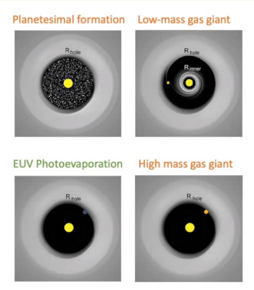
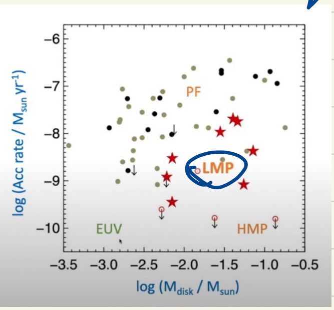
# Sagan Summer Workshop – Techniques. Observations & diagnostics of PPDs: inner disk

1. inner disk: magnetic field line.
2. dust & gas in the inner disk: a few Myrs.
3. accretion rate → understand nature of TD.
   center is optically thin in continuum.




All can create same SED profile
→ can be distinguished from
log (accretion rate) – log ($M_{disk}$/$M_{sun}$) diagram




4. probes of disk: dynamics, structure, chemistry

NIR spectroscopy:
- K-band CO 2.3 μm (CO overtone) $\Delta v = 2$
- L-band $H_2O$ 3 μm
  $C_2H_2$, $CH_4$
- M-band CO $\Delta v = 1$ 4.7 μm (CO fundamental)
  vibrational transition

MIR spectroscopy: (12–18 μm)
OH. $H_2O$. HCN. $C_2H_2$. $CH_4$ $NH_3$....
(water & organics)

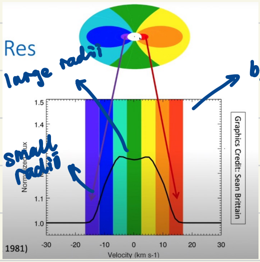
disk chemistry. planetesimal formation
solid migration. disk surface accretion.

## fundamental & overtone in IR spectroscopy.

Any resonant frequency above the fundamental frequency is referred to as an *overtone*. In the IR spectrum, overtone bands are multiples of the fundamental absorption frequency. As you can recall, the energy levels in the Harmonic Oscillator approximation are evenly spaced apart. Energy is proportional to the frequency absorbed, which in turn is proportional to the wavenumber, the first overtone that appears in the spectrum will be twice the wavenumber of the fundamental. That is, first overtone $v = 1 \rightarrow 2$ is (approximately) twice the energy of the fundamental, $v = 0 \rightarrow 1$.

5. high spectral resolution as a surrogate for high angular resolution.

→ take advantage of disks are rotating.




by observing emission lines dispersed in wavelength

→ we can also measure something about disks. as a function of radius.

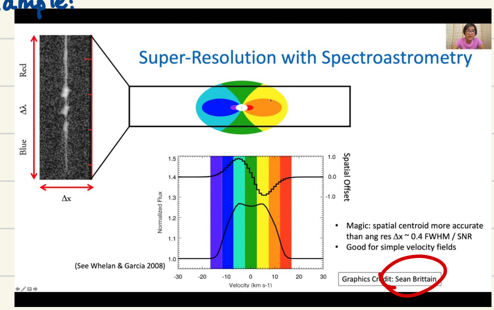
derive from the velocity → inner & outer radii of disks.

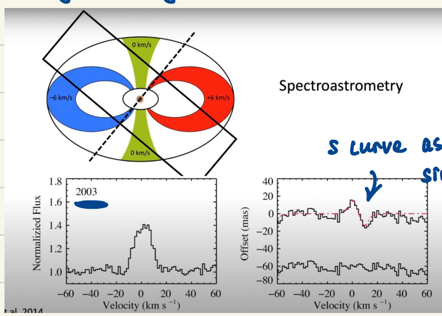
6. spectroastrometry: detect forming planets & circumplanetary disks.
(super-resolution) (birth place of moons)

circumplanetary disk
HD100546
Brittain+2014
Brittain+2019

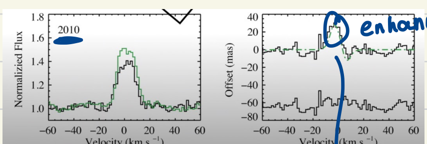
spatial central of the emission as a function of velocity. only valid for central disk

Example:

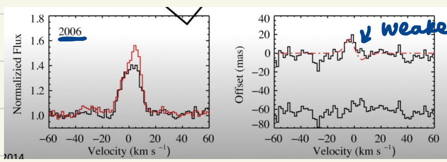


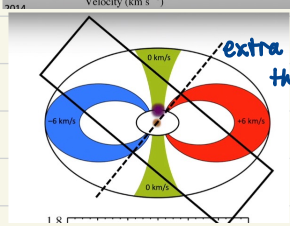

S curve as expect for a simple disk




enhanced



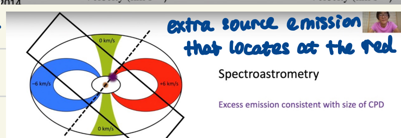

weakened.

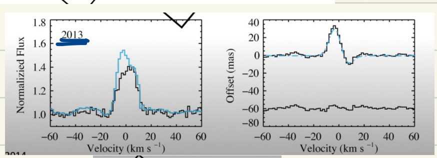


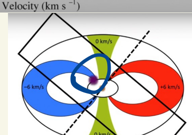

extra excess at the "green" velocity

reason:

extra source emission that locates at the red velocity

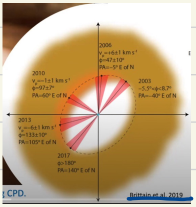


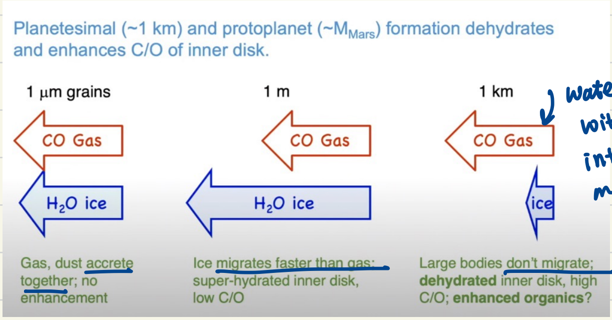
planet
Migration: follow inward accretion of materials.

until the inner disk dissipate. → proto-planets imprint themselves in the disk

⇛ 

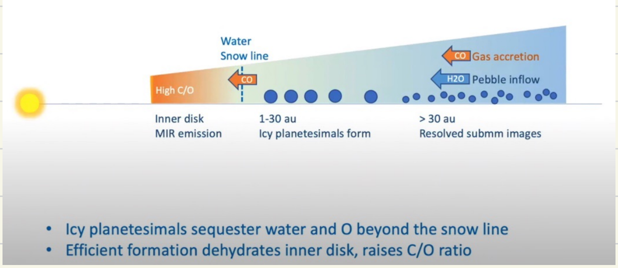

7. MIR molecular spectroscopy

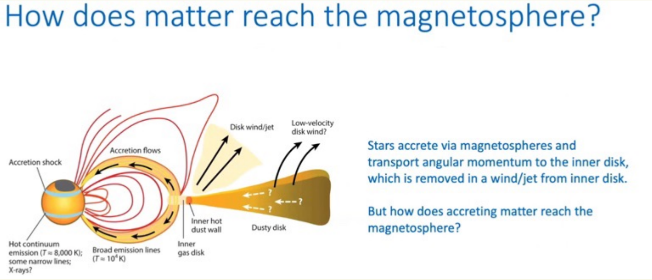
solid aerodynamics & C/O of inner disk




Water evaporates within snowline introduce oxygen, making C/O ratio lower.

planetesimals & C/O of inner disk.




8. 

Summary

**UV/optical spectroscopy**

1. well studied
2. diverse questions/issues:

a. how star accrete: via magnetospheres not boundary layers

b. demographics of stellar accretion rates bear on: gas dissipation timescale of inner disk, nature of transition disks

**infrared spectroscopy**

much less well studied

a. disk structures & sub-structures: measure inner gas disk radii, identify orbiting gaseous circumplanetary disks

b. disk chemistry: probe planetesimal formation, an otherwise elusive process?

c. disk dynamics: do disks accrete through their atmospheres?