AUTOSLIT3

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Quick Overview

    AUTOSLIT is a program designed to compute the slit positions for the
    slit mask of the LRIS spectrograph. AUTOSLIT is based upon AUTOFID2,
    a similar program for the NORRIS spectrograph, by Alain Picard and
    John Cromer. AUTOSLIT3 is a complete rewrite of earlier versions
    of AUTOSLIT carried out to incorporate the additional flexibility in
    designing slitmasks to be produced by a numerically controlled mill,
    to improve the astrometric model, and to add other desirable new
    features.

    Earlier versions supported the numerically controlled punch
    to fabricate multi-slit masks for LRIS; AUTOSLIT3 supports only
    the mill and allows LRIS observers to take full advantage of its
    many new capabilities in designing slit-masks.

    AUTOSLIT version 3.20 adds one new output file (a region file compatible
    with the display server DS9), provides an indication
    of the current gap between the CCDs in both the LRIS-B and LRIS-R

CCD mosaics, and outputs the center of field in the epoch J2000.
Pickoff mirrors on slitmasks are no longer supported at Keck nor in this release.

At present for version 3.20 and higher, until further notice, it is strongly
recommended that all object and centerfield positions be input with epoch 2000.

Some basic feature are:

Performs all calculations needed to transform Right Ascension
and Declination coordinates to the coordinates of the slitmask
including refraction and precession of the stars.

AUTOSLIT3 can handle conventional slits, tilted slits, boxes,
arcs, and other user defined shapes for slits.

The user specifies an hour angle and position angle
for the observations.

An interactive mode to allow the user to change or delete
any slit assignments with which he/she is unhappy.

A Hardcopy of the final setup may be created.

Output files include all relevant information to make
bookkeeping and slitmask alignment easier.

The input features of AUTOSLIT3 have been significantly
improved over earlier versions so it is now much
easier to vary one or more parameters and run multiple tries.

The latest astrometric fits have been incorporated
into AUTOSLIT3. Also a confusion between equinox and
epoch in earlier versions of the code has been corrected.
In AUTOSLIT3 the equinox is used to precess the coordinates.

AUTOSLIT3 allows the adjustment of the position angle and field
center during the interactive phase of the design of a slitmask.

Using AUTOSLIT

AUTOSLIT3 requires the PGPLOT graphics subroutine library. Also a
Postscript printer is required to print the hardcopy output.

Copy the software package from the Keck LRIS ftp archive.
Compile the source code for your environment if necessary.

These two steps are described in Appendix A, which gives the
locations from which you can obtain the code as well as the
address of the AUTOSLIT3 WWW page.

Appendix B gives a detailed list of the files in the top
level directory for AUTOSLIT3, and in the subdirectories
for the source code, executable code, and example files.

Set up the input file that assigns values to the AUTOSLIT3 parameters
and that defines the specification of the
special slits. This file and the file containing the list of objects
should be in a working directory where you wish to have all your
input and output files. As described later, the easiest way
to make this file is to edit the template file we provide.

The format of both the parameter/special slit file and the

object list file are described in detail below.

Change directories to the working directory.

Type "autoslit3/bin/autoslit3" to invoke AUTOSLIT3.

AUTOSLIT3 is inherently interactive. The orientation of the
interactive display corresponds to the normal astronomical convention
of N up and E left (for position angle 0 degrees). (The orientation
has been changed from that of earlier versions.)

AUTOSLIT3 Parameters

    AUTOSLIT3 requires several user parameters to be defined at the
beginning of each run. A complete list of the currently supported
parameters is given below.

    The position angle is the angle between the LRIS slit and the North
direction, measured using the usual astronomical convention that a positive
angle corresponds to a slit which is oriented more towards the East, and
0 degrees position angle corresponds to the slit aligned with the
North direction.

    A 150 g/mm grating has been received for use with LRIS. This
ruling is sufficiently coarse that the full width of a spectrum
only covers part of the width of the LRIS detector. Hence one will
be able to observe with 2 ranks of multislits along the length of
the LRIS slit, thus doubling the effective slit length for objects
where low dispersion is acceptable. When this grating is tested and
becomes available the necessary code for dual rank operation (which
is effectively only a modification of the overlap rejection algorithm) will
be added to AUTOSLIT3. At the present time, only single ranks of
multi-slits are supported.

The list of accepted parameters is given below.

        FILENAME   (Character) The input file containing the
                      LRIS field objects.

        FILEOUT   (Character) Output file. The root file name
                      for the output files. If you enter abcdef.file1 here,
                      the output files will be abcdef.file1, abcdef.file2,
                      and abcdef.file3, while the Postscript hardcopy will
                      be in abcdef.ps. The output ds9 region file will be
                      in abcdef.reg.

        PRIORITY   (Numeric) Limiting priority for object plots. Objects
                      with higher priority than this value are plotted with a
                      different symbol.

        RANK_TOP   [1|2] - number of slit ranks in top half (Only RANK=1
                      is supported at present.)

        RANK_BOT   [1|2] - number of slit ranks in bottom half (Only RANK=1
                      is supported at present.)

        WSLIT   (real) Width of slits in arc-sec (SLIT_WID is also
                      accepted)

        SLIT_LEN   (real) Minimum slit length in arc-sec.

```
      SLIT_SEP     (real) Minimum slit separation in arc-sec.

      EPOCH        (real) Epoch for slitmask use.  Actually this is the equinox,
                        but is called EPOCH for historical reasons.

      TEMP         (real) Temperature of atmosphere, in degrees Celsius
                   (Used in refraction calculation)

      PRESS        (real) Pressure of the atmosphere in mm of Hg.
                   (Used in refraction calculation)

      WAVE         (real) Wavelength of light to use in atmospheric
                   refraction computations.

      LAT          (real) Latitude of the observatory in decimal degrees.

      POS_ANGL     (real) Position angle in decimal degrees

      HOUR_ANG     (real)  Hour angle at which you expect to use this
                   slitmask in decimal hours.  (Used in refraction
                   computations.)

      ENG_TEST     (boolean) Set up for astrometric engineering tests.
                   Regular LRIS observers should never use this feature !

      ADC          (boolean) Prepare masks using a scale value appropriate
                   for use of the atmospheric dispersion corrector. This
                   parameter defaults to TRUE, since the ADC is expected to
                   be used for all LRIS observations after June, 2007.

      INTERACT     (boolean) Allows for interactive slitmask assignments
                   (This should almost always be used.)

      VERBOSE      (boolean)  Give a more verbose screen output.  The
                   hardcopy plots and the output files themselves are
                   unaffected.

         For the values of the boolean keywords, any string beginning
         with one of the letters [tyTY] denotes true/yes, while any
         string beginning with one of the letters [fnFN] denotes
         false/no.


To produce your parameter file, edit the template file given
in Appendix C and in the examples sub-directory.
In the parameter file, lines beginning with the symbol # are ignored.

The default values for these parameters are listed below and are also
in the autoslit.inc include file.  If you do not set the value for
a particular parameter, the parameter will revert to the
default value.  The default values for the appropriate set of
site parameters (air pressure, latitude, temperature, etc)
are those characteristic of the Keck Observatory.


Parameter                            Keyword        Default Value
-------------------------------------------------------------
input parameters and special slits file [none]      "autoslit.in"
input file of objects                FILENAME       "autoslit.obj"
primary output file                  FILEOUT        "autoslit.file1"
priority for plot symbol change      PRIORITY       700
rank of top half of slit (1 or 2)    RANK_TOP       1
rank of bottom half of slit (1 or 2) RANK_BOT       1
```

```
width of slit [arc-sec]            WSLIT (or SLIT_WID)
                                            1.0
minimum slit length (arc-sec)      SLIT_LEN     5.0
minimum slit separation (arc-sec)  SLIT_SEP     2.757
engineering slit width             [none]       1.0
epoch of use                       EPOCH        "today"
   The correct term is equinox, which should be set to TODAY.
   For historical reasons this is called EPOCH.
temperature                        TEMP         0.0
air pressure at Keck               PRESS        486.0
wavelength for refraction          WAVE         6000.0
latitude of Keck                   LAT          19.828
position angle                     POS_ANGL     0.0
hour angle                         HOUR_ANG     0.0
is this an engineering test?       ENG_TEST     false
atmos dispersion corrector in use? ADC          true
interactive slit selection?        INTERACT     true
verbose output?                    VERBOSE      false

suffix for outfile2                [none]       "file2"
suffix for outfile3                [none]       "file3"


interactive plotting device        [none]       "/xwin"
hardcopy plotting device           [none]       "/vps"
```

(Both the /xwin and /xdisp PGPLOT options for the interactive plotting
device should work for Unix (Sun) workstations. The xdisp driver has
the advantage that the display window does not disappear when the
program terminates.)

As of 2011, the use of pickoff mirrors (keyword MIRROR) is no longer supported.

As of 2011, the default value for the equinox
(keyword EPOCH for historical reasons) is that of the input
centerfield position instead of TODAY. In a future version
of AUTOSLIT (see the discussion in the section ``Future Upgrades'')
this should be restored to TODAY.

The Interactive Display

While AUTOSLIT3 will assign the objects in your list to slitlets in
the slitmask on the basis of priorities and object locations, one
usually needs to tune up the slit assignments using the INTERACTIVE
mode. In particular, that way you can make sure the slits are placed
on objects as close as possible to the center of the frame in X, so
that the spectra will all cover approximately the same wavelength region.
The size of the detector in the X direction determines the range
off the centerline within which objects can be placed and still have
the desired spectral coverage. With the large CCD mosaic now in use,
which is somewhat wider (larger in the X direction) than the
single 2048x2048 pixel CCD originally used with LRIS,
this is less critical, but still merits attention.
Remember that the spectral coverage for an object way at the edge
of the field in X will be quite different from that of an object
near the center of the field.

In the INTERACTIVE mode, several new features have
been incorporated into the menu in AUTOSLIT3. The most
useful new keys are M (mark the location of an object), C (move the
field center), and P (specify the position angle).

The keys currently recognized are listed below. The key must be hit
when the mouse is within the boundaries of the plot of the setup.

I to get info about an object
O to try to assign a slit to an object
B to try to assign a box slit of the default size to an object
D to remove a slit assignment
W to wipeout all normal slits assigned
Z to wipeout all slits (including special slits)
R to redraw the plot
L to list objects in slits
M to mark the location of a specific object on your object list
(space-bar) to get the (X,Y) coordinates on the mask (in mm) for a point
C to specify a (relative) offset in arc-sec of the field center
P to specify the field position angle
Q to exit this routine

(Typing any other letter key produces the list above.)

(The "Mark" option is case sensitive, i.e. A3 is not the same as a3.)

Important Notice Users -- Please Read This

When using AUTOSLIT3 in the interactive mode, you may
offset the field center (C) or change the position angle (P).
Please note that the output file FIELD.file1 contains the updated
field center in the J2000.0 epoch and the final adopted position angle.

Make sure that in your coordinate file for use at the telescope
you use this UPDATED position angle and centerfield RA, Dec.
DO NOT use the original input value if you change
either the PA or the centerfield.

Slit Widths Supported

With the replacement of the numerically controlled punch originally
used to fabricate LRIS slitmasks by a numerically controlled mill,
the width of the slitlets is no longer restricted by the width
of the available punches. Any slit width is now allowed, with a
minimum value determined by the width of the end mills
available at Keck.

CARA uses 0.020 inch (0.7 arc-sec) as their normal
tool bit size. Smaller tool bits (0.015 in, or 0.53 arc-sec)
are available.

All the slits, with the exception of boxes and certain special slits,
must have the same slit width.

Do not use slits smaller than 0.7 arc-sec wide without prior
consultation with CARA staff.

The Special Slits

AUTOSLIT3 enables the use of four non-standard slit types:

tilted slits, arc slits, line segment slits, and boxes. These
slits are defined in the second section of the input parameter
file. Definition blocks are structured as follows:

        (1) tilted slits

            TILTS <int>
            <object> <pos angle> <min up> <min down>
            <object> <pos angle> <min up> <min down>
            ...

            The first line specifies the number of tilted slits to be
            defined. Each subsequent line defines one tilted slit.
            Each slit is defined by the name of the object on which
            the slit will be placed (from the input object file), the
            position angle of the slit, and the minimum extent of
            the slit in arc-seconds, above and below the position
            of the object.

            Tilted slits are tied to positions on the sky and hence
            will rotate appropriately when the slitmask position angle
            is changed.

            A simple program to calculate the position angle and other
            information for tilted slits is available (tilted_slit.f)
            and should be used prior to running AUTOSLIT3 to help
            the user create the appropriate input file entries for tilted slits.

            Tilted slits could in principle tilt off the area of the LRIS
            slitmask. AUTOSLIT3 does not check for this.

        (2) arc slits

            ARCS <int>
            <name> <ra> <dec> <epoch> <radius> <PA start> <PA end>
            <name> <ra> <dec> <epoch> <radius> <PA start> <PA end>
            ...

            The first line specifies the number of arc slits to be
            defined. Each subsequent line defines one arc slit. Each
            slit is defined by a name (arc slits need not be placed on
            objects), the position of the center of curvature of the
            arc, the epoch of the center position coordinates, the
            radius of curvature in arc-sec, and the position angle
            with respect to the center of curvature
            at which the arc segment begins and at which it ends.
            The RA and Dec of the center
            should each be defined by three numbers (hours|degrees,
            minutes, seconds), separated by whitespace.
            Arc slits are calculated as a set of line segments
            0.5 mm apart along the arc.

            Arcs, unlike normal slits, are not lengthened during the
            process of filling out the mask once the objects on it
            have been selected. You must make sure to add some length
            to allow for the sky spectrum etc.

PLEASE BE SURE TO CHECK the layout of all special slits, and especially
all arcs, in the interactive display carefully and adjust the
parameters as required.

Non-vertical special slits (i.e. all special slits except boxes)
are always defined to have the specified width along the dispersion.
Recall that the end mill used has a finite width. The minimum

width across the slit goes as (slit-width along the dispersion)*cos(angle)
As the special slit becomes closer to horizontal than to vertical,
this can become smaller than the width of the tool. In such a case,
the mill control program will reject that slit.

In general one is safe with 1 arc-sec wide slits whose tilt from
vertical is not more than 30 deg. For narrow slit widths or in
case there is any doubt, send the mill file to Hawaii
sufficiently in advance for a check of the file to be made there on
the computer that operates the mill, so that the special slit can
be redesigned if necessary.

        (3) line segment slits (Design your own complex shaped slit)

            SEGMENTS <int>
            <name1> <ra> <dec> <epoch>
            <name1> <ra> <dec> <epoch>
            <name1> <ra> <dec> <epoch>
            <name2> <ra> <dec> <epoch>
            <name2> <ra> <dec> <epoch>
            <name2> <ra> <dec> <epoch>
            <name2> <ra> <dec> <epoch>
            ...

            The first line specifies the number of points to be
            defined for line segment slits. Each subsequent line
            defines one point in a line segment slit. Each point is
            defined by the name of the line segment slit (line segment
            slits are not placed on objects), the position of the
            point, and the epoch of the position coordinates. All
            consecutive line segment points which share the same slit
            name will be connected to form a single slit. For
            example, the above declaration would create two slits, one
            with 3 points (name1), and another with 4 points (name2).
            See the file Examples/test.in for more examples. Note
            that the value on the first line of the block indicates
            the number of points in the line segment slits, not the
            number of slits.

        (4) box slits - used to put bright guide stars into a mask.

            BOXES <int>
            <object> <size>
            <object> <size>
            ...

            The first line specifies the number of box slits to be
            defined. Each subsequent line defines one box slit. Each
            slit is defined by the name of the object on which the
            slit will be placed (from the input object file), and the
            size of the box, in arc-seconds.

            Boxes are always squares aligned along the X,Y axes of
            the multislit mask. They are not tied to the sky and hence
            do not rotate when the position angle of the slitmask is altered.

            Boxes are allowed to interfere with other boxes, i.e. to have
            the same position along the height of the slit.

    The order of the slit definition blocks does not matter.
    Multiple definition blocks are also allowed, i.e., two sets of
    arc slits. The only requirement is that the number of slit
    definition lines in any given block must match the number

given on the declaration line, i.e., 'ARCS 4' must be followed
by 4 arc slit definitions.

An Example of a Parameter/Special Slit file

AUTOSLIT3 will prompt you for the name of the parameter/special
slit file. This file consists of two sections, with a structure as
follows:

        <keyword>   <value>
        <keyword>   <value>
        ...
        END

        <special slit definition block>
        <special slit definition block>
        ...
        END

All words are case-insensitive, and spacing is not important.

An example of a parameter/special slit file is given in Appendix C.

The Object List File

As in earlier versions of AUTOSLIT, AUTOSLIT3 requires a file containing
the list of objects which you would like to consider for inclusion
in a multi-slit mask. This file, whose format has not changed,
must contain one-line descriptions of each object of
interest in the field, in a format identical to that originally used for
Palomar Observatory's Norris spectrograph. This format is
described in more detail in the file GET_OBJ.C, but is summarized
as follows:

Each object description line consists of:

        <name> <prior> <mag> <ra> <dec> <epoch> <equinox> <ra_pm> <dec_pm>

    where

        <name>   = object identifier (or name)
        <prior>   = object priority as assigned by the observer
        <mag>   = object magnitude
        <ra>   = object right ascension: <hours> <minutes> <seconds>
        <dec>   = object declination: <degrees> <minutes> <seconds>
        <epoch>   = epoch of the object's coordinates
        <equinox> = object equinox
        <ra_pm>   = object proper motion in right ascension in arcsec/yr
        <dec_pm> = object proper motion in declination in arcsec/yr

Note that the equinox specified here is used to precess the coordinates
to the time when the mask will be used (i.e. ``today''). In earlier
versions of AUTOSLIT, the epoch field was incorrectly used for that purpose.
It is highly recommended at the present time that the equinox of the centerfield
be set to 2000.0 in order to minimize precession errors and enable
a workable DS9 output region file for the mask.

Although the order of the fields is important, spacing between the
fields does not matter.

The lines may be given in any order, *except* the first line,
which should have a priority of '9999' and should provide the
coordinates of the center of the field of interest.

An example of an object input file is given in Appendix D.

Priorities and Object Assignments

The allocation algorithm assigns all the special slits first.
They are assigned internal priorities with default values of
2100 for tilted slits, 2200 for arcs, 2300 for line segments,
and 2400 for boxes. Do not assign priorities in excess of 2000
to objects on your normal slitmask list.

A conflict is equivalent to an overlap along the length of the slit
(i.e. the Y direction) between two objects. This
applies to the actual position (plus or minus any specified
height for the special objects) and plus or minus the minimum
object separation (defined in autoslit.inc).

You will be informed if there is a conflict among the special
slits you have specified. After that, if you are using the
INTERACTIVE mode, you may choose the rest of the objects
in your slit-mask. If there is a conflict, AUTOSLIT3 will
refuse to make the requested assignment.

If there are multiple special slits of a given category, they
are prioritized within each category, with the first tilted
slit having higher priority than the second one, etc. The base
priority for each type of special slit is given in the include file
autoslit.inc.

The Gaps in the CCD Mosaic

The present LRIS-R and LRIS-B detectors are both mosaics of CCDs
instead of a single large monolithic CCD. Because of the need for
providing readout and control circuits to each CCD in the mosaic,
there are physical gaps between the CCDs. These gaps
cut out a short rectanglar area in the LRIS focal plane
for each of the red and blue cameras. The rectangle has its
long side along the dispersion and its short side along
the length of the LRIS long slit.

If the image of an object on the sky as viewed in the LRIS
focal plane falls into one of these gaps, its image will
not appear on the LRIS image, or if a slitmask is in use, its
spectrum will not be obtained.

These gaps have been minimized during the design
and fabrication of the CCD mosaics, but they are still large,
with the blue detector mosaic having a smaller gap than the
red side mosaic. The large red side gap is indicated
in the four output Postscript plots as dashed lines.
The smaller blue side gap is indicated as dotted lines.
The upper limit to the blue side gap is the same as that
of the red side gap. The interactive display also shows
the two gaps.

If you choose to place an object within one or both of these

gaps, there will be a warning message from the interactive
display, but the slit placement will be allowed, if consistent
with other constraints such as minimum separation to any
previously assigned slit.

One might choose to do this, for example, to place an
object within the area of the LRIS-R gap, but outside
the area of the LRIS-B gap. For such an object one would
obtain only a LRIS-B spectrum. The LRIS-R slitmask spectum
will not contain a spectrum of this object.

At present (July 2011), the CCD gap locations as seen on the sky
are indicated correctly to within an accuracy of about 1 arcsec.
The CCD gap locations as projected on to the sky may change
if the instrument is realigned or recollimated, which happens
very rarely.

In the past, the slit-mask plates were restrained in their holders
(and slightly curved to fit better the telescope focal plane
by a bar which ran in the dispersion direction along the middle of
the mask. The bar was opaque. Recently new slitmask
holders were designed and fabricated with the curvature controlled
without the need for the bar. Thus there is no longer any
occulted area within the LRIS itself. Only the gaps between the
CCDs in the detector mosaics produce issues of
unavailable areas within the nominal LRIS field.

Checking the Slit-Masks

It may be desirable to check the mask before the mill file is sent
to the Keck Observatory. A program has been written for this
purpose called "check_mask3". This program, which requires the
PGPLOT subroutine library, is installed in the Autoslit3 directory.
It takes the output file from Autoslit3 that is sent to the milling
machine and produces a Postscript file which contains a full size
image of the multi-slit mask. The postscript file is called
"pgplot.ps" and can be printed on any Postscript printer.

Since the mask is large, the image is on two sheets of standard
size paper, for the top and bottom of the mask respectively.

This program is self explanatory and very easy to use.

Astrometry

Two astrometric models are used in AUTOSLIT3. The first and
most critical is the model that relates the position of an
object on the sky (RA, Dec) into position on the slitmask.
The baseline model, adopted before LRIS was completed from the
details of the instrument and telescope design, was that of a
fixed telescope focal plane scale of 0.7253 mm/arc-sec
projected onto a bent slitmask.   (See the the LRIS Manual
of Operations for details.)

Once LRIS was in use at the telescope this initial
model was found to be inadequate and was refined
by adding a small "touchup fix". The latest version of
the "touchup fix" (August 1997) is used in AUTOSLIT3.

A detailed discussion of the procedures, measurements and
analysis for determining this is given in the following three
LRIS reports:

    The LRIS Focal Plan Astrometry - J.G.Cohen - December 1993

    Report on the Alignment of the LRIS Slitmasks Based On Tests Conducted
    During the January 1994 LRIS Commissioning Run - J.G.Cohen, January 1994

    The Slitmask Astrometry of the LRIS - J.G. Cohen and P.L. Shopbell,
    December 1996

It should be noted that only a major change to the instrument
might affect the values of the parameters used in this aspect
of the astrometric model for LRIS.

In addition, AUTOSLIT3 predicts the (X,Y) positions of objects on
the focal plane CCD detector in pixels as an aid for slitmask alignment.
The astrometric model for this has been developed in a series
of reports on the LRIS spatial distortion. The latest of these is:

    The Spatial Distortion in the LRIS - Addendum 5, The Scale Change
    Introduced by the New LRIS Dewar - J.G. Cohen and P.L. Shopbell,
    Nov. 7, 1996 (15 pages)

The specific X,Y (CCD) predictions in Autoslit3 use this model for the
new LRIS Dewar. It should be noted that if changes are made to the
LRIS optics or mechanical mountings (new Dewar, recollimation,
re-alignment, etc.) the predicted X,Y(CCD pixels) may no longer
be sufficiently accurate and new parameters for the fits in this
model may be required.

To facilitate updating the code, should a more complex and more
accurate astrometric model become available in the future, the
corrections from the baseline model are implemented only in the
output file containing the positions for the numerically controlled
mill that fabricates the LRIS slitmasks. Thus the X,Y (mm) positions
in the slitmask in the output files intended for the user are slightly
different from those in the file used to fabricate the slitmask.

The two astrometry models are isolated within two subroutines,
ccd_coord_predict and slit_astrometry. Updating the astrometric
model just requires updating one or both of these subroutines.

Coordinate Systems

The LRIS coordinate system is defined in the LRIS Manual of Operation.
The origin is the optical axis, and the X axis goes through the
center of the LRIS entrance field. In this coordinate system,
the slitmask covers the region X = 174 to 436 mm, and Y = -174 to
174 mm. Thus in this coordinate system, the center of the slitmask
is at X = 305.0 and Y = 0.0 mm.

The slitmask punch originally used to fabricate LRIS slitmasks
has an internal coordinate system whose origin is at X = 412.95,
Y = 167.8 mm. Its Y coordinate axis is opposite to that of
the LRIS coordinate system (i.e. 180 degrees off). The X coordinates are
in the same direction for both frames, there is just an offset
between coordinate systems.

To avoid confusion and aid in code maintenance, all calculations in
AUTOSLIT3 are done in the LRIS coordinate system until the stage where
the output files are written.

Coordinate Change for the Milling Machine

The milling machine uses a coordinate system which is different from
the nominal LRIS coordinate system used here and from that used with
the slitmask punch. In particular, X and Y must be interchanged.
This is done only at the very end when the output file intended for
the numerically controlled mill is written. The file
"mill_coords.ps", a Postscript file, illustrates the orientation and
zero points for the mill and the nominal LRIS coordinate system on the
slitmask. A hardcopy of this figure is in Appendix G.

The Keck mill has a very sophisticated computer control system. It is
possible to preview mask design files to check whether any
constraints imposed during the fabrication process for the masks
are violated. In case of doubt, contact CARA staff to arrange
a test of your AUTOSLIT3 mill file.

Engineering Mode

A mode is available, intended ONLY for engineering tests, which
does not put in any modifications to the original baseline LRIS
astrometric model, which bypasses all overlap checking, and which
produces a slit-mask with 1 x 1 arc-sec boxes (unless a different
slit width is specified in the parameter file)
around each selected object.

This can be used to produce a mask with hundreds of such boxes
around objects with high quality astrometric positions, and one
can use such a mask for checking the LRIS astrometric model.
THIS MODE SHOULD NOT BE USED BY NORMAL LRIS OBSERVERS.

Maximum Number of Slits

AUTOSLIT3 will allow you to define up to 100 slits, except in
engineering mode, where that is relaxed to 500 boxes.

Programming Considerations

     All of the important parameters relating to the geometry of the LRIS
     spectrograph have been grouped together in an include file called
     autoslit.inc. This file must be located in the same directory as
     the source code, autoslit3.f.

     If it become necessary to change the parameters of the slitmask,
     this can be easily done by:

     Changing the relevant parameters in autoslit.inc

     Recompiling AUTOSLIT3 as follows: while in the AUTOSLIT directory,
     type
          % make autoslit3

     This will recompile and link AUTOSLIT3 with the new parameters.

     The following is a list of files which must be present for autoslit to
     be compiled:
               Makefile, autoslit3.f, autoslit.inc, math.inc

     Further, the following must be located in a "lib" subdirectory:

```
assign_slits.f       manual_slits.f     refract.f           write_setup.f
ccd_coord_predict.f  match_slits.f      slit_astrometry.f   xy.f
draw_hard.f          params.f           slits.f
get_data.f           plot.f             write_mill.f
isort.f              precess.f          write_objects.f
```

```
env.c   get_key.c  get_obj.c
```

Also the two include files, autoslit.inc and math.inc, must be in
the lib subdirectory, as well as Makefile.

A detailed list of the required files and directories is
given in Appendix B.

AUTOSLIT.INC

An extract from the include file autoslit.inc that contains many of
the important spectrograph definitions which might be altered by
the user is given below. If one of the values is altered, the
program will have to be recompiled to force Autoslit3 to use
the new value.

```
C     Slit widths, lengths, and separations:
      REAL*4     DEF_SLIT_WID,DEF_SLIT_LEN,DEF_SLIT_SEP
      PARAMETER (DEF_SLIT_WID=1.0,               ! normal width, length,
     :           DEF_SLIT_LEN=5.0,               ! and separation of
     :           DEF_SLIT_SEP=2.757)             ! slits [arc-sec]
C     Physical constants:
      REAL*8     DEF_TEMP,DEF_PRES,DEF_WAVE,DEF_LAT,DEF_POS_ANGLE,DEF_H
      PARAMETER (DEF_TEMP=0.0D0,                 ! temperature
     :           DEF_PRES=486.0D0,               ! air pressure at Keck
     :           DEF_WAVE=6000.0D0,              ! wavelength for refraction
     :           DEF_LAT=19.828D0,               ! latitude of Keck
     :           DEF_POS_ANGLE=0.0D0,            ! position angle
     :           DEF_H=0.0D0)                    ! hour angle
C     Spectrograph:
      INTEGER*4 NORM_SLITS,ENG_SLITS
      REAL*4     PUNCH_LEN,CCD_SIDE,CCD_SCALE,
     :           XS_SLIT,YS_SLIT,
     :           X_CENTER,Y_CENTER,
     :           SCALE,MASK_ANGLE,MASK_BEND
      PARAMETER (
     :           NORM_SLITS = 100,      ! number of slits for normal use
     :           ENG_SLITS  = 500,      ! number of slits for engineering
     :           PUNCH_LEN  = 3.0,      ! length of punch used [not used]
     :           CCD_SIDE   = 2048.0,   ! size of ccd in pixels
     :           CCD_SCALE  = 0.15767,  ! mm per pixel of ccd at slitmask
     :           XS_SLIT    = 215.9,    ! length of the x side of the slitmask
     :           YS_SLIT    = 335.6,    ! length of the y side of the slitmask
     :           X_CENTER   = 305.0,    ! center of mask in x coordinates
     :           Y_CENTER   = 0.0,      ! center of mask in y coordinates
     :           SCALE      = 0.7253,   ! scale of mask in mm/arcsec
     :           MASK_ANGLE = 8.06,     ! angle of mask in focal plane in deg
     :           MASK_BEND  = 1.94)     ! angle of bend in mask in deg
```


The mathematical parameters that were formerly in autoslit.inc,
such as conversion factors from radians to arc-sec,
have been moved to a new include file called math.inc.

            The Output from AUTOSLIT3

The output from AUTOSLIT3 consists of 3 text files, a Postscript
plot file with four pages of plots, and a region file (added
in July 2011). The region file (courtesy of Caltech graduate student
Andrew Newman) provides an input to the popular display server
DS9 such that if you have an image with a world coordinate system
(i.e. one for which RA and Dec can be determined for each pixel),
then loading the region plot into DS9 will overlay the slitmask onto
the sky field within the display. This is extremely useful both in
designing the slitmask and in preparing charts of the setup/alignment
stars for each slitmask; these are required for slitmask alignment.

     If you use the epoch 2000 for your centerfield coordinate,
then the region file will be correct. If you do not use 2000,
then the region file will not be useful. Please see the comments
in the section Future Upgrades for details on this point.

    Alignment of the slitmask at the telescope in the past
required use of both the printed file output and a hardcopy of the
graphics output from Autoslit. The hard copy device for AUTOSLIT3
is a Postscript printer in the portrait (vertical) mode.

   The current (early 2011) slitmask alignment scheme for LRIS is
similar to that used for Deimos. It is based
on using the fixed MAGIQ guider for crude alignment, which gets an
alignment star somewhere inside its respective box. This is followed
by imaging with the blue side of LRIS for fine alignment. (The readout time
of the LRIS-B detector array is much faster than that of the red one,
and the change of configuration between imaging and multislit
spectroscopy is faster as well. Hence the choice of LRIS-B for slitmask
alignment. With this procedure, all that is required is finding charts of the
alignment stars, each of which should be assigned a box at least 4 arcsec
on a slide or larger. At least five alignment stars well distributed
over the LRIS field should be assigned within each slitmask.

     Four figures are produced as Postscript files. The first is labeled
"Mask Layout.....". It contains a view of the slit mask as seen from
above. The two arrows on the periphery of the frame denote the
locating notches for inserting the frame into the LRIS slit mask
holders and for locating the plate on the slit mask machine table.
There is also an arrow indicating north and east. The frame displays
all the objects in the field, and indicates where the assigned slits
are. You can use this frame to check that the slit-mask has been made
correctly.

     The second file is labeled "Seen on CCD:...". This file shows
the mask as seen by the LRIS optics and CCD camera. There is an
inversion in x from the first output plot, as shown by the pair of
arrows indicating north and east. Otherwise this plot is identical
to the first plot.

     The third plot is also labeled "Seen on CCD:...". It is
identical to the second plot, but for each assigned slit, on the left
side of the frame is given the (x,y) coordinates of the object in the
slit in the LRIS coordinate system, while on the right side of the
field are given the object name and magnitude, all at the appropriate
y height for the object. This plot is extremely useful in checking at
the start of your run that the correct slitmasks have been installed
in LRIS, working on slitmask alignment, etc. You should bring a
printed copy of it for each multi-slit you plan to use.

     The final plot is also labeled "Seen on CCD...". It displays
only the objects that are selected to be in slits. The full length of
the slit is shown. The objects are labeled with their names and

their magnitudes.

For each plot, the location of the notches that define the placement
of the slitmask in the milling machine and in the slitmask holder
re indicated by small arrows.

Other useful files:

README contains a more detailed description of compiling this program

TECHDOC contains a 1 sentence listing for each subroutine indicating
its function.

*** PLS read this section completely***

Future Upgrades:

Until July 2011, the default mode of operation of AUTOSLIT was
to read the input coordinate list, and precess it to the equinox
TODAY. Then the calculations necessary for defining the layout
of the slitmask were carried out, and the results given in the output
files and plots. One resulting confusion among observers was that in
the output files, the centerfield coordinates were given with the
equinox TODAY rather than 2000. We have attempted in the current version
to make the equinox of the centerfield in the AUTOSLIT output files
much clearer.

In July 2011, ouput of a DS9-type region file for use with the image
display server was added. This is very useful. However, the standard
format for this file only allows for 1950 and 2000 coordinates. The
logical thing to do would have been to precess the input centerfield
and object coordinates to TODAY, which presumably is very close to the
date at which the slitmask would be used at the telescope, as we have
done in the past. We then would need to precess the information for
constructing the region file back to 2000.

While trying to implement this, it was discovered that the precession
routines used within AUTOSLIT are not sufficiently accurate to do this
and maintain a precision of better than 0.05 arcsec over the 11 years
since TODAY (i.e. July 2011). It will require some work to find a more
accurate precession routine whose code is free and publicly available,
to revise the internal code within AUTOSLIT to implement the forward
and backward precession as required, and to test the revisions. So we
(J. Cohen and P. Shopbell) decided for the present to ignore this problem.

This is a real problem and we hope to fix it in the next version. But
meanwhile the present version of AUTOSLIT (3.20) yields slitmasks which
work well and which are correct in all respects to within 0.05 arcsec.
Clearly this must be fixed before TODAY and 2000 differ by more than
20 years, but that gives us plenty of time for the non-trivial required
coding modifications.

Comments and Suggestions:

Comments, suggestions, reports of bugs, etc. should be directed to
J.Cohen, at least until the shakedown period for this completely
new version of AUTOSLIT is over and CARA becomes responsible for
its maintenance, which never seems to happen.

Judith Cohen
jlc@astro.caltech.edu

Appendix A Downloading and compiling autoslit

The source code, a compiled version, and the help files can be obtained
via anonymous ftp from

ftp://astro.caltech.edu/users/pls/Autoslit/

or from

ftp://ftp.keck.hawaii.edu/pub/lris/autoslit3.

There is also a WWW page (http://astro.caltech.edu/~pls/autoslit).

Compile instructions are given on the website and provided in the
README and Makefile files, once the source code has been extracted.

The latest version of the source code can always be obtained from
the link:

http://astro.caltech.edu/~pls/autoslit/autoslit.tar.gz

For those wanting to use a pre-built binary, a selection of those
can be downloaded from:

http://astro.caltech.edu/~pls/autoslit/binaries/

Note that these are provided for a small selection of hardware and
operating systems and may require certain libraries to be available.
Please e-mail pls@astro.caltech.edu should you require a binary for
a machine of a different architecture; we will try to assist.

Appendix B   List of required files

In the main directory, autoslit3.f, autoslit.inc, math.inc,
autoslit3.doc, README, TECHDOC, and the Makefile.
Also the coordinate system layout figure, mill_coords.eps.
(Other useful codes include tilted_slit.f and check_mask3.f.)

In the lib subdirectory, the following Fortran files:

assign_slits.f	manual_slits.f	refract.f	write_setup.f
ccd_coord_predict.f	match_slits.f	slit_astrometry.f	xy.f
draw_hard.f	params.f	slits.f	
get_data.f	plot.f	write_mill.f	

```
isort.f              precess.f             write_objects.f

and the following c files:
env.c   get_key.c  get_obj.c

the Makefile and the two include files (autoslit.inc and math.inc),
which are just links to those in the top level directory.

in the examples subdirectory:
test1.in and grid.in
test.objs and grid.objs
test1.file1, test1.file2, test1.ps

in the bin directory (or wherever you choose)
autoslit3


Appendix C

Two examples are given.  In the first, the grid test case,
there are no special slits, while in the second test case there
are several arcs and tilted slits.

Grid test case parameter file:
# Header comment
FILENAME        grid.objs
FILEOUT         grid.file1

Priority        750
Press           455.5
#Mirror         x0y0
Pos_Angl        90
WSlit           1.0
Interact        True
Verbose         No
# Eng_Test      True
#
# several comments together
# ....
#
END

# Special slits:
END


Arc/tilted slit test parameter file
# Header comment
FILENAME        test.objs
FILEOUT         test.file1

Priority        750
Press           455.5
#Mirror         1-73
Pos_Angl        0
WSlit           1.0
ADC             False
Interact        True
Verbose         No
# Eng_Test      True
#
# several comments together
# ....
#
```

```
END

# Special slits:
Tilts 3
Y        45      5       5
# 1-31   10      20      30
1-85     115     8       2
CF10     -25     4       12

Arcs 3
arc1     19 51 29.45   18 40  1.00  1950.0      25      0       180
# arc2   19 51 26.63   18 37 19.00  1950.0      10      -45     45
arc3     19 51 37.69   18 37 21.80  1950.0      15      -105    -10
arc4     19 51 34.11   18 38 50.30  1950.0      20      135     -135
END
```

Appendix D Example of an object input file

The beginning of the object list file for the grid test case is given
below. The object input file for the arc/tilted slit case is similar,
but longer, and is given in its entirety in the examples directory.
The object input file has the format: name, priority, magnitude, RA,
Dec, epoch, equinox, and proper motion. The equinox field is now used
for precession, correcting an earlier error of using the epoch field,
so make sure that the equinox field is filled in appropriately.

```
(60)%% more grid.objs
CENTER     9999   0.00    15 10 33.00   12 15 30.00  2000.0  2000.0  0.0  0.0
x0y0        700  20.00    15 10 33.00   12 15 30.00  2000.0  2000.0  0.0  0.0
x10y0       700  20.00    15 10 33.682  12 15 30.00  2000.0  2000.0  0.0  0.0
x0y10       700  20.00    15 10 33.00   12 15 40.00  2000.0  2000.0  0.0  0.0
x10y10      700  20.00    15 10 33.682  12 15 40.00  2000.0  2000.0  0.0  0.0
x-10y0      700  20.00    15 10 32.318  12 15 30.00  2000.0  2000.0  0.0  0.0
x-10y10     700  20.00    15 10 32.318  12 15 40.00  2000.0  2000.0  0.0  0.0
x0y-10      700  20.00    15 10 33.00   12 15 20.00  2000.0  2000.0  0.0  0.0
x10y-10     700  20.00    15 10 33.682  12 15 20.00  2000.0  2000.0  0.0  0.0
x-10y-10    700  20.00    15 10 32.318  12 15 20.00  2000.0  2000.0  0.0  0.0
x30y0       700  20.00    15 10 35.047  12 15 30.00  2000.0  2000.0  0.0  0.0
x0y30       700  20.00    15 10 33.00   12 16 00.00  2000.0  2000.0  0.0  0.0
x-30y0      700  20.00    15 10 30.953  12 15 30.00  2000.0  2000.0  0.0  0.0
```

Appendix E Example of output files

Sample output files for the first two output files from Autoslit3
are given.   The first gives the details of the normal and special slits
assigned in the slitmask. This file is useful for slitmask alignment
purposes. The second is the file that list the X,Y coordinates of
all the objects in the input list. Only the beginning of this file
is shown.

```
(62)%% more test.file1
#                                          #
#  ****         AUTOSLIT  3.0 OUTPUT        ****  #
#  ****        Mon Oct 20 13:09:26 1997     ****  #
#                                          #
#                                          #
#  ========================================  #
#              Autoslit Parameters          #
#  ----------------------------------------  #
#                                          #
#  Files:                                   #
#  ----------------------------------------  #
```

```
#   Input object file:          test1.objs   #
#   Output listing file:        test1.file1  #
#   Output stage coordinate file:  test1.file2  #
#   Output file for the punch/mill: test1.file3  #
#   -----------------------------------------   #
#                                               #
#   Physical parameters:    [default]  [input]  #
#   -----------------------------------------   #
#   Temperature [C]:             0.0       0.0  #
#   Air pressure [mm of Hg]:   486.0     198.0  #
#   Latitude:                   19.83     19.83 #
#   Wavelength [A]:           6000.0    6000.0  #
#   Position angle:              0.00     45.00 #
#   Hour angle:                  0.00      0.00 #
#   Epoch:                  [center]   2000.00  #
#   Slit width [arc-sec]:        1.00      3.00 #
#   Slit length [arc-sec]:       5.00      5.00 #
#   Slit separation [arc-sec]:   2.76      2.76 #
#   -----------------------------------------   #
#                                               #
#   Slit layout parameters:                     #
#   -----------------------------------------   #
#   Top half of mask:    *single* rank of slits #
#   Bottom half of mask: *single* rank of slits #
#   Special plot symbols have priority  >   750 #
#   Slit selection:                 interactive #
#   Pickoff mirror in use:                FALSE #
#   Atmos dispersion corrector in use:     TRUE #
#   Engineering run:                      FALSE #
#   -----------------------------------------   #
#                                               #
#   Slit inventory:          assigned/declared  #
#   -----------------------------------------   #
#   Number of standard slits:            24    #
#   Number of boxes:                    0/  0  #
#   Number of tilted slits:             2/  2  #
#   Number of arc slits:                1/  3  #
#   Number of line segment slits:       0/  0  #
#   =========================================   #
#                                               #
#   =========================================   #
#                Center of Field                #
#   -----------------------------------------   #
#   Center of Field is:                         #
#   RA  =   14h   29m   40.020s    [2000.00]    #
#   DEC = -  5d   57m   26.000s                 #
#   =========================================   #
#                                               #
#   =========================================   #
#                 Slit Setup                    #
#   -----------------------------------------   #
#   X_STAR     Y_STAR      MIN_Y       MAX_Y    Percent   CCD_X    CCD_Y Prior
      Name           Mag   #
   101.96133 156.86742    171.37343    156.86742 100.0000  1004.2  1100.9  2200
      arc4          0.000
    80.51526 275.03802    279.50546    270.65359  50.4690   864.3   330.5  2101
      Y            13.870
   205.17894  96.66530    101.45148     94.41214  67.9919  1670.5  1495.2  2100
      CF10         13.640
   119.93607 138.65129    142.40982    123.86235  20.2643  1119.7  1219.6   900
      1-40         14.690
   201.25655 209.66850    212.99808    207.74945  63.4371  1644.5   755.3   900
      1-77         12.650
#   =========================================   #
```

The X_STAR, Y_STAR, MIN_Y, and MAX_Y are given in mm in slitmask
coordinates. The slits start off being 4 arc-sec (2.9 mm in length),
unless a different value is specified in SLIT_LEN. After object
selection is completed, the slits are then increased to their maximum
length consistent with a minimum separation of SLIT_SEP arc-sec (with
a default value of 2 mm = 2.8 arc-sec) to give the maximum possible
length for the night sky spectrum at the ends of each slit.

The Percent is the ratio of (Y_STAR - MIN_Y)/(MAX_Y - MIN_Y)
for each slit. Those slits with the Percentage less than 10 or more than
90 may have the stars too close to the edge of the slit for good spectra.
The CCD_X and CCD_Y are the pixels of the CCD in which the object
is predicted to appear.

The centerfield coordinates in this file include
corrections for precession to the current epoch but not for
atmospheric refraction. Thus these centerfield coordinates
can now be used as input to the Keck Telescope drive
and control system (DCS) for pointing the telescope.

(63)%% more test.file2
    ****   AUTOSLIT 3.0 OUTPUT   ****
    ****   Mon Oct 20 13:08:48 1997   ****

    ==
                Autoslit Parameters

    Files:

    Input object file: test1.objs
    Output listing file: test1.file1
    Output stage coordinate file: test1.file2
    Output file for the punch/mill: test1.file3

    Physical parameters: [default] [input]

    Temperature [C]:   0.0   0.0
    Air pressure [mm of Hg]:   486.0   198.0
    Latitude: 19.83   19.83
    Wavelength [A]:   6000.0   6000.0
    Position angle: 0.00   45.00
    Hour angle: 0.00   0.00
    Epoch: [center] 2000.00
    Slit width [arc-sec]:   1.00   3.00
    Slit length [arc-sec]:   5.00   5.00
    Slit separation [arc-sec]:   2.76   2.76

    Slit layout parameters:

    Top half of mask: *single* rank of slits
    Bottom half of mask: *single* rank of slits
    Special plot symbols have priority >   750
    Slit selection: interactive
    Pickoff mirror in use: FALSE
    Atmos dispersion corrector in use: TRUE
    Engineering run: FALSE

    Slit inventory: assigned/declared

```
                 --------------------------------------------
                 Number of boxes:                      0/ 0
                 Number of tilted slits:               0/ 2
                 Number of arc slits:                  0/ 3
                 Number of line segment slits:         0/ 0
                 ==========================================
                 ==========================================
                            Objects in Field
                 --------------------------------------------
                    Name              Mag      X       Y
                 --------------------------------------------
                    Y                13.87   332.43 -107.24
                    CF10             13.64   207.77   71.13
                    1-73             14.79   258.70  -16.00
                    T,CF11           12.20   202.67   80.06
                    A4               12.20   348.69   51.02
                    1-46             12.29   294.85   78.73

                 ==========================================
```

     The X and Y coordinates here are given in mm in the official
LRIS coordinate system, which has X going from 174 to 436, and
Y from -174 to 174 mm.

The file intended for the mill has the same header structure,
which the mill control computer ignores. This is followed
by a set of blocks which resemble the one given below, which defines
a normal slit. This contains the X,Y,Z coordinates of the 4 corners
that define the slit (Z = 0 always), together with a fifth corner
which repeats the first one to form a closed rectangle.

```
newrow
   174.300003  129.618027    0.000000
   164.287582  129.618027    0.000000
   164.287582  128.892746    0.000000
   174.300003  128.892746    0.000000
   174.300003  129.618027    0.000000
newrow
```


Appendix F Alignment of Gratings and Mirror in LRIS

In tests carried out in April 1997 with the slitmask alignment
test hole pattern of drawing 108811A,
the support bar of the slitmask frame falls at the following
Y(CCD, pixels) location in the LRIS focal plane CCD detector:

Grating/Mirror	Y location (pixels)	Delta from Ideal (Y=1024 pixels)
Mirror	1090	+66
300/5000	1033	+9
600/5000	1003	-21
600/7500	1015	-9
1200/7500	999	-25

The LRIS optics were realigned in August 1997 to correct the pointing
of this mirror. Hence the value adopted for AUTOSLIT3 is
(mirror - grating) = 0 pixels in Y (as of August 1997).

The LRIS pointing origin was also redefined so as to point at the center
of the mask in August 1997. Furthermore, the zero point of the
Keck 2 Cass instrument rotator was adjusted at that time based
on tests with star trails to determine the correct value. Contact

CARA for details.

Appendix G Layout of the Mill Coordinate System