Manual of the MEKSY package for SOT-SP & The description of the SOT-SP Level-2 data

MEKSY Team

Ver. 0.6-E

Contents

Chapter 0

Change Log

- Ver. 0.0, 2007. 1. 10. T. Yokoyama (Japanese Ver.)
- Ver. 0.1, 2007. 1. 25. M. Shimojo (Japanese Ver.)
- Ver. 0.2, 2007. 2. 2. Y. Katsukawa (Japanese Ver.)
- Ver. 0.3, 2007. 2. 3. T. Yokoyma (Japanese Ver.)
- Ver. 0.4, 2007. 2. 15. Y. Katsukawa (Japanese Ver.)
- Ver. 0.5, 2007. 3. 5. T.Yokoyama (Japanese Ver.)
- Ver. 0.6, 2013. 2. 13. M. Shimojo for SDAS and Translate to English

Chapter 1

Introduction

1.1 Prefare

The document described how to make Level-2 data from Level-1 data of SOT-SP and how to analyze the Level-2 data.

1.2 What is the Level-2 data?

The SOT-SP Level-2 data is made from the Level-1 data by the following processes.

- Fitting of the Stokes Profile (Based on the Milne-Eddington model)
- Resolving the 180 degree ambiguity of the azimuth angle

The SOT-SP Level1 data are the calibrated full-Stokes profiles.

1.3 Location of the Software Package

The MEKSY package is the software pacakge for deriving the magnetic field vectors from the full-stokes profiles of the Fe lines. The package includes the FORTRAN program for the inversion process and the IDL procedures for the Front-End of the FORTRAN program. In the Solar Data Analysis System (SDAS), Astronomical Data Center/NAOJ, there is the MEKSY software package at the following directory.

```
/nfs/share/soft_develop/sot/sp/sotsp_inv
```

Under the MEKSY directory, there are the following directories for storing the components of the package.

`bin/` Commands and Shellscripts

`data/` data

`idl/` Procedures of IDL

`doc/` Documents

`setup/` Configuration files for IDL

`src/` Sources of the commands

Chapter 2

Setup

2.1 Setup the command path

To use the MEKSY package, you need to add the command path at your configuration file of the shell. When you use “csh” or “tcsh”, please insert the following line in your “.cshrc” file.

```
set path = (/nfs/share/soft_develop/sot/sp/sotsp_inv/bin ${path})
```

Note : In the SDAS, the command path is already inserted in your configuration file. You do not need the additional procedure to use the MEKSY package

Chapter 3

Display the Level-2 data on IDL

3.1 Start up the SSW-IDL included the MEKSY package

In the SDAS, SSW-IDL can be started using the following command.

```
sagami$ SSWidl
```

The command is includes the setup procedure for the SOT-SP and MEKSY packages.

3.2 Read the SOT-SP Level-2 data

The format of the SOT-SP Level-2 data is the FITS format with the IMAGE extension. The special IDL procedure for Level-2 data "sotsp_read_rst" is useful for reading the data.

```
IDL> dir='/nfs/share/soft_develop/sot/sp/sotsp_inv/data/'
IDL> file=dir+'level2/2006/12/11/sprst20061211_031010_007342.fits'
IDL> sotsp_read_rst,file,index,data,idata,coordinates,time,slitpos $
IDL>  ,par_type=par_type,par_unit=par_unit $
IDL>  ,ipar_type=ipar_type,ipar_unit=ipar_unit,straylight=straylight
% READFITS: EOF encountered attempting to read extension 42

Note : You can neglect the warning message ``EOF encounterred ...''.
```

After reading the data using "sotsp_read_rst", there are "data" and "idata" in the memory.

```
IDL> help,data,idata
DATA            FLOAT     = Array[998, 512, 4]
IDATA           LONG      = Array[998, 512]
```

"data" is the flowing array and includes the magnetic field strength, azimuth angle,.... "idata" includes the status of the fitting. The axises of "data" are indicates;

1st axis: the direction of the SOT-SP scanning
(Basically, it is equal to the East-West direction of the Sun)

2nd axis the direction of the y-axis of the SOT-SP CCD
(Basically, it is equal to the North-South direction of the Sun)

3rd axis the parameters of the fitting.

"sotsp_read_rst" has the option "read_level". You can select the parameters that are read into the memory by the option. The option has three levels.

- 0 (default): Magnetic Field Strength, Inclination Angle, Azimuth Angle, Ratio of Scatter Light and Status of Fitting
- 1: Default + Doppler Velocity (6301.5A & 6302.5A), Doppler Width, Ration of Opacities between Line and Continuum, Ratio of Damping Width to Doppler Width、Source Function 、Gradient of Source Function、Width of Macro Turbulent、Doppler Shift of the stray light、Strength of Continuum, Polarization Degree
- 2: All data in the Level-2 data file

3.3 Convert to the MAP format of SSW-IDL

The data of Level-2 can be converted to the MAP format of SSW-IDL using the following command.

```
IDL> sotsp_index2map,index,data,map,par_type,par_unit $
IDL>   ,idata,imap,ipar_type,ipar_unit
```

3.4 Display of the magnetic field vectors

You can display the magnetic field vectors on the map of the normal component of the magnetic field strength using the following commands.

```
IDL> sotsp_mkmag3map,map[0],map[1],map[2],mapbx,mapby,mapbz
IDL> plot_map,mapbz
IDL> plot_vmap,/over,mapbx,mapby $
IDL>,limit=100,scale=0.002,iskip=10,jskip=10 $
IDL>,/sample,index_size=1000
```

"plot_vmap" has the options; "limit" option: the minimum field strength for display, "scale": the size of the arrows, "iskup" & "skip": the interval of the arrows, "sample": display the reference arrow, "inidex_size": the size of the reference arrow.

Chapter 4

Fitting on IDL using the MEKSY Procedures

In the chapter, the procedure of the fitting on IDL is described. Although the commands of the fitting are written by FORTRAN, you can execute the FORTRAN commands from IDL using the MEKSY IDL procedures. Hence, you do not need to consider the FORTRAN programs.

4.1 Basic Procedure

The basic procedure on IDL for the fitting is as follows. The input parameter is only the filenames of the Level-1 data.

Note: If you execute the fitting program along the following procedure, it takes very very long time to complete the fitting. We recommend to use the procedure for the PC cluster that is described in the next section.

```
IDL> files_prof=findfile('./SP3D*.fits')
IDL> sotsp_invprep,files_prof,outfile_stray=file_stray  ; Pre-Process
IDL> sotsp_fit,files_prof,outfile=file_level1_5  ; Fitting
IDL> sotsp_write_rst,file_level1_5,$
IDL>  files_prof,file_stray,outfile=file_level2 ; Post-Process
IDL> sotsp_mkql,file_level2 ; Making the Quick Look Images(PNG)
```

4.2 Procedure for Parallel Processing using the PC Cluster

It takes very long time to complete the process by "sotsp_fit" command. For example, 14 hours are needed for processing the 1k x 1k image by one CPU (x86 3GHz). Hence, SDAS provides you the PC cluster system. The procedure of the fitting using the PC cluster is as follows.

Note: The PC cluster system can be used from “sagami” & “suruga” in SDAS.

```
IDL> files_prof=findfile('./SP3D*.fits')
IDL> sotsp_invprep,files_prof,outfile_stray=file_stray
IDL> sotsp_fit,files_prof,/gridengine $
IDL>   ,outfiles_fitparams=files_fitparams
```

The ”sotsp_fit” procedure automatically submits the jobs to the PC cluster. The command prompt ”IDL>” is come back soon, but the jobs are executing on the PC cluster. You can check the status of the jobs using the `bjobs` UNIX command.

```
IDL> $ bjobs
JOBID   USER    STAT  QUEUE      FROM_HOST   EXEC_HOST   JOB_NAME   SUBMIT_TIME
1980    shimojo RUN   all_japan_ sagami      solar-pc1   MEKSY_p000 Feb 14 08:54
1982    shimojo RUN   all_japan_ sagami      solar-pc1   MEKSY_p002 Feb 14 08:54
1981    shimojo RUN   all_japan_ sagami      solar-pc2   MEKSY_p001 Feb 14 08:54
1983    shimojo RUN   all_japan_ sagami      solar-pc2   MEKSY_p003 Feb 14 08:54
1984    shimojo PEND  all_japan_ sagami                  MEKSY_p004 Feb 14 08:54
1985    shimojo PEND  all_japan_ sagami                  MEKSY_p005 Feb 14 08:54
1986    shimojo PEND  all_japan_ sagami                  MEKSY_p006 Feb 14 08:54
1987    shimojo PEND  all_japan_ sagami                  MEKSY_p007 Feb 14 08:54
1988    shimojo PEND  all_japan_ sagami                  MEKSY_p008 Feb 14 08:54
1989    shimojo PEND  all_japan_ sagami                  MEKSY_p009 Feb 14 08:54
1990    shimojo PEND  all_japan_ sagami                  MEKSY_p010 Feb 14 08:54
1991    shimojo PEND  all_japan_ sagami                  MEKSY_p011 Feb 14 08:54
1992    shimojo PEND  all_japan_ sagami                  MEKSY_p012 Feb 14 08:54
1993    shimojo PEND  all_japan_ sagami                  MEKSY_p013 Feb 14 08:54
1994    shimojo PEND  all_japan_ sagami                  MEKSY_p014 Feb 14 08:54
1995    shimojo PEND  all_japan_ sagami                  MEKSY_p015 Feb 14 08:54
```

When the message is displayed and ”RUN” presents at some of the rows in the 3rd column ”STAT”, your jobs are executing well.

10 minutes later, please execute `bjobs` again.

```
IDL> $ bjobs
No unfinished job found
```

When the message is displayed, your all jobs finish. After completing the jobs on the PC cluster, you need to execute the post-processing, as follows.

```
IDL> sotsp_merge_fmd,files_fitparams, $
IDL>  outfile=file_level1_5 ; Merge of the files
IDL> sotsp_write_rst,file_level1_5,files_prof, $
IDL>  file_stray,outfile=file_level2
IDL> sotsp_mkql,file_level2
```

4.3 Parameters for the "sotsp_fit" procedure

When the parameters of "sotsp_fits" are changed from the default value, you can use the following options.

```
IDL> sotsp_fit,files_prof,verbose=1,i_slit1=3,i_slit2=5, $
IDL>  /flag_output_syn_prof
```

It is an example of using the options of "sots_fits" IDL procedure. The set of the options indicates

- verbose = 1 : message level = 1
- i_slit1=3, i_slit2=5: execute the fitting from slit #3 to slit #5.
- /flag_output_syn_prof: output the stokes profiles that are the result of the fitting.

The other examples of the options are;

```
IDL> sotsp_fit,/norun, ...
  ; make the inputs file for the FORTRAN programs but do not run.
```

```
IDL> sotsp_fit,/gridengine,nprocs=16,queue='all-japan-short', ...
  ; execute the process on the PC cluster. Degree of Parallel is 16
  ; and use ``all-japan-short'' queue.
```

```
IDL> sotsp_fit,/gridengine,/show_message
  ; execute the processes on the PC cluster
  ; and display the progress of the processes
```

Appendix A

Appendix

A.1 The parameter of the fitting.

Note1: Zero of the inclination indicates the direction from Sun to the observer. Note2: Zero of the azimuth indicate the right of the image (the west of the Sun).

```
fieldstrength:   magnetic field strength  (Gauss)
inclination:     inclination (degree)
azimuth:         azimuth (degree)
linestrength:    ratio of the opacity between line and continuum
dopplerwidth:    doppler width (mA)
damping:         ratio of damping width to doppler width
dopplervelocity: doppler velocity (km/s)
sourcefunct:     source function
sourcegrad:      gradient of the source function
macroturbulence: macro turbulence (km/s)
strayfraction:   ratio of stray light
strayshift:      doppler shift of stray light (mA)
```

At the pixels that have weak polarization, only following parameters are used and the other parameters are set to zero.

```
linestrength:      ratio of the opacity between line and continuum
dopplerwidth:    doppler width (mA)
damping:           ratio of damping width to doppler width
dopplervelocity:  doppler velocity (km/s)
sourcefunct:     source function
sourcegrad:      gradient of the source function
macroturbulence: macro turbulence (km/s)
```

A.2 the status of the fitting

```
 0: success of fitting
 1: fitting is not executed by the mask that is made by users.
 2: fail of fitting
 3: anomalous of the profile, or fail of the initial guess
 4: anomalous of the profile, or fail of the initial guess
 5: not enough the photons to the fitting
10: success of fitting (for weak polarized pixel only)
12: fail of fitting (for weak polarized pixel only)
```