*SCHED*uling Spacecraft Observations

Practicalities, issues and challenges

Giuseppe Cimò

Joint Institute for VLBI ERIC

*SCHED*uling Spacecraft observations

Standard VLBI scheduling program → (NRAO) SCHED
both for VLBI and single-dish mode

- Program from the ‘80s written in Fortran (66, 77, 90)
- SCHED requires a .key file with frequency setup and a scan schedule
- SCHED produces a text file (.vex), which contains the info for the telescopes
- The telescopes use the .vex file to generate commands for the antennas

Frequency setup

- Spacecraft frequency and general baseband configuration
- Telescope-specific settings → IF, LO, Backend,…

Scan schedule

- Slow tracking → VEX/MEX and JUICE
- Fast tracking → Radioastron and GPS/GNSS

Calibrators

- Search for suitable calibrators
- Create phase-referencing schedule

Frequency setup

Finding the S/C transmission frequency

- Thanks, ESOC friends!
- No issue for JUICE

Two modes:

- Single dish
  - 4 overlapped channels of 4MHz with a 10kHz shift
  - centred on S/C signal
- VLBI
  - 4, 8 or 16 channels of 8 or 16MHz
  - S/C signal centred in one of the channels
  - Wide band for calibration purposes

```
nchan    = 4
bits     = 2
obfilter = 4
freqref  = 8417.99,8417.98,8417.97,8417.96
pol      = RCP
netside  = U
pcal     = off
format   = mkiv1:4
barrel   = roll_off /
!-----------------------------------------------------------
   firstlo= 8080,8080,8080,8080
   ifchan  =   A1,A1,A1,A1
   bbc     =   1,   2,   3,   4
   format = MARK5B   station  =  ONSALA60 /
!-----------------------------------------------------------
   firstlo= 7650,7650,7650,7650
   ifchan  =   A,   A,   A,   A
   bbc     =   1,   2,   3,   4
  format = MARK5B   station  = METSAHOV /
!-----------------------------------------------------------
   firstlo=7600,7600,7600,7600
   ifchan='A1','A1','A1','A1'
   bbc = 1,2,3,4
   format   = Mark5B station  = WARK12M /
!-----------------------------------------------------------
   firstlo=7600,7600,7600,7600
   ifchan='A1','A1','A1','A1'
   bbc = 1,2,3,4
   station  = YARRA12M /
!-----------------------------------------------------------
   firstlo=7600,7600,7600,7600
   ifchan='A1','A1','A1','A1'
   bbc = 1,2,3,4
   station  = HOBART12 /
!-----------------------------------------------------------
   firstlo=7600,7600,7600,7600
   ifchan='A1','A1','A1','A1'
   bbc = 1,2,3,4
   station  = KATH12M /
!-----------------------------------------------------------
  firstlo=7680,7680,7680,7680
   ifchan='1N','1N','1N','1N'
   bbc = 1,3,5,7
   station  = KASHIM11 /
!-----------------------------------------------------------
  firstlo=8080,8080,8080,8080
   ifchan='1N','1N','1N','1N'
   bbc = 1,3,5,7
   station  = YAMAGU32 /
!-----------------------------------------------------------
   firstlo=8080,8080,8080,8080
   ifchan='A','A','A','A'
```

Issues:

- Non-standard frequency requires ad hoc setups for each station
- Changes in telescope hardware

Scheduling the pointings

S/C coordinates from SPICE kernels

- SPICE SCHED exists BUT only for correlation purpose at the VLBA.
  No telescope work with SPICE SCHED for pointing.

Two options for standard SCHED:

- Station capable of non-sidereal tracking
  - We provide a separate file with the orbit (format varies with antenna).
  - The coordinates format varies with the stations.
    Eg. Ef likes RADEC J2000, Kwazars apparent RADEC, Ys Az-El, and Hart has developed its own way to calculate the coordinates.
- Not all antennas are able to perform non-sidereal tracking
  - In this case we provide the actual list of scans on the vex file, like any other VLBI observation.

Sidereal tracking requires scheduling hundreds (or thousands) of scans

- Slow tracking → Planetary probes
- Fast tracking → Earth (and moon) satellites
  - Cross-eyed pointing: one schedule per station
  - Signal is too strong: attenuation needed during the S/C scans
  - S/C detected on sidelobes during calibration scans
  - The starting and breaking the antenna every 15 seconds can be very demanding for the antennas

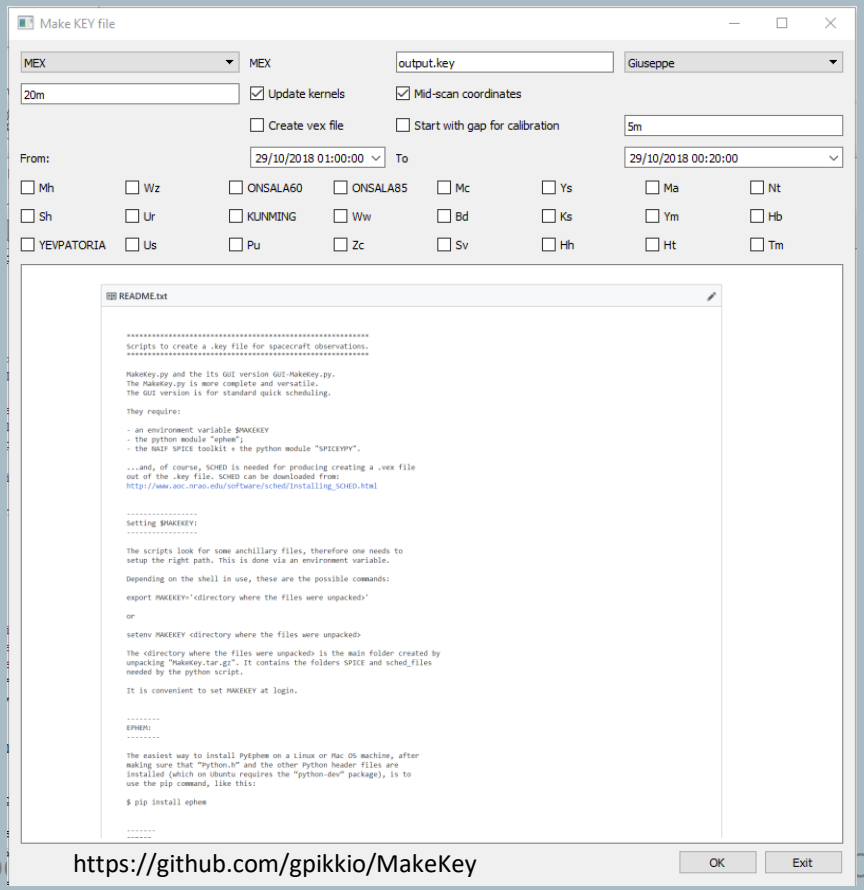
Makekey script

Typical schedule:

- 3 minutes on the phase calibrator
- 3-minute scan on the S/C

Issues

- Generation of hundreds of pointing coordinates
- Scan sync between arrays/antennas

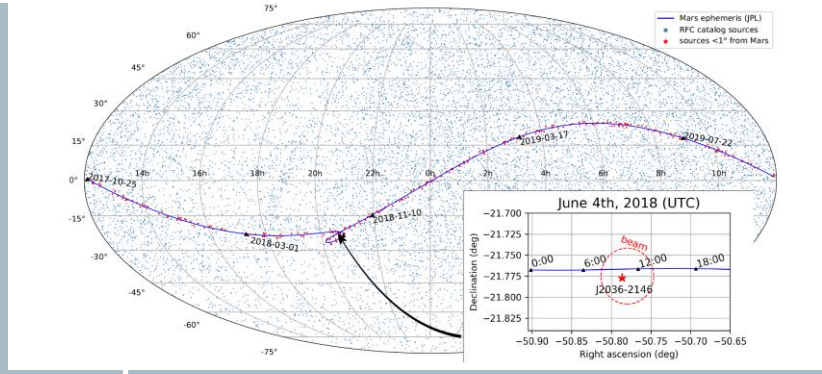


https://github.com/gpikkio/MakeKey

```
setup = $MYSCHED/Setups/mex16CAL.x
setup = $MYSCHED/Setups/mex8x16FLYBY.x
prestart=0
stations = ONSALA60,Hh,Mc,Ys,Bd,Sv,Zc

! It starts in occultation
!source=J1230+1223 dur=34:00 gap=0:30 / !
group 5 repeat 2
source=J1230+1223 dur=3:00 gap=1:00 / ! FF0
source=J1232-0224 dur=2:00 gap=1:00 / ! Cal0
source=cal5 dur=2:00 gap=1:00 / ! Cal5
source=J1232-0224 dur=2:00 gap=1:00 / ! Cal0
source=J1222+0413 dur=3:00 gap=1:00 / ! FF2

source=J1232-0224 dur=1:00 gap=0:00 / !

! Phase referencing scans
source=J1232-0224 dur=2:00 gap=0:30 / !
source=MEX362-1820 dur=2:00 gap=0:30 /  !


! Phase referencing scans
group 2 repeat 2
source=J1232-0224 dur=2:00 gap=0:30 / !
source=MEX362-1820 dur=2:00 gap=0:30 /  !
group 2 repeat 1
source=J1232-0224 dur=2
source=MEX362-1830 dur=
group 2 repeat 1
source=J1232-0224 dur=2
source=cal5 dur=2:00 ga

stations = Bd
```

```
source=171200 dur=00:15 /
source=171215 dur=00:15 /
source=171230 dur=00:15 /
source=171245 dur=00:15 /
source=171300 dur=00:15 /
source=171315 dur=00:15 /
source=171330 dur=00:15 /
source=171345 dur=00:15 /
gap=1:00 source=J0825+0309 dur=4:00 /
gap=1:00 source=172000 dur=00:15 /
gap=0:00 source=172015 dur=00:15 /
source=172030 dur=00:15 /
source=172045 dur=00:15 /
source=172100 dur=00:15 /
source=172115 dur=00:15 /
source=172130 dur=00:15 /
source=172145 dur=00:15 /
source=172200 dur=00:15 /
source=172215 dur=00:15 /
source=172230 dur=00:15 /
source=172245 dur=00:15 /
source=172300 dur=00:15 /
source=172315 dur=00:15 /
source=172330 dur=00:15 /
```

Conclusions and Suggestions



PySCHED

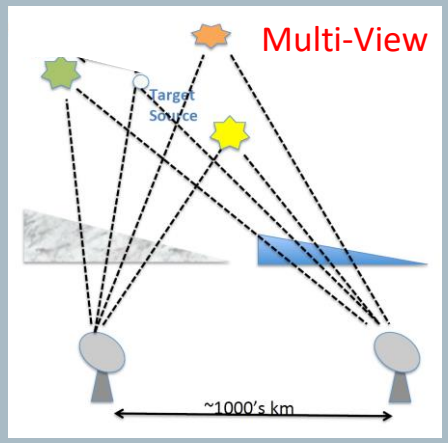
- Refactored version of SCHED in python
- Easy to script
- Tests are in progress

More flexibility is needed with frequency setup

- Scripting (Py)SCHED
- Better communications with antennas or EVN Support

Scheduling and calibration → Reducing complexity:

- In-beam calibration
  - EVN experiment EC064 + 4 epochs with VLBA
- Multiview VLBI
  - Multiple observations around the target
  - No need for source switching or (very) close calibrator
  - Huge improvement in calibration



(Survey around the predicted orbit)