A730 / 13 Sep 2023

- Galaxy distribution functions, e.g., luminosity or mass functions:
  - The Schecter function: $\Phi(L) = (\Phi^*/L^*)(L/L^*)^{\alpha}\exp(-L/L^*)$
  - Units?
  - How do you compute total comoving luminosity or mass?
  - Implications for α ? Typical values for α?

- Large scale structure:
  - What are the scales?
  - What are typical environments? Extreme?
  - Where does the MW live and is it typical?
  - Does environment impact galaxy formation/evolution?

- Big Bang:
  - What are the key epochs or eras?
  - Primordial abundances? Implications?
  - Structure formation: when does this occur?
  - What drives reionization? When does it occur?
    - How do CMB data constrain this?

- Galaxy formation:
  - What are galaxies made of?
  - What is the assembly process?
  - Where are the baryons?

A730 / 13-18 Sep 2023

- Stellar Evolution
  - Big picture: what are stars good for anyway?
  - What is (the significance of) the Main Sequence (big picture)?
  - Beyond the MS: How well do we know the evolutionary stages for stars?
    - As a function of mass? Metallicity?
    - Why are high-mass stars particularly important?
  - What is the larger significance of core He burning?

- Understanding stellar populations
  - H-R diagrams: Why are these useful?
    - Reading: Noël+2007, Lewis+2015
    - What is the data they use? Compare their CMDs.
  - Where (in the HR diagram) are the most luminous stars?
    - What determines their frequency in stellar populations?
  - What're the difference between Pop I & II ?
    - What is the age-velocity relationship?
  - Can we resolve stars in external galaxies?
  - Integrated star-light $\mathcal{L}$: how much comes from stars of different luminosity ($L_\star$)?
    - Does it depend on wavelength λ?
    - Can you compute the dependence of $\mathcal{L}$ on $L_\star$ and λ?

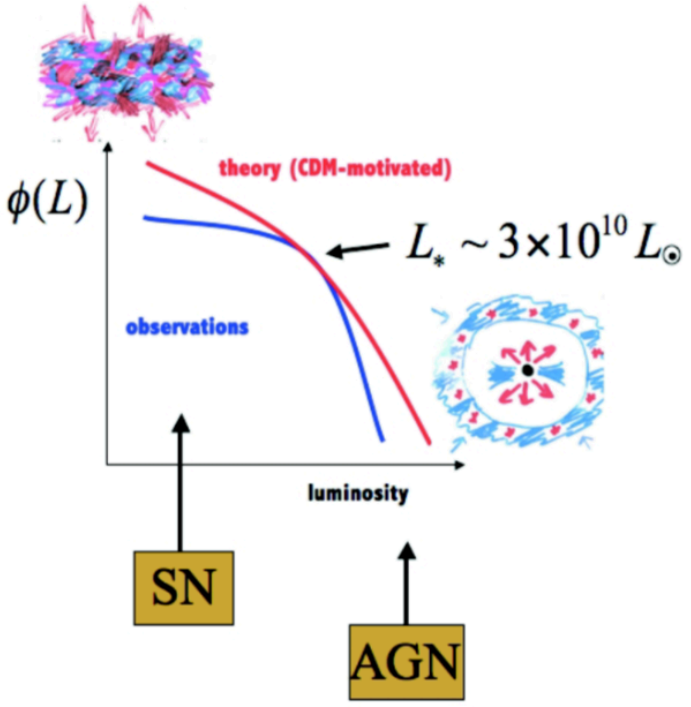
A730 / 13-25 Sep 2023

- Stellar Population Synthesis (SPS)
  - What are the key ingredients?
  - What are these / how do they different from standard SPS?
    - Fuel Consumption theorem
    - Differential Populations Synthesis
    - Simple Populations Synthesis and why it works

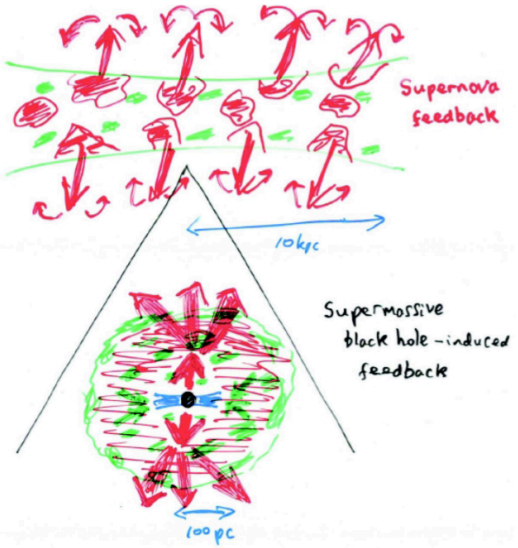
- Chemical Evolution
  - Abundances: definitions and observations
  - Where do the heavy elements come from (in detail)?
  - Abundance patterns in the MW:
    - significance / implications for galaxy formation?
  - Model ingredients
  - What is the G dwarf problem? Is it a problem?

A730 / 25 Sep – 02 Oct 2023

- ISM:
  - Phases of the ISM
    - What's so hard about detecting molecular gas?
    - What's the difference between dust and molecules?
      - And where you measure them?
  - Line diagnostics:
    - How do you measure ionization, T_e, n_e, reddening and metallicity?
    - What is the Balmer decrement?
    - For what phase(s)?
    - What is a forbidden line? Why forbidden?
    - What is the BPT diagram and why interesting?
  - Star-formation:
    - What are the tracers?
    - How are they complimentary
    - How do you measure rates (SFR)?
      - What are the uncertainties?
  - Feedback:
    - Sources?
    - Motivation(s) that feedback is important for galaxy formation?
    - On what mass-scales are different sources important?



Joe Silk

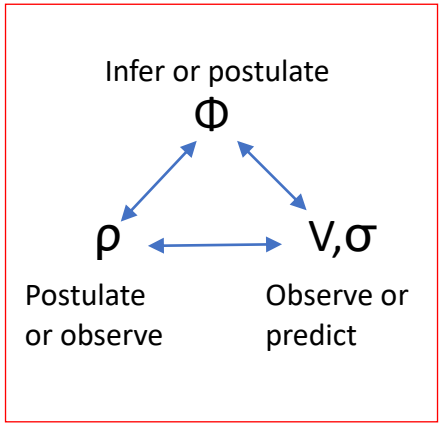


A730 / 02-04 Oct 2023

- Environment:
  - Structure scales: galaxies, groups, cluster, filaments
  - Trends
    - Morphology-density relationship – what is it?
    - Does it depend on galaxy mass?
  - Processes:
    - Field vs group vs cluster
  - Pre-processing:
    - What is it?
    - Why important?
  - Clusters:
    - Where do they form?
    - When do they form?
    - What does ‘form’ mean?
    - (more for cosmo: What is the S-Z Effect?)

A730 / 02-09 Oct 2023

- Potentials and Energetics
  - What are the key ingredients?
    - Gravitational force law
    - Divergence theorem
  - Potential and kinetic energy
  - The Virial Theorem
  - Circular and escape velocities
  - Spherical systems - examples
  - Time-scales: dynamical, free-fall, crossing
- Dynamical relaxation: N-body encounters
- Instabilities to collapse: Jean's length
- Rotation curves
  - Tully-Fisher: derivation and phenomenology
    - Faber-Jackson and the Fundamental Plane for systems with KE not dominated by rotation
  - Disk-halo degeneracy
- Collisionless Boltzman Equation
  - Stellar velocity (dispersion) ellipsoid
  - Asymmetric drift



A730 / 11 Oct 2023

- Milky Way
  - What are the key stellar components?
    - How are the physically differentiated?
    - How were the observationally determined?
    - Star-counts and the Malmquist bias
  - Chemical cartography:
    - Whare are the implications of the [α/Fe], [Fe/H] distribution?
  - What is the evidence for a Galactic bar?
  - Galactic rotation:
    - Quadrants, tangent points
    - Oort's constants: A and B
  - Solar motion and the LSR
    - Lagging motions
      - What's another term for this?
      - Why does it depend on color?
    - Parenago's discontinuity: implications?

A730 / 16 Oct 2023

- Disk Galaxies
  - Structural properties
    - What are the trends along the Hubble Sequence? (stars and gas)
    - How do these trends lend themselves to quantitative schemes for a physical classification?
  - Freeman's law: What is it? Are there departures?
  - Bulge-disk decomposition: why important?
    - Profiles: Type-I and II disk profiles – what are they?
    - Sersic profile – how is this related to B/D?
  - Oval distortions and bars
    - Are bars short- or long lived? How do we know?
    - What do bars to to stellar orbits?
  - Spiral structure
    - What is the winding problem? How is it solved
  - Scaling relations: enumerate…
  - Disk heating:
    - Relate to MW disk structure
    - Relate to models of disk formation, gas cooling.

- Elliptical Galaxies
  - What are their basic properties?
  - What distinguishes ellipticals from spirals?
  - Describe an alternative classification scheme than the base of the tuning fork.
  - How does this alternative classification relate to (explain or reconcile with) their …
    - ISM properties?
    - Stellar populations?
    - Stellar kinematics?

    … compared to spiral galaxies
  - Scaling relations:
    - enumerate and contrast to Tully-Fisher for spirals
  - Fast- vs slow-rotators: What do they tell us?
  - X-ray gas: Why are the brightest x-ray galaxies Ellipticals? What are the source(s)?
    - Do spirals emit x-rays? What are the source(s)?

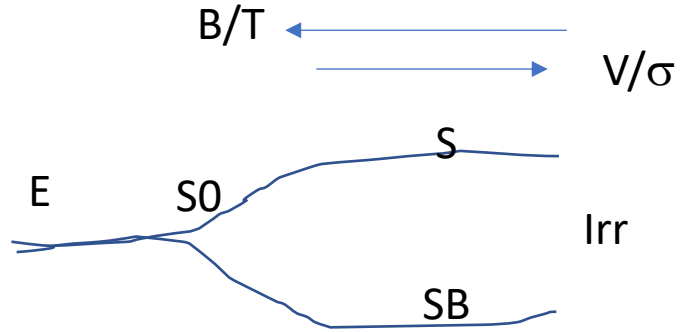
In-class Exercise:

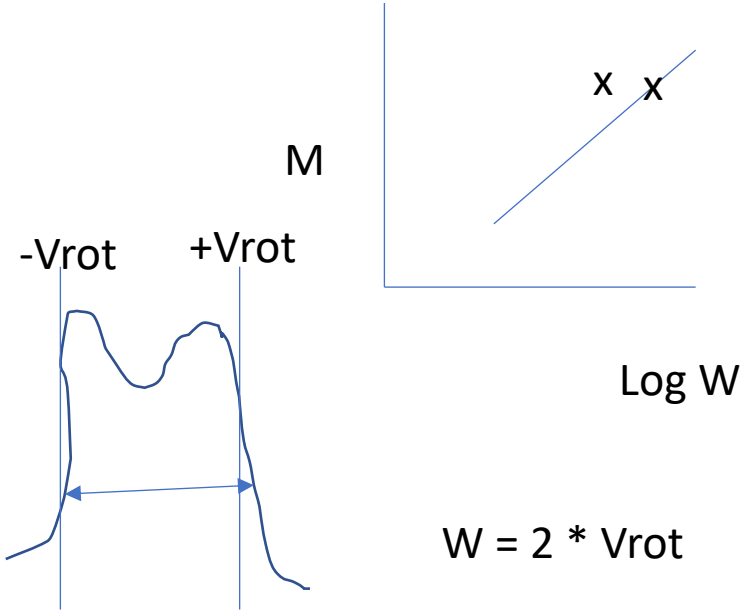
- Work in groups;
- Divide up the effort
- Write answers on the Board

1. What is the Fundamental Plane (FP)?
   a) Write down a formula describing the FP.
2. Describe the observational parameters:
   a) What are they?
   b) How are they measured?
3. Compare to the Tully-Fisher (TF) relation for spirals.
   a) Write down the TF relation, as observed
   b) Write down the derivation of the TF relation
4. Why does the observed TF relation not depend on stellar surface-brightness while the FP relation does?

Thinking astrophysically about galaxies -I

- How would you characterize the Hubble sequence in terms of V/σ? Are there any surprises? What does 'The Comb' fix?
- TF-relation: how should it differ for early-type galaxies? Dwarfs?
  - How do integrated line-profiles depend on rotation curve shape?
- Where do you find lenticular galaxies?
- What kind of orbits might you expect for lenticulars in cluster? For more spheroidal systems?





Thinking astrophysically about galaxies -II

- Why does super-massive black-hole mass (M_{BH}) correlate better with bulge mass than total galaxy mass? How might that impact our inference about the role of SMBH on SF quenching?
- [Mg/Fe] and the G-dwarf problem: does late-time low-metallicity (primordial?) gas accretion raise or lower [Mg/Fe] in the outskirts of galaxies? Are the outskirts young? Does enriched gas migrate outwards?

Thinking astrophysically about galaxies -III

- How should sSFR at a given mass correlate with environment today? Yesterday? (yesterday = $1/H_0$ = ? *Please calculate now*).
  - What clue does the the *lack* of SFE = star-formation efficiency dependence (SFR/ M_{HI}) on environment provide?
- M_{HI}/L_B -- what should this depend on and can you predict M_{HI} from optical properties? Why?

H_0=70 km/s/Mpc
Mpc=3.09e19 km
sec/yr=3.14e7

$1/H_0$ ~ 14 Gyr

Thinking astrophysically about galaxies -IV

- Is dust redenning and attenuation the same for ionized gas and star-light? Even at the same projected location within an external galaxy?
- Why might stellar bars have population gradients? (What are bars? Why do they form?) What observational effects might be in play?