Measuring the $^{39}K(p,\gamma)^{40}Ca$ reaction with DRAGON

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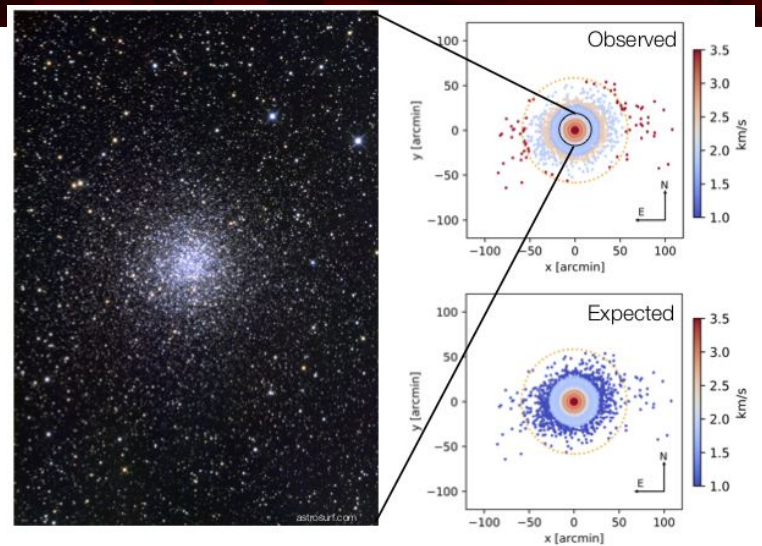


P. Bianchini et al 2019 ApJL 887 L12

Globular clusters: what are they and what's the motivation in studying them?

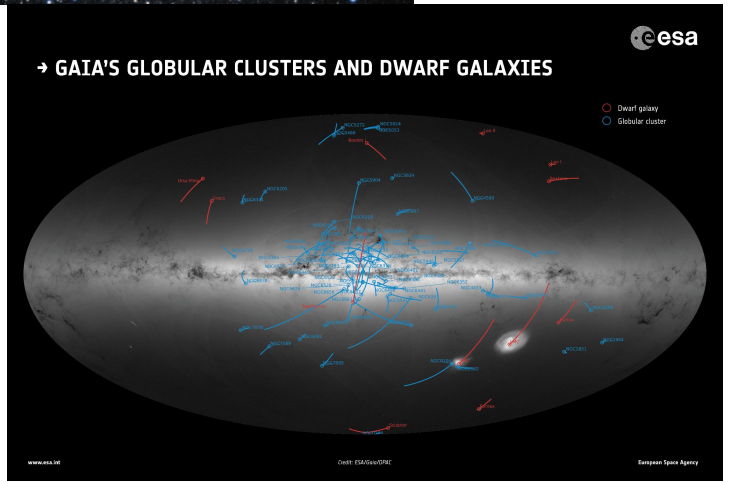
What *are* globular clusters?

Ancient, dense groups of stars near the galaxy

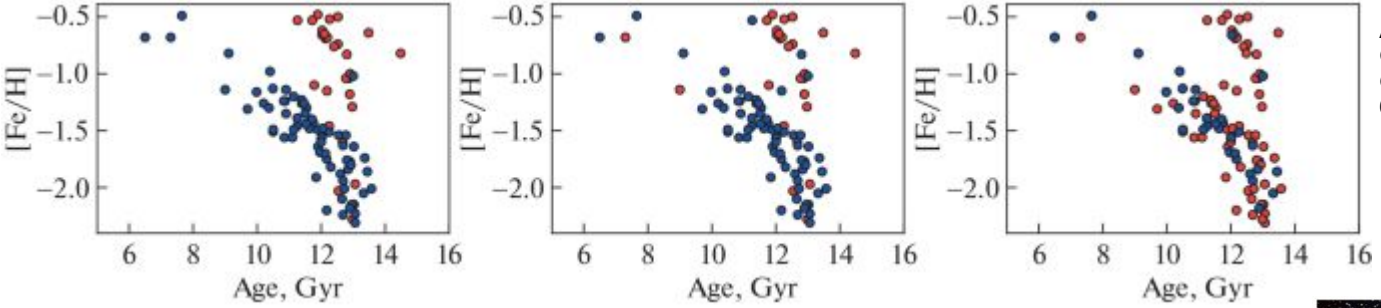
Spherical, containing 10^4-a few 10^6 stars

Old stars but not a single ancient population (I'll come back to this)

Dense enough that collisions between stars might take place



Using globular clusters!



Arkelyan, N.R., Pilipenko, S.V. Globular Cluster as Indicators of Galactic Evolution. Astron. Rep. 66, 191–199 (2022)

Blue clusters - accreted

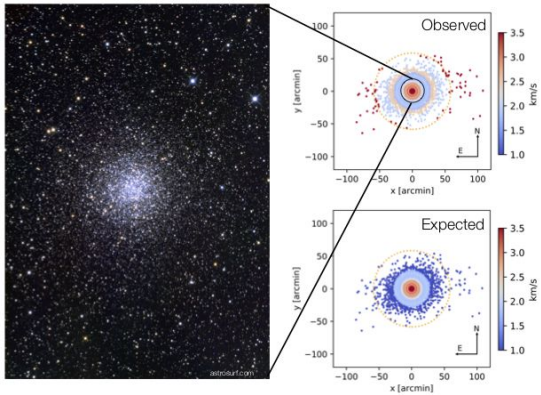
Red clusters - formed as part of the Milky Way

Hierarchical model of galaxy formation - galaxies merging, lower mass galaxy tidally disrupted

Bring their GCs with them!

Information about the origin of the GCs preserved in the properties of their stellar populations, spatial dist + dynamics of the GCs

Also used to test dark-matter models



P. Bianchini et al 2019 ApJL 887 L12

Multiple stellar populations

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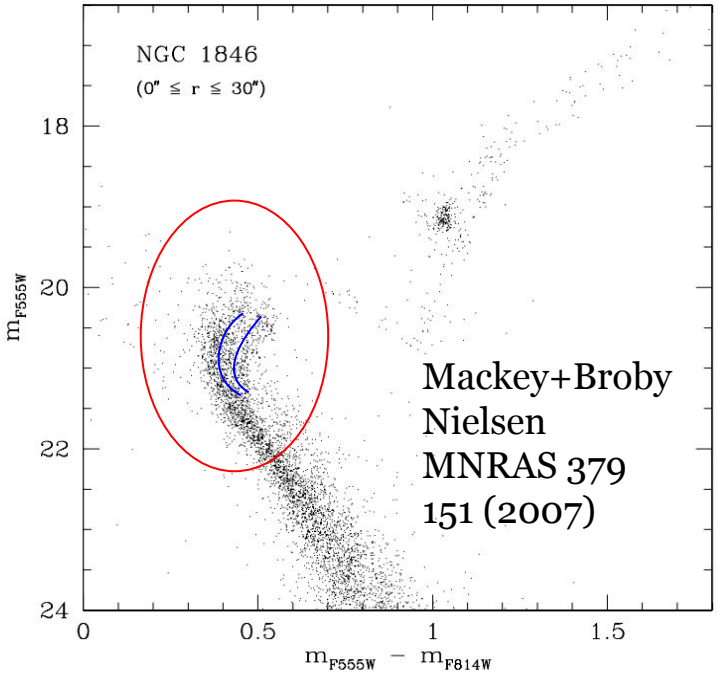
Originally we thought that GCs were pristine relics of the ancient universe (like me)

That isn't the case:

Evidence includes photometric (multiple turnoffs from the main sequence)

Spectroscopic (elemental anomalies which can't have been caused by the current stars)



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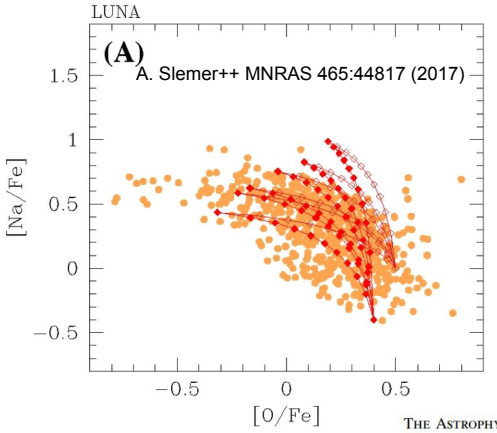
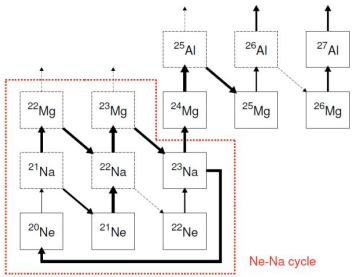
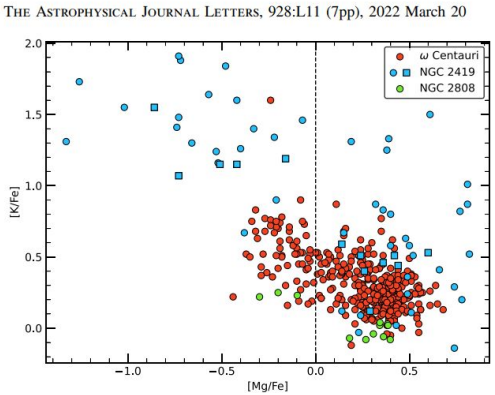




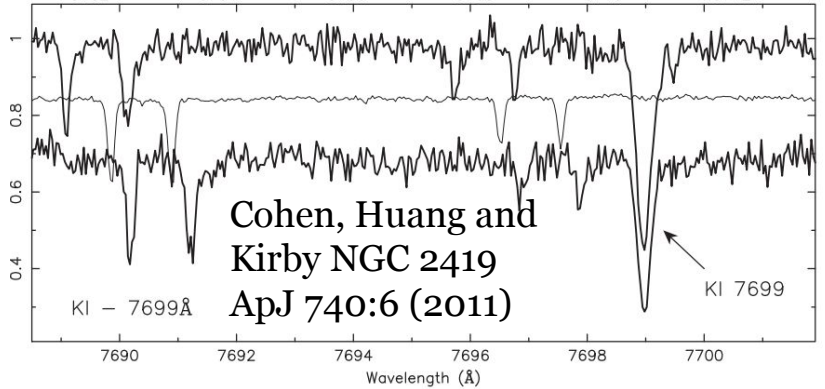


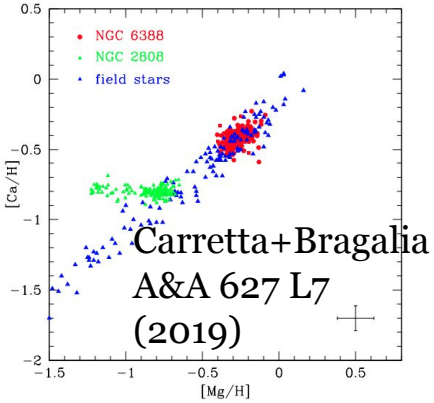
Elemental anomalies

The most famous elemental anomaly in GCs: Na/O anticorrelation

Some (but not all) GCs (NGC 2808, 2419, ω Centauri) also have a Mg/K anticorrelation

The origin of these anomalies is unclear





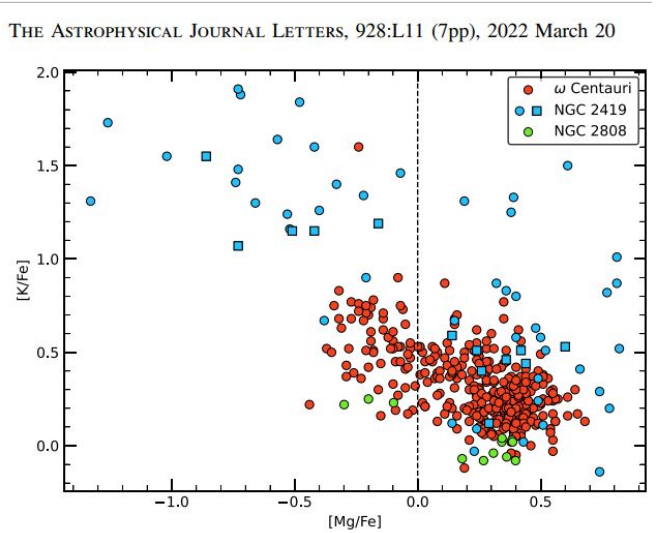
The ^{39}K(p,γ) reaction

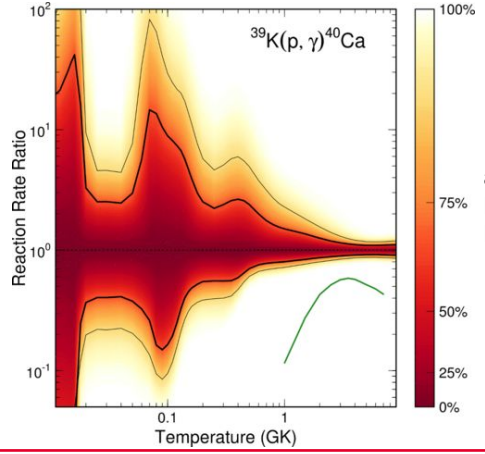
NGC 2419 shows Mg-K anticorrelation - unclear the polluting site for the globular clusters

^{39}K(p,γ)^{40}Ca destroys ^{39}K - key uncertainty identified in sensitivity studies

Previous studies identified a wide range of plausible reaction rate within the astrophysically relevant region

Need better constraints on this - resonance strength depends on the proton width so measure this! :)





R. Longland, J. Dermigny, and C. Marshall
Phys. Rev. C 98, 025802 – Published 23 August 2018

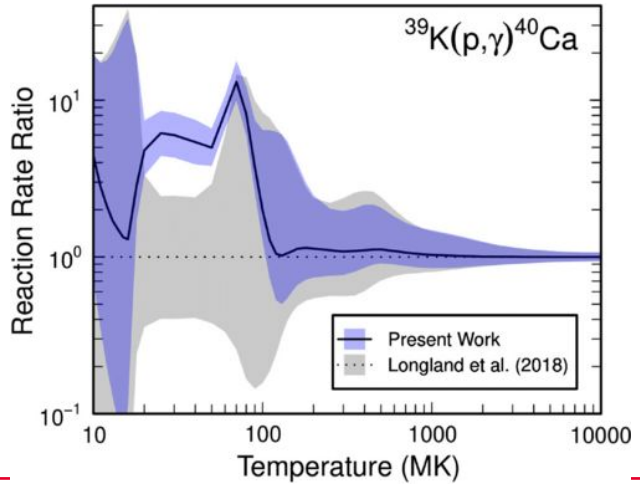
Existing Experiments

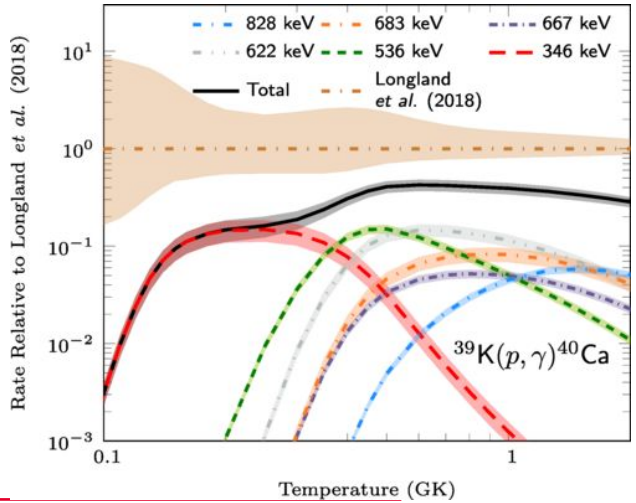
Not the only study of this reaction:

0.156 vs 0.004 meV for the 335-keV resonance(!)

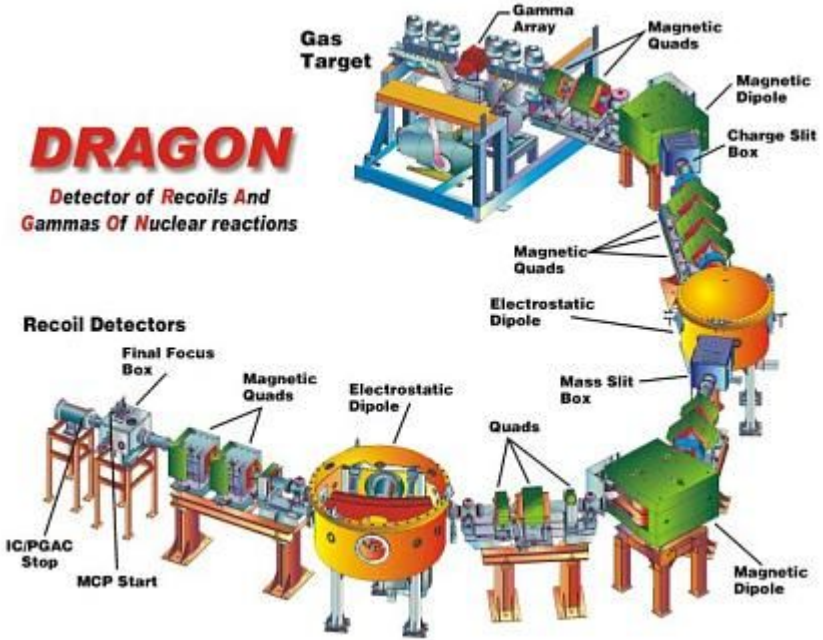
Why the large disagreement?

Scholz++ PRC 107 065806 (2023) Notre Dame



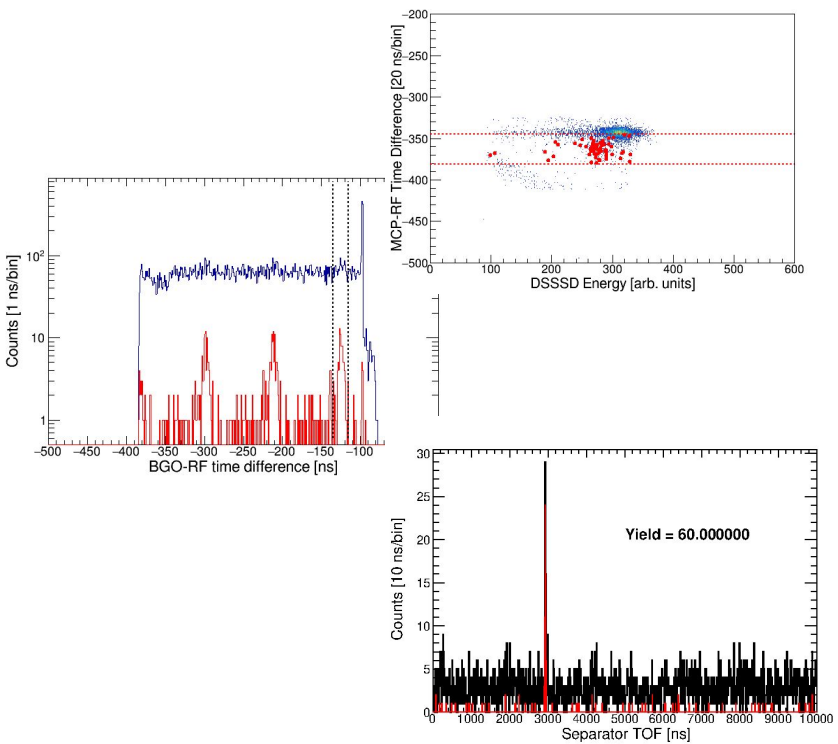


Measuring $^{39}K(p,\gamma)^{40}Ca$ with the DRAGON



- ^{39}K beam onto the windowless gas target of the DRAGON
- $^{39}K(p,\gamma)^{40}Ca$ reaction
- γ rays detected in BGO array
- ^{40}Ca recoils selected by the separator
- Hit gas ionisation chamber+DSSSD at the focal plane

Experimental Observables



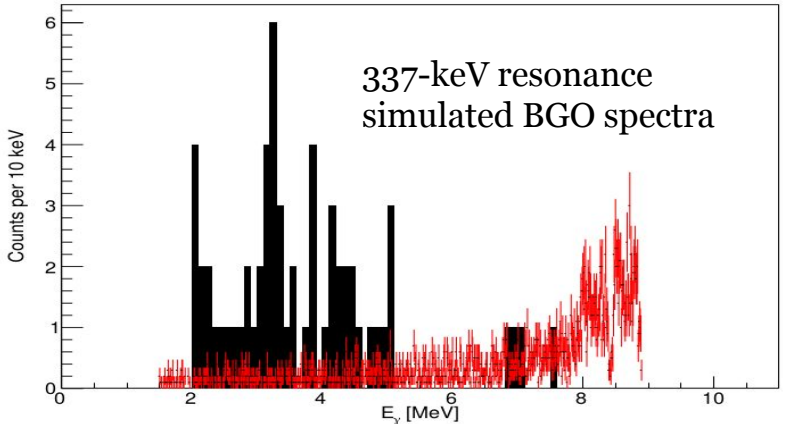
- Identify ^{40}Ca recoils (and exclude ^{39}K leaky beam) by times of flight
- BGO-DSSSD timing
- Accelerator RF-BGO timing
- Energy at the focal plane vs time difference
- Can use these gates to reduce the background in the separator time-of-flight from ^{39}K leaky beam

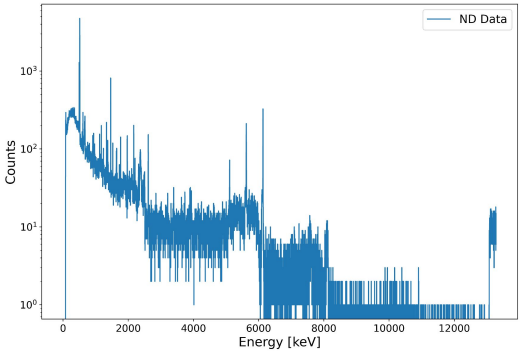
Measuring $^{39}K(p,\gamma)^{40}Ca$ with the DRAGON

DRAGON experiment suggests only weak branching directly to ground but assumed = 1 in Scholz*

*This is the literature value! I assumed the same thing until my simulations ran…

Lesson: better γ-ray decay data is useful even if not directly applicable to resonance strengths

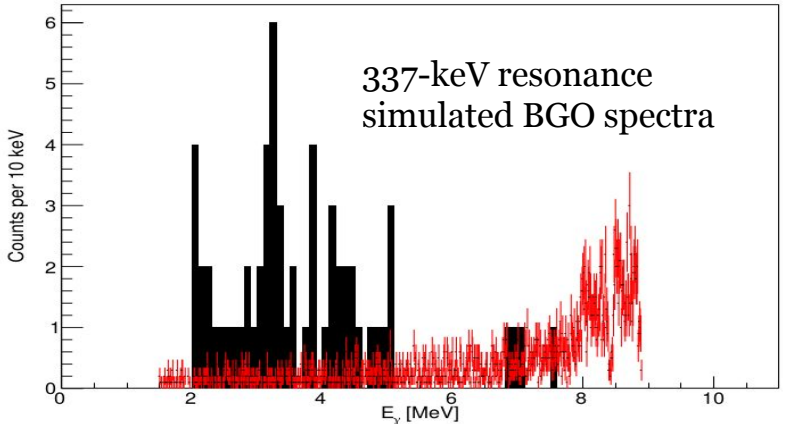


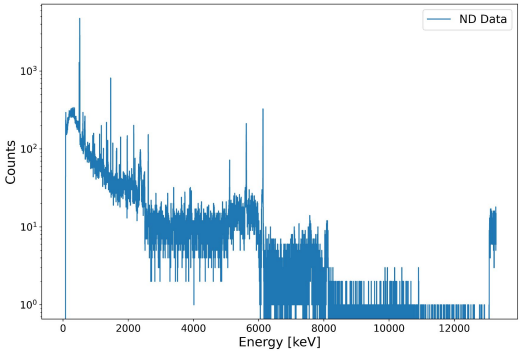


Measuring $^{39}K(p,\gamma)^{40}Ca$ with the DRAGON

Need to know γ branching to get efficiency :(

We (Shahina!) is using the Notre Dame data to try to ID possible ^{40}Ca transitions which we can use in our simulations to try to make sure that the different datasets eventually agree with each other





Thanks to…

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Probing historic pollution of globular clusters and nucleosynthesis in classical novae: a direct measurement of the $^{39}K(p,\gamma)^{40}Ca$ reaction rate with the DRAGON

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