STScI | SPACE TELESCOPE SCIENCE INSTITUTE

EXPANDING THE FRONTIERS OF SPACE ASTRONOMY

The Hubble Space Telescope (HST) Advanced Camera for Surveys (ACS) Quicklook Application

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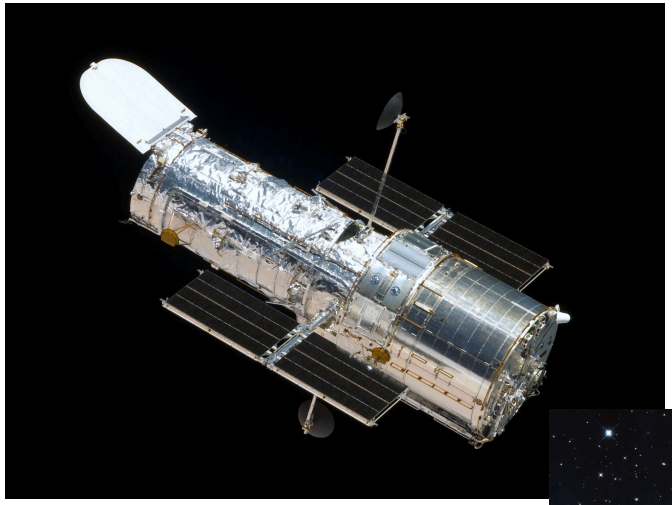
October 19, 2017

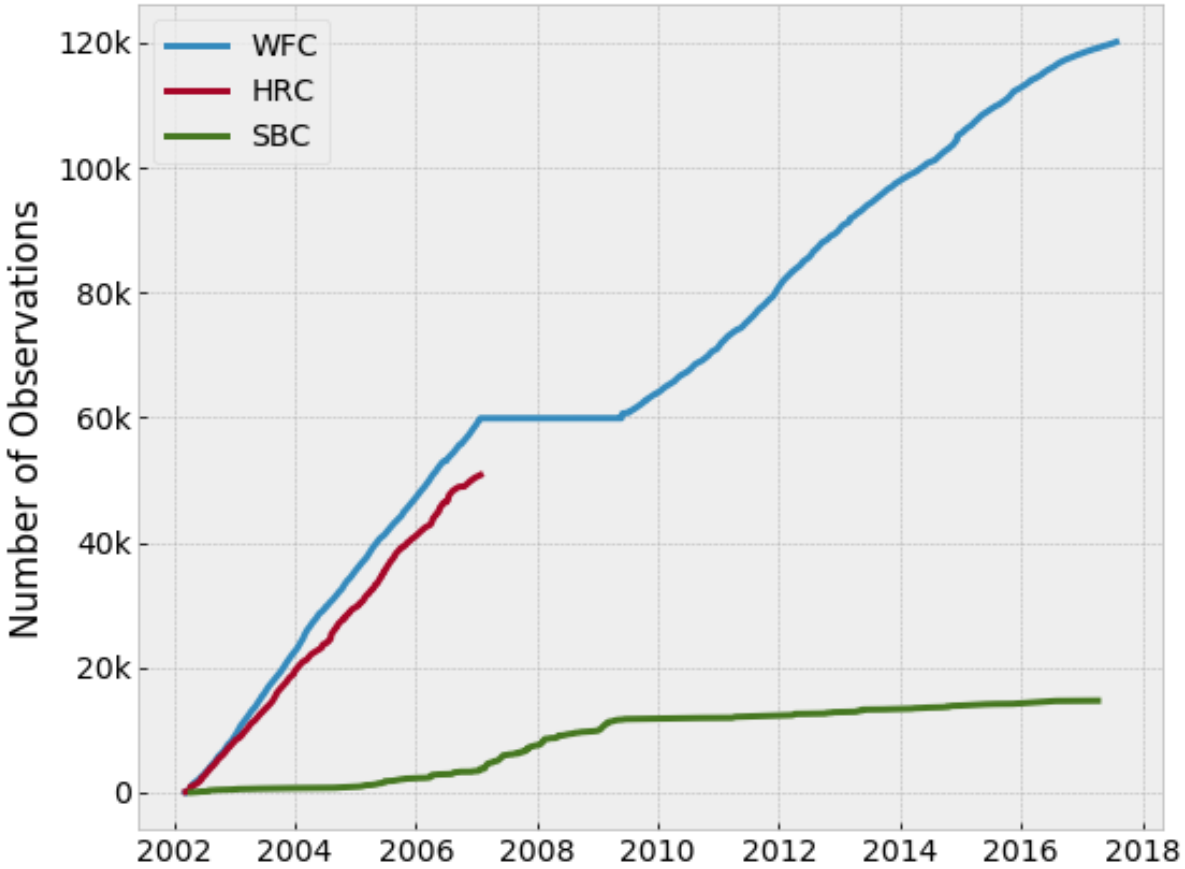
The Hubble Space Telescope (HST)

- HST was launched in 1990
- Over the years it has housed 12 instruments
- 5 Servicing Missions
- Currently there are 4 instruments on board:
  - Cosmic Origins Spectrograph (COS) (2009)
  - Space Telescope Imaging Spectrograph (STIS) (1990)
  - Wide Field Camera 3 (WFC3) (2009)
  - Advanced Camera for Surveys (ACS) (2002)



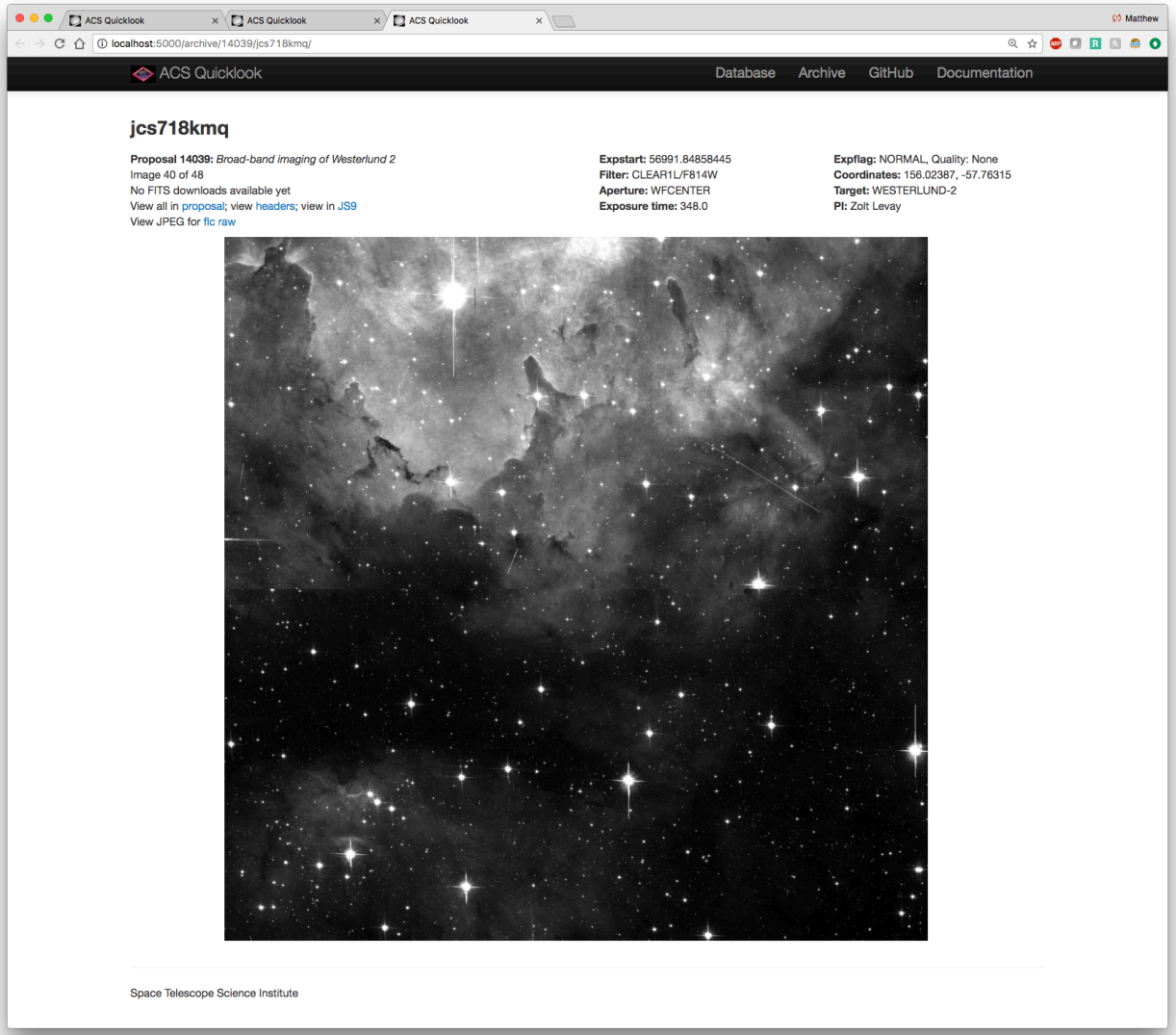
The Advanced Camera for Surveys (ACS)

- Comprised of three detectors:
  - Wide Field Channel (WFC)
  - High Resolution Channel (HRC)
  - Solar Blind Channel (SBC)
- ACS experienced an electronics failure in 2006, temporarily disabling the WFC detector and permanently disabling the HRC detector.



The HST/ACS Quicklook Application (`acsql`)

- Database-driven web application for discovering and viewing HST/ACS images and corresponding metadata
- All publicly-available on-orbit data
- Comprised of four major components:
  - NFS Filesystem
  - MySQL Database
  - Python/Flask-based Web Application
  - Software Package
- Inspired by a similar application for the HST/WFC3 instrument (“WFC3 Quicklook”)



Data Structure: FITS Files

FITS = Flexible Image Transport System

Extension	Purpose	Image Dimensions (pixels)	Data Type
0	Primary header	–	String
1	SCI, Chip 2	(4096, 2048)	Float
2	ERR, Chip 2	(4096, 2048)	Float
3	DQ, Chip 2	(4096, 2048)	Integer
4	SCI, Chip 1	(4096, 2048)	Float
5	ERR, Chip 1	(4096, 2048)	Float
6	DQ, Chip 1	(4096, 2048)	Integer

ACS/WFC FITS file structure

Extension	Purpose	Image Dimensions (pixels)	Data Type
0	Primary header	–	String
1	SCI	(1024, 1024)	Float
2	ERR	(1024, 1024)	Float
3	DQ	(1024, 1024)	Integer

ACS/WFC and ACS/SBC FITS file structure

Data Structure: FITS file headers and key metadata

```
SIMPLE  =                    T / data conform to FITS standard
BITPIX  =                   16 / bits per data value
NAXIS   =                    0 / number of data axes
EXTEND  =                    T / File may contain standard extensions
NEXTEND =                    6 / Number of standard extensions
GROUPS  =                    F / image is in group format
DATE    = '2016-09-22'         / date this file was written (yyyy-mm-dd)
FILENAME= 'j6mf16lhq_raw.fits                        ' / name of file
FILETYPE= 'SCI      '          / type of data found in data file

TELESCOP= 'HST'                / telescope used to acquire data
INSTRUME= 'ACS   '             / identifier for instrument used to acquire data
EQUINOX =               2000.0 / equinox of celestial coord. system

             / DATA DESCRIPTION KEYWORDS

ROOTNAME= 'j6mf16lhq                           ' / rootname of the observation set
IMAGETYP= 'DARK              ' / type of exposure identifier
PRIMESI = 'ACS   '             / instrument designated as prime

             / TARGET INFORMATION

TARGNAME= 'DARK                            ' / proposer's target name
RA_TARG =   0.000000000000E+00 / right ascension of the target (deg) (J2000)
DEC_TARG=   0.000000000000E+00 / declination of the target (deg) (J2000)

             / PROPOSAL INFORMATION

PROPOSID=                 9433 / PEP proposal identifier
LINENUM = '16.055        '     / proposal logsheet line number
PR_INV_L= 'Bernstein                       ' / last name of principal investigator
PR_INV_F= 'Gary                ' / first name of principal investigator
PR_INV_M= '                    ' / middle name / initial of principal investigat

             / EXPOSURE INFORMATION

SUNANGLE=            93.563698 / angle between sun and V1 axis
MOONANGL=            33.222004 / angle between moon and V1 axis
SUN_ALT =            68.062172 / altitude of the sun above Earth's limb
FGSLOCK = 'FINE                ' / commanded FGS lock (FINE,COARSE,GYROS,UNKNOWN)
GYROMODE= '3'                  / number of gyros scheduled, T=3+OBAD
REFFRAME= 'GSC1    '           / guide star catalog version
MTFLAG  = ' '                  / moving target flag; T if it is a moving target

DATE-OBS= '2003-01-27'         / UT date of start of observation (yyyy-mm-dd)
TIME-OBS= '15:20:01'           / UT time of start of observation (hh:mm:ss)
EXPSTART=   5.266663890058E+04 / exposure start time (Modified Julian Date)
EXPEND  =   5.266665048715E+04 / exposure end time (Modified Julian Date)
EXPTIME =          1000.000000 / exposure duration (seconds)--calculated
```

`APERTURE` – Portion of detector used during observation
`DATE-OBS` – The date of the start of the observation
`DEC_TARG` – The declination of target in the night sky
`DETECTOR` – The detector used (WFC, HRC, or SBC)
`EXPSTART` – The exposure start time
`EXPFLAG` – The quality of the exposure
`EXPTIME` – The duration of the exposure
`FILTER` – The wavelength filter used during observation
`IMAGTYP` – The type of image (e.g. “EXTERNAL”)
`OBSTYPE` – The type of observation (e.g. “IMAGING”)
`proposal_type` – The type of proposal (e.g. “CAL”)
`PROPID` – The 5-digit proposal ID
`RA_TARG` – The right-ascension of the target in the night sky
`rootname` – The 9-character unique identifier for the observation
`SUBARRAY` – Boolean value for if an image was a full-frame or not
`TARGNAME` – The name of the observation target (e.g. “Saturn”)
`TIMEOBS` – The time of the start of the observation

Data Structure: ACS FITS Filetypes and Rootnames

`<rootname>_<filetype>.fits`

Rootnames consist of a 9-character identifier corresponding to a unique observation

Available filetypes:

`raw` - the raw, uncalibrated data that comes directly from HST
`flt` - nominally calibrated data
`flc` - nominally calibrated data corrected for Charge Transfer Efficiency (CTE) deficits.
`drz` - geometric distortion-corrected data
`drc` - geometric distortion-corrected and CTE corrected data
`spt` - telescope telemetry data
`jit` - telescope pointing data
`jif` - telescope drifting data
`crj` - cosmic ray rejected data
`crc` - cosmic ray rejected plus CTE corrected data
`asn` - observation association table.

Intended Users and Use Cases

- The primary user of the **`acsql`** application are ACS Instrument Analysts at STScI
- They use ACS data to perform instrument calibration and monitoring
- External users to STScI are possible since **`acsql`** is non-proprietary

Use case 1: Visually inspect an image from the ACS archive

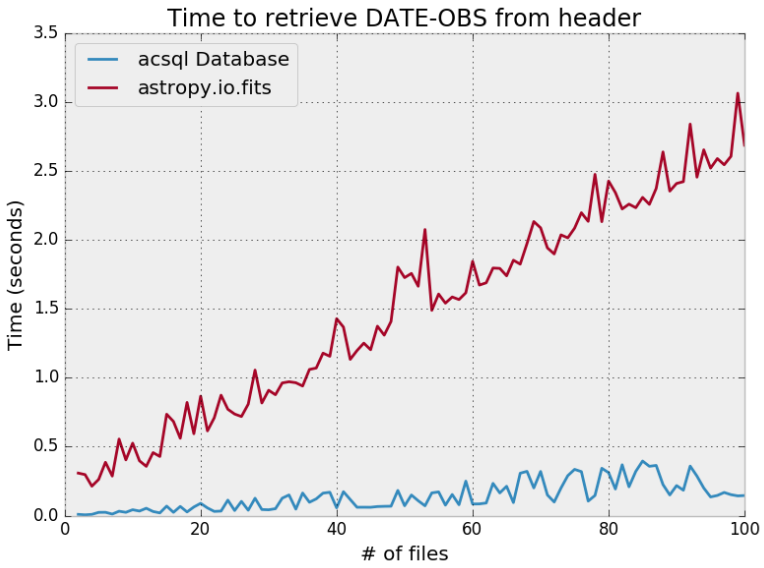
Use case 2: Determine which datasets exist in the ACS archive for a given set of observational parameters

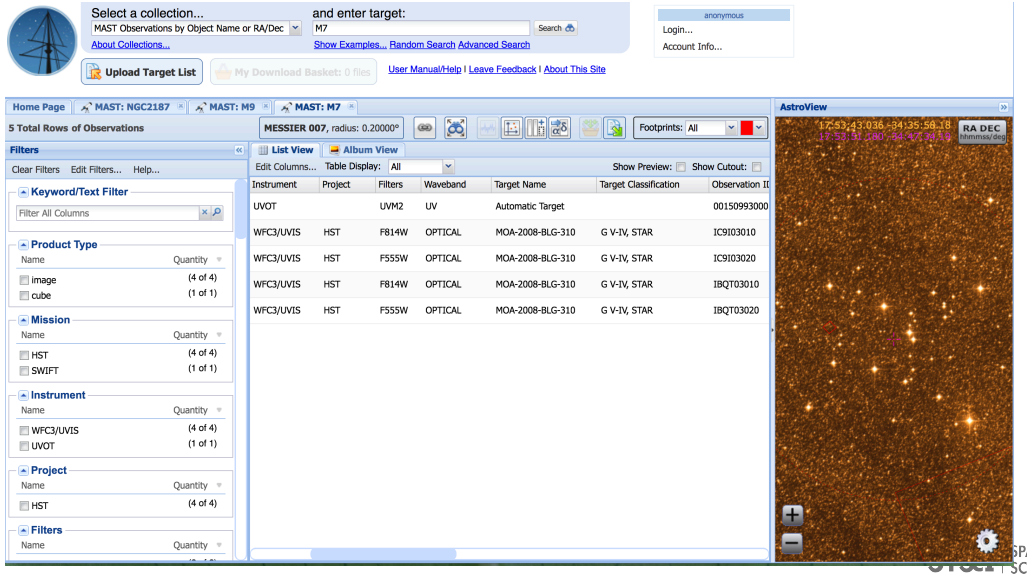
Use case 3: Determine the observational parameters for a given dataset

Use case 4: Programmatically analyze images across custom datasets

Motivation

- Limitations in the FITS file structure (namely File I/O)
- Limitations in the current STScI data archive
  - Data retrieval latency
  - Data discovery
  - Data redundancy
- **`acsql`** is a centrally-located instantly-accessible data archive with one-to-one correspondence with the ACS FITS file headers
  - No complicated data retrieval process
  - No need for file I/O
  - Intuitive database queries





Implementation: Version Control, Programming Standards, and API Documentation

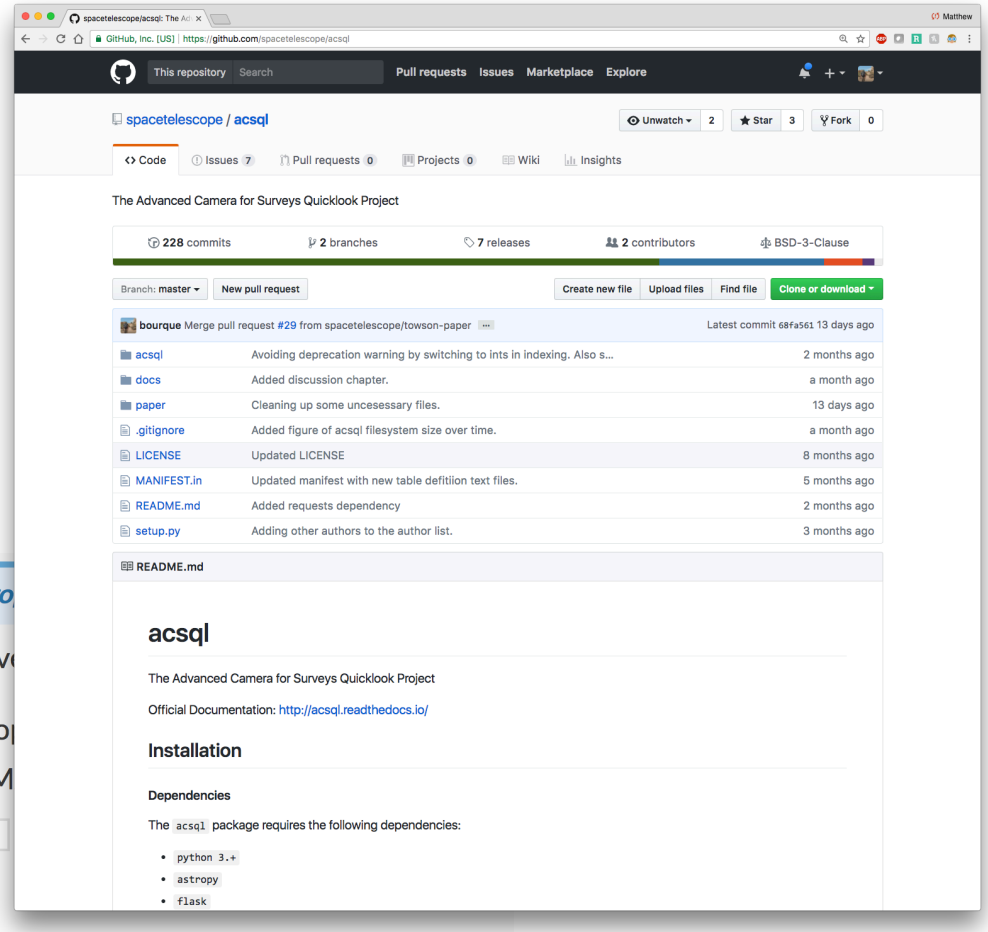
- Style Guide for Python (PEP8)
- Style Guide for Python Docstrings (PEP257)
- `numpydoc` Documentation Convention
- `git` + `GitHub`
- `readthedocs`

```
def get_proposal_type(proposid):
    """Return the ``proposal_type`` for the given ``proposid``.

    The ``proposal_type`` is the type of proposal (e.g. ``CAL``,
    ``GO``, etc.).  The ``proposal_type`` is scraped from the MAST
    proposal status webpage for the given ``proposid``.  If the
    ``proposal_type`` cannot be determined, a ``None`` value is returned.

    Parameters
    ----------
    proposid : str
        The proposal ID (e.g. ``12345``).

    Returns
    -------
    proposal_type : int or None
        The proposal type (e.g. ``CAL``).
    """
```



ingest.ingest.get_proposal_type(*pro*)

Return the `proposal_type` for the giv

The `proposal_type` is the type of pro

`proposal_type` is scraped from the M

given `proposid`. If the `proposal_type`

returned.

Parameters: **proposid** : str

The proposal ID (e.g. `12345`).

Returns: **proposal_type** : int or None

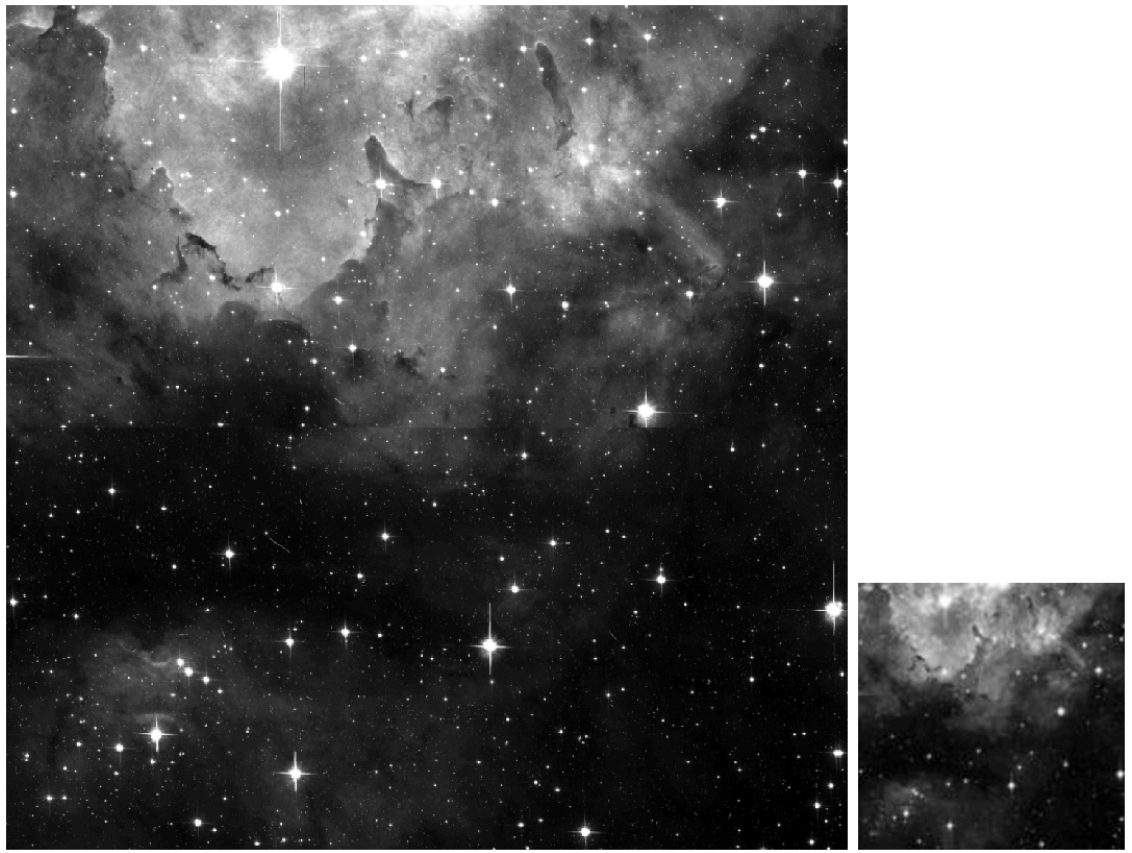
The proposal type (e.g. `CAL`).

Implementation: Filesystem

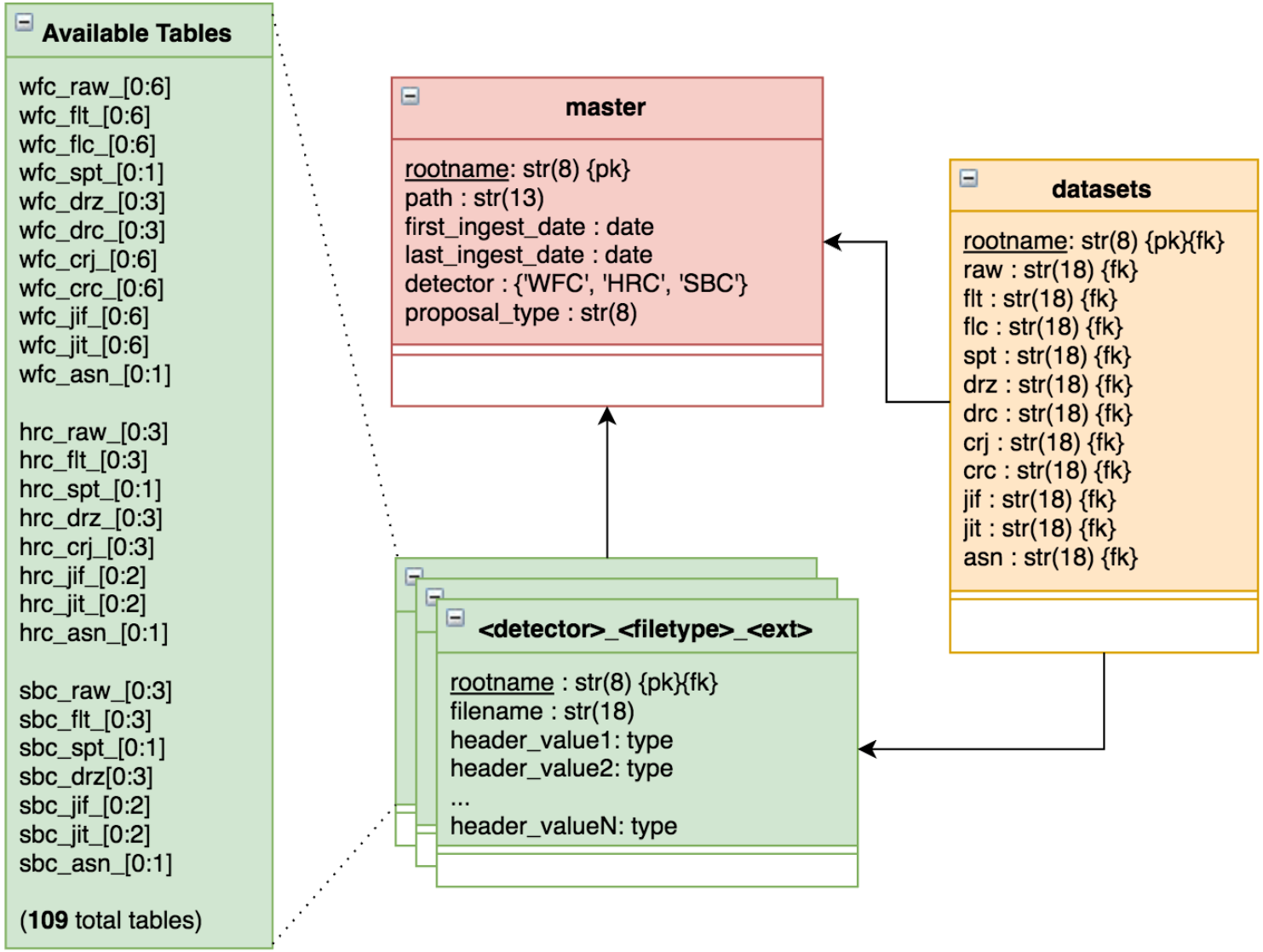
```
filesystem/
    jcp0/
        jcp001kwq/
            jcp001kwq_flc.fits
            jcp001kwq_flt.fits
            jcp001kwq_raw.fits
            jcp001kwq_spt.fits
            jcp001kwq_jif.fits
            jcp001kwq_jit.fits
        jcp001010/
            jcp001010_asn.fits
            jcp001010_drc.fits
            jcp001010_drz.fits
            jcp001010_jif.fits
            jcp001010_jit.fits
        jcp014tyq/
            ...
        jcp001kt1/
            ...
        ...
    jcp3/
        ...
    jcp7/
        ...
    ...
```

```
jpegs/
    12780/
        jbw901jtq_flc.jpg
        jbw901jtq_flt.jpg
        jbw901jtq_raw.jpg
        jbw901jxq_flc.jpg
        jbw901jxq_flt.jpg
        jbw901jxq_raw.jpg
        ...
    12781/
        jbx101f5q_flc.jpg
        jbx101f5q_flt.jpg
        jbx101f5q_raw.jpg
        jbx101f7q_flc.jpg
        jbx101f7q_flt.jpg
        jbx101f7q_raw.jpg
        ...
    12783/
        ...
    12787/
        ...
    ...
```

```
thumbnails/
    12780/
        jbw901jtq_flt.thumb
        jbw901jxq_flt.thumb
        ...
    12781/
        jbx101f5q_flt.thumb
        jbx101f7q_flt.thumb
        ...
    12783/
        ...
    12787/
        ...
    ...
```



Implementation: Database Schema



Implementation: MySQL and SQLAlchemy

- **SQLAlchemy**: Python **SQL** toolkit and Object Relational Mapper

```python
class Master(base):
    """ORM for the  master table."""
    def __init__(self, data_dict):
        self.__dict__.update(data_dict)

    __tablename__ = 'master'
    rootname = Column(String(8), primary_key=True, index=True, nullable=False)
    path = Column(String(15), unique=True, nullable=False)
    first_ingest_date = Column(Date, nullable=False)
    last_ingest_date = Column(Date, nullable=False)
    detector = Column(Enum('WFC', 'HRC', 'SBC'), nullable=False)
    proposal_type = Column(Enum('CAL/ACS', 'CAL/OTA', 'CAL/STIS', 'CAL/WFC3',
                                'ENG/ACS', 'GO', 'GO/DD', 'GO/PAR', 'GTO/ACS',
                                'GTO/COS', 'NASA', 'SM3/ACS', 'SM3/ERO',
                                'SM4/ACS', 'SM4/COS', 'SM4/ERO', 'SNAP'),
                           nullable=True)
```

```python
def load_connection(connection_string):
    """Return ``session``, ``base``, and ``engine`` objects for
    connecting to the ``acsql`` database.

    Create an ``engine`` using an given ``connection_string``. Create a
    ``base`` class and ``session`` class from the ``engine``. Create an
    instance of the ``session`` class. Return the ``session``,
    ``base``, and ``engine`` instances.

    Parameters
    ----------
    connection_string : str
        The connection string to connect to the ``acsql`` database. The
        connection string should take the form:
        ``dialect+driver://username:password@host:port/database``

    Returns
    -------
    session : sesson object
        Provides a holding zone for all objects loaded or associated
        with the database.
    base : base object
        Provides a base class for declarative class definitions.
    engine : engine object
        Provides a source of database connectivity and behavior.
    """

    engine = create_engine(connection_string, echo=False, pool_timeout=100000)
    base = declarative_base(engine)
    Session = sessionmaker(bind=engine)
    session = Session()

    return session, base, engine
```

Implementation: MySQL and SQLAlchemy

```
def orm_factory(class_name):
    """Create a SQLAlchemy ORM Classes with the given ``class_name``.

    Parameters
    ----------
    class_name : str
        The name of the class to be created

    Returns
    -------
    class : obj
        The SQLAlchemy ORM
    """

    data_dict = {}
    data_dict['__tablename__'] = class_name.lower()
    data_dict['rootname'] = Column(String(8), ForeignKey('master.rootname'),
                                   primary_key=True, index=True,
                                   nullable=False)
    data_dict['filename'] = Column(String(18), nullable=False, unique=True)
    data_dict = define_columns(data_dict, class_name)
    data_dict['__table_args__'] = {'mysql_row_format': 'DYNAMIC'}

    return type(class_name.upper(), (base,), data_dict)
```

```
WFC_raw_0 = orm_factory('WFC_raw_0')
WFC_raw_1 = orm_factory('WFC_raw_1')
WFC_raw_2 = orm_factory('WFC_raw_2')
WFC_raw_3 = orm_factory('WFC_raw_3')
WFC_raw_4 = orm_factory('WFC_raw_4')
WFC_raw_5 = orm_factory('WFC_raw_5')
WFC_raw_6 = orm_factory('WFC_raw_6')

WFC_flt_0 = orm_factory('WFC_flt_0')
WFC_flt_1 = orm_factory('WFC_flt_1')
WFC_flt_2 = orm_factory('WFC_flt_2')
WFC_flt_3 = orm_factory('WFC_flt_3')
WFC_flt_4 = orm_factory('WFC_flt_4')
WFC_flt_5 = orm_factory('WFC_flt_5')
WFC_flt_6 = orm_factory('WFC_flt_6')

WFC_flc_0 = orm_factory('WFC_flc_0')
WFC_flc_1 = orm_factory('WFC_flc_1')
WFC_flc_2 = orm_factory('WFC_flc_2')
WFC_flc_3 = orm_factory('WFC_flc_3')
WFC_flc_4 = orm_factory('WFC_flc_4')
WFC_flc_5 = orm_factory('WFC_flc_5')
WFC_flc_6 = orm_factory('WFC_flc_6')
```

Implementation: Data Ingestion Software Algorithm

1. Identify newly available data
2. Loop over **`rootnames`** in parallel
    3. Update **`master`** table with information about **`rootname`**
    4. Loop over available filetypes for given **`rootname`**
        5. Create Python dictionary with metadata about file
        6. For each FITS extension, extract header information and update **`header`** table
        7. Update **`datasets`** table
        8. If filetype is **`raw`**, **`flt`**, or **`flc`**, then create JPEG
        9. If filetype is **`flt`**, then create Thumbnail

Encapsulated within **`ingest.py`**, **`make_file_dict.py`**, **`make_jpeg.py`**, **`make_thumbnail.py`**

Implementation: Logging

```
08/15/2017 11:05:26 INFO: User: bourque
08/15/2017 11:05:26 INFO: System: plhstins1.stsci.edu
08/15/2017 11:05:26 INFO: Python Version: 3.5.2
08/15/2017 11:05:26 INFO: Python Path: /envs/anaconda3/envs/astroconda3/bin/python
08/15/2017 11:05:26 INFO: Numpy Version: 1.11.2
08/15/2017 11:05:26 INFO: Numpy Path: /site-packages/numpy
08/15/2017 11:05:26 INFO: Astropy Version: 1.2.1
08/15/2017 11:05:26 INFO: Astropy Path: /site-packages/astropy
08/15/2017 11:05:26 INFO: SQLAlchemy Version: 1.1.4
08/15/2017 11:05:26 INFO: SQLAlchemy Path: /site-packages/SQLAlchemy-1.1.4-py3.5-linux-x86_64.egg/sqlalchemy
08/15/2017 11:05:26 INFO: Gathering files to ingest
08/15/2017 11:06:00 INFO: j8zh21xv: Updated master table.
08/15/2017 11:06:01 INFO: j8zh21xv: Updated HRC_flt_0 table.
08/15/2017 11:06:01 INFO: j8zh21xv: Updated HRC_flt_1 table.
08/15/2017 11:06:01 INFO: j8zh21xv: Updated HRC_flt_2 table.
08/15/2017 11:06:01 INFO: j8zh21xv: Updated HRC_flt_3 table.
08/15/2017 11:06:01 INFO: j8zh21xv: Updated datasets table for flt.
08/15/2017 11:06:01 INFO: j8zh21xv: Creating JPEG
08/15/2017 11:06:02 INFO: j8zh21xv: Creating Thumbnail
08/15/2017 11:06:02 INFO: j8zh21xv: Updated HRC_raw_0 table.
08/15/2017 11:06:02 INFO: j8zh21xv: Updated HRC_raw_1 table.
08/15/2017 11:06:03 INFO: j8zh21xv: Updated HRC_raw_2 table.
08/15/2017 11:06:03 INFO: j8zh21xv: Updated HRC_raw_3 table.
08/15/2017 11:06:03 INFO: j8zh21xv: Updated datasets table for raw.
08/15/2017 11:06:03 INFO: j8zh21xv: Creating JPEG
08/15/2017 11:06:04 INFO: j8zh21xv: Updated HRC_spt_0 table.
08/15/2017 11:06:05 INFO: j8zh21xv: Updated HRC_spt_1 table.
08/15/2017 11:06:05 INFO: j8zh21xv: Updated datasets table for spt.
08/15/2017 11:06:05 INFO: j8zh21xv: End ingestion
```

Implementation: Web Application

Built using Flask, a Python-based web framework

`acsql_webapp.py` — Runs web application on **`localhost`** or server

`data_containers.py` — Various functions for gathering and returning data used by application

`form_options.py` — Stores data needed for database query form

`query_form.py` — Builds and validates database queries through web application

`query_lib.py` — Contains tools for executing database queries through web application

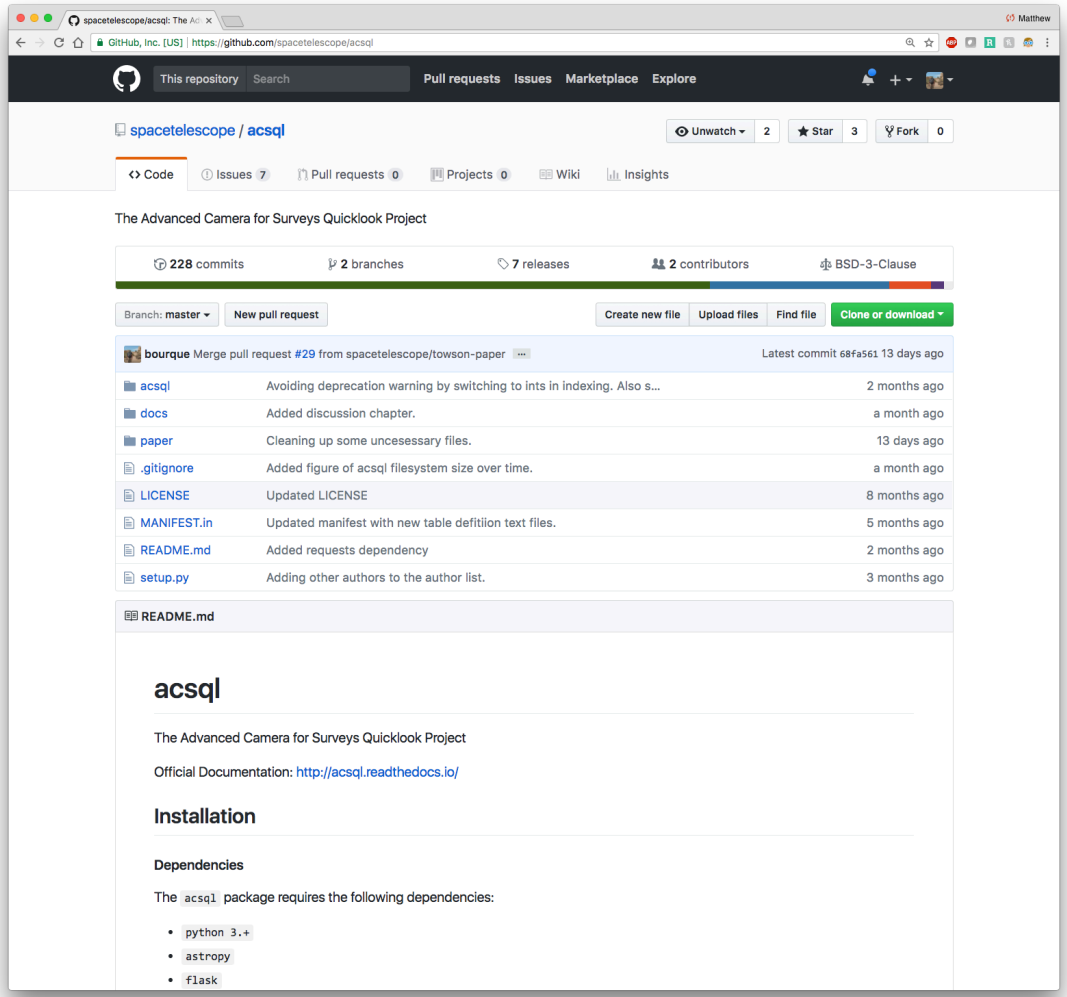
`static/css/*.css` — **`CSS`** templates

`static/js/*.js` — **`JavaScript`** functions

`templates/*.html` — **`HTML`** templates

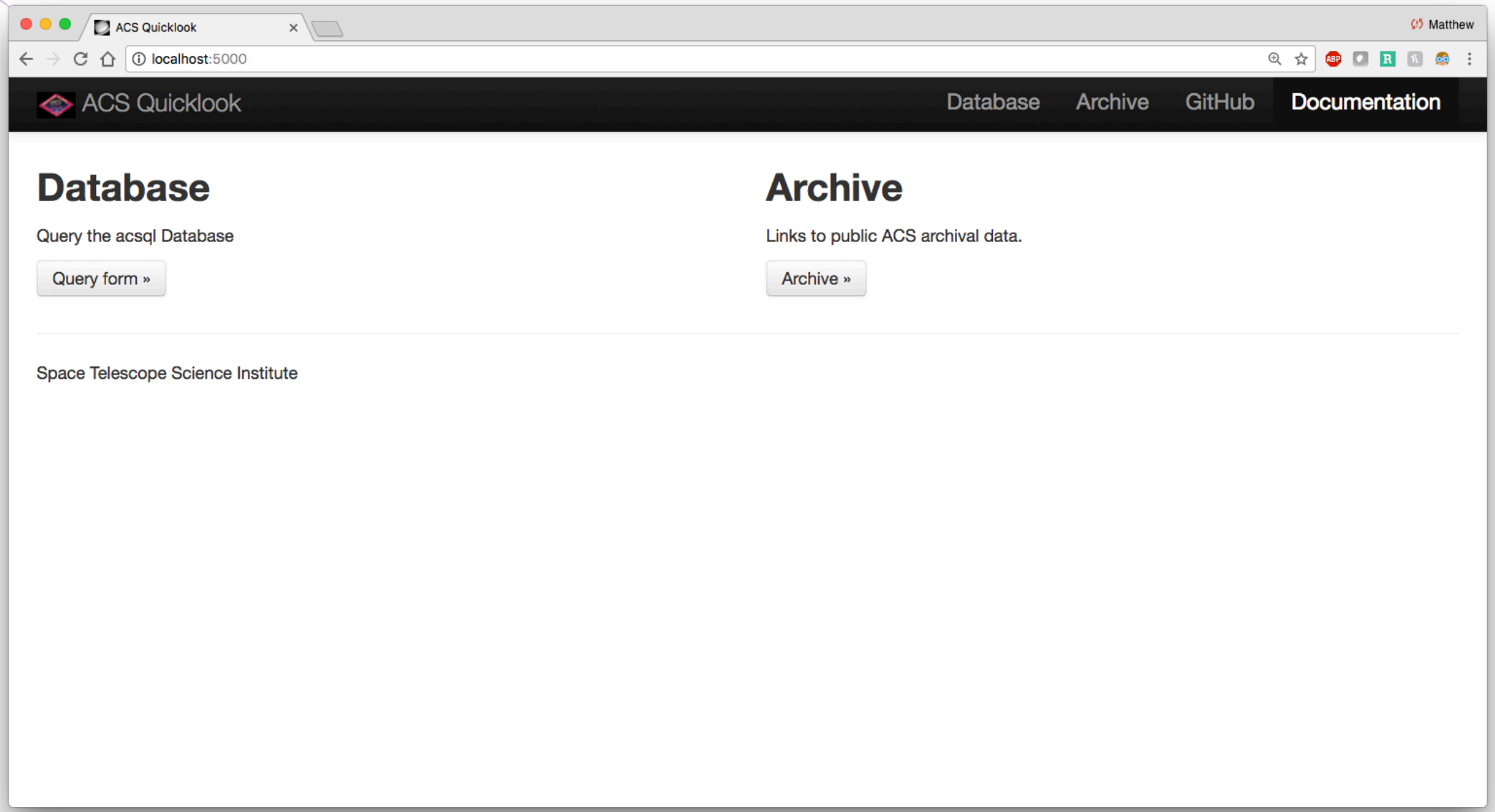
Implementation: acsql Package

```
acsql/
    __init__.py
    database/
        __init__.py
        database_interface.py
        make_tabledefs.py
        queries.py
        reset_database.py
        table_definitions/
            *.txt
        update_tabledefs.py
    ingest/
        __init__.py
        ingest.py
        make_file_dict.py
        make_jpeg.py
        make_thumbnail.py
    scripts/
        __init__.py
        ingest_production.py
    utils/
        __init__.py
        config.yaml
        utils.py
    website/
        __init__.py
        acsql_webapp.py
        data_containers.py
        form_options.py
        query_form.py
        query_lib.py
        static/
            css/
                *.css
            img/
                jpegs
                thumbnails
            js/
                *.js
        templates/
            *.html
```

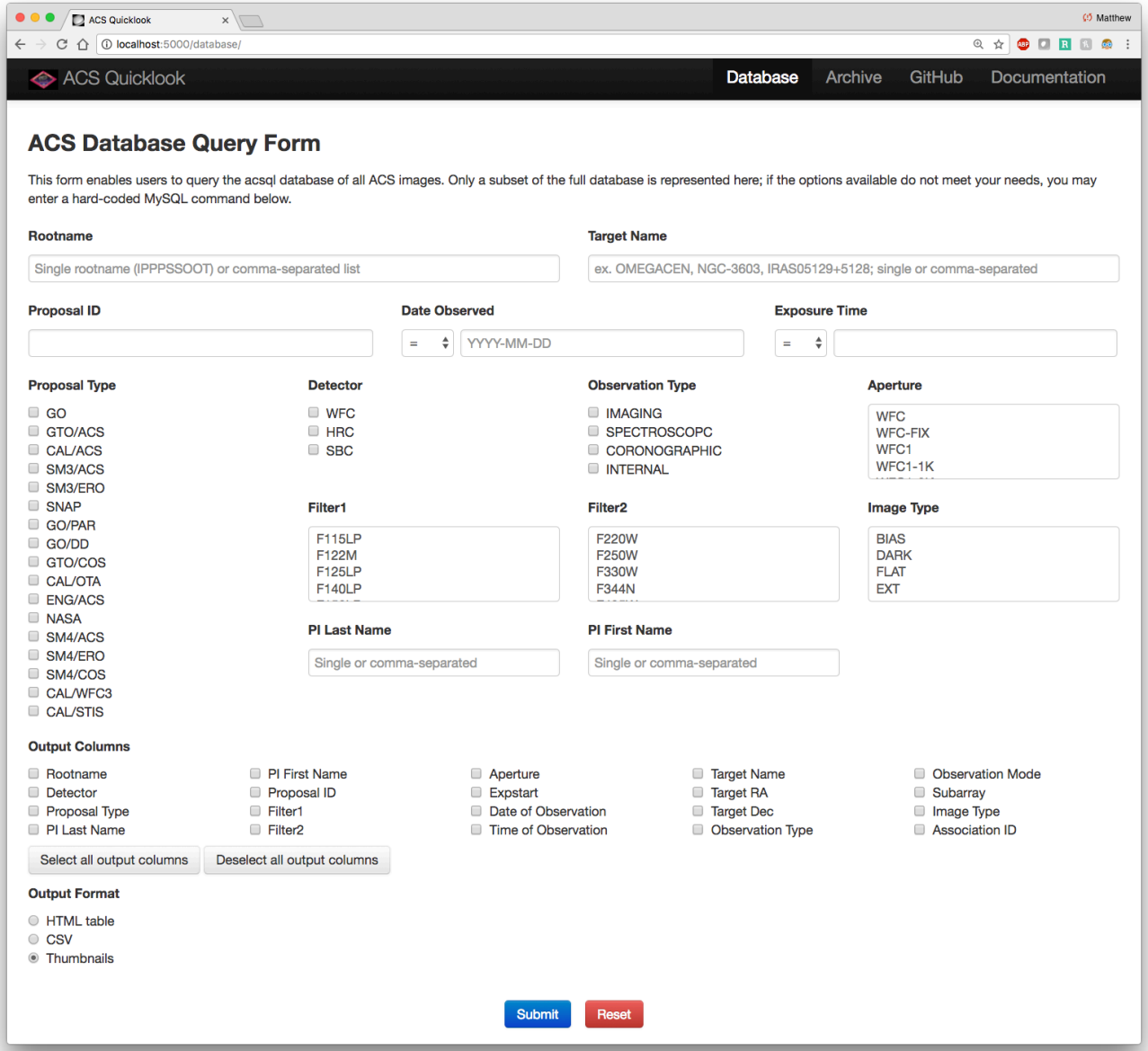


Available at http://github.com/spacetelescope/acsql

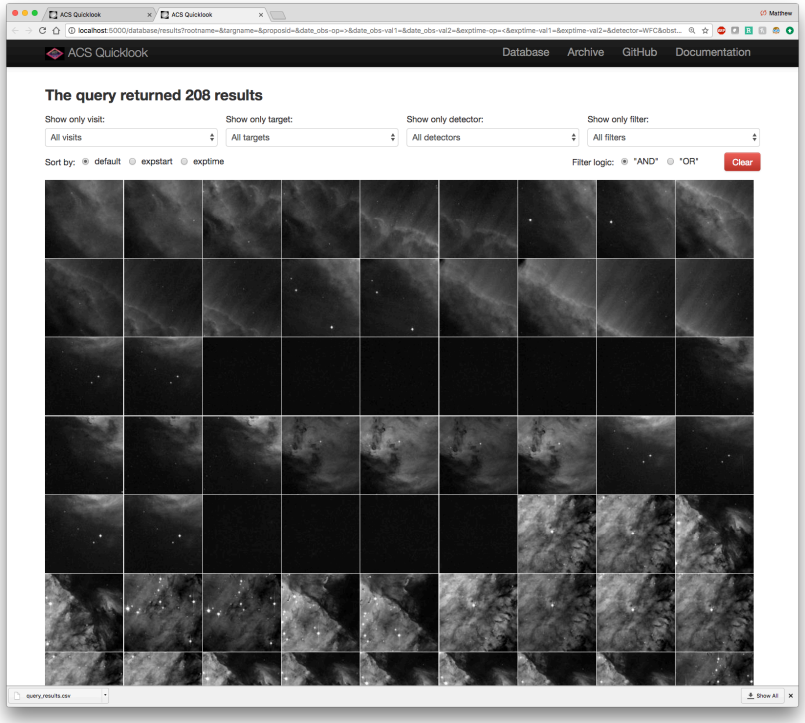
Web Application: Homepage



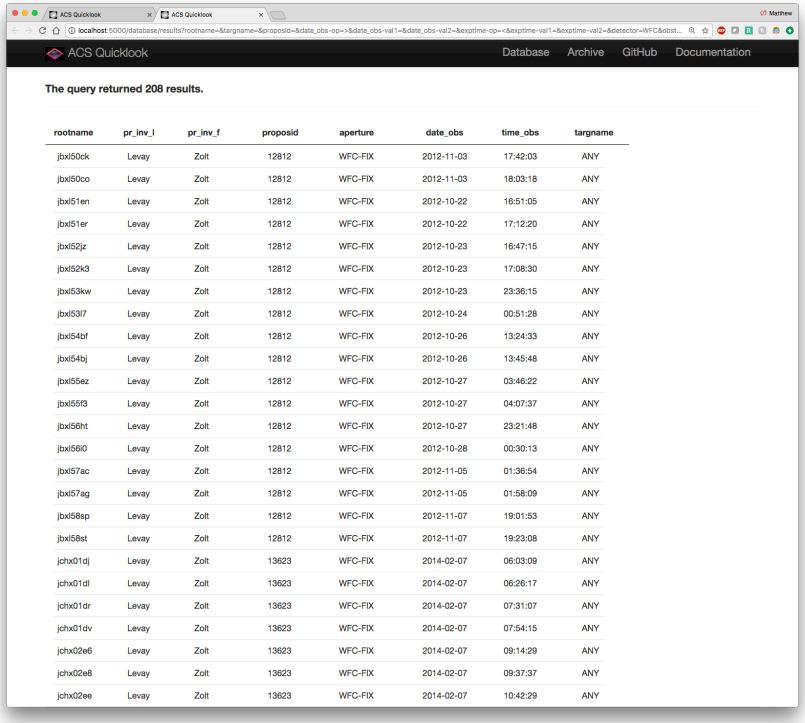
Web Application: Database Query Page



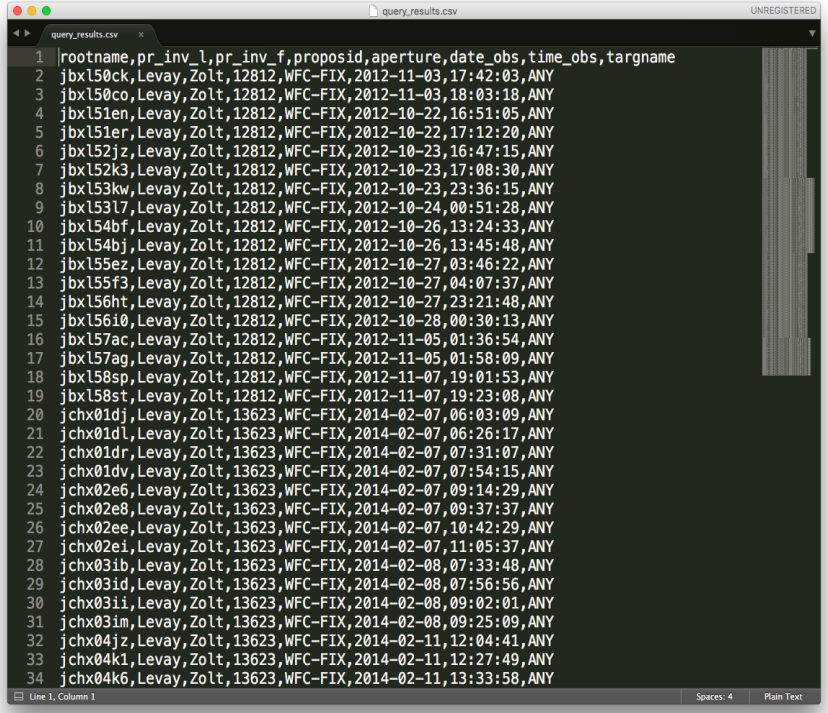
Web Application: Query Results



Thumbnails

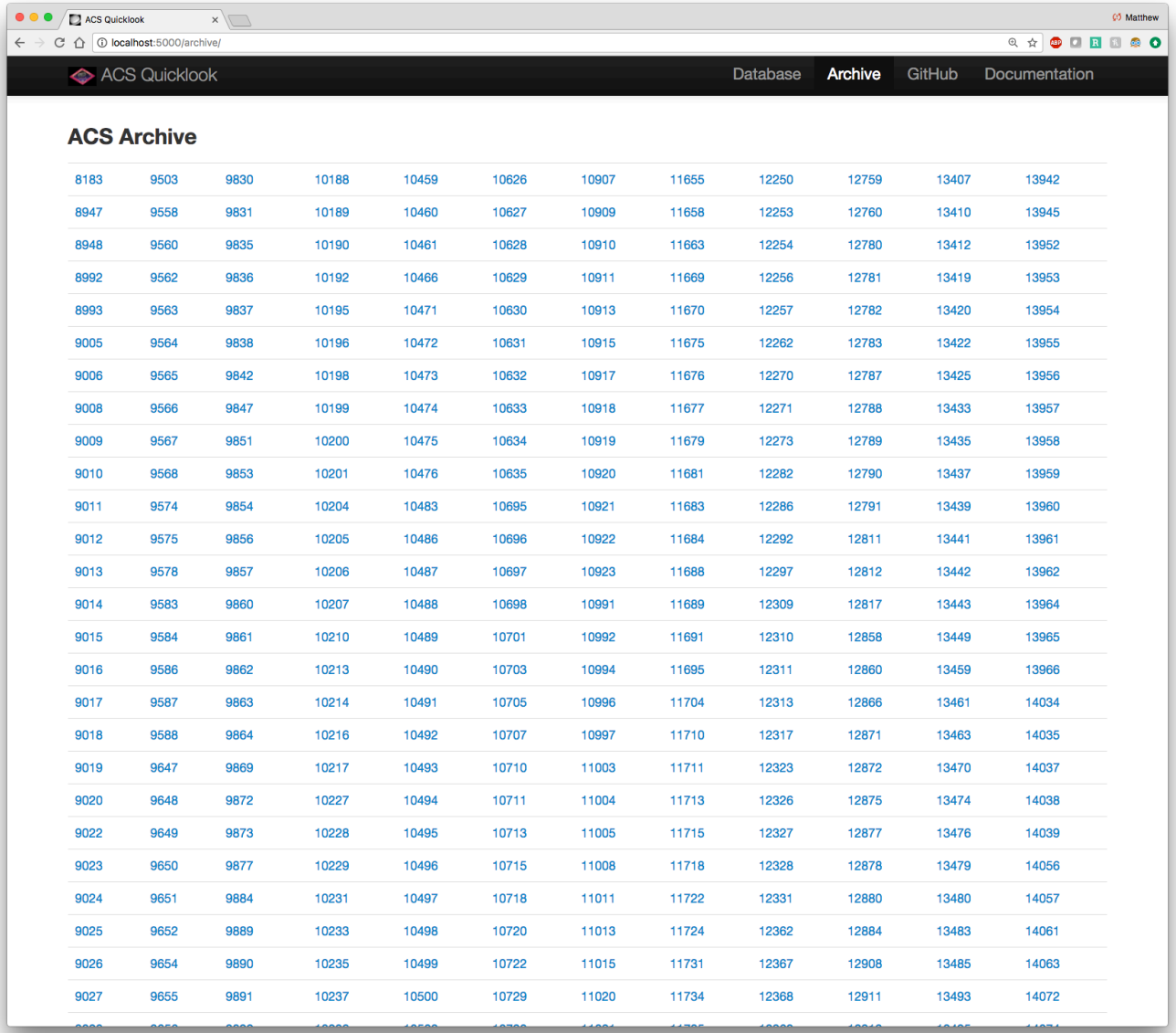


HTML Table

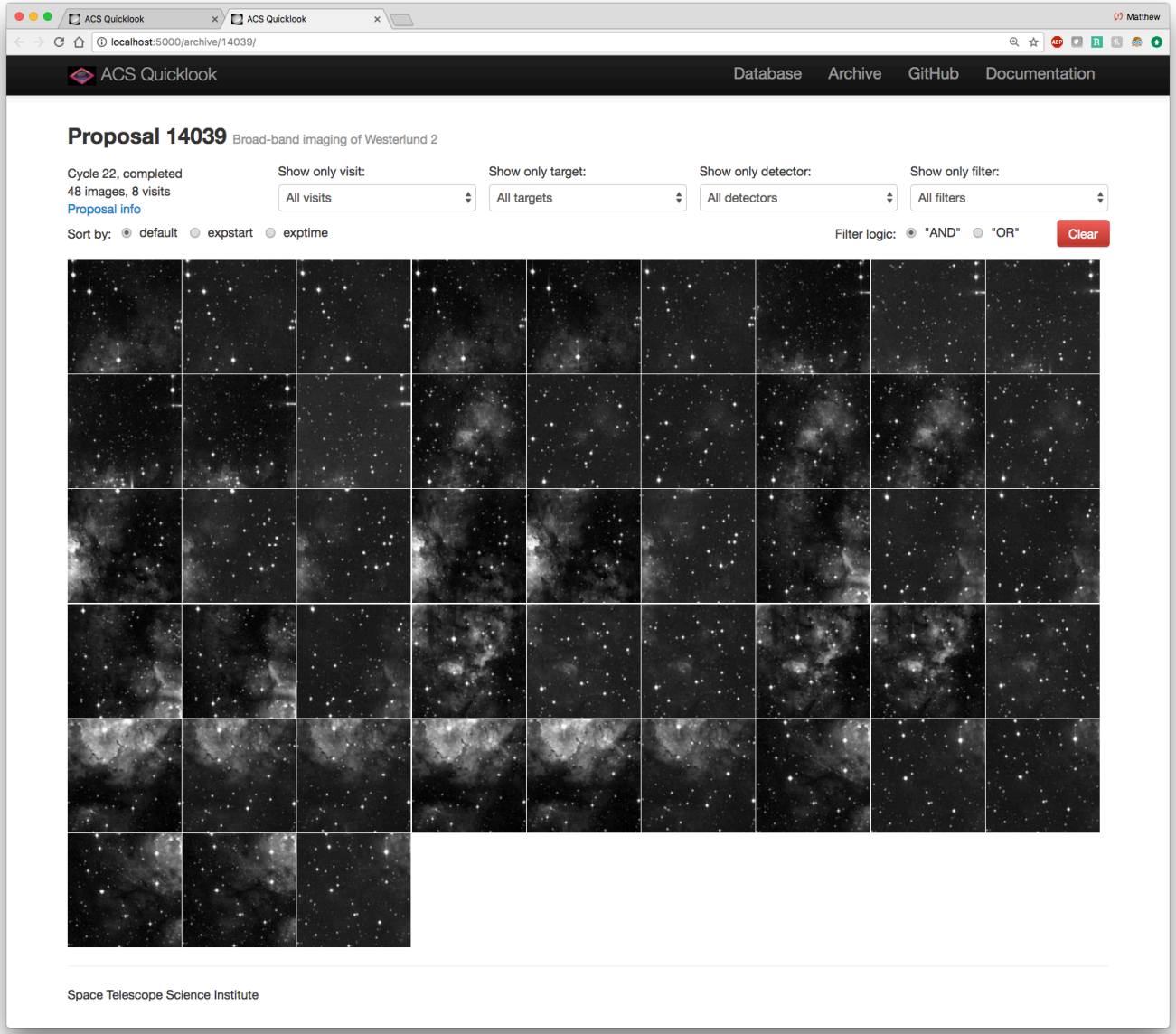


CSV File

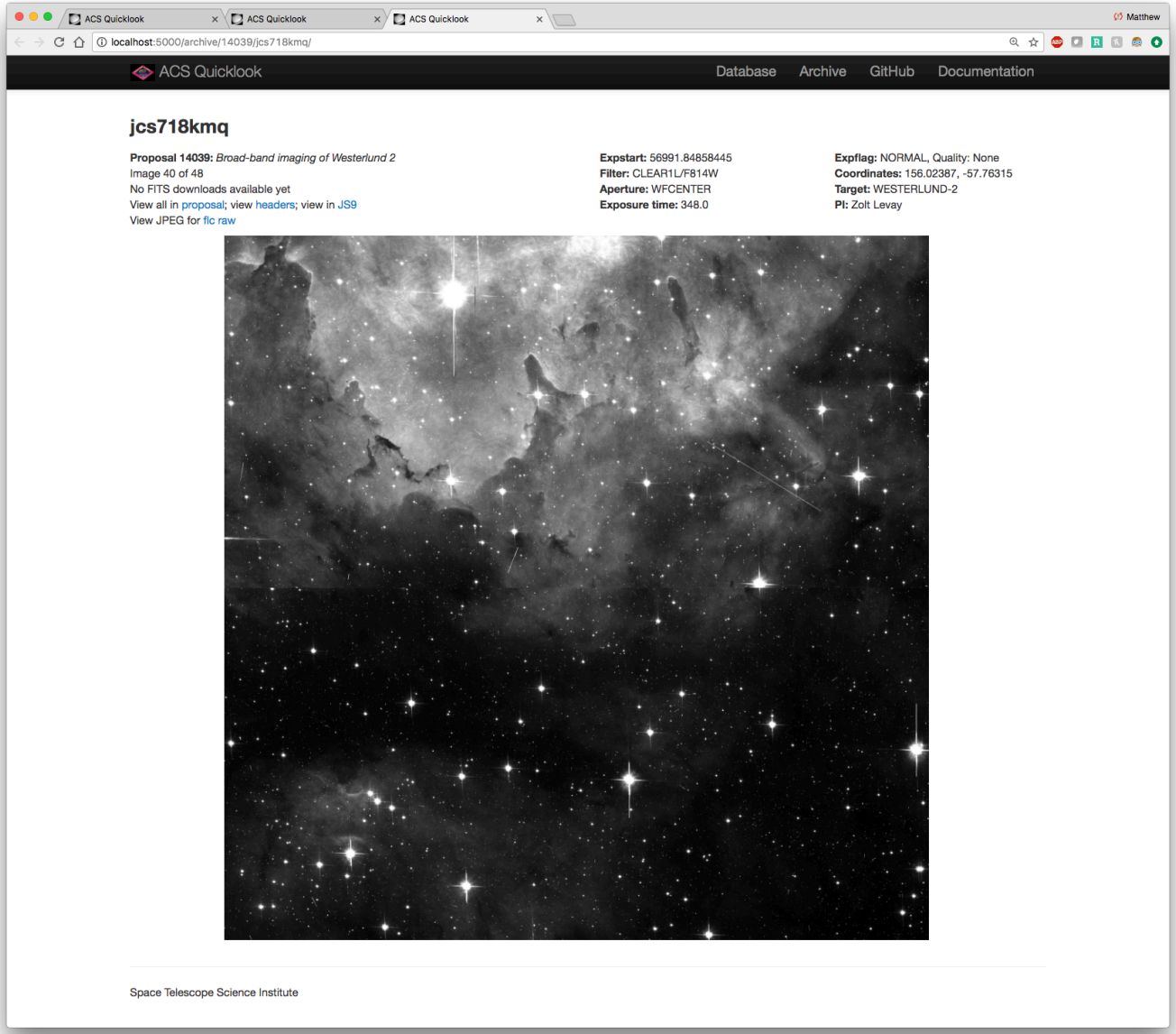
Web Application: ACS Archive



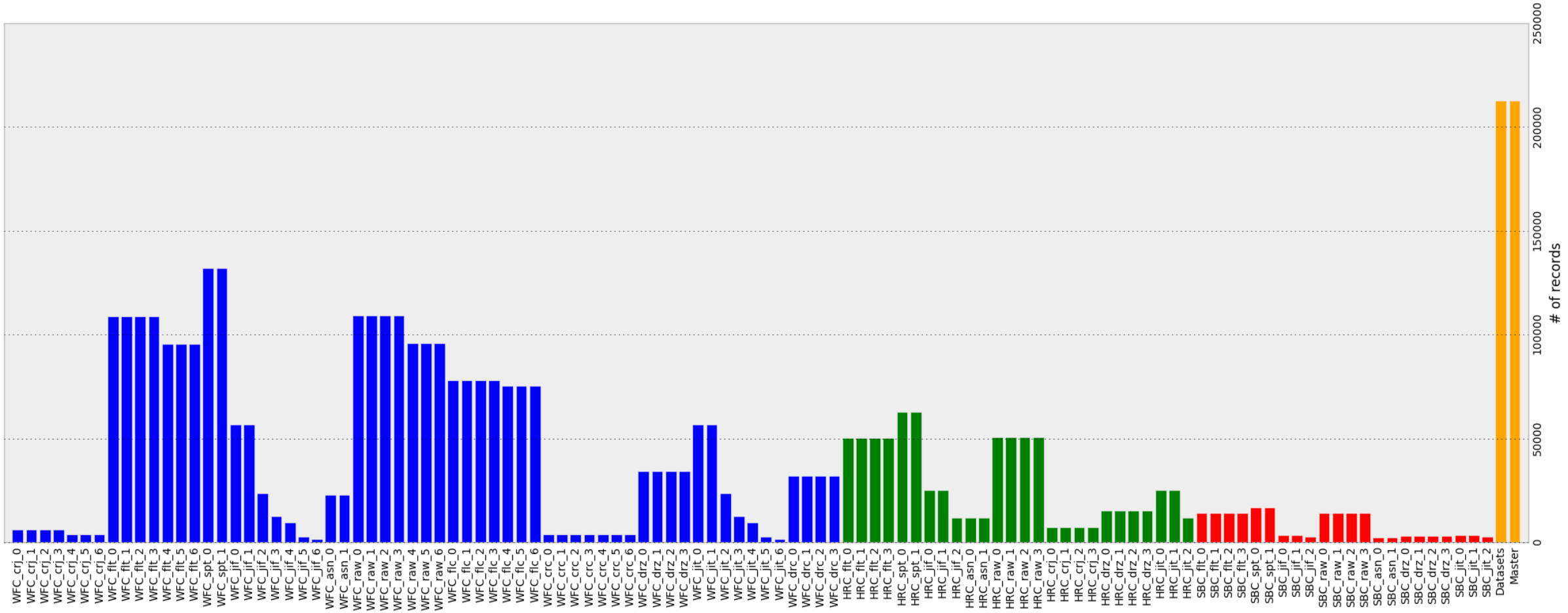
Web Application: View Proposal



Web Application: View Image

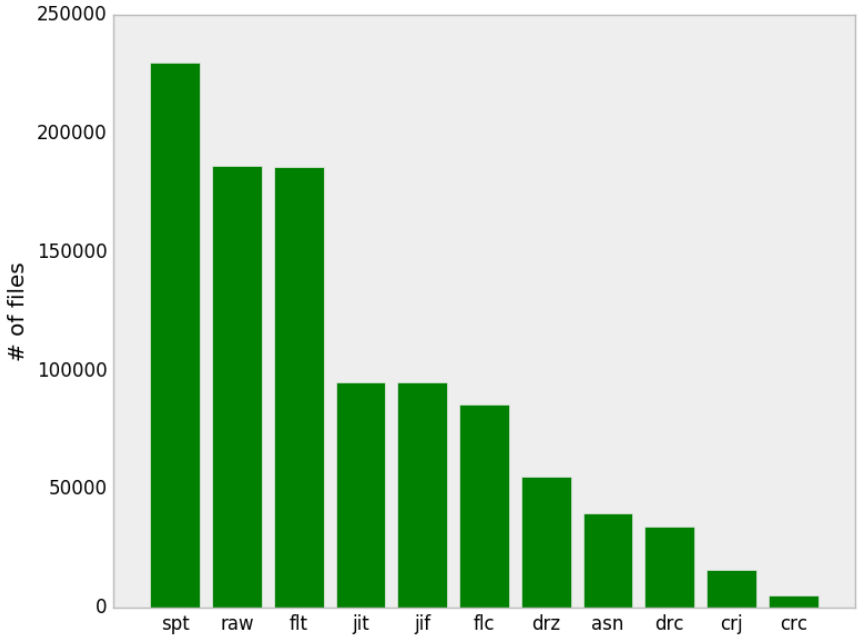


Deliverables

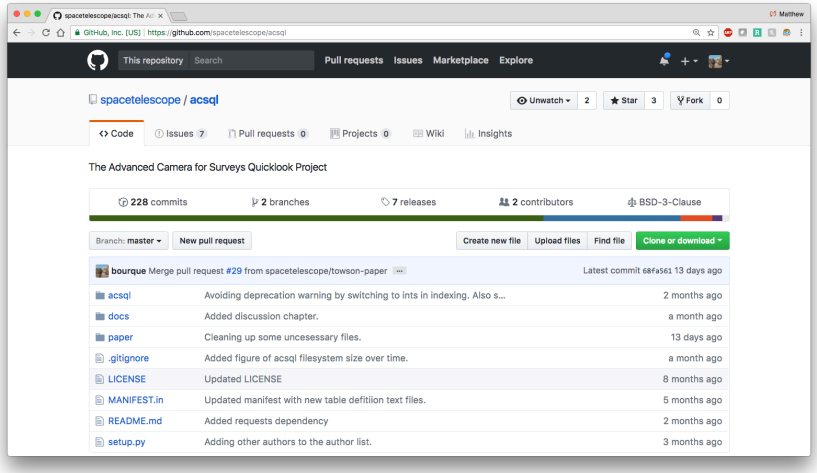


Database Deliverable

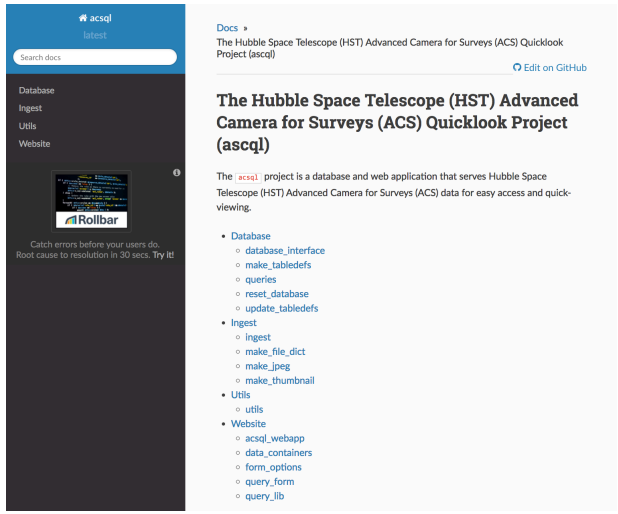
Deliverables



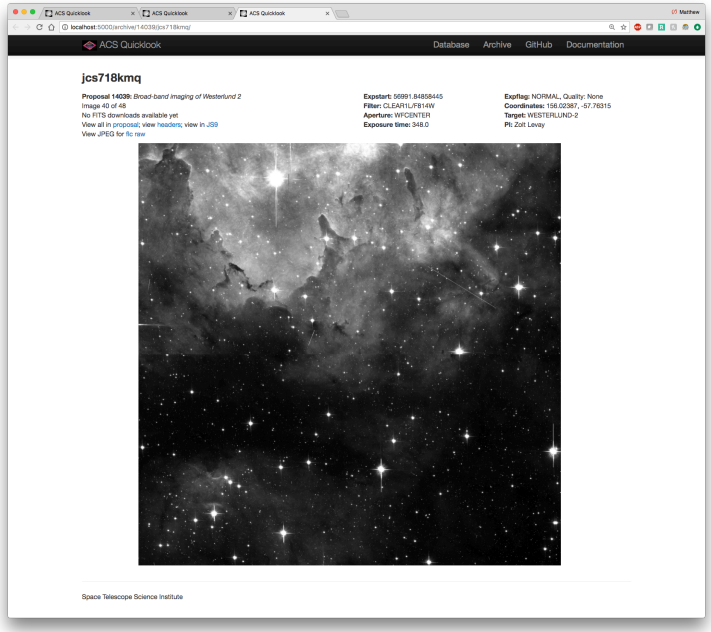
Filesystem Deliverable



Software Package Deliverable



API Documentation Deliverable



Web Application Deliverable

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