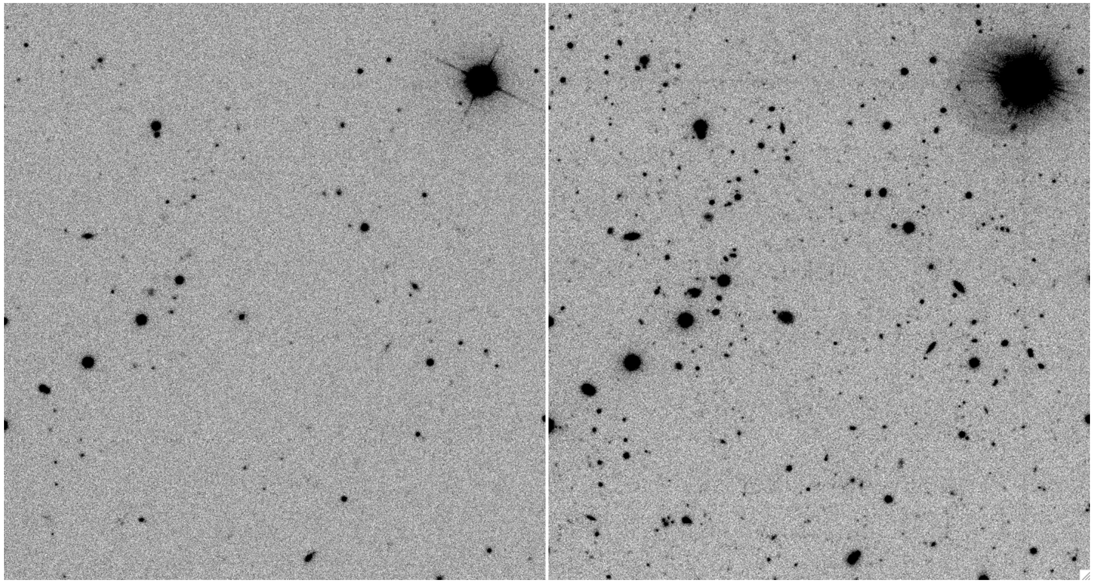
Time Domain Surveys: Variability

Time Domain Surveys: Variability

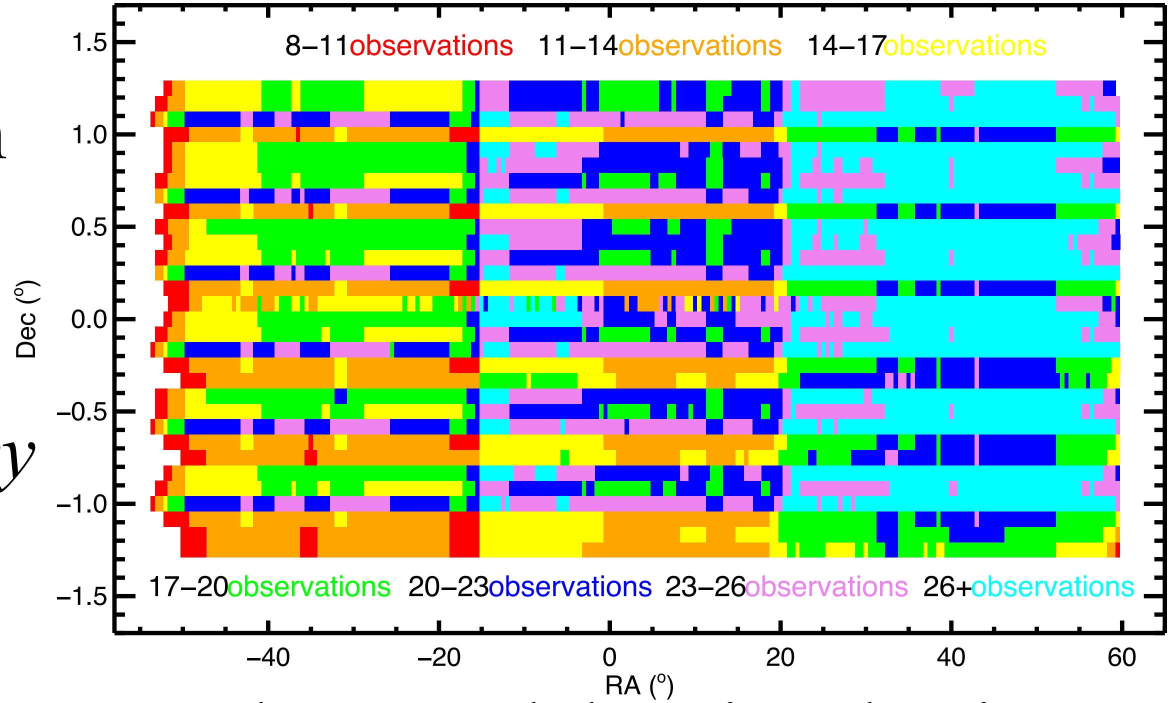
- Time domain science will be hot in the next decade, particularly in the era of the *Rubin Observatory (previously LSST)*.



- Movies of the sky record transient phenomena, such as explosions, bursts, quasars, transits, variable stars and flares (see the *LSST Science Book* Chapter syllabus link)
- Rubin Obs. will scan the sky once every few nights
  - the typical time between observations of an object in a time domain survey is called the *cadence*

Time Domain Surveys: Variability

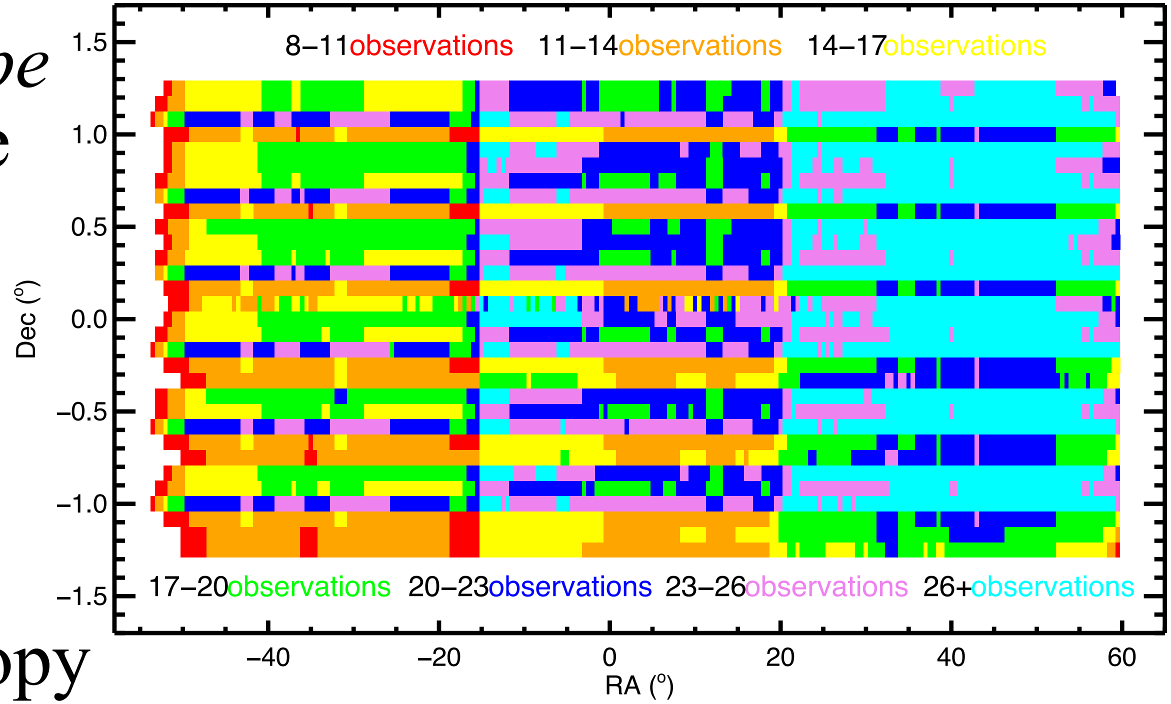
- Current surveys with a time domain component include the *ZTF* and recently completed *Dark Energy Survey* (both linked from the syllabus)



- No current survey has a cadence and duration that is close to matching the *LSST*, but *SDSS Stripe 82* (pictured) is a useful testbed for time domain science
- The cadence of *SDSS Stripe 82* is a little strange, being a combination of annual and daily imaging runs (as we shall see) but it's illustrative of time domain information

Temporal Queries of SDSS Stripe 82

- The full *SDSS Stripe 82* database is huge (about 100 times larger than an SDSS run of comparable area)
  - so we don't have a local copy



- But, HTM indexing is rapid for this sort of application (matching multiple observations that are very close in position...i.e. multiple observations of the same object)
- So, the online *SDSS Catalog Archive Server* coupled with careful construction of an *SQL* query works well

Temporal Queries of SDSS Stripe 82

- The *SDSS Stripe 82 Catalog Archive Server* is linked from the syllabus (it's different to the one that we used in earlier lectures to query the single-epoch SDSS data)
- To return all objects within 0.3 arcseconds of a sky position (*ra, dec)*, at any time of observation, use, e.g.:
- *SELECT p.ra, p.dec, p.psfmag_g, f.mjd_g, n.distance*60 FROM fGetNearbyObjEq(ra,dec,0.3/60) n, PhotoPrimary p, Field f WHERE n.objID = p.objID and f.fieldID = p.fieldID*
- Here, the "*n*" is the database of HTM indexes, the "*p*" is the database of imaging information for primary objects and the "*f*" database records the time that each image was observed
- The *_g* variables convey the fact that we only want to return magnitudes and times of observation (MJD) in the g-band

Temporal Queries of SDSS Stripe 82

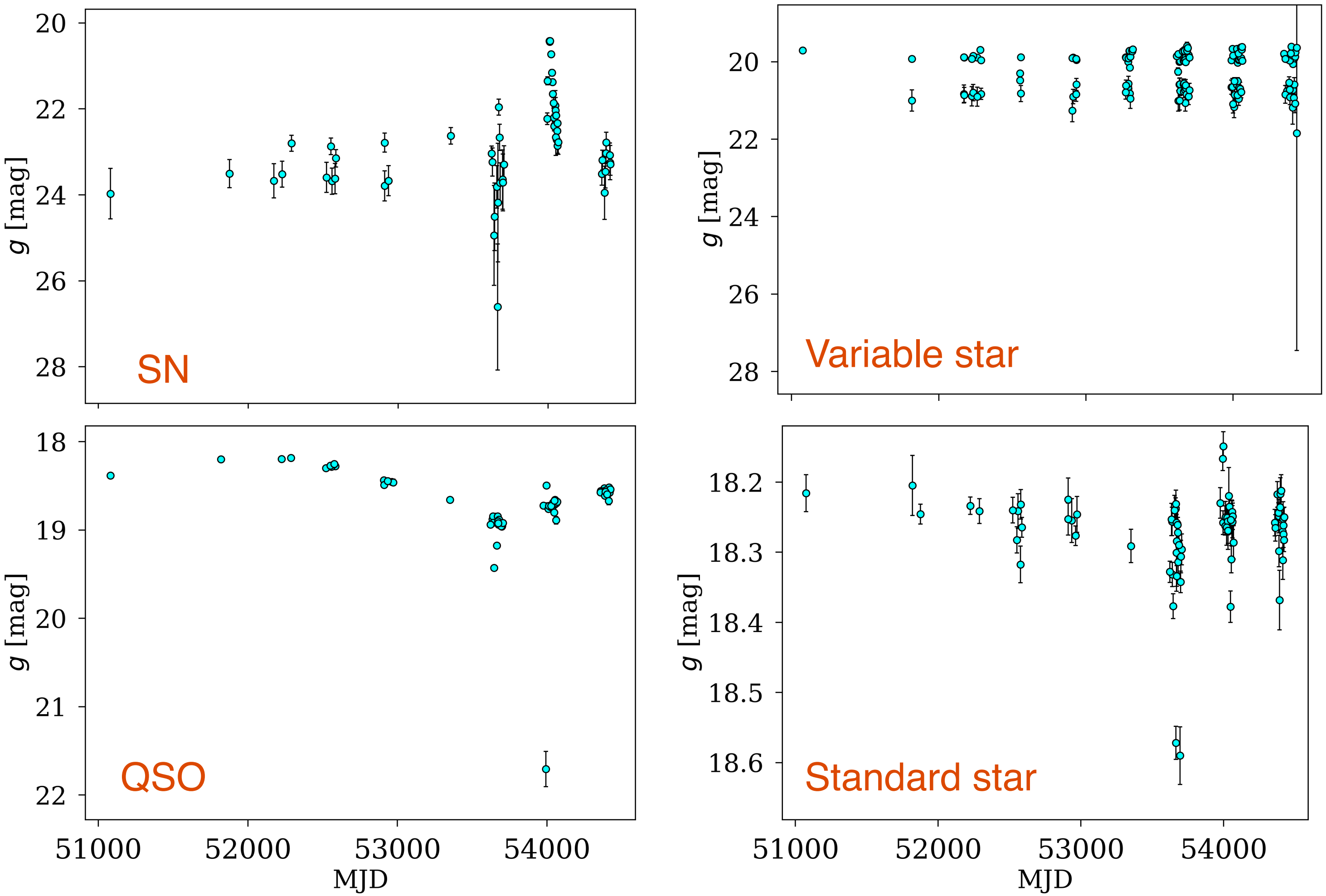
- Code in my week12 directory can *remotely* run the query

  *SELECT p.ra, p.dec, p.psfmag_g, f.mjd_g, n.distance*60 FROM fGetNearbyObjEq(ra,dec,0.3/60) n, PhotoPrimary p, Field f WHERE n.objID = p.objID and f.fieldID = p.fieldID*

- The code is called stripe82query.py and takes RA and Dec as arguments passed at the command line
- The output will be the same whether you use my Python code or the online query, but my code can be spawned from other Python code using, e.g., *os.system*
- The output can be directed to a file and read back in:
  - *os.system("python stripe82query.py 29.2256832 0.4208970 > sqlresult.data")*

Classifying light curves

- We will consider four classes of objects: non-variable (standard) stars, variable stars, supernovae, and quasars.



Classifying light curves

- General rule of thumb:
  - SNe flare by 2-4 magnitudes on day timescales.
  - Quasars get brighter/fainter by 0.5-1 mag over long timescales, average change is more than noise.
  - Variable stars can have regular outbursts (e.g., patterns) and can have 0.5-1 mag variability amplitude.
  - Non-variable stars are relatively steady, variability amplitude usually <0.2 mag mostly from outliers.

Python tasks

1. Query the SDSS Stripe 82 database and retrieve the time domain data for (α,δ) = (29.2256832, 0.4208970), (35.3756676, 0.0017000), (45.299833, -0.55386111), (58.175468, 0.218697) and (60.829041,-1.240793)
   - Plot *g* (y-axis) against *MJD* (x-axis) for *all the objects on one plot*...why does the cadence looks as it does?
   - Each object may have an observation at *mjd_g = 0* for the *run* that corresponds to the coadded data (*run = 106* or *run =206*)...you can remove this observation
2. Plot *MJD* against *g* for *each individual object*
   - Try to determine which of these objects is a *supernova*, which are *normal stars,* which is a *quasar* and which is a *short-period (a few days) variable star*

Python tasks

3. I drew some of these objects from the *SDSS stripe 82 Variable Source* and *Standard Star* Catalogs (linked from the syllabus) so they are not necessarily representative of typical sources in *Stripe 82*

- Find a few objects in the coadded imaging file at */astro/astr8020/varcats/varcat-ra30-60-minflux_ngood1-mincoadd_flux_ngood2.fits* that have more than 25 observations (i.e. *FLUX_NGOOD* > 25 in every band)
- Download these objects' time domain information from the *Stripe 82 SQL Server* and plot *MJD* against *g* for each object
- Does a typical object in *Stripe 82* have much variability (i.e. does it look like the *normal stars* from task 2)?