GISMO

NCS Software Interface and FITS File Description

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Version 0.5
April, 2012

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Space Administration

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Change Log

Version	Date	Description	Author
0.4	3/10/2012	Added IMBF-scan table info	A. Kovács
0.5	4/12/2012	Expanded to include general GISMO fits file description	S. Maher

Introduction

This memo is a brief description of the interface between the GISMO software and the IRAM software system in terms of reading astrometry and other observation information from the NCS system. It describes each piece of data used from IRAM systems. It also describes the GISMO-specific parts of the FITS file.

Please feel free to provide comments or questions to Attila (attila@submm.caltech.edu) or Steve (stephen.f.maher@nasa.gov).

GISMO Pipeline

The GISMO system creates, for each scan, a *raw* file with detector data, housekeeping, and an IRIG-B timestamp. The starting and stopping of the raw file creation is triggered by NCS "Elvin" messages. GISMO merging software then merges the GISMO raw file with an NCS "IMBF" FITS file to create a GISMO *merge* file. The IRIG-B timestamp is used to correlate the data. The merge files are used as input to the CRUSH software for data reduction.

Elvin Messages

The following Elvin messages are used by the GISMO system to drive the archiving system and subsequent merging pipeline:

1. "scanInfo.overview"
2. "scanInfo.scanStarted"
3. "scanInfo.subscanStarted"
4. "scanInfo:makeIMBFitsStarted"
5. "scanInfo:makeIMBFitsDone"
6. "scanInfo.cancelled"

GISMO FITS File

The GISMO FITS file is organized as follows. The detailed contents will be described in the remaining sections.

HDU Name	Description

Primary	Static configuration and astrometry
GISMO Configuration	GISMO system configuration
GISMO Data	Detector data, housekeeping and astrometry

Static Configuration & Astrometry

The merging process uses FITS "header" information from the following IRAM HDUs (also known as "tables") and keys for configuration data. **These fields appear in the GISMO pimary header in the FITS file**. Notes related to how CRUSH (used for GISMO data reduction) interprets this data are also included as well as comments by IRAM personnel.

Source IRAM HDU	IRAM and GISMO Header Key	CRUSH Notes	IRAM Comments
PRIMARY	PROJID		
"	MJD-OBS	CRUSH uses this to calculate the apparent epoch (e.g. J2012.21), for precessing catalog equatorial coordinates when converting to/from horizontal. Also, based on the MJD conditional configuration settings are loaded by CRUSH, allowing date-dependent configs.	
"	LST		
"	TIMESYS		

"	LONGOBJ	CRUSH uses this as the nominal coordinates for the map it produces. It is not used for the astrometry of the scanning.	
"	LATOBJ	"	
IMBF-Scan	TELESCOP		
"	TELSIZE		
"	SITEELEV		
"	SITELONG	Prior to version 2.11-2 CRUSH used -3d 23' 55.51", which agrees with the value in the header. As of version 2.11-2 CRUSH relies on the header value.	
"	SITELAT	Prior to version 2.11-2 CRUSH used 37d 4' 6.29", which agrees with the value in the header. As of version 2.11-2 CRUSH relies on the header value.	
"	TAMBIENT		
"	PRESSURE		
"	HUMIDITY		

| " | TIPTAUZ | CRUSH uses this value to apply automatic opacity correction to the data. The 225GHz measurement is converted to a 2mm tau using Juan Pardo's ATM for the CSO (which is probably OK for IRAM also). Note, that the 2mm tau is ~2.5 times lower than tau(225GHz), thus even an error of 0.1 in the 225GHz value results in just ~4% error in the 2mm flux. Focus quality likely affects the calibration accuracy more that that. In April 2012 we have shown that our tau correction yields a 6% rms blind calibration for PWV ranging 1--10 mm at all elevations. However, the user is free to specify a more accurate tau value at reduction, based on e.g. polynomial fits to the daily measurements. | |

"	TIPTAUE		
"	DATE-TIP		
"	OPERATOR		
"	UT1UTC		
"	TAIUTC		
"	ETUTC		
"	GPSTAI		
"	POLEX	[OK] CRUSH does not use these values for astrometry (specifically for the conversion between horizontal and equatorial coordinates). These are sub-arcsec corrections for the jitter in Earth's axis, thus irrelevant to GISMO.	celestial pole offsets (see IERS Bulletin A). Used to determine apparent position of sources.
"	POLEY	"	"

"	CTYPE1	CRUSH uses these keys to determine the coordinate system, in which the tracking coordinates BASLONG/ BASLAT are. CRUSH can deal with horizontal (ALON/ALAT), equatorial (RA/DEC), ecliptic (ELON/ELAT), galactic (GLON/GLAT) and super-galactic (SLON/SLAT) coordinate systems. The projection part of the value is not used, but SFL is assumed for incorporating 'true' angle offsets.	
"	CTYPE2	"	
"	MOVEFRAM	[OK] (It would be nice if it were used, as a boolean 'T' for solar-system objects, and 'F' otherwise).	Not used, but AS could set this for the April run. Is implemented from 27. April 2012: MOVEFRAM 1: Planet or Satellite MOVEFRAM 0: Other
"	WOBMODE		
"	THIRD_RE		
"	ZERO_POL		
"	PHI_POL		
"	EPS_POL		
"	COL_SIN		
"	COL_COS		

"	TIPTAUC		
"	OBJECT	CRUSH uses this in naming the output map, which contains the object name, and the OBJECT key also appears in the output FITS image.	
"	WINDDIR		
"	WINDVELM		
"	WINDVEL		
"	FOCUSX		
"	FOCUSY		
"	WOBTHROW		
"	WOBDIR		
"	EQUINOX	CRUSH uses this to determine the coordinate epoch (for equatorial and ecliptic coordinates) in which the tracking center BASLONG/ BASLAT are reported, as well as the nominal object coordinates given by LONGOBJ/ LATOBJ.	
"	OBSID	CRUSH uses this for constructing the default output map name together with OBJECT.	

"	RXHORI	Assuming these are the Nasmyth H/V offsets of the observing pointing model. Can you also check that these are correctly recorded in the FITS headers?	Yes, these are specified via the pointing model, and cannot be set via PAKO, but in the pointing model parameter file. (would need to be tested)
"	RXVERT	"	"
"	RXHORICO	[OK] Same as above, but assuming these are user-specified corrections. Also, is the correction on top of the RXHORI value, or does RXHORI already include this? Where does this come from (a user setting from PAKO, or some other source)?	Yes, these are additive user-specified offsets. (also never used) The Nasmyth offsets specified in PAKO appear in the table of the second HDU (IMBF-scan)
"	RXVERTCO	"	"
"	DATE-POI		
"	P1COR	[OK] CRUSH assumes that the effective pointing model uses P1+P1COR.	Yes, user specified correction on top of P1 in the pointing model.
"	P2COR	"	set pointing in PAKO
"	P3COR	"	
"	P4COR	"	
"	P5COR	"	
"	P6COR	"	

"	P7COR	"	set pointing in PAKO
"	P8COR	"	
"	P9COR	"	
"	P4CORINC	"	
"	P5CORINC	"	
"	DATE-TIP		
"	DATE-WEA		
"	REFRACTI		
"	P1	CRUSH uses these values (together with the corrections e.g. P1COR, and P4CORINC) to construct an observing pointing model according to Greve et al. 1996. The user can later supply CRUSH with a best estimate of the true pointing model, so that CRUSH automatically calculates and applies the necessary pointing corrections at reduction. This way, we reached 2.5" blind pointing rms over the 7 days of the 2011 April run, fitting only P4,P5,P8,P9 and Nasmyth H,V offsets on ~440 pointing observations.	

"	P2		
"	P3		
"	P4		
"	P5		
"	P6		
"	P7		
"	P8		
"	P9		
IMBF-antenna	SUBSXOFF		
"	SUBSYOFF		
"	FOTRANSL		
"	FEEDANGL		
"	SETYPE01		
"	SETIME01		
"	SEXOFF01		
"	SEYOFF01		
"	SEXSTA01		
"	SEYSTA01		
"	SEXEND01		
"	SEYEND01		
"	SESPES01		
"	SESPEE01		
"	OBSTYPE		
"	SUBTYPE		

"	SYSTEMOF	[OK]	Yes, identical in the IMBF-subreflector header.
		NOTE: This also appears in IMBF-subreflector and we're assuming they're identical.	'horizontalTrue', True for true angles on the sky.
		CRUSH uses this to determine the system, in which LONGOFF/ LATOFF are reported. As of version 2.11-2 CRUSH can deal with 'horizontal', 'horizontalTrue', 'projection' and 'equatorial' (same as 'projection') values.	'horizontal' without cos(elevation) multiplier. See PAKO manual, mostly used is 'projection' (alpha, delta) in 'true' angles.

Beyond the header keywords, GISMO now also merges the table from the 'IMBF-scan' HDU, containing the observing offsets (Specifically, row n of the table is converted into header keys SYSOFFn, XOFFSETn, and YOFFSETn). Conforming to PAKO, and anticipating future additions to the suite of possible offsets, the upcoming version of CRUSH (2.11-2) can process the following offset types:

SYSOFF	CRUSH Notes	IRAM comments
NASMYTH	These are Nasmyth pointing offsets entered by the user in PAKO. As of CRUSH version 2.11-2 these values are used, but need to be tested more thoroughly!	
TRUEHORIZONTAL	Projected (SFL) horizontal offsets, entered in PAKO. As of CRUSH version 2.11-2, these are accumulated to the tracking center reported by BASLONG/BASLAT. Needs to be verified/tested.	

PROJECTION	Projected (SFL) offsets in equatorial (RA/DEC), entered in PAKO. As of CRUSH version 2.11-2, these are accumulated to the tracking center reported by BASLONG/BASLAT. Needs to be verified/tested.	
EQUATORIAL	**[not yet implemented in PAKO]** It will be the same as 'PROJECTION', but with a more descriptive name. As of CRUSH version 2.11-2, these are accumulated to the tracking center reported by BASLONG/BASLAT. Needs to be tested, when implemented in PAKO.	
BASIS	**[not yet implemented in PAKO]** Projected (SFL) offsets in the basis system of coordinates. As of CRUSH version 2.11-2, these are accumulated to the tracking center reported by BASLONG/BASLAT. Needs to be tested, when implemented in PAKO.	
DESCRIPTIVE	**[Not yet implemented in PAKO]** Not (yet) supported by CRUSH since it's definition itself is unclear at this point.	
HORIZONTAL	**[Not implemented in PAKO]** Raw (unprojected) horizontal offsets, with an absolute azymuth increment. There is no obvious reason why the user would ever use an unprojected offset. Therefore, the is no support for in in CRUSH.	

GISMO Configuration HDU

The first extended HDU, "GISMO Configuration", contains a table with one row and the following columns:

Column Name	Description
LSYNC	See additional documentation
DSYNC	See additional documentation
FRAMESPERSECOND	Calculated frames per second of acquisition system
HIGHRESMODEENABLED	Whether "high res" mode is enabled (deprecated)
FIRMWAREID	Version of firmware
SETTLE	Number of 50 MHz samples to skip
NUMBERSAMPLES	Number of 50 MHz samples to read
SCALEFACTORC	See additional documentation
PROPORTIONALGAIN	See additional documentation
SECONDSTAGEBIAS	Bias of seconds stage for each mux column (4J, counts)
SECONDSTAGEFEEDBACK	Feedback of seconds stage for each mux column (4J, counts)
THIRDSTAGEBIAS	Bias of third stage for each mux column (4J, counts)
THIRDSTAGEFEEDBACK	Feedback of third stage for each mux column (4J, counts)

DETECTORBIAS	Detector bias for each mux column (4J, counts)
VREF	Counts of first stage row-select DAC

Time Resolved Astrometry

The merging process uses the following HDUs (also known as "tables") and columns in the IMBF FITS file for time dependent data. The columns are contained in the "GISMO Data" HDU, which is the second extended HDU (third including the primary HDU). The values are interpolated from the IRAM data to the (faster) GISMO data.

Data Columns Common to IRAM and GISMO

IRAM HDU	IRAM & GISMO Column	CRUSH Notes
IMBF-Antenna	MJD	
"	LST	CRUSH uses this for converting between horizontal and equatorial coordinates (in apparent epoch).
"	LONGOFF	As of 2012, CRUSH uses these scanning offsets in the coordinate system specified by SYSTEMOF. Adding these to the tracking center (BASLONG/BASLAT in the given EQUINOX, precessed to the apparent epoch, and converted to horizontal via LST and SITELONG/SITELAT) calculates the commanded telescope position in azimuth/elevation. CRUSH can deal with horizontal or equatorial offsets.
"	LATOFF	"

"	CAZIMUTH	CRUSH used this prior to 2012. As we found out, despite the name, these are not true commanded astronomical azimuth/elevation coordinates -- and the reason for our pointing problems in April 2011. Seems like the inclinometer corrections (and perhaps others) are not included in these. The naming (commanded azimuth) imply that these are the true 'azimuth' and 'elevation' of the tracked source. To avoid confusion perhaps these columns should be renamed, or at least the description in the FITS header should be more indicative. AS: Will change the description when I find out what they actually are
"	CELEVATIO	"
"	BASLONG	As of 2012, CRUSH uses these together with the CTYPE1, CTYPE2 (and EQUINOX) header keys as the tracking center. CRUSH can deal with horizontal (ALON/ALAT), equatorial (RA/DEC), ecliptic (ELON/ELAT), galactic (GLON/GLAT) and super-galactic (SLON/SLAT) coordinate systems.
"	BASLAT	"
"	TRACKING_AZ	CRUSH uses these to get actual telescope position, on top of the commanded values derived from BASLONG/BASLAT and LONGOFF/ LATOFF. Seems like these are (commanded - actual) values. Also it seems like, these are raw AZ errors without the $\cos(EL)$ term, i.e., TRACKING_AZ = (commanded AZ) - (actual AZ)
"	TRACKING_EL	"

"	AZIMUTH	These are encoder values, not astronomical coordinates, as is correctly indicated by the header comment.
"	ELEVATION	"
"	MJDFAST	
"	PARANGLE	The name implies that it is 'parallactic angle' (which is defined as the rotation of the azimuth axis relative to the RA axis). However, it looks like that this is some sort of position angle. In any case, CRUSH does not use this value. Instead, it calculates the parallactic angle from the horizontal coordinates of the tracking center, and adds the Nasmyth rotation with cos(EL) to map pixels onto sky. The following formulae are used to calculate the parallactic angle (PA): tan(PA) = A/B, where A = -cos(phi) sin(az) B = sin(phi) cos(el) - cos(phi) sin(el) cos(az) in terms of azimuth (az), elevation (el), and geodetic latitude (phi) of the site.

Data Columns Specific to GISMO

GISMO HDU	GISMO Column	Notes
GISMO Data	DAC	The DAC counts of the linearized detector feedback signal - averaged (128E, counts)

"	SAE	The Scaled Accumulated Error from the feedback system. Scaling dependent on configuration (128E)
"	UT	UT time (D, seconds)
"	FRAME_COUNTER	Frame counter from acquisition system (J, unitless)
"	NUMBER_OF_SAMPLES	The number of acqusition system samples coadded for this sample (J, samples)
"	TIME_ADJUSTMENT_OCCURRED	Indicates a IRIG time adjustment was applied to the time model (B, boolean)
"	TIME_ADJUSTMENT	The amount of time adjustment (D, seconds) (typically < 1 mS every 20-30 seconds))
"	SUMMARIZED_DIGITAL_INPUT	Values of TTL input module (6B, boolean)
"	CALFLAG	Not used