Tied-array beam holography

The method currently relies on the codebase `taholog` developed by Pedro Salas and described in the article by Salas et al. 2020. The code relies on the `holog` codebase developed by Michiel Brentjens.

For long-term usability purpose, both codebases have been upgraded from Python 2 to Python 3 running `2to3` and corrected manually post facto. Initial testing has been performed on `dragnet` using a singularity image (definition file listed at the end of this document). taholog-python3.def:

```
BootStrap: docker
From: nvidia/cuda:12.4.1-devel-ubuntu22.04

%labels
    AUTHOR vohl@astron.nl

%files
    /lofastr/holog_full_package /holog
   /lofastr/SumThreshold /SumThreshold
%post
    ln -snf /usr/share/zoneinfo/$TZ /etc/localtime && echo $TZ > /etc/timezone
    # Install essential packages
    apt-get update && apt-get install -y build-essential \
        vim \
        build-essential \
        gfortran \
        vim \
        git-all \
        python3 \
        python3-pip \
        openssh-server

    ln -s /usr/bin/python3 /usr/bin/python

    # Install OpenMPI
    echo "Install OpenMPI"
    apt-get install -y openmpi-bin openmpi-doc libopenmpi-dev

    # Install Python dependencies
    pip3 install numpy scipy cython six pyslalib tables pandas tqdm h5py \
                 matplotlib astropy astroquery photutils aplpy \
                 ipython ipyparallel dask lmfit lofarantpos pyfftw numba rocket-fft \
                 scikit-learn seaborn cupy-cuda12x mpi4py

    cd /holog
    python setup.py build
    python setup.py install

    cd /SumThreshold
    python setup.py install

    echo "export LS_COLORS='rs=0:di=01;34:ln=01;36:mh=00:pi=40;33'" >> ~/.bashrc
    echo "export GREP_OPTIONS='--color=auto'" >> ~/.bashrc
    echo "PS1='\e[33;1m\u@\h: \e[31m\W\e[0m\$ '" >> ~/.bashrc

%environment
    TZ=Europe/Amsterdam

%runscript
    exec python3 "$@"
```

which was built using vagrant and singularity on macos 14.2.1 (23C71) (e.g. `sudo singularity build taholog.sif taholog-python3.def`).

A few parameters first need to be set in main.py (which could be turned into command line arguments in the future):

```
target_id = 'L697741' # SAS id of the observation with the map (many rings)
reference_ids = 'L697733,L697735,L697737,L697739'
trunk_dir = '/data/location/'
cs_str = 'cs' # In CEP4 the files are stored in a CS directory.
average_t_dt = 60 # seconds. Set it to the length of the observation unless you want to make beam movies.
```

Logs are also stored automatically to:

```
logfile = 'taholog_{0}.log'.format(target_id)
```

Target and reference ids are the same as the observation data which in principle should be available on the LOFAR long term archive (LTA). The initial test has been performed for an HBA observation still available on CEP4.

The python3 version can currently be run using: `python main.py --verbose True --debug False >> taholog_L697741_parallel.out 2>&1`, where debug enables multi-processing or not.

This last command can be run using the singularity image, either using singularity exec or shell options, e.g:

```
SING="taholog.sif"
```

```
alias p3="singularity exec -B /data/location,$HOME $HOME/singularity/$SING python"
alias p3s="singularity shell -B /data/location,$HOME $HOME/singularity/$SING"
```

where taholog.sif is stored at `$HOME/singularity`.

HBA Observation Specification

These are the parameters from the parsets for the 5 simultaneous observations. Fly's Eye observations for 4 remote stations, 7 TAB rings for the core stations all in XXYY mode. HBA_DUAL with 110_190.

Observation	Stations	Target	Subband list	Mode	#Sub/fil	Tab rings	Ring size (rad)	Antenna set	Filter	Start	End
L697733	RS210	3C147	77,102,127,152,177,202,227,277,327,377	XXYY	512	0	0	HBA_DUAL	110_190	2019-03-11 17:35:00	2019-03-11 17:36:00
L697735	RS509	3C147	77,102,127,152,177,202,227,277,327,377	XXYY	512	0	0	HBA_DUAL	110_190	2019-03-11 17:35:00	2019-03-11 17:36:00
L697737	RS310	3C147	77,102,127,152,177,202,227,277,327,377	XXYY	512	0	0	HBA_DUAL	110_190	2019-03-11 17:35:00	2019-03-11 17:36:00
L697739	RS307	3C147	77,102,127,152,177,202,227,277,327,377	XXYY	512	0	0	HBA_DUAL	110_190	2019-03-11 17:35:00	2019-03-11 17:36:00
L697741	CS101, CS103, CS024, CS001, CS031, CS032, CS026, CS501, CS302, CS017, CS401, CS301, CS028, CS030, CS201, CS013, CS021, CS011, CS002	3C147	77,102,127,152,177,202,227,277,327,377	XXYY	512	7	8.33e-4	HBA_DUAL	110_190	2019-03-11 17:35:00	2019-03-11 17:36:00

LBA Observation Specification

COBALT1 parsets from the Salas et al. paper (L645357 and L650445) were taken from `head02:/home/mol/cobalt1-parsets` .

Observation	Stations	Target	Subband list	Mode	#Sub/file	Tab rings	Ring size (rad)	Antenna set	Filter	Start	End
L645351	RS210	3C196	188,204,231,256,264,272,287,315,334,347	XXYY	512	0	0	LBA_OUTER	LBA_30_90	2018-03-20 19:45:00	2018-03-20 19:55:(
L645353	RS509	3C196	188,204,231,256,264,272,287,315,334,347	XXYY	512	0	0	LBA_OUTER	LBA_30_90	2018-03-20 19:45:00	2018-03-20 19:55:(
L645355	RS310	3C196	188,204,231,256,264,272,287,315,334,347	XXYY	512	0	0	LBA_OUTER	LBA_30_90	2018-03-20 19:45:00	2018-03-20 19:55:(
L645357	CS001, CS002, CS003, CS004, CS005, CS006, CS007, CS011, CS013, CS017, CS021, CS024, CS026, CS028, CS030, CS031, CS032, CS101, CS103, CS201, CS301,	3C196	188,204,231,256,264,272,287,315,334,347	XXYY	512	9	0.001474	LBA_OUTER	LBA_30_90	2018-03-20 19:45:00	2018-03-20 19:55:(

	CS302, CS401, CS501										
L650437	RS210	3C48	188,204,231,256,264,272,287,315,334,347	XXYY	512	0	0	LBA_OUTER	LBA_30_90	2018-04-19 09:20:00	2018-04-19 09:30:0
L650439	RS509	3C48	188,204,231,256,264,272,287,315,334,347	XXYY	512	0	0	LBA_OUTER	LBA_30_90	2018-04-19 09:20:00	2018-04-19 09:30:0
L650441	RS310	3C48	188,204,231,256,264,272,287,315,334,347	XXYY	512	0	0	LBA_OUTER	LBA_30_90	2018-04-19 09:20:00	2018-04-19 09:30:0
L650443	DE605	3C48	188,204,231,256,264,272,287,315,334,347	XXYY	512	0	0	LBA_OUTER	LBA_30_90	2018-04-19 09:20:00	2018-04-19 09:30:0
L650445	CS001, CS002, CS003, CS004, CS005, CS006, CS007, CS011, CS013, CS017, CS021, CS024, CS026, CS028, CS030, CS031, CS032, CS101, CS103, CS201, CS301, CS302, CS401, CS501	3C48	188,204,231,256,264,272,287,315,334,347	XXYY	512	9	0.001474	LBA_OUTER	LBA_30_90	2018-04-19 09:20:00	2018-04-19 09:30:0

HBA Observations from 2024-02-20

These observations should have mimicked the setup of the L6977XX observations from 2019, but now in TMSS.

Observation	TMSS blue print	Stations	OBSID
FE	https://tmss.lofar.eu/schedulingunit/view/blueprint/6105	RS210, RS307, RS310, RS509	2036944
BF	https://tmss.lofar.eu/schedulingunit/view/blueprint/6108	Core stations with only CS002 on the Superterp	2036952

The Fly's Eye observations of the remote stations were part of a single observation, so different stations are stored as different beams (`L2036944_SAP000_BXXX_S0_P000_bf.h5`).

LBA Observations from 2024-08-28

These observations should have mimicked the setup of the L6504XX observations from 2018, but now in TMSS.

Observation	TMSS blue print	Stations	OBSID
FE	https://tmss.lofar.eu/schedulingunit/view/blueprint/8482	RS210, RS307, RS310, RS509	2047309
BF	https://tmss.lofar.eu/schedulingunit/view/blueprint/8484	Core stations	2047321