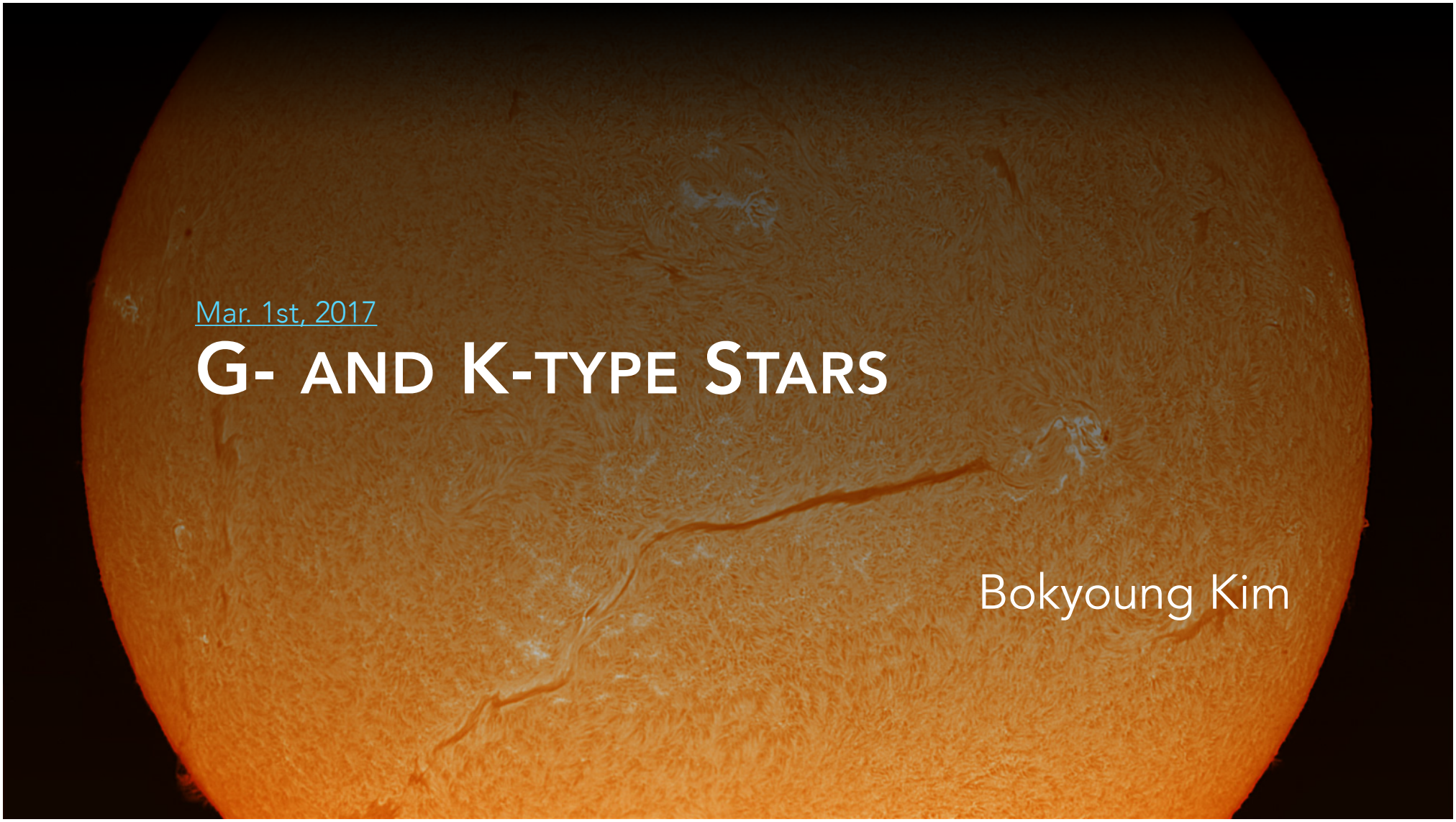
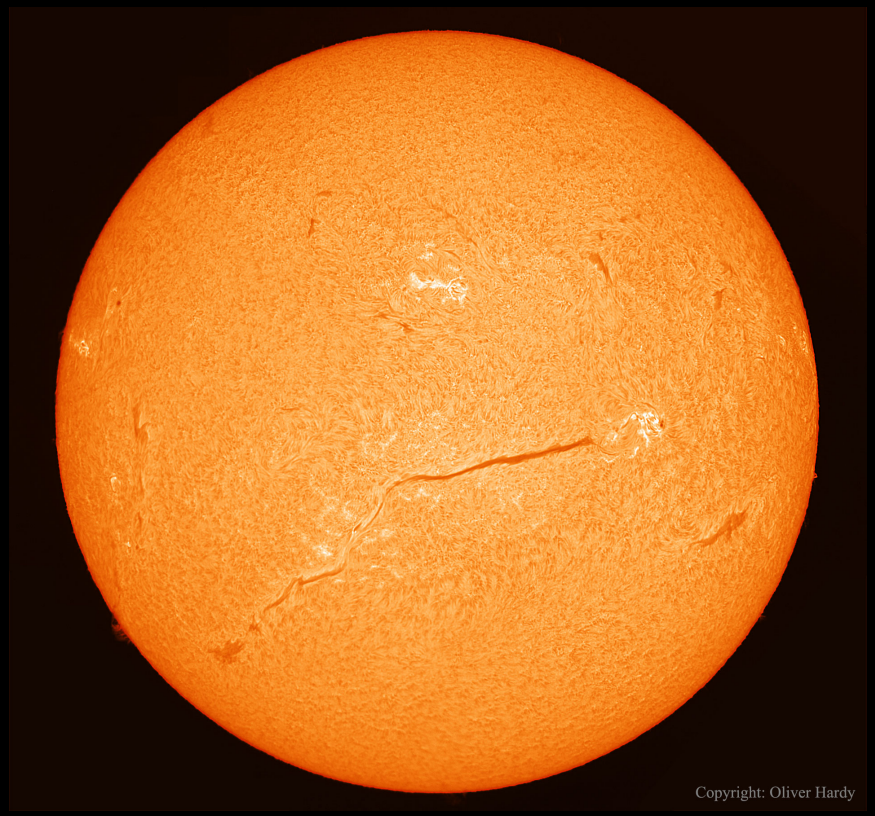


Mar. 1st, 2017

G- and K-type Stars

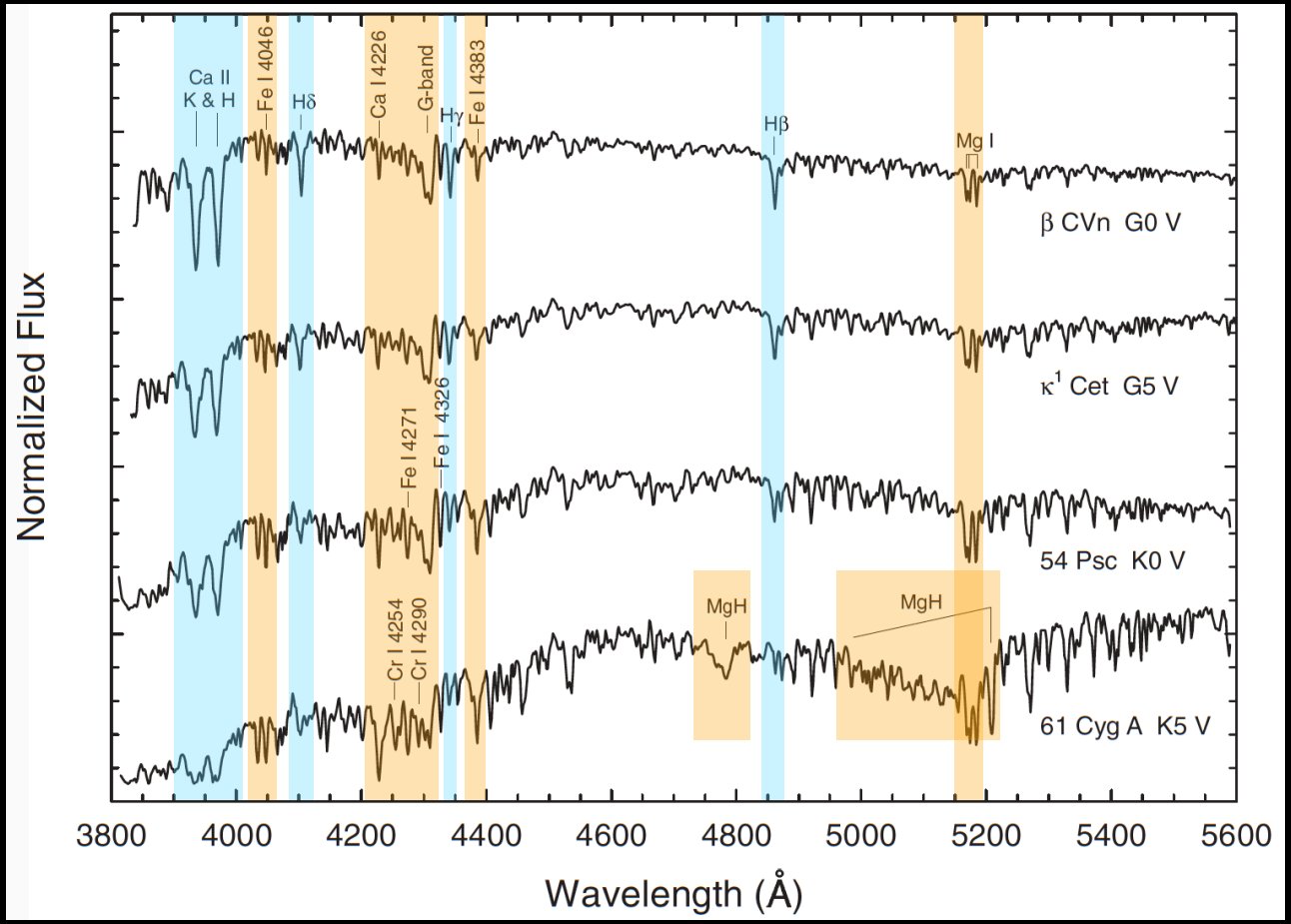
Bokyoung Kim

G- and K-type Stars



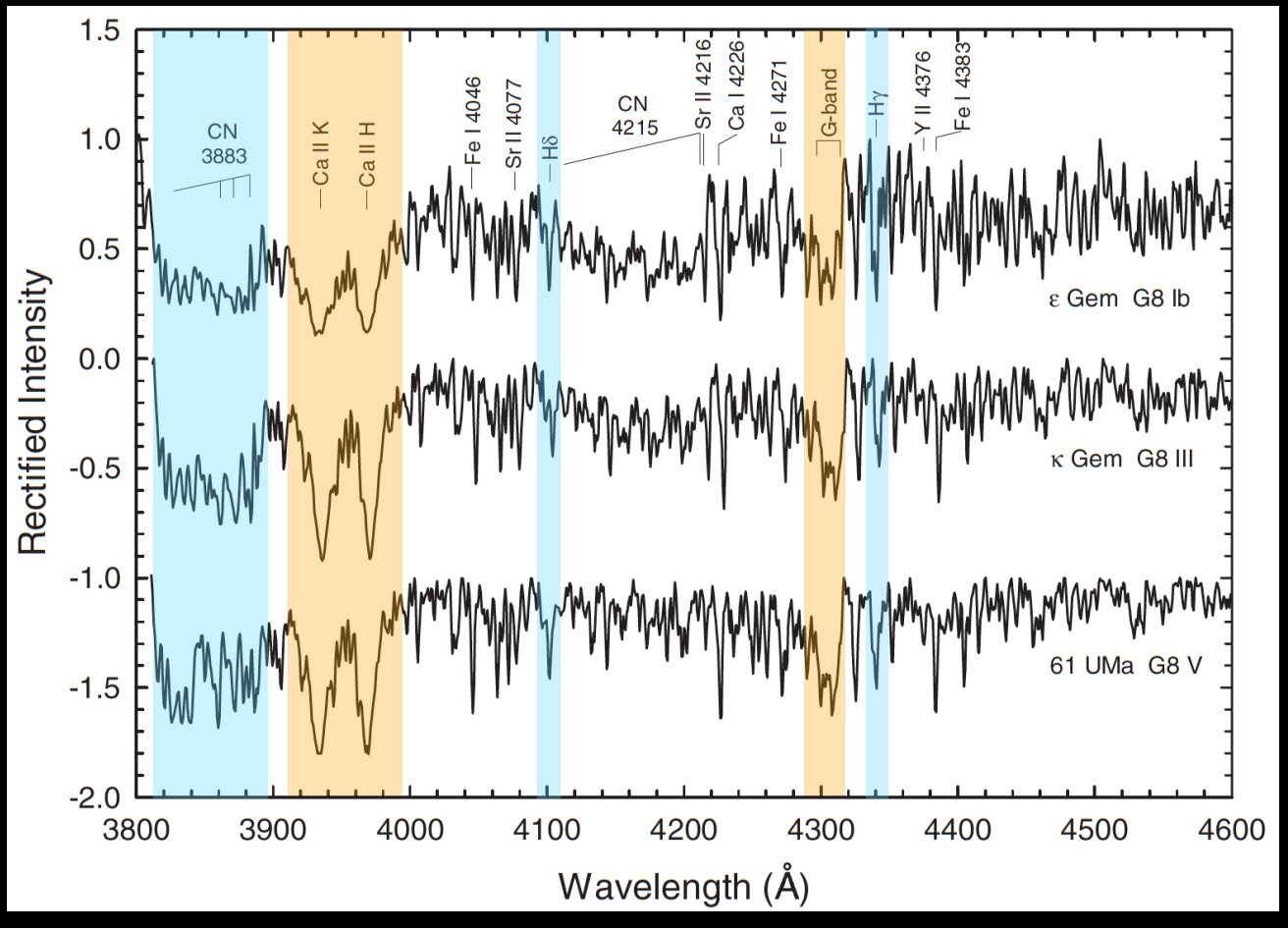
- having uniform spectral sets
- dwarfs
  - having planets around stars
- giants
  - dominant sources of evolved stars
  - peculiar stars, having dredge-up convection effects
- supergiants
  - dramatic changes in spectral type and luminosity

Optical Range: Temperature Criteria



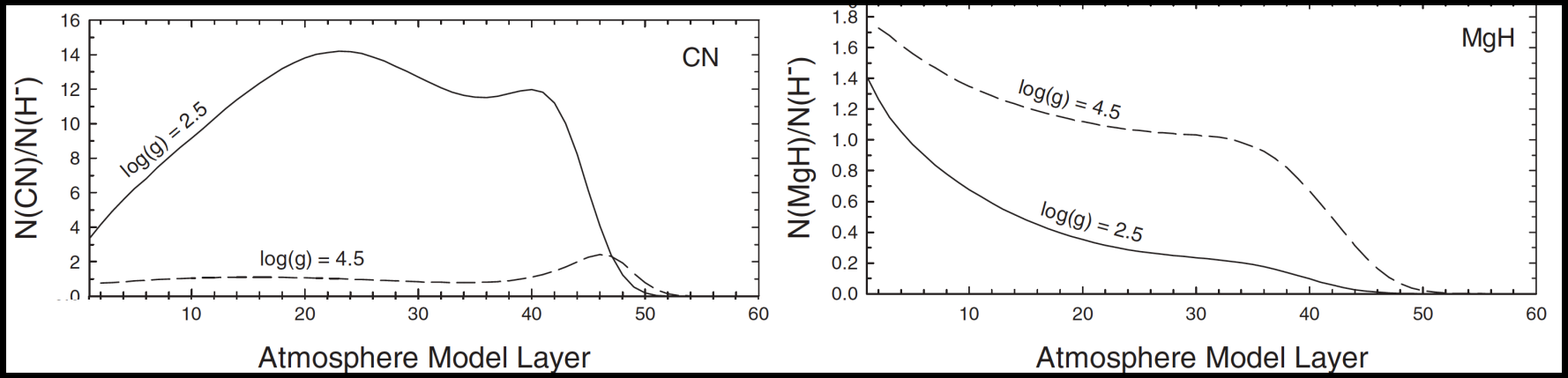
- Hydrogen line fade.
- General metallic lines increase.
- Ca II H & K: not useful
- Mg I triplet increases.
- MgH bands become significant.
- Cr I triplet gives precision to give types for K.

Optical Range: Luminosity Criteria



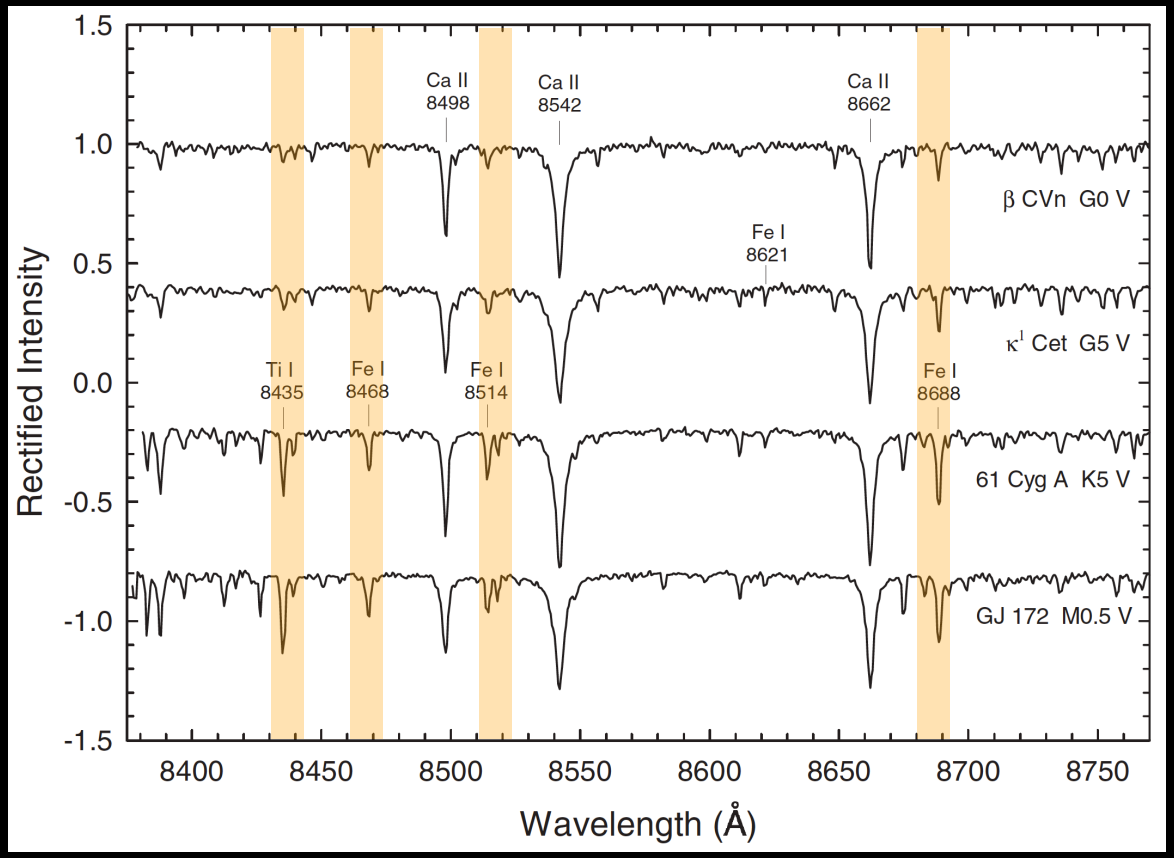
- CN bands: strong positive luminosity effect
  - ↔ CH, MgH, CaH (negative)
  - – due to H^- bound-free, and free-free absorption
- MgH, TiO blend become sensitive later K5 type.
- Mg I triplet for late-G to mid-K
- Wilson-Bappu luminosity effect in Ca II H & K core and Mg II h & k lines.

Molecular Dissociation and H^-



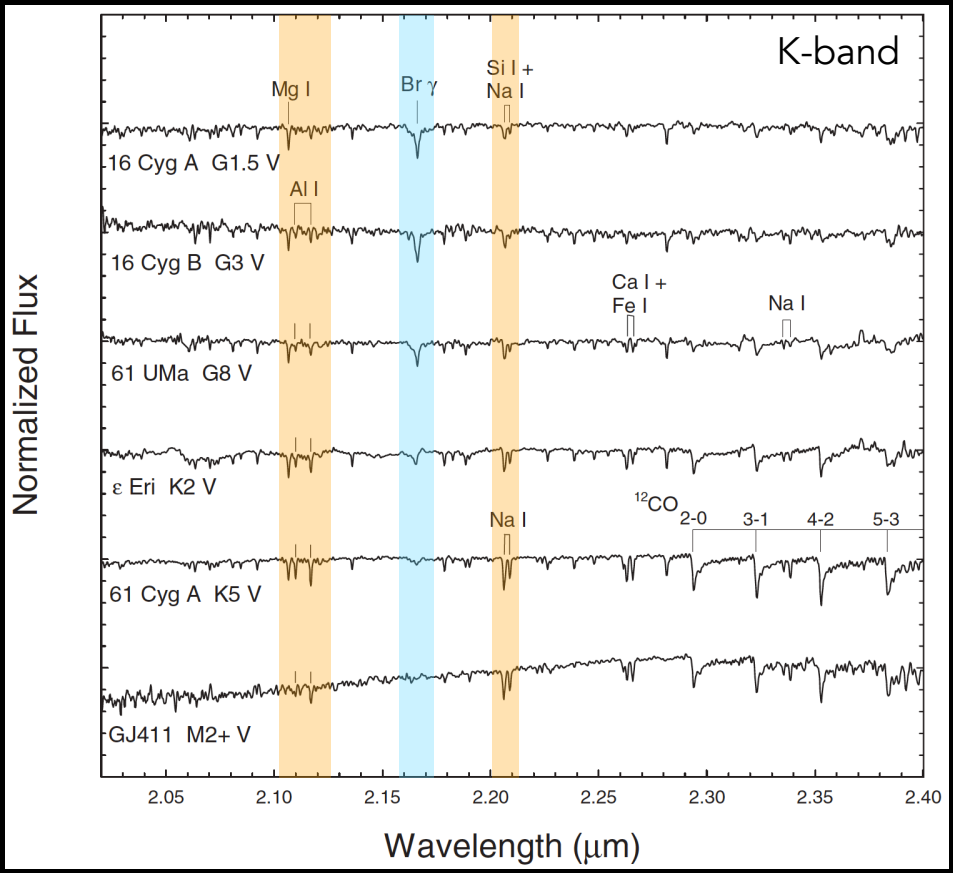
- Giants / Supergiants
  - MgH/H^- in a giant is much smaller than in a dwarf of the same T_{eff}.
  - CN/H^- is larger than in a dwarf.
- MgH/H^- and CN/H^- ratios with pressure will track the strengths of the MgH and CN bands.

Infrared Range: Near Infrared



- As temperature decreases
  - metallic lines increase in strength
  - maximum of SED shift into NIR
- Fe I and Ti I become significant for later type stars
- Paschen series disappear around G0 type.
- Ca II triplet is useful for luminosity classification.

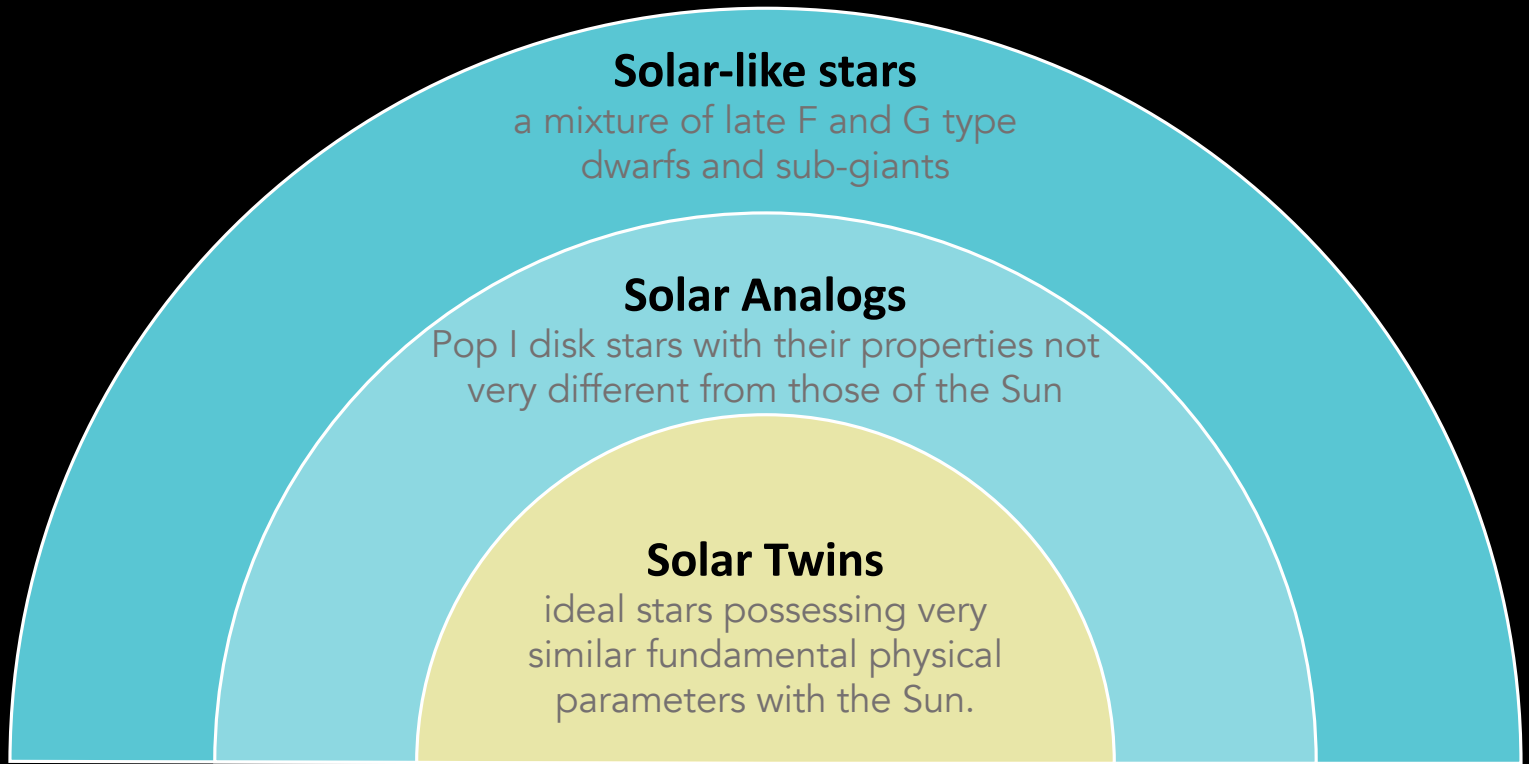
Infrared Range: J-, H-, K-, and L-Band



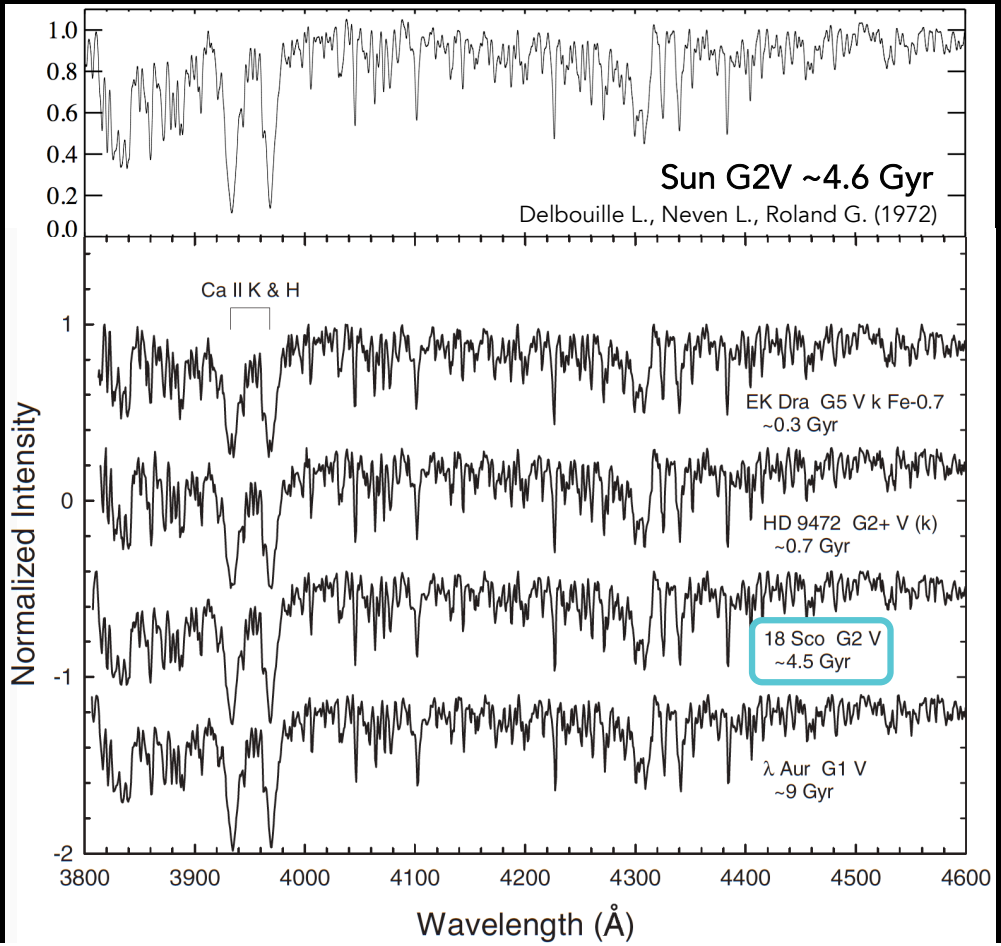
- J-band:
  appropriate H lines to mid-K
- H-, K-, L-band:
  appropriate H lines to mid-G
- Neutral metallic lines (Mg I, Si I, Ca I, Al I, Fe I) become prominent.
- The ratio of H lines to metallic line is used for temperature discrimination.
- from mid-K, better to switch to longer wavelength regions due to the dominant molecular bands.

Solar Twins: Classification

- Why do we care about solar twins?
  → to compare and to calibrate our perspective of the Sun in theoretical and empirical ways.

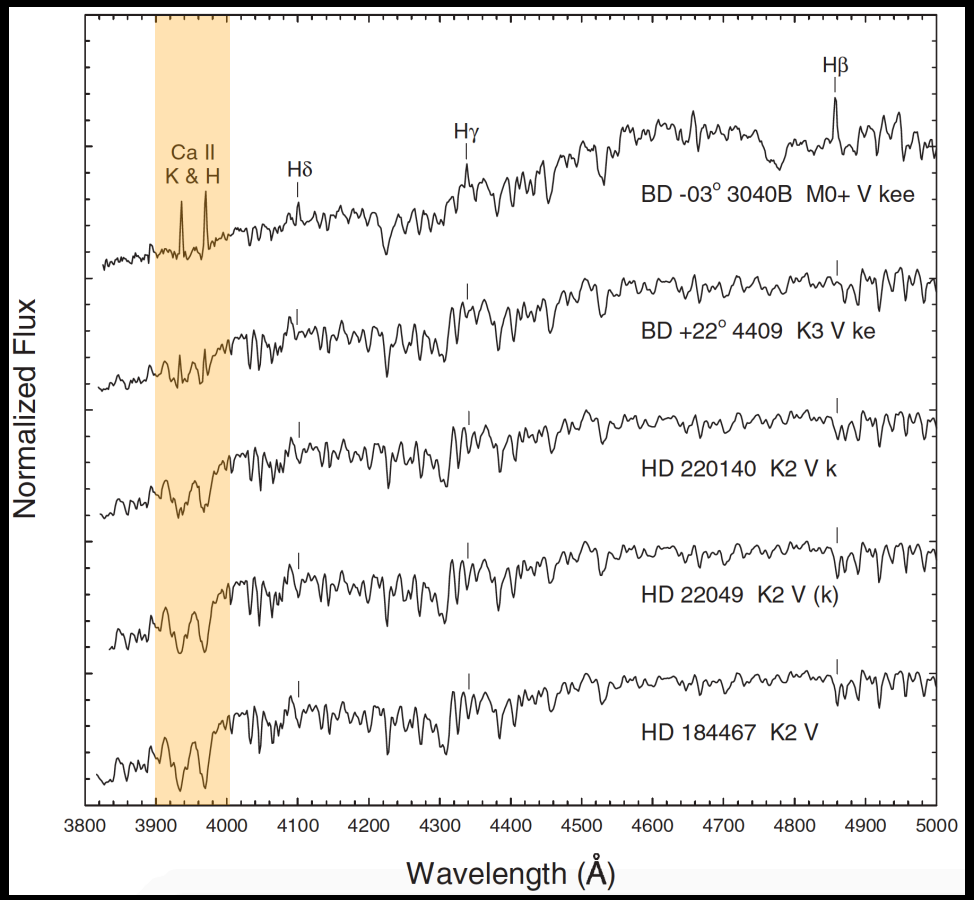


Solar Twins: Spectral Features



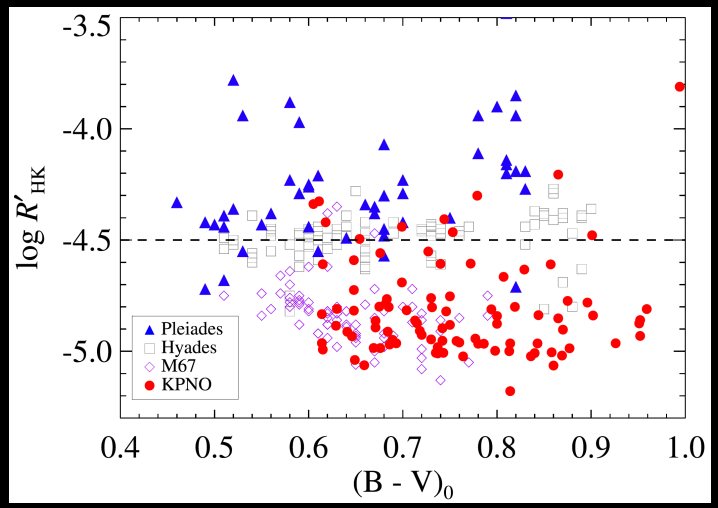
- 18 Sco
  - a candidate of solar twin, picked by Lowell Workshop
  - "We are not done."
- Fundamental parameters
  - temperature, luminosity, metallicity, and activity
- Method
  - Medium-resolution spectroscopy

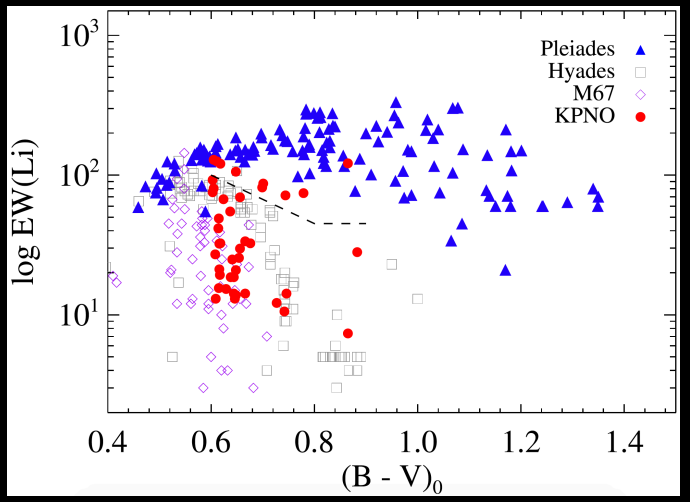
Chromospheric Activity



- Best indicators
  - emissions in the cores of
    - the Ca II H & K lines
    - the Hα line
    - the Ca II triplet lines
  - Na I D lines
  - Mg I b triplet
- Gray classification (Gray et al., 2003)
  - based on the emissions in the cores of Ca II H & K lines
  - (k), k, ke, kee
- Chromospherically active stars tend to be variable.

Quantitative Measure of Activity

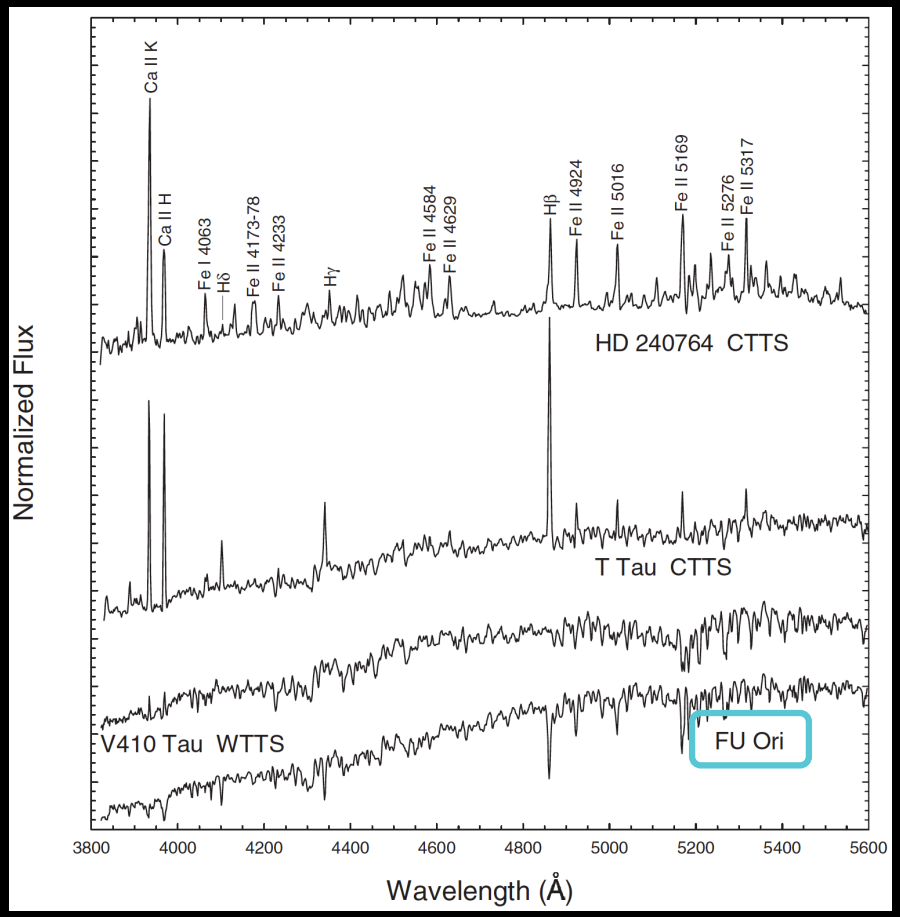




- log R'_{HK}
  - independent of effective temperature
  - measure of depths of the Ca II H & K in relation to the nearby continuum
  - should consider metallicity and luminosity effects

- Having an estimate of stellar age
  - isochrones comparison
    - comparison of a star's luminosity and temperature with a grid of isochrones
    - metallicity measurements are needed.
  - the depletion of lithium abundance

T Tauri Stars: Pre-Main Sequence Stars

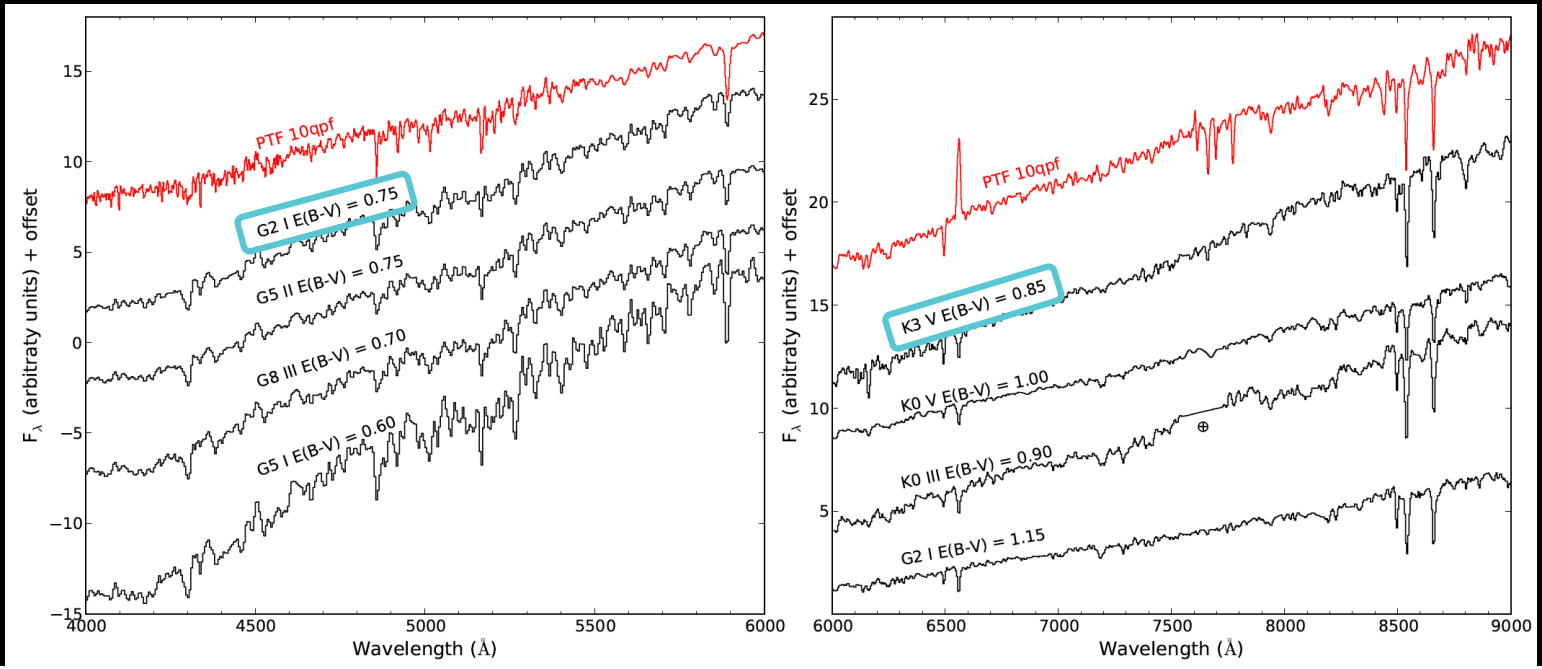


- Pre-main sequence precursors of solar-type stars
- Classification (based on W(Hα))
  - weak-line T Tauri (WTTS; < 10Å)
  - classical T Tauri (CTTS)
    - stronger Balmer emission
- Strong Li absorption
  → young objects
- P Cygni profiles for Hα and Ca II H & K
  → having mass outflow

Image Credit: ALMA

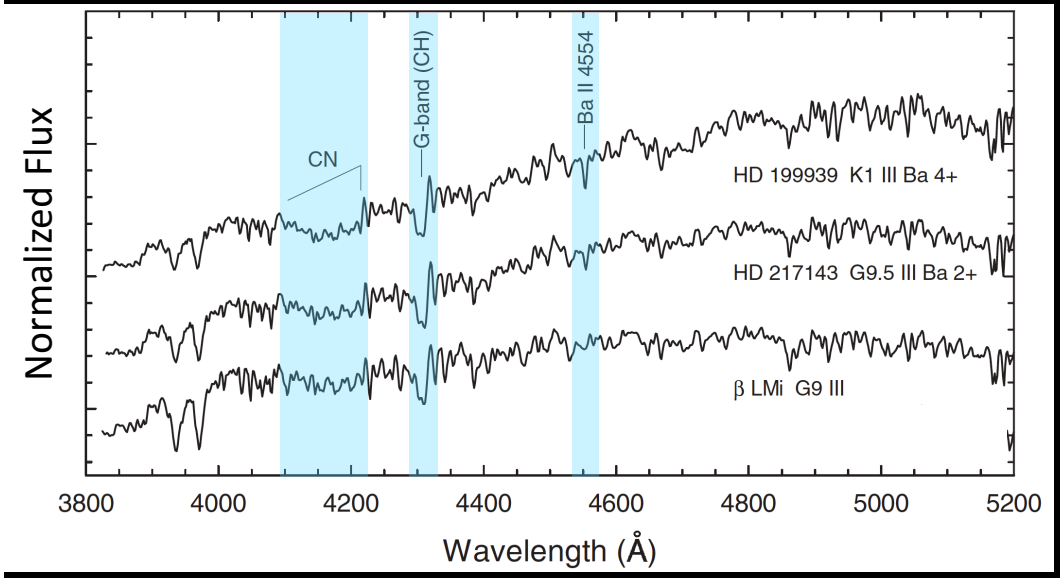
T Tauri Stars: FU Ori Group

- Shows a mixture of supergiant spectra that gradually change to later types.
- PTF 10qpf (Miller et al., 2011)
  - pre-, post-outburst observations of FU Ori like young stellar object



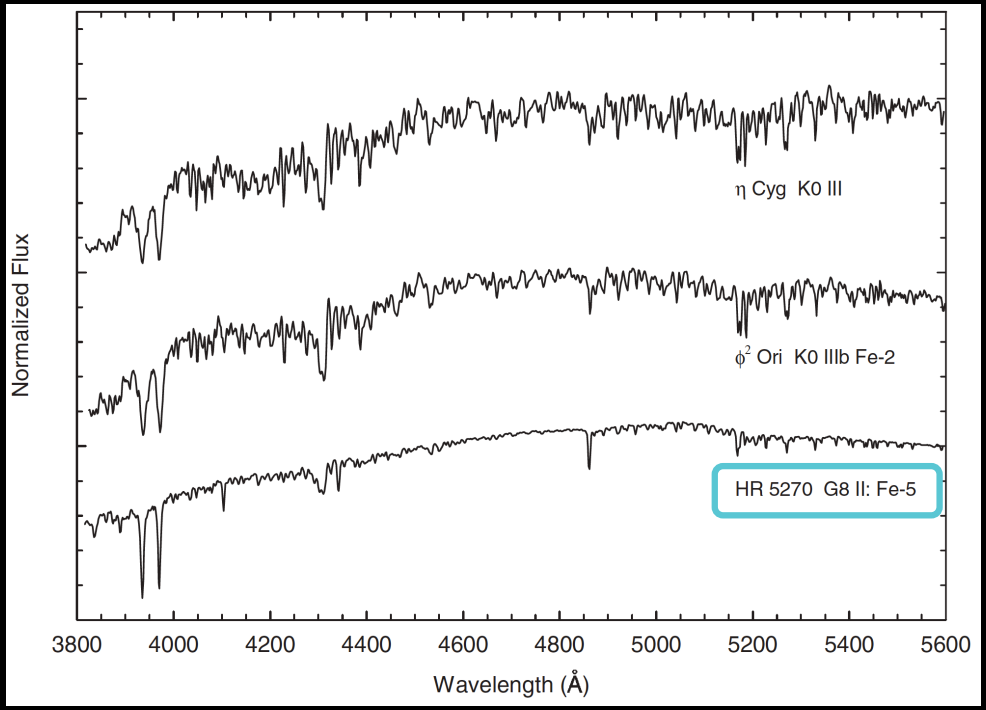
Chemically Peculiar Giants: Barium Stars

- Abundance has changed from original state due to deep convection (dredge-up).
- Enriched material is transferred to the companion barium stars (giants or dwarfs)



- Bond-Neff depression (3500Å ~ 4500Å)
  - Broad continuum drop
  - Abundances are lower than normal
  - The flux from Bond-Neff depression is redistributed into the IR.
    - Hypothesis: due to the thermal emission from circumstellar material caused by the mass transfer from WD binary companion

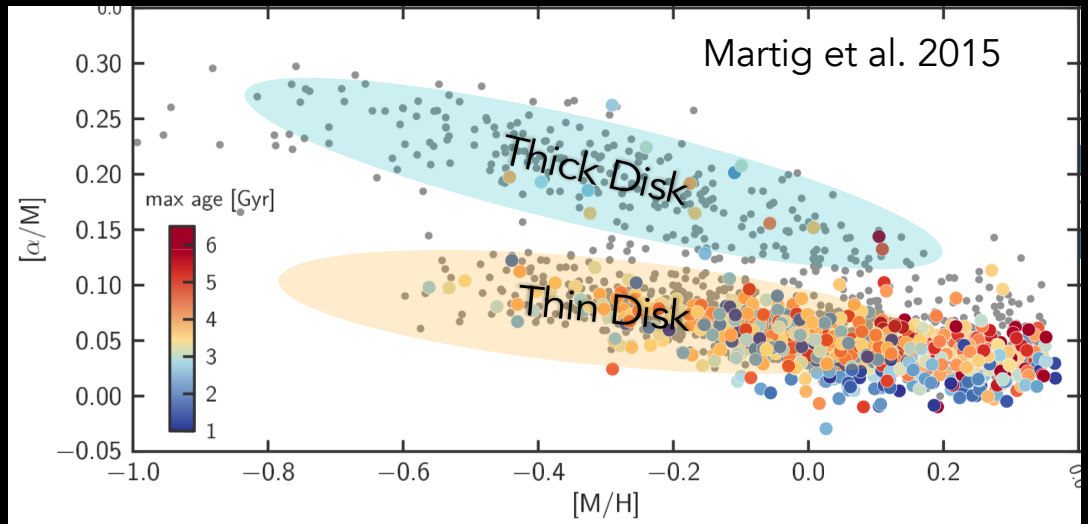
Population II stars

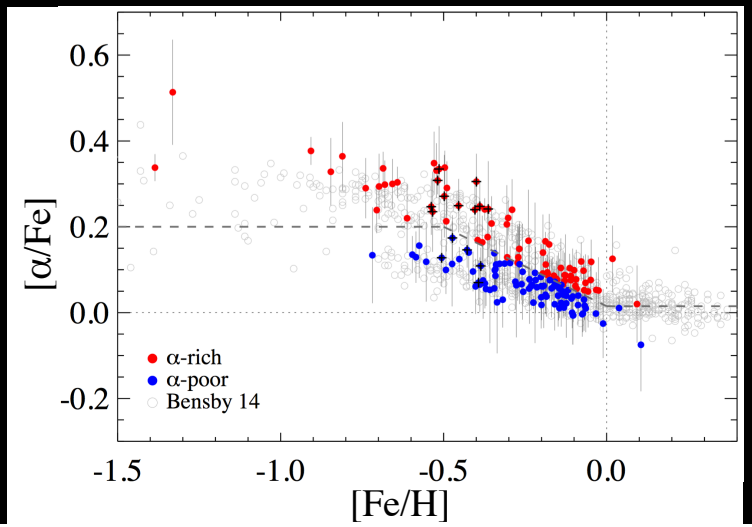


- Implications of Population II stars
  - important tracers of the early epochs of Galactic formation
  - help understand nucleosynthesis products and their mixing
  - give insight into the nature and interplay of various stellar populations
    - → G- and K- types are good targets for studying chemical evolution of the Galaxy.

Population II Stars and Chemical History

- Abundance reflects chemical enrichment history.
  - [Fe/H]: a time-dependent parameter.
  - [α/Fe]: useful indicator to find an evidence for chemical enrichment sources, such as Type II supernova
- Two distinct trands on [α/Fe] vs. [Fe/H] for disk FGK dwarfs (Bergemann et al. 2014; Bensby et al. 2014) or giants (Chiappini et al. 2015; Martig et al. 2015)



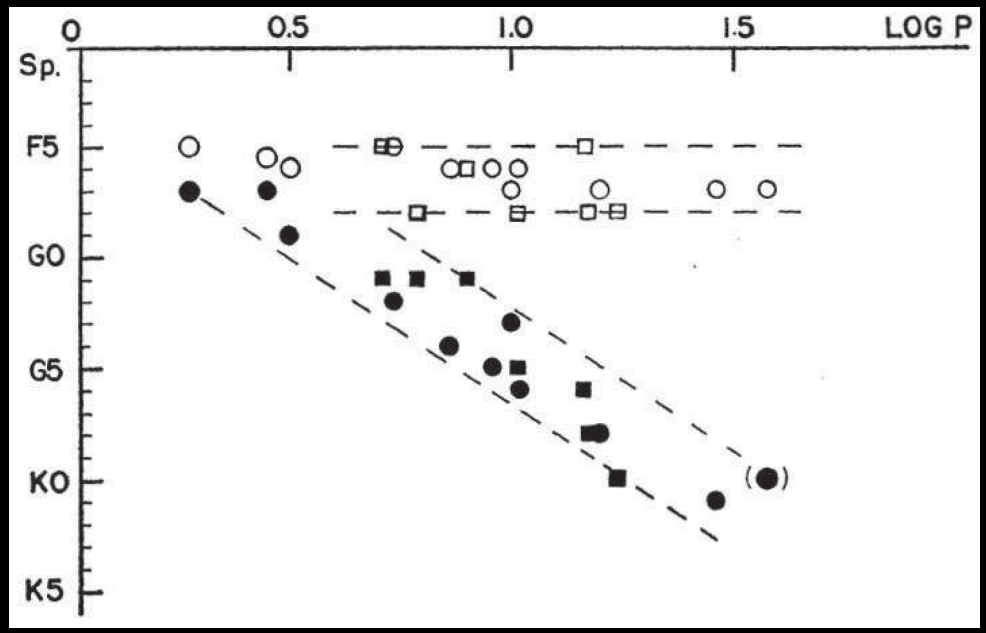


Cepheid Variables: Classification

- Classical Cepheids
  - Population I stars
  - found in the Galactic plane
  - a magnitude brighter than Type II
  - Period: 2 ~ 50 days
- Type II Cepheids (W Virginis Variables)
  - Population II
  - found in the Galactic halo and globular clusters
  - Period: 0.75 ~ 30 days

Image Credit: HST

Spectral Types of Classical Cepheids

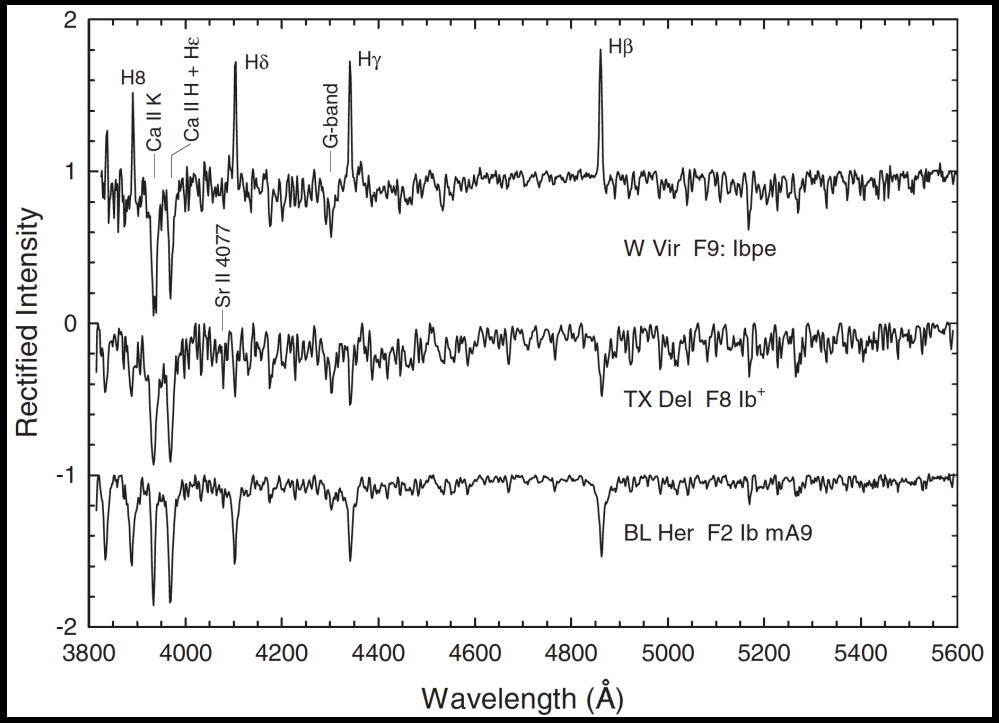


open symbols: maximum light

filled symbols: minimum light

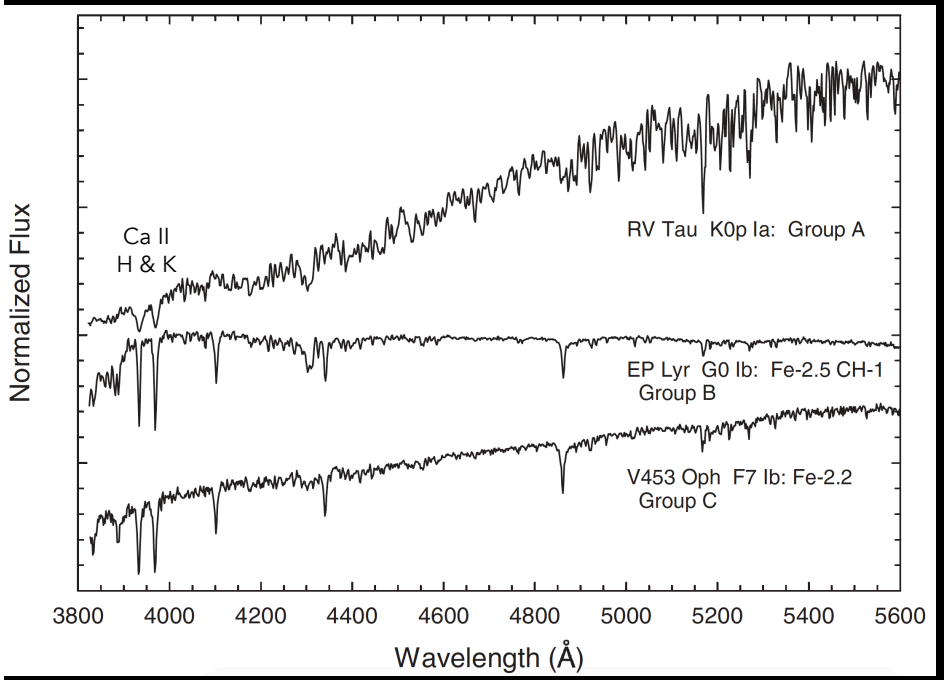
- At maximum light: F5 ~ F8
- At minimum light: spread to later types as period increases.
  - Weaker metal lines are found to match with those of non-variable supergiants, regardless of periods.
  - Strong lines and the hydrogen lines (Hδ and Hγ) becomes significant as both the amplitudes and periods of the light variations increased.

Spectral Types of Type II Cepheids



- Metal-weak stars
- Hydrogen emission lines
- mid-A ~ G0
  - no clear spectrum-period relation
- atomic metal species (Fe I, Ca I, Cr I, and Ca II for earlier types)
- BL Her
  - short–period type II Cepheid
- TX Del
  - classified as Type II
  - Balog & Vinko (1995) argued it is actually a classical Cepheid based on its derived radius.
  - spectral data supports Balog & Vinko.

Other Types of Variables



- RV Tauri Stars
  - a set of rare, pulsating red supergiants
  - Group A
    - having G- or K-type spectra, but some irregularities, such as TiO bands
  - Group B
    - F5~G0, but Ca II H & K are weaker or earlier than their spectral types
  - Group C
    - like Group B, but without variations in CH and CN bands
- SRd (yellow semiregular variable stars)
  - having strong emission in the Balmer lines at maximum.
  - CN bands are weak or absent
  - overall morphology indicates types later than F.