The Unified MBFits Writer
for APEX, Effelsberg, and SOFIA

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APEX, Effelsberg, SOFIA - upGREAT

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The Unified MBFits Writer

- All three telescopes write (or plan to write) raw data in MBFits format
- FFTS spectrometers developed at MPIfR at all three telescopes
- Wish to have common software for data taking and writing based on APEX FitsWriter
MBFits Raw Data Format

- For single-dish, multi-beam, continuum and spectral observations
- Official FITS convention, fully documented
- MBFits Dataset is a set of FITS files in a directory structure that contains all data of a scan relevant for interpretation of the data
MBFIts Raw Data Format

- Self-contained, contains all data for
  - Instrumental setup
  - Backend data
  - Interpolated telescope and wobbler position at BE time
  - Commanded and actual telescope position
  - Wobbler position
  - Instrument-specific monitor data
  - ...

APEX FitsWriter

- Developed 2004, reliable and performant working horse since then
- Implemented in Python
- Writes MBFits raw data datasets for all spectral resolving and continuum instruments
  - Exceptions: VLBI and some PI instruments
APEX FitsWriter

- Used for all possible frontend-backend combinations without modifications
  - No need to modify code for new instruments
  - Configured during runtime
  - Any number of frontend-backend combinations (FEBEs) during one observation
APEX
Most demanding instruments

- **A-MKID (continuum)**
  - 21,600 (850 µm) + 3,520 (350 µm) Pixels, 30 ms integration time
  - ~3 MB/s

- **PI230 (heterodyne)**
  - 1 Pixel (32 GHz bandwidth), 524,288 spectral channels, 200 ms integration time
  - ~10 MB/s

- **LASMA (heterodyne, 2016)**
  - 7 Pixels (345 GHz), each 524,288 spectral channels, 200 ms integration time
  - ~70 MB/s
Effelsberg

• New K-band receiver
  - 18 – 26.5 GHz, up to 8 GHz bandwidth
  - 2 pixels, each with 2 polarizations and 4 spectral windows, each with 65,536 spectral channels, 100 ms
  - Zoom mode (0.3 GHz bandwidth) with 28 x 65,536 spectral channels
  - ~70 MB/s

• Decision to switch to APEX FitsWriter for all receivers
  - Exceptions: VLBI, Pulsar receivers
upGREAT developed by MPIfR and University of Cologne

- 14 (1.9 – 2.5 THz) + 7 (4.7 THz) pixels, each 131,072 spectral channels, 200 ms integration time
- ~55 MB/s
The challenge

• Formats of backend data (main input) and raw data (output) are common, but

• Software environments vastly different otherwise
  – APEX: ESO's ACS with CORBA-based communication
  – Effelsberg: communication based on UDP and TCP
  – SOFIA – upGREAT: KOSMA file IO

• Separate observatory specific parts from generic parts (Unified MBFits Writer)
FitsWriter - Interfaces

- ObsEngine
- Command Interface
- Backend
- Backend TCP Interface
- Monitor Points
- Monitor Interface (push or pull)
- MBFITS Dataset
Command Interface

• Implements 2 commands
  - `start(scanObject)`
  - `stop(status)`
  - Synchronous commands with return values (ok or error message)

• Implementation depends on software environment
  - APEX: ACS (based on CORBA)
  - Effelsberg: TCP multicast messages
  - upGREAT: KOSMA file IO
Observing cycle

- create Fits files
- start taking monitor data
- establish TCP connection to BE

- Backend sends data to FitsWriter over TCP connection
- FitsWriter receives Monitor Data
- FitsWriter writes data to MBFITS Dataset

- close TCP connection to BE
- stop taking monitor data
- write all data to Fits files
- close Fits files
Scan Object

- Hierarchically structured Python object with complete description of scan
  - Frontend and backend setup
  - Source and off positions
  - Description of scan pattern
  - Pointing parameters
  - ...

- Passed by start command in serialized form, must be de-serialized in FitsWriter
  - APEX: pickeled Python object
  - Effelsberg: YAML string
  - upGREAT: YAML string
Backend TCP interface

- FitsWriter receives data from each backend involved in scan over TCP connection
- One binary data package per integration
- Header:
  - Timestamp (midpoint of integration interval)
  - Phase number
  - Structural Information
- Payload
- Format identical for APEX, Effelsberg, upGREAT
Monitor Interface

- Monitoring data pushed to or pulled by FitsWriter:
  - Telescope and Wobbler positions
  - Environmental data
  - Instrument specific data
- Monitoring data must bear timestamp of data generation
  - Times of telescope and wobbler positions independent off backend timestamps
Monitor Interface

- Implementation depends on software environment
  - APEX: ACS Notification Channels and ACS-specific polling methods
  - Effelsberg: TCP multicast messages
  - upGREAT: KOSMA file IO
APEX FitsWriter
Internal Structure

**FitsWriter**
- ObsEngine
- Command Interface
- PipelineManager
- HeaderFiller

**BE Pipeline**
- TcpClient
- PackagePreparator
- BEInterpolator
- CoordTransf
- PackageWriter
- DataparWriter

**Monitor Pipeline**
- Positions
- WobblerInterpolator
- MonitorWriter

**MBFITS Dataset**
- ARRAYDATA
- ARRAYDATA
- ARRAYDATA
- DATAPAR
- MONITOR

**Backends**
- NC Positions
- NC Wobbler
Unified MBFits Writer

**APEX Fits Writer**
- Command Interface
- apexPipelineFactory
- apexCoordTransf
- Positions
- Wobbler
- WobblerInterpolator

**Unified MBFits Writer**
- PipelineManager
- HeaderFiller
- BE Pipeline
  - TcpClient
  - PackagePreparator
  - BEInterpolator
    - PackageWriter
    - PackageWriter
    - PackageWriter
    - DataParserWriter
- Monitor Pipeline
  - MonitorWriter

LOC: ~4,000 ~16,000
Unified MBFits Writer

Effelsberg Fits Writer
- Command Interface
- effbgPipelineFactory
- effbgHeaderFiller
- effbgCoordTransf
- Positions

Unified MBFits Writer
- PipelineManager
- HeaderFiller

BE Pipeline
- TcpClient
- PackagePreparator
- BEInterpolator
- PackageWriter
- DataparWriter

Monitor Pipeline
- MonitorWriter

LOC: ~3,000 ~16,000
Current Status

- **APEX:**
  - In production since September 2015

- **Effelsberg:**
  - In final development phase, will go in test operation in the next weeks, production later 2015
  - Successful performance tests to limit of available backend hardware (~70 MB/s)

- **SOFIA – upGREAT:**
  - In early development phase
  - Planned for spring 2016