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SPIDER230 experiences: Taurus A transit at 11.2 GHz

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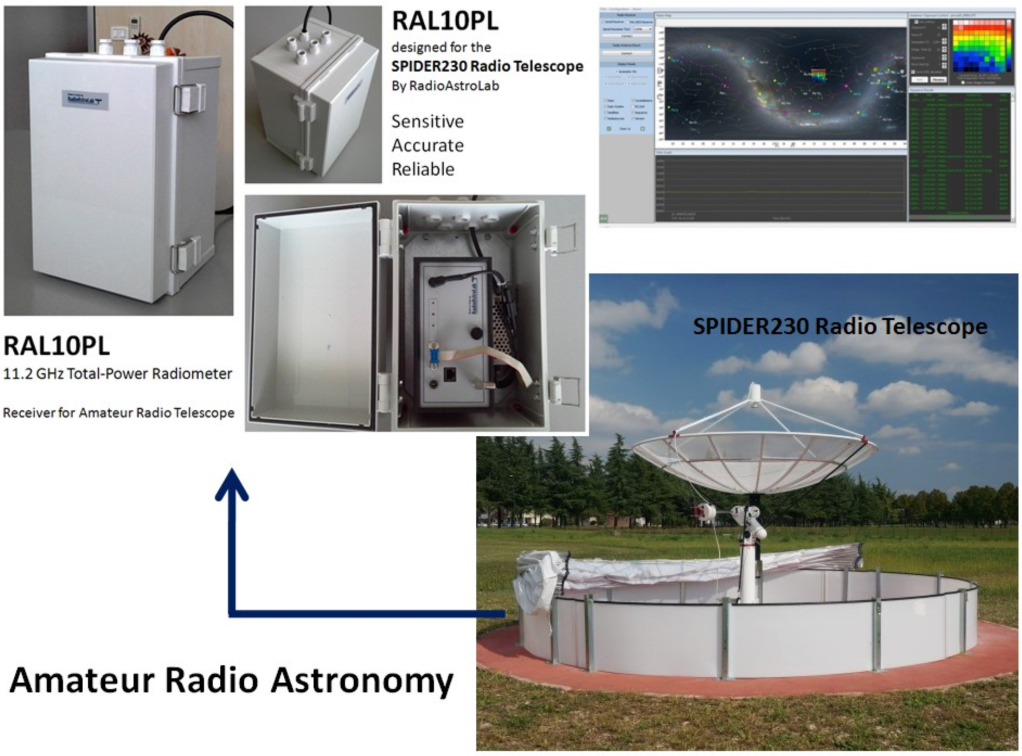

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This article describes an experiment carried out with the radiotelescope *SPIDER230*: the registration of the radio source *Taurus A* (M1) transit. The results underline the performance of the instrument and lend themselves to some interesting observations on observational radio astronomy techniques.

The experiment was conducted by Dr. Filippo Bradaschia, CEO of *Primaluce Lab*, *RadioAstroLab* partner in the construction of the *SPIDER230* radiotelescope that we thank for his cooperation. The receiving station, installed at Polo Tecnologico of Pordenone (Fig. 1), includes the *11.2 GHz RAL10PL Total-Power* receiver specially made by *RadioAstroLab* for *SPIDER230* and the antenna system (circular 2.3 meters diameter parabolic reflector) with equatorial mount, motorization and dome of protection made by *Primaluce Lab.* The instrument is completely controlled via an Ethernet line by *RadioUniverse* software.

Fig. 1: *SPIDER230* radiotelescope used to record *Taurus A* (M1) transit.

Specified design criteria adopted for the *RAL10PL* receiver, for the antenna and for the pointing system, the *RadioUniverse* software for data acquisition and data processing, guarantee to *SPIDER230* an high sensitivity and stability required for radio astronomy observations. We have repeatedly underlined how the sky observation in the frequency band close to 10 GHz offers several advantages:

- Reduced sensibility to external radio interferences;
- Possibility to use antennas of acceptable dimensions;
- Higher resolution capabilities related to higher radio frequencies.

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These benefits allow you to install a radio telescope also in the "home garden", however in an urban environment without too many penalties related to interferences. In any case, it is always advisable to check the suitability of the site for installation. The main disadvantages are related to the reduced number of radio sources observed with amateur or semi-professional radio telescopes. Objects observed by *SPIDER230* (at 11.2 Ghz frequency) are:

- **SUN:** flux of about 3 milion Jansky [1 Jy = 10^{-26} W/(m^2·Hz)]
- **MOON:** flux of about 30000 Jansky
- **CASSIOPEA A:** flux of about 600 Jansky
- **M17:** flux of about 550 Jansky
- **TAURUS A (M1):** flux of about 500 Jansky
- **ORION A (M42):** flux of about 480 Jansky

It's easy to note that the *Moon* is 100 times fainter than the *Sun* and *Cassiopea A* is 50 times weaker than the *Moon*. Due to the intensity of the Sun, the observation of our star with *SPIDER230* requires the setting of the minimum amplification factor for the receiver and the insertion of a 15 dB attenuator along the coaxial line. The transits of the *Moon* are easily recorded by setting medium-low amplification factors (without attenuator), while the other items are more difficult to record. The need to verify the instrument limit performance, encouraged by the excellent sensitivity and stability measurements found for the *Moon*, has brought Dr. Filippo Bradaschia to schedule the data recording using the transit technique with *RadioUniverse* control software.

During *RAL10PL* receiver's design, some simulations were carried out to verify, at least theoretically, the suitability of the system as a radio telescope. We remember that the instrument is a Total- Power radiometer running at a 11.2 Ghz frequency with high sensitivity and stability. The last feature is particularly important for a radio astronomy receiver: environment temperature changes cause small variations in the gain of the receiving chain that make it very difficult to measure, causing drifts and fluctuations in data recording . The problem is most evident when the radio source to be observed is weak and the setted amplification factor is greater. The issue is resolved by adopting appropriate design criteria and thermo-stabilizing the receiver electronic circuits. Remain the daily temperature that affect the *RAL10_LNB* external unit (Fig. 1), installed on the antenna: in this case it is quite easy to characterize the behavior from the thermal point of view and adopt appropriate procedures for compensation.

The following images show the results of simulations planned to investigate the possibility of receiving *Taurus A* with *SPIDER230*. The simulations are theoretical and consider an ideal behavior of the receiving system, perfectly thermally stabilized. The response of the radio telescope was calculated by setting the parameters of the receiver that will be actually used in the experiment. The antenna reception diagram and the radio source emissive one have been approximated as a uniformly illuminated circular apertures, simplifying the assessment of the spacial “filtering” effects that the antenna does on the true radio source profile. These simulations, while being very simplified, have the advantage to highlight the performance of the radio telescope. The *Taurus A* flux at a 11.2 Ghz frequency is about 500 Jy.

Calculations show that the variation in the antenna noise temperature due to the radio source transit is about 1 K and that the variation in receiver measured signal power is about 0.16 dB (Fig. 2).

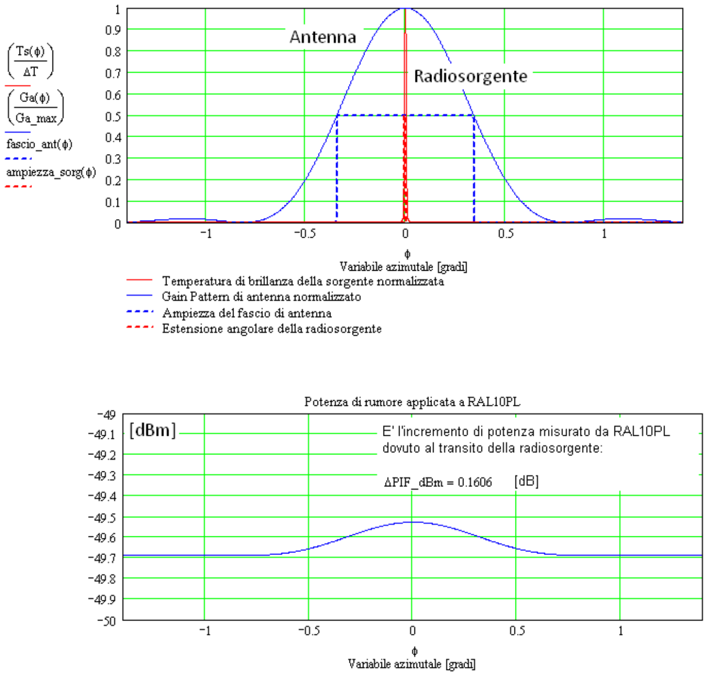

Fig. 2: The *Taurus A* emission profile looks very "diluted" by the significant difference between the amplitude of the beam receiving antenna and the angular extent of the source (top graph). The chart below shows the signal power estimated increase, seen by *RAL10PL* receiver, due to the radio source.

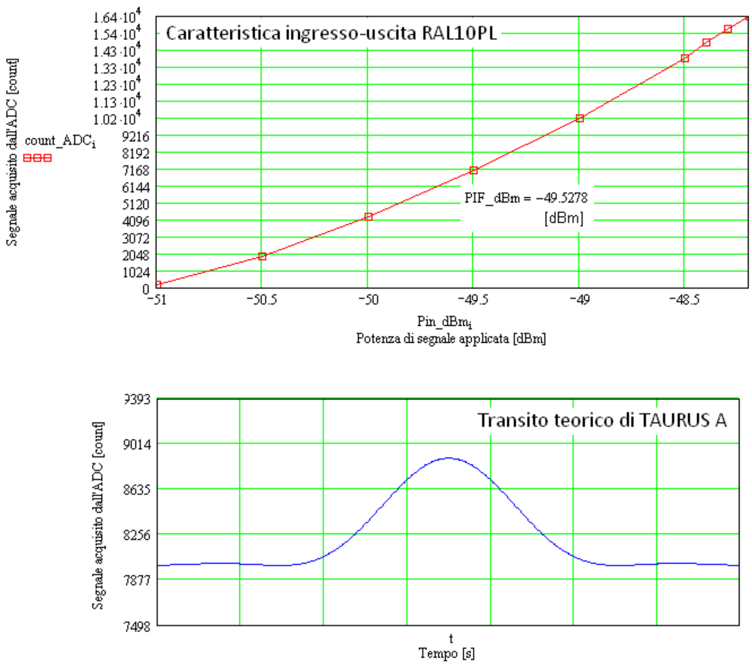

Fig. 3: *RAL10PL* receiver input-output characteristic (determined in laboratory) and *SPIDER230* theoretical response of *Taurus A* transit.

The *Taurus A* transit simulation is shown in Fig 3, where we see the input-output characteristic curve of the *RAL10PL* receiver obtained in laboratory and used for the simulation. The graph shows the maximum power of the received signal in correspondence of the peak transit.
We verify the correspondence of the theoretical simulation with experimental data.

The transit technique used for measurement consists of identify the object for which you want to record the radio emission, point the telescope in the sky area in which the object will move in the near future (eg 30 minutes later) and stop the telescope in that position. Because of the apparent sky rotation (caused by the rotation of Earth), the object will move towards the area of sky pointed by the antenna, will be intercepted by the receive beam and will pass through.

On February 24th 2014, *PrimaLuce Lab* technicians have pointed the *SPIDER230* antenna to *Taurus A* (the *M1* nebula in Taurus constellation that emits synchrotron radiation caused by electrons in fast spiral motion around magnetic field lines generated by the pulsar inside) recording a first 15 degrees transit, which showed a peak. Plotting the intensity data obtained on the sky map they have verified that this increase occurred precisely at the theoretical position of *Taurus A*(Fig. 4).

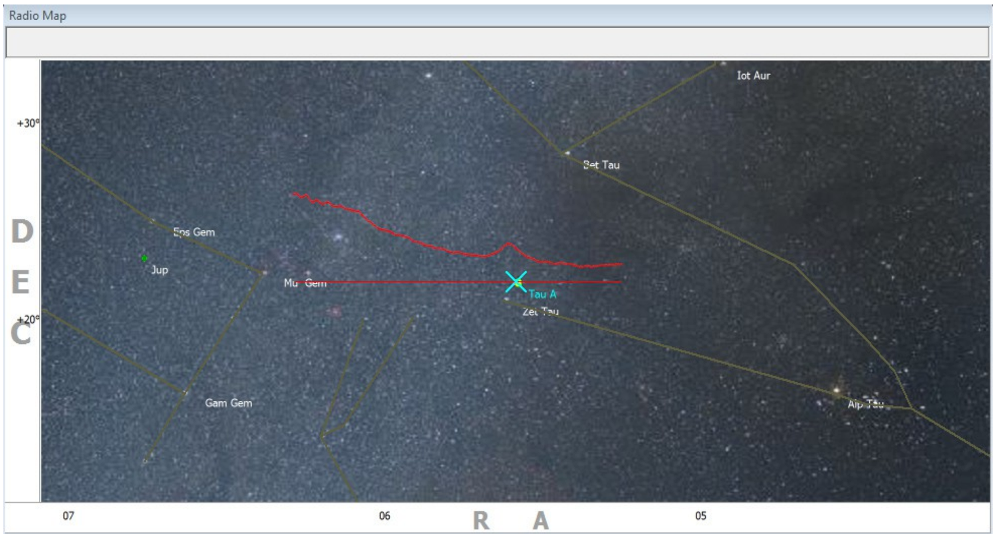

Fig. 4: Verifying the first *Taurus A* transit with the *RadioUniverse* software.

To validate this registration, on March 9th 2014, 5 consecutive transits of the same area of the sky have been performed, this time 4 degrees each. SPIDER230 allows you to automatically record consecutive transits (Fig. 5). *RadioUniverse* records, for each transit, a CSV file with 4 columns: each row is a record and contains date, Right Ascension, Declination and radio signal of the recorded point. So the different results obtained can be processed, for example by averaging the values to reduce random noise, increasing the visibility of the radio source. In the picture 6 we see the result of the processing of the 5 transits: the average curve is highlighted by red thick.

The "average" curve clearly shows the *Taurus A* transit which was also confirmed by the analysis of Istituto di Radioastronomia di Bologna (IRA). The experimental results verify, taking into account the approximations related to the simulation, the theoretical recording, see Fig. 3

SPIDER230 is able to record even faint radio sources.

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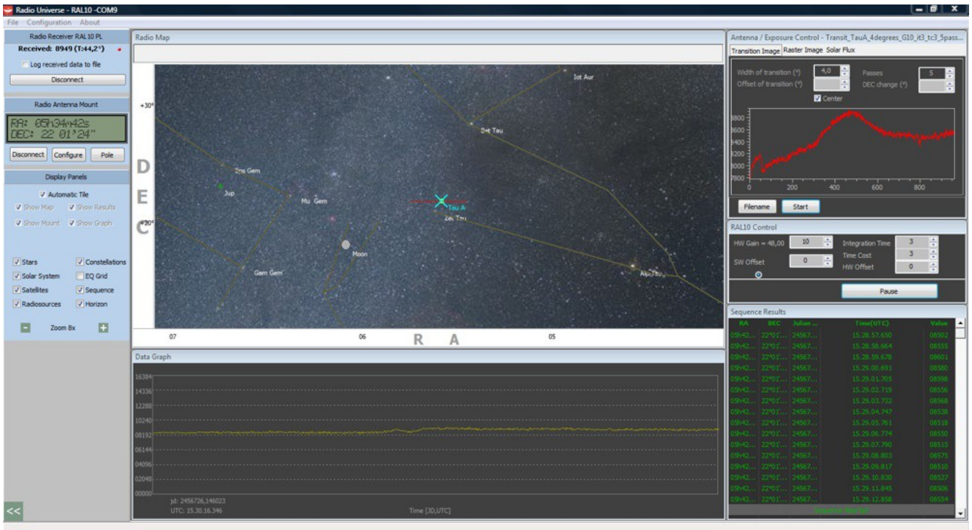

Fig. 5: *Taurus A* transits validation performed with *RadioUniverse* software.

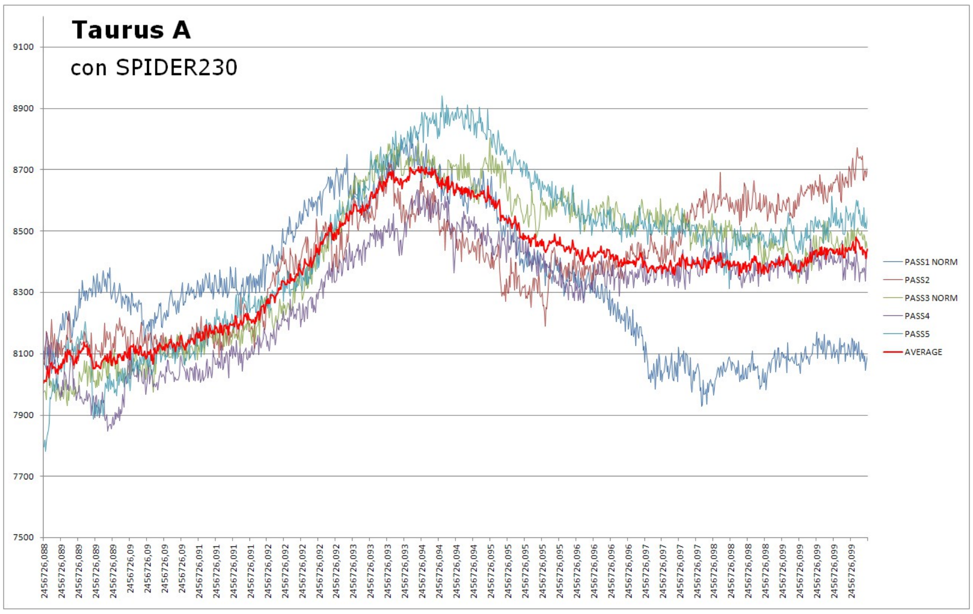

Fig. 6: *Taurus A* (M1) radio source transits.

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