Giotto - RPA : How to save unique and invaluable data twenty-five years after their collect?

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ABSTRACT

Giotto mission was the ESA's first deep space mission. It was designed to pass as close as possible to the Halley's comet nucleus. This was achieved on 1986, March 13rd.

Although the spacecraft was damaged during the encounter, the mission was extended to allow an encounter with a second comet named Grigg-Skjellerup, in 1992.

One of the scientific objectives of the mission was to measure and study the three-dimensional distributions of plasma particles in the vicinity of the comets. RPA (Rème Plasma Analyzer) was dedicated to achieve it. Data collected by the on-board electronics were transmitted on ground, treated with DOS decommutation programs in near-real time, and saved on magnetic tapes.

At the end of the 90es, CNES have secured these data by transferring it from tapes on its perennial archive system known as STAF. During the 2000es, as the Rosetta's encounter with comet Churyumov Gerasimenko approaches, the scientific interest is growing for Giotto's data. Unfortunately, data stocked on STAF mostly consist of undocumented raw telemetry.

With the help of one of the Co-I's experience, we work, for over a year, to restore these data. To achieve this, it was necessary not only to find the documents of the time, but also to run softwares designed in the 80s on the operating systems of today.

This paper presents the actions that we conducted, the results obtained and the lessons we have learned on the perennisation of space data.

INTRODUCTION

The Giotto mission was designed to study Comet P/Halley. The major objectives of the mission were to:

- obtain color photographs of the nucleus,
- determine the elemental and isotopic composition of volatile components in the cometary coma, particularly parent molecules,
- characterize the physical and chemical processes that occur in the cometary atmosphere and ionosphere,
- determine the elemental and isotopic composition of dust particles,
- measure the total gas-production rate and dust flux and size/mass distribution and derive the dust-to-gas ratio,

- investigate the macroscopic systems of plasma flows resulting from the cometary-solar wind interaction.

The mission was given the go-ahead by ESA in 1980, and launched on an Ariane 1 rocket on 2 July 1985 from Kourou. The craft was controlled from the European Space Agency ESOC facilities in Darmstadt initially in Geostationary Transfer Orbit (GTO) then in the Near Earth Phase (NEP) before the longer Cruise Phase through to the encounter. Attitude determination and control used sun pulse and IR earth sensor data in the telemetry to determine the spacecraft orientation.

Halley's Encounter

The adventure began with Giotto almost 150 million km from Earth. At 21:00 UT on 12 March 1986, the spacecraft's instruments first detected hydrogen ions 7.8 million km from Comet Halley. 22 hours later, Giotto crossed the bow shock of the solar wind (the region where a shock wave is created as the supersonic solar particles slow to subsonic speed) and entered the dusty coma.

The first of 12 000 dust impacts were recorded 122 minutes before closest approach. Data continued to be transmitted as Giotto closed in to within a distance of 1372 km, but the rate of dust impacts rose sharply as the spacecraft passed through a jet of material which streamed away from the nucleus.

Only 7.6 seconds before closest approach, the spacecraft was sent spinning by an impact from a 'large' (one gram) particle. Contact with the Earth was lost, as spacecraft antenna was no longer pointed at the Earth. After 32 minutes Giotto re-stabilized itself and continued gathering science data. Unfortunately the dust shield no longer protected Giotto's instruments and some irreversible damage were caused to some of these.

Another impact destroyed the Halley Multicolor Camera, but not before it took spectacular pictures of the nucleus at closest approach.

Figure 1: Comet Halley's nucleus as seen by Giotto

Giotto's trajectory was adjusted for an Earth flyby and its science instruments were turned off on 15 March 1986 at 02:00 UTC.

Grigg-Skjellerup encounter

Giotto was commanded to wake up on 2 July 1990 when it flew by Earth in order to sling shot to its next cometary encounter.

The probe then flew by the Comet Grigg-Skjellerup in 10 July 1992 which it approached to a distance of about 200 km. Afterwards, Giotto was again switched off on 23 July 1992.

In 1999 Giotto made another Earth flyby but was not reactivated.

DATA PERENNISATION OF THE RPA EXPERIMENT

Giotto mission was composed of 10 experiments, including Magnetometer, Plasma Analyzer, or Multimeter Camera. Most of the data collected by these instruments are now archived in the Planetary Data System (PDS) and in the ESA's Planetary Science Archive. But data from Energetic Particle Analyzer (EPA), Neutral Mass Spectrometer (NMS), and Rème Plasma Analyzer (RPA) are not.

Since 2000, under the leadership of CDPP, and with the help of CESR laboratory (now IRAP), a number of actions have been undertaken to built a perennial archive of data from the RPA experiment.

Actions conducted during the year 2000

The first perennisation operations were conducted in CNES at the turn of the 2000s. This was to transfer the data stored on magnetic tapes to the permanent archiving system (STAF) of CNES. On this occasion, it was discovered that the data stored on magnetic tapes were unusable because of the lack of crucial informations: tapes content, files syntactic information, data product documentation ,…

A first contact was then made with RPA's PI team, fortunately located in CESR to a few tens of meters from CNES, in order to collect data and documentary elements that this team could have. This didn't help to identify the bands and / or their content but a set of 34 files was collected

This set was composed of :

- 20 files covering the period from March 11, 1986, 21h00 until March 14, 04h39, ie encounter with Halley's comet ,
- 14 files covering the period from July 10, 1992, 05h06 until July 11, 21h20, ie the encounter with the G / S comet.

CESR also sent two printed document:

- the "Bible", a document describing the operation of instruments making up the experience and the syntax of the telemetry [1],
- a note describing the main GSEb software features, software designed by the Space Science Laboratory (Berkeley) in order to treat data from RPA experiment [2].

Unfortunately, CESR had only an executable version of the software and sources could not be found.

Then, the involvement of CESR's scientists in the CLUSTER mission did not allow them to devote more time to help in data perennisation and actions were stopped at this time with this incomplete result.

All data files were archived in the STAF and documents were digitalized and delivered into the CNES document management system.

The Rosetta mission to the rescue of Giotto

Approaching date of the survey of the Churyumov Gerasimenko comet by the Rosetta mission, scheduled for 18 months from August 2014, the scientist's interest for Giotto's data was abruptly awakened. Two years ago, the CDPP then decided to restart the perennisation actions of the RPA data..

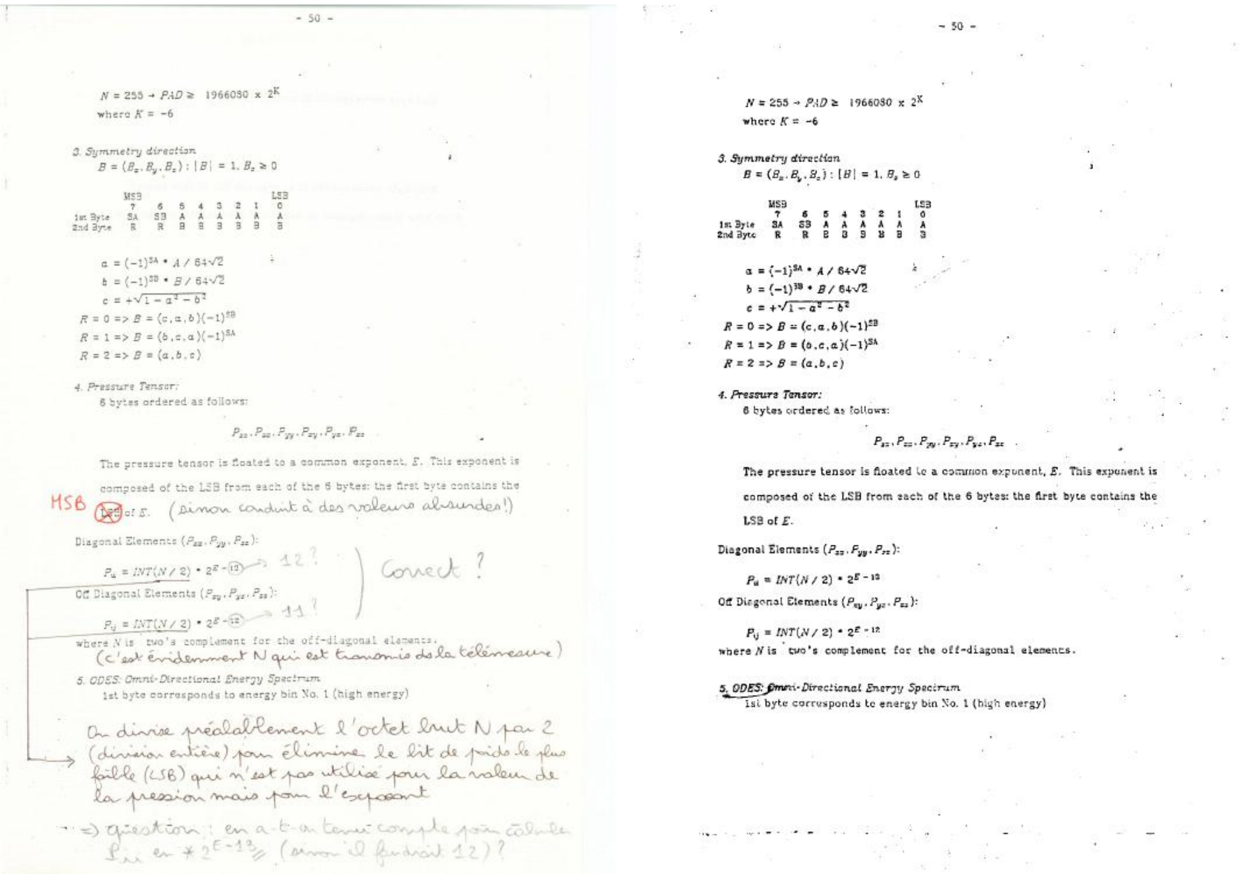
Following a meeting between the CDPP and the CESR, it was decided to attempt to create a software to read and uncompress files previously saved in STAF. This software was intended to extract the parameters scientifically useful in order to encode them into perennial files formats (in this case the CDPP format) and to ensure their semantic description.

To validate the results thus obtained, it was considered to use the outputs of the GSEb software.

Developing a data reader: a not so simple "easy task"

Developing software to read data when you have their description is not, at first sight, an insurmountable task. Due to heavy damages caused to RPA by the Halley's dust impacts, we however expected to encounter some difficulties with the state of the data itself: missing words, corrupted records, ...

In fact the first problem came from the documentation, especially the one that describes the data organization and that we call the "Bible". We have to deal with two versions of this same document, one of these, called the "annotated Bible", was retrieved by C. Mazelle (one of the CESR's Co-I) in his archive boxes a short time before.


- 50 -

$N = 255 \rightarrow PAD \geq 1966080 \times 2^K$
where $K = -6$

3. Symmetry direction
$B = (B_x, B_y, B_z) : |B| = 1, B_z \geq 0$

	MSB 7	6	5	4	3	2	1	LSB 0
1st Byte	SA	SB	A	A	A	A	A	A
2nd Byte	R	R	B	B	B	B	B	B

$a = (-1)^{SA} \cdot A / 64\sqrt{2}$
$b = (-1)^{SB} \cdot B / 64\sqrt{2}$
$c = +\sqrt{1 - a^2 - b^2}$
$R = 0 \Rightarrow B = (c, a, b)(-1)^{SB}$
$R = 1 \Rightarrow B = (b, c, a)(-1)^{SA}$
$R = 2 \Rightarrow B = (a, b, c)$

4. Pressure Tensor:
6 bytes ordered as follows:

$$P_{xx}, P_{zz}, P_{yy}, P_{xy}, P_{yz}, P_{xz}$$

The pressure tensor is floated to a common exponent, E. This exponent is composed of the LSB from each of the 6 bytes: the first byte contains the
MSB ~~LSB~~ of E. (sinon conduit à des valeurs absurdes!)

Diagonal Elements (P_{xx}, P_{yy}, P_{zz}):

$P_{ii} = INT(N/2) \cdot 2^{E-13}$ → 12?

Off Diagonal Elements (P_{xy}, P_{yz}, P_{xz}):

$P_{ij} = INT(N/2) \cdot 2^{E-12}$ → 11?

Correct ?

where N is two's complement for the off-diagonal elements.
(c'est évidemment N qui est transmis de la télémesure)

5. ODES: Omni-Directional Energy Spectrum
1st byte corresponds to energy bin No. 1 (high energy)

On divise préalablement l'octet brut N par 2 (division entière) pour éliminer le bit de poids le plus faible (LSB) qui n'est pas utilisé pour la valeur de la pression mais pour l'exposant

⇒ question : en a-t-on tenu compte pour calculer P_{ii} en $* 2^{E-13}$ (sinon il faudrait 12) ?

- 50 -

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where N is two's complement for the off-diagonal elements.

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Figure 2: The same page issued from the "annotated bible" (left) and from the "original bible" (right)

Figure 2 presents one of the formulas used to uncompress data: as we can see the "annotated bible" proposes some information and corrections to the original version. If some of these information seem to be clearly established (use of the MSB convention for example), others seem more doubtful (exponents of the pressure tensors).

On the same page 50, paragraph 5 provides the method to determine the symmetry directions. Both versions of the "bible" do not differ, and give the formula to be applied depending on the value of the variable R which must be between 0 and 2. But when we read the values of the telemetry, we found R between 0 and 3 ...!

We found a dozen of such cases, and only some of these have been solved with the help of C. Mazelle.

At the same time, unexpected problems on data have appeared, such as longer records than expected, or nested records one inside the other.

All these problems led us to the conclusion that the only way to solve these problems was to use the GSEb to validate our corrective hypothesis.

Resurrection of GSEb

The GSEb software is an interactive visualization and analysis tool of Giotto's data, designed by the Space Science Laboratory at Berkeley.

It allows to extract level 2 data (physical parameters in calibrated values) from the telemetry files, to plot graphics and to save the numeric values in ASCII files.

This software is designed to run under DOS, the graphic part requires and EGA (Enhanced Graphic Adaptator) card to work properly. If such requirements represent the 1986 state of the art in software engineering, it was not trivial today, to configure a computer as well.

Initially, we configured a PC with Windows 98. We tested the software's fonctionnalities and note that the majority of them runs properly.

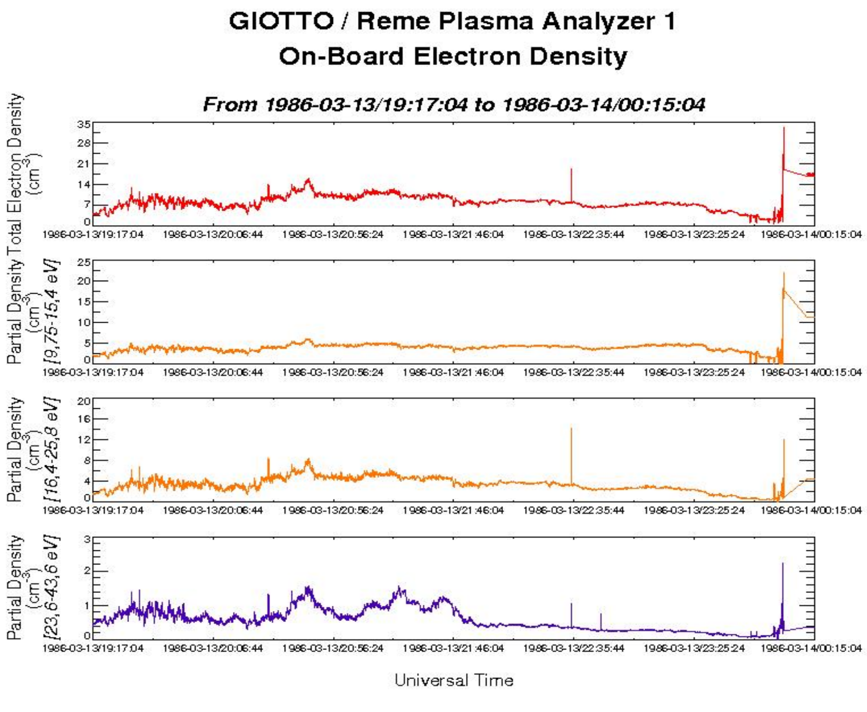
However, it 's not possible to save the numerical values in ASCII files. The reason why is that the data are "flushed" in the output file during the display of graphics. But with the current processors, this display time is too short to "flush" full data.

On the other hand, it proved impossible to create a command file to chain the operations (TM file loads, defining the parameters to be extracted, writing the output file, ...), because the software waits keyboard inputs.

The ability to emulate both the DOS system and the keyboard led us to test the feasibility to run GSEb in a Linux environment. The test was completely successful, both as regards the execution of GSEb in Linux via a DOS emulator, as for saving data in ASCII files with the use of time delays between the commands, but also for ability to work in non-interactive mode with command files.

With the help of GSEb User’s Manual, we initially focused on simple parameters such as electron density, or velocity. It was then easy to extract data and to present it to CESR's scientists. However, we weren't out of troubles.

C. Mazelle showed us that the data were in GRT (Ground Recieved Time) and explained us how to convert in SCET (SpaceCraft Event Time). He also explained us how to extract and process data in order to avoid modulation artifacts due to the spin of the spacecraft. We still had to rearrange records in chronological order, to identify and eliminate outliers. Figure 3 shows the results obtained for the electron density during the encounter with Halley's comet.



CONCLUSION

Despite the loss of a large amount of data (especially the ones during the cruise phase), data on Halley and G/S encounters are about to be saved. The CDPP could not achieve this without the invaluable assistance of C. Mazelle, one of the Giotto's Co-I, located in the CESR near the CNES.

However, throughout the rehabilitation work, we have matured our thinking on what process to put in place to ensure the data perennisation of space missions. Three points seem crucial:

- Prevention of technological obsolescence: if today the situation is less critical than in 1986, the fact remains that it is essential that the telemetry and data processing tools must be developed in standard languages and independent from the operating system. Once delivered to an Archive (as defined in OAIS), it is critical that the "Archive" ensures, on a regular basis, of its ability to install, use and understand these tools.
- To ensure of the completeness of the documentary elements: the extreme case of the Giotto's "bible" shows that the Archive must ensure that the mission documentation contain all the information needed to read and describe the data delivered to the Archive. It is a prerequisite in order to maintain or to migrate the data readers.
- Generally, it is important for the Archive to take part of the mission as early as possible. Thus it is possible to advise the scientific team on the choice of data formats and software architecture, validate the completeness of the documents (and if necessary to make them evolve) while scientists are devoted to the mission. If this is not possible before or during the mission, the Archive, however, must ensure the knowledge transfer from scientists to its own team as soon as possible.

These few actions should provide the capability for the Archive to have the sufficient knowledge in order to achieve a full perennisation of the data.

REFERENCES

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[2] – D.W. Curtis: Giotto RPA UCB/SSL GSEB Program, Edit.1, 1987

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