WHITE PAPER

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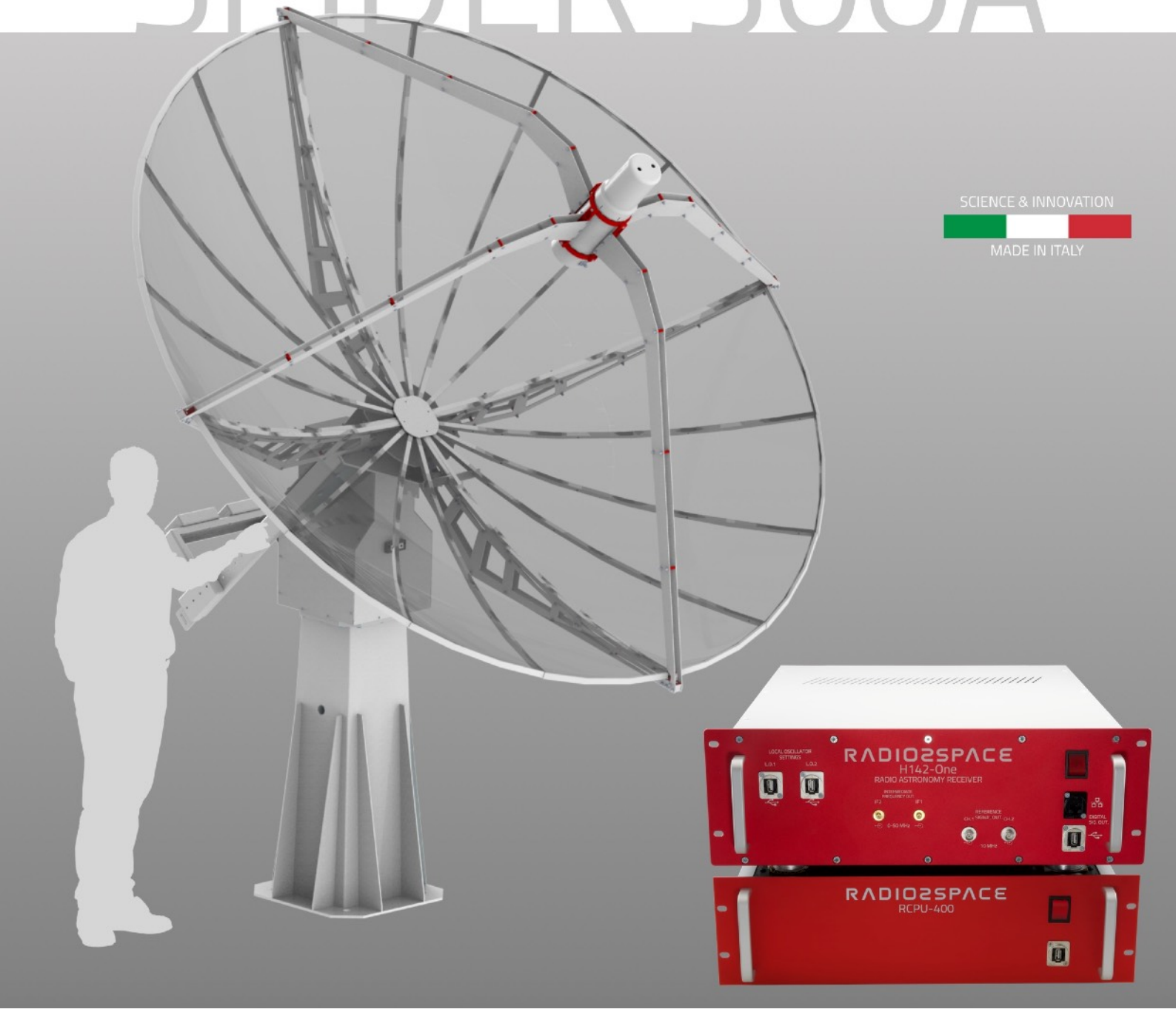
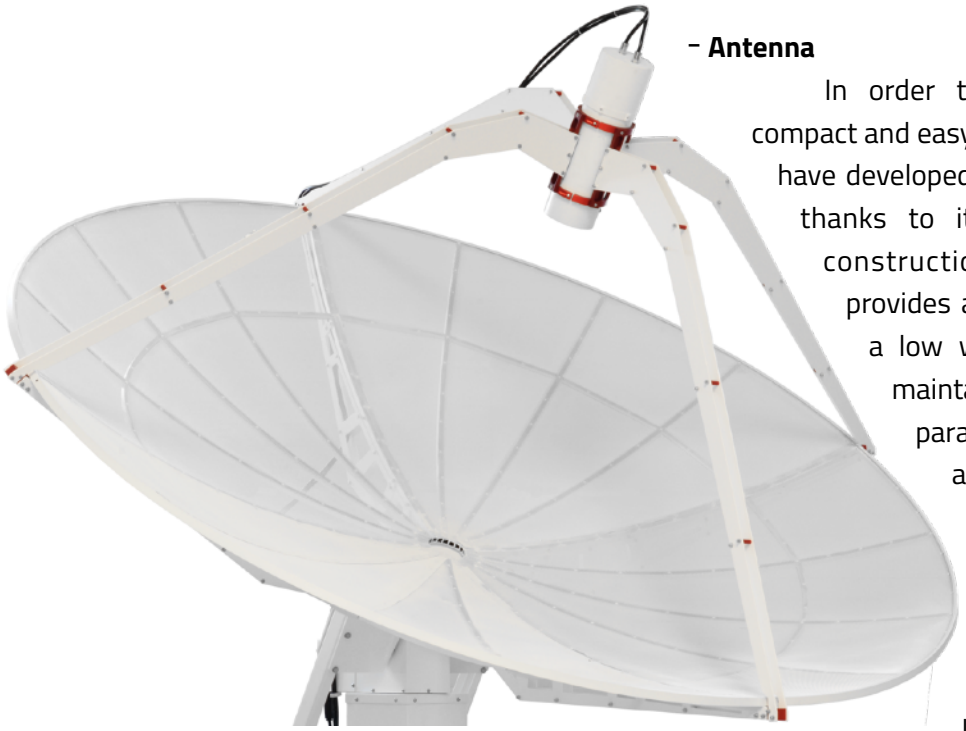
Radio2Space is a brand of PrimaLuceLab iSrl, via Roveredo 20/b, 33170 Pordenone, Italy.

SPIDER 300A



SPIDER 300A ADVANCED RADIO TELESCOPE

SPIDER 300A is a complete system, consisting of all elements that guarantees the reception and recording of the radio waves coming from space. Thanks to its high technology specifically developed by PrimaLuceLab, SPIDER 300A radio telescope allows you to get advanced level results with a reliable and easy to use radio telescope.

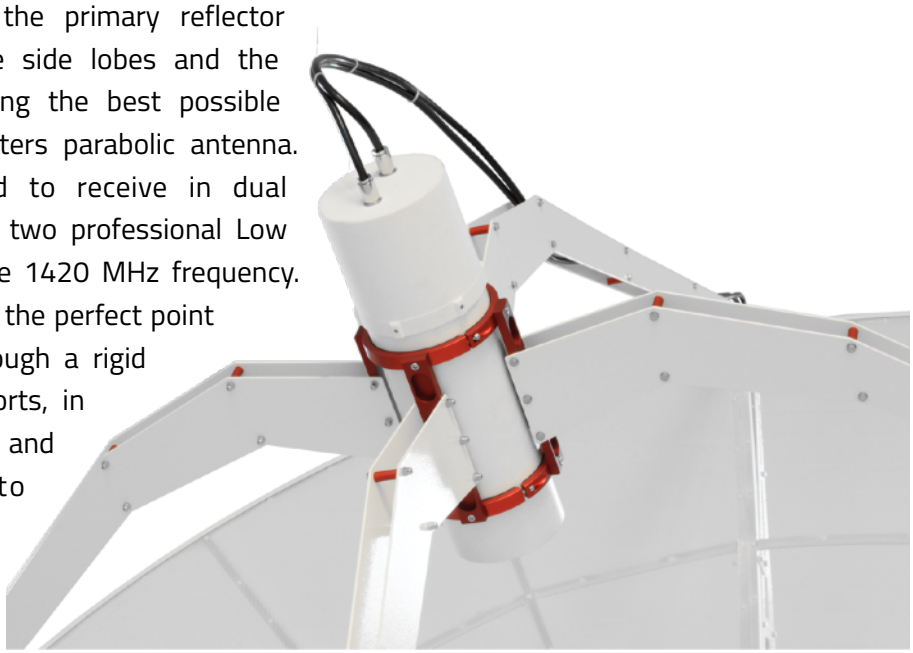


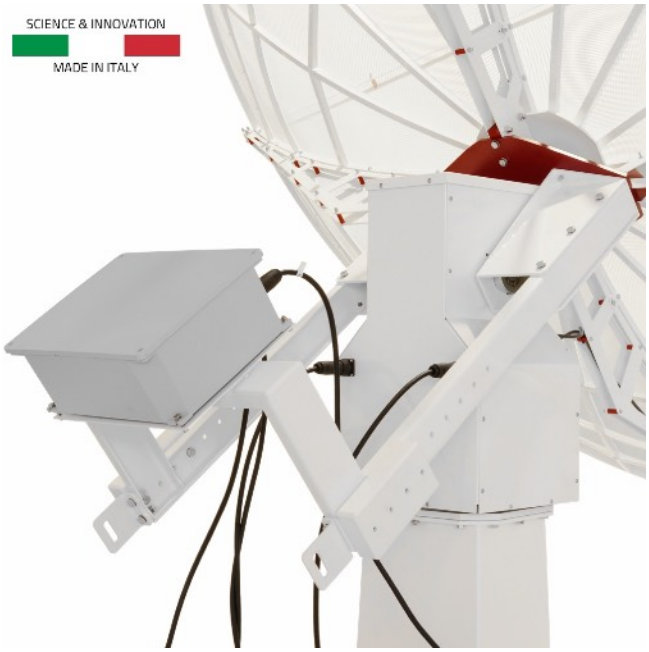
- **Antenna**

In order to get a powerful but still compact and easy to handle radio telescope, we have developed the ***WEB300-5*** antenna that, thanks to its 3 meters diameter and construction in fine metallic mesh, provides a large collection surface with a low weight. Special rear supports maintain the rigidity of the whole parabolic antenna on the mount avoiding bending and ensuring the effectiveness of the pointing system. They also help to maintain a perfect parabolic shape with a maximum error of less than lambda/20.

- **Feed horn**

Developed specifically for 1420 MHz PrimaLuceLab Radio telescopes, the ***H-FEED*** feed horn is designed for optimal illumination of the primary reflector allowing high gain, minimise side lobes and the spillover effect, thus obtaining the best possible performance from the 3 meters parabolic antenna. The feed horn is designed to receive in dual polarisation with support for two professional Low Noise Amplifiers (LNA) for the 1420 MHz frequency. The feed horn is positioned in the perfect point of focus of the antenna through a rigid support with 4 double supports, in order to have low obstruction and with a focusing device to precisely focus and maximise the performance of the entire radio telescope.





- Mount

Radio astronomy can be done both by day and night time and even when cloudy, since the 1420 MHz radio waves are not blocked by clouds. For this reason, in order to take advantage of this opportunity we have designed the ***WP-100*** altazimuth mount, weatherproof, that allows you to leave the SPIDER 300A radio telescope permanently installed outside. Equipped with automatic tracking and goto system controlled by the radio telescope software, it allows you to frame with great precision the Universe radio sources and move the antenna with a continuous and precise tracking. The WP-100 mount has 100 Kg load capacity and a very high precision pointing and tracking (encoders read resolution 0,0015°). Thanks to the optional weather station integrated with RadioUniversePRO control software, it can be also equipped with a special electronic security system which "parks" the antenna pointing the Zenith (the vertical position) when the wind exceeds 50 Km/h, so that the radio telescope moves and is safety locked in the position that offers the lower resistance to the wind.

- Pier

The WEB300-5 antenna, for its large diameter, can generate a big effort on the ground and, considering the weight of the WP-100 mount, it requires a very firm and robust anchoring system. The new ***C106-HEAVY*** pier offers all of these features, being in the meantime designed to keep the SPIDER 300A radio telescope permanently installed safety on the field.

The radio telescope and the C106-HEAVY need to be installed on a reinforced concrete base, on which the base of the column is fixed by means of special high strength bolts.
Along with the installation and operation manuals for the radio telescope, an example of concrete base design (that the user has to prepare to install the SPIDER 300A and that he has to verify based on terrain type of the radio telescope installation location) is supplied.

- **Receiver**

In order to get the best possible performance with the 3 meters diameter antenna of the SPIDER 300A, the new **H142-One** receiver has been specially developed, a 1420 MHz superheterodyne type radiometer/ spectrometer, double conversion (type UP/DOWN) with 50 MHz received instantaneous bandwidth (RF = 1.395MHz-1.445) and 14-bit analog to digital converter. The H142-One receiver has a 1024 channels *spectrometer* (61 KHz each) that are displayed and processed in real time by the control software supplied with the radio telescope. Thanks to the high gain and the low electronic noise of this receiver, the SPIDER 300A radio telescope is able to record many radio sources in the Universe.

- **Software**

SPIDER 300A comes with RadioUniversePRO, the first software specifically designed to allow everyone get professional level radio astronomy results but in easy way. The software allows you to control all the components of the radio telescope, check parameters and operations. On the left column, controls for the mount position and the pointed coordinates are shown, together with unwrapping monitor for cable management. On the right column, the receiver controls with real time recorded data allows to verify data. In the central part of the window, different tabs allow to operate the SPIDER radio telescope and record results. At the same time RadioUniversePRO offers many advanced options, customisations and typical functions of professional radio telescopes they may be used by expert users that find in RadioUniversePRO the same modus operandi of the large-sized radio telescopes.

RadioUniversePRO can be installed on a standard Windows computer and it's compatible with Windows 10. Pre-requisites:

- Intel i3 processor (at least 5th generation)
- 4GB RAM
- 4 USB ports
- 2 ethernet ports
- mouse and keyboard
- screen with FullHD resolution (1920x1080)

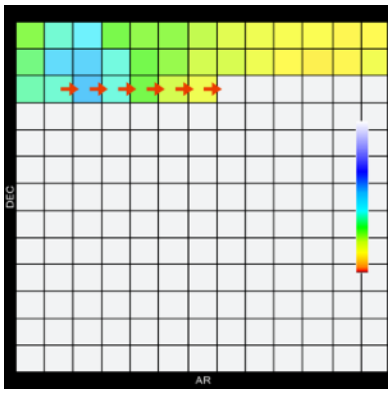
RadioUniversePRO: key features

- Control software for SPIDER radio telescopes
- Intuitive and easy-to-use: in single a screen it shows all the controls of the radio telescope
- Mount control: it allows you to remotely control all WP-100 alt-az computerized mount and German computerized equatorial mounts equipped with an ASCOM driver (it requires the installation of ASCOM platform)
- Receiver control: it allows you to connect and control H142-One receivers
- Data save in graphic format (PNG) and raw (FITS) compatible with NASA FITS Viewer.
- IF Monitor: it shows in real time the received band with FFT.
- BBC Tools: it allows you to identify artificial interferences and cancel them from recorded data.
- Offset alignment: automatic mount alignment on radio sources.
- Source visibilities: list of radio sources visible in the sky and that can be pointed to by the radio telescope.
- Gain calibration: it calculates the radio telescope gain curve to calibrate measurements using the optional SPIDER noise calibrator.
- OnOff: it automatically performs On-Off measurements on the selected source radio.
- Spectrometer: it displays the on-off spectrum of the observed radio source.
- Total Power Plots: it displays the radiometric data as a function of time and performs transits with the Cros Scan technique.
- Mapping: it allows you to set recording parameters of a radio image, view the result and save it.
- Planetarium: it shows the whole sky with stars, constellations, position of the planets and the main sources of natural radio waves of the Universe (feature to be activated with one of the next releases of RadioUniversePRO).

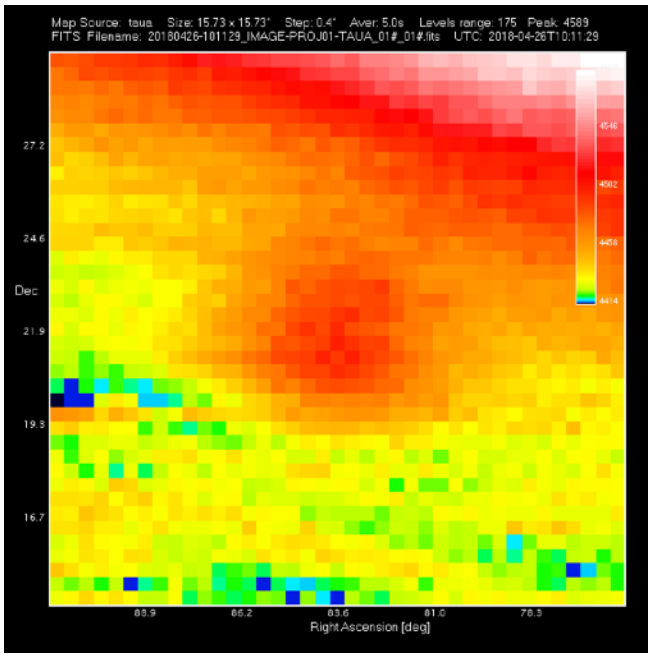
EXAMPLES OF RESULTS WITH SPIDER radio telescopes

SPIDER radio telescope allows you to make radio astronomy studies on many radio sources and to record different types of results as *transits, spectra* and *radio-maps*. Here you find a few examples of studies recorded with SPIDER radio telescope.

Taurus A radio map:



Taurus A is the radio source in Taurus constellation that corresponds to the Crab Nebula (M1), the supernova remnant exploded on July 4, 1054 and noted by Chinese and Arabian astronomers of the time. A radio telescope is different from an optical telescope by many aspects: one of these is that it collects radio waves from a single area in the sky. Just to give an example, it's like having a telescope with a CCD camera that comes with a single large pixel. In order to create radio maps, technique consists in moving the antenna with small movements and, for every sky position, record radio waves coming from space tracking the sky apparent movement. Then the SPIDER antenna is moved to a new position and record the next pixel value. For every pixel, RadioUniversePRO software calculates the total amount of radio waves captured and displays this value with a color based on a color scale chosen by the user. RadioUniversePRO software allows you to point the radio telescope to the precise sky position of the radio source, visualize in real time the bandwidth spectrum in frequency so you can see if you have artificial signal in it (allowing you to filter these from your recordings) and define radio map specifications.



With a 3 hours capture time, setting the following parameters in RadioUniversePRO:

Map dimensions: 15 x 15 degrees
Pixel separation: 0,4 degrees
Integration time for every pixel: 5 seconds

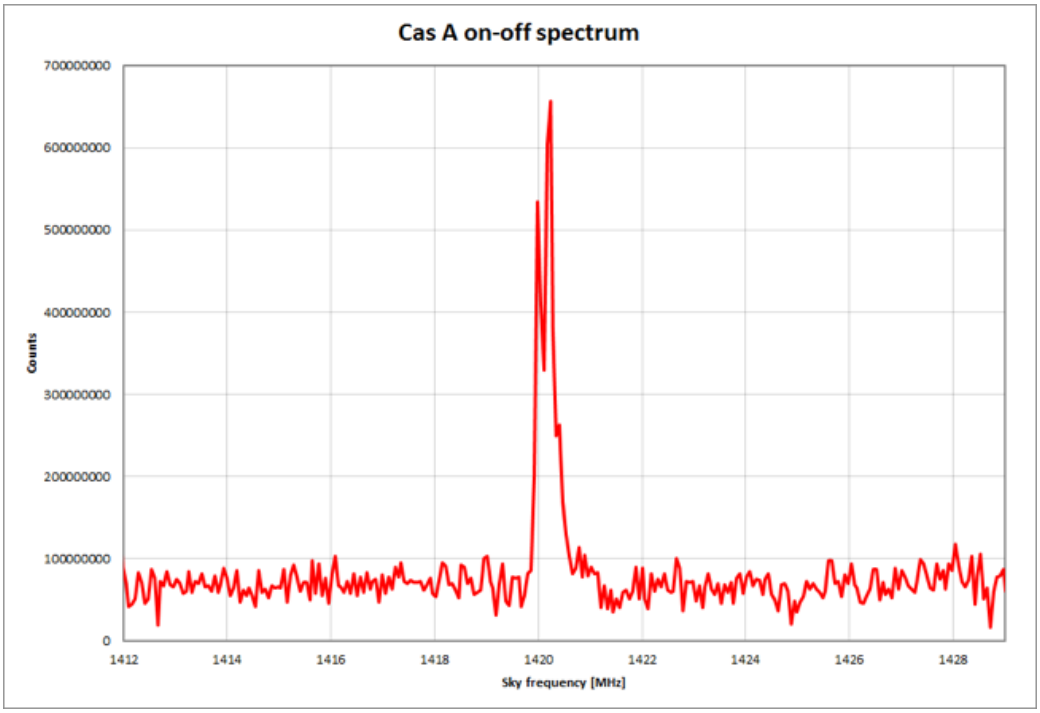
The result is the map that we show in the image. You can easily see the increase of the signal at the center of the map, corresponding to Taurus A position. The increase in the visible signal at the top right of the image is the Milky Way, in fact Taurus A does not lie perfectly on the plane of our galaxy but it is a few degrees away (as confirmed by the radio map).

Cassiopea A Hydrogen line detection:

Cassiopeia A is a very important supernova remnant for radio astronomy since it's the brightest extrasolar radio source in the sky when studying at frequencies above 1 GHz. This feature makes it a conquest within the reach of radio telescopes equipped with not huge antennas, but it is still a relatively weak radio source. In fact, having a flux of around 2400 Jansky at a frequency of 1420 MHz, it's a lot weaker than the Sun that is around 40000 Jansky!

Thanks to the high sensitivity of SPIDER radio telescope's H142-One receiver, it is possible to record radio signals coming also from objects outside the Solar System. Then we used the advanced features of SPIDER and RadioUniversePRO software to record the incoming signal from Cassiopea A during the day and in the presence of clouds.

In order to to highlight the emission line of neutral hydrogen at 1420 MHz it's possible to create an on-off calibrated spectrum. For this operation we used the On-Off feature of RadioUniversePRO with spectrum recording: by recording data from the source radio ("on" position) and then calibrating it to a point in the sky away from the radio source ("off" position), the result is a calibrated spectrum. The result is visible in the image below, you can see how the SPIDER radio telescope has perfectly highlighted the emission of the hydrogen line at 1420 MHz.



INSTALLATION AND TRAINING SERVICES

SPIDER 300A is designed to be shipped around the World. The main components are pre-assembled, so installation is relatively simple: the radio telescope can be installed on site in complete autonomy from 2-3 people, following the provided installation manual and user manual. On request PrimaLuceLab offers both an ***installation service*** and a ***training service*** at the installation site, which is performed by its specialised technicians. In order to let PrimaLuceLab installation team perform the optional installation service, if the customer request also the installation service the customer is required to bring to the installation location (and have ready the day before PrimaLuceLab team arrival at the customer installation location) all the needed tools like (but not limited to):

- Heavy lifting machine with operator and accessories to properly move the heavy parts of the SPIDER 300A radio telescope (every part may weight up to 150 kg and be as long as 3 meters)
- Ladder at least 2 meter high
- Meter
- Cutter
- Soldering iron and solder wire
- Hot air gun
- Screwdrivers set
- Caliber
- Nipper
- Extension cord
- 17mm, 18mm, 36mm, 41mm wrenches
- Adjustable wrench
- Bubble level
- Multimeter

The **installation service** includes the presence of PrimaLuceLab experienced staff for all assembly operations - on the concrete base already made by the customer according to the plans provided by PrimaLuceLab - and subsequent function tests. On request PrimaLuceLab offers ***training service***: at the installation site, which is performed by PrimaLuceLab team. The optional **training service** will take place - depending on the needs of the customer - immediately or can be delayed to a later remote intervention.

EXPERTISE

Before the delivery of the SPIDER 300A radio telescope you must meet all the conditions described in this document. If this is not the case, you will not be able to start up the system. If the installation is performed together with a third-party specialised company, Customer must deliver this manual within the times indicated in the following planning guide to the third-party Company.

PLANNING GUIDE

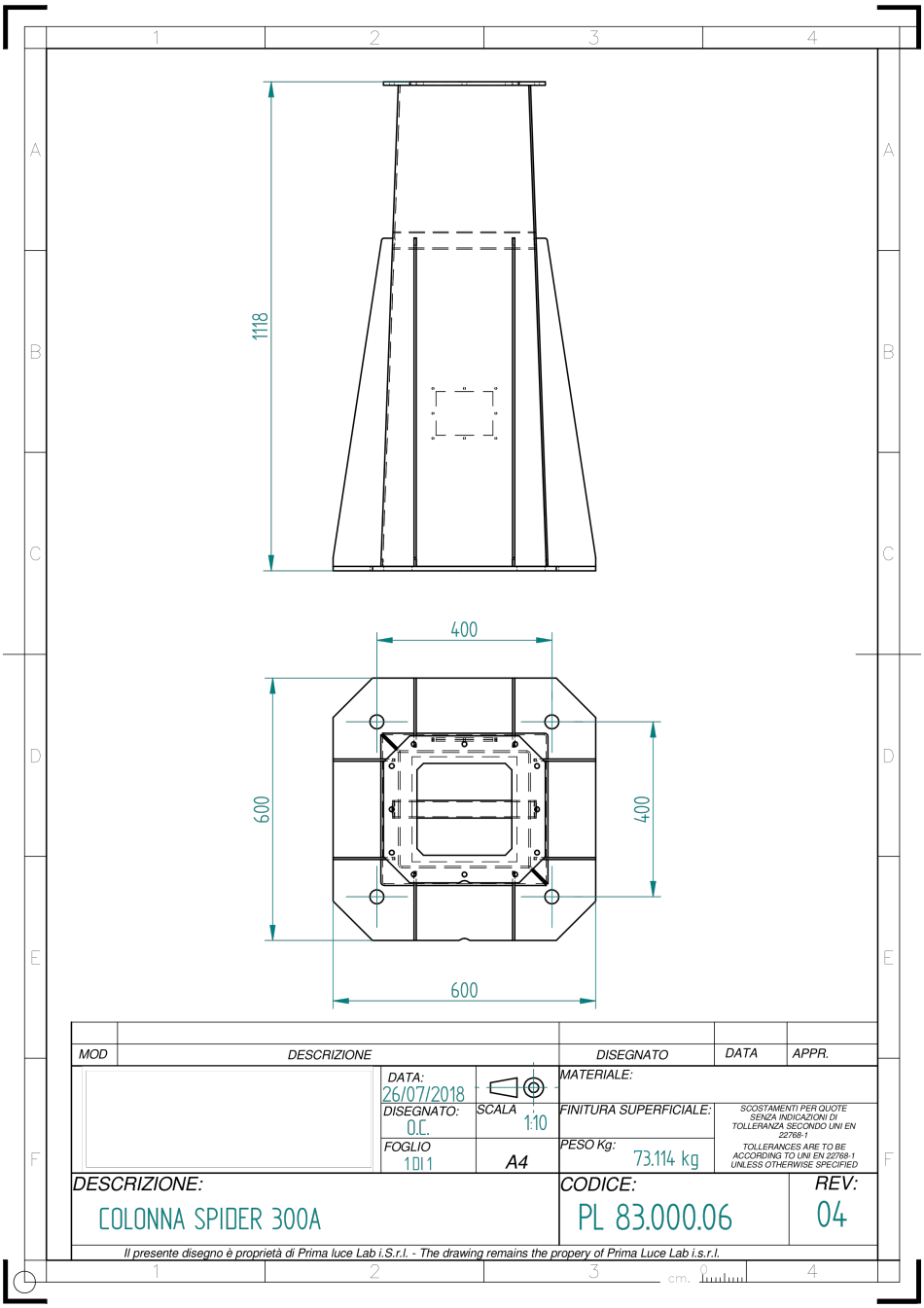
This chapter provides a general overview of the measures and preparations that the customer will have to take before the delivery of the SPIDER 300A radio telescope. More detailed information is contained in the respective paragraphs.

Period before delivery	Planning Criteria	proceedings
6 weeks	Staff and training	- Appoint a responsible for the preparations for receiving the radio telescope. - Select the personnel responsible for the operation and maintenance of the radio telescope. - Establish deadlines for the training of specialized personnel.
5 weeks	Place of installation	- Establish the location for the machine setting, taking into account the dimensions according to the layout and the maximum distance between the control room (internal) and the radio telescope (external) - Check for soil characteristics: geological parameters and planarity. - Keep in mind the size and weight of the machine. - Verify that the environment conditions are met: room temperature, maximum wind speed recorded in the past. - Check the transport route: access to the site, route travel, etc. - Since the radio telescope must be installed outdoors check the possibility of setting up a surveillance and/ or protection system for the radio telescope.
4 weeks	Electrical system	- Provide electrical connections close to the location of radio telescope. - Check that the cable section and protective fuses are dimensioned in accordance with the applicable regulations. Caution: Since the SPIDER 300A radio telescope is composed by an element (receiver) to be installed inside (control room) and one (mount and antenna) to be installed outside, it is necessary to provide a separate electrical connection to each element.

Period before delivery	Planning Criteria	proceedings
3 weeks	Concrete base and cable duct	- Based on the drawings at the end of this manual, make the concrete plinth in the area of installation of the radio telescope. - Prepare an underground duct from the base on which the radio telescope is going to be installed to the control room. The duct must contain the coaxial cables connecting the two LNAs to the receiver and the power supply and control cable of the mount. The duct must have a minimum diameter of 15 cm (6 inc). Since the 2 LNA power cables have a large diameter (to avoid signal leakage), they are rigid so the channel must not have narrow curves that prevent cable passage. - Prepare 2 groundings, that has to be dimensioned based on the legislation of the country of installation. One grounding will be closed to the pier base and one grounding will be in the control room (to connect the surge protectors of the receiver).
2 weeks	Installation of cable connections	- Have LNA power cables and electrical wiring and power supply cables are to be installed in the in-ground conduit by qualified personnel (electrician). The cables are shipped from PrimaLuceLab to the customer in advance on the delivery of the telescope.
1 week	Safety	- Before the delivery of the SPIDER 300A radio telescope, ensure that all safety conditions are complied according to the regulations in force in the Country of use.
At installation and start-up	Installation	- Have the connection of the SPIDER 300A radiotelescope made by specialized professionals.

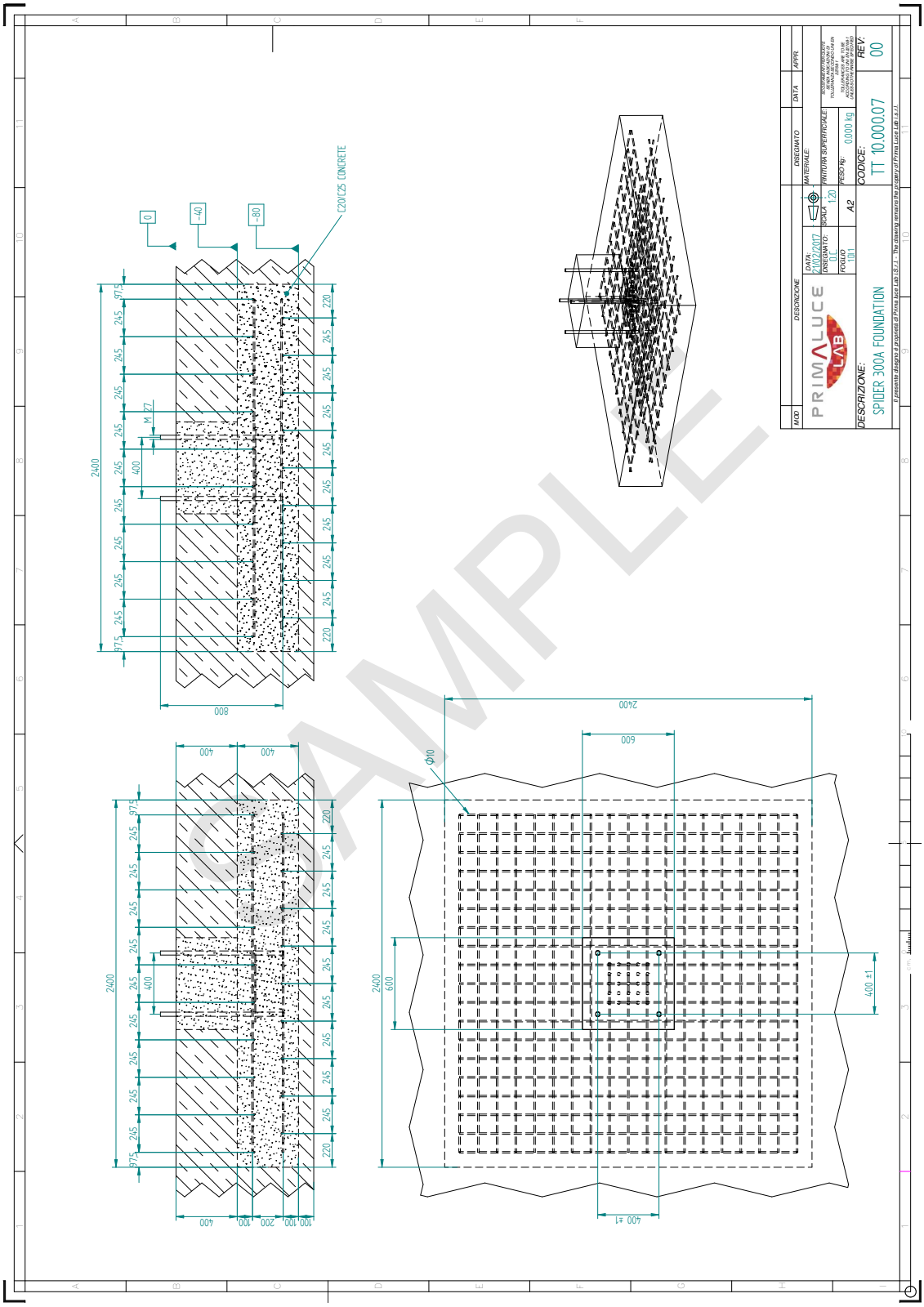
PLACE OF INSTALLATION

The SPIDER 300A advanced radio telescope must be installed outdoors and, in order to guarantee the necessary stability and to keep to the environmental conditions (rain, wind, etc.), it is necessary to make a reinforced concrete plinth with specially sized foundations as outlined below. If you need a competent service, especially for soil characteristics, you can show the professional the "Installation site" section and the foundation scheme / installation scheme. In this section you will find the scheme of foundation to be prepared to ensure the operation of the SPIDER 300A radio telescope. Only if the foundation's features meet the requirements of PrimaLuceLab, the stability of the SPIDER 300A radio telescope is guaranteed. The SPIDER 300A radio telescope is equipped with a dedicated column for ground anchorage and to support the efforts generated by the 3 meter diameter parabola.



SUGGESTED FOUNDATIONS DIMENSIONS

PLEASE NOTE: suggested foundations dimensions change based on the substrate type so you **HAVE** to contact us before making your foundations, letting us know your location substrate. If you need help, we can help you in design of foundations.



ENVIRONMENTAL CONDITIONS

The SPIDER 300A is designed for mount and antenna installation outside. The environmental conditions to be met for proper operation are:

	Condition
Temperature	from -10 °C / 14 °F to +50 °C / 122 °F
Maximum wind speed during use	50 Km/h (30 mph)
Maximum wind speed in stow position	150 Km/h (90 mph)

The receiver of the SPIDER 300A radio telescope is installed inside, in a control room specially protected by environmental phenomena (rain, snow, hail). It is preferable to install the receiver in a room with temperature as constant as possible.

ATTENTION: because of unpredictable natural events that are not covered by the warranty, if the wind is too high we designed a "safe release" mechanism that disconnect the mesh material from the antenna body and save the rest of the radio telescope. This way you can change only part of the antenna damaged by the wind with a new element of the antenna (that you can request to us as spare part).

Extended temperature version: For operation in extreme temperature conditions (lower or higher than the above table condition), a version of SPIDER 300A specially designed mount is to be required and specifically requested by the customer prior of the order.

Wind speed is one of the most important parameters to consider for the safe use of the radio telescope installed outside. SPIDER 300A radio telescope is safe for installation in external environments and does not require coverage. For safe use, you have to:

- When not in use, the SPIDER 300A radio telescope is to be placed in the stow position with the antenna pointing to the vertical (Zenith). In this way the antenna offers the minimum wind resistance.

- When in use, the SPIDER 300A radio telescope is designed for operations with winds up to 50 Km/h (30 Mph). When the wind speed is higher, place the SPIDER 300A radio telescope in Stow Position and, if necessary, lock the antenna with the stop rod. The UltraSonic Wind Sensor for SPIDER radio telescopes (optional) allows you to constantly monitor the wind, using the RadioUniversePRO software provided with the radio telescope. This will automatically move the SPIDER 300A to stow position when the wind exceeds the 50 Km/h (30 Mph) safety threshold.

ELECTRICAL SYSTEM

The instructions contained in the "Electrical System" section must be supplied to a Company specializing in electrical installations. These instructions are generally valid worldwide but may vary depending on the Country of installation of SPIDER 300A, depending on the prescriptions of the electrical systems used in their respective Countries.

Power: the receiver and the power supply box are equipped with a power supply unit that must be connected to a power socket with the following characteristics:
- Worldwide (excluding USA and Canada): 230 V with Schuko socket or according to Country regulations. The Schuko connector is included in the SPIDER 300A radio telescope.
- For USA and Canada: 115 V with AC outlet according to US standards.

Connection values: voltage variations over and above the normal levels compromise the proper operation of the SPIDER 300A radio telescope. A voltage stabilizer should be used.

	SPIDER 300A
Rated voltage at 50 Hz ± 1 %	230V
Max power absorption	1000W

Ups. If necessary, connect the plant to a UPS (UPS) unit with the following advices:
- for the sizing of the UPS, the behavior in case of short-circuit and overload of the UPS system should also be considered.
- Overload capacity of the UPS system: ≥200% for 0.5 s.
Note: Sizing of the UPS must be absolutely defined by the supplier of the UPS!

Lightning protection. Due to the possible emission of radio waves and therefore the creation of strong interference, a lightning arrestor system can not be installed near the SPIDER 300A radio telescope. The lightning protection system therefore should provide:
Passive protection on the antenna + mount structure: the highest point of the radio telescope when positioned in stow position is the one that covers the 2 LNAs and it's made of non-metallic material. In the event of a lightning striking the SPIDER 300A radio telescope, the electric current could freely flow through the entire structure and discharged to terrain. SPIDER 300A is provided with a special connection point on the column to be connected to the ground sink that the customer has to put in place according to the regulations in force in the Country of installation of the radio telescope.
Passive receiver protection: to prevent electric current from electrocution or electrostatic currents reaching to the receiver located in the radio telescope control room, the SPIDER 300A is equipped with special electrostatic voltage dischargers to be installed before the receiver: equipped with a special socket, it must be connected to the ground system, allowing the discharge of any electric current generated by the lightning strike before it reaches the receiver.

RECEIVING THE RADIO TELESCOPE

Customers can request PrimaLuceLab to transport the radio telescope to the final installation position. The length of the transport path must not exceed the one agreed per contract and it will have to be free of steps or ramps.

What should the customer do?

After delivery, please check that no component of the radio telescope has been damaged during transport. Any visible damage due to transport must be documented on the transport letter with any possible photographic documentation, which should be countersigned by the driver. Any damage caused by transport, not visible to the naked eye, must be reported no later than 6 days to PrimaLuceLab.
Unless otherwise agreed, the transport of the radio telescope to the final installation site must be provided by the customer. The transport path to the site of the radio telescope must be defined in good time before the telescope is delivered. The installation site must be free of obstacles.

	Dimensions of SPIDER 300A boxes	Weight of SPIDER 300A boxes
Antenna and mechanical supports	1940 x 1940 x h750 mm	120 Kg
Mount and pier	1580 x 980 x h1400 mm	200 Kg

Customer Responsibility

PrimaLuceLab cannot be held responsible for any damage to things or people caused or caused during the installation by the customer. In particular:
- All transport operations must be carried out as required by the relevant provisions.
- The radio telescope must be installed on a concrete plinth that must conform to the plans provided by PrimaLuceLab.

The concrete plinth must be prepared by the client prior to the installation of the radio telescope and must have the channel with the power cables already in place. The customer must prepare the earthing system (to which the radio telescope is to be connected) according to the regulations in force in the Country of installation of the radio telescope. Store transport equipment in the location of the machine in case of any future need.

Transportation Cautions:

Lift, transport and deposit the SPIDER 300A radio telescope with caution. The radio telescope mount and antenna must be removed with great care and attention from the transport boxes and must be placed close to the installation site. The SPIDER 300A antenna has a large diameter so you need to be very careful in order not to damage its parts during installation (especially the aluminum mesh). The SPIDER 300A antenna and mount are very heavy. To be moved and lifted it requires more people AND the use of special moving or lifting machines (without which the installation process is not possible).

POWER AND DATA CABLES

The SPIDER 300A radio telescope is made of elements to be installed outside (antenna and mount) and others to be installed inside (receiver and and control computers). All elements must be properly powered and must be connected to each other with special data cables provided with the radio telescope. In particular:

Power

The power supply of the external elements (antenna and mount) is made through the special cable that connects the mount to the control box to be placed in the control room and therefore no external power point is required. The power supply must be provided starting from the control room where the 2 elements must be powered, connecting each one to a power socket.

Data and RF cables

Data cables connect the external elements to the internal ones with a total of 3 cables. The 2 LNAs installed on the antenna are connected with 2 coaxial cables specially dimensioned to avoid data loss for distances (between external radio telescope and internal receiver) up to max 50 meters. Distances up to 100 meters are possible but this will introduce gain loss and we strongly suggest lower distances. To allow proper antenna handling, each coaxial cable is made up of 2 parts:

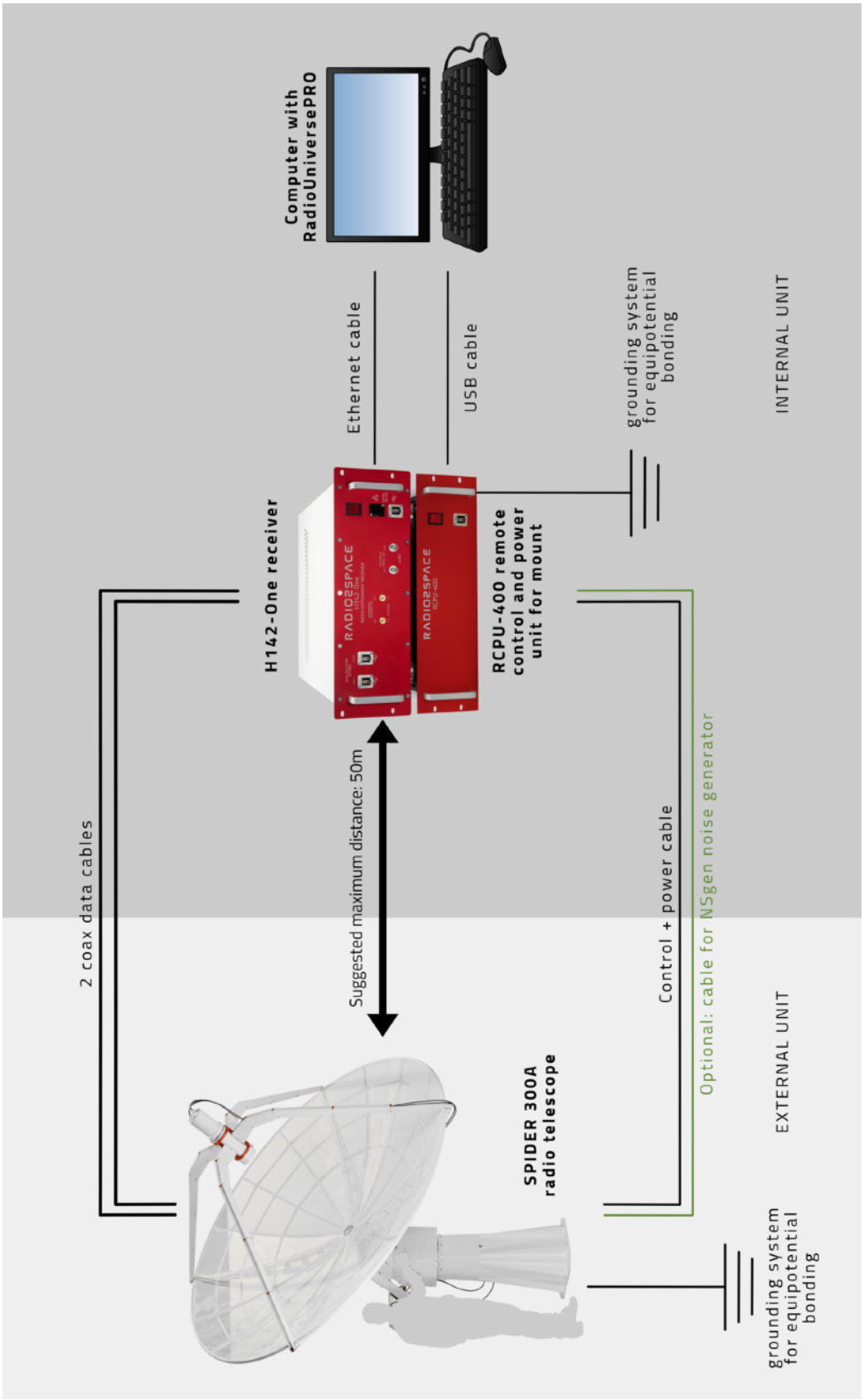
n.2 Ecoflex 10 coaxial cables that connect LNAs to the cables in the channel
n.2 Ecoflex 10 coaxial cables installed in the channel (as indicated by the PrimaLuceLab project) and that connect the radio telescope to the receiver RF inputs placed in the control room at a maximum distance of 50 meters.

The mount is connected to the control computer via the same cable that also provides power to the motors (the cable has a multi-wire braided cable specially designed to avoid interference). The cable must be inserted into the channel connecting the outside radio telescope to the internal control room (along with the LNA connection cables). Inside the control room, the cable has a dedicated control box to be placed next to the receiver and connected to a control PC (where RadioUniversePRO software is installed) with a USB port.

Note on Radio Frequency Interferences:

SPIDER is designed to record frequencies from 1395 MHz to 1445 MHz. In order to allow proper capture of natural origin radio waves coming from space, it requests that radio frequency interferences must not be present in the installation location. PrimaLuceLab cannot be held responsible of any radio interference that may be captured by the SPIDER radio telescope.

RADIO TELESCOPE AND CONTROL ROOM CONNECTIONS



GENERAL SPECIFICATIONS

Optics	Prime focus
Primary reflector diameter	3 m
Focal ratio	0,33
FWHM Beamwidth	4,9°
Surface precision (rms)	Lambda/20
Reflector material	Aluminum
Gain	0.0009 K/Jy
Polarization	circular, double
Central frequency	1420 MHz
Receiver band	50 MHz
Noise temperature	50 K
Channels number	1024
A/D converter	14 bits
Elevation range	0-90°
Azimuth range	0-360°
Max slewing speed (wind speed < 60 km/h)	90°/min Azimuth 90°/min Elevation
Encoders read resolution	0,0015°
Higher wind speed (operativity)	50 Km/h
Higher wind speed (survival)	150 Km/h