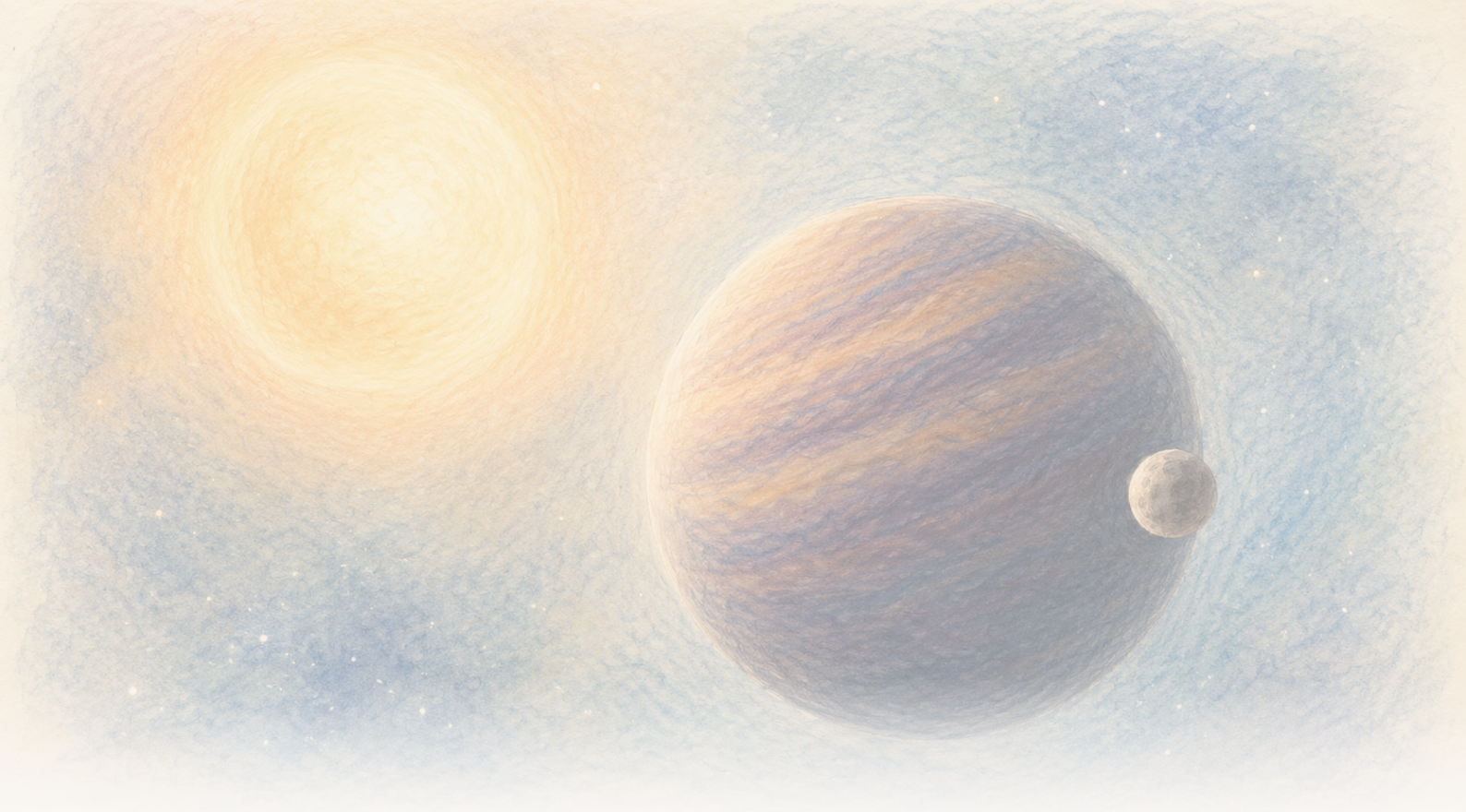

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WHAT THE PAPER SAYS · WHAT IT DOESN'T · WHY IT MATTERS

Brown dwarf tokko guyyoota 171 keessatti irra deddeebi'ee raafamu fakkaata. Addunyaan dhokataan tokko isa harkisaa ta'uu danda'a, garuu data'n ammallee lama hayyama

High-quality spectra 23 motion CD-35 2722 B keessatti strong periodic shift reveal godhu. Preferred model one eccentric companion minimum mass near Jupiter's dha, garuu two-object model same signal mimic gochuu danda'a, slow brown-dwarf variability principle'n possible ta'ee hafa, fi word "exomoon" as keessatti settled boundary hin qabu.

Written by Cinzia Vaglio · Cross-checked by Matteo · Edited by Michele Renda · Figures by Cinzia Vaglio, Laura Nesso and Nova Vela · AI-assisted, human-reviewed

Paper: *Planetary-mass exosatellite detected around the substellar companion of a star*, Kevin Hoy, Alice Zurlo, Pablo A. Pena R., Jana Kohler, Silvano Desidera, Raffaele Gratton, Cecilia Lazzoni, Simon Petrus, Florian Rodler, Jonathan Smoker, Valentina D'Orazi, Ilaria Carleo and Ilaria Giovannini, Nature 655, 865-869 (2026) · DOI: 10.1038/s41586-026-10751-w

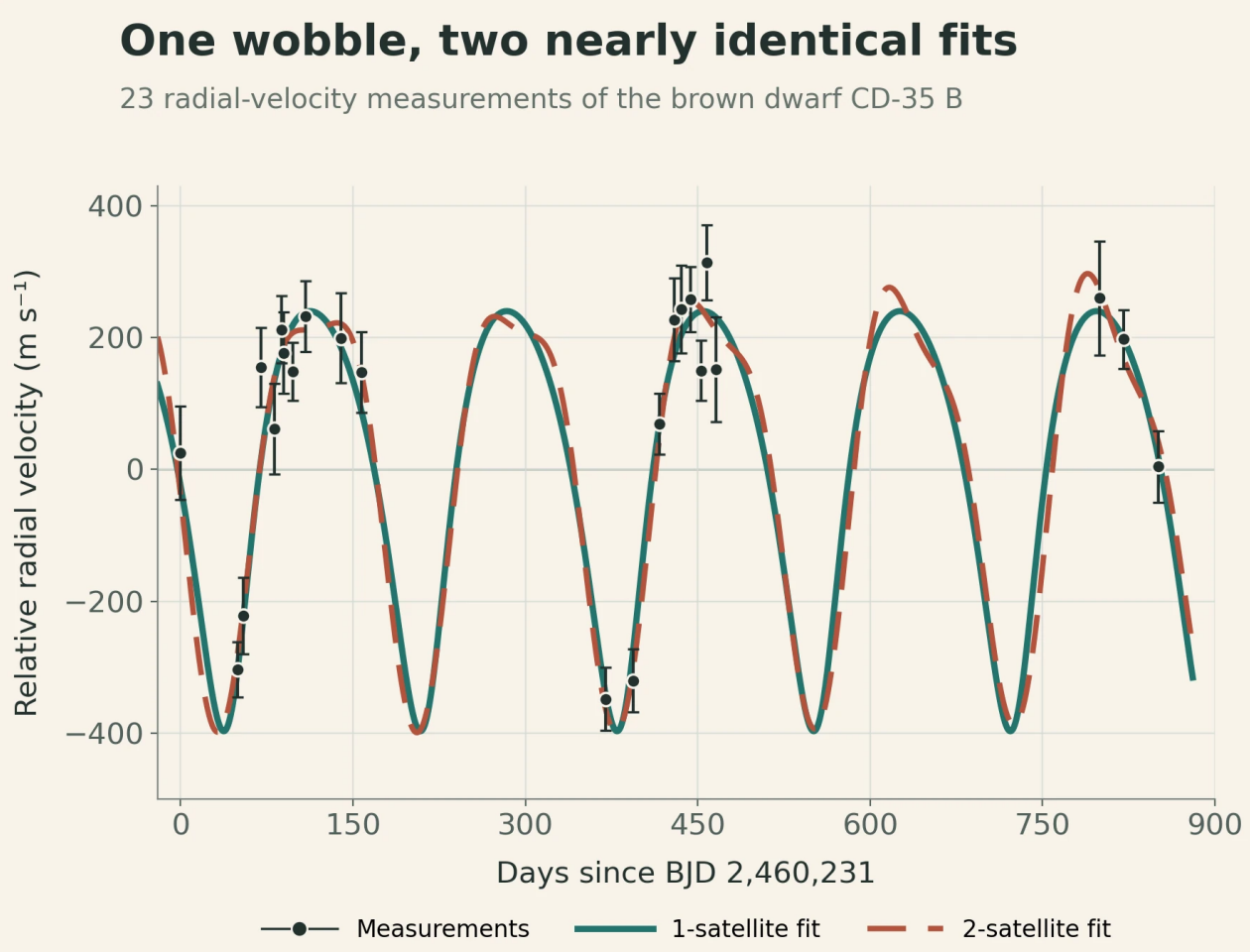
Brown dwarf tokko guyyoota 171 keessatti irra deddeebi'ee raafamu fakkaata. Addunyaan dhokataan tokko isa harkisaa ta'uu danda'a, garuu daataan ammallee lama hayyama

Astronomeroonni CD-35 2722 B akka qabxii of ifa ofii isaatti, urjii inni marsu irraa adda ta'ee, arguu danda'u. Inni brown dwarf dha, maassaa haala giant pilaaneetota fi urjiilee gidduu jiru keessatti: tilmaamaan 37 Jupiter masses ta'uun, typical giant pilaaneetii caalaa massive dha, garuu normal hydrogen-burning urjii miti. Object xiqqaa brown dwarf mataa isaa marsuu danda'u garuu arguu hin danda'an. Yoo confirmed ta'e, innermost object sun satellite substellar object guddaa tokko marsu, substellar object sun immoo urjii tokko marsu, hierarchy mul'ate jalqabaa ta'a.

Wanti isaan bakka isaa argu rhythm dha. Nights muraasa irratti, ifa brown dwarf xiqqoo jijjiirama godha yeroo Lafa garaa socho'u. Nights biroo irratti, jijjiirama opposite yeroo brown dwarf Lafa irraa fagaachaa socho'u. Akkaataa kun naannoo **171 days** hunda irra deebi'a.

Motion back-and-forth kun unseen companion tokko uumu danda'a: objects lama shared giddugala of maassaa marsu yeroo ta'u, smaller tokko guddaa caalaa tokko marsa, garuu guddaa caalaa tokko illee loop baay'ee xiqqaa godha. Rhythm kun orbiitii yoo ta'e, Nature barruu haaraan planetary-mass object tokko loop CD-35 2722 B naannoo safarame explain gochuuf preferred explanation ta'ee dhiyeessa.

Kun remarkable possibility dha, moon photograph miti. High-quality observing nights digdamii sadii cimaa periodic mallattoo agarsiisu. Mallattoo sana world taasisuun moodeela barbaada, daataa ammaa architecture tokko caalaa ammallee hayyama. Brown dwarf mataa isaa keessaa slow jijjiiramoota illee guutumaan exclude hin godhan.



Gurraacha qabxiilee fi dogoggora bars nightly radial-velocity safartuuwwan 23 dha. Jajjabaa fi dashed qaxxaamuroota best-fitting tokko- fi two-satellite moodeelota dha. Near overlap isaanii daataa periodic wobble mul'isuu danda'u, garuu sirna architecture ammallee determine hin goone maaliif akka ta'e agarsiisa; qaxxaamura tokko iyyuu kallattii image companion miti.

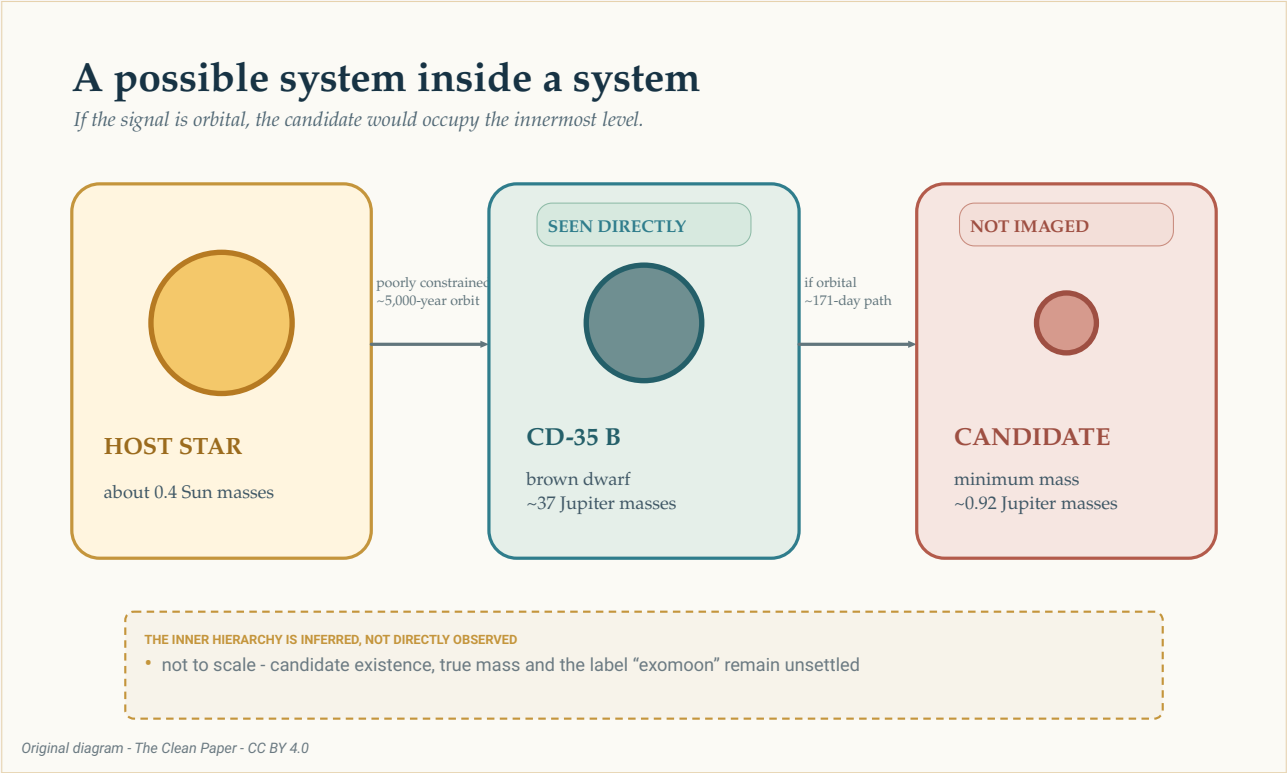
Original chart — The Clean Paper; data from Hoy et al., Nature (2026), Figure 1 source workbook CC BY 4.0

Sirna tokko sirna biraa keessa

CD-35 2722 B **brown dwarf** dha: object familiar gareewwan gidduu. Typical giant pilaaneetii caalaa massive dha, garuu normal hydrogen-burning urjii akka ifuuf maassaa gahaa hin qabu. Barruu tilmaamame maassaa isaa naannoo **37 Jupiters** fayyadama.

Brown dwarf kallattii imaging'n discovered, jechuun telescopes ifa isaa host urjii ifa irraa adda resolve godhan. Sky irratti urjii irraa waa'ee 2.8 arcseconds fagoo mul'ata. Wide orbit pair walitti hidhu poorly beekamaa dha, garuu ammaa tilmaamota highly stretched path gara **5,000 waggoota** fudhatu akeeku.

Periodic mallattoo orbiitii yoo ta'e, inferred architecture kan filatame sadarkaa tokko gadi keessaa kaa'a: urjii tokko brown dwarf'n orbited, brown dwarf sun immoo planetary-mass companion'n orbited.



Mallattoo orbiitii yoo ta'e, kan filatame danda'amaa hierarchy kana keessatti innermost sadarkaa qabata. Brown dwarf qofa kallattiin seen. Outer orbit urjii naannoo poorly constrained, inner path gara 171-day immoo safarame wobble brown dwarf irraa inferred. Sizes fi fageenyawwan safartuu irratti miti.

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danda'amaa hierarchy kun drawing keessatti salphaa dha. Fiizikaalaa reality fi vocabulary isaa settled miti. Planetary-mass body brown dwarf marsu moon, pilaaneetii ykn simply satellite jedhamaa? Astronomers accepted rule gaaffii kana settle godhu hin qaban. Barruu kanaaf broader jecha **exosatellite** fayyadama.

Nights 23 akkamitti wobble ta'an

Team CD-35 2722 B (its NASA Eyes on Exoplanets entry ilaali) CRIRES+ fayyadamuun observe godhe; kun high-resolution spectrograph European Southern Observatory Very Guddaa Telescope irratti. October 2023 fi February 2026 gidduutti observing epochs 26 argatan. Tokko mallattoo baay'ee xiqqaa qaba ture; lama poor weather keessatti fudhataman reject godhamanii repeated; **high-quality nights 23** hafe.

Spectrograph ifa bal'aa akkaataa sararoota'tti facaa'a. Madda Lafa garaa ykn Lafa irraa fagaatee socho'u, sararoota sun tiny amount jijjiirama godhu. Repeated safartuuwwan motion line-of-sight kana

radial velocities jedhama. Hidden body hin agarsiisan. Body mul'ate unseen pull jalatti akkamitti socho'aa ta'uu danda'u agarsiisu.

Strongest periodicity safartuuwwan keessatti near 170 days. Qorannoo's **0.1% false-alarm-carraa daangaa** ce'a. Daangaa kun qormaata yaadota bu'uuraa jalatti noise periodogram peak yoo xiqqaate kana cimaa yeroo meeqa uuma gaafata. Satellite exists carraa 99.9% miti; tokko companion ykn lama companions jira moo jedhu irratti mataan isaa homaa hin himu.

> **Radial-velocity mallattoo maal mirkaneessu danda'a?**
>
> Radial velocity repeated spectral-line jijjiiramawwan motion observer garaa fi observer irraa fagaachuu measures'tti jijjiira. Repeating akkaataa equations orbit'n fit godhamuu danda'a, researchers period, safarame wobble hammamtaa fi xiqqaa companion maassaa irraa hubatuuf. Garuu mala companion kallattii photograph hin godhu. Stellar ykn substellar atmosphere illee spectral sararoota jijjiirama gochuu danda'a, observing schedules misleading rhythms uumu danda'u, orbiitii arrangements adda addaa walii fakkeessuu danda'u. Mallattoo, fiizikaalaa explanation isaa fi name inferred object kennamu gaaffilee adda adda.

Saamudaa fudhachuu orbiitii deebii dura attention deserves. Radial-velocity safartuuwwan keessumaa gadi-aanaa ta'an afur akkaataa keessatti weight guddaa qabu. Isaan pairs lama keessatti mudatan, gabaafame haalawwan gaarii jalatti, fi xiinxala barreessitoonni tokko qabxii at a yeroo keessaa baasuu repeat yeroo godhan tokko tokko mallattoo uume miti. Haa ta'u malee, danda'amaa orbiitii phases keessaa kutaa qofa sampled. Nights digdamii sadii waggoota lama caalaa keessatti spread ta'uun continuous coverage miti.

Barreessitoonni danda'amummaa half-year artefact illee qoran. Imperfect correction Lafa's changing motion ykn instrument profile false annual mallattoo uumu danda'a; saamudaa fudhachuu sun half Lafa waggaa, ykn **182.5 days**, alias godha. Preferred period **171.11 days**, shakkii +0.53/-0.36 days waliin; barreessitoonni kun 182.5 days irraa waa'ee 20 istaandaardii deviations fagaata jechuun gabaasa godhu. Lafa's changing motion, seeing, atmospheric water vapour ykn examined instrument amaloota waliin walitti dhufeenya hin argine illee gabaasa godhu. Controls kun barbaachisaa dha. Orbiitii explanation modeling'f compelling enough godhu, garuu object mataa isaa identify hin godhan.

Orbiitii deebii salphaan: companion tokko

Preferred moodeela keessatti, object tokko eccentric, ykn somewhat stretched, orbit brown dwarf naannoo every 171.11 days hordofa. Fitted orbit eccentricity naannoo **0.27** fi semi-major axis naannoo **0.200 astronomical units** — giddugaleessa Earth-Sun fageenya keessaa gara tokko fifth — qaba.

Safarame wobble amplitude naannoo **318 metres tokkoon tokkoon lammaffaa**. Motion sana irraa, moodeela companion xiqqaa maassaa naannoo **0.92 yeroowwan Jupiter's maassaa** kenna.

Jechi *xiqqaa* barbaachisaa dha. Radial velocity orbiitii motion keessaa kutaa toward fi away irraa us qofa safara. Orbit edge-on yoo viewed, motion hedduun sarara sana irratti mul'ata. Face-on caalaa yoo

viewed, motion guddaan sky keessatti darba; safarame wobble sanuma uumuuf companion caalaa massive barbaachisa.

Astronomers bu'aa akka **m sin(i)** barreessu: maassaa × sine unknown inclination, ykn viewing angle, orbit. Daataa product sana constrain godha, true maassaa mata isaa qofaan miti. Waa'ee 0.92 Jupiter masses kanaaf gadi-aanaa bound dha, sirrii maassaa object safartuu miti.

> **Viewing angle mass maaliif dhoksa?**
>
> Circular track side irraa ilaalu yaadi. Runner repeatedly gara kee fi irraa kee socho'a, motion kutaa sun easy measure. Amma wal-fakkaataa track above irraa ilaali. Runner irra caalaa view kee keessa lateral socho'a, gara kee ykn irraa kee xiqqoo.
> Radial velocity jalqabaa kutaa qofa arga. Herregaa faaktara `sin(i)` orbiitii motion keessaa sarara of sight keenya irratti qabxii godhu hammam akka ta'e ibsa. Inclination `i` hanga beekamutti, inferred maassaa xiqqaa ta'ee hafa.

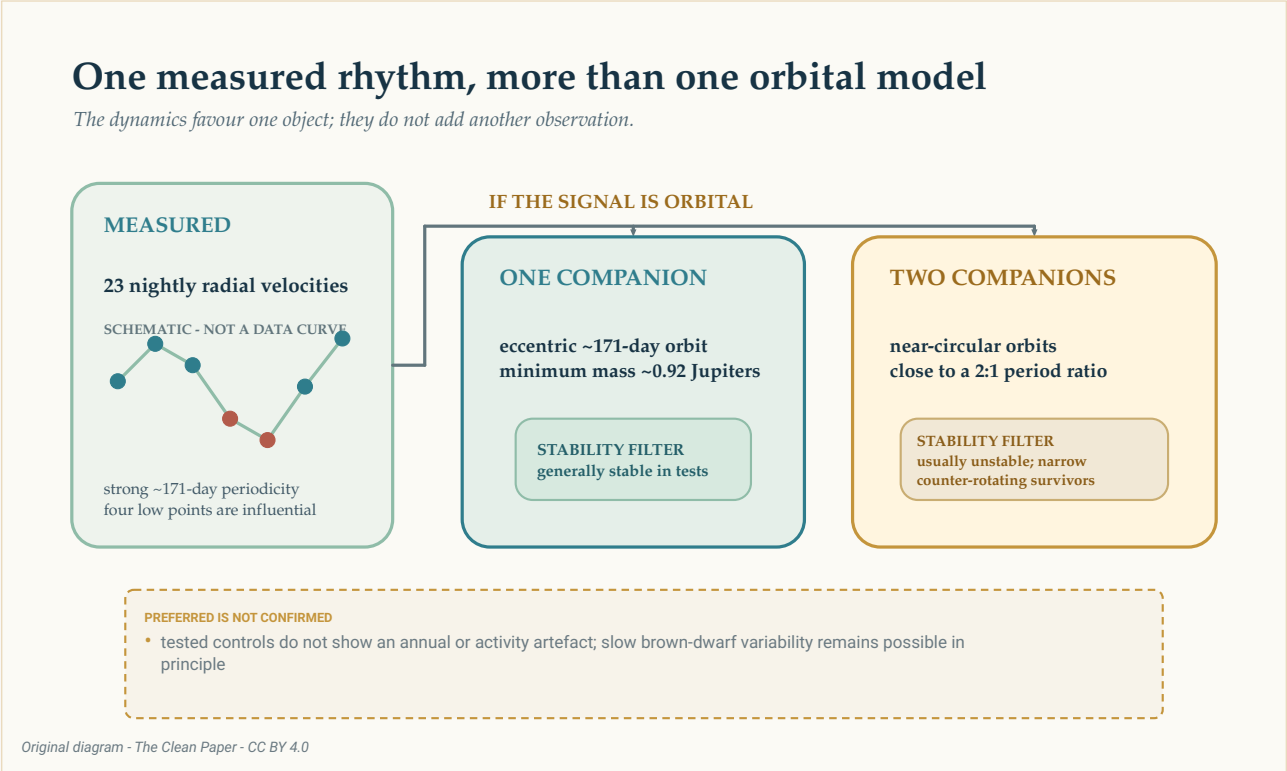
Barreessitoonni orbit kun persist gochuu danda'aa moo quickly destroy itself jedhu illee gaafatan. Lakkoofsaa qormaatawwan one-companion moodeela generally tasgabbaa'aa argan. Kun mallattoo'f physically amansiisaa hiika godha. Lammaffaa detection miti.

Deebiin awkward: companions lama tokko fakkeessuu danda'u

Eccentric radial-velocity mallattoo ambiguity beekamaa tokko qaba. Haalawwan muraasa jalatti, objects lama dhihoo circular orbits, tokko biraa caalaa waa'ee twice as dheeraa period qabu, walitti makame akkaataa tokko object stretched orbit irratti fakkaatu uumu danda'u.

Ambiguity kun as mul'ata. Two-companion moodeela ammaa safartuuwwan outer mallattoo near 171 days fi shorter-period inner mallattoo waliin fit gochuu danda'a. Observing yeroowwan every sadarkaa evenly saamudaa hin goone waan ta'eef, shorter mallattoo aliases hedduu qaba. Nights selected 23 dheeraa gaps waan qabaniif, yaalii periods adda adda visits gidduu unseen cycles lakkoofsota adda adda count godhanii wal-fakkaataa safartuuwwan waliin align godhachuu danda'u. Kan filatame periods near 14, 70, 88 fi 115 days kanaaf alternative fits tokko poorly sampled shorter mallattoo dha; four independently detected rhythms miti.

Barreessitoonni poorly constrained 13-to-17-day window reject godhu. Naannoo sana keessatti fit convincing period tokko isolate hin godhu: hedduu closely spaced furmaatawwan below waa'ee 20 days low-cadence safartuuwwan deebisee uumu, guutuu window carraan isaa guddaa saamudaa fudhachuu artefact. Remaining windows keessaa gara 88-day furmaata gara 70- fi 115-day alternatives caalaa caalaatti gaarii fit godha, garuu barruu beekamaa lammaffaa period himannaa gochuuf enough miti. Tabulated isa gaarii fit keessatti, outer object's xiqqaa maassaa waa'ee 0.87 Jupiter masses fi inner object's waa'ee 0.22 Jupiter masses. Lakkoofsota kun disfavoured moodeela describe godhu; established worlds lama safartuuwwan miti.



Gara 171-day mallattoo orbiitii yoo ta'e, wal-fakkaataa broad radial-velocity akkaataa tokko eccentric companion ykn lama near-circular companions close to lama gara tokko period reeshiyoo'n represented ta'uu danda'a. Stability qormaatawwan one-object hiika caalatti filatu, garuu moodeela image hin taasisan ykn slow brown-dwarf variability boca hunda rule out hin godhan.

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Stability shallaggiiwwan walbira qabuu sharpen godhu. Tested two-companion arrangements baay'een object tokko muraasa hundred simulated waggoota keessatti eject godhan. Surviving configurations narrow fi unusual naannoo keessatti, orbits dhihoo wal-fakkaataa plane keessa garuu opposite directions keessatti sochoosu. Host urjii further tasgabbaa'aa hin taane naannoowwan introduce godhe.

Kun tokko eccentric companion tested two-companion sirnoota caalaa prefer gochuuf sababa dha. Nature simpler moodeela filate ragaa miti. Stability danda'amaa interpretations radial velocities safarame booda filter godha; qaxxaamura irratti mul'ate qabxii dabalataa hin uumu.

Eccentric orbit tokko circular lama fakkaachuu akkamitti danda'a?

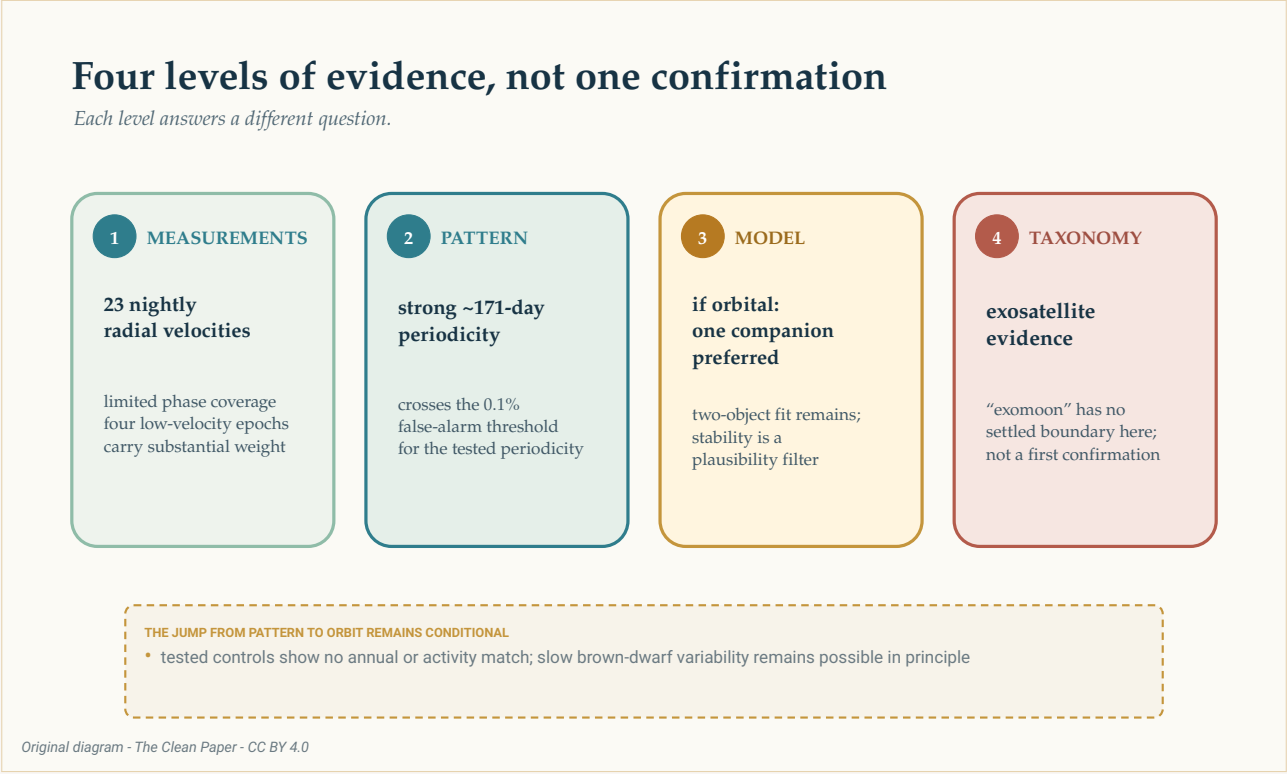
Perfect circular orbit salphaa repeating radial-velocity wave uuma. Eccentric orbit distortions wave sana irratti dabalata. Circular orbits lama periods near lama gara tokko reeshiyoo qaban combine godhanii, mallattoo tokko ijoo rhythm kennu, biraa similar distortion kennu.
Kun **orbiitii degeneracy** dha: fiizikaalaa sirnoota adda adda similar safartuuwwan uumu. Caalaa ilaalchawwan yeroo moodeelota adda velocities tilmaaman tie break gochuu danda'u. Dynamics qormaata proposed sirna tokko tokko survive godhu moo gaafachuun gargaara, garuu ilaalchawwan sana bakka bu'uu hin danda'u.

Rhythm brown dwarf irraa dhufuu danda'aa?

Brown dwarf silent qormaata maassaa miti. Atmosphere isaa rotate godha, clouds uuma, magnetic sochii qabaachuu danda'a. Changing fuula akkaataawwan spectral sararoota reshape godhanii motion imitate gochuu danda'u.

CD-35 2722 B tilmaamame maximum rotation period waa'ee **0.65 days**, 171 days caalaa baay'ee gabaabaa. Team cimaa gabaabaa rotation mallattoo ykn convincing cloud-/granulation-like mallattoo sochii moodeelota tested keessatti hin recover godhne. Annual saamudaa fudhachuu fi instrumental hangawwan illee examine godhanii 171-day rhythm waliin match hin argine.

Checks kun alternatives narrow godhu, garuu barruu intrinsic variability hunda eliminated himannaa hin godhu. Long-timescale magnetic sochii ykn atmospheric circulation brown dwarf keessatti principle'n rule out hin godhamne. Remaining possibility kun orbiitii moodeelota beside kaa'amuu qaba, booda them hidden miti.



Ragaa distinct sadarkaalee keessa ol ka'a: nightly radial velocities 23 limited sadarkaa coverage waliin; cimaa gara 171-day periodicity; preferred one-companion moodeela mallattoo orbiitii yoo ta'e; finally unsettled "exomoon" label. Ladder safartuu, istaatistikii akkaataa, fiizikaalaa hiika fi taxonomy addaan baasa; confirmation arrow miti.

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Exomoon dhaa?

Solar Sirna keessatti, moon pilaaneetii marsa. CD-35 2722 B brown dwarf dha; inferred companion true maassaa ammallee unknown. Familiar names yeroo object tokko planet-brown-dwarf daangaa bira, object biraa moon-planet daangaa bira taa'u strained ta'u.

Barruu jalqabaa confirmed exomoon himannaa hin godhu. Lakki exomoon yet confidently detected jedhu, planetary-mass **exosatellite** ragaa dhiyeessa, sirna uncontroversial detection gara tarkaanfii tokko jechuun waama. danda'amaa novelty discussion conditionally jalqaba: mallattoo legitimate ta'uu yoo mirkaneesse.

Caution kun bu'aa duwwaa hin godhu. Faint brown dwarf companion irraa radial velocities kallattii safaruun difficult dha. Continued ilaalchawwan mallattoo preserve yoo godhan, sirna planet-search malleen celestial hierarchy keessatti sadarkaa biraa gadi reach gochuu danda'u agarsiisa.

Kan biraa observing season qabxiilee dabaluu caalaa gochuu danda'a. Tokko- fi two-companion moodeelota particular fuuldura yeroowwan irratti adda velocities tilmaamu. Safartuuwwan missing orbiitii phases fill godhan 171-day rhythm persists moo qoru, four gadi-aanaa qabxiilee dhiibbaa hir'isu, competing qaxxaamuroota diverge godhu.

Ammaaf, honest image haaraa moon brown dwarf beside hanging miti. Speektrumii, night booda night repeated, xiqqaa periodic jijjiirama baatu dha. World tokko rhythm sana keessa jiraachuu danda'a. Achievement isaa, inference guutuu dha fakkeessuu malee isa irraa hammam tilmaamuu dandeenyu barachuu dha.

Cuunfaa gabaabaa

Astronomeroonni kallattiin imaged brown dwarf CD-35 2722 B radial velocity high-quality nights 23 keessatti October 2023 fi February 2026 gidduu safaran. Spectral sararoota cimaa periodic jijjiirama near 171 days agarsiisu. Preferred orbiitii moodeela tokko eccentric companion xiqqaa maassaa near 0.92 Jupiter masses qaba, garuu true maassaa unknown sababni orbiitii inclination unknown. Lama near-circular companions broad mallattoo sanuma mimic gochuu danda'u, ta'us tested two-object configurations baay'een dynamically tasgabbaa'aa hin taane. Four low-velocity epochs influential dha, orbiitii sadarkaa coverage limited hafe: ilaalchawwan selected kutaalee danda'amaa 171-day marsaa qofa saamudaa godhan, every sadarkaa continuously trace hin godhan. Qormaatawwan rotation, annual saamudaa fudhachuu, weather ykn examined instrument amaloota madda ta'uu identify hin goone, garuu long-timescale brown-dwarf variability principle'n rule out hin godhamne. Unseen object kallattiin imaged hin taane, one-object moodeela preferred dha confirmed miti, planetary-mass body brown dwarf marsu exomoon dha jedhuuf settled rule hin jiru.

Sakatta'a ifaa

Wanti mul'ate: Nightly radial-velocity safartuuwwan digdamii sadii CD-35 2722 B irratti cimaa gara 171-day periodicity qabu. Brown dwarf itself kallattiin imaged; proposed companion miti.

Wanti barreessitoonni prefer godhan: Mallattoo orbiitii yoo ta'e, tokko eccentric companion xiqqaa maassaa near Jupiter's ammaa daataaf simplest dynamically amansiisaa hiika kenna.

Wanti banaa hafe: Companions lama radial velocities fit gochuu danda'u, tested sirnoota usually tasgabbaa'aa hin taane ta'us; long-timescale brown-dwarf variability principle'n excluded miti; unknown viewing angle true companion maassaa undetermined dhiisa.

Wanti barruu hin establish goone: Jalqabaa confirmed exomoon, kallattiin seen satellite, exactly tokko orbiting object, true maassaa 0.92 Jupiter masses, ykn preferred fiizikaalaa moodeela sirrii carraa 99.9%.

Wanti amanamummaa dabalu: Continued radial-velocity safartuuwwan caalaa orbiitii phases hammatan, 171-day mallattoo persists moo qoran, fi yeroowwan tokko- fi two-companion moodeelota adda tilmaamota godhan saamudaa godhan.

Maddoota

Hoy et al., Planetary-mass exosatellite detected around the substellar companion of a star, Nature 655, 865-869 (2026)
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Hoy et al., reduced data and analysis code for Nature_Hoy-2026
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