Specifications for spectra eligible for

BeSS

(Be Stars Spectra Database)

A collaboration between LESIA (Paris-Meudon Obervatory)
and the ARAS group (amateur astronomers)

Version	Date	Author	Revision
1,3	31/08/2011	F. Cochard	Add indicative resolution (BSS_ESRP, and so on). Precisions on heliocentric velocity correction. Add keyword BSS_SAT. Addition for BeSS format extended usage.
1.2	10/06/2008	F. Cochard	Several important modifications : mandatory resolution, processing ((BSS_VHEL, BSS_COSM, BSS_NORM), limitations in ASCII codes
1.0	22/02/2007	C. Neiner	Addition of informations about echelle and multiobjects spectra and archives of files. Update of the text. Removal of Appendix C. Release of the first official version.
0.4	15/09/2006	S. Dearden	Translation in English
0.3	27/08/2006	F. Cochard	Change of keywords BSS_OBS to BSS_SITE + precision on object definition
0.2	07/072006	F. Cochard	Addition of a few fields, plus other details
0.1	03/04/2006	F. Cochard	First version for internal use

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Introduction

Within the framework of a collaborative effort between professional and amateur astronomers, a team at LESIA laboratory of the Paris-Meudon Observatory initiated a project to create an on-line database of Be stars spectra for the scientific community. This database is compatible with the Virtual Observatory (VO) standard for data queries, i.e. it is accessible through queries defined by VO in addition to being directly accessible via its website. This database authorises not only to download but also to upload spectra on the World Wide Web.

The present document is intended for people who will insert the BeSS format in their softwares or who will prepare spectra to be uploaded in BeSS. The objective is to describe in detail the required characteristics necessary for a spectrum to be accepted in this database, not only the technical requirements (pre-processing, calibration...) but also the formatting aspects (FITS keywords). The present document also describes the processing carried out by the application that integrates spectra in the BeSS database.

This document is equally applicable to spectra yet to be observed (a requirement requested from observers wanting to record stellar spectra with a view to adding them to the database) as well as existing spectra - one of the goals of this tool is to allow better use of the existing data acquired over many previous years.

In the first section, the required characteristics for a spectrum to be eligible for the database are outlined. In the second section, the required FITS file format is described in detail. Finally, a description of the rules used to test FITS files is provided in Appendix.

The BeSS fits file format contains the minimum list of keywords required to upload spectra in the BeSS database. However, since spectra can be used for general exchanges independently from BeSS, at upload BeSS adds some important keywords in the header of the spectra if they are not present yet, based on the observer, instrument, and site records. In particular this concerns the following keywords: RA, DEC, EQUINOX or RADECSYS, TELESCOP, DETNAM, INSTRUME, BSS_LAT, BSS_LONG, BSS_ELEV, BSS_ESRP or BSS_ITRP, and BSS_SRPW. In this way, fits spectra downloaded from BeSS are usable by anyone in other context.

General principles

Before we consider the technical details of this specification, the following general points should be taken into account:

- Spectra are provided to the database in the form of FITS files. The incorporation of a spectrum into the database consists in reading the FITS header information and extracting the keywords to allow the identification of the spectrum.
- All informational elements that describe a spectrum must be given in the FITS file. The incorporation of a spectrum into the database therefore consists of reading and processing of the FITS header file information totally automatically. No manual treatment is involved.
- If a FITS file to be incorporated in the database does not conform to the specification defined in this document, it will be rejected by the database at the time of attempted upload.
- The spectral database is available to amateur as well as professional astronomers. The rules applying to spectra are strictly identical for everyone.
- The first characteristic of a spectral file is to be totally compatible with the official FITS specification as defined at http://fits.gsfc.nasa.gov

- BeSS follows, for FITS keywords, the specification of the FITS consortium, as defined at the above URL. However, certain keywords necessary for the BeSS database have not been defined in these recommendations. In this case, keywords have been defined for the BeSS database and start by the prefix "BSS_".
- In certain cases, the BeSS software application may add informations to the FITS header, but it will never erase information. All data given in the original FITS file header will be saved, even if it is not required for incorporation of the file into the database.
- The remaining of the FITS file (apart from the header) will under no circumstances be modified.
- Any observer adding a spectrum to the BeSS database has to retain independently and without limit of time the raw and calibration images that produced the final spectrum.

I. Requirements for the spectra

There are several types of characteristic parameters for spectra that are defined in the form of FITS keywords. The first parameter type is a mandatory requirement and the submitted spectrum will be rejected if the keyword is absent or incorrect. The second parameter type can be reconstructed from information in other keywords if they are present in the spectrum (e.g. the geographical coordinates of the site of observation can be missing from the FITS header if the name of the site is given and known in the database). In this case, the FITS header will be completed during the automatic integration of the spectrum. The third parameter type is optional: if a keyword is present, it will be taken into account; however if it is absent the spectrum will still be accepted in the database.

1. Strictly mandatory parameters

i. Object

The object has to be a Be star listed in the BeSS catalogue of Be Stars. This catalogue contains all known classical Be stars. (However, if a user thinks a Be stars has been omitted in the BeSS catalogue, the user can contact the administrators.)

ii. Acquisition Parameters

The FITS header must contain the name (in OBSERVER keyword) of at least one author of the spectrum (observer, person who performed the reduction, ...). If this author is already recorded in BeSS, it can be indicated by any name alias known in BeSS.

Iii. Spectral processing

Only pretreated and calibrated spectra can be accepted in the database. The preprocessing consist in the correction of the following elements:
- Dark subtraction
- BIAS (or Offset) correction
- Flat Field correction
- Geometrical corrections (such as rotation, smile, spectral line slant)
- Sky background subtraction
- Spectral extraction
- Linear wavelength calibration

Any other processing (heliocentric velocity, continuum normalization, telluric lines correction, cosmics) is **clearly advised against**. However, a keyword is defined for each of these processing, and indicates if the processing has been performed. If the correction has been done, the matching keyword is mandatory.

Note that "normalization" (defined in keyword BSS_NORM) means that the spectrum is corrected from the continuum (and does not refer to scaling).

About the heliocentric velocity correction.
The convention used for the heliocentric velocity correction (Vhelio) is the redshift one : it is the escape velocity, positive if the Earth is going to the opposite direction to the star.
Lambda_corrected = Lambda_initial * (1 - Vhelio / c), where c is the velocity of light.
Two keywords are used for the heliocentric velocity correction : the 'actual correction' (in BSS_VHEL, mandatory) and the 'correction to be applied' (in BSS_RQVH, optional).
The 'correction to be applied' is calculated from the stellar coordinates, observing site coordinates, and observing date & time.
If the velocity is not heliocentrically corrected (preferred), the 'actual correction' keyword

(BSS_VHEL) contains "0".

If the correction has been performed (advised against), the 'actual correction' should be equal to 'velocity to be applied'.

If 'correction to be applied' is not present, BeSS will add it in the header.

2. Requested parameters

i. Object

The object must be identified:

– either by its coordinates (Right ascension RA and declination DEC) in the FK5 system and equinox 2000, with a precision of at least 0.2 arcseconds. In addition to RA and DEC coordinates, at least one of the two other parameters "2000" (equinox) or the "FK5" (coordinate system) must be included,

– or by any of the names of the object.

ii. Acquisition parameters

– At least two of the three following parameters must be included in the FITS file header of the spectrum:

1. The UT date and time of the start of exposure (in DATE-OBS), with a precision of at least one second.
2. The UT date and time of the end of exposure (in DATE-END), with a precision of at least one second.
3. The total exposure time (in EXPTIME). This exposure time corresponds to the duration from the start to end of the acquisition. In the case of co-added multiple exposures, it is not the effective exposure time (the real time the CCD was exposed to light) but the total acquisition time between the start of the first exposure and the end of the last exposure. This data will be used in the temporal analysis of Be stars.

– In a spectrum has been taken from the ground, the FITS header must contain either the name of the observing site (in BSS_SITE), or the coordinates of this site (latitude in BSS_LAT, longitude in BSS_LONG, and altitude in BSS_ELEV). Note that the database includes a list of observing sites already known to BeSS. If you indicate the name of the site rather than its coordinates, this name has to be exactly the same as the one recorded in BeSS.

– If a spectrum has been taken by a satellite, the satellite name is given in a separate keyword (BSS_SAT), instead of the observing site. In this case, the observing site form will contain satellite data (apogee, perigee, period).

– The FITS header must contain either the name of the equipment used (in BSS_INST), or the name of each parts of this equipment (telescope in TELESCOP, spectrograph in INSTRUME, CCD camera in DETNAM). Note that the database includes a list of equipments already known to BeSS. If you indicate the name of the equipment rather than its parts, this name has to be exactly the same as the one recorded in BeSS. The concept of equipment is used in its broadest sense: it represents the whole observing setup (telescope + spectrograph + detector CCD) employed in the acquisition of the spectrum. When one piece of equipment can be set up in more than one configuration (e.g. several gratings for one spectrograph), it is mandatory to define each different configuration as different equipments in BeSS.

– The FITS header should contain the real spectral resolution (in BSS_ESRP), and the wavelength used for calculation (in BSS_SRPW). This value should be close to the typical resolution of instrument (defined in the Instrument record). If the spectral resolution is significantly different

from the typical instrument resolution (e.g. if the spectrum has been binned), the reason / method for binning should be given (in BSS_BINN). If the real resolution is not given in the header, BeSS will add in the spectrum header a separate keyword (BSS_ITRP) containing the typical resolution of the instrument used to obtain the spectrum (as an indication).

–   BeSS accepts echelle spectra. In order to upload an échelle spectrum in BeSS, it is necessary to separate them into individual orders and to save each order in the form of a FITS file that respects the BeSS format described here. In order to keep the orders associated, the keyword BSS_ORD is defined, that provides the root of the name of the order files for an échelle spectrum.

Example: BSS_ORD = OHP20030808_obj0013n
Then, all the FITS files of the different spectral orders must be named as:
OHP20030808_obj0013n*.fits, where * is the order number.
If this keyword is not present, the spectrum is considered as a simple spectrum and not an échelle spectrum. The order numbers must include at least as many digits as the greatest order number of the échelle spectrum. For example, if the orders extend from 1 to 123, one should write 001 to 123 (or 0001 to 0123...).

–   BeSS accepts spectra obtained with multiobject instruments. In order to upload a spectrum obtained with a multiobject instrument in BeSS, it is necessary to separate them into individual spectra and to save each spectrum in the form of a FITS file that respects the BeSS format described here. In order to keep the spectra associated, the keywords BSS_FLD, BSS_FRA and BSS_FDEC, which provide the diameter of the field of view of the multiobject instrument and the (RA and DEC) coordinates of the centre of the observed field, are defined.

3. Optional parameters

i. Object

It is possible to indicate in the spectrum header the projected rotational velocity (vsini), V magnitude and/or spectral type of the star, if you have precise information about those values. If these data are not yet present in the BeSS catalogue of Be stars, they will then be added.

ii. Processing of the spectrum

Certain parameters are deliberately ignored on purpose by BeSS:
- The flux calibration
- The signal-to-noise (S/N) ratio, which depends too highly on the measurement method.

If these informations are present in the FITS header of a spectrum, they will be kept, but BeSS will not used them.

II. Format for Spectra and the FITS File

The requirements described previously are fulfilled by incorporating specific keywords in the FITS file header. In this section, we move on to describing the details of these keywords as well as the possible allowed values. We also indicate which unit to use for each keyword.

The first criterion that the FITS file for a spectrum must fulfil is to satisfy fully the FITS specification (http://fits.gsfc.nasa.gov). In particular a line of a FITS header contains only three fields: the keyword, its value, and a possible comment. The keywords can appear in any order in the header.

Reminder : in a FITS keyword, only ASCII characters between 20 and 7E (hex) are accepted.

All keywords not explicitly mentioned in this document will be ignored by the application. In no circumstances can these additional keywords be the cause of rejection of a spectrum by BeSS.

Only those FITS files that have a single HDU (Header Data Unit) are taken into account. Moreover, only 1D spectra are accepted. The keyword **NAXIS** must therefore take the value 1.
However, BeSS accepts archives of such FITS files, either .zip archives or .tar.gz archives, as long as these archives are not bigger than 15 Mb. In this way a user can upload in BeSS several spectra in one go. Note, however, that if one spectrum of the archive does not respect the format described here, all the spectra of the archive will be rejected.

1. Object

Right Ascension
- Keyword = RA (mandatory except if the object is defined only by its name)
- Format = float
- Units = decimal degrees
- Valid Range = 0 – 360
- Example: 269.076867

Declination
- Keyword = DEC (mandatory except if the object is defined only by its name)
- Format = float
- Units = decimal degrees
- Valid Range = -90 to +90
- Example: +42

Equinox
- Keyword = EQUINOX (optional if RADECSYS is present or if the object is defined only by its name)
- Format = float
- Units = none
- Valid Range = 2000
- Example: 2000.

Coordinate system
- Keyword = RADECSYS (optional if EQUINOX is present or if the object is defined only by its name)
- Format = char

- Units = none
- Valid Range = FK5
- Example: FK5

Object name
- Keyword = OBJNAME (mandatory except if the object if defined by RA, DEC, EQUINOX/RADECSYS)
- Format: char
- Units: none
- Valid Range: ASCII displayable characters
- Example: "HD 37490" or "EM* MWC 9"

Object spectral type
- Keyword = BSS_STYP (optional)
- Format: char
- Units: none
- Valid Range: ASCII displayable characters
- Example: "B3IVpe"

Vsini
- Keyword = BSS_VSIN (optional)
- Format: real
- Units: km/s
- Valid Range: 0 - 1000
- Example: 335

Object V magnitude
- Keyword = BSS_VMAG (optional)
- Format: real
- Units: none
- Valid Range: -27 - +30
- Example: 6.54

2. Acquisition Conditions

Date-Time of start of exposure
- Keyword = DATE-OBS (mandatory except if DATE-END and EXPTIME are present)
- Format: char (70 char max)
- Mandatory format: yyyy-mm-ddThh :mm:ss[.ss…]
- Example: 2006-02-25T13 :34 :43.5543

Date-Time of End of Exposure
- Keyword = DATE-END (mandatory except if DATE-OBS and EXPTIME are present)
- Format: char (70 char max)
- Mandatory format: yyyy-mm-ddThh :mm:ss[.ss…]
- Example: 2006-02-25T13 :34 :43.5543

Exposure Time
- Keyword = EXPTIME (mandatory except if DATE-OBS and DATE-END are present)
- Format: float
- Units: seconds
- Valid Range: >= 0

- Example: 323.54

Equipment name
- Keyword = BSS_INST (mandatory, except if TELESCOP, DETNAM and INSTRUME are present)
- Format: char (40 characters max)
- Example: C11 + LhiresIII (2400lpm) + Audine C. Buil

Telescope
- Keyword = TELESCOP (mandatory except if BSS_INT is present)
- Format: char (40 characters max)
- Example: C11

Detector
- Keyword = DETNAM (mandatory except if BSS_INT is present)
- Format: char (40 characters max)
- Example: Audine

Spectrograph
- Keyword = INSTRUME (mandatory except if BSS_INT is present)
- Format: char (40 characters max)
- Example: Elodie

Observation Site Name
- Keyword = BSS_SITE (mandatory, except if BSS_LAT, BSS_LONG and BSS_ELEV are present or if BSS_SAT is present)
- Format: char (40 characters max)
- Example: OHP 193

Latitude of the observation site
- Keyword = BSS_LAT (mandatory, except if BSS_SITE or BSS_SAT is present)
- Format: real
- Units: decimal degrees
- Valid Range: -90 - +90
- Example: 45.54

Longitude of the observation site
- Keyword = BSS_LONG (mandatory, except if BSS_SITE or BSS_SAT is present)
- Format: real
- Units: decimal degrees
- Valid Range: 0 - 360
- Example: 15.35

Altitude of the observation site
- Keyword = BSS_ELEV (mandatory, except if BSS_SITE or BSS_SAT is present)
- Format: real
- Units: meter
- Valid Range: 0 - 9000
- Example: 1234.56

Satellite, if spectrum taken from a satellite
- Keyword = BSS_SAT (mandatory for a satellite)

- Format: char
- Units: none
- Valid Range: ASCII displayable characters (40 characters max).
- Example: IUE

Observer
- Keyword = OBSERVER (mandatory)
- Format: char
- Names must be comma delimited; ASCII character set only
- Note: There can be more than one observer defined by the same keyword.
- Example: "Christian Buil, Valerie Desnoux"

Reference wavelength
- Keyword = CRVAL1 (mandatory). *This keyword defines the wavelength for the reference pixel given in CRPIX1 (see below).*
- Format: real
- Units: Angstrom or nm
- Valid Range: 300 - 10000
- Example: 6233.45

Dispersion
- Keyword = CDELT1 (mandatory)
- Format: real
- Units: Angstrom/pixel or nm/pixel
- Valid Range: >0 and < 30
- Example: 0.116

Reference pixel for the reference wavelength
- Keyword = CRPIX1 (mandatory). *This keyword defines the pixel where reference wavelength (CRVAL1) is given. It is usually the first pixel of the image – in this case, value is 1.*
- Format: floating point
- Units: none
- Valid Range: no limit
- Example: 1.0

Unit of wavelength
- Keyword: CUNIT1 (mandatory)
- Format: char
- Units: none
- Valid Range: "Angstrom, nm"
- Example: "nm"

Type of X data
- Keyword: CTYPE1 (mandatory, axis format)
- Format: char
- Units: none
- Valid Range: "wavelength"
- Example: "wavelength"

Effective Spectral Resolving Power
- Keyword = BSS_ESRP (optional)

- Format : real
- Unit: none
- Valid Range : positive
- Example: 17000

Instrument Typical Resolving Power
- Keyword = BSS_ITRP (optional)
- Format : real
- Unit: none
- Valid Range : positive
- Example: 17000

Spectra Resolving Power Wavelength (reference wavelength for resolution calculation)
- Keyword = BSS_SRPW (optional)
- Format : real
- Unit: unit defined by CUNIT1
- Valid Range : positive
- Example : 6563

Binning
- Keyword = BSS_BINN (mandatory if effective resolution is significantly different from instrument typical resolution). This keyword gives the reason for binning and/or the method used.
- Format : char
- Unit : none
- Valid Range : ASCII displayable characters (40 char. max)
- Example : "Poor SNR, binned with fixed step of 5nm"

Root name of the échelle order spectra
- Keyword = BSS_ORD (mandatory if it is an echelle spectrum)
- Format = char
- Unit = none
- Valid Range = ASCII displayable characters
- Example: OHP20030808_obj0013n

Field diameter for a multiobject spectrum
- Keyword = BSS_FLD (mandatory if it is a multiobject spectrum)
- Format: float
- Units: decimal degrees
- Valid Range: 0.0003 - 5
- Example : 0.417

Right ascension of the center of the field for a multiobject spectrum
- Keyword = BSS_FRA (mandatory if it is a multiobject spectrum)
- Format: float
- Units: decimal degrees
- Valid Range: 0 - 360
- Example: 12.34

Declination of the center of the field for a multiobject spectrum
- Keyword = BSS_FDEC (mandatory if it is a multiobject spectrum)
- Format: signed float

- Units: decimal degrees
- Valid Range: -90 - +90
- Example: +20.56

3. Processing

Applied heliocentric correction
- Keyword = BSS_VHEL (mandatory)
- Format: signed float
- Units: km/s
- Valid Range: -200 to +200 (BSS_VHEL is the escape velocity, or redshift)
- Example: -9.45

Heliocentric correction to be applied
- Keyword = BSS_RQVH (optional)
- Format: signed float
- Units : km/s
- Valid Range : -200 - +200 (BSS_RQVH is the escape velocity, or redshift)
- Example : -9.45

Atmospheric line correction
- Keyword = BSS_TELL (mandatory if correction has been performed)
- Format: char
- String describing the process employed :
  - "none" if no correction is applied (preferred),
  - "removed, no indication of method" (if method is unknown),
  - "methodxx", where methodxx is a clear description of method used, when it is known.
- Example: "correction of atmospheric lines with the file h2o.dat"

Cosmic rays removal
- Keyword = BSS_COSM (mandatory if correction has been performed)
- Format: char
- String describing the process employed :
  - "none" if no correction is applied (preferred),
  - "removed, no indication of method" (if method is unknown),
  - "methodxx", where methodxx is a clear description of method used, when it is known.
- Example: "correction of cosmic ray strikes by sigma-kappa"

Continuum normalisation
- Keyword = BSS_NORM (mandatory)
- Format: char
- String describing the process employed :
  - "none" if no correction is applied (preferred),
  - "corrected, no indication of method" (if method is unknown),
  - "methodxx", where methodxx is a clear description of method used, when it is known.
- Example: "normalised with the IRAF continuum routine (spline 3 order 2)"

Appendix A: The keywords and rule file

The software application that integrates spectra into the BeSS database is required to verify all the above keywords and rules in order to guarantee the integrity of the database. This is carried out by a generic routine that reads and decodes a rule file that describes in detail the various elements. The file syntax is as follows:

If the first character is a parenthesis then it is a rule.
Otherwise the line is the description of a keyword.

A rule contains keywords or keyword sets in parentheses separated by operators.
The recognised operators are:
- the comma, that acts as the AND operator,
- the ¦ sign, that acts as the OR operator,
- the ^ sign, that acts as the XOR operator,
- the ! sign, that acts as the NOT operator.

The rule ends with the character E or W according to whether it is associated with an error (E) or a warning (W) while attempting to insert a spectrum in BeSS.

Keyword descriptions are composed of 3 fields separated by an undefined number of spaces or tabs.

Field 1 is the keyword name.
Field 2 is the keyword type (int, flt, str, date, bool), not case sensitive.
Field 3 is the range of validity:
- for int and flt, the range is [min:max] or [val1,val2,val3]
- for str, the range is [min_num_of char:max_num_of_char] or [str1,str2,str3]
- for dates, a format name defined in the programme and placed between braces {} is required
- for bool, the range is [T,F].
- if there are no limit, the range is []

Appendix B: File Contents and Rules

The rules file content is as follows:
SIMPLE   bool   [T]
BITPIX   int   [8,16,32,-32,-64]
NAXIS   int   [1:1]
(NAXIS) E
NAXIS1   int   [1:500000]
(NAXIS1) E

RA   flt   [0:+360]
DEC   flt   [-90:+90]
EQUINOX flt   [2000]
RADECSYS str   [FK5]
OBJNAME str   [1:40]
(RA, DEC, (EQUINOX|RADECSYS)) | (OBJNAME) E
(!((OBJNAME) , (RA | DEC | EQUINOX | RADECSYS))) W
DATE-OBS date [{DATE_ISO}]
DATE-END date [{DATE_ISO}]
EXPTIME flt   [0:20000]
(DATE-OBS,DATE-END)|(DATE-OBS,EXPTIME)|(EXPTIME,DATE-END) E
((!DATE-OBS)|(!DATE-END)|(!EXPTIME)) W
CRVAL1   flt   [300:10000]
CDELT1   flt   [1E-4:30]
CRPIX1   flt   []
CTYPE1   str   [Wavelength]
CUNIT1   str   [Angstrom,nm]
(CRVAL1, CDELT1, CRPIX1, CTYPE1, CUNIT1) E
OBSERVER str   []
(OBSERVER) E

BSS_INST str   [1:40]
TELESCOP str   [1:40]
DETNAM   str   [1:40]
INSTRUME str   [1:40]
(BSS_INST) | (TELESCOP, INSTRUME, DETNAM) E
(!((BSS_INST) , (TELESCOP | INSTRUME | DETNAM))) W

BSS_SITE str   [1:40]
BSS_LAT flt   [-90:+90]
BSS_LONG flt   [0:+360]
BSS_ELEV flt   [-200:+5500]
(BSS_SITE) | (BSS_LAT, BSS_LONG, BSS_ELEV) E
(!((BSS_SITE) , (BSS_LAT | BSS_LONG | BSS_ELEV))) W
BSS_VHEL flt   [-200:+200]
(BSS_VHEL) E
BSS_TELL str   []
BSS_COSM str   []
BSS_NORM str   []
BSS_STYP str   []
BSS_VSIN flt   [0:1000]

BSS_VMAG flt   [-27:30]
BSS_ORD str   []
BSS_FLD flt   [0.0003:1]
BSS_FRA flt   [0:+360]
BSS_FDEC flt   [-90:+90]
BSS_RQVH flt [-200:+200]
BSS_ESRP flt []
BSS_ITRP flt []
BSS_SRPW flt []
BSS_BINN str []