Time and Coordinates

astropy

astropy.time

Python's built-in `datetime` package handles standard dates and times, e.g.,

```
In [1]: import datetime
```

```
In [2]: # January 4, 2020
        dt = datetime.datetime(2020, 1, 4)
```

```
In [3]: # January 4, 2020 10:30AM
        dt = datetime.datetime(2020, 1, 4, 10, 30)
```

but it doesn't support astronomical formats (e.g., Julian Date, Modified JD) or precise timing (e.g., pulsar timing)

astropy.time

The `astropy.time` subpackage provides support for representing date/time information with higher precision, and transforming between different formats (e.g., JD, MJD) and scales (e.g., TAI, UTC, solar system barycentric)

Key object: `Time`

```
In [4]: from astropy.time import Time
```

astropy.time

value(s)   *format*   *scale*

```
In [5]: t = Time(58852.76, format='mjd', scale='tai')
```

astropy.coordinates

For representing and transforming astronomical coordinates and velocities

For example: you are given a set of equatorial (RA/Dec) coordinates in sexagesimal form:

```
00:48:26.4 +85:15:36
```

and you would like to transform these to Galactic coordinates (l, b) in decimal form

```
122.86494563, 22.3886423
```

astropy.coordinates

For representing and transforming astronomical coordinates and velocities

Key object: `SkyCoord`

```
In [1]: from astropy.coordinates import SkyCoord
        import astropy.units as u

In [2]: c = SkyCoord(ra='00:48:26.4',
                     dec='+85:15:36',
                     unit=(u.hourangle, u.degree))
        c

Out[2]: <SkyCoord (ICRS): (ra, dec) in deg
            (12.11, 85.26)>

In [3]: c.galactic

Out[3]: <SkyCoord (Galactic): (l, b) in deg
            (122.86494563, 22.3886423)>
```

astropy.coordinates

Key object: `SkyCoord`

High-level object for representing, transforming, re-formatting, interacting with sky coordinates

```
In [4]: SkyCoord(ra=12.11*u.deg, dec=85.26*u.deg,
                 distance=147*u.pc)

Out[4]: <SkyCoord (ICRS): (ra, dec, distance) in (deg, deg, pc)
            (12.11, 85.26, 147.)>
```

Also supports distance and velocity data

```
In [5]: SkyCoord(ra=12.11*u.deg, dec=85.26*u.deg,
                 distance=147*u.pc,
                 pm_ra_cosdec=10*u.mas/u.yr, pm_dec=21*u.mas/u.yr,
                 radial_velocity=-92.4*u.km/u.s)

Out[5]: <SkyCoord (ICRS): (ra, dec, distance) in (deg, deg, pc)
            (12.11, 85.26, 147.)
         (pm_ra_cosdec, pm_dec, radial_velocity) in (mas / yr, mas / yr, km / s)
            (10., 21., -92.4)>
```

astropy.coordinates

Key object: `SkyCoord`

Also: array-valued coordinate data!

```
In [6]: SkyCoord(ra=[12.11, 15.45, 82.2]*u.deg,
                  dec=[85.26, 23.4, -11.34]*u.deg)

Out[6]: <SkyCoord (ICRS): (ra, dec) in deg
            [(12.11,  85.26), (15.45,  23.4 ), (82.2 , -11.34)]>
```
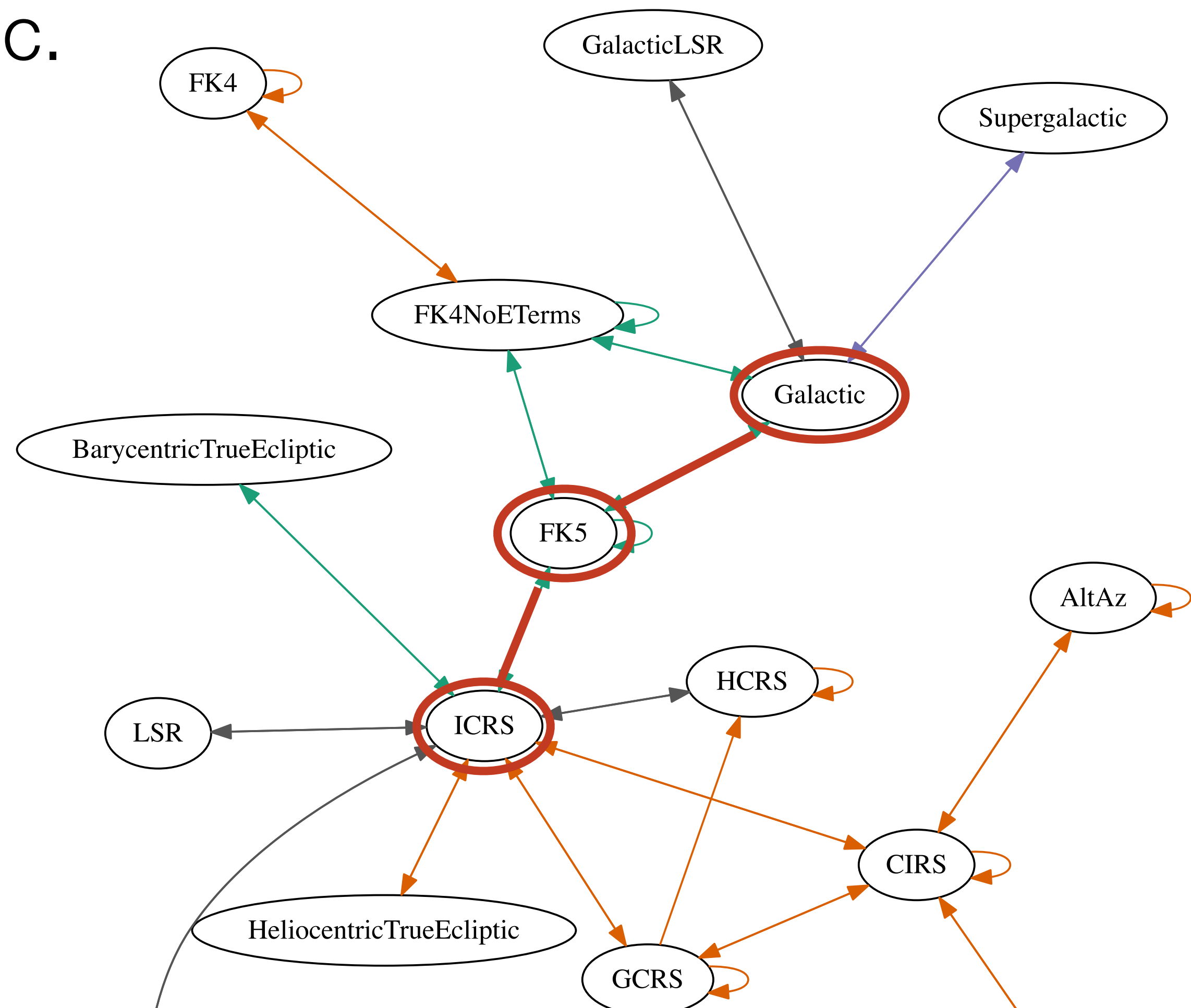
astropy.coordinates

Supports many coordinate *frames*
    e.g., ICRS (J2000 equatorial), Galactic, FK5,
    AltAz (Horizontal), etc.

The frame transform graph:

astropy.coordinates

Each frame has its own *class* implemented in astropy.coordinates:

```
In [7]:  c = SkyCoord(ra=[12.11, 15.45, 82.2]*u.deg,
                      dec=[85.26, 23.4, -11.34]*u.deg)

         from astropy.coordinates import Galactic
         c.transform_to(Galactic())

Out[7]:  <SkyCoord (Galactic): (l, b) in deg
             [(122.86494563,  22.3886423 ), (126.00948245, -39.40982015),
              (214.00989281, -23.4238516 )]>
```

array-like times/coordinates

The core objects in both `astropy.time` and `astropy.coordinates` accept scalar *or* array-valued data! Most operations (transformations, re-representation) will be much faster with array-valued objects vs. looping over scalar-valued objects!

```python
In [9]:  ra = [1., 2., 5., 10.] * u.deg
         dec = [-10., -20., -30., -40.] * u.deg
         SkyCoord(ra=ra, dec=dec).transform_to('galactic')

Out[9]:  <SkyCoord (Galactic): (l, b) in deg
             [( 87.54484429, -69.54375295), ( 66.26011125, -77.76707822),
              (  8.49560981, -82.52603149), (312.64746887, -76.91171264)]>
```

```python
In [10]:  # NOT:
          for i in range(len(ra)):
              SkyCoord(ra=ra[i], dec=dec[i]).transform_to('galactic')
```

This will generally be slower!

Tutorial

Open up `astropy_coordinates.ipynb` and dive in!