Microscopic Study of the Triple-α Reaction

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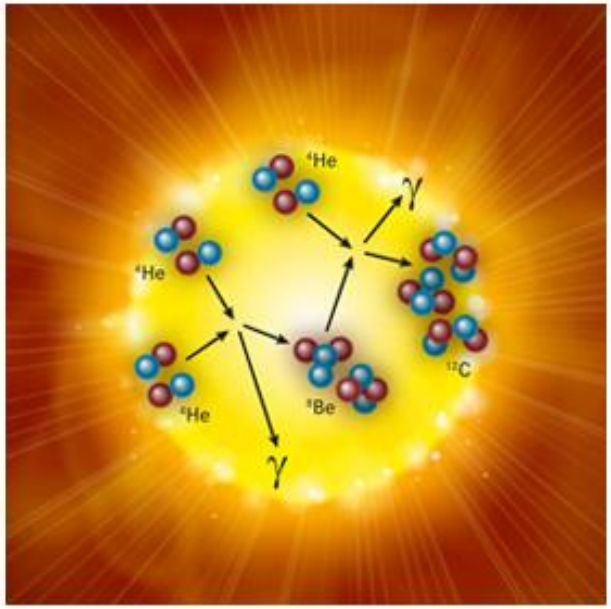
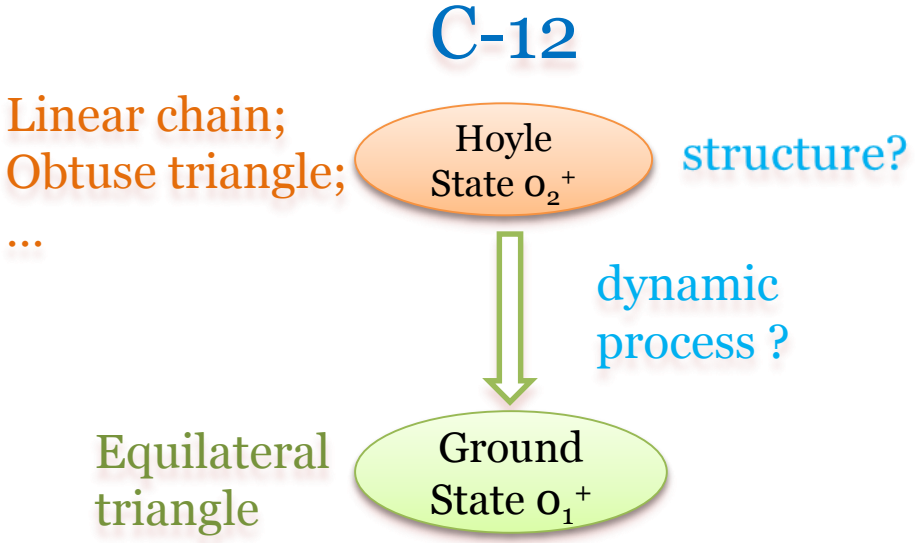


Illustration: Courtesy of Forschungszentrum Jülich GmbH

http://www.scientificamerican.com/article/hoyle-state-primordial-nucleus-behind-elements-life/



- Purpose
  - To study structure of Hoyle state (linear chain config. here)
  - To investigate the dynamic vibration of linear chain config.

❖ Method

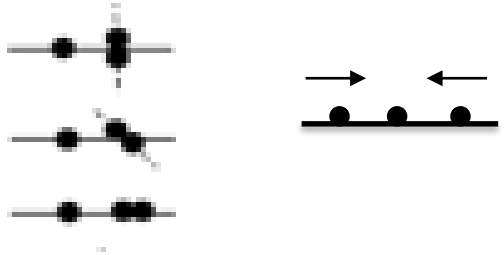
- Density-Constrained Time-Dependent-Hartree-Fock with Skyrme force

$$i\dot{\psi}_\lambda(\boldsymbol{r},t) \equiv \hat{h}(\boldsymbol{r},t)\psi_\lambda(\boldsymbol{r},t)$$

$$\rho(\boldsymbol{r}) = \langle\Phi(t)|\,\hat{\rho}(\boldsymbol{r})\,|\Phi(t)\rangle$$

- 3D-Cartesian box
- Two collision processes

(1) ^{8}Be+^{4}He (2) Triple collision of three ^{4}He



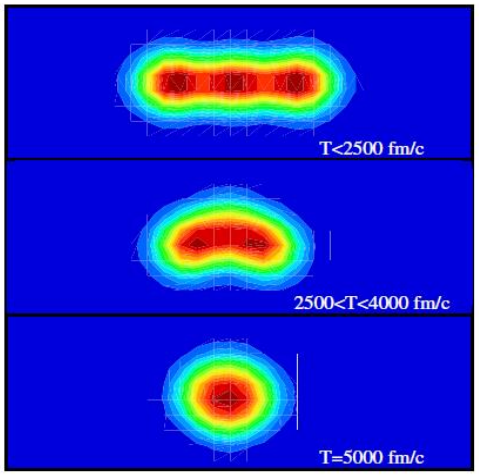
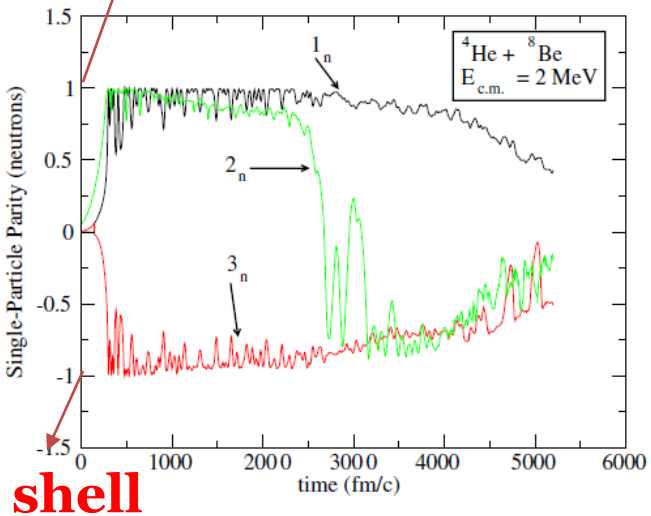


FIG. 1 (color online). Selected density profiles from TDHF time evolution of the ^{4}He + ^{8}Be head-on collision for initial Be orientation angle $\beta = 0°$ using the SLy4 interaction. The initial energy is $E_{\text{c.m.}} = 2$ MeV.

s or d shell



p shell

FIG. 2 (color online). Single-particle parities of the neutron states during the collision of the ^{4}He + ^{8}Be system as a function of time at $E_{\text{c.m.}} = 2$ MeV.

❖ Results

- Density evolution
- Single-particle parities evolution
- Potential energy evolution

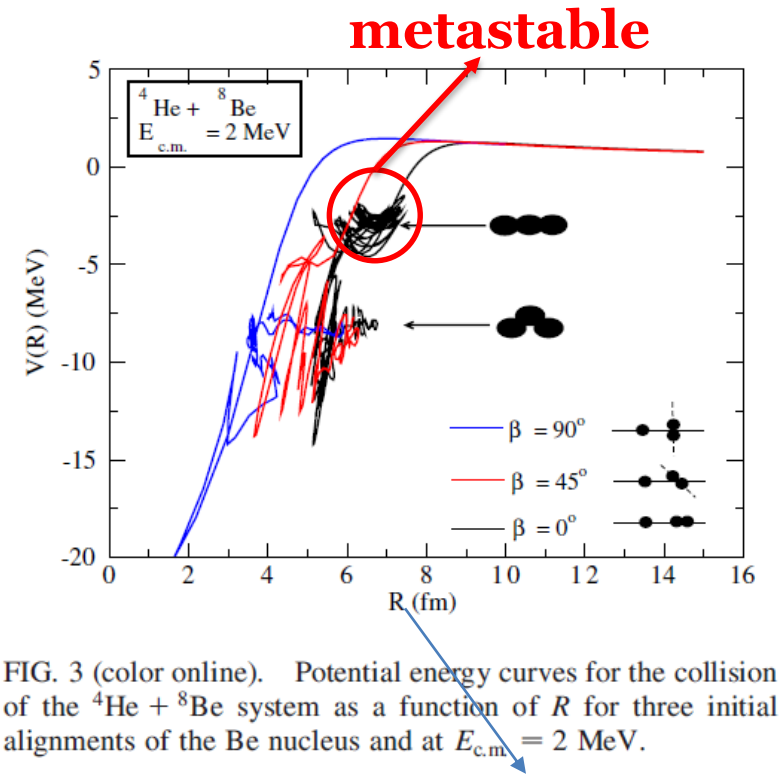


FIG. 3 (color online). Potential energy curves for the collision of the ^{4}He + ^{8}Be system as a function of R for three initial alignments of the Be nucleus and at $E_{c.m.}$ = 2 MeV.

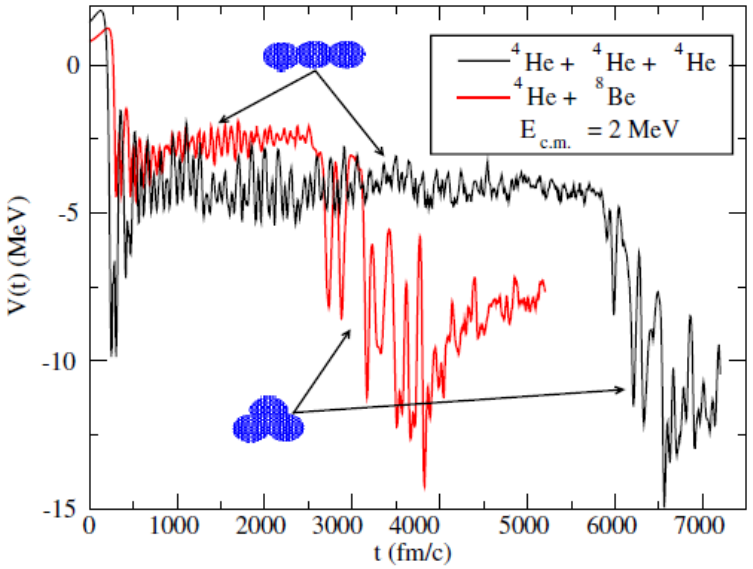


FIG. 4 (color online). Time development of the potential energy for the head-on collision of the ^{4}He + ^{8}Be and the ^{4}He + ^{4}He + ^{4}He systems for $E_{c.m.}$ = 2 MeV.

❖ Conclusion

- Collision leads to the formation of linear chain state of three α-like clusters
- Linear chain configuration is metastable, which can transform to a triangular configuration before relaxing into a configuration near ground state.