DAWN'S GAMMA RAY AND NEUTRON DETECTOR (GRAND)

CERES BUNDLE DESCRIPTION

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CONTENTS

WHAT'S IN THE CERES BUNDLE?

The Ceres bundle contains raw, calibrated, and derived data products for Dawn's encounter with dwarf planet Ceres from March 2015 through October 2018 (see [1] for timeline). See the Operations Summary in this report for a description of instrument operations and performance during Ceres encounter. The data are accompanied by supporting documents and browse files, which provide a graphical overview. For further information on the GRaND archive and instrument, see [2-4]. The Ceres bundle includes the following collections.

DATA RAW COLLECTION

The Dawn GRaND Raw Collection for Ceres encounter includes gamma ray and neutron counting data and histograms. These are an intermediate data product derived from spacecraft science and housekeeping telemetry using reversible process. All higher order data products included in the bundle were derived from the raw data. The data are grouped into directories by date range. These contain GRaND housekeeping (HK), gamma-ray

(GAMMA), and neutron (NEUTRON) counting data and histograms. A detailed description of the format and contents of the raw data is provided by [3].

DATA CALIBRATED COLLECTION

The Dawn GRaND calibrated data collection contains corrected, time-series pulse height spectra in energy units for the bismuth germanate (BGO) scintillator subsystem. Peak areas extracted from the spectra and subjected to geometry and cosmic-ray corrections can be used to determine the concentration of elements within Ceres' regolith. The data reduction and calibration procedures are described by [5].

The collection also contains spacecraft ephemeris, pointing, and geometry (EPG) information for every science data recorded during Ceres encounter. This information can be related to raw and calibrated spectra and counts using the unique SCLK identifier that accompanies each record. The EPG data file also contains estimates of live time needed to determine counting rates, and the corrected triples count rate, which is a proxy for the flux of galactic cosmic rays. The information contained in the file and methods to determine live time and geometry corrections is described by [6]. Shape files used in the derivation of geometry corrections are provided in the Ancillary bundle (urn:nasa:pds:dawn-grand-ancillary).

ERRATA

The TRIPLES_RATE values presented in the EPG file for the last mission phase (C2E: Ceres X2 Elliptical) have not been corrected to account for rollover of the TRIPLES scaler, which occurs when TELREADOUT = 455s. This issue is described in more detail in [2] and can be corrected using the GRD_LIVETIME_TABLE provided in the ancillary bundle.

DATA DERIVED COLLECTION

The Dawn GRaND data derived collection contains maps of counting data and elemental concentrations determined by the Dawn Science Team. The maps are rectangular projections (cylindrical and/or quasi-equal-area pixels), described in the label accompanying each file. The following products are included. Methods used to derive the maps and their scientific interpretation are described by [7].

- GRD_TPE_NEUTRON_COUNTS – Thermal + epithermal (TPE) neutron counting rate map

A map of thermal + epithermal neutron counting rates binned on twenty-degree quasi-equal-area pixels is provided. The map was determined from a time series of the rate of neutron capture by lithium in the lithium-loaded glass scintillator, part of the +Z phoswich sensor on GRaND. Neutrons in the thermal and epithermal energy range contribute to the reaction. The data were acquired while in the spacecraft was in Low Altitude Mapping Orbit (LAMO) about 385 km from Ceres' surface (about 0.8 body radii altitude). Prior to mapping, the time series counting data were subjected to corrections for variations in the flux of galactic cosmic rays and measurement geometry.

- GRD_HYDROGEN_MAP - Water equivalent hydrogen (WEH) map

A global map of the concentration of hydrogen within the regolith of dwarf planet Ceres on twenty-degree quasi-equal-area pixels is provided. Hydrogen concentrations were determined from thermal + epithermal (TPE) neutron

counting data acquired while in LAMO.

- GRD_SMOOTHED_HYDROGEN_MAP – Smoothed WEH map.

A smoothed global map of the concentration of hydrogen on 2-degree equal-angle pixels is provided.

- GRD_IRON_GAMMA_COUNTS_MAP – Map of the 7.6-MeV net counting rates

A global map of gamma ray counting rates binned on twenty-degree quasi-equal-area pixels is provided. The map was determined from a time series of net counting rates for the 7.6 MeV gamma ray peak produced by neutron capture with Fe within Ceres' regolith. The data were acquired by GRaND in LAMO. Prior to mapping, the time series counting data were subjected to corrections for variations in the flux of galactic cosmic rays and measurement geometry.

- GRD_IRON_MAP – Map of iron

A global map of the concentration of iron on twenty-degree quasi-equal-area pixels is provided. Iron concentrations were determined from the map of 7.6-MeV net counting rates and TPE counting rates.

MISCELLANEOUS COLLECTION

The miscellaneous collection contains gaskell_claudia_2014_05_13_dec1_140802.stl, a binary stereolithography file. The shape data contained in this file were used to derive solid angles reported in the ephemeris, pointing, and geometry (EPG) file found in the calibrated collection. The STL format is open source and is fully described in the accompanying label. See [6] for a description of the methods. Note that the shape data are provided in the now obsolete Claudia fixed frame. The SPICE Planetary Constants Kernel dawn_vesta_v04b.tpc included in the collection contains rotational constants specific to Claudia and is intended for use with the shape model.

BROWSE COLLECTION

The browse collection contains graphical presentations of the data found in the raw, calibrated and derived collections. For each raw directory (GRD-L1A-Y1M1D1-Y2M2D2_YCMCDC),[3] an accompanying browse file provides statistics (records and gaps), instrument settings, strip charts of selected parameters, and pulse-height spectra. The browse files accompanying the calibrated collection include a graphical mission timeline and BGO pulse height spectra by mission phase. The browse files accompanying the calibrated collection provide a graphical presentation of each of the map products.

DOCUMENT COLLECTION

The document collection contains the bundle description (this document). The BGO calibrated data processing and ephemeris, pointing and geometry documents [5,6] are also included as secondary members of the collection.

OPERATIONS SUMMARY

GRaND was powered on and configured for science data acquisition on 13-Mar-2015 as Dawn approached Ceres (CSA). With the exception of data loss during two instances of S/C entry into safe mode, GRaND operated continuously in NORMAL mode with negligible data loss throughout the primary mission at Ceres, which ended on 19-Jun-2016, corresponding to the end of CSL Cycle 8. Data loss during safe mode occurred in CSR from 24- to 27-Apr-2015 (see GRD-L1A-150424-150501_YCMCDC-STA.TAB) and at the end of CSS from 1- to 7-Jul-2015 (see GRD-L1A-150701-150701_YCMCDC-STA.TAB).

At the beginning of Ceres encounter, the BGO and +Z Phoswich sensors had noticeable gain loss, likely due to darkening of the scintillators due to radiation damage. On 28-May-2015, the BGO HV was increased from 125 DN (735 V) to 127 DN (747 V) to compensate for the observed loss in gain. The BGO HV setting briefly returned to 125 DN following recovery from safe mode on 7-Jul-2015. Soon thereafter (15-20 Jul during CTH), a HV permutation study was carried out to determine optimal settings for the BGO sensor (see GRD-L1A-150715-150722_YCMCDC-STA.TAB). Based on an analysis of the data, the optimal setting was determined to be 127 DN. On 20-Jul-2015, the HV for the phoswiches and plastic scintillators were increased to 185 DN (+Z), 173 DN (-Y), 178 DN (+Y), and 182 DN (-Z). These settings were retained for the rest of the primary mission and the extended mission, with exceptions noted below.

In June of 2015 in Ceres Science Survey (CSS), the GRaND team noticed bursts of counts in several sensors. These occurred in rapid succession at the peak of a solar energetic particle event (18-22 June). The pattern repeated twice in the days that followed the passage of the energetic particles (22-Jun and 25-Jun). The bursts were interpreted as being the result of Fast-Fermi acceleration of electrons at a bow shock formed by a transient atmosphere at Ceres [8]. The SEP event and bursts can be observed in data found in the following directories: GRD-L1A-150613-150620_150626 and GRD-L1A-150620-150627_150828.

Dawn's first extended mission at Ceres began on 19-Jun-2016 while the spacecraft was in low altitude mapping orbit. On 10-Aug, during CXL, the BGO HV was decreased to 123 DN (724V) to measure high energy gamma rays up to 11 MeV, with the aim of searching for gamma rays produced by neutron capture by Ni (8.5- and 9-MeV) within Ceres' regolith. The BGO HV was restored to 127 DN on 1-Sep at the beginning of transfer to Juling orbit (CTJ). To acquire accompanying background data, the voltage was lowered again to 123 DN in Juling orbit (CXJ, from 21-Oct to 3-Nov) and in the GRaND orbit (CXG, from 14-Dec to 11-Jan).

In 2017, data were lost from 14-Jan through 26-Jan when the spacecraft entered safe mode. Data were lost again from 24-Apr to 02-May as a result of another entry into spacecraft safe mode and a delay in getting GRaND properly configured. A few hours of data were lost on June 3 because of poor DSN signal strength during solar conjunction. These data were overwritten before there was an opportunity to try and recover the data gap.

Note that during recovery from safe mode, multiple commands are sent to GRaND to configure the instrument for science data acquisition. During configuration, the counting system is unstable. Changes in the instrument state can be seen by examining the state file (.STA) in the LEVEL1A_AUX subdirectory for data downlinked following safe mode recovery. For example, the state file in GRD-L1A-170126-170201 shows changes in instrument settings during recovery from safe mode on 26-Jan-2017.

During CXO, while the spacecraft was at high altitude, the BGO HV was adjusted to explore the effect of gain on the gamma ray pulse height spectrum. The HV was decreased to 121 DN on 13-Jun-2017 and then decreased further to 119 DN on 20-Jun. The BGO HV was restored to 123 DN on 27-Jun. The performance of GRaND was deemed acceptable and no further adjustments to instrument settings were made through the end of the mission.

In Dawn's second extended mission, the spacecraft maneuvered resumed low-altitude operations at Ceres. GRaND reacquired Ceres in an intermediate altitude orbit (C2I) and acquired high spatial-resolution mapping data in an elliptical orbit with low periapsis (C2E), less than 50-km from Ceres' surface. The elliptical orbit campaign commenced on 9-Jun. The spacecraft completed 123 orbits before it ran out of hydrazine on 31-Oct-2018. The loss of the spacecraft was confirmed on 1-Nov. The last GRaND data were downlinked on 26-Oct. The elliptical data were acquired under ideal conditions, with no solar interference and negligible data loss. Nevertheless, for 10 of the 123 orbits, the spacecraft was pointed away from Ceres to downlink data through the main antenna. These orbits have limited utility for elemental analyses.

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