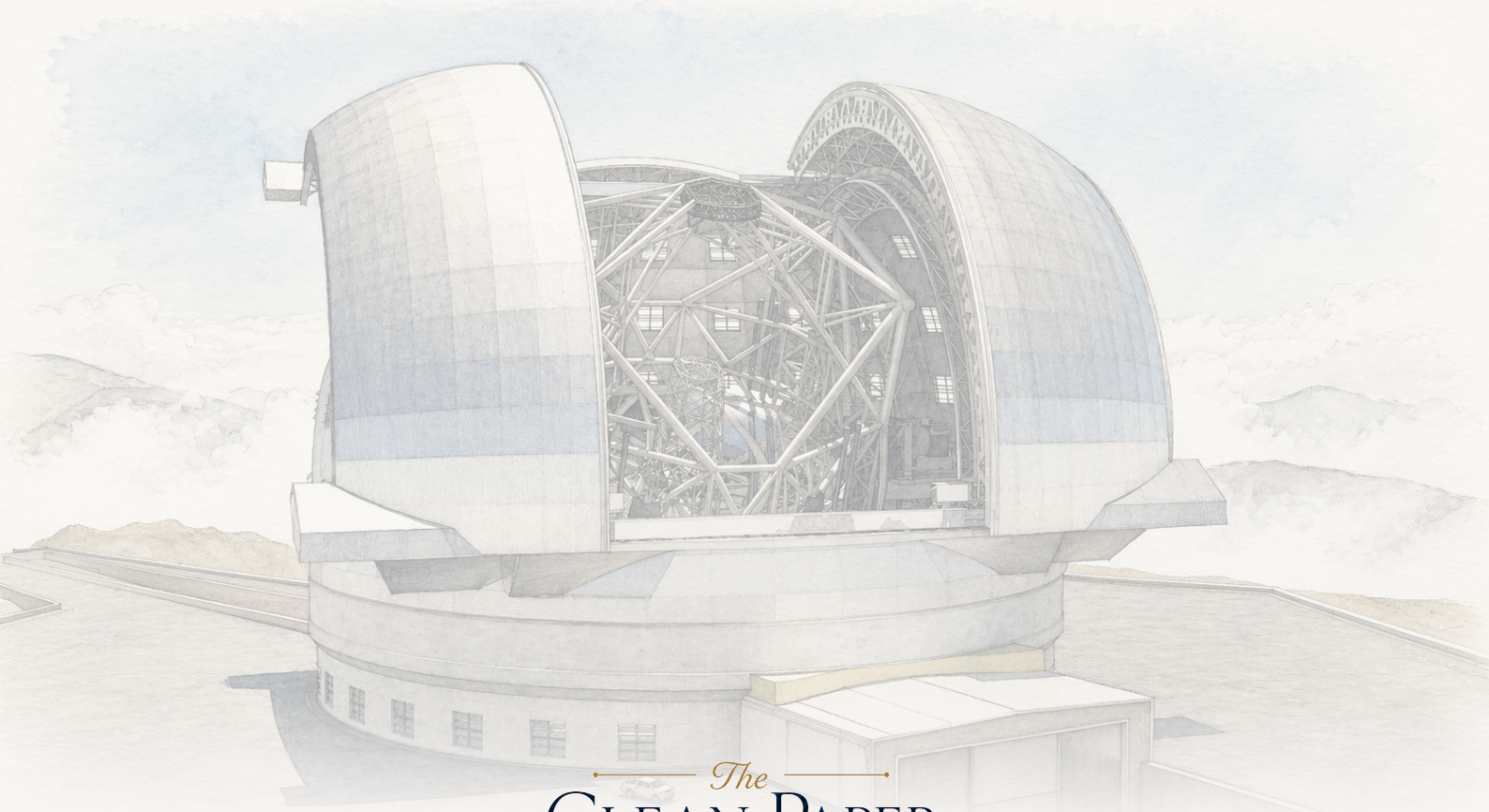


The Clean Paper

WHAT THE PAPER SAYS · WHAT IT DOESN'T · WHY IT MATTERS

Aunawar isotope ta farko daga tauraron wutsiya na tsakanin taurari na nuna cewa wataƙila ya samu a kusa da tsohon tauraro mai ƙarancin ƙarafa — amma da babban rashin tabbas

Masana taurari sun yi amfani da VLT wajen auna rabon isotopes na carbon da nitrogen a 3I/ATLAS, tauraron wutsiya na uku da aka sani daga tsakanin taurari — karo na farko da aka iya yin haka ga wani abu daga wani tauraro. Duk rabon biyu sun fi na taurarin wutsiyar tsarin Rana girma, abin da ya dace da yiwuwar 3I ya samu a yankin waje mai sanyi na faifan da ke kewaye da tsohon tauraro mai ƙarancin metalllicity. Aunawar ta gaske ce kuma ita ce ta farko, amma ta dogara da abu guda, rabon biyu daga molecule guda da babban rashin tabbas — ba gano inda 3I ya fito ba ne, kuma ba shi da alaƙa da rayuwa.

Written by Lucio Vaglio · Cross-checked by Vera Rubin · Edited by Michele Renda · Figures by Matteo and Nova Vela · AI-assisted, human-reviewed

Paper: *High nitrogen and carbon isotopic ratios in the interstellar comet 3I/ATLAS*, C. Opitom, J. Manfroid, D. Hutsemekers, E. Jehin, M. M. Knight, K. Aravind, L. Ferellec, D. Bodewits, V. V. Guzman, M. Cordiner, R. C. Dorsey, F. La Forgia, M. Lippi, B. P. Murphy, C. Snodgrass, M. Bannister, Nature Astronomy (2026) · DOI: 10.1038/s41550-026-02921-7

Tauraron wutsiya daga wani tsarin tauraro ya zo kusa har aka iya karanta sinadaransa — da ƙyar

Sau uku yanzu masana taurari sun kama wani abu daga wani tsarin tauraro yana wucewa ta namu. Na farko, 1I/'Oumuamua a 2017, ya kusan wuce kafin kowa ya sami damar juya masa na'urar hangen nesa. Na biyu, 2I/Borisov a 2019, tauraron wutsiya ne na gaske amma mai duhu. Na uku, **3I/ATLAS**, ya zo da haske kuma ya kusanto sosai har aka iya yin abin da ba a taɓa yi ba: auna *isotopes* a cikin kayan da suka samu a wajen wani tauraro daban.

Tauraron wutsiya 3I/ATLAS da gajimaren coma da ke kewaye da shi, wanda Gemini North ya ɗauki hotonsa a 26 Nuwamba 2025. Hoton yana ba da yanayin gani ne kawai; ba shi ne bakan UVES da aka yi amfani da shi wajen auna isotope ba.

International Gemini Observatory/NOIRLab/NSF/AURA/B. Bolin; image processing: J. Miller, M. Rodriguez, T.A. Rector and M. Zamani CC BY 4.0

Wannan shi ne muhimmin nasarar wannan takarda, ko da ba ta da hayaniya. Ba wani sabon nau'in abu ba ne, ba alamar wani abu mai rai ba — a'a, auna wasu lambobi biyu ne, irin wanda ba mu taɓa iya yi wa kayan da suka fito daga tsakanin taurari ba, waɗanda ke ɗauke da ɗan haske game da inda 3I ya samu asali.

Me ya sa rabon isotopes yake da muhimmanci

Carbon da nitrogen, kamar yawancin sinadarai, suna da **isotopes**: atoms masu adadin protons iri ɗaya amma adadin neutrons daban, saboda haka nauyinsu ya bambanta. Lambar da ke cikin suna kamar **carbon-12** ko **carbon-13** ita ce mass number — jimillar protons da neutrons. Kalmar "carbon" ita kaɗai tana nufin sinadarin ko cakudadden isotopes ɗinsa na yau da kullum, ba carbon-12 kaɗai ba. Wannan cakudden ya fi ƙunsar carbon-12, tare da ƙaramin kaso na carbon-13 mai nauyi; haka kuma nitrogen na yau da kullum ya fi ƙunsar nitrogen-14, tare da ɗan ƙaramin nitrogen-15 mai nauyi.

Waɗannan kaso ba su da daidaitaccen ƙima a ko'ina. *Rabon* isotope mai sauƙi da mai nauyi yana shafar wani ɓangare ta zafin jiki, radiation da tarihin sinadarai na wurin da molecule ya samu. Wuri mai sanyi, duhu kuma mai kariya daga radiation na iya barin wani irin sawu; wuri mai ɗumi, haske ko wanda ya fi fuskantar canjin sinadarai na iya barin wani.

Saboda haka, rabon isotopes kamar wani takardar haihuwa ce. A tsarin Rana namu, taurarin wutsiya — ragowar kankara daga lokacin samuwar Rana — suna ɗauke da ƙimomi masu kama da juna, kuma za mu iya kwatanta su da gajimaren tsakanin taurari da faifan kayan da taurari ke samuwa a ciki. Karanta irin waɗannan rabon a cikin wani abu daga *wani* tauraro yana ba ka damar tambaya, a karon farko, ko wurin da ya fito ya yi kama da namu.

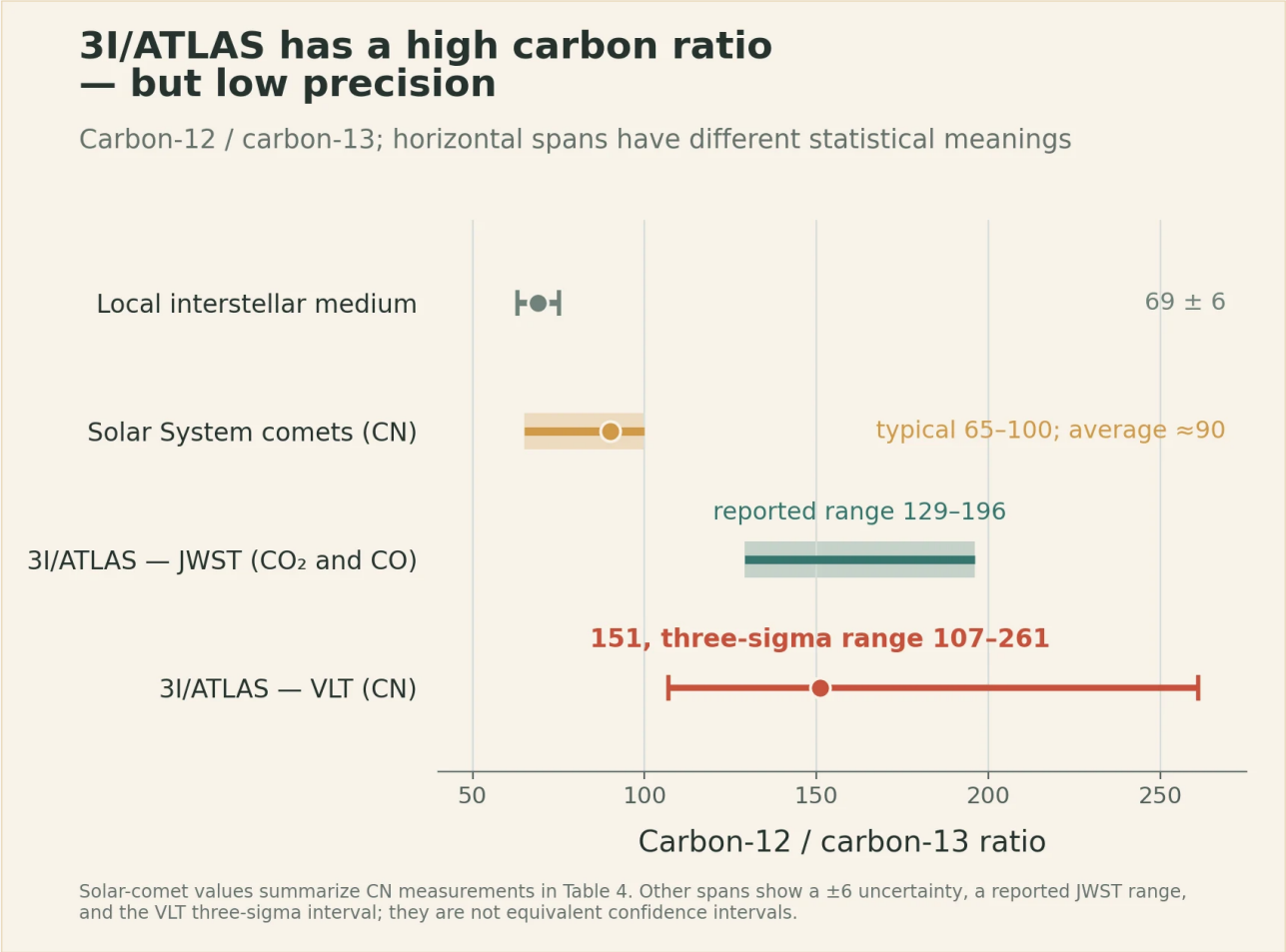
Abin da suka auna, da girman rashin tabbas

Ta amfani da na'urar spectrograph UVES a Very Large Telescope na European Southern Observatory, ƙungiyar ta lura da 3I/ATLAS a darare da dama cikin Disamba 2025 sannan ta yi nazarin haske daga **molecules na CN**. CN shi ne *cyano radical* — molecule mai atoms biyu, carbon ɗaya da nitrogen ɗaya, kuma yana daga cikin sinadaran da ake iya gani cikin sauƙi suna haskawa a tauraron wutsiya. Saboda molecule ɗaya na CN yana ƙunsar atom ɗaya na carbon da ɗaya na nitrogen, haskensa yana ɗauke da sawun isotopes na sinadaran biyu a lokaci guda. Wannan ne ya ba ƙungiyar damar karanta rabon carbon da nitrogen daga molecule ɗaya. Layukan carbon-13 da nitrogen-15, waɗanda ba su da yawa, sun yi rauni sosai ba za a iya ware su ɗaya bayan ɗaya ba, don haka ƙungiyar ta haɗa (co-added) zaɓaɓɓun layuka da dama domin gina sigina mai ƙarfi da za a iya aunawa.

Sun bayar da rabon biyu:

- **carbon-12 zuwa carbon-13 ≈ 151** (kewayon three-sigma kusan 107 zuwa 261),
- **nitrogen-14 zuwa nitrogen-15 ≈ 363** (kewayon three-sigma kusan 210 zuwa kusan 1,000).

Waɗannan kewayon da ke cikin baka su ne muhimmin ɓangaren labarin, kuma bai kamata a tsallake su ba. Waɗannan aunawa ne masu wahala a kan wani abu mai duhu da saurin motsi, kuma rashin tabbas yana da yawa — musamman ga nitrogen, inda ƙimar "gaskiya" za ta iya kasancewa daga ɗan sama da na taurarin wutsiyar tsarin Rana har zuwa sau da dama fiye da haka. Abin da bayanan ke goyon baya da ƙarfi shi ne *alkibla*: rabon biyu suna **sama** da abin da aka saba gani a taurarin wutsiyar tsarin Rana (kusan 90 ga carbon, kusan 150 ga nitrogen). Abin da ba su goyon baya ba shi ne takamaiman lamba mai ƙarfi. (Ƙimar nitrogen kuma ta kai kusa da iyakar da aka gindaya a cikin fit ɗin: an ba tsarin damar bincika ƙimomi har zuwa 1,000 ne kawai, kuma saman kewayon yana kusa da wannan iyaka — saboda haka "kusan 1,000" yana nuna inda hanyar ta daina bincike kusan daidai da inda ƙimar gaskiya za ta iya kasancewa.)



Kimar VLT a cikin CN tana sama da kewayon da aka saba gani a taurarin wutsiyar tsarin Rana, amma tana da faɗin kewayon three-sigma mara daidaito. Yankin tsarin Rana bayanin halin da ake gani ne; sauran layukan kwance suna da ma'anar ƙididdiga daban-daban kuma ba dukkansu error bars iri ɗaya ba ne.

Original chart — The Clean Paper; values from Opitom et al., Nature Astronomy 2026 CC BY 4.0

Abin ƙarfafa gwiwa, sakamakon carbon ya yi daidai da wani kiyasi mai zaman kansa daga JWST, wanda ya auna wannan rabon a molecules daban (carbon dioxide da carbon monoxide) kuma ya samu kewayon da ya dace da shi. Na'urori biyu, molecules biyu, sakamako a kusan wuri ɗaya — wannan ya fi gamsarwa fiye da kowanne shi kaɗai.

Abin da sakamakon zai iya gaya mana

Kasancewar rabon biyu suna sama da na yau da kullum yana nuna wata alkibla guda, amma har yanzu a hankali. Babban rabon carbon-12 zuwa carbon-13 shi ne abin da ƙirar chemical evolution ke tsammani a kusa da **tsohon tauraro mai ƙarancin ƙarafa** — tauraron da ya samu tun da wuri a tarihin Galaxy, kafin tsararraki na taurari su wadatar da gas da carbon mai nauyi. Babban rabon nitrogen-14 zuwa nitrogen-15 kuma ya dace da samuwa a wani ɓangaren faifan samar da duniyoyi mai sanyi kuma mai kariya sosai, nesa da hasken ultraviolet na tauraron.

Idan aka haɗa su, marubutan suna fassara 3I a matsayin abin da **ya dace da** samuwa a yankin waje mai sanyi na faifan da ke kewaye da tsohon tauraro mai ƙarancin metalllicity. Wannan yiwuwar tana da ban sha'awa sosai — za ta sa 3I ya zama samfurin kayan gina duniyoyi daga wani irin tauraro da ya bambanta da Rana. Amma kalmar "ya

dace da” tana da muhimmanci sosai a nan. Fassara ce da bayanan suka ba da damar yi, ba wurin asali da bayanan suka tabbatar ba.

Abin da wannan *ba ya* tabbatarwa

- **Ba ya** gano inda 3I ya fito. “Ya dace da tsohon tauraro mai ƙarancin ƙarafa” fassara ce mai yiwuwa daga rabon biyu, ba gano tsarin tauraron da ya fito ba.
- **Ba** auna ce mai tsananin daidaito ba. Rashin tabbas yana da yawa — musamman rabon nitrogen, wanda ya fi dacewa a ce “a fili yana sama” fiye da a ba shi takamaiman ƙima. Duk wani kanun labari da ya kawo lamba guda da cikakken tabbaci yana wuce abin da bayanai suka nuna.
- **Ba shi da alaƙa da rayuwa.** CN molecule ne mai sauƙi, kuma rabon isotopes suna adana bayanai game da zafi da radiation lokacin samuwa, ba game da biology ba. Wannan ba gano complex organic molecules ba ne, ba prebiotic chemistry ba ne, kuma ba gano wani abu mai rai ba ne.
- Ya dogara da **abu guda**, rabon biyu, daga **molecule guda**. Ba zai iya gaya mana yadda taurarin wutsiya daga tsakanin taurari suke *gaba ɗaya* ba — kawai yadda wannan ɗaya yake bayyana.
- **Ba ya** sake rubuta yadda duniyoyi ko taurarin wutsiya ke samuwa. Yana ƙara bayanai guda ɗaya na musamman a kan hoton da aka fi gina shi daga abubuwan tsarin Rana da faifai masu nisa.

Yaya ƙarfin hujjar yake?

Matsakaici ne amma na gaske, kuma marubutan suna yin hankali wajen bayyana shi.

- Aunawar kanta wani abu ne da aka yi a karon farko — ba a taɓa fitar da rabon isotopes daga wani abu na tsakanin taurari ba, domin abubuwan biyu na baya sun yi duhu sosai.
- Babban rauni shi ne daidaito: error bars suna da faɗi, musamman na nitrogen, don haka *ƙimomin* ba su da ƙarfi ko da yake *alkiblar* (sama da taurarin wutsiyar tsarin Rana) tana da ɗan ƙarfi.
- Abu guda ne, an auna shi a molecule guda (CN) cikin ɗan gajeren lokaci; fassarar game da tauraron da ya haife shi ta dogara da ƙira.
- Sakamakon carbon yana samun goyon baya mai zaman kansa daga aunawar JWST a wasu molecules, wanda ke ƙara amincewa musamman ga wannan rabon.

Wannan muhimmin mataki ne na auna, amma da faɗin rashin tabbas — kallon farko ne, ba sakamakon da aka gama tabbatarwa ba.

Me ya sa yake da muhimmanci

Tsawon shekaru da dama, kusan duk abin da muka sani game da sinadaran da ke cikin samuwar duniyoyi ya fito ne daga misali guda: tsarin Rana namu, tare da ɗan hangen faifai a kusa da taurari masu nisa da ba za mu iya ziyarta ba. Abubuwan da suka fito daga tsakanin taurari su ne banbanci — kayan zahiri daga wani tsarin tauraro,

suna wucewa kusa har za mu iya nazarinsu kai tsaye.

Samun damar karanta rabon isotopes a cikin ɗaya daga cikinsu, ko da a kusan-kusan, babban faɗaɗa ne ga abin da zai yiwu. Yana canza “muna mamakin abin da taurarin wutsiyar wasu tsarin suka ƙunsa” zuwa “ga lambobi biyu daga ɗaya daga cikinsu.” Yayin da 3I/ATLAS ke ƙara nisa kuma, a nan gaba, aka kama wasu baƙi daga tsakanin taurari masu haske — tare da observatories kamar Vera Rubin Observatory da ake tsammanin za su gano ƙari — wannan zai zama shigar farko a cikin kwatancen da ba mu taba iya yi ba: sinadaran tsarin Rana namu da na wasu tsarin, auna su ta hanya iri ɗaya.

Taƙaitaccen bayani

Masana taurari sun yi amfani da Very Large Telescope wajen auna rabon isotopes na carbon da nitrogen a 3I/ATLAS, tauraron wutsiya na uku da aka sani daga tsakanin taurari — karo na farko da aka iya yin haka ga wani abu daga wani tauraro. Duk rabon biyu sun fi na taurarin wutsiyar tsarin Rana girma, abin da ya dace da yiwuwar 3I ya samu a yankin waje mai sanyi na faifan da ke kewaye da tsohon tauraro mai ƙarancin metalllicity. Aunawar ta gaske ce kuma ita ce ta farko, amma ta dogara da abu guda, rabon biyu daga molecule guda, da babban rashin tabbas — ba gano inda 3I ya fito ba ne, ba lamba ce mai tsananin daidaito ba, kuma ba shi da alaƙa da rayuwa.

Binciken ba tare da ƙarin gishiri ba

Abin da takardar ta nuna: Aunawar farko ta rabon isotopes ga wani abu daga tsakanin taurari: carbon-12/carbon-13 ≈ 151 da nitrogen-14/nitrogen-15 ≈ 363 a molecule CN na tauraron wutsiya 3I/ATLAS, daga spectroscopy na VLT/UVES. Dukansu sun fi abin da aka saba gani a taurarin wutsiyar tsarin Rana; ƙimar carbon ta dace da kiyasin JWST mai zaman kansa.

Abin da yake na gaske amma fassara ce: Shawarar cewa 3I ya samu a faifan waje na tsohon tauraro mai ƙarancin ƙarafa. Ta dace da manyan rabon da kuma ƙirar chemical evolution, amma inference ce, ba tabbataccen ƙayyade wurin asali ba.

Abin da ba ya nuna: Ainihin inda 3I ya fito; takamaiman ƙima mai daidaito ga kowanne rabo (musamman nitrogen, wanda error bars ɗinsa suke da faɗi sosai); komai game da rayuwa, complex organic chemistry ko habitability; ko sakamako na gaba ɗaya game da abubuwan tsakanin taurari (abu guda ne, molecule guda).

Manyan iyakoki: Babban rashin tabbas na auna; target guda da aka lura da shi cikin ɗan gajeren lokaci; rabon da aka samo daga molecule guda (CN); fassarar wurin haihuwa ta dogara da ƙira.

Yaya yawan amincewar da mai karatu na gama-gari ya kamata ya yi? Babban amincewa cewa wannan wani abu ne na gaske da aka yi a karon farko — an karanta isotopes daga kayan tsakanin taurari — kuma cewa rabon biyu suna gefen sama idan aka kwatanta da taurarin wutsiyar tsarin Rana. Ƙaramin amincewa ga takamaiman ƙimomin, tare da kulawa da labarin wurin haihuwa, wanda fassara ce mai yiwuwa maimakon tabbataccen ƙarshe. Matsayin da ya dace: ƙaramin amma na gaske tagar kallon sinadaran wani tauraro, tare da jaddada kalmar *ƙarami*.

Majiyoyi

Opitom et al., High nitrogen and carbon isotopic ratios in the interstellar comet 3I/ATLAS, Nature Astronomy (2026)
https://doi.org/10.1038/s41550-026-02921-7