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Definition of Keck Interferometer Level 1 data FITS files

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1.   Introduction

This document describes the FITS (Flexible Image Transport System) format specification used for the Keck Interferometer (KI) Level 1 data. For more information on FITS, see "Definition of the Flexible Image Transport System (FITS)", Astronomy & Astrophysics, vol. 376, p. 359. Currently this standard covers the Level 1 data for the visibility amplitude, or V^2 mode, but will be extended to other KI modes. In this document, the Level 1 V^2 format will be referred to as KIV2_L1. KI Level 1 data are time-averaged visibility data (typically representing 5 seconds of data) with instrumental biases removed and are fully described at http://msc.caltech.edu/KISupport/v2/KIV2dataProducts.html. The V^2 mode is described in detail in "Fringe Visibility Estimators for the Palomar Testbed Interferometer", by M. Colavita, Pub. of the Astronomical Society of the Pacific, vol. 111, p.111.

Files in this format are produced from the standard Level 1 files and may be used as input for the Level 2 processing programs for KI data (wbCalib and nbCalib). KIV2_L1 files are intended primarily for recording the KI Level 1 data necessary for the calibration stage (Level 2) in a format familiar to the astronomical community. Each KIV2_L1 file contains data from only 1 night, but multiple files may be given as input to the Level 2 processing programs. KIV2_L1 files are produced via the MSC Level 1 database. See the KI Support page (http://msc.caltech.edu/KISupport/index.html) for instructions.

Note that for Level 2 data, the MSC uses the FITS defintion adopted by the International Astronomical Union (IAU) working group on optical interferometry. This format is for distributing calibrated visibility data. See http://www.mrao.cam.ac.uk/ jsy1001/exchange/ for more details.

2.   FITS file structure

The structure of a generic FITS files consists of the primary header and data unit (HDU) followed by extensions, which are optional. The data in KIV2_L1 files are given in binary table extensions. The header information is given as keyword/value/comment sets. The keywords used are standard FITS keywords where appropriate (ORIGIN, OBJECT) and are Level 2 IAU standard keywords where appropriate.

A valid KIV2_L1 FITS file must contain one KI_BASELINE table, at least one KI_SOURCE table and one or more KI_SUM or KI_SPEC tables. The KI_ANC and KI_CALIB tables are optional. These tables are defined in the following sections, which contain lists of keywords or column headings, data values or types

and descriptions. Allowed data types are: I = integer (16 bit), A = character, E = real (32-bit), D = double (64-bit) and L = logical.

2.1.   Header keywords

The primary HDU header is composed of the following keywords and comes at the beginning of the file. The first 4 keywords are required by the FITS format definition. The HISTORY lines contain the information from the info file (see Level 1 file defintions).

SIMPLE	L	Does the file conform to FITS standards
BITPIX	I	Number of bits used for pixel values
NAXIS	I	Number of axes in the array, = 0 in this case
EXTEND	L	Can the dataset contain extensions
ORIGIN	A	Institution that originated this FITS file
TELESCOP	A	Telescope that made the observations
INSTRUME	A	Instrument that made the observations
INSTMODE	A	Instrument observing mode
FITSDATE	A	Date FITS file was written (YYYY-MM-DD)
FILENAME	A	FITS file name
HISTORY	A	Lines describing the version of software used to produce the Level 1 data
COMMENT	A	Contact information
END		

3.   Table specifications

All KIV2_L1 tables are in the FITS binary table format. The data items are represented in separate columns. This is version 2 (Keyword KIV2_VER), which contains major revisions from version 1 (see Appendix 1).

3.1.   KI_BASELINE

This table conveys the baseline information in the form of the ENU (East, North, Up) vector and a bias term. This information is necessary to calculate the u and v spatial frequencies of a given observation. Additionally, this table contains a baseline name and time information which allows data from the KI_VIS2 table to be matched with the data from other tables. The table contains one row for each baseline from only one telescope array.

Keywords

	KIV2_VER	I	KI V^2 Level 1 FITS version number
	EXTNAME	A	Extension name
	ARRNAME	A	Array name for the baseline(s), ex. Keck Interferometer

Column Headings

	BASELINE_NAME	A(20)	Unique name for each baseline
	DATE	A(10)	Date of baseline specification (format YYYY-MM-DD)
	TIME	D	UTC time of baseline specification (seconds)
	E	D	Baseline East component (meters)
	N	D	Baseline North component (meters)
	U	D	Baseline Up component (meters)
	C	D	Baseline bias term (meters)
	BASELINE_ORIG	A(7)	Origin of baseline terms. Values are DEFAULT (no baseline telemetry was present), PRESET (baseline from telemetry) and BFIT (baseline calculated by bFit program)

3.2. KI_SUM

The KI_SUM table contains the values from a V^2 sum file in a binary table. Each column of the sum file is represented as a column in the KI_SUM table. In addition, there is a BASELINE_NAME which must correspond to a row in the KI_BASELINE table. Each sum record is contained in one row of the table. All columns without specified units are dimensionless.

Keywords

KIV2_VER	I	KI V^2 Level 1 FITS version number
EXTNAME	A	Extension name

Column Headings

MJD	D	Modified Julian Day
TIME	D	UTC time (seconds)
OBJECT	A(32)	Source name
FDL_DELAY	D	Fast delay line optical path (meters)
LDL_DELAY	D	Long delay line optical path (meters)
WB_NPH	D	Wide-band photon flux (DN)
WB_INCV2	D	Wide-band incoherent V^2
WB_COHV2	D	Wide-band coherent V^2
WB_WAVELENGTH	D	Wide-band wavelength (microns)
SP_NPH	D	Summed spectrometer photon flux (DN)
SP_INCV2	D	Summed spectrometer incoherent V^2
SP_COHV2	D	Summed spectrometer coherent V^2
SP_WAVELENGTH	D	Summed spectrometer wavelength (microns)
JITTER	D	Phase jitter (radians)
NFRAMES	I	Number of frames
NLOCKS	I	Number of locks
FRAC_LOCK	D	Fractional time locked
FTRATE	I	Fringe tracker rate (Hz)
WB_RC	D	Wide-band ratio correction
SP_RC	D	Summed spectrometer ratio correction
CALFLAG	I	Calibration flag
INT_TIME	D	Integration time (seconds)
BASELINE_NAME	A(20)	Baseline name, must correspond to an entry in the KI_BASELINE table

3.3. KI_SPEC

The KI_SPEC table contains the values from a V^2 spec file in a binary table. Each column of the spec file is represented as a column in the KI_SPEC table. The BASELINE_NAME column must correspond to a row in the KI_BASELINE table. Each spec record is contained in one row of the table. All columns without specified units are dimensionless. The number of columns will vary with the number of spectrometer channels.

Keywords

	KIV2_VER	I	KI V^2 Level 1 FITS version number
	EXTNAME	A	Extension name

Column Headings

	MJD	D	Modified Julian Day
	TIME	D	UTC time (seconds)
	OBJECT	A(32)	Source name
	FDL_DELAY	D	Fast delay line optical path (meters)
	LDL_DELAY	D	Long delay line optical path (meters)
	JITTER	D	Phase jitter (radians)
	FTRATE	I	Fringe tracker rate (Hz)
	CALFLAG	I	Calibration flag
	INT_TIME	D	Integration time (seconds)
	BASELINE_NAME	A(20)	Baseline name, must correspond to an entry in the KI_BASELINE table
	NCHAN	I	Number of spectrometer channels

For each channel (n), where n starts at 1

	CHn_WAVELENGTH	D(8.6)	Spectrometer channel n wavelength (microns)
	CHn_NPH	D	Spectrometer channel n photon flux (DN)
	CHn_INCV2	D	Spectrometer channel n incoherent V^2
	CHn_COHV2	D	Spectrometer channel n coherent V^2
	CHn_RC	D	Spectrometer channel n ratio correction

3.4.   KI_SOURCE

This table contains information about the target sources and is optional. Included is coordinate and size information used in the calibration stage (Level 2 processing). Each source is listed on a separate line. If values for proper motion, parallax and angular size are not available from the data set, a value of 0 will be given.

Keywords

	KIV2_VER	I	KI V^2 Level 1 FITS version number
	EXTNAME	A	Extension name

Column Headings

	OBJECT	A(32)	Source Name
	RA	D	Right ascension at equinox (degrees)
	DEC	D	Declination at equinox (degrees)
	EQUINOX	F	Equinox
	PMRA	D	Proper motion in right ascension (degree/yr)
	PMDEC	D	Proper motion in declination (degree/yr)
	PARALLAX	D	Parallax (degree)
	DIAM	D	Angular size (milliarcsec)
	DIAMERR	D	Error in angular size (milliarcsec)
	SPECTYP	A	Spectral type
	ROLE	A(3)	Source role, allowed values are TRG and CAL
	CALFOR	A(32)	If ROLE = CAL, name of target source for which this object is a calibrator

3.5.   KI_ANC

The KI_ANC table contains the values from a V^2 ancillary data file in a binary table. Each column of the anc file is represented as a column in the KI_ANC table, except the V^2 and photon count values which are given in the KI_SUM table. Each anc record is contained in one row of the table. All columns without specified units are dimensionless.

Keywords
	KIV2_VER	I	KI V^2 Level 1 FITS version number
	EXTNAME	A	Extension name

Column Headings
	MJD	D	Modified Julian Day
	TIME	D	UTC time (seconds)
	OBJECT	A(32)	Source name
	WL_NRMS	D	Wide-band flux rms/mean
	WL_RATIO	D	Wide-band flux ratio (Keck 1/Keck 2)
	SP_RATIO	D	Averageg spectrometer ratio (Keck 1/Keck 2)
	ST1_NPH	D	Star tracker 1 flux (DN)
	ST2_NPH	D	Star tracker 2 flux (DN)
	STRATE	I	Star tracker rate (Hz)
	K1_AZIM	D	Keck 1 azimuth (radians)
	K1_ELEV	D	Keck 1 elevation (radians)
	K1_AZIMER	D	Keck 1 azimuth error (radians)
	K1_ELEVER	D	Keck 1 elevation error (radians)
	K2_AZIM	D	Keck 2 azimuth (radians)
	K2_ELEV	D	Keck 2 elevation (radians)
	K2_AZIMER	D	Keck 2 azimuth error (radians)
	K2_ELEVER	D	Keck 2 elevation error (radians)
	AO1_NPH	D	Keck 1 AO wave-front sensor photon flux
	AO1_RATE	I	Keck 1 AO correction loop rate (Hz)
	AO1_DTGN	D	Keck 1 AO tip-tilt loop gain
	AO1_DMGN	D	Keck 1 AO deformable mirror loop gain
	AO2_NPH	D	Keck 2 AO wave-front sensor photon flux
	AO2_RATE	I	Keck 2 AO correction loop rate (Hz)
	AO2_DTGN	D	Keck 2 AO tip-tilt loop gain
	AO2_DMGN	D	Keck 2 AO deformable mirror loop gain
	ST1_RMS	D	Star tracker jitter RMS for Keck 1
	ST2_RMS	D	Star tracker jitter RMS for Keck 2

3.6. KI_CALIB

The KI_CALIB table contains the values from a V^2 calib data file in a binary table. All columns without specified units are dimensionless. Note that due to the format of the ratio file (see http://msc.caltech.edu/KISupport/v2/calib.html) not all columns are present for all rows. Null values (NaN) are used for columns not relevant to a particular row.

Keywords

	KIV2_VER	I	KI V^2 Level 1 FITS version number
	EXTNAME	A	Extension name

Column Headings

	TIME	D	UTC time (seconds)
	OBJECT	A(32)	Source name
	CAL_MODE	A(32)	Calibration mode
	CHAN	I	Channel number
	X	D	X quadrature value or bias (DN)
	Y	D	Y quadrature value or bias (DN)
	N	D	Photon count or bias (DN)
	NUM	D	Energy measure (X^2+Y^2) (DN)
	B_RN	D	Read noise bias (DN)
	DN_PER_PHOT	D	DN per electron
	PHOT_RATIO	D	Keck 1/Keck 2 photon ratio
	RATIO_CORR	D	Ratio correction
	FREQUENCY	D	(Hz) [Mid-IR V2 Observations only]
	PHI	D	(Rad) [Mid-IR V2 Observations only]

A.   Sample Header

When we have one...

B.   Version history

B.1.   Version 2.1

- Add string length specifiers to column definitions where missing in KI_BASElINE and KI_CALIB tables.

- Add additional KI_CALIB column definitions for Mid-IR V2 observations.

- Add additional KI_ANC column definition for star tracker jitter RMS.

- Add header keywords TELESCOP and INSTMODE.

B.2.   Version 2

- Change time fields to MJD and UTC seconds.

- Add header keywords to main HDU containing processing history and data origin information.

- Add KI_ANC table.

- Add KI_CALIB table.

- Change SOURCE table keywords to match Level 2 standard.