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Panel discussion: next steps for OIFITS

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ABSTRACT

The second version of the optical interferometry data exchange format (OIFITS 2) was published in January 2017. OIFITS 2 was intended to address the needs of future interferometric instruments, allow description of correlated measurement errors, and standardize header keywords for bookkeeping and data discovery. We report on a panel discussion held during the conference “Optical and Infrared Interferometry and Imaging VI” with the aims of raising awareness of OIFITS 2, identifying any difficulties in migrating to the new version, and planning for future development of OI data standards.

1. INTRODUCTION

A data exchange standard for optical (visible and infrared) interferometry, OIFITS, was developed during 2002 to 2003, and published in 2005.¹ OIFITS is a registered FITS convention*, built on top of the standard astronomical FITS file format.^{2,3} Version 1 of the OIFITS standard was adopted by all of the major astronomical optical interferometers operating at that time, including COAST, NPOI, IOTA, CHARA, VLTI, PTI and the Keck Interferometer.

Discussions to define a new version of OIFITS began in 2010. Contributions were invited from the entire optical interferometry community, and discussion of a series of draft standards was coordinated using a wiki page. This definition process was completed during 2014. The OIFITS 2 standard was finally published in 2017.⁴ The new version introduces primary header keywords for data discovery, a more precise specification of differential visibility data, support for describing instrumental polarisation and correlations between data, and the possibility of storing flux measurements. Updated versions of the 2017 OIFITS 2 standard are released on arXiv at <https://arxiv.org/abs/1510.04556>. One update has been released since Ref. 4 was published, on 6th September 2017. This update removes the redundant DATE-OBS keyword from the OI_INSPOL table and makes minor corrections to the explanatory text.

The FITS tables defined by OIFITS 2 and their purpose are summarised in Table 1. Version 2 introduces *mandatory* primary header keywords to summarise the provenance and content of the dataset, new *mandatory* columns in OI_ARRAY giving the photometric field-of-view (FOV) of each array element, and new *optional* keywords and columns in OI_VIS to enable storage of properly-identified complex coherent fluxes, complex visibilities, and differential chromatic visibilities. Three new *optional* tables are defined. The OI_FLUX table allows storage of raw or calibrated flux measurements. The OI_CORR and OI_INSPOL tables describe the correlations and instrumental polarisation of the data stored in OI_VIS, OI_VIS2, OI_T3 and OI_FLUX tables.

At the time of writing, OIFITS 2 has been adopted by the GRAVITY and MATISSE second-generation instruments at VLTI. The following software libraries for reading and writing OIFITS 2 are available on GitHub:

oifitslib C library maintained by John Young: <https://github.com/jsy1001/oifitslib>

OITools Java library maintained by JMMC: <https://github.com/JMMC-OpenDev/OITools>

YOIFITS Yorick library maintained by Éric Thiébaud: <https://github.com/emmt/YOIFITS>

OIFITS.jl Julia library maintained by Éric Thiébaud: <https://github.com/emmt/OIFITS.jl>

A validation tool supporting both versions 1 and 2 of the OIFITS standard has been written by JMMC. This is available as a web application at <http://oival.jmmc.fr/index.html>. Example output from the validator is shown in Fig. 1.

JMMC OIFits Validator Help

Aspro2_Altair_MIRC_GT_1_47493-1_75256-8ch_S1-S2-E1-E2-W1-W2_2018-08-02_FAKE.fits Granules (1) Primary HDU keywords (40) Check report OI_Tables (6)

TOP / OIFits / Granules

target_name	s_ra	s_dec	l_exptime	l_min	l_max	em_res_power	em_min	em_max	facility_name	instrument_name
Altair	297.6962729166666	8.868321194444444	300.0	58332.21246957373	58332.29578990722	40.68705	1.4749312E-6	1.7525688E-6	CHARA	MIRC_GT_1_47493-1.75256-8ch

TOP / OIFits / Check report

Analysing File: jmmc-olexplorer181555335490237662viewer
Analysing table [OI_VISA4]
INFO Skipping non-standard OIFITS column 'OI_VISA4_VISDATA' with format [RC]
INFO Skipping non-standard OIFITS column 'OI_VISA4_VISERR' with format [RC]
0 warnings, 0 severe errors

Details on failures...

TOP / OIFits / Primary HDU keywords

Display primary HDU keywords (40)

TOP / OIFits / OI_Tables

This file gets 6 OI tables:
#1 OI_TARGET #2 OI_ARRAY #3 OI_WAVELENGTH #4 OI_VIS #5 OI_VISA #6 OI_T3

TOP / OIFits / Tables / #1 OI_TARGET (1 rows)

Keywords

name	value	description	type	unit
EXTNAME	OI_TARGET	extension name	A	
NAXIS2	1	number of table rows	J	
EXTVER	1	extension version	J	
OI_REVN	1	revision number of the table definition	J	

Table data

TARGET_ID	TARGET	RAEPO [degrees]	DECEO [degrees]	EQUINOX [years]	RA_ERR [degrees]	DEC_ERR [degrees]	SIYSVEL [meters / second]	VELTYP	VELDEF	PMRA [degrees / year]	PMDEC [degrees / year]	PMRA_ERR [degrees / year]	PMDEC_ERR [degrees / year]	PARALLAX [degrees]	PARA_ERR [degrees]	SPECTYPT
1	Altair	297.696	8.868	2000	0	0	-26600	UNKNOWN	OPTICAL	1.49E-4	1.07E-4	0	0	5.415E-5	1.583E-7	A7/n

TOP / OIFits / Tables / #2 OI_ARRAY (6 rows)

Keywords

name	value	description	type	unit
EXTNAME	OI_ARRAY	extension name	A	
NAXIS2	6	number of table rows	J	
EXTVER	1	extension version	J	
OI_REVN	1	revision number of the table definition	J	
ARRNAME	CHARA	array name for cross-referencing	A	
FRAME	GEOCENTRIC	coordinate frame	A	
ARRAYX	-2476998.047780274	[m] array center X-coordinate	D	m(meter)meters
ARRAYY	-4647390.089884061	[m] array center Y-coordinate	D	m(meter)meters
ARRAYZ	3682240.6122966344	[m] array center Z-coordinate	D	m(meter)meters

Table data

TEL_NAME	STA_NAME	STA_INDEX	DIAMETER [meters]	STAXYZ [meters]
T	S1	1	1	0 0 0
T	S2	2	1	-18.362 -5.747 28.124
T	E1	3	1	-176.956 125.332 249.634
T	E2	4	1	-154.012 70.396 221.437
T	W1	5	1	-130.689 -175.072 172.794
T	W2	6	1	-111.729 -89.091 165.08

TOP / OIFits / Tables / #3 OI_WAVELENGTH (8 rows)

Keywords

name	value	description	type	unit
EXTNAME	OI_WAVELENGTH	extension name	A	
NAXIS2	8	number of table rows	J	
EXTVER	1	extension version	J	
OI_REVN	1	revision number of the table definition	J	
INSNAME	MIRC_GT_1_47493-1.75256-8ch	name of detector for cross-referencing	A	

Table data

EFF_WAVE [meters]	EFF_BAND [meters]
1.475E-6	3.966E-8
1.515E-6	3.966E-8
1.554E-6	3.966E-8
1.594E-6	3.966E-8
1.634E-6	3.966E-8
1.673E-6	3.966E-8
1.713E-6	3.966E-8
1.753E-6	3.966E-8

TOP / OIFits / Tables / #4 OI_VIS (60 rows)

Keywords

name	value	description	type	unit
EXTNAME	OI_VIS	extension name	A	
NAXIS2	60	number of table rows	J	

Figure 1. Screenshot of the web-based OIFITS validator provided by JMMC at <http://oival.jmmc.fr/index.html>. The dataset being validated is a simulated observation with CHARA/MIRC created for the 2018 imaging “beauty” contest, and is a completely valid OIFITS 1 file.

Table 1. Summary of the FITS Header-Data Units (HDUs) defined by the OIFITS 2 standard. New features in version 2 are highlighted in red.

HDU	Intent	Cross-ref. key(s)	Multiplicity
(Primary Header)	CONTENT = 'OIFITS2' + metadata		1
OI_TARGET	Object coordinates	TARGET_ID	1
OI_ARRAY	Station coordinates, FOV	ARRNAME, STA_INDEX	1..N
OI_WAVELENGTH	Observation wavelengths	INSNAME	1..N
OI_VIS, OI_VIS2, OI_T3	OI observables, reference for differential OI_VIS	ARRNAME, INSNAME, CORRNAME	0..N
OI_FLUX	Raw or calibrated fluxes/spectra	ARRNAME, INSNAME, CORRNAME	0..N
OI_CORR	Sparse correlation matrix	CORRNAME	0..N
OI_INSPOL	Time-variable instrumental polarisation (Jones matrix)	ARRNAME, INSNAME	0..N

The oifitslib and OITools libraries listed above include command-line tools. In particular, the oifitslib library provides a validation tool called `oifits-check`.

A panel discussion was held during the SPIE conference “Optical and Infrared Interferometry and Imaging VI”, to address the following questions:

1. Are there mistakes or inconsistencies in the OIFITS 2 definition that require correction?
2. What difficulties have been encountered in migrating to OIFITS 2?
3. What software tools for reading, writing, or manipulating OIFITS 2 files would be most useful to the community?
4. What should be the future development directions for optical interferometry data standards?

The presentation by Urvashi Rau (paper 10701-31) in this conference discussed possible synergies between optical and radio interferometry image reconstruction methods, in particular the potential for using VLBI algorithms with OI data. This would require a means for loading OI data into the CASA software package.

This paper reports the main points raised during the panel discussion, and the follow-up actions that were agreed.

2. REPORT ON DISCUSSION

The panel members made a brief presentation, after which questions and comments were invited from the audience. This section summarises the substantive points that were raised and the panel’s responses.

The panel reported that OIFITS 2 had been adopted for the second-generation VLTI instruments GRAVITY and MATISSE. Most of the new features are being used, with the exception of storing correlations between the measured data in the new OI_CORR table. In discussing the reasons for this, it became apparent that there was some confusion within the community (and indeed the panel members!) about the current definition of OI_CORR and its suitability for common use cases. We suggest that some realistic examples of correlated datasets be developed in order to clarify any confusion. The next imaging “beauty” contest should also include correlated data, as well as other OIFITS 2 features.

The CHARA array has not yet adopted OIFITS 2, but is expected to do so in the future. Possible barriers to adoption of OIFITS 2 throughout the OI community were discussed, and it was clear that the main impediment was lack of effort, coupled with the absence of any immediate scientific need. The most likely source of software engineering effort is the Jean-Marie Mariotti Centre (JMMC), which has already contributed a general-purpose Java library (OITools) and a

*The Registry of FITS Conventions: https://fits.gsfc.nasa.gov/fits_registry.html

validation tool. Divergent opinions were expressed as to whether a general-purpose Python library is also needed. Some felt that the `astropy.io.fits` module is adequate for most purposes.

Members of the audience expressed some concern that making the `OI_ARRAY` table compulsory in OIFITS 2, when it had been optional in OIFITS 1, would prevent some existing OIFITS 1 files from being upgraded to the new standard. We would like to point out that little can be gained from upgrading files to version 2 without taking advantage of any of the new features, except to make the files readable by software that cannot read version 1. At the time of writing we are not aware of any software tools that can only read version 2. Given that version 2 was designed to be backwards compatible with reading software developed for version 1, writing software to support both versions 1 and 2 is straightforward. For these reasons we don't believe there is a compelling case for making `OI_ARRAY` optional in OIFITS 2.

Performance issues when working with large OIFITS datasets, such as simulated observations with the future Planet Formation Imager, were also reported. The HDF5 format[†] was mentioned as a more performant alternative to FITS; HDF5 has previously been suggested as a storage format for radio interferometry data.⁵ Other alternatives to FITS are discussed in Ref. 6. Arguments against moving to HDF5 were put forward from the floor. HDF5 is in the process of switching from open source to a commercial software model, although the core software library remains open source. Also there has been considerable investment in OIFITS, and FITS in general, particularly by the European Southern Observatory. Given that a lack of resources to work on OIFITS development was also raised as a concern, it does not seem prudent to embark on wholesale changes to the standard at this time.

3. CONCLUSIONS

Migration from version 1 to version 2 of the OIFITS standard has thus far been limited to the VLTI. It appears that more widespread adoption within the OI community has been held back by a lack of effort and limited perceived benefits, rather than any particular deficiencies in the format. The comments made by the audience during the panel discussion indicated that the OI community values the existence of a common data format, and wishes to see it continue to be supported and developed in the future. To this end, we plan several follow-up actions in the near term. These actions are focused on enhancing and demonstrating the scientific benefits of adopting OIFITS 2:

- JSY to seek participation in defining version 3 of the CASA MeasurementSet (MS) with a view to enabling OIFITS to MS conversion; and
- JSY to suggest ways of testing and publicising OIFITS 2 features as part of the next biennial imaging contest.

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[†]<https://portal.hdfgroup.org/>