INCREASING THE COLD TIME OF THE CAY S/X CRYOSTAT

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José Antonio López Fernández, Félix Tercero Martínez, José Antonio Abad
Carlos Almendros, José María Yagüe

The S/X cryostat is in current use since 1994 on VLBI (EVN and CORE) sessions. Details about this receiver are on several CAY technical reports (1,2,3,4,5). One of the lacks of this cryostat is the cold time (temperature of the cold stage in the order of 20 kelvin). This cold time was a week in winter and three days during summer time. Since several years, we have performed many test trying to increase this cold time but they were not successful. Finally, during the last test we succeed to increase this cold time. First, decreasing the emissivity of the internal walls by polishing and second placing molecular sieves (zeolites).

1 Previous

In the CAY technical report nº6 of 1994 (2) we established the design of the cryostat. From the thermal design we have got the following thermal loads:

Stage	*Qgas (W)*	*Qrad (W)*	*Qcond (W)*	*Qamp (W)*	*Qtotal (W)*	*Temp (K)*
Radiation Shield	0.025	3	0.1	------------	3.125	60
Cold	0.002	0.009	0.96	0.36	1.3	17

Table I: Estimated thermal loads on the S/X cryostat for a 10^{-5} mbar internal pressure.

The estimated pressure inside the cryostat is 10^{-5} mbar, and this is only possible for a cold cryostat with no leaks. The estimated emissivity is 0.1.

1.1 Pressure effect on thermal load.

Apparently, there is no reason for the cryostat to have any problems for the cold down time or for the cold time period. Nevertheless, from a deep analysis, we observe that the final temperature for both stages is heavily pressure dependent. This dependence is shown on table II:

Pressure, mbar	*Qtotal Rad . Shield (W)*	*Temp. Rad. Shield (K)*	*Qtotal Cold.(W)*	*Temp. Cold (K)*
10^{-5}	3.125	60	1.3	17
10^{-4}	3.35	60	1.32	17
10^{-3}	5.6	75	1.5	22
$2x10^{-3}$	8.1	105	1.7	35
10^{-2}	28	>150	3.3	>50

Table II: Estimated thermal loads for different pressures.

From the previous table, we observe that an increase of the pressure by 200 could be responsible of a dramatic reduction of the cold time.

1.2 Emissivity effect on thermal load.

Another contribution to the thermal load is the radiation load. This is dependent on the emissivity of the dewar material. In table III we can verify the effect of a reduction of the emissivity of this material:

Emissivity	*Qtotal Rad. Shield (W)*	*Temp. Rad. Shield (K)*	*Qtotal Cold. (W)*	*Temp. Cold (K)*
0.1	3.125	60	1.3	17
0.05	1.8	50	1.3	16
0.01	0.5	45	1.3	15

Table III: Estimated termal loads for different emissivities of the radiation shield.

2 Gas release from solids.

The increase of pressure inside the cryostat is due to external leaks and outgassing, especially thermal desorption (2). As this last effect was very important in our cryostat, we were obligated to pump with a rotary pump even when the cryostat were cooling down until 40 Kelvin at the cold stage.

Thermal desorption (6) is the heat-stimulated release of gases or vapors previously adsorbed on the interior walls of the system. The rate of desorption is a function of the molecular binding energy, the temperature of the surface, and the number of monolayer of surface coverage. Gas is sorbed onto surface by physisorption and chemisorption. Physisorbed molecular are bonded to surface by weak Van der Waal's forces, adsorption at energies greater is known as chemisorption.

All solids are held together by a cohesive force that is unbalanced on the surface and has a very weak attraction for other molecules. These forces have an attraction for molecules in a fluid stream similar to magnetic attraction and cause them to adhere to a surface. The most obvious example of this phenomenon would be water condensing on the bathroom mirror. To have any significant amount of adsorption, one needs a tremendous amount of surface area.

The molecules spend a certain time on the surface, called the residence time. The desorption time will also crease with time as the surface layer become depleted. This residence time has a strong dependence on the temperature. The room temperature residence time for water adsorbed on a metal is 10^5 seconds. At higher temperatures, 350º C, this residence time decays to 10^{-5} seconds. This shows the interest on baking the cryostat in order to pump it efficiently. Cooling the surface has a dramatic effect on the residence time of all molecules. The residence times become very long and cooled surfaces become traps.

3 Thermal load reduction.

Any reduction of the thermal load means two different actions: to avoid an increase of pressure inside the cryostat and to reduce the emissivity of the radiation shield.

3.1 *Stabilization of pressure inside the cryostat.*

We can stabilize the pressure inside the cryostat using one of the following process: baking, increase of cryogenic pumping and chemical cleaning. The first two ones will have an effect on the physisorption and the third on the chemisorption.

An increase of temperature reduces the residence time and pumping at the same time will be very efficient. Increasing the pumping speed of a cryogenic pump is possible increasing the pumping surface. This can be achieved using adsorbers. Molecular sieves, zeolites (7,8), are a unique and valuable adsorbent. They are crystalline, hydrated metal aluminosilicates with a number of unusual properties. Their significance as commercial adsorbents depends on the fact that the crystal contains interconnecting cavities of uniform size, separated by narrower openings, or pores, of equal uniformity. These cavities have a tremendous combined surface area and pore volume available for adsorption of water or other materials. Under favorable conditions the process of evacuation and refilling the cavities may be repeated indefinitely.

Surface area is the key to a good commercial adsorbent and zeolites have a big surface area. An adsorbent particle can be considered something like a large ball of spaguetti that has been compressed down into a very small size. It has a tremendous amount of surface area for its outside volume. Some commercial adsorbents have surface areas as much as 800 square meters per gram. There are other phenomenon in surface adsorption. The adsorbing forces tend to be focused or concentrated as the surface is rolled into a cylinder or pore. As this pore diameter approaches the diameter of the molecule being adsorbed, it starts concentrating the condensing forces. We refer to this phenomenon as capillary condensation.

The adsorbed gas in the zeolites can be evacuated by baking. The process is called regeneration. After some test we estimate that heating the zeolites by 50 degrees over room temperature is enough

Finally, the only practical process to remove the chemisorbed molecules is by chemical cleaning. We have found that ethanol is well suited for that.

3.2 *Emissivity reduction.*

It is possible to reduce the emissivity of the radiation shield by polishing. This estimation was made after several test on our cryostat.

4 S/X cryostat improvement.

In the photograph the cryostat, after the following improvements, is shown:

- Polishing of the radiation shield.
- Chemical cleaning with ethanol.
- Installation of two zeolites molecular traps.
- Additional cabling for baking and regeneration.

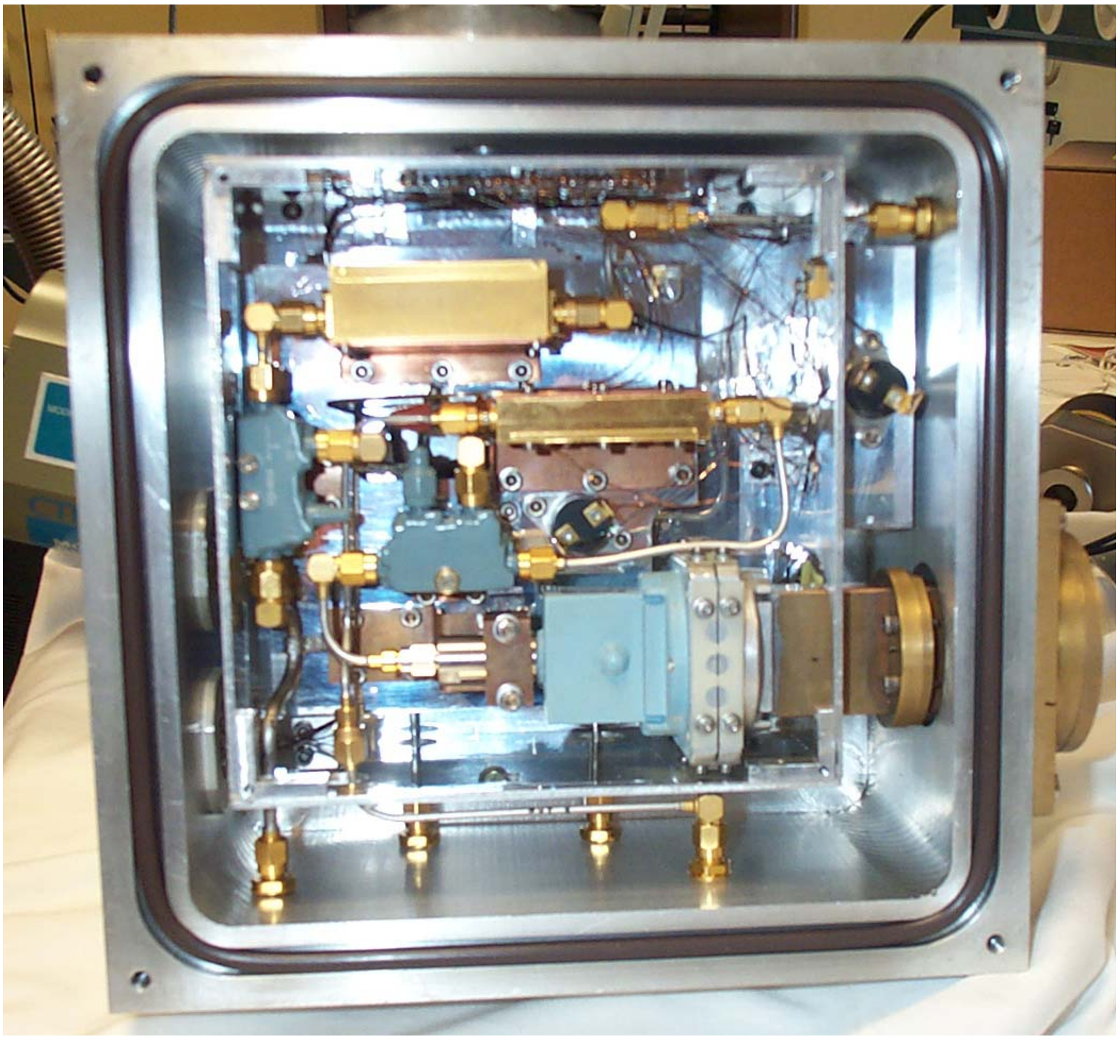

Figure 1: S/X cryostat after improvement. The molecular trap for the radiation shield is shown on the upper right side. The molecular trap for the cold stage is below the S-Band amplifier on the upper left side.

4.1 Molecular traps.

In figure 2, we show the molecular traps. The traps consist on a aluminum box with a grid of holes drilled on one of the faces. Approximately 10 grams of zeolites could be placed inside each box. A resistor (7 W, 100 ohms) is installed inside to perform the regeneration. Two thermostats, 70ºC, are placed closed to the traps to avoid dangerous warming during regeneration. Due to the small dimensions of the cryostat, the temperature of the whole dewar reaches 70ºC. This facilitates the thermal stimulated desorption and increase the efficiency of the pumping with a rotary pump.

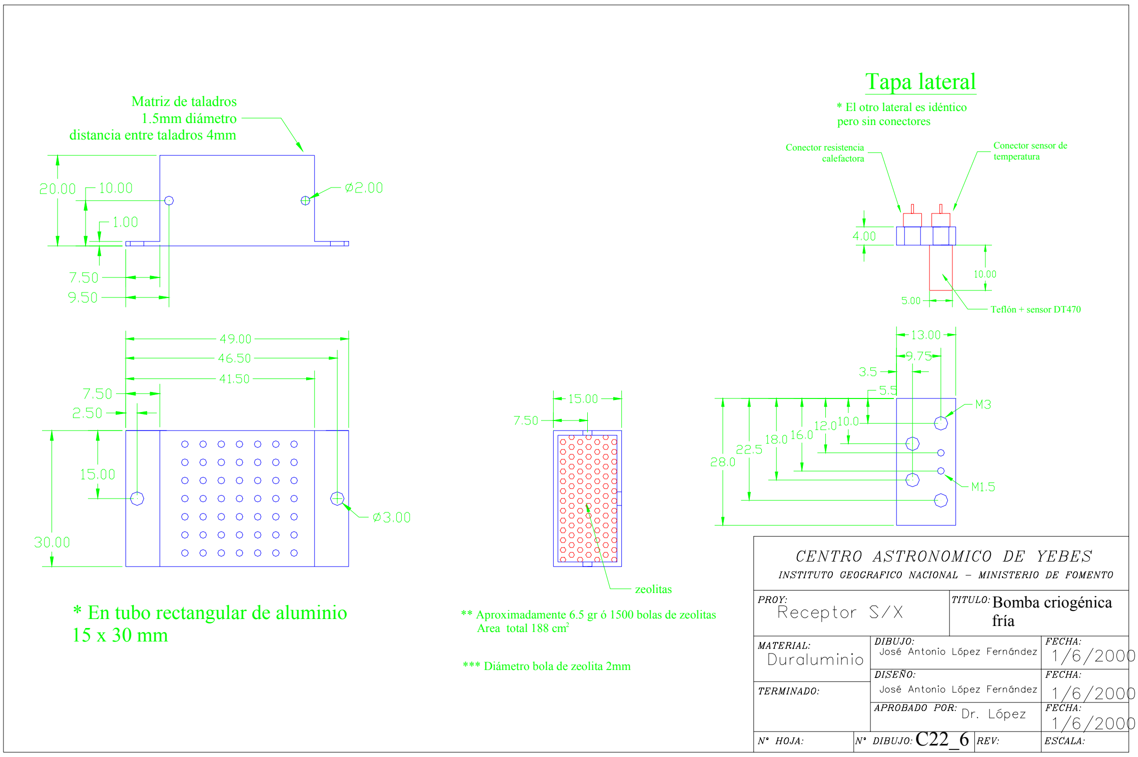

Figure 2: Zeolites molecular trap.

4.2 Modifications in the cryogenic control.

The cryogenic control unit OAY-12 (4) has been modified by adding a switch which switches ON or OFF the regeneration. When the regeneration is ON, the molecular traps are heated until 70ºC are reached, a LED indicator ON shows that the regeneration is ON. When this temperature is reached the thermostat is open, the LED is OFF and the temperature starts decreasing. When temperature is 45ºC, the thermostat is closed, the LED is ON and the regeneration is stopped. The layout is shown in figure 3.

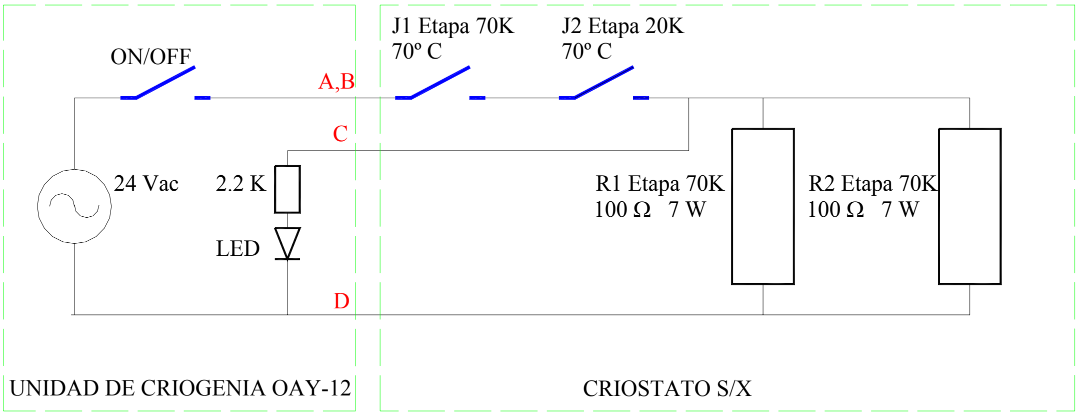

Figure 3: Layout of regeneration system.

4.2 *Pin-out modifications.*

In tables IV and V we show the pin-out of the cryostat connectors after modifications:

Pin cryostat side	*Pin OAY-12 side*	*Signal*
A	**A**	**24 Vac in**
B	**B**	**24 Vac in**
C	**C**	**24 Vac out (LED)**
D	**D**	**24 Vac in (return)**
G	**G**	**Sensor 22K +**
J	**J**	**Sensor 77K -**
S	**S**	**Sensor 22K -**
T	**T**	**Sensor 77K +**

Table IV: Pin out of temperature connector.

Pin connector Microtech	*Pin cryostat side*	*Signal*
3 Banda S	**N**	**Vd2 Banda S**
4 “	**P**	**Vg2 “**
5 “	**R**	**Vd1 “**
6 “	**L**	**Vg1 “**
7 “	**D**	**GND Banda S**
1 Banda X	**U**	**Vd1 Banda X**
2 ”	**H**	**Vg1 “**
3 ”	**G**	**Vd2 “**
4 “	**F**	**Vg2 “**
5 “	**E**	**Vd3 “**
6 “	**K**	**Vg3 “**
7 “	**V**	**GND Banda X**
LED S +	**S**	**Led Banda S**
LED X +	**T**	**Led Banda X**
GND	**J**	**GND Led’s**

Table V: Pin out of amplifiers connector.

5 *Results.*

The S/X cryostat with the mentioned modifications has been tested successfully. As a first conclusion, the cryostat doesn't need to be pumped during cooldown. For good performance it is enough to pump for one day, stop pumping and then start the cooldown. This procedure reduces the problem with non desirable gas absorption by the dewar.

The cryostat, as a second conclusion, stays cold for long periods of time. At the moment of this report we have verified a cold time of more than two months.

In figures 4 and 5 we show the temperature and pressure performance inside the cryostat over a week. The small peak on the graph is due to a lack of power during cooldown. We can observe, a constant performance: 50 K and 20 K. The measurement of the vacuum is erroneous due to a lack of accuracy of the measurement gauge and is only approximate.

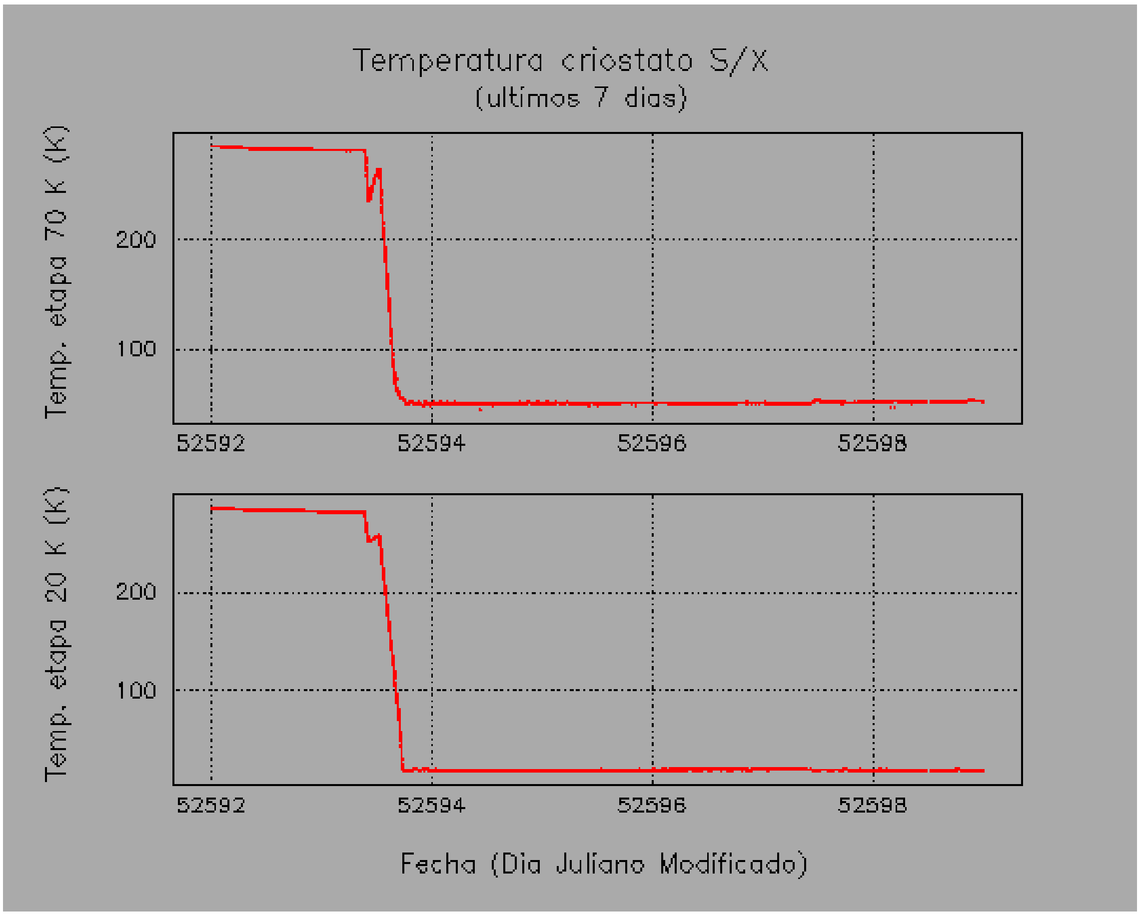

Figure 4: Cryostat temperature performance over a week.

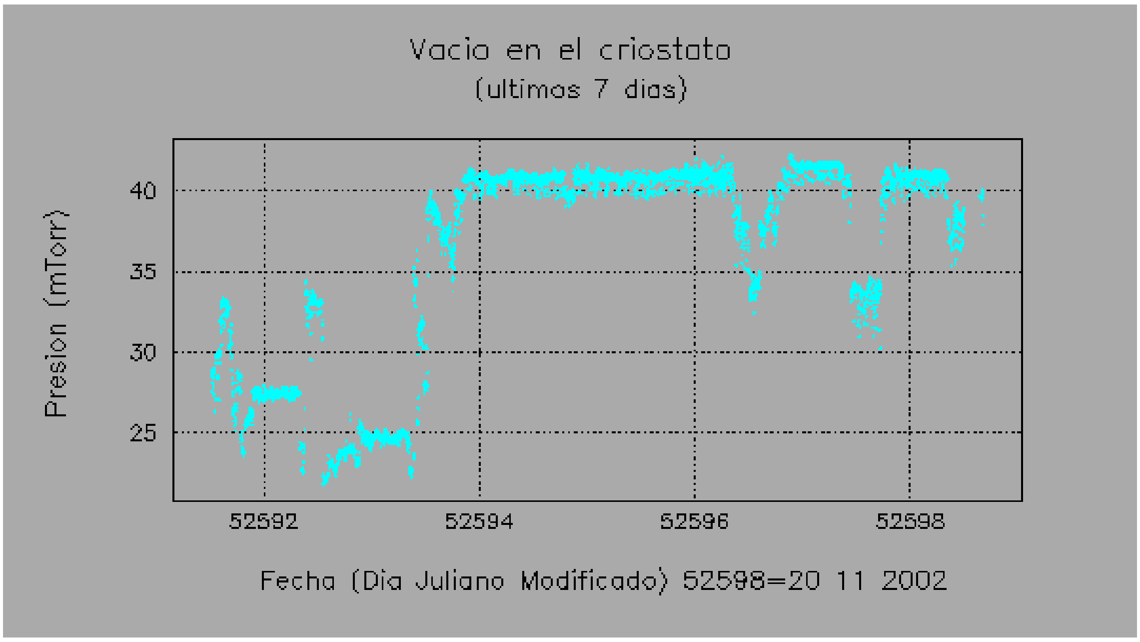

Figure 5: Cryostat vacuum performance over a week.

In figures 6 and 7 we show the performance over 24 hours.

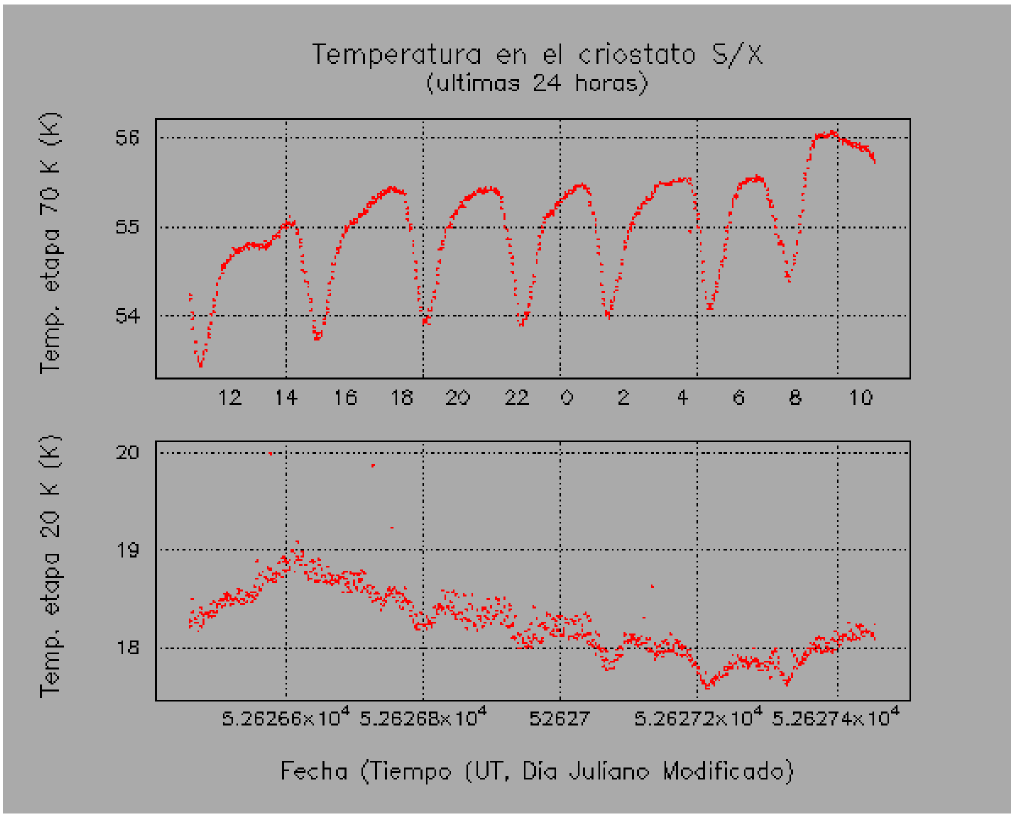

Figure 6: Cryostat temperature performance over 24 hours.

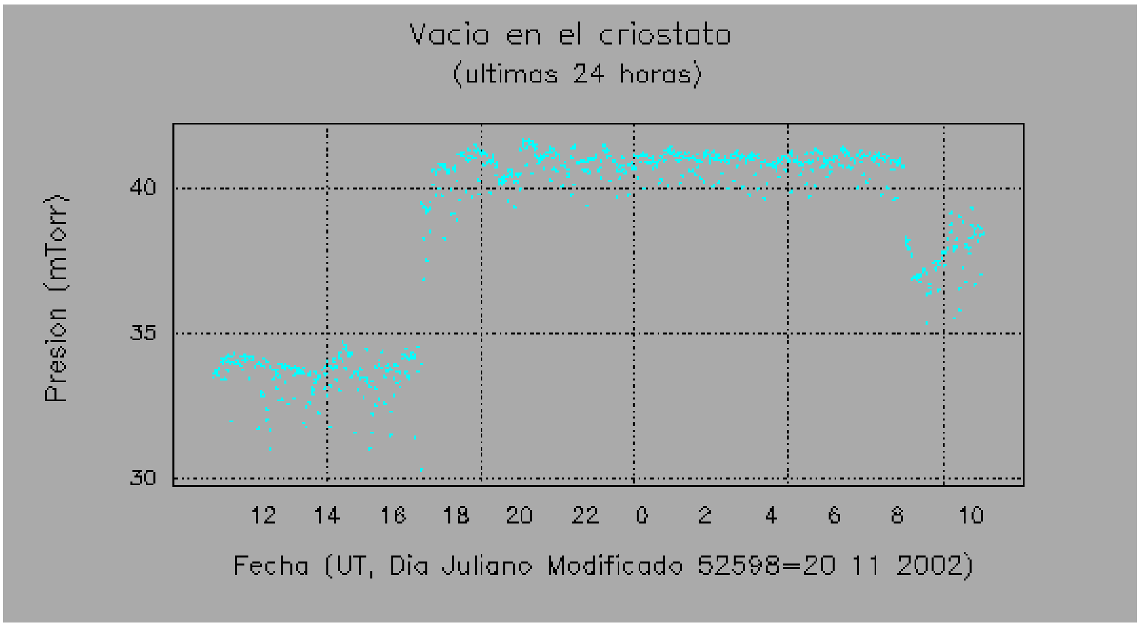

Figure7: Cryostat vacuum performance over 24 hours.

6 *Bibliography.*

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