User manual for the 2dcoude exposure meter

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Queries to
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1 Introduction

An exposure meter was installed in Tull Spectrograph Two (2dcoude) in February 2009. It collects and uses light that would otherwise be lost by 2dcoude, and so does not degrade the 2dcoude throughput.

The exposure meter was upgraded in February 2010 when the unreliable 5-filter filter wheel was replaced by the current 7-filter filter wheel.

2 Basic operating principle

The optomechanical layout of the exposure meter is shown in figure 1. Light en route from the spectrograph collimator to the prisms and echelle grating passes through corrector plate number 1. This corrector plate is antireflection coated to minimize Fresnel reflection losses from its two surfaces, however, there is still a net reflection loss from the two corrector surfaces of between 1.25% and 1.5% of the light incident on the corrector. Each of the two reflections is a collimated beam of 190 mm diameter. This light is collected by an 8” Celestron telescope and focused. A field stop at this focus limits the exposure meter field of view to 40 arcsecond, 10 arcseconds more than the maximum slit length. Following the field stop is a Fabry lens that collimates the light with a 12.5 mm diameter, and produces an image of the 2.7 m primary mirror on the photomultiplier tube (PMT) photocathode. A filter wheel is placed in the collimated light immediately following the Fabry lens. Pulses from the PMT are counted by a counter, and this counter is operated by the exposure meter software on the computer running the spectrograph. The software presents a GUI to the user, and, talks and listens to the instrument control software ICE. To protect the PMT from the destructive effect of exposure to too bright light, a lockout system turns off the PMT when high-light situations are detected. Once the fault condition is removed, the lockout system turns the PMT back on.

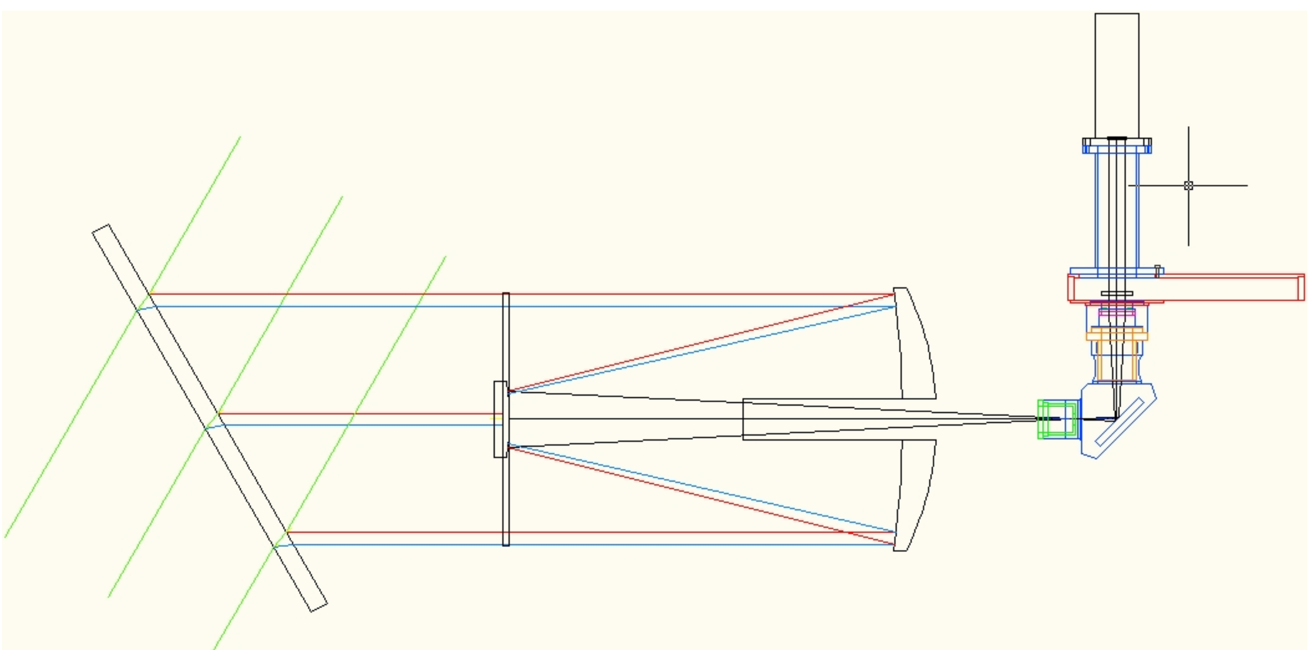


Figure 1: the optomechanical layout of the 2dcoude exposure meter. The light from the collimator is at left (green) passing through corrector plate #1 from top to bottom. The Celestron telescope is in the center, with the photometer at right. In follow-the-photons order, the components are the pinhole (green), diagonal mirror (blue), Fabry lens (green) in it’s mount (gold, blue, magenta), filter wheel (red) with filter (black), PMT spacer tube (blue), and PMT(black).

3 Summary of useful quick-start facts

Before describing the exposure meter hardware and software in detail, the following list of quick start facts will help many observers

- Before using the exposure meter for the first time:
  - execute the command *unlearn empars* with ICE. This will initialize the ICE parameter file that controls the exposure meter.
  - make sure your parameter file for the ICE task *object* has the parameter *emtot* in it (see section 5.2.2). If it does not, then issue the command *unlearn object* at the ICE prompt.
- Make sure the GUI *PMT Power* button is on (colored red) when using the exposure meter. Clicking the button toggles the on/off state of the power.
- Turn the PMT power off by clicking the *PMT Power* button (button turns gray) on the exposure meter GUI:
  - at the end of the night
  - before going into the spectrograph room with a flash light only (turning on the room lights automatically turns off the PMT)
- There is a green LED indicator light near the spectrograph room front door that is illuminated when the PMT power is on (see figures 2 and 1). The switch below the light allows the PMT to be turned off manually, and is useful when you are going into the spectrograph room with a flash light.
- Integrations using the exposure meter can be taken using the ICE command line with commands such as *Object 3 600 "Object name" emtot=2100000*
- When the exposure meter is disabled in ICE (*emenable=no* in *empars*), the exposure meter can be used manually to monitor the flux. Press the *Free Run* button on the GUI and adjust the display using the *Max Exp Time* and *Max Int Count* values on the GUI
- When either the *Max Exp Time* or *Max Int Count* values are changed in the *Control Values* section of the exposure meter GUI, the *Set* button must be clicked to make the changes go into effect. If ICE is set to allow the exposure meter to control the integration, then the integration time in ICE will also be updated.
- The command *M* (for Modify) can be issued to ICE during an integration. This allows the integration time to be changed at the ICE prompt, and ICE communicates the change to the exposure meter GUI.
- When the exposure meter is enabled within ICE (*emenable=yes* in *empars)*, the CCD is read out by the first occurrence of either of the following two events
  - the maximum user-specified exposure time is reached
  - the maximum user-specified integrated exposure meter count is reached
- The signal-to-noise of the spectrum increases as the square root of the number of exposure meter counts (in the normal case where the spectrum is neither readout noise limited nor sky noise limited).
  - for TS23, an exposure meter count of ~2,250,000 gives a S/N of ~250:1 per extracted pixel (half resolution element) at 550 nm for G stars.
- Exposure meter parameter *emdump* in ICE parameter file *empars* determines if the exposure meter data is saved in the data file. This is necessary for precision radial velocity observing. When the exposure meter data is saved in the FITS data file, the data frame is a *multi-extension* FITS file. This means that a file extension must be given is IRAF utilities that process those frames. For example, the *[0]* in the following commands
  - display name[0] 1
  - imhead name[0] l+
- When the exposure meter data is being saved in the FITS file, the extension must be given in the command specified in parameter *command* of *obspars*. The common command string of 'command= display %s 1' should be changed to:
  - command= display %s[0] 1
- A filter is selected from the 7-filter filter wheel by clicking the required filter button on the exposure meter GUI. The filter name is written into the FITS data frame header.

* The mean value of the PMT dark current is 8 counts per second.
* When taking calibration frames, disable the exposure meter within ICE by setting parameter *emenable* to *no* within *empars* (to be verified: ICE commands *zeros*, *flats* and *comps* disable the exposure meter automatically). It will only be appropriate to have the exposure meter enabled when an *object* or *test* frame is being taken.
* When the 2.7 m coude calibration source is inserted into the optical path, the PMT is turned off automatically. If the PMT had been turned on, it is turned back on when the calibration source is retracted.
* Observers can tune up the focus by maximizing the count rate. This is easy on a stable night, and harder when there is a lot of seeing motion.
* The typical user will probably never have to click the *Plug Strip* button. This should be avoided as it takes around 30 seconds for the host computer and exposure meter to sync up after such an event. If this is clicked, there is an *Are you sure?* pop-up dialog box.

4 The exposure meter hardware

4.1 The control electronics

The exposure meter electronics are in the spectrograph room ante room. Their location can be seen on the wall and bench top in figure 1. Figure 2 shows a close up of the wall-mounted lock-out electronics.

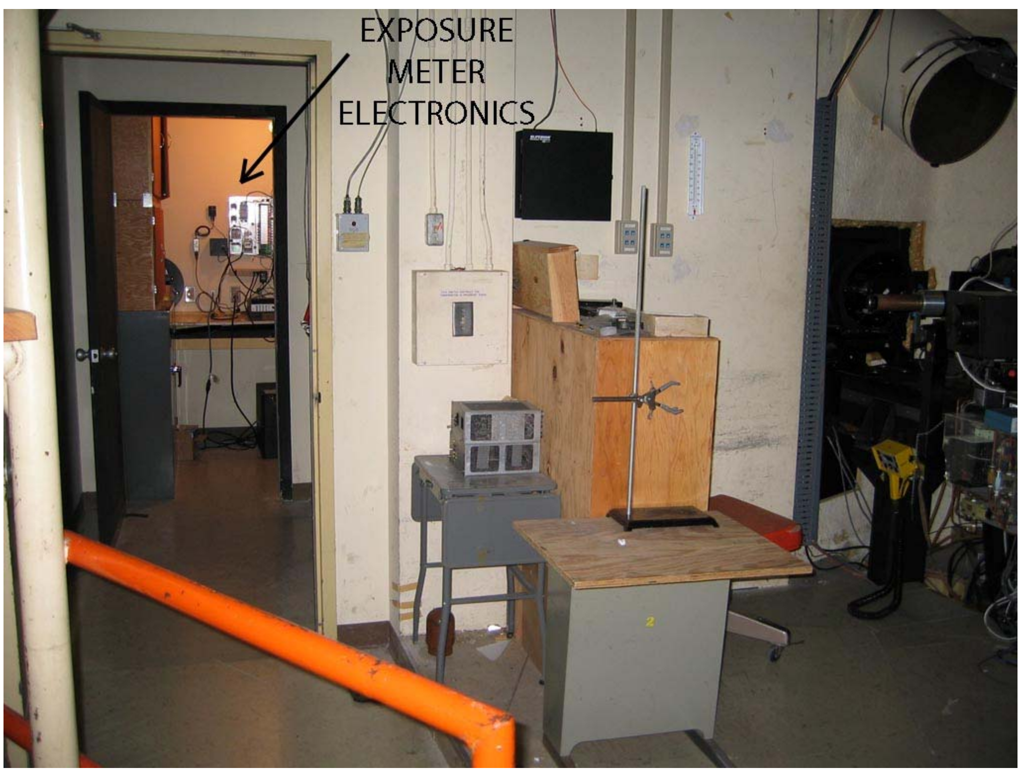


Figure 1: location of the exposure meter electronics relative in the 107" coude spectrograph area (taken before the slit room wall was installed).

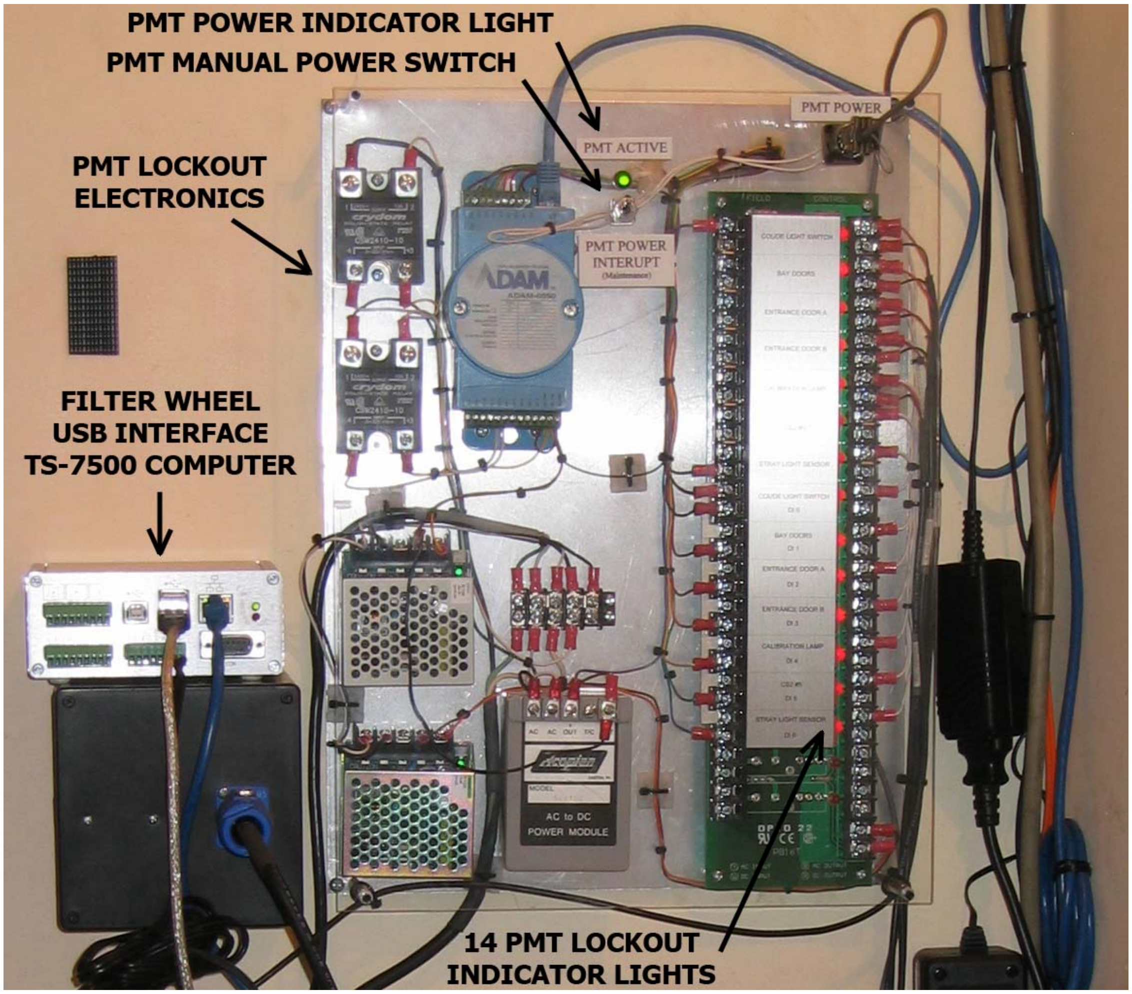


Figure 2: the exposure meter filter wheel controller and lockout electronics

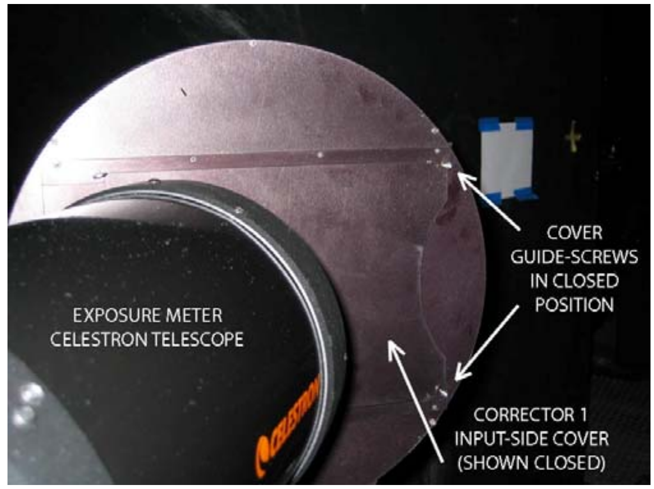
4.2 The 2dcoude corrector 1 covers

2dcoude corrector 1 was remounted to accommodate the exposure meter, and now has new covers. The rear cover is designed to be both a cover for the corrector, and a baffle for the exposure meter. The exposure meter sees light that comes off the inside of the cover and through the corrector. The opening and closing of the covers is documented in figures 3 through 6.

To open the input-side cover, pull it gently by its handle all the way until it stops on its limits and is square to the rest of the hardware. While in this position, finger tighten one or both of the cover locking screws as identified in figure 3. Be careful not to touch the corrector lens at the front of the exposure meter telescope.

To close the input-side cover, loosen the cover lock screws and gently push the cover all the way in to the position shown in figure 4. The guide pins will ride up on guide ramps about 10 mm before the end of travel. Make sure they go to the end of travel. Do not tighten the lock screws intended for locking the cover open.

Opening and closing the corrector 1 exit-side cover is documented in figures 5 and 6. Pull the locking pin up out of the open or closed hole while pressing the blue button on the locking pin. When opening the cover, make sure the green handle of the locking pin is left in the position shown in figure 5 so that the handle does not vignette light going to the spectrograph 91 cm mirror.



Figures 3 & 4: 2dcoude corrector 1 covers shown open and closed

Figures 5 & 6: 2d coude corrector 1 exit-side covers shown open and closed.

5 The exposure meter software

The exposure meter hardware is run by the program *emeter* that presents a GUI to the user. Program *emeter* talks to *ICE*, and *ICE* talks to *emeter*. This section describes how to use *emeter* and *ICE*.

5.1 Program *emeter*

To start the exposure meter software, either

- Click the exposure meter icon if one is presented by the user account, or
- At an Oberon command line prompt (Unix prompt, not ICE prompt), type

  ```
  Oberon> ~pso/emeter &
  ```

  This is a link to the current version of emeter, and so using this link will ensure that the latest version is run.

The GUI shown in figure 7 will be displayed.

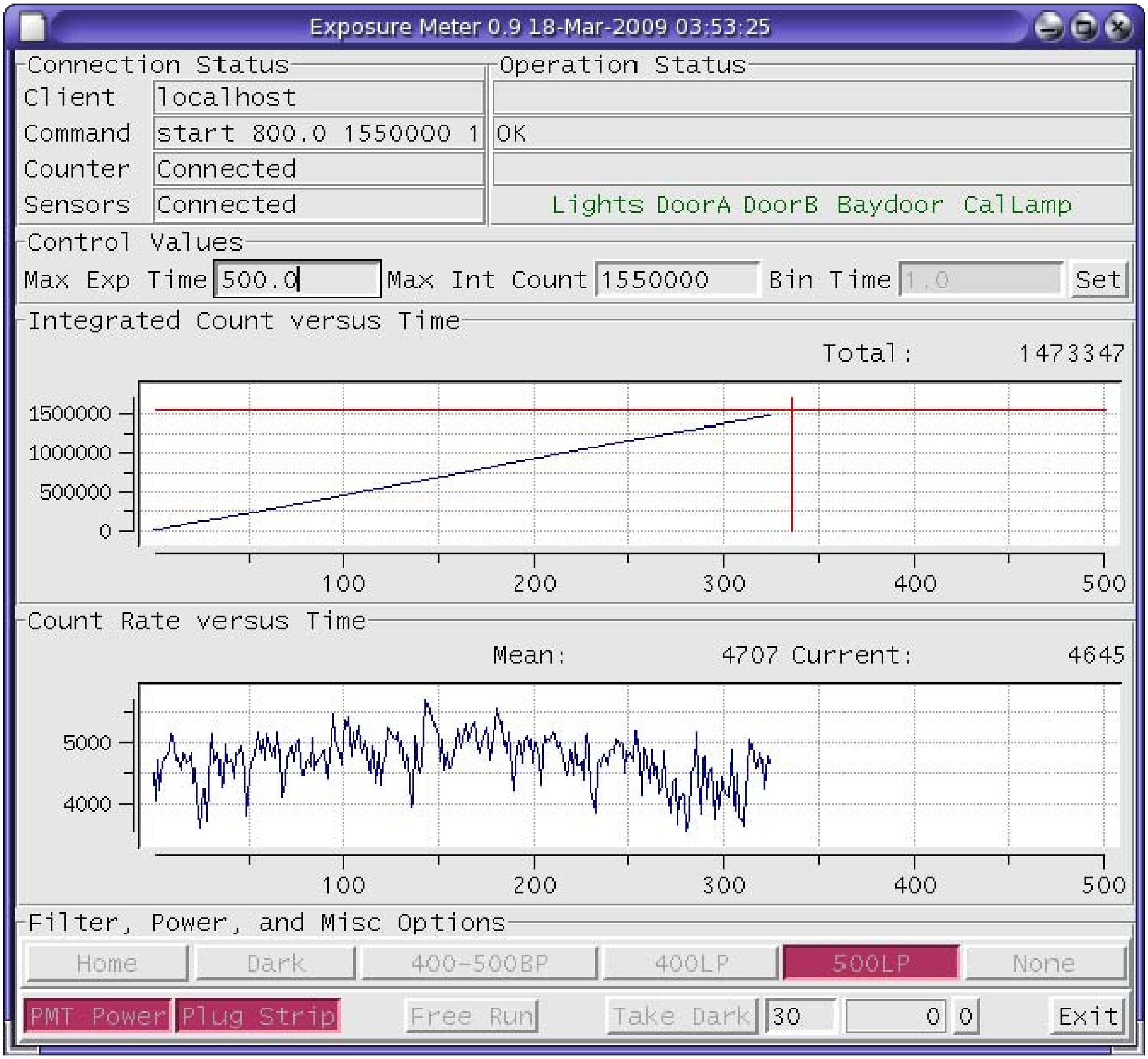


Figure 7: the Graphical User Interface of the exposure meter software (this figure is currently out of date as it shows the GUI for the older 5-filter filter wheel). In this example, the maximum integration time was 500 s and the maximum integrated count value was 1,550,000. The integration will complete at ~340 seconds when the integrated count value reaches the maximum allowed.

5.2 ICE parameter files

ICE interacts with the exposure meter via the two tasks *empars* and *object*.

5.2.1 empars

The exposure meter can be controlled from ICE via the exposure meter parameter file empars. At the ICE prompt, type *empars<enter>*. The current parameter file is:

```
                                   I R A F
                    Image Reduction and Analysis Facility
PACKAGE = icex
   TASK = empars

(emenabl=                  yes) Enable use of the EMeter
(emtotcn=              1500000) Total EMeter exposure count
(embinti=                   1.) Binning time for EMeter measurements
(emfilte=                     ) Exposure meter filter
(emdump =                  yes) Save the EMeter info to image extension
(emclose=                  yes) Close the EMeter interface after readout
(eminfo =                     ) Optional EMeter information for image headers
(emdark =                   no) Measure exposure meter dark rate
(emdarkt=                   60) Integration time for dark rate measurement
(emdarkd=                    8) Default dark rate if none calculated
(emhost =            localhost) Exposure meter host
(emdebug=                   no) Debug the EMeter interface
(mode   =                   ql)
($nargs =                    0)
```

5.2.2 The *object* parameter file

The ICE task *object* is commonly used to take data frames. It now has the new parameter *emtot* as shown in the listing below. If *emtot* is not in your parameter file, run *unlearn objects* at the ICE command prompt.

```
                                   I R A F
                    Image Reduction and Analysis Facility
PACKAGE = icex
   TASK = objects

nexpo   =                    3  Number of exposures
exptime =                 800.  Exposure time (seconds)
objectti=        HD135204 + I2  Object title
(emtot  =              1550000)
(verbose=                  yes)
(mode   =                   ql)
```

Parameter *emtot* is a *hidden* parameter, meaning that the user isn’t prompted on the ICE command line for this value. That can be seen in the listing above because the parameter name is in parentheses.

Parameter *emtot* can be set in one of two ways. It can be edited in the parameter file in the usual way by running *epar object* at the command prompt. It can also be added to the command line with commands such as:

```
ic> object 3 800 “HD135204 + I2” emtot=1600000
```

or, the user will be prompted for nexpo, exptime, and objecttitle with:

```
ic> object emtot=1600000
```

5.2.3 The *observation* parameter file

The ICE task *obspars* has parameter *command* in it, whose operand is a command to execute each time the CCD reads out. It is commonly used to display the image that has just been acquired. This command needs modification when the exposure meter data is being saved to the image FITS file. The FITS extension for the image, [0], must be appended to the file name. This modification to *command* also works when the exposure meter data is not being used. Parameter *command* in *obspars* will typically be:

```
                              I R A F
                Image Reduction and Analysis Facility
PACKAGE = icex
   TASK = obspars

...
 (command=      display %s[0] 1) Postprocessing command
...
```

6 Filters

There is a 7-filter filter wheel. The bandwidth red-limit with some filters is set by the ~630 nm red cutoff of the exposure meter photomultiplier tube (PMT). The PMT quantum efficiency curve is shown in figure 9.

6.1 The current filters

The current filter selection and associated ICE filter position numbers are:

#1 Dark filter named *Dark* (a piece of black metal, used as a dark slide)
#2 400-500 nm blue bandpass filter, named *400-500BP*
#3 400 nm long pass filter named *400LP* (the filter-PMT bandwidth is 400-630 nm)
#4 500 nm long pass filter named *500LP* (the filter-PMT bandwidth is 500-630 nm). This filter is the one used with the iodine cell as the iodine lines are in the 500-630 nm wavelength spectral region.
#5 blank (~340-630 nm bandwidth)
#6 blank (~340-630 nm bandwidth)
#7 blank (~340-630 nm bandwidth)

6.2 Filter wheel operation

The filter wheel is operated from the exposure meter GUI and from ICE. To change the filter, press the GUI button of the filter you want and wait until the button turns red.

6.3 Filter specifications

Two filter diameters are possible. They can either be 25 – 25.4 mm in diameter, or, standard amateur 1.25-inch filters. The filter thickness can be up to approximately 5 mm. The current dark filter and 3 optical filters are 1 mm thick.

7 Displaying the exposure meter data from the FITS file

The exposure meter data that has been stored in a FITS image file can be printed as text, and plotted as a graph. The IRAF commands are these:

- For a text printout of the data, the IRAF packages *tables* and *ttools* must be loaded, and then the command *tprint* is used. For example:

```
cl> tables
ta> ttools
tt> tprint file_name.fits[1]
```

- For a graphical display of the data, the IRAF packages *tables* and *tbplot* must be loaded, and then the command *sgraph* can be used. For example:

```
cl> tables
ta> tbplot
tb> sgraph "file_name.fits[1] time value"
```

  It is important to note that the quotes are essential.

8 The photomultiplier tube characteristics

The photomultipler tube is a Hamamatsu H6180-01. It is a robust module that self limits when exposed to excess light. Its output response is shown in figure 8, and its responsive quantum efficiency is shown in figure 9.

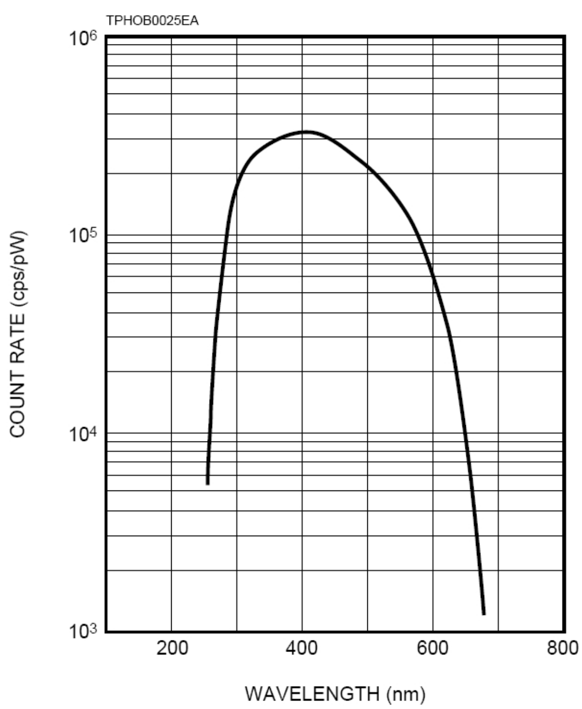


Figure 8: the output response of the exposure meter PMT

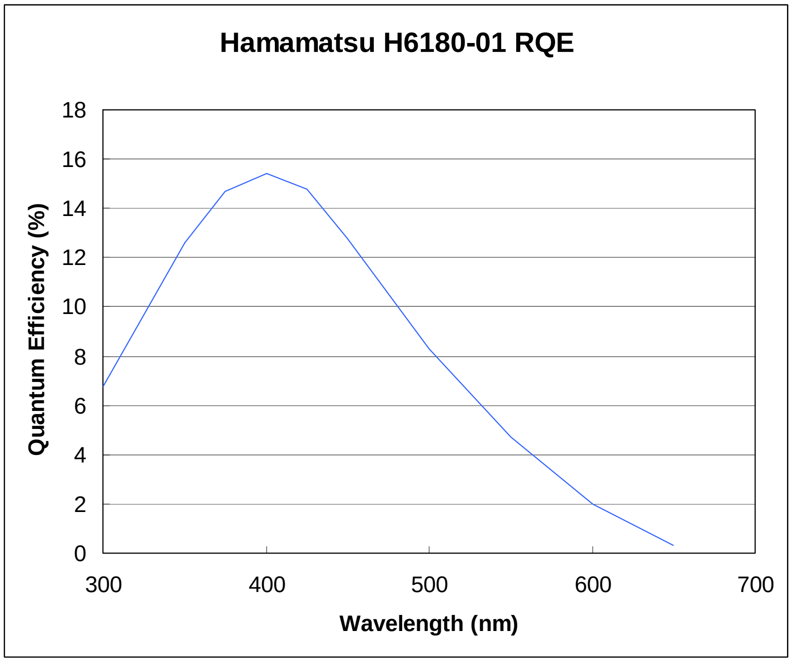


Figure 9: Responsive Quantum Efficiency of the exposure meter PMT