

# Reassessment of the radiative y-decay branch of the Hoyle state

17th Russbach school on Nuclear Astrophysics 13.03.22 - 20.03.22

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## The 3α-process



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 $\Gamma_{\alpha} \sim 99.96\%$ 



#### **Fred Hoyle**

London Daily Express/Pictorial Parade

The Universe: Past and Present Reflections by Sir Fred Hoyle

fantastic calculating detailed pre large nur omers doj Obviously perfect ansy The issue is proximations, ten work on th tions are quite r shall presume to The nebulosity to small particles. a fogging of the dis the fogging is so extr stars that lie behind th this fogging effect proc really due to the materia out the light of the stars Jut the light of the stars and the properties of the grains indicate that the stars of the grains indicate that the stars in the stars indicate that menus or une properues or une grams muncane they are remarkably similar in their physical properties, in their sizes. Whatever observations properties, in men sizes. Whatever observations are being made, they always seem to turn out the gan for me in a very inunexpected result

DEFINING the universe to be everything there is, manifestly we cannot be expected to understa exactly, since to do so we would nee complete command of the las

#### **The Universe: Past and Present Reflections**

Engineering and Science, November, 1981. pp. 8–12

"Some supercalculating intellect must have designed the properties of the carbon atom, otherwise the chance of my finding such an atom through the blind forces of nature would be utterly minuscule"

behind. Measurecalculations that, once evaporated, w grains would recondense by a conditions that seems this difficult





# The $3\alpha$ -process



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## The $3\alpha$ -process

The rate of the triple-alpha process is given as

$$r_{3\alpha} \propto \Gamma_{rad} \exp\left(-Q_{3\alpha}/kT\right)$$
  
The radiative width of the Hoyle state

C.E. Rolfs and W.S. Rodney. Cauldrons in the Cosmos: Nuclear Astro- physics. Theoretical Astrophysics. University of Chicago Press, 1988. ISBN 9780226724577. URL https:// books.google.no/books?id=BHKLFPUS1RcC.

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• The lifetime of stars



Sun: http://fav.me/d5spggh

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Could affect properties such as:

- The lifetime of stars
- Subsequent nucleosynthesis processes

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Nuclear chart: https:// people.physics.anu.edu.au/~ecs103/chart/



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https://www.groups.ph.tum.de/en/nucastro/tum-nuclear-astrophysics/



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# It is important to know this quantity precisely!

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## Previous measurements of the radiative branching ratio of the Hoyle state



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#### SiRi - Silicon Ring



- Silicon-strip particle detector
- Particle identification using  $\Delta E$ -E method
- ΔE: 130 μm, E: 1550 μm
- Resolution  $\approx 100 \text{ keV}$

M. Guttormsen, A. Bürger, T.E. Hansen, and N. Lietaer. The siri particle- telescope system. Nuclear Instruments and Methods in Physics Research Sec- tion A: Accelerators, Spectrometers, Detectors and Associated Equipment, 648 (1):168 – 173, 2011. ISSN 0168-9002. doi: https://doi.org/10.1016/j.nima. 2011.05.055.

#### The experiment

#### OSCAR - Oslo Scintillation Array



- 30 large volume LaBr3-detectors
- Each detector is 3.5 inch x 8 inch / 8.9 cm x 20.3 cm
- Resolution at 662 keV  $\approx 2.8\%$  4.0%
- Intrinsic timing resolution < 1 ns



#### The experiment

#### How can we measure the radiative branching ratio of the Hoyle state?





## How can we measure the radiative branching ratio of the Hoyle state?









#### Where does the uncertainty originate from?



![](_page_21_Picture_3.jpeg)

#### Determination of the radiative branching ratio of the Hoyle state

![](_page_22_Figure_1.jpeg)

#### Where does the uncertainty originate from?

![](_page_23_Figure_1.jpeg)

![](_page_24_Figure_1.jpeg)

J. B. Swint, A. C.L. Barnard, T. B. Clegg, and J. L. Weil. Cross sections as a function of energy for the scattering of protons from 12C. Nuclear Physics, 86 (1):119–129, 1966. ISSN 00295582. doi: 10.1016/0029-5582(66)90295-1.

Beam increased from 10.7 MeV to 16 MeV Lower cross-section, but we have more control Higher beam intensity and longer beam period Al-frame replaced by Ta-frame

![](_page_25_Figure_1.jpeg)

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Beam increased from 10.7 MeV to 16 MeV Lower cross-section, but we have more control Higher beam intensity and longer beam period Al-frame replaced by Ta-frame Analysis is ongoing, let's look at some of the data!

#### E-det energy vs delta-e energy

![](_page_26_Figure_2.jpeg)

![](_page_27_Figure_1.jpeg)

![](_page_28_Figure_1.jpeg)

![](_page_29_Figure_1.jpeg)

![](_page_30_Figure_1.jpeg)

- the radiative width of the Hoyle state.
- Reanalysis and analysis of data from new experiment is underway.
- Investigate the consequences of a raised rate in astrophysical models will be performed in collaboration with S. Goriely at ULB, Belgium.

#### • Results support the measurement from Kibédi *et al.* (2019) of a raised value for

![](_page_32_Picture_1.jpeg)

https://kurzgesagt.org

Unfortunately this video does not exist yet...