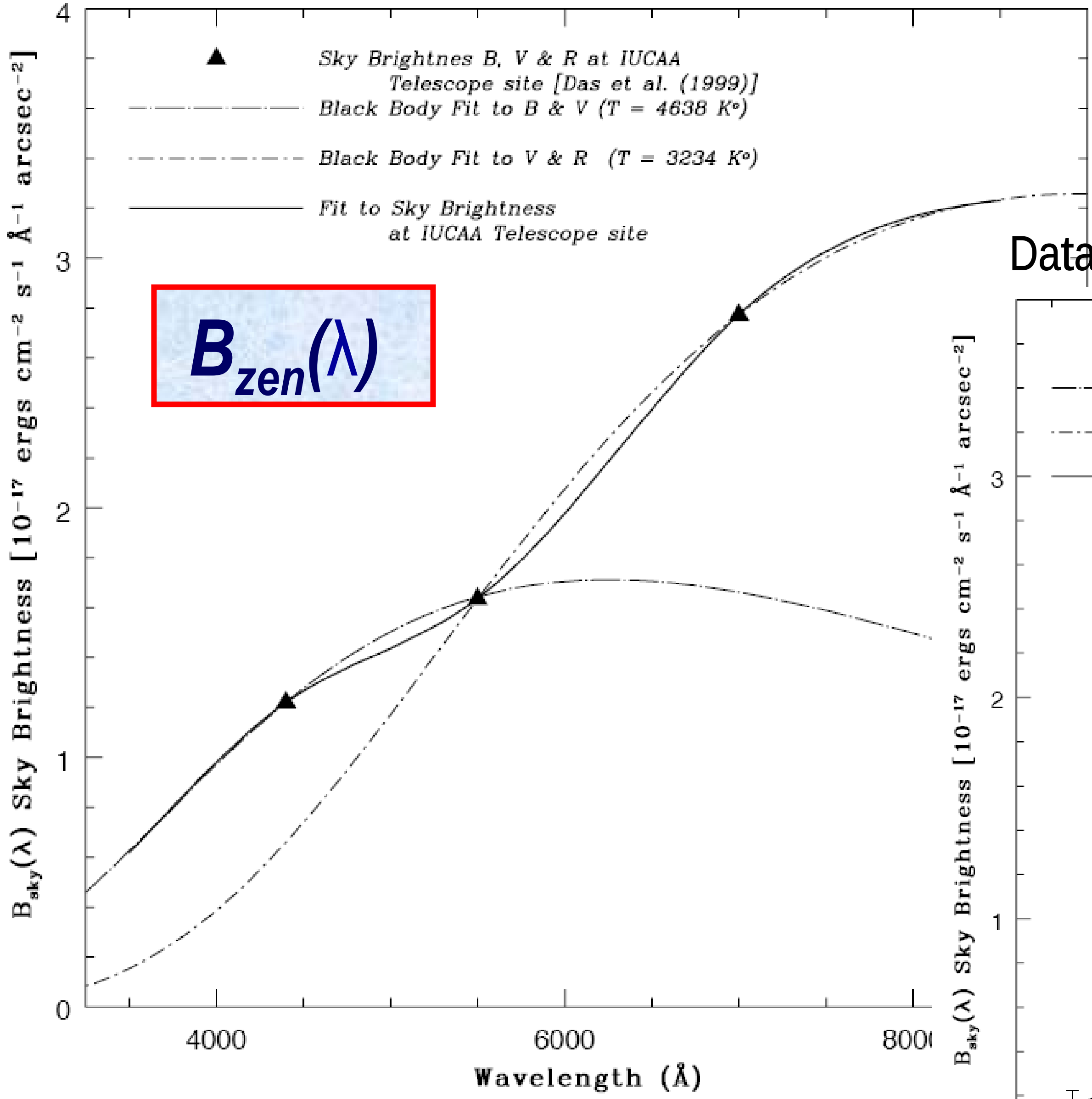
$f(\rho)$: scattering function

ρ : Moon-Object angular distance (scattering angle)

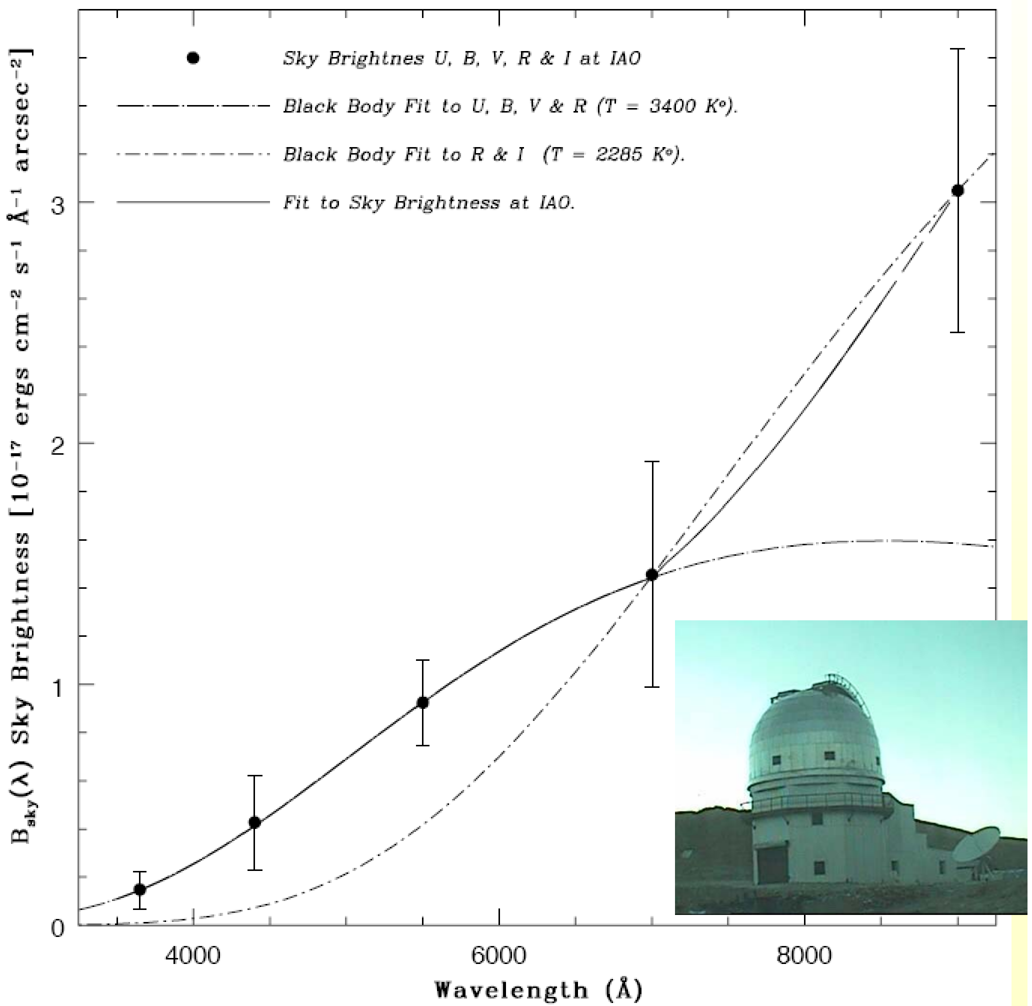
$I^*(\varphi)$: illumination of the moon. φ **:** Lunar Phase angle

Zenith Sky Brightness

Data from: http://www.iiap.res.in/iao/site.html



$B_{zen}(\lambda)$



$$B_0(Z, \lambda) = B_{zen}(\lambda)\, X_s(Z)\, 10^{-0.4\, k(\lambda)\, (Xs - 1)} .$$

Sky Background Estimation

$f(\rho)$: scattering function

$f(\rho)$ - 2 component term, composed of :

Rayleigh scattering function $f_R(\rho)$ (Atmospheric Gases)

Mie scattering function $f_M(\rho)$. (Atmospheric Aerosols)

$$f_R(\rho) = C_R\,[1{:}06 + \cos 2(\rho)]$$

(Rozenberg, 1966).

C_R is the proportionality constant which we determine by integrating and normalizing $f_R(\rho)\, d\rho$ over the whole solid angle.

$$\int f_R(\rho)d\omega \quad = \quad 2\pi C_R \int_0^{\pi} [1.06 + \cos^2(\rho)] \sin(\rho) d\rho = 1.$$

$C_R = 1.34 \times 10^{-12}$ arcsec $^{-2}$

$$f_M(\rho) = C_M\, 10^{-9\rho/2\pi} \qquad \text{for } \rho \geq 10°$$

$$\int f_M(\rho)d\omega \quad = \quad 2\pi C_M \int_0^{\pi} 10^{-9\rho/2\pi} \sin(\rho) d\rho = 1.$$

$C_M = 4.44 \times 10^{-11}$ arcsec $^{-2}$

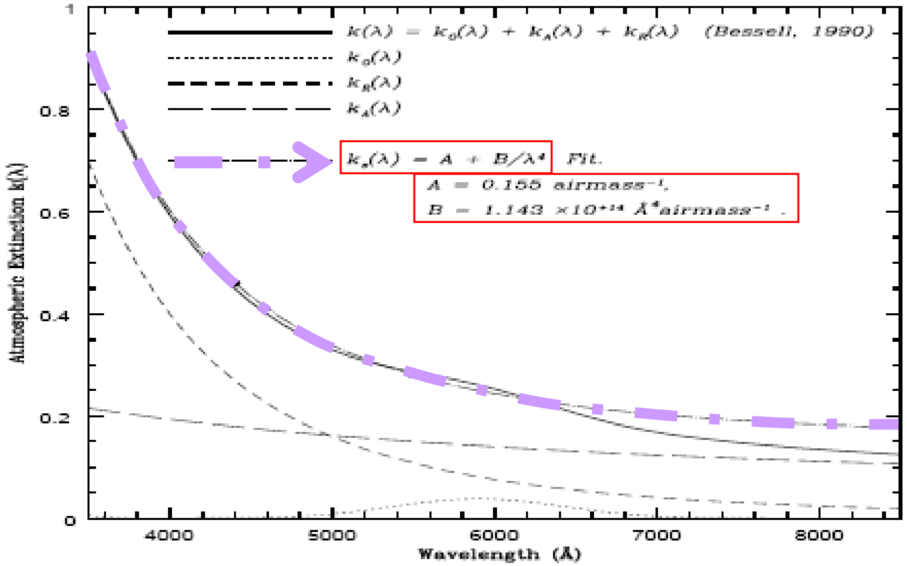
$$f_M(\rho) = C'_M\, \rho^{-2} \qquad \text{for } \rho \leq 10°$$

C'_M is computed by matching Boundary at $10°$

$C'_M = 10^{1.75}\, C_M = 2{:}50 \times 10^{-9}$ arcsec $^{-2}$

Sky Background Estimation

$f_R(\rho)$ and $f_M(\rho)$ have been individually normalized.



The total scattering function $f(\rho)$ will have to be a weighted sum of $f_R(\rho)$ and $f_M(\rho)$ so that $f(\rho)$ is also normalized.

We determined the parameters A and B from a simple 2 component extinction model $k_s(\lambda)$.

$k_s(\lambda) = A + B/\lambda^4$ B = 1.143 X 10^{14} Å^4 airmass^{-1} A = 0.155 airmass^{-1}

These two parameters provide the proportion between $f_R(\rho)$ and $f_M(\rho)$, since scattering is directly related to the extinction.

$$
\begin{aligned}
f(\rho,\lambda) &= \frac{1}{k_s(\lambda)}\left(A\cdot f_M(\rho) + \frac{B}{\lambda^4}\cdot f_R(\rho)\right) \\
&= \frac{1}{k_s(\lambda)}\left(A\cdot C_M 10^{-\rho/40} + \frac{B\cdot C_R}{\lambda^4}[1.06+\cos^2(\rho)]\right) \quad \text{for} \quad \rho \geq 10^\circ. \\
&= \frac{1}{k_s(\lambda)}\left(A\cdot 10^{1.75} C_M \rho^{-2} + \frac{B\cdot C_R}{\lambda^4}[1.06+\cos^2(\rho)]\right) \quad \text{for} \quad \rho < 10^\circ.
\end{aligned}
$$

ρ in degrees

Sky Background Estimation

$$B_{moon}(Z,Z_m,\varphi,\rho,\lambda) = f(\rho)\ I^*(\varphi)\ 10^{-0.4k(\lambda)\,Xs(Zm)}\ [\,1 - 10^{-0.4k(\lambda)\,Xs(Z)}\,].$$

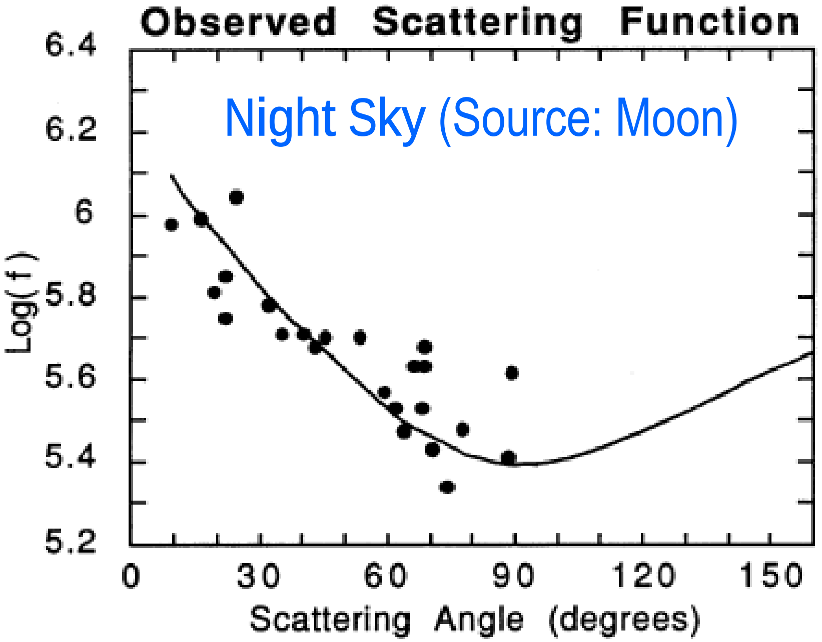


FIG. 1–The scattering function, $f(\rho)$, as deduced from the moonlight observations reported in this paper and in Krisciunas 1990. That is, for the observations, all the quantities in equation (15) are known so that the scattering may be solved for. The scattering function is a function of the scattering angle, ρ. The scattering function from equation (21) is drawn as the smooth curve.

$$f(\rho) = 10^{5.36}\,[1.06 + \cos^2(\rho)] + 10^{6.15-\rho/40}\ , \qquad (21)$$

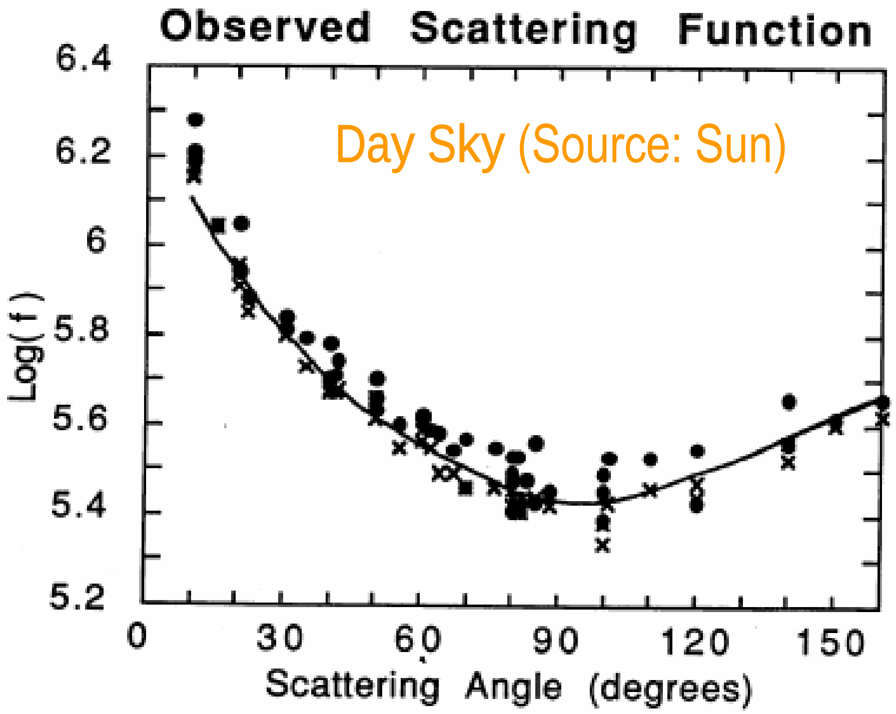


FIG. 2–The scattering function, $f(\rho)$, as deduced from the sunlight observations reported in Pyaskovskaya-Fesenkova 1957. As in Figure 1, all the quantities in equation (15) are known so that the scattering function may be determined. The scattering function is plotted versus the scattering angle, ρ, for sites with extinction coefficients of 0.15 (crosses) and 0.24 (dots). The scattering function from equation (21) is drawn as the smooth curve. Note that the scatter about the model is small and that there is no significant difference between the two sites, as this is the empirical justification that the functional form of equation (15) is valid.

Mie scattering by aerosols – highly forward scattering, Rayleigh scattering dominates for scattering angles greater than 90deg.

Sky Background Estimation

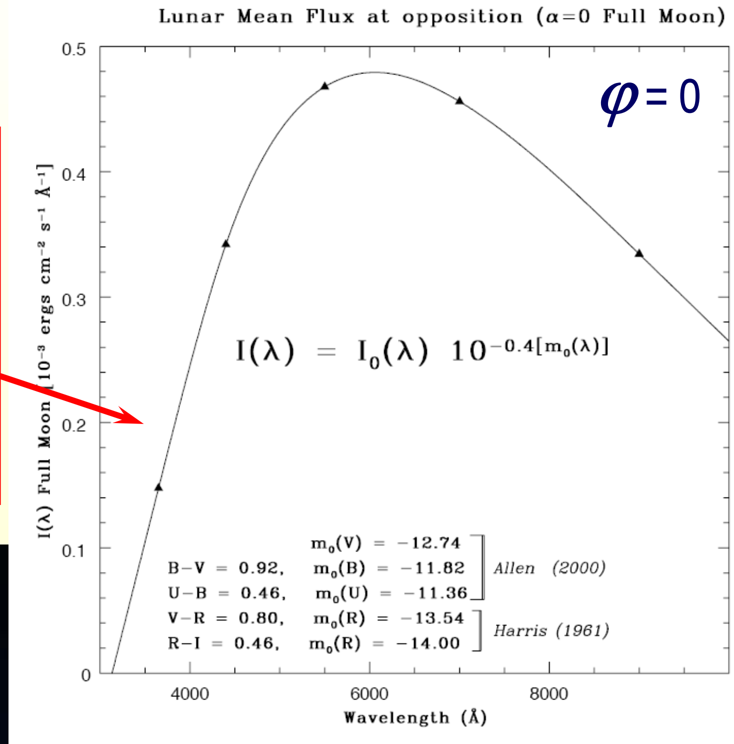
$I^*(\varphi)$: illumination of the moon. φ : Lunar Phase angle

The illuminance of the Moon $I^*(\varphi)$ depends on the phase φ of the Moon and on $m_0(\lambda)$ the apparent mean opposition ($\varphi = 0$) magnitude of the Moon.

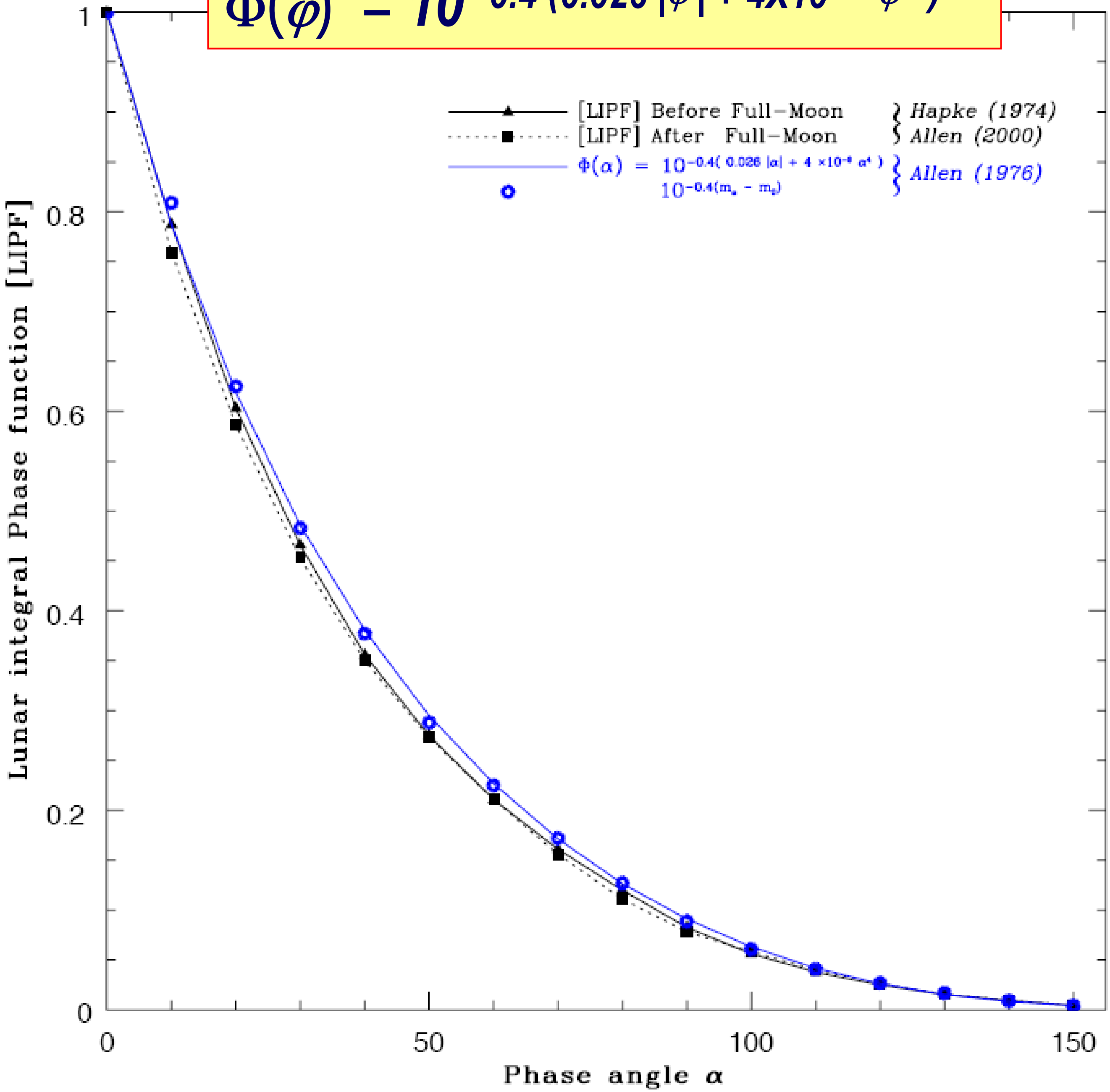
$$I^*(\varphi) = I_0(\lambda) .10^{-0.4(m_0(\lambda) + 0.026|\varphi| + 4X10^{-9}\varphi^4)}$$

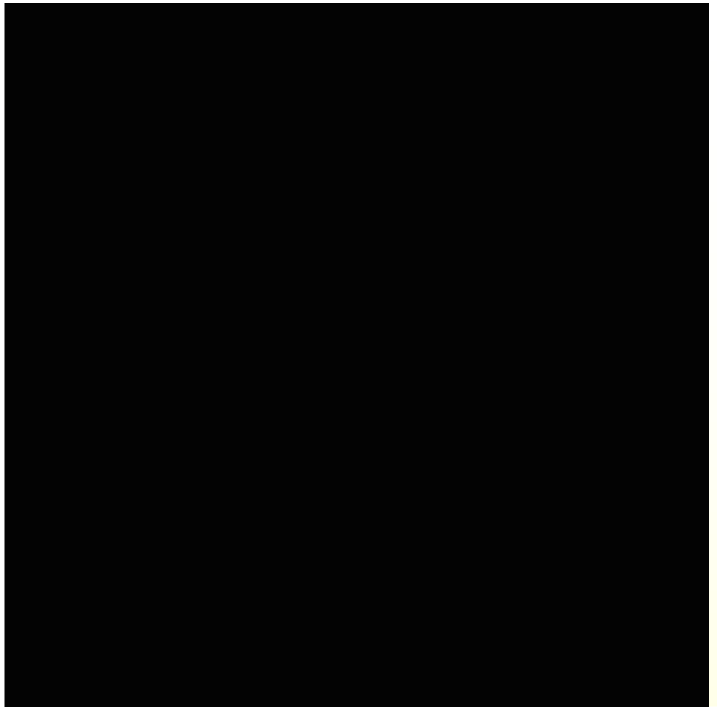
$$= \Phi(\varphi) . I_0(\lambda).10^{-0.4(m_0(\lambda))}$$

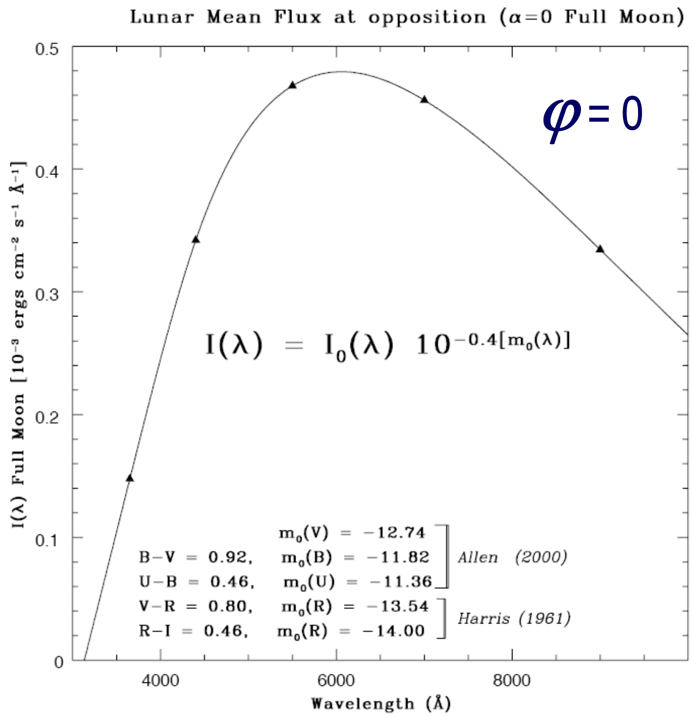
$$\Phi(\varphi) = 10^{-0.4(0.026|\varphi| + 4X10^{-9}\varphi^4)}$$



$$\Phi(\varphi) = 10^{-0.4\,(0.026\,|\varphi| + 4X10^{-9}\,\varphi^{4})}$$







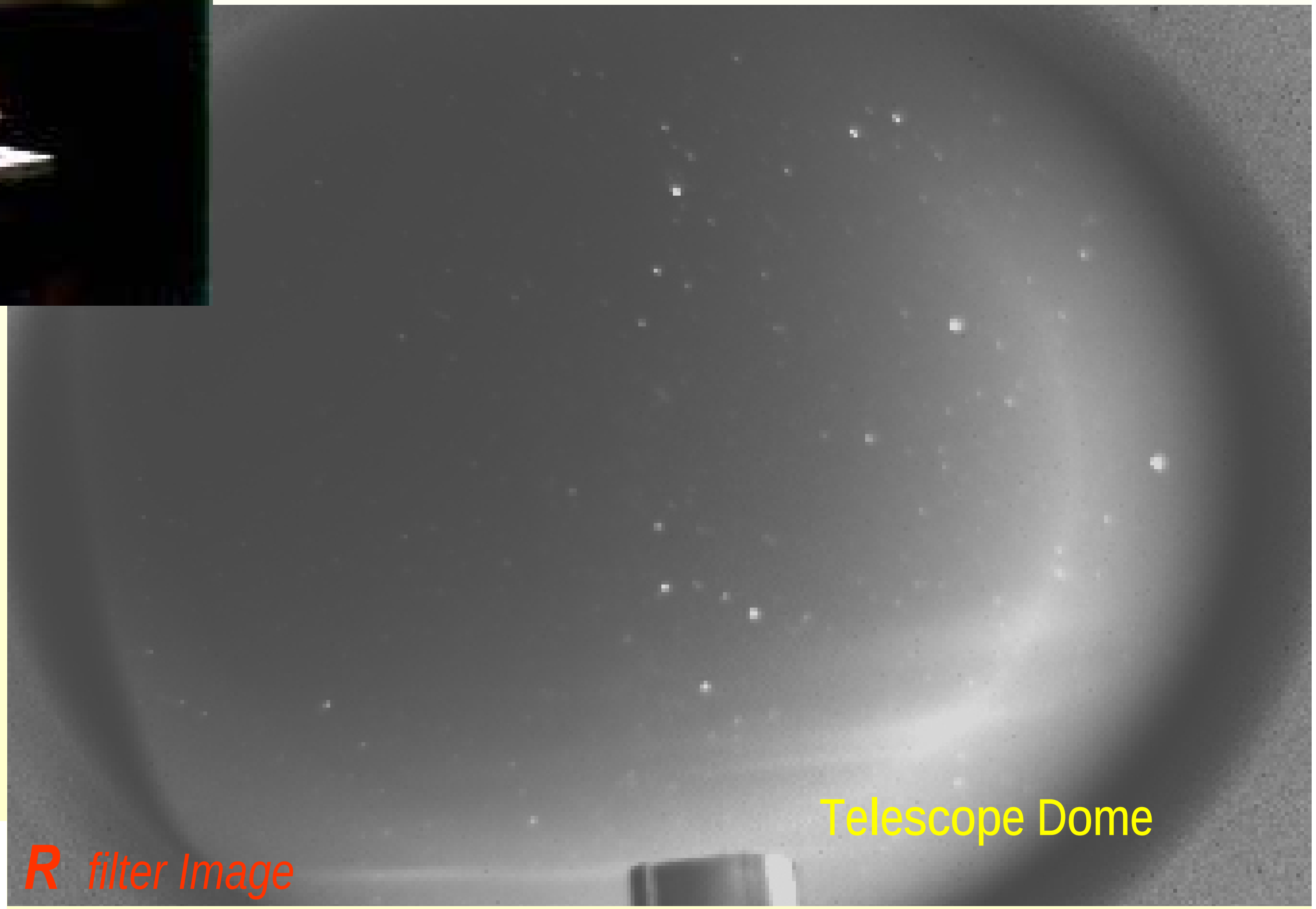
Sky Background Estimation

Verification of the estimated model background sky radiation ***B*(λ, *t*)**

Observations were made with a ***f /1.8***, 6.5mm wide angle lens mounted on a ST6 CCD camera.

Standard ***B***, ***V***, and ***R*** *fi*lters were used in front of the lens.

lens was kept a little out of focus to increase the stellar psf to ~ 3 pixels so that stellar photometry could be performed for calibrating the sky.



Sky Background Estimation

$$B_0(Z, \lambda) = B_{zen}(\lambda)\, X_s(Z)\, 10^{-0.4\, k(\lambda)\, (Xs - 1)} .$$

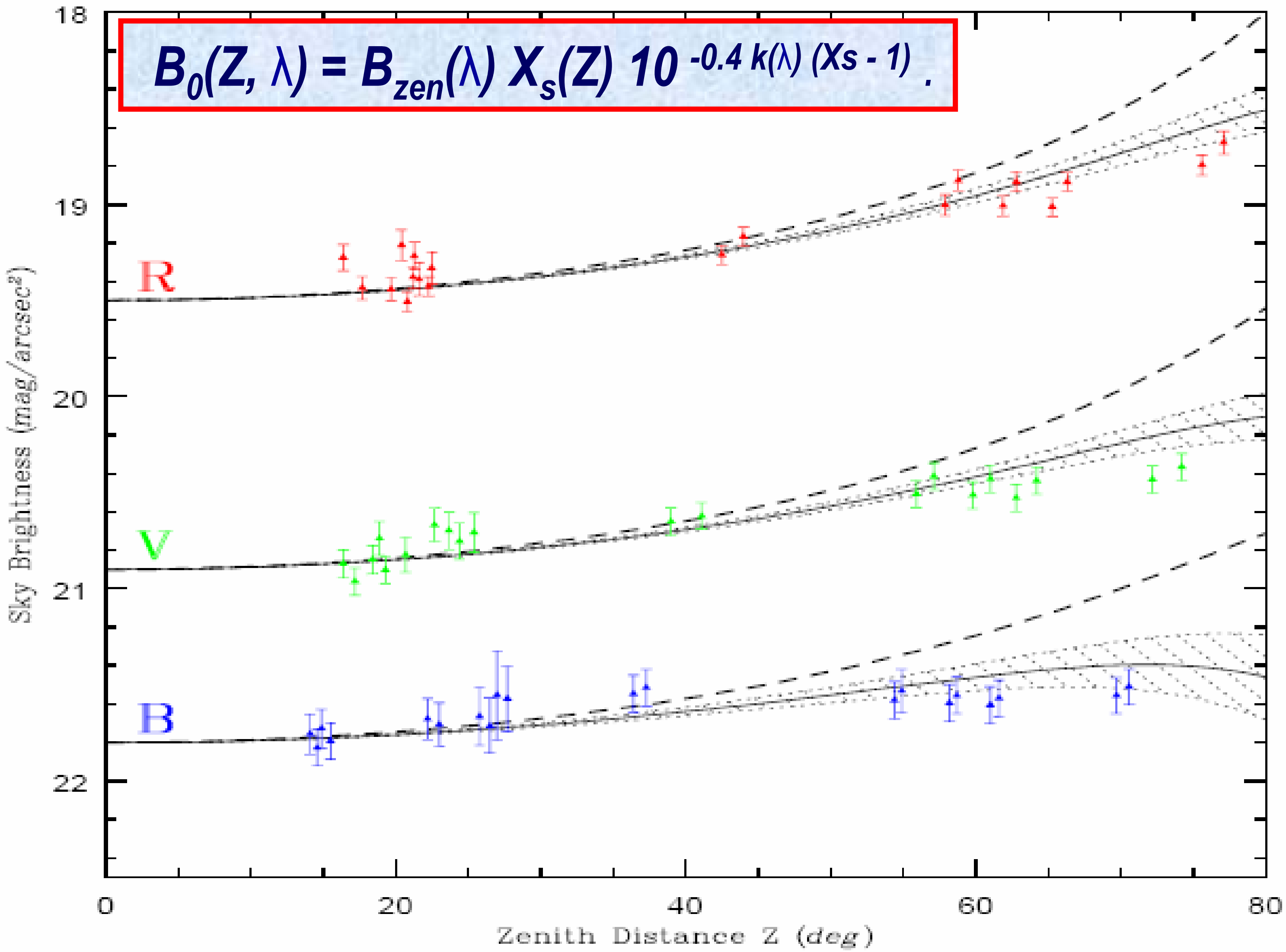


Figure 4. *Variation of observed Moon less sky brightness with the zenith distance in B, V and R filters at IUCAA Telescope site. Over-plotted is Eq. 17 with $B_{zen}(\lambda)$ estimated by Das, Menon, Paranjpye and Tandon (1999). The hashed region around the curve is the uncertainty in estimation of $B_0(Z, \lambda)$ from Eq. 17 due to the errors in $k(\lambda)$. Over-plotted is also Eq. 16 (dashed line) which deviates from observations at about $z = 50°$.*

Sky Background Estimation

$$B_{observed}(Z, Z_m, \varphi, \rho, \lambda) - B(Z, Z_m, \varphi, \rho, \lambda)$$

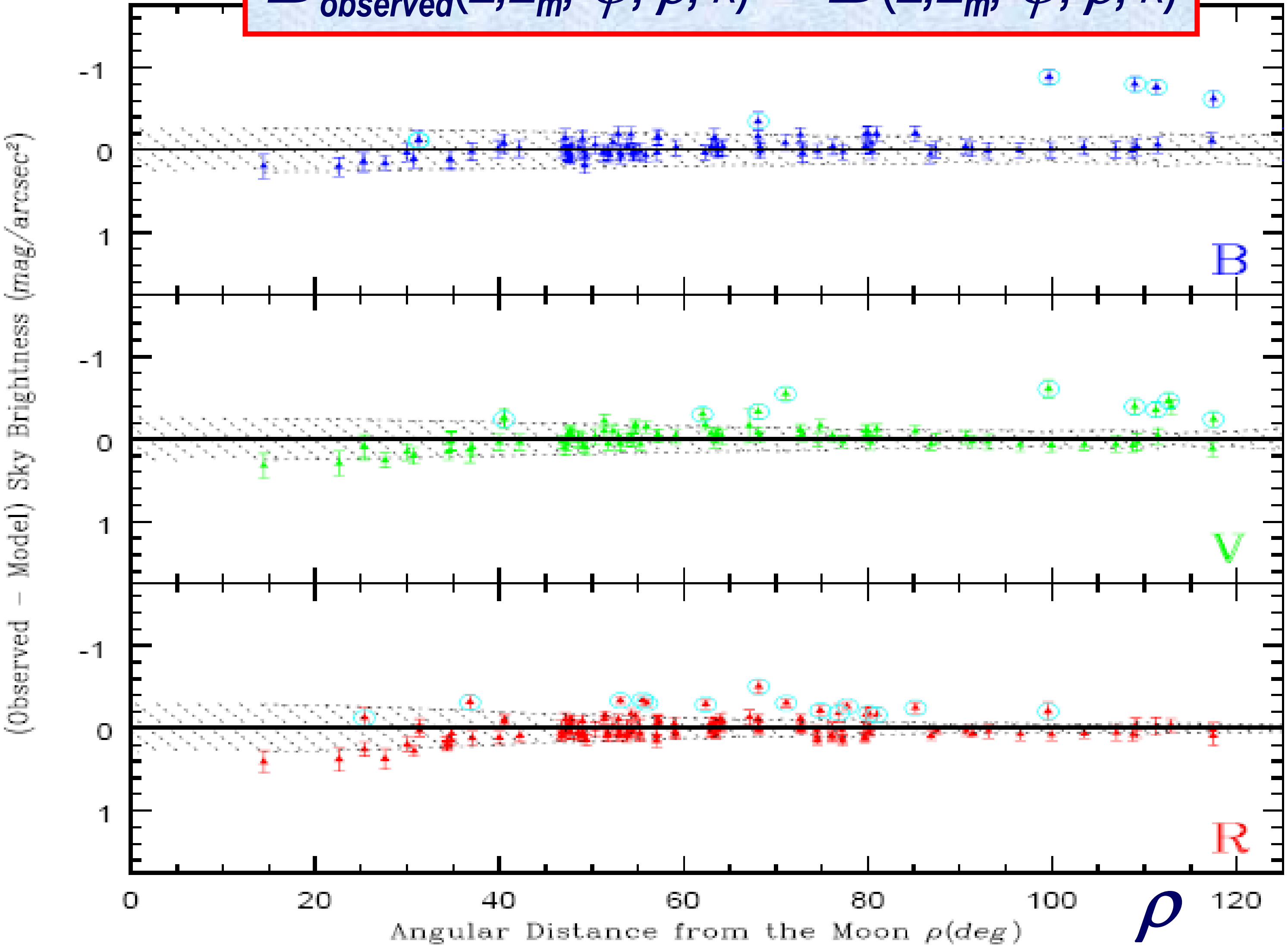


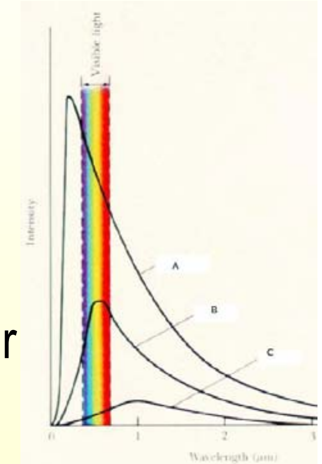
Figure 5. *Difference between observed and estimated model background sky radiation in B, V and R filters. The circled points are for the sky brightness observations made on high cirrus clouds. The hashed region again here is the uncertainty in the estimation of* $B(Z, Z_m, \phi, \rho)$ *due to the errors in* $k(\lambda)$.

Model Object Flux

The Spectral Type of the star is used for determining T_{eff} of the star from a look-up table

A blackbody spectrum is constructed using T_{eff} . This blackbody spectrum is scale to observed *V* magnitude m_V for determining $F(\lambda)$.

$$F(\lambda) = F_{V\,0} \,.\, 10^{\,0.4\, m_V} \,.\, B(T_{eff}\,, \lambda) \;/\; B(T_{eff}\,, \lambda_V)$$



$$P_\lambda = \frac{2\pi h c^2}{\lambda^5 (e^{(hc/\lambda kt)} - 1)}$$

$\lambda_V = 5500$ Å

$B(T_{eff}\,, \lambda)$: blackbody spectrum.

$F_{V_0} = 3.75 \times 10^{-9}$ $erg\ cm^{-2}\ s^{-1}$ Å^{-1} is the $m_V = 0$ ***mag*** offset for an A0V star

Instead of a blackbody spectrum, Kurucz model stellar atmosphere or the spectral database can easily be used. Instead of determining T_{eff} of the star, relevant data file containing model flux or database spectra is selected.

In addition, instead of a stellar spectrum a power-law spectrum could also be used.

$$F(\lambda) = F_{V0} \cdot 10^{0.4 m_V} \cdot \left(\frac{\nu}{\nu_V}\right)^{-\alpha} = F_{V0} \cdot 10^{0.4 m_V} \cdot \left(\frac{\lambda_V}{\lambda}\right)^{-\alpha}$$

Signal-to-Noise Calculation

$$S(\text{in } e^-) = T_0(\lambda) \cdot A_T \cdot (F(\lambda) + A_{bg}B(\lambda)) \left(\frac{\delta\lambda(s,\delta\lambda_0)}{E_{ph}(\lambda)}\right) \cdot t + n_{pix}N_D t.$$

Transmittance — Object Flux — Background Sky

Energy per photon

Eph(λ) = ***hc/*** λ

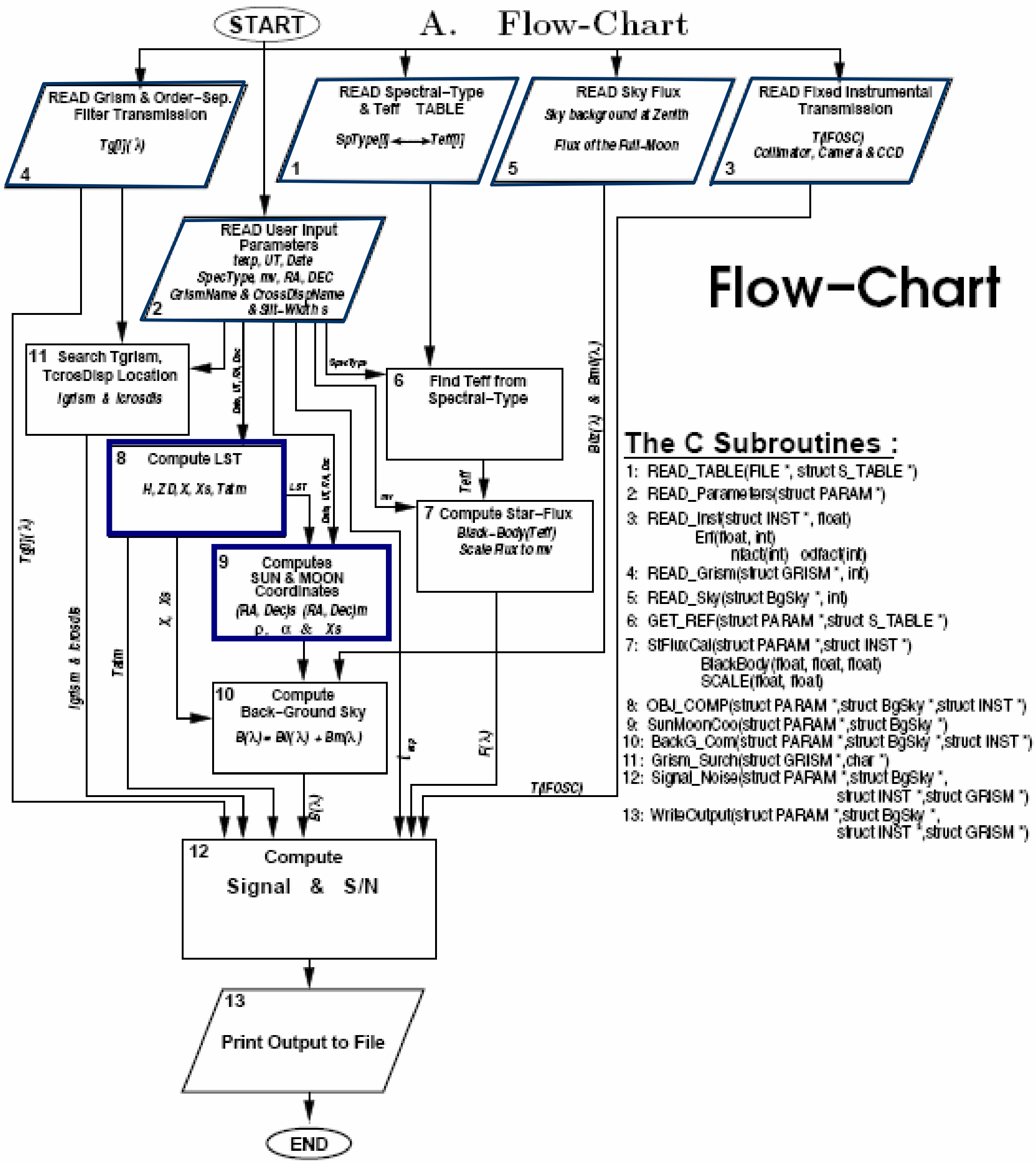
For simplicity, let us denote,

$$K_0(\lambda) = \frac{T_0(\lambda) \cdot A_T}{E_{ph}(\lambda)}.$$

The signal to noise (***S/N***) (Howell, 1992) :

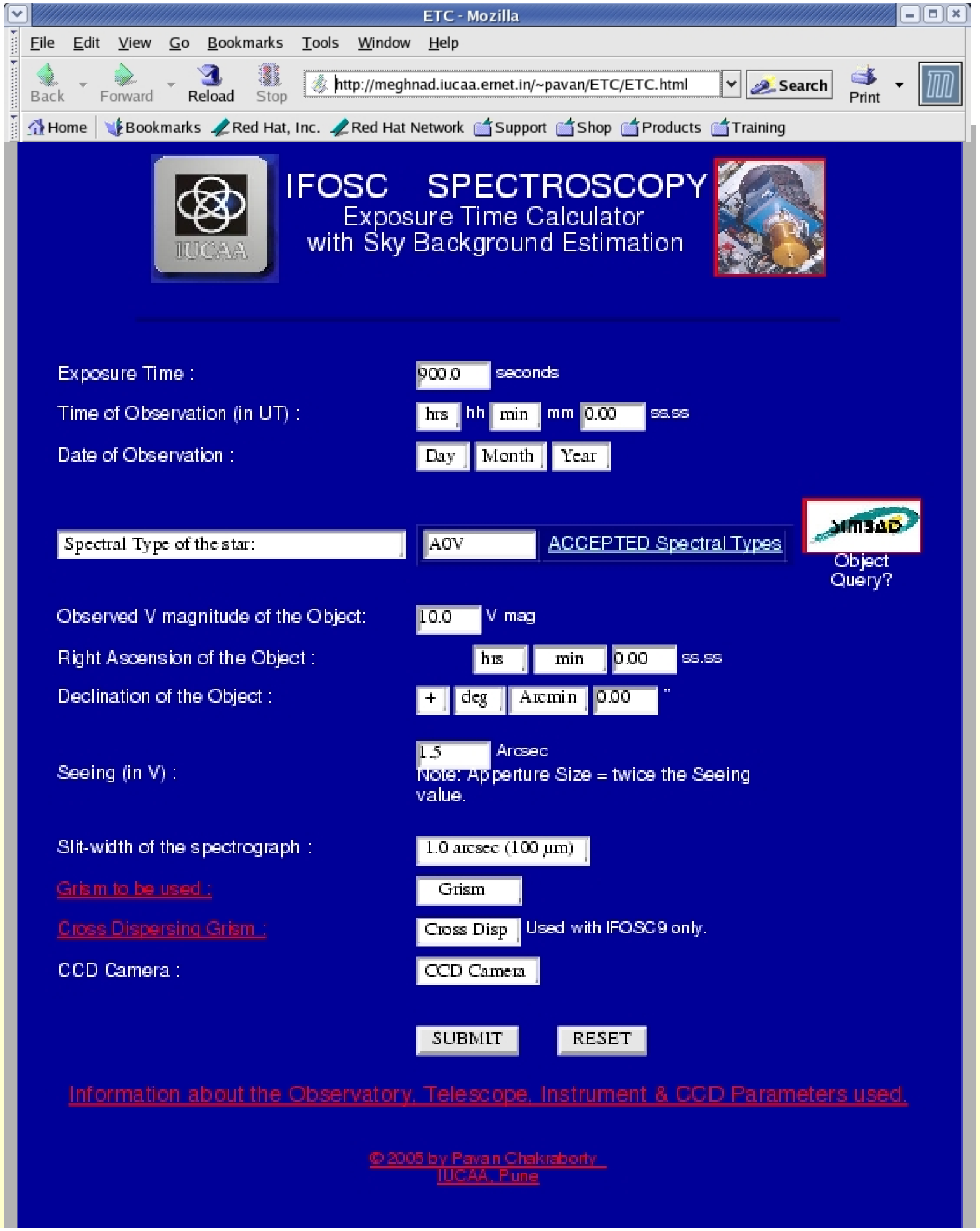
$$S/N = \frac{K_0(\lambda) \cdot F(\lambda)\delta\lambda \cdot t}{\sqrt{K_0(\lambda)\left[F(\lambda) + A_{bg}B(\lambda)\right]\delta\lambda \cdot t + n_{pix}(N_D \cdot t + N_{ro}{}^2)}},$$

User Friendly Implimentation



The core programme in the ETC which calculates the signal to noise, is written in ANSI C.

User Friendly Implimentation



The core programme in the ETC which calculates the signal to noise, is written in ANSI C.

The user interface is a web based graphically interactive ***HTML***, ***cgi*** script.

Presently it can be accessed online through the IUCAA webpage from:

http://meghnad.iucaa.ernet.in/~pavan/ETC/ETC.html

http://www.iucaa.ernet.in/~pavan/ETC/ETC.html

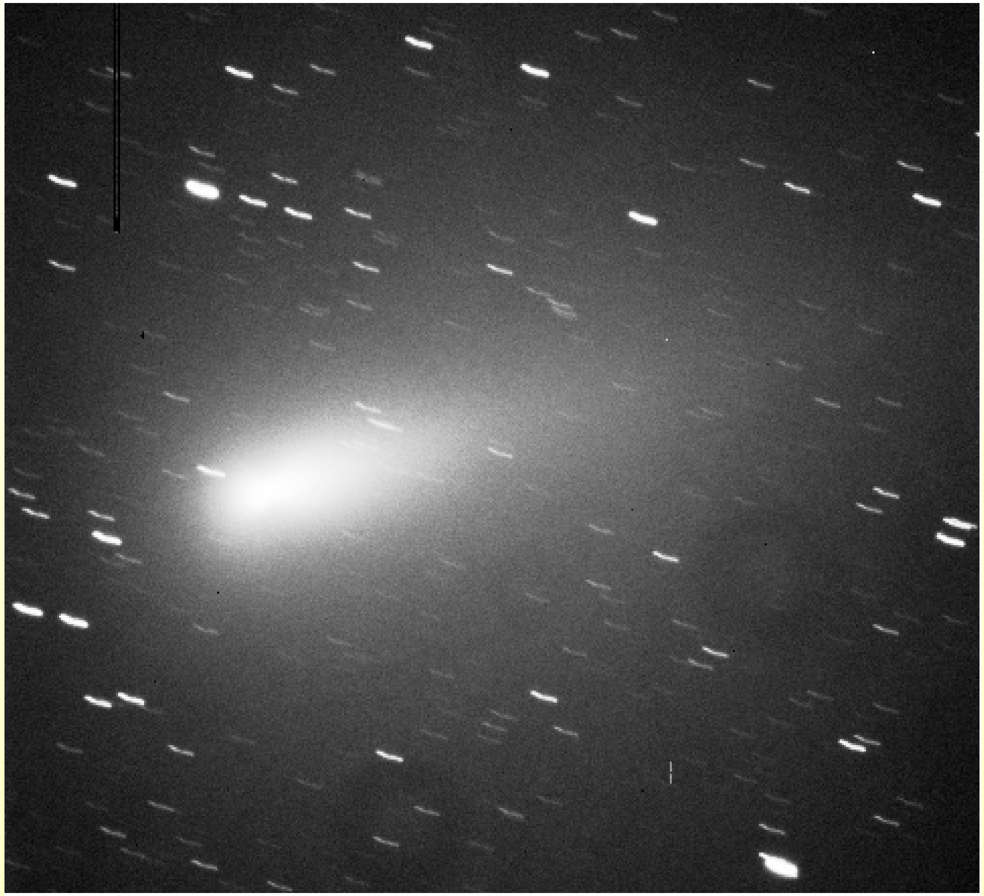
Comet Observation from IGO

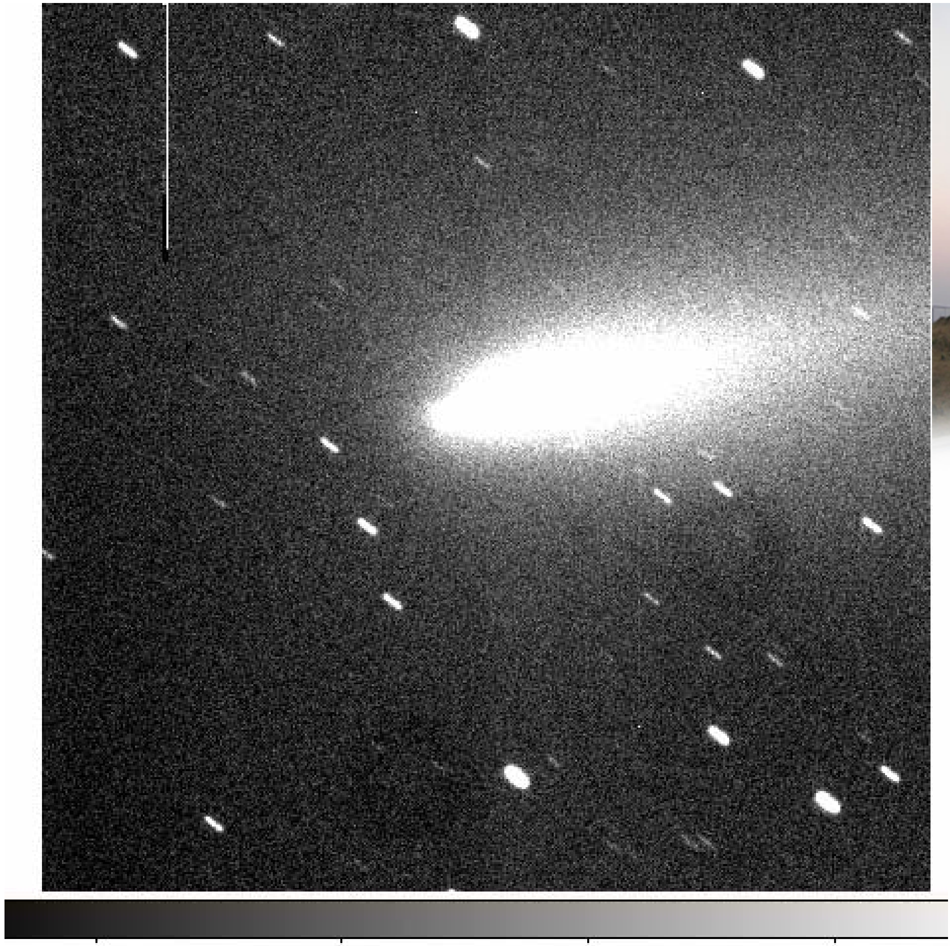
Comet Observation from IGO

Guiding at Differential Rate

P73/B on March 12, 2006

P73/C on March 11, 2006



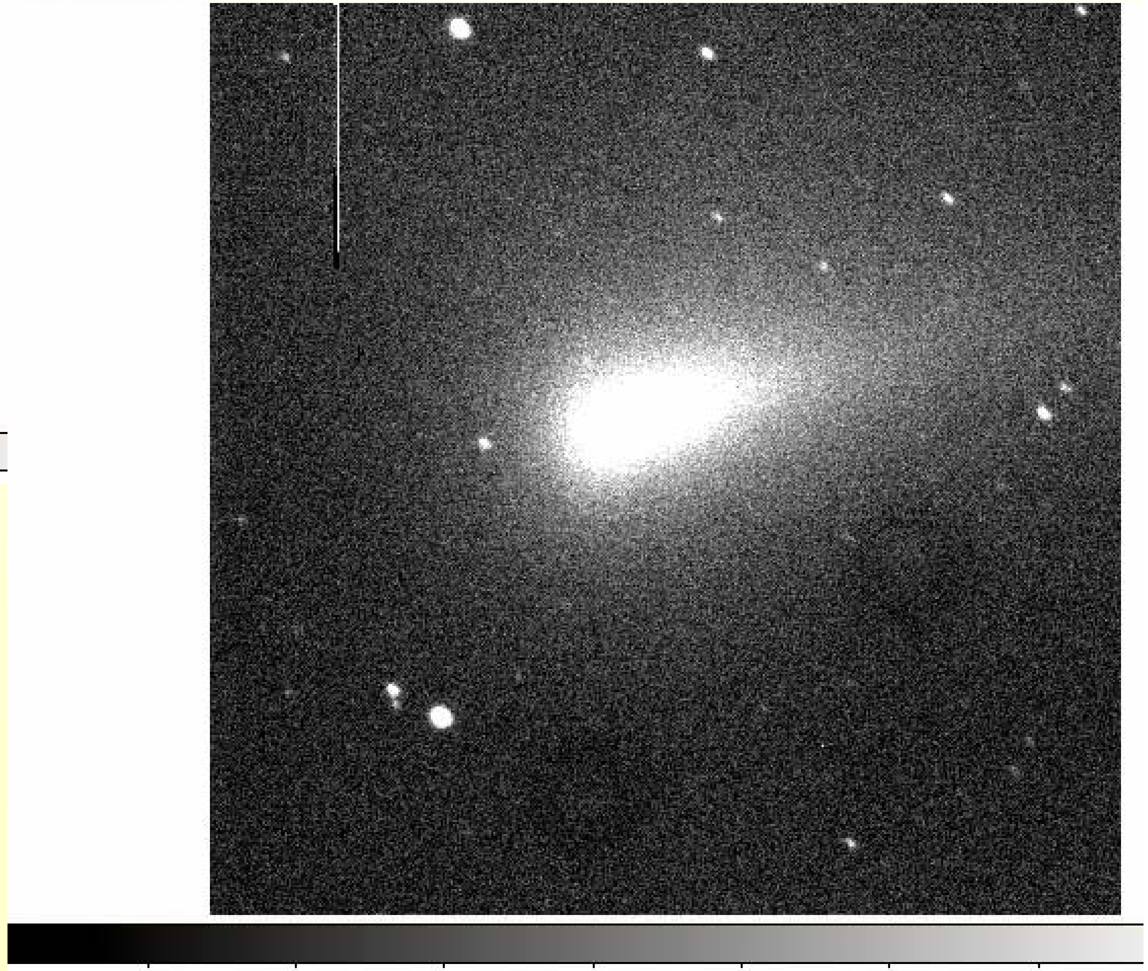


The Stability of the Guiding at Differential Rate

P73/C on March 17, 2006

dRA/dt = 578.69’’/h dDEC/dt = -363.43”/h

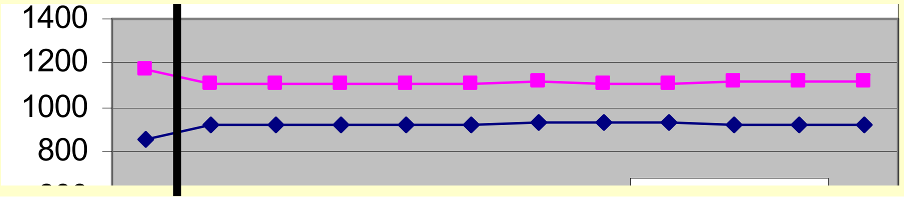
UT 22:23:12 to 23:03:42



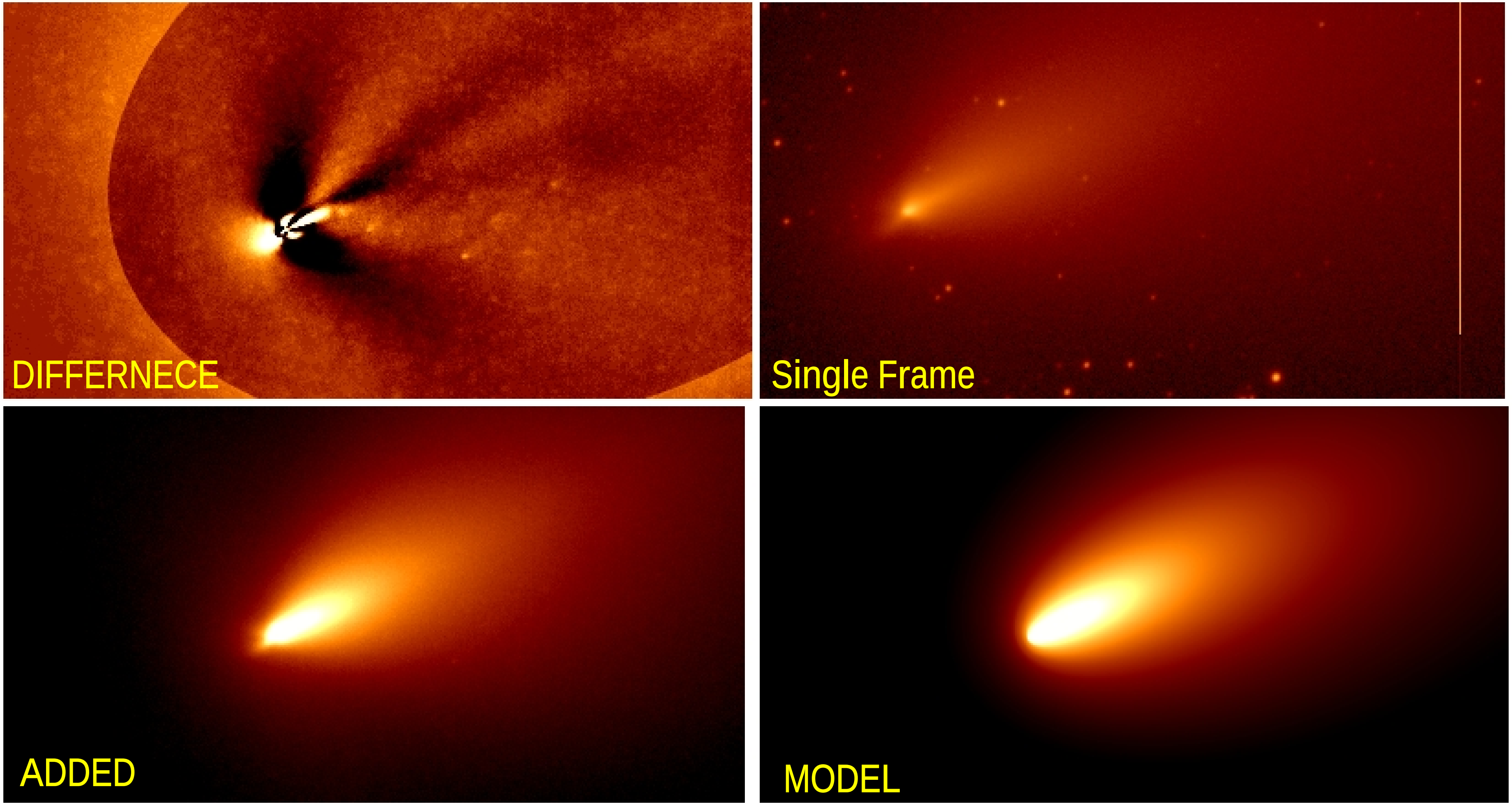
P73/B on March 17, 2006

dRA/dt = 716.81’’/h dDEC/dt = -519.41’’/h

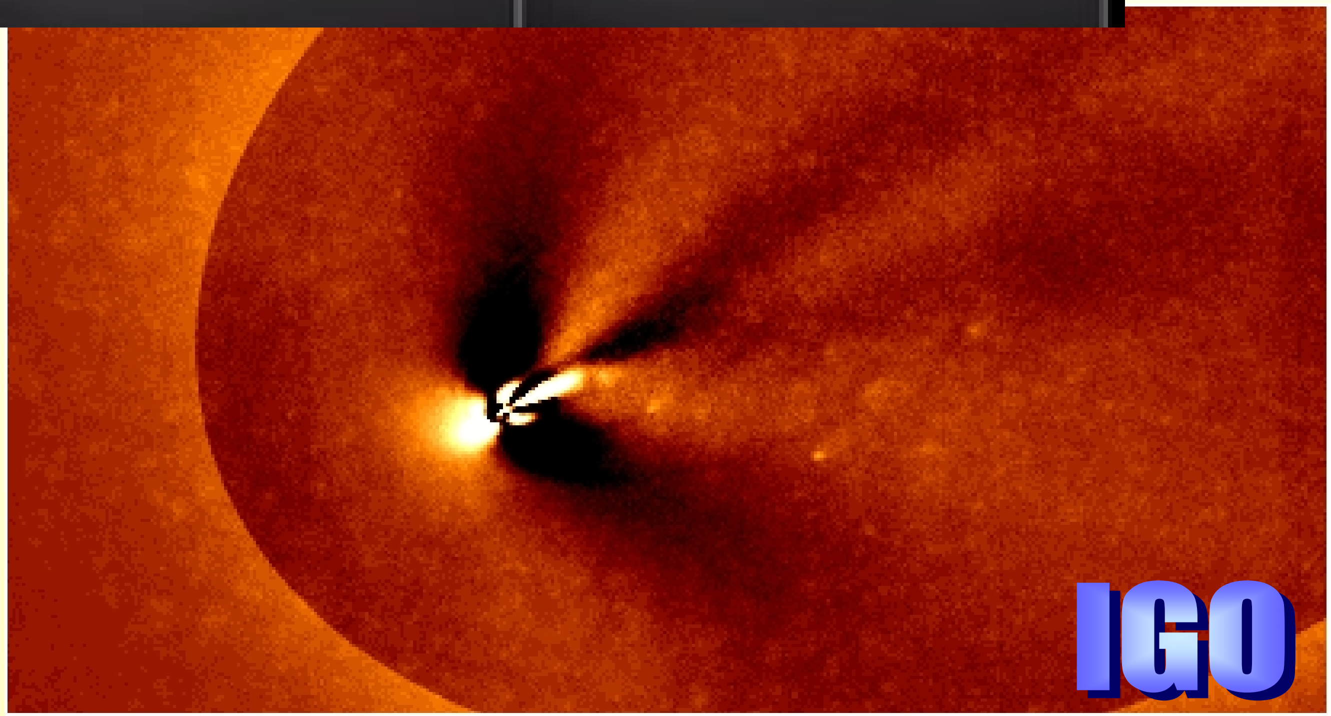
UT 23:07:43 to 23:44:09



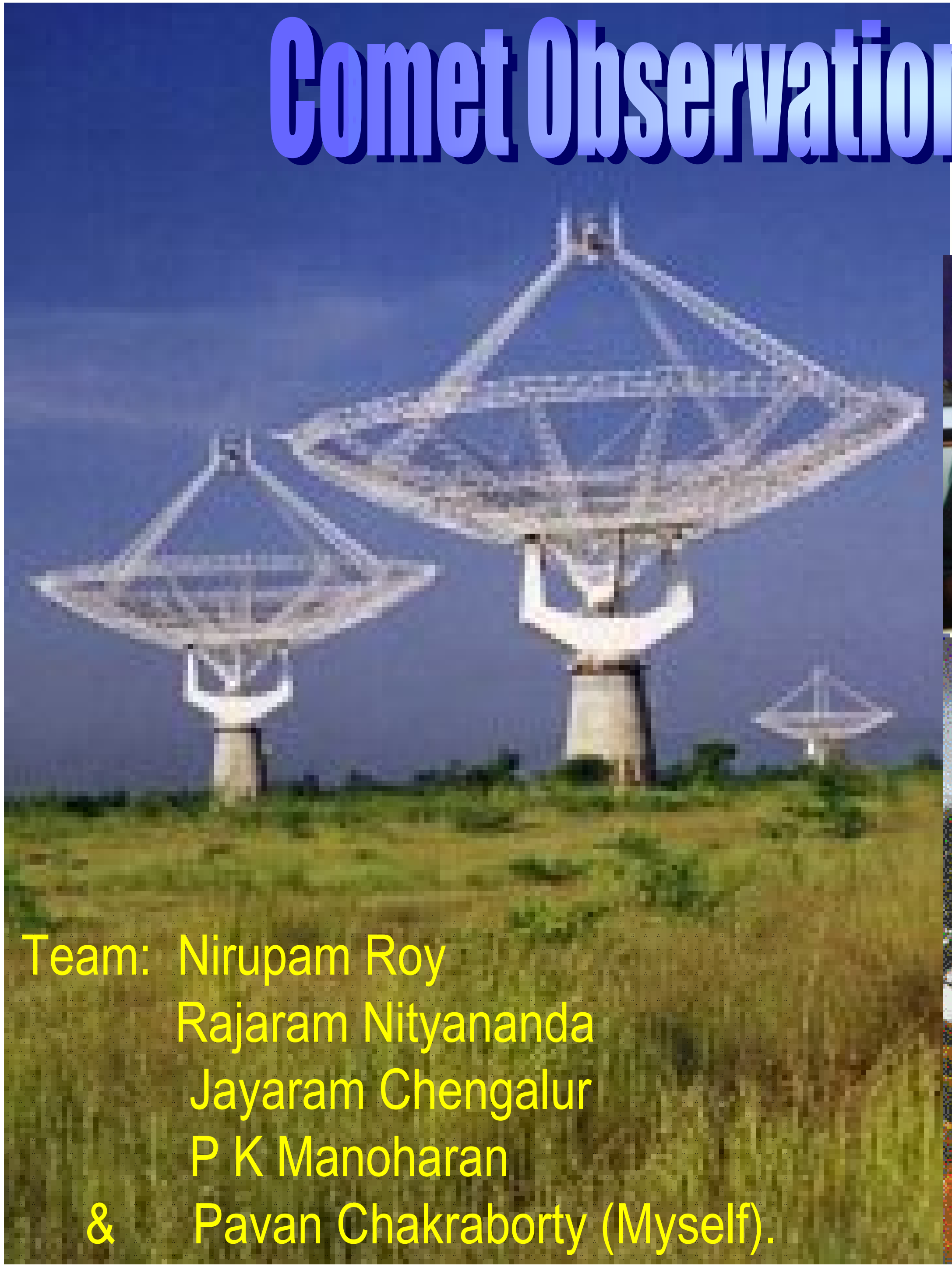
Comet Observation from IGO



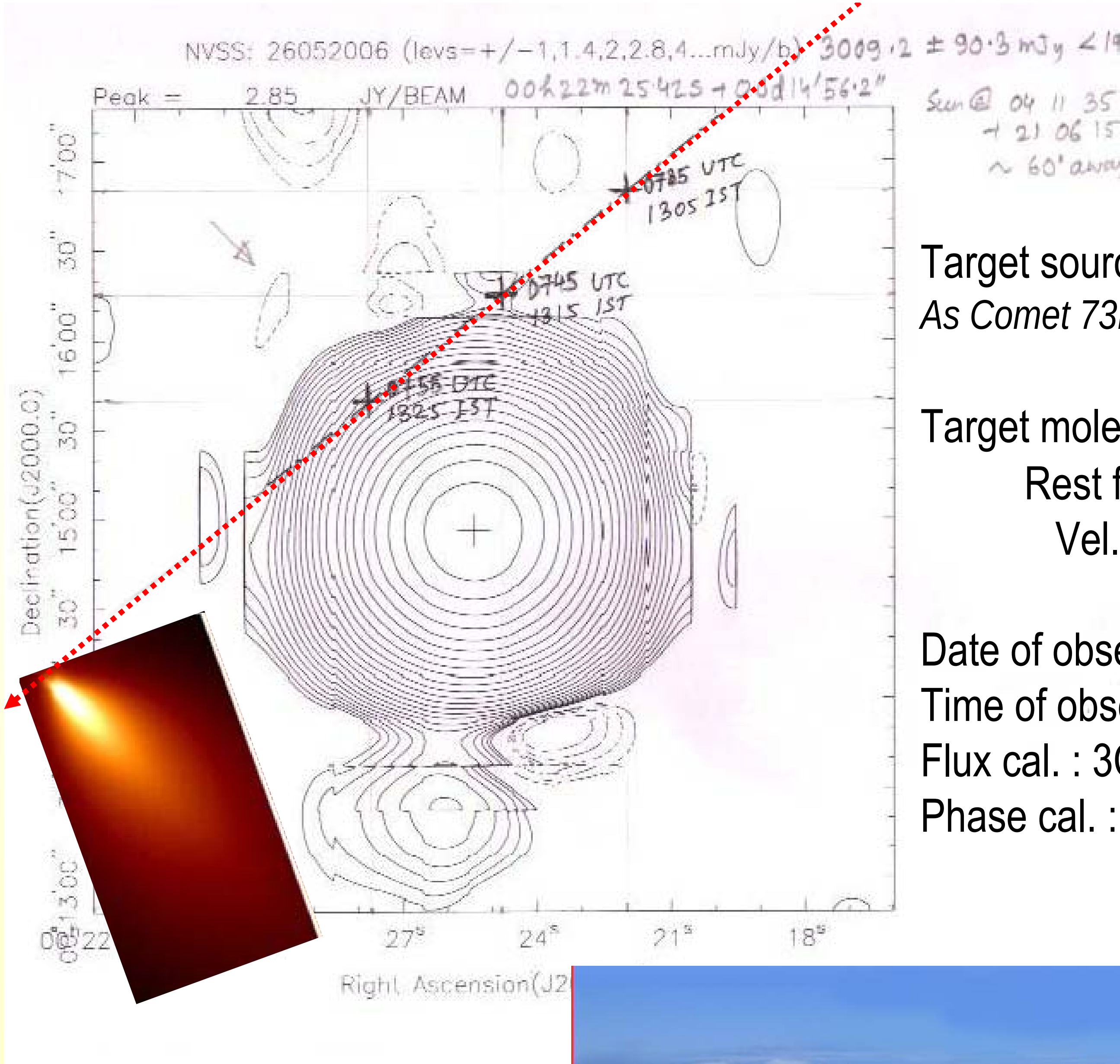
Comet Observation



Comet Observation from GMRT & Ooty



Team: Nirupam Roy
Rajaram Nityananda
Jayaram Chengalur
P K Manoharan
& Pavan Chakraborty (Myself).



Target source : 0022+002 NVSS 26052006

As Comet 73P/Schwassmann-Wachmann 3-B occults it.

Target molecule: CH_3CHO (Acetaldehyde)

Rest frequency : 1065.075 MHz

Vel. resolution: ~ 1.1 km/s

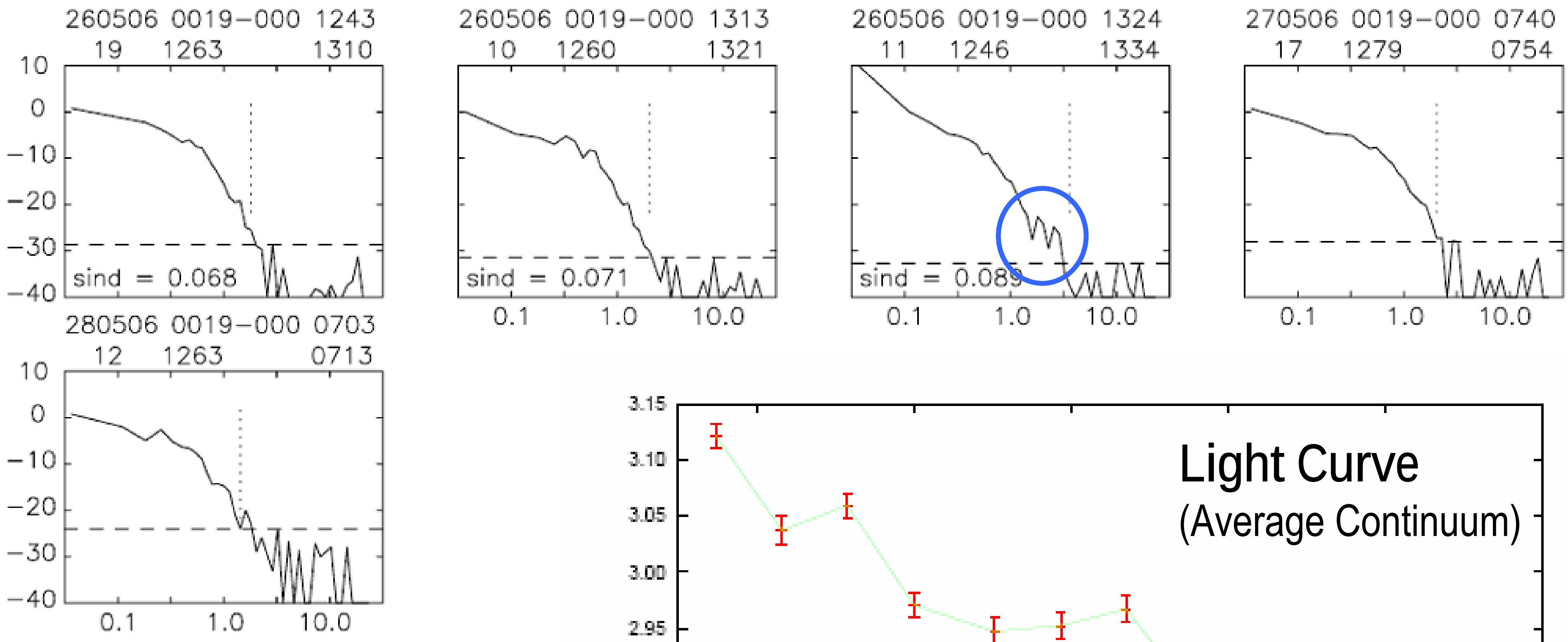
Date of observation : 26th May, 2006

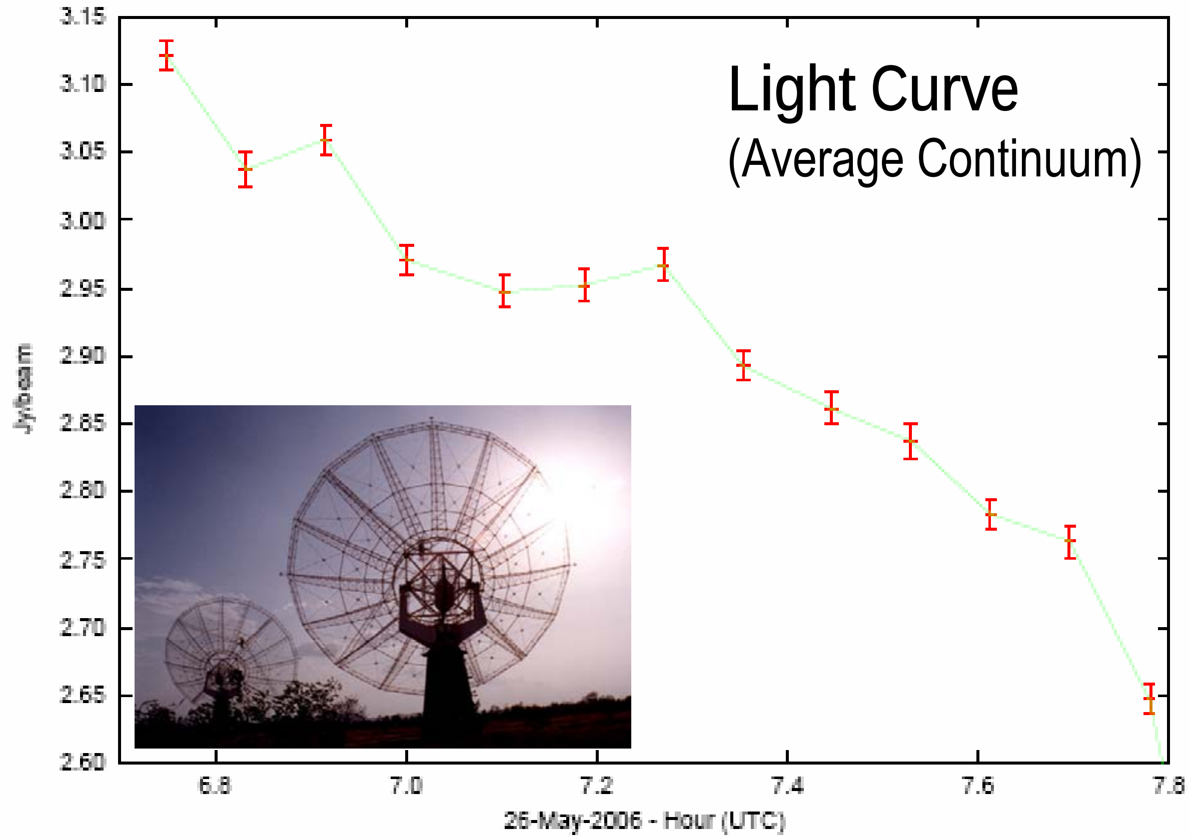
Time of observation : 1200 - 1330 hrs IST

Flux cal. : 3C48 for 10 min.

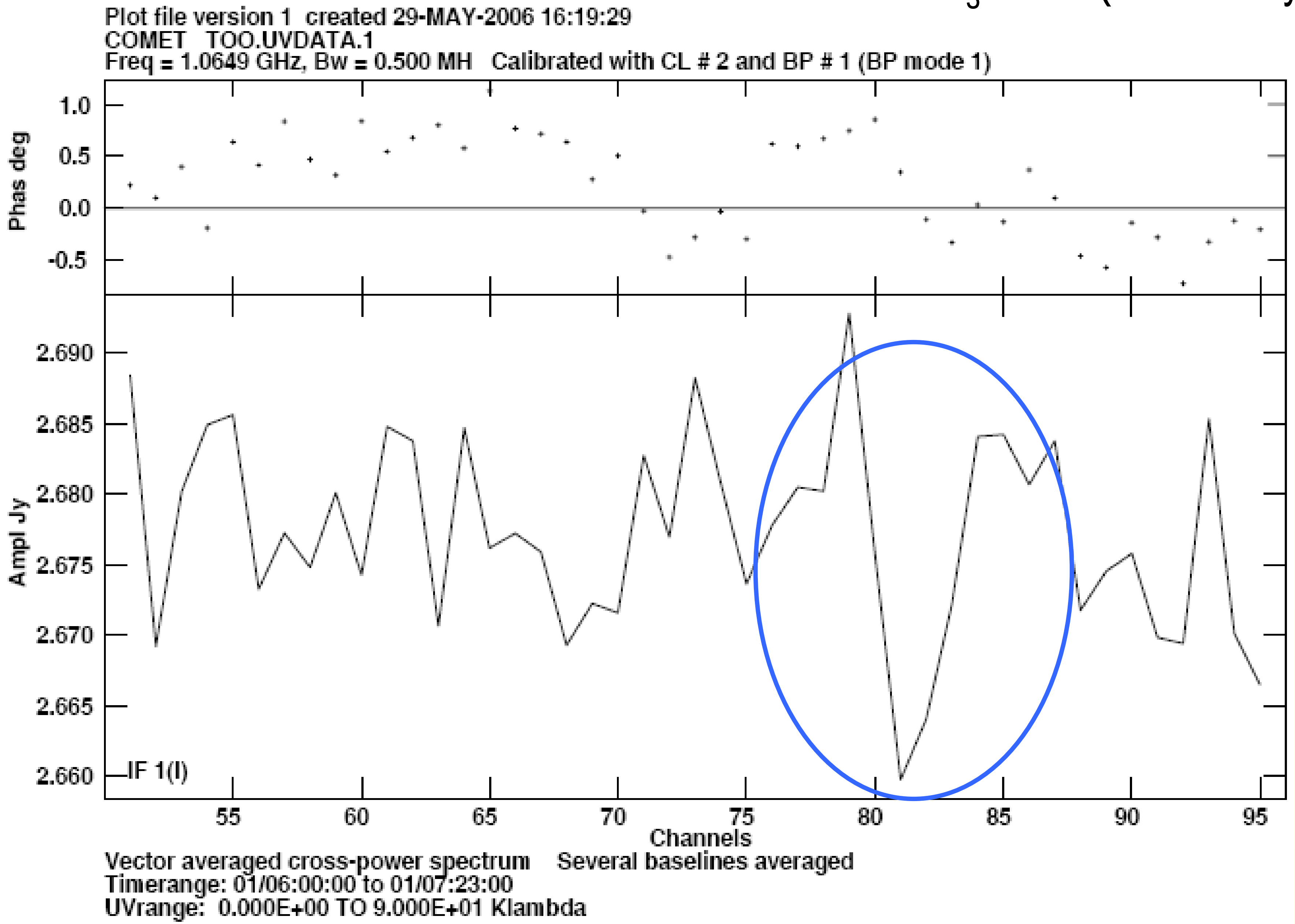
Phase cal. : 0022+002 for 20 min.

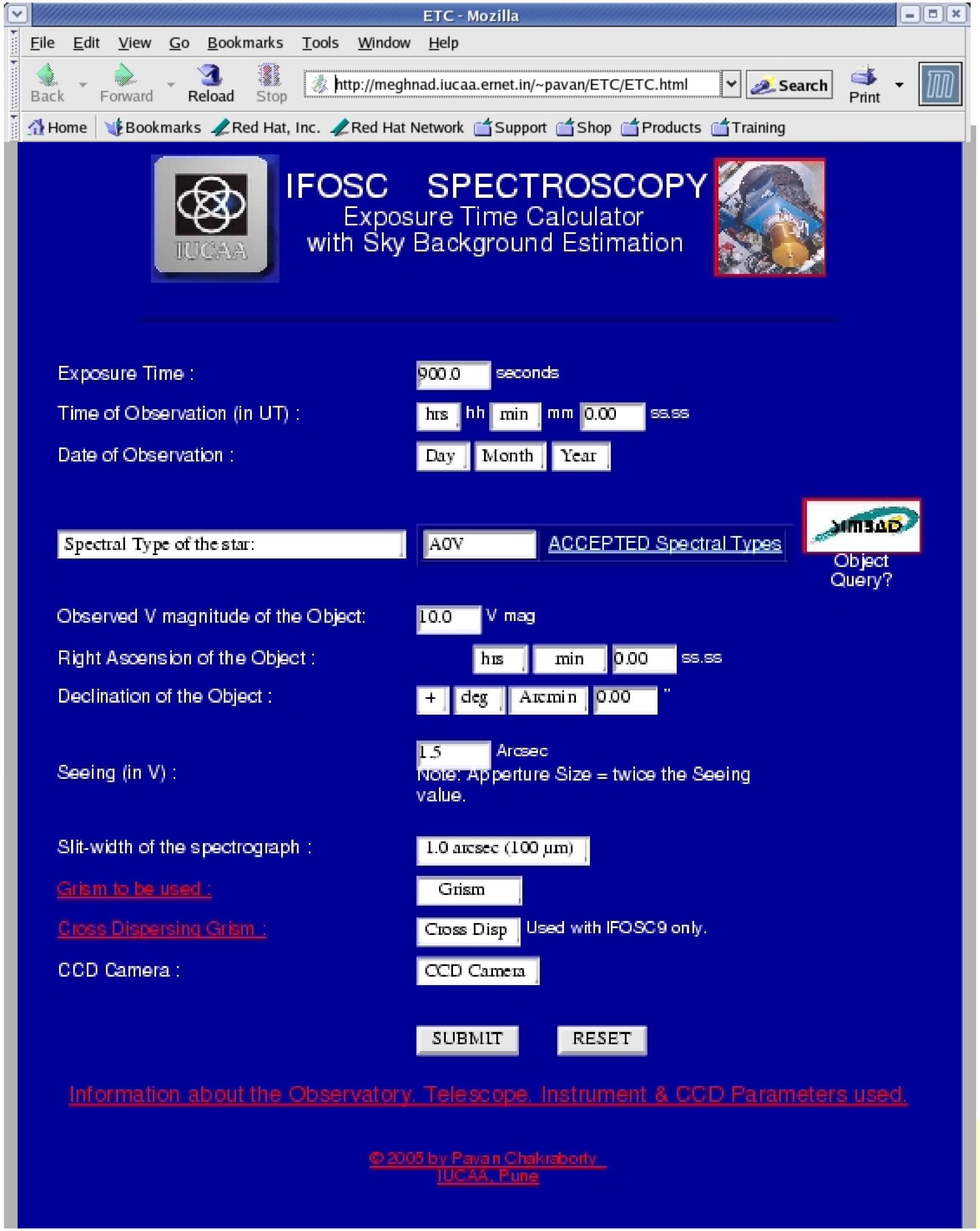
Sintilation



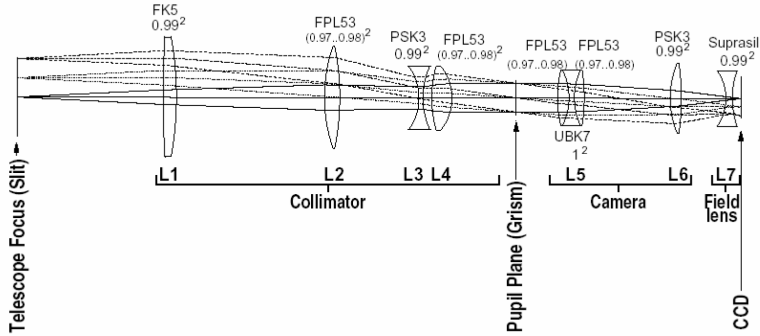


CH_3CHO (Acetaldehyde)





Acrobat Document



Exposure Time Calculator for IFOSC and Sky Background Estimation.

Pavan Chakraborty[1,2*], H. K. Das[1], and S. N. Tandon[1]

[1] *Inter University Center for Astronomy and Astrophysics (IUCAA) Post Bag 4. Ganeshkhind. Pune - 411 007. India.*

[2] *Assam University, Silchar - 788 011, Assam, India.*

BASI (2005) 33 1-23