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Wiki page: https://wikihost.nscl.msu.edu/astrotown2012/doku.php?id=wiki:first_stars_chemical_evolution_cosmology_fields_o_shea

DropBox folder w/all external emails, talk slides, etc. available: for access email oshea@msu.edu (you must have a DropBox account to access it).

BBN

- Maxim Pospelov
    - Successes: D, He, possibly Li
    - Problems: Li, possibly D
    - last 10 years synergy of BBN
    - BBN Success:
        - He agrees with obs. sub-4%
        - D ~25%
    - BBN Problems:
        - Li is now discrepant by a factor of 3-5
        - D observations are scattered (scatter due to sys error or physical?)
        - He statistics may not be sufficient to measure Yp
    - Li-6 Plateau would indicate that something intervened
        - Should be extremely faint in standard BBN.
        - Groups can't kill Li6 in observations - it seems that several groups agree there's something there.
    - Li7 two problems:
        - Discrepancy in abundance
        - Trend to lower abundance at lower metallicity. (Maybe just a scatter in measurements? No scatter above)
        - Beers: At higher metallicity there are more massive mini halos and it is dangerous to look at progenitor population. something happening below [Fe/H] = -3. Problem will break in few years. old star could not rotate that fast unless mass transfer in past

        - Heger: stars rotate faster initially, destroying Li by mixing it into stellar core
        - Iron may not be a good indicator for low metallicity stars.
        - Agreed that discrepancy in trend is due to stellar astrophysics. (Well, two people agreed, but there is evidence that this is at least part of the probelm - low-Z globular clusters, for example)
        - Knowing if the stars with Li7 measurements are in binary systems or not may help.
    - Li7 Possible Solutions:
        - Be7 + n reaction (well studied)
        - 3He fusion cannot be scaled down by x3 or 4
        - new reactions that could find resonance with strength to impact BBN
        - reactions measured in lab at correct resonance would help
        - There are only a handful of reactions, could measure them.
        - more calculations
        - Maybe Li7 has been destroyed
        - CMB measured globally while Li7 is measured very locally, perhaps baryon density should be lower where Li7 is measured.
    - BBN Story:
        - limited by systematic errors and astrophysics modeling
    - BBN Experiments:
        - 1. Cooke & Pettini, 2012 constrain D/H measurement? (2-4% measurement)
        - 2. more non-stellar obs. of Li7, Li6 (Howk et al) and at lower metallicities?
        - 3. Li6 present in metal poor stars? (technically difficult)
            - Beers: Only brave observer, need factor of 10 increase in collection
            - Settled in 5-10 years.
        - 4. more obs. of metal poor stars to examine Spite plateau
            - Beers: have enough obs. look at exceptional objs. that are at very low metallicity and known to be in very tight binaries (CS 2276-837, maybe?)
        - 5. improve measurements of He3-alpha reaction beyond 5-10%, sort tau_n controversy
        - 6. future of CMB if Planck successful: Yp, Neff
    - BBN Theory:
        - 1. do we need ultimate code at sub-%?
        - 2. Li7,Li6 check outside of astro settle diffusional settling
            - Not just lithium
            - Not clear how well models are fitting
            - Beers: obs. reached point where difficult issues need to be addressed
                - theory of stellar atmosphere needs to be improved
        - 3. Ab-initio calculations of key reactions
        - 4. Li has different ionization history since it stayed singly ionized
            - Diffusion calculated incorrectly due to this
            - O'Shea: At which redshift?
        - 5. Look for sterile neutrinos
        - 6. constrain primordial ranges for all light elements up to and including C?
    - Cultural Issues (Interacting with other disciplnes)

        - 1. Promote experts who work across fields to understand the whole problem.
        - 2. improve error bars in literature
            - Beers: True error bars are from interpretation, since do not know limit of unknowns. need nature of area in atmosphere where measurements are performed
        - 3. ''unknown unknowns'', do not find models that fit SBBN

First Stars (Pop III Stars)

- Brian O'Shea
    - Pop3 stars:
        - massive (100, 1000 Msolar)
        - form in isolation
    - Recent Accomplishments:
        - binary pop3 seen in simulations (Turk,Abel,O'Shea '09)
        - multiple-star systems seen (Greif et al. 2011,12; Clark et al. 2011)
        - MHD simulations (small impact, but only simple implementation)
        - none obs yet
            - O'Shea: end to mult-star sys.
            - Truran: how do you identify a Pop III star?
            - extremely metal poor DLA obs (Cooke et al. 2011). possibly explained via pop3 enrichment (Kobayashi et al. 2011)
        - recent rediscovery Pop III not important for
        - Extremely metal-poor DLA observed (Cooke et al. 2011)
    - Open Questions
        - mutiplicity of formation?
        - What are the distribution of rotation rates in Pop II?
            - O'Shea: Extremely important and we don't know much
            - Simulations are not good enough
            - Can't do this for galactic stars
        - likely initial mass? varies from red-shift?
            - Not treating magnetic fields correctly.
            - mean mass higher than substantial mass
        - What are fundamental challenges for nuclear synthesis w.r.t. Pop II?
            - At low metallicity assumptions made in stellar evolution become suspect
            - Beers: distinguish bw small # of stars.
            -
    - How can we address these questions
        - Grid based codes and another code assume different mean masses.
            - Important to include effects of
                - opacity realisticly
                - MHD
                - improved chemistry
        - stellar evo calc. for pop3 w/ varied rotation rates, Esn over ~10-100 Msun range (maybe even SAGB) -compare to low metallicity stars,stellar halo
            - Need to connect Pop III star simulations to what we see
    - What is needed
        - Primordial chemistry and opacity break down at high density

                ■ converged nucleosynthesis cals. covering range of masses, rotation rates, explosion energies
                    ● Tie Pop III stars chemically to low
    ○ Intersection w/ Subfields
        ■ Nuclear physics through stellar evo/nucleosynthesis cals.
            ● Need all sort of different physics in GCE simulation
            ● Fields: Do we know what the right physics or is it difficult to incorporate?
            ● good grasp outside of star surface
            ● agree on primordial chem, radiation transport and mag fields need to be accounted for
                ○ Very expensive to include these
- Beers: What we can do is stop asking the wrong question about, " When will we find the Pop III star?" Instead ask what are the limits on the numbers of such objects. This will come from SkyMap.
    - Thinks people who have found Pop I are those looking at Quasars
        - Would have been ignored and deleted in the early days due to selection issues.
    - brightest star below metallicity -3 is ninth magnitude (Has a BD number)
- Strader: Should people look in galactic bulge?
    - O'Shea: More stars exist in the bulge hard to get a fiber on one star.
    - Beers: someone looking into it. not of the bulge, ended up in the bulge. look around the bulge
        - Look for C enhanced metal poor stars
    - Heger: sum up metals, most from pop3 ends up in higher metallicity objs. can see distinct signature?
    - O'Shea: unique abundances, ultra dwarfs
    - Beers: Many stars below -3 are turn-off stars Intrinsically bright. giants confused with dwarfs. Hard to observe carbon in these stars. Possible that signature is there just can't see it, have not obs. cool stars to see carbon

Chemical Evolution (GCE)

- Jay Strader:
    - Globular Clusters
    - Showed [Na/Fe] vs [O/Fe]
        - Evidence that these stars are also enhanced in He
        - Due to enhancement in
        - first seen looking at CN bands
        - favorite origin in massive AGB stars
            - O'Shea: What do you mean massive?
            - Strader: need to get to 5, 6, 7, 8, even 9 solar masses.
                - Happens at high temperature at area where convection gets deeper so processing can happen.
    - Evidence for self enrichment in clusters
    - Claim: Globular cluster have lost factor of ten of mass.
        - O'Shea: How do you lose stars without losing gas?
        - Strader: needs to occur at same time, fine tuning, no agreement
    - Globular stellars make up a few percent of the inner halo
        - fraction of stars originated in cluster is huge

- If you look at indiv field star a fe percent of stars have these signatures consistent with globular clusters
- Fornax cluster
  - gc make up large cluster of mass
  - Chemical abundance have same inhomeg as in Milky Way

  - O'Shea: stars stripped still maintained by Fornax
- Beers: Why no globular clusters sub -3?
  - something fundamental preventing formation. not enough gaseous mass?
- Truran: How many do you expect to see at -3?
  - Beers: Zero
- Don't end up w/ anti-correlations
- relevant p capture reactions known still insufficient
- Beers: This is another example where freq. will tell us a great deal. 25-30 yrs Bob Craft said, "We see it in gcs, but not in field" WIth SDSS looked in field and we say 3.72%+/-0.002
- Beers: Kinematics which show equilibrium show outer halo not inner?
- ?: need massive AGB, need H,..., don't allow any 3rd generation
  - look at abundance inside gc.
  - Should have dredge up
  - Do observe it in massive AGB
  - why not see correlated enrichment in nuclei?
  - must be fast rotation
  - More reasonable to have massive AGB
    - something must happen to model that isn't clear
- Strader: seen all the way up to -.5
- ?: Never seen a AGB model that finishes

- Beers Missing:
  - Lots of surveys done and we should continue
  - follow up of field stars and dwarf galaxies
    - Ultra faint dwarf galaxy has low mass but has the number of stars of an open cluster (~1000) Mass is dark matter dominated
    - nature of nucleosynthesis that created chemical abundances
    - nature of imf and star formation history resulting in formation
    - well measured freq. Need to know what it doesn't do as well. (this is the way forward)
  - Long term high res 5-10 year monitoring of various types of stars
    - binary freq. as function of metallicity
    - nature of binary orbit: type, long-period, eccentricity, correlations w/ obs patterns
      - orbits are thousands of years at high eccentricty
    - Connection between binarism and Li depletion at low metallicity? **see BBN**
      - Beers: suspicious of tight binary first two spectra was a sub -3 tight binary
      - O'Shea: when will we see some of the other surveys?
        - Beers: 6 months
  - Directed searches for high r-process stars to establish
    - relative freq. as a function of metallicity
    - low-metallicity limit to r-II phenomenon?

- Fun Facts!
  - 2nd cool dwarf with [Fe/H] < -3.0 known
  - most metal poor [Fe/H] = -3.4and Eu-enriched r-II star yet found [Eu/Fe] = +2
- Beers: First dwarf with atmosphere with heavy r-process?
- Modeling Needs:
  - improved yields as function of mass and metallicity (particularly > 8 Mo)
  - Actinide Boost, we don't yet understand it
  - Detailed models of milky way formation describing build blocks
  - Beers: need a full set
  - Heger: can be a whole range of distributions for each metallicity
  - Beers: need underlying body of knowledge, missing information
  - O'Shea: Shown three components responsible for most variation.
    - One unanswered question is what happens when we deviate from solar at low metallicity? Interesting to see it for massive stars
  - Beers: list of 12 elements to start, since there will be a lot of stars from all populations
  - Heger: knowing 12 elements does not help us much.

Summary

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