SCIENTIFIC CASES FOR RECEIVERS UNDER DEVELOPMENT (OR UNDER EVALUATION)

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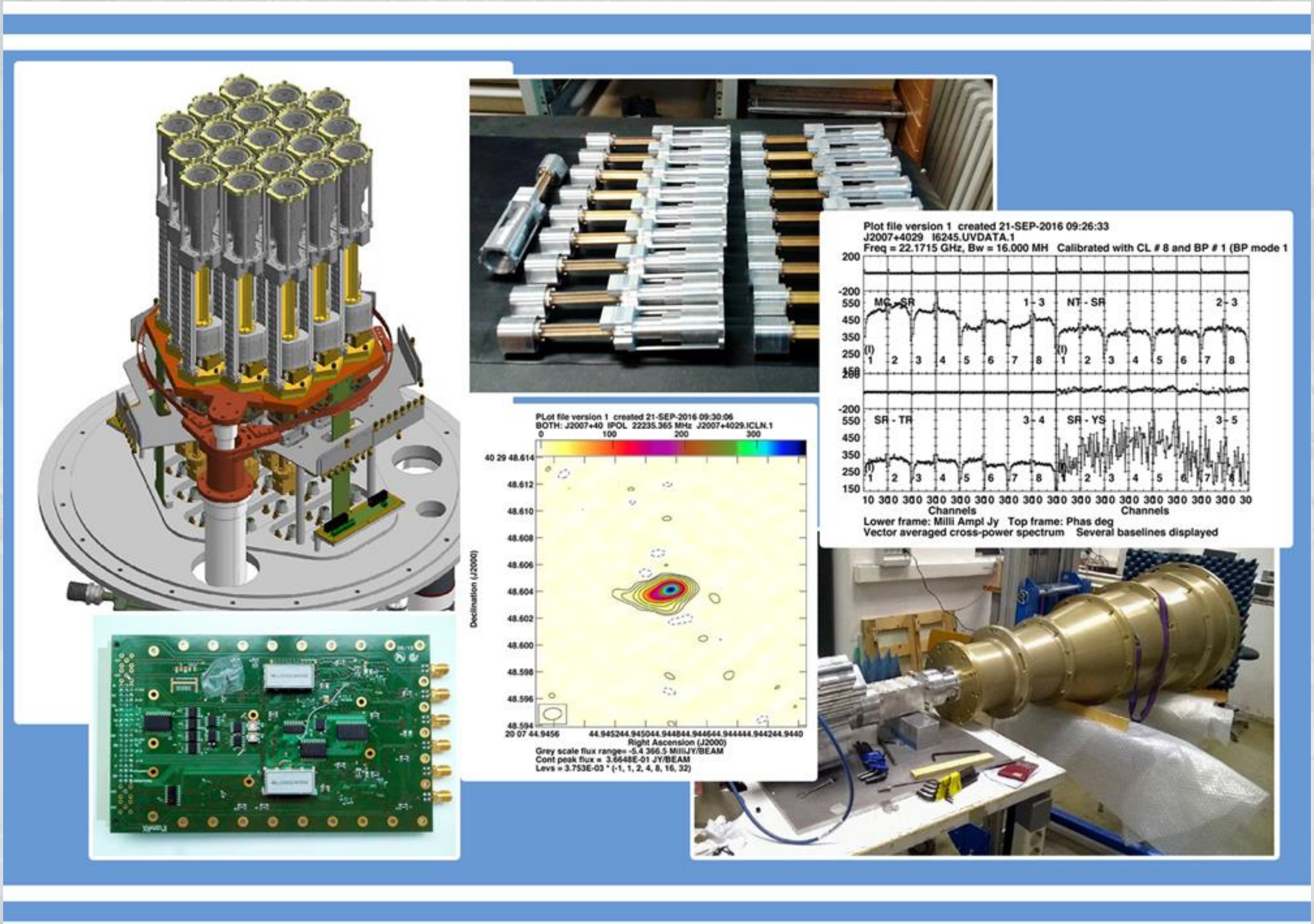
Part I – Infrastructure

Part II - Italian receivers and the International context

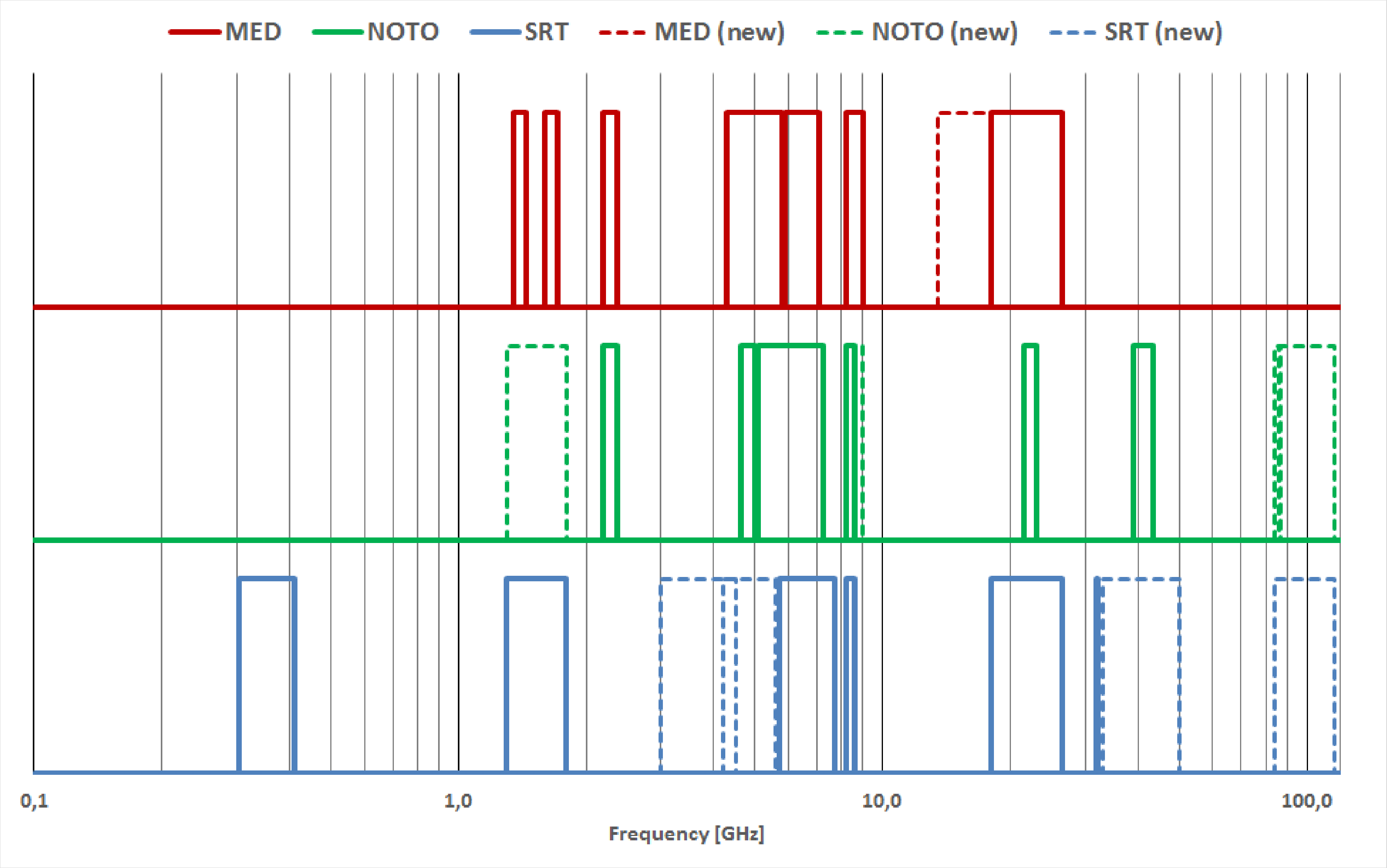
Part III - Scientific perspectives of the Italian Radio Telescopes

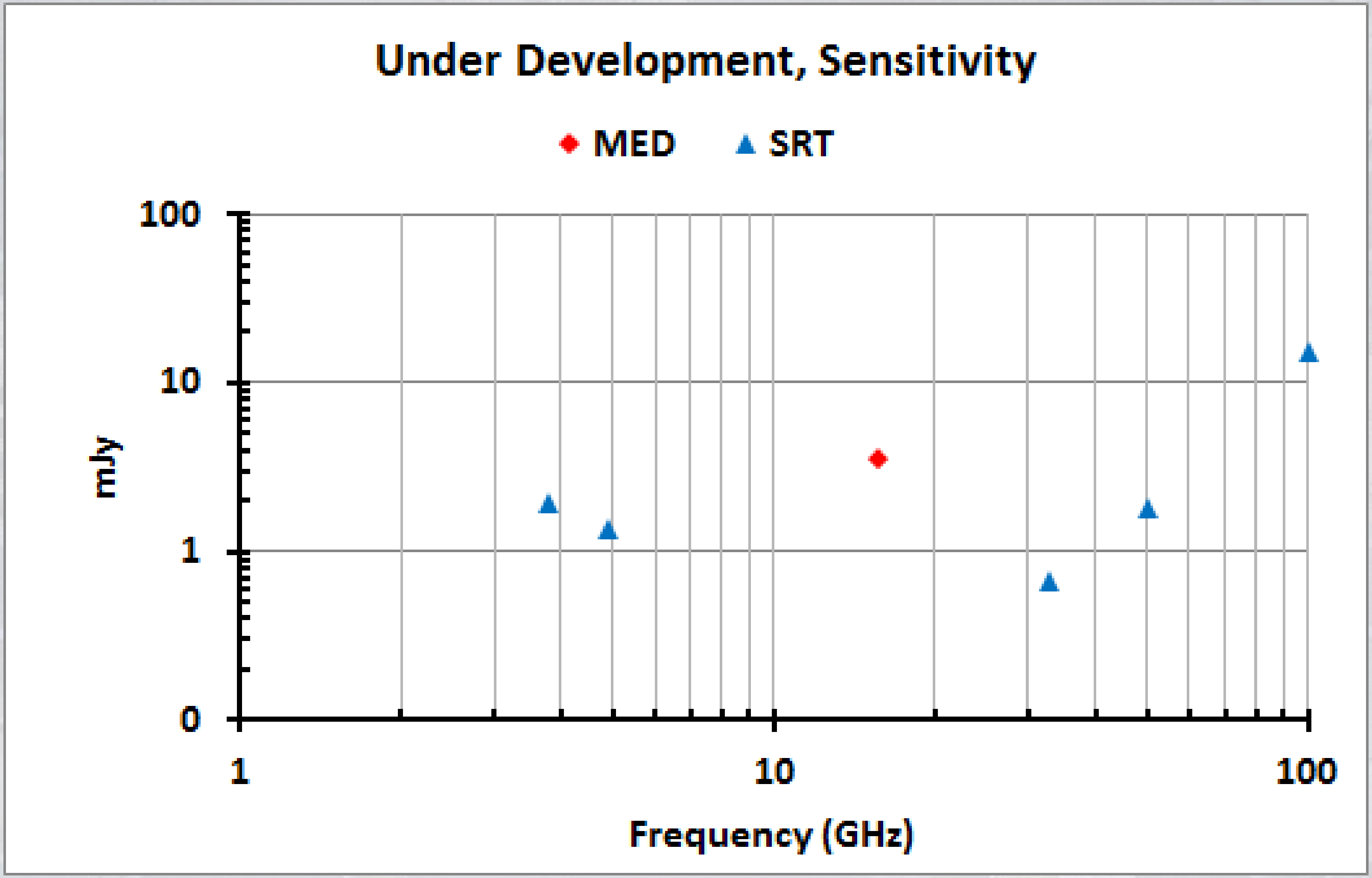
Part IV – Recommendations

Appendices


Plot file version 1 created 21-SEP-2016 09:26:33
J2007+4029 I6245.UVDATA.1
Freq = 22.1715 GHz, Bw = 16.000 MH Calibrated with CL # 8 and BP # 1 (BP mode 1
MC - SR
1 - 3
NT - SR
2 - 3
SR - TR
3 - 4
SR - YS
3 - 5
Channels
Lower frame: Milli Ampl Jy Top frame: Phas deg
Vector averaged cross-power spectrum Several baselines displayed
PLot file version 1 created 21-SEP-2016 09:30:06
BOTH: J2007+40 IPOL 22235.365 MHz J2007+4029.ICLN.1
Declination (J2000)
Right Ascension (J2000)
Grey scale flux range= -5.4 366.5 MilliJY/BEAM
Cont peak flux = 3.6648E-01 JY/BEAM
Levs = 3.753E-03 * (-1, 1, 2, 4, 8, 16, 32)

Receivers under development / under evaluation		
Receiver ID	Frequency coverage [GHz]	
	Min	Max
MED Ku	13,5	18
NOTO L	1,3	1,8
NOTO S/X	2,2	2,36
	8,18	8,98
NOTO W (ex-MPIFR)	85,945	86,545
NOTO W (ex-IRAM)	84	116
SRT S	3	4,5
SRT Clow	4,2	5,6
SRT Q	33	50
SRT W (ex-IRAM)	84	116


MED
NOTO
SRT
MED (new)
NOTO (new)
SRT (new)
0,1
1,0
10,0
100,0
Frequency [GHz]


Under Development, Sensitivity
MED
SRT
100
10
1
0
mJy
1
10
100
Frequency (GHz)

SRT S-band receiver

Frequency range of the S-band receiver is different from that of the typical S-band front ends at the EVN telescopes

A number of scientific goals for the SRT S-band 7-beams receiver can be summarized as follows:

a) To probe, through the discovery of new highly relativistic binary systems, **alternative Gravity theories**, and in general **enlarge the available pulsar sample**.
b) To monitor the sample of pulsars of the European Pulsar Timing Array experiment aimed at the **detection of the gravitational wave background** in the nanoHertz regime.
c) To map the large scale properties of **magnetic fields in clusters of galaxies**.
d) To understand the **polarized synchrotron emission of our Galaxy** in order to infer the galactic contribution to the polarized Cosmic Microwave Background.
e) To produce calibrated **images of Supernova Remnants** and improve the knowledge of their spectra.

Also, the multi feed properties of the S-band receiver make it suitable for the realization of **large-area sky surveys.**

SRT Clow-band receiver

The decision to build a Clow-band front end has been motivated mainly by the possibility to join EVN/global VLBI observations at this frequency.

The availability of both Clow- and Chigh-band receivers at SRT will be of importance for polarization studies.

Typical science cases for Clow-band VLBI observations are related to:

a) study of **continuum emission from optically thin emission regions**.
b) Jets of radio loud active galactic nuclei, such as radio galaxies and blazars.
c) Jets from compact binaries.
d) In **young radio sources**, it is possible to monitor the advance velocity of hot spots.
e) The study of **transient phenomena**.
f) The study of **continuum emission from compact Galactic and extragalactic sources** (e. g. AGN and SN remnants).
g) Polarization properties of AGN and compact sources; VLBI studies of polarization in young compact radio sources like CSO and CSS, and VLBI studies of Rotation Measure properties in quasar and blazar jets.
h) Spectroscopic observations of some **molecular transitions like the OH line** at 4660.42 and 4765.562 MHz, **and the formaldehyde (H_2CO)** line at 4829.66 MHz.

Being MED and NOTO already equipped with C-low band receivers, there is also great potential for **Italian VLBI network** coordination in this band

SRT Clow-band receiver

Among the possible SD applications of the Clow-band receiver, we mention:

a) Study of the **interstellar gas properties** by means of observations of recombination lines (in particular Hydrogen ones) both galactic (e.g. Ultra-Compact HII regions) and extragalactic ones (e.g. in starburst galaxies).
b) Study of **galactic and extragalactic** emission/absorption and – possibly – maser emission produced by the **formaldehyde molecule**.
c) Single-dish **total intensity and polarization studies of extended sources** (> 10 arcmin) like Galactic emission, giant radio galaxies or radio relics in galaxy clusters.
d) Study of **background point-like sources** in nearby galaxy clusters (RM grid) **to measure the cluster magnetic field**.
e) **Formaldehyde absorption line ratios** can be used **as gas density tracers** if both the 4829.66 MHz and the 14.470–14.500 GHz transition lines can be observed. **Synergy with the Medicina telescope**.

Other science drivers for a Clow-band receiver at the SRT have been identified during the Workshop "**Science with the Sardinia Radio Telescope**" and were related to the study of active binary stars, polarization of the CMB and SETI experiments.

SRT Q-band receiver

The Q-band and W-band receivers share a number of possible science cases to be addressed with observations in the VLBI network. Among them we mention:

a) Physics of **supermassive black holes** and tests of **general relativity**.
b) Physics of relativistic jets. In synergy with very high energy observations this would allow to investigate the origin of γ-ray emission in relativistic outflows and the surrounding of supermassive black holes.
c) Young Stellar Objects, star forming regions in our Galaxy and Supernovae Remnants.
d) VLBI observations in both the Q and W, for t the **detection of SiO masers in Mira variables** and other evolved stars.

Synergy with international arrays like VERA and KVN, operating in the Q band as well.

Among the main scientific goals that can be exploited with SD observations using the multi-feed SRT Q-band receiver we mention:

a) Mapping Galactic filaments by means of SiO, CH_3OH and high density tracers observations.
b) Survey of **Complex Organic Molecules (COMs) in high-mass star-forming regions**.
c) Galactic maser surveys. Class I methanol masers at 36 and 44 GHz in star-forming regions can be observed to investigate their distribution, morphology and the kinematics of maser emission.
d) Study of **methanol megamasers in starbursts and AGN** are useful to probe their demographics and investigate the possible link with *feedback* mechanisms in galaxies. A 36.2 GHz survey with SRT could also be included in a VLBI initiative for maser proper motions.

SRT and Noto W-band receivers

A number of scientific goals for the W-band receivers under development at both SRT and NOTO have been identified.

Among the main science cases that can be investigated with mm-VLBI observations we mention:

a) The study of the **physical properties, formation, structure and kinematics of relativistic jets**, the relation between the jet and the central black hole, the jet polarization properties and the connection with the surrounding magnetic field.
b) Physical properties of regions affected by scatter broadening, such as SgrA*, which cannot be efficiently studied at lower frequency.
c) (Binary) supermassive black holes.
d) Monitoring of **flares and outbursts in AGN**.
e) Kinematics, distribution, polarization and variability of **SiO masers in evolved stars**.
f) A science case on Mira variable stars requiring Q- and W-band observations with the SRT has been already reported.

SRT and Noto W-band receivers

Concerning SD we mention:

a) Science cases based on the study of **CO transitions**, for instance:

- **mapping of Galactic filaments**.
- Multi-line studies of **methanol Class I and II Galactic masers** in star-forming.
- Observations of **CO in local galaxies** to compare molecular gas mass profiles with dust mass and atomic/HI gas mass profiles obtained with other telescopes.
- **CO emission in intermediate z starbursts** can probe a crucial phase in galaxy evolution, covering almost half the age of the Universe and the most dramatic change in star-formation activity.
- **Molecular gas in HI-selected galaxies** can be used to estimate the total gas content..
- SRT mapping could be used in **charting molecular outflows in AGN** with broad CO(1-0) emission.
- Observations of **molecular tracers** (CO and other mm probes) **in low-metallicity dwarf galaxies**, although difficult, can be potentially rewarding especially in terms of isotopologues and the possibility of estimating column densities through optically thin emission.

a) By means of **3mm observations in nearby galaxies and starbursts** several isotopologues (including $H^{13}CO^{+}$(1–0), $H^{13}CN$(1–0) and $HN^{13}C$(1–0)) may be detected to compute accurate line ratios and reveal a wealth of chemistry as a diagnostic of source obscuration and excitation.

b) **Dense-gas tracers** such as HCN(1–0), HCO^{+}(1–0), HNC(1–0), or CS(2–1) may be **used to study the dense gas distribution in nearby galaxies**, including AGN, starbursts, Luminous and Ultra-Luminous Infrared Galaxies.

c) The **SiO(2–1) transition at 86.85 GHz can be observed to probe shocks in AGN** to disentangle the physics of dense outflows around the AGN itself.

d) The **Sunyaev-Zeldovich effect in galaxy clusters can be detected** and used to investigate the properties of cluster galaxies and the intra cluster medium, as well as the cosmological parameters.

MEDICINA Ku-band receiver

A number of SD science cases for the Ku-band receiver at MED were identified at the time of the construction proposal, namely:

a) **Continuum and polarization studies of galactic and extragalactic radio sources**; detection and spectral energy distribution of GPS/CSS populations.
b) Blind, **large-area surveys** of the sky..
c) **Source variability monitoring**, also in synergy with projects at other frequencies. Among such collaborations.

Also, spectral line studies (both Galactic and extragalactic) will benefit by the continuous coverage of the radio band from 12 to 26 GHz at MED.

With respect to VLBI observations, observations in the Ku band are possible with the VLBA and GBT. The addition of the Medicina telescope to the VLBA or the EVN sub-array at 2 cm will improve the observations both in terms of UV coverage, resolution and sensitivity.

VLBI science cases in the Ku band include studies on:

a) Physics and kinematics of **radio jets**.
b) **Evolution of black hole systems**.
c) **Magnetic field and polarization properties of blazars** and connection with multi-frequency (gamma-ray) observations.
d) Spectroscopic studies include **methanol maser studies** of collapsing gas clouds at stellar birthplaces and protoplanetary discs.

It is worth mentioning that 15 GHz is the observing frequency of the **MOJAVE project** (http://www.physics.purdue.edu/astro/MOJAVE/), one of the VLBA Key Science Projects. MOJAVE is a long-term program to monitor radio brightness and polarization variations in active galaxies jets.

NOTO L + S/X band receiver

With respect to the currently installed S/X at NOTO, the L+S/X front end would offer the advantage of providing the telescope with the possibility to perform **observations in the L band**, and to have a **larger** S/**X bandwidth**. The scientific cases that can be addressed in the L and S/X bands with this receiver are discussed in the following.

L band: this band is of **great interest for VLBI obser**vations, for both continuum and spectroscopy studies. VLBI in fact allows for higher sensitivity through a larger collecting area, better RFI rejection and great temporal and spectral resolution as supported by DBBC back-ends. Possible VLBI scientific applications include spectroscopic observations of **OH galactic masers, OH maser distribution** in low redshifts galaxies and **HI distribution** in nearby galaxies. The L band is also extensively used in the continuum for **AGN studies** with the EVN array. Finally, we want to mention two science cases that can be considered of importance also in the international context, namely:

a) **FRB**. The discovery frequency of these sources is generally ≈ 1 GHz, so the L-band receiver is the ideal one for high angular resolution follow ups.

b) Search for ExtraTerrestrial Intelligence (**SETI**) project. L-band is the traditional search band for SETI and the VLBI potential in this context, even with small arrays, has already been demonstrated [7].

It is worth noting that, since accurate imaging is not in general required in neither FRB or SETI searches, even a simple three-stations array (MED, NOTO, SRT) could be adequate for these, and similar, studies.

S/X band: this coaxial receiver will be **mostly used for geodetic observations** within the IVS network, similarly to what is happening with the currently available S/X receiver at the Noto telescope. The larger bandwidth available with the new S/X receiver would allow the participation of NOTO in a wider range of geodetic experiments.

RECEIVERS UNDER DEVELOPMENT/UNDER EVALUATION

SRT

- **S-band receiver: 7 feeds, @3 GHz, Δν = 1.5GHz**
- **Clow-band receiver 1 feed, @5 GHz, Δν = 1.4GHz**
- **Q-band receiver 19 feeds, @43 GHz, Δν = 17GHz**

SRT and Noto W-band receivers

- **Ex-IRAM (1 at SRT, 2 at Noto)1 feed, @86-116 GHz, cooled, Δν = 0.5 GHz**
- **Ex-MPIfR (Noto only) 1 feed, @86 GHz, cooled, Δν = 0.1 GHz**

Medicina

- **Ku-band receiver 2 feeds, @15 GHz, Δν = 4.5 GHz**

Noto

- **L + S/X band receiver**