

Glossary of *Terms*

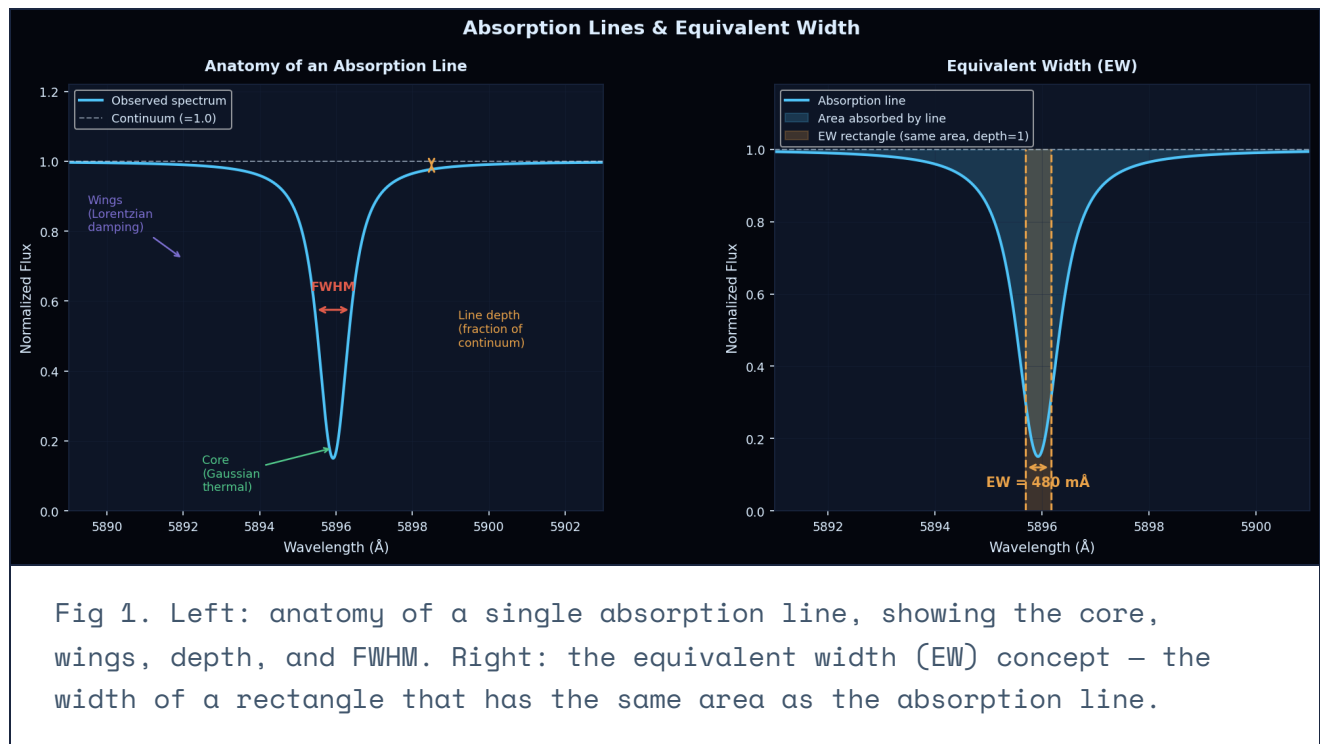
Stellar Spectroscopy · Elemental Abundances · Exoplanetary Chemistry · Science Architecture

— 72 terms across 9 sections.

SECTION 1

The Spectrum

A spectrum is light spread out by wavelength — like a rainbow, but for a star. The terms below describe the key features encountered throughout the Codex.



Spectrum *SPEK-trum*

DEFINITION The distribution of electromagnetic radiation from an object, spread out by wavelength or frequency. A stellar spectrum shows how much light the star emits at each wavelength.

PLAIN ENGLISH Think of it as a detailed "chemical fingerprint" of a star. Just as a supermarket barcode contains information encoded in bars of different widths, a stellar spectrum contains information about the star's composition encoded in the depths and positions of absorption lines.

UNITS Wavelength in Angstroms ($\text{\AA}$) on x-axis; normalized flux (0 to 1) on y-axis

EXAMPLE The HARPS spectrum of 55 Cancri A covers 3780–6910 $\text{\AA}$ at a resolution of $R \sim 115,000$.

SEE ALSO Absorption line, Continuum, Spectral resolution (R)

Absorption Line

DEFINITION A dark feature in a stellar spectrum where atoms in the stellar photosphere have absorbed photons of a specific wavelength, removing that light from the outgoing beam.

PLAIN ENGLISH Imagine a star's light as a full rainbow. Atoms in the outer layers of the star act like tiny "notch filters" — each element absorbs only its specific colours (wavelengths). The result is a rainbow with dark gaps at precise positions. Each gap is an absorption line, and each element has a unique set of gap positions — its spectral fingerprint.

UNITS	Wavelength in Angstroms (Å)
EXAMPLE	The sodium D1 line at 5895.92 Å is one of the most prominent absorption features in the optical spectrum of a K-type star like 55 Cancri A.
SEE ALSO	Equivalent Width (EW), Continuum, FWHM

Continuum	
DEFINITION	The smooth underlying flux level of a stellar spectrum, representing light from the photosphere unaffected by discrete atomic transitions. In a normalized spectrum, the continuum equals 1.0.
PLAIN ENGLISH	The "baseline" of the spectrum — the bright background against which dark absorption lines appear. Measuring a line's depth requires knowing the continuum level precisely. For metal-rich stars like 55 Cnc ([Fe/H]=+0.32), so many lines overlap that finding the true continuum is challenging.
UNITS	Normalized flux (dimensionless, set to 1.0)
EXAMPLE	In the 5000–5400 Å region of 55 Cnc's spectrum, iron lines are so dense that the continuum must be estimated using model atmosphere predictions.
SEE ALSO	Normalization, Equivalent Width

Equivalent Width (EW)

DEFINITION

A measure of the total absorption by a spectral line, defined as the width (in Angstroms) of a rectangular notch with depth equal to 1 (complete absorption) that has the same area as the actual line profile.

PLAIN ENGLISH

The EW is a single number that captures "how much light does this line remove?" regardless of the line's shape. A line that removes a lot of light has a large EW. A faint line has a small EW. The EW is what we measure from the spectrum to eventually calculate how much of each element is present.

UNITS

Angstroms ($\text{\AA}$) or milliAngstroms ($\text{m\AA}$). $1 \text{ \AA} = 1000 \text{ m\AA}$. Most lines: 5–300 $\text{m\AA}$.

EXAMPLE

The Na I D1 line in 55 Cnc has $\text{EW} \approx 480 \text{ m\AA}$ (strong). A typical Fe I line has $\text{EW} \approx 50\text{--}80 \text{ m\AA}$ (moderate). A P I line has $\text{EW} \approx 12 \text{ m\AA}$ (weak — needs high S/N to detect).

SEE ALSO

Absorption line, Gaussian profile, Voigt profile, Curve of growth

FWHM — Full Width at Half Maximum

DEFINITION

The width of a spectral line measured at half the maximum line depth. A standard measure of line sharpness.

PLAIN ENGLISH

If a line's deepest point is 0.3 (flux = 0.3 below continuum = 1.0), the FWHM is the wavelength width measured where the line depth equals $0.3/2 = 0.15$. Narrower lines (small FWHM) are easier to measure and less likely to blend with neighbouring lines. Used in the EW uncertainty formula: $\sigma_{\text{EW}} \approx 1.5 \times \text{FWHM} / \text{S/N}$.

UNITS	Angstroms (Å)
EXAMPLE	A typical HARPS Fe I line has FWHM $\approx 0.08\text{--}0.12$ Å. The Na D lines have FWHM $\approx 0.5\text{--}1.0$ Å due to their strong pressure-broadened wings.
SEE ALSO	Broadening, Spectral resolution

Spectral Resolution (R)	
DEFINITION	A dimensionless number defined as $R = \lambda / \Delta\lambda$, where λ is the wavelength and $\Delta\lambda$ is the smallest wavelength difference the instrument can separate. Higher R = sharper, more detailed spectra.
PLAIN ENGLISH	Resolution tells you how close together two spectral features can be while still appearing as two separate lines. At $R = 115,000$ (HARPS), two lines just 0.05 Å apart can be distinguished. At $R = 42,000$ (ELODIE, used in 2010), lines must be 0.14 Å apart to be separated. This is why HARPS gives us 3× better detail.
UNITS	Dimensionless ratio
EXAMPLE	HARPS: $R \sim 115,000$. ELODIE (2010 thesis): $R \sim 42,000$. The [O I] 6300.304 Å line and its Ni I 6300.336 Å blend are only 0.032 Å apart — only resolved at $R > 100,000$.
SEE ALSO	HARPS, ELODIE

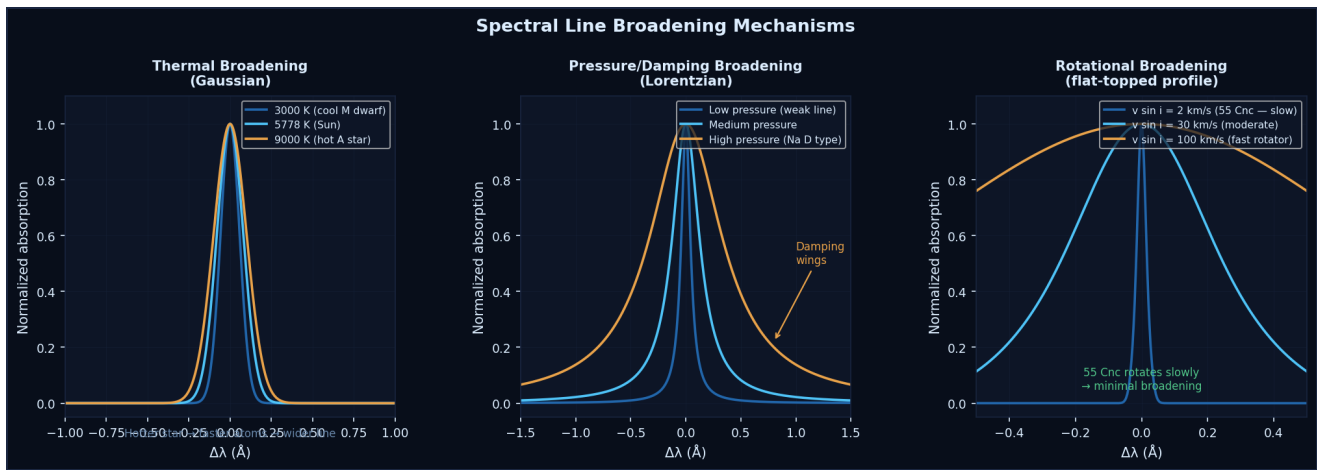


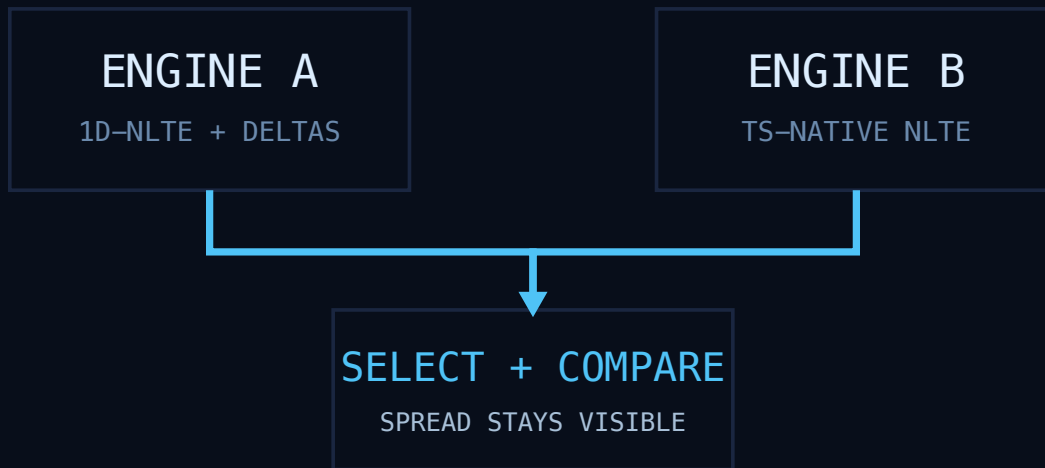
Fig 2. The Na D doublet shown at four different spectral resolutions. At $R=2,000$ (red), the two lines are completely blended. At $R=115,000$ (HARPS, blue), both lines are cleanly resolved and the pressure-broadened wings are visible – critical for accurate EW measurement.

SECTION 2

Codex Architecture

These terms describe how the Codex checks results, freezes references, and keeps the scientific record honest. Entries are alphabetical.

TWO-ENGINE FLOOR



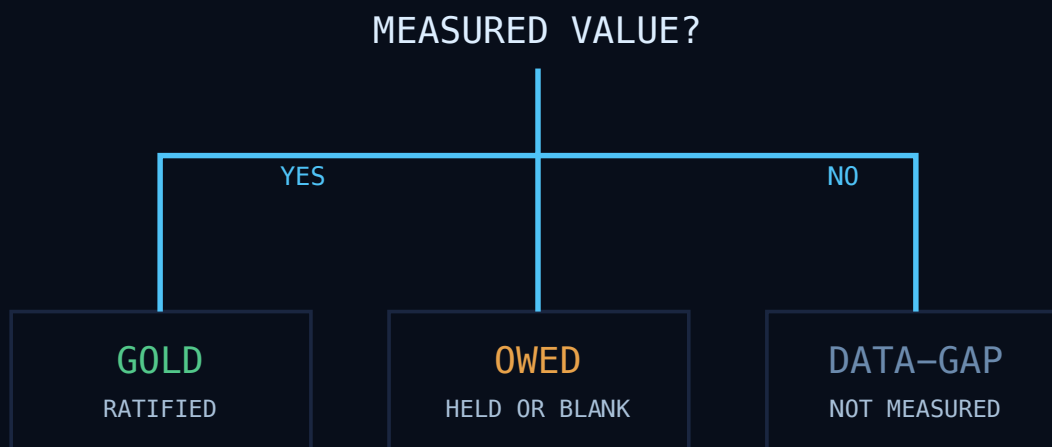
Two independent engines make agreement testable. A disagreement stays visible.

THREE-GATE PROMOTION



Promotion is strict: all three gates must pass. Missing means fail.

RATIFIED FREEZE TIERS



Freeze tiers separate measured-but-held results from true data gaps.

1D-NLTE vs 3D-NLTE Scale

DEFINITION

The distinction between abundances calculated with a one-dimensional atmosphere and non-local thermodynamic equilibrium corrections, and those calculated with a three-dimensional atmosphere and the same physics. The Codex applies a ratified 1D-to-3D correction to iron. Other metals remain on the 1D-NLTE scale until matching grids exist. Ratified by RYA-553; broader grid work is deferred to RYA-550.

Blank-Cause Honesty Tripwire

DEFINITION

A guard in `pipeline/provenance_honesty.py` that refuses to publish a “no independent-gf line survives” claim when a row has surviving lines or a measured value. The verdict emitter and gold-reference builder share the guard. It prevents a measured result from hiding behind a false blank cause. Ratified by RYA-596 and RYA-653.

CODEX_STATE_REGISTER.md

DEFINITION

The mutable state ledger. Every state-changing pull request updates it. A register-freshness guard blocks a pull request that changes a state surface without updating the register. Ratified by RYA-659.

Corroboration-Accept Standing Rule

DEFINITION

An alternative acceptance gate for cases where ionization balance stops on precision rather than value. The rule has five bounded criteria and lives in `docs/SCIENCE_STANDARDS.md`. Titanium with the Mallinson 2024 atom was its first use. Ratified by RYA-545.

Cross-Engine Mix Gate

DEFINITION

A loud-fail guard in `pipeline/engine_selection.py`. It raises when per-line winner selection produces a material disagreement between Engine A and Engine B at the element level. This prevents silent averaging.

Disposition Report

DEFINITION

A machine-generated, per-element report at `data/audit/element_disposition_report.json`. It reads the current phase_c verdict, gold reference, two-engine artifact, and tracker. It classifies each element as PASS held, PASS candidate, provisional flip, owed with cause, or data-gap. The report runs before every freeze and is not hand-editable. Ratified by RYA-663.

Element Status Tracker

DEFINITION

The analyst-facing state table at `data/audit/element_status_tracker.csv`. It is generated from the phase_c verdict, `config/physics_regime_rya400.yaml`, and an editorial sidecar. Hand-editing the CSV breaks the build. Ratified by RYA-654.

Engine A

DEFINITION

The 1D-NLTE production path. It measures an equivalent width or uses synthesis-v2, then applies a per-line NLTE correction from a one-dimensional correction table. The table may come from PySME-derived, MPA, Korotin, INSPECT, or `nlte_cno` data. Engine A supplies the reported gold-reference value for most elements. Ratified by RYA-525.

Engine B

DEFINITION

The Turbospectrum-native NLTE synthesis path. It runs per line with the Gerber TS-native NLTE deck and uses native departure coefficients where a validated model atom exists. It runs beside Engine A for cross-engine verification. Ratified by RYA-533 and RYA-525.

Four-Noun Naming Convention

DEFINITION

The rule that state artifacts use one of four nouns: Catalog for a master enumeration, Register for mutable state facts, Tracker for work or progress, and Reference for frozen validated truth. “Gold” is reserved for a Reference modifier. Ratified by RYA-631.

Gold Reference (gold vN)

DEFINITION

A frozen, hashed, write-once solar abundance reference at `data/reference/solar/solar_abundances_vN.csv`. It is promoted from a phase_c verdict with `scripts/promote_solar_reference.py --apply`. A correction creates vN+1 rather than editing a frozen file. `data/reference/solar/CURRENT` names the active version.

HFS-Resolved Synthesis

DEFINITION

Synthesis in which an atomic line is expanded into its hyperfine-structure components before fitting. The Codex uses it for Mn, Co, Cu, V, Sc, Ba II, Eu II, Na, and Al. Lithium at 6707 Å is not used as an HFS test in warm F stars because depletion can mimic a synthesis failure. Ratified by RYA-269.

Idempotent Correction

DEFINITION

A correction that is safe to request more than once because the pipeline recognizes an already-corrected state. The iron 1D-to-3D correction checks `method_scale`, so re-emitting cannot apply it twice. Ratified by RYA-553.

Ledger Consistency Guard

DEFINITION

A continuous-integration guard that compares the element status tracker, phase_c verdict, and gold reference. It reports any disagreement that lacks a documented ratified divergence. Zero undocumented failures is the target. Ratified by RYA-632.

LEDGERS.md

DEFINITION

The repository-root startup index. It names the canonical register, tracker, catalogs, holdings manifest, and `SEQUENCE.md` read-set. Every session begins by reading that set. Every state-changing pull request updates at least one member. Ratified by RYA-659.

Owed Tier

DEFINITION

A ratified freeze tier that carries no frozen value even when the phase_c verdict contains a measurement. It is used when a value exists but has not been approved as gold-frozen. “Owed-HELD” and “owed-BLANK” are different states. Ratified by RYA-522.

Owed-HELD vs Owed-BLANK

DEFINITION

The distinction between a measured value held from promotion and an element with no measurement. **owed-HELD** means the verdict contains a value that is not yet gold. **owed-BLANK** means no value has been measured. The blank-cause honesty tripwire keeps the states separate. Ratified by RYA-596.

phase_c Verdict

DEFINITION

The canonical per-element abundance verdict produced by [scripts/phase_c_verdict_rya371.py](#). It combines equivalent-width measurements, NLTE corrections, dedicated synthesis channels, and ratified corrections. Each element has one row with its abundance, method, tier, and verdict status. Gold references are built from this channel.

physics_regime

DEFINITION

A per-element classification in [config/physics_regime_rya400.yaml](#). It distinguishes elements measured by equivalent width from elements sourced by synthesis. The tracker generator uses it to separate a verifier's blind spot from a true measurement gap. Ratified by RYA-654.

Ratified Freeze Tier

DEFINITION

A per-element assignment of [gold](#), [owed](#), or [data-gap](#). It controls whether a phase_c verdict value is promoted into the frozen reference. Ryan ratifies each assignment; the computation does not. Ratified by RYA-522.

Ratified GET-DATA Divergences

DEFINITION

Elements that the phase_c verifier reports as having no measurement even though a synthesis or Kitt Peak atlas channel carries a real value. Co, N, K, and Cu are registered in [data/audit/known_verdict_divergences.yaml](#) and pinned by test. They are annotated divergences, not measurement gaps.

Scaled-Drawin vs Ab-Initio (H-Collision Recipe)

DEFINITION

Two families of hydrogen-collision recipes in NLTE model atoms. Scaled-Drawin recipes are empirical and can overpredict corrections. Ab-initio recipes derive the collision physics directly and are often smaller. The model-atom vintage audit records which family each element uses and whether the difference is material. Ratified by RYA-546.

Science Product Package (SPP)

DEFINITION

The per-star release deliverable. Each released star receives one PDF with twelve standard sections covering identity, provenance, parameters, abundances, science products, cross-region checks, anomalies, line diagnostics, uncertainty, caveats, data provenance, and method provenance. Each package is write-once, hashed, and versioned with its gold reference. Ratified by RYA-668.

SEQUENCE.md

DEFINITION

The newest-first landing log at the repository root. Each merged ticket gets one line stating what landed and what it unblocks. It is a narrative overlay on the register, not a state machine. Ratified by RYA-666.

Sirius

DEFINITION

The HP ProBook 450 that serves as the authoritative production runner. Abundance computation and continuous-integration tests run there. The Mac is used for research, development, and pull-request review, not production computation. Ratified by RYA-517 and RYA-567.

State Surface

DEFINITION

A file listed in `pipeline/state_surfaces.py`. Changing one triggers the register-freshness guard. Examples include the verdict generator, gold builder, `config/stars.yaml`, and `config/constants.py`.

Three-Gate Promotion

DEFINITION

The strict test for promoting an element from `owed` to `gold`. Gate 1 requires Engine B to recover the external anchor within 0.05 dex. Gate 2 requires the model atom to pass the validate-don't-tune firewall. Gate 3 requires the absolute dCE to remain within its band against the two-engine artifact. All three gates must pass. A missing gate fails. Ratified by RYA-561.

Two-Engine Floor

DEFINITION

The architecture that runs Engine A and Engine B for every element with a validated model atom. Cross-engine spread is reported as a diagnostic and is never silently averaged into the result.

CROSS_ENGINE_MIX_GATE flags a material conflict between per-line selection and element-level aggregation. Ratified by RYA-525.

Validate-Don't-Tune

DEFINITION

The Codex firewall that forbids tuning an atom or grid to reproduce an anchor. The physics must produce the anchor. The anchor tests the model; it is not the model's target.

SECTION 3

Line Profiles and Broadening

Real spectral lines are not infinitely sharp — they are broadened by several physical mechanisms. Understanding broadening is essential for choosing the right profile model (Gaussian vs Voigt) and for measuring accurate equivalent widths.

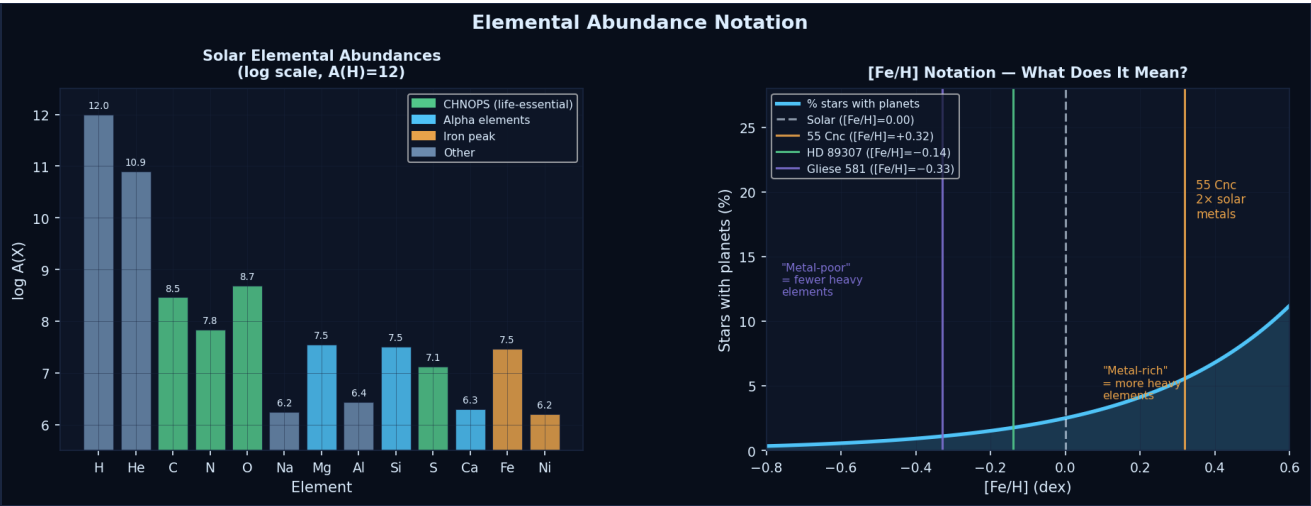


Fig 3. The three main broadening mechanisms. Left: thermal broadening (Gaussian) – hotter stars have broader lines because atoms move faster. Centre: pressure/damping broadening (Lorentzian) – higher pressure widens the line wings. Right: rotational broadening – fast-rotating stars show flat-topped lines. 55 Cancri A rotates slowly ($v \sin i = 2.3 \text{ km/s}$), so rotational broadening is negligible.

Thermal Broadening	
DEFINITION	Broadening of a spectral line caused by the random thermal velocities of atoms in the stellar photosphere. Atoms moving toward/away from us Doppler-shift the absorbed wavelength, smearing the line into a Gaussian shape.
PLAIN ENGLISH	Imagine a thousand sodium atoms all absorbing light at 5895.92 Å. But they're not sitting still — they're moving randomly (thermal motion). Atoms moving toward us absorb slightly bluer wavelengths; atoms moving away absorb slightly redder ones. The result: absorption is spread over a small wavelength range, creating a bell-curve (Gaussian) shaped line.
UNITS	Wavelength (Å); characterized by Gaussian σ or FWHM
EXAMPLE	For 55 Cnc ($T_{\text{eff}} = 5196 \text{ K}$), thermal broadening gives $\sigma_{\text{thermal}} \approx 0.07\text{--}0.10 \text{ Å}$ for typical lines.

SEE ALSO

Gaussian profile, FWHM, Voigt profile

Pressure Broadening / Damping

DEFINITION

Broadening caused by collisions between the absorbing atom and surrounding gas particles, which perturb the atom's energy levels and allow absorption over a range of wavelengths. Creates Lorentzian-shaped wings extending far from the line centre.

PLAIN ENGLISH

When sodium atoms collide with neighbouring hydrogen and helium atoms thousands of times per second in the dense photosphere, the collisions momentarily shift the energy levels, allowing absorption at wavelengths slightly offset from 5895.92 Å. This creates broad "wings" on either side of the line core. The Na D lines are extreme examples — their wings extend ± 3 Å from centre.

UNITS

Wavelength (Å); characterised by damping constant γ_{vdW} (van der Waals)

EXAMPLE

Na D lines ($\text{EW} \approx 480 \text{ mÅ}$): heavily damped, broad wings. A weak Fe I line ($\text{EW} \approx 50 \text{ mÅ}$): negligible damping wings. Voigt profile required for lines with $\text{EW} > 150 \text{ mÅ}$.

SEE ALSO

Voigt profile, Lorentzian, Damping constant

Gaussian Profile

DEFINITION

A bell-curve shaped line profile: $F(\lambda) = 1 - A \times \exp(-1/2((\lambda - \lambda_0)/\sigma)^2)$. Describes lines dominated by thermal and instrumental broadening.

PLAIN ENGLISH	The same bell curve as a normal distribution in statistics. For weak lines ($EW < 80 \text{ m}\text{\AA}$), the Gaussian is an excellent approximation because thermal broadening dominates. For strong lines (Na D, Mg b), the Gaussian misses the pressure-broadened wings and underestimates the EW by up to 25%.
UNITS	Depth A (dimensionless, 0 to 1), width σ ($\text{\AA}$)
EXAMPLE	A Fe I line at $5328 \text{ \AA}$ with $EW = 75 \text{ m}\text{\AA}$: well-fitted by Gaussian. Error vs Voigt $< 2\%$.
SEE ALSO	Voigt profile, Lorentzian, Thermal broadening

Lorentzian Profile	
DEFINITION	A profile with broader, slower-decaying wings than a Gaussian: $L(x) = 1/(1 + (x/\gamma)^2)$. Describes lines dominated by pressure/damping broadening.
PLAIN ENGLISH	Named after physicist Hendrik Lorentz. Falls off as $1/x^2$ instead of the Gaussian's $\exp(-x^2)$ — much slower. This captures the damping wings of strong lines. However, a pure Lorentzian overestimates the core depth. The correct profile for stellar lines is the Voigt (convolution of Gaussian + Lorentzian).
UNITS	Half-width γ ($\text{\AA}$)
EXAMPLE	The damping wings of Na D extend several Angstroms — clearly Lorentzian in shape.
SEE ALSO	Gaussian profile, Voigt profile, Pressure broadening

Voigt Profile *VOIGT*

DEFINITION The mathematically correct line profile for stellar absorption lines: the convolution of a Gaussian (thermal + instrumental broadening) and a Lorentzian (pressure/damping broadening). Implemented efficiently using the Faddeeva function.

PLAIN ENGLISH For weak lines, the Voigt profile automatically reduces to a Gaussian (the Lorentzian component is negligible). For strong lines, the Voigt profile captures the broad wings that a pure Gaussian misses. This is why we use Voigt as our standard fit for all lines with $EW > 80 \text{ m\AA}$.

UNITS Four parameters: amplitude, centre wavelength ($\text{\AA}$), Gaussian FWHM ($\text{\AA}$), Lorentzian FWHM ($\text{\AA}$)

EXAMPLE Na D1 at $5895.92 \text{ \AA}$: Voigt fit with $\text{fwhm}_G \approx 0.16 \text{ \AA}$, $\text{fwhm}_L \approx 0.40 \text{ \AA}$. $EW \approx 480 \text{ m\AA}$. Using Gaussian instead would give $EW \approx 360 \text{ m\AA}$ — 25% too small.

SEE ALSO Gaussian profile, Lorentzian, EW, Damping

Rotational Broadening ($v \sin i$)

DEFINITION Broadening caused by stellar rotation. The near limb moves away from us; the far limb moves toward us. Both absorb at slightly different wavelengths, broadening lines and flattening their tops.

PLAIN ENGLISH A spinning star has one edge moving toward you (blueshifted) and the other edge moving away (redshifted). Both edges have the same absorption lines, but shifted in opposite directions. The result is a line that appears wider and more flat-topped. $v \sin i$ is the rotation speed times the sine of the inclination angle (how tilted the rotation axis is relative to our line of sight).

UNITS	km/s
EXAMPLE	55 Cancri A: $v \sin i = 2.3$ km/s — very slow rotator. Rotational broadening is negligible. The Sun: $v \sin i \approx 2$ km/s. A hot A-type star like Vega: $v \sin i \approx 20$ km/s — significantly broadened.
SEE ALSO	FWHM, Spectral resolution

SECTION 4

Stellar Parameters

Four numbers completely describe the model atmosphere of a main-sequence FGK star. Getting these right is fundamental — errors in stellar parameters propagate into every elemental abundance we measure.

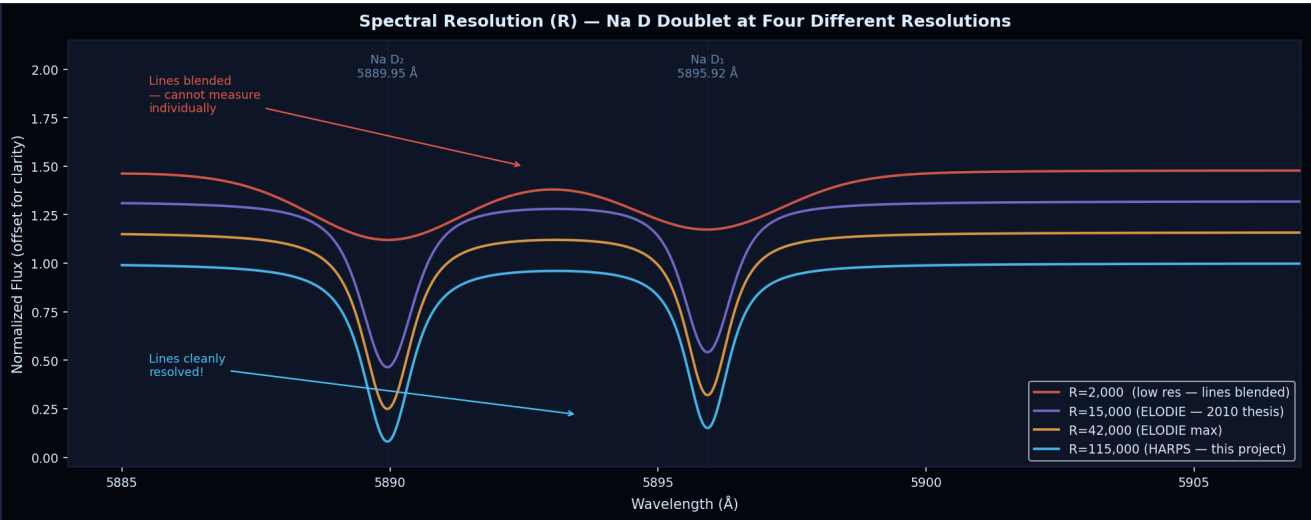


Fig 4. Stellar spectral types from hot blue O stars to cool red M dwarfs. Our primary targets (FGK stars, highlighted) span 3,700–7,500 K and include the Sun (G2), 55 Cancri A (K0), and HD 89307 (G0). Gliese 581 (M3) falls outside this range and requires special treatment.

T_{eff} – Effective Temperature *T-eff*

DEFINITION The temperature of a perfect blackbody that would emit the same total power as the star. In practice: the temperature of the outer photosphere where visible light escapes.

PLAIN ENGLISH T_{eff} is the single most important parameter for a star. It determines which atoms are ionized vs neutral, which controls which absorption lines appear. A star at 5196 K (55 Cnc) looks slightly more orange than the Sun (5778 K) because it emits relatively more red light. Hotter = bluer = more energetic photons.

UNITS Kelvin (K)

EXAMPLE 55 Cnc: $T_{\text{eff}} = 5196 \pm 24$ K (from CHARA interferometry). Sun: 5778 K. A-type star Vega: 9600 K.

SEE ALSO Spectral type, $\log g$, Model atmosphere

$\log g$ – Surface Gravity

DEFINITION The base-10 logarithm of the gravitational acceleration at the stellar surface, in cgs units (cm/s^2). Determines atmospheric pressure, which affects line widths and the balance between neutral and ionized atoms.

PLAIN ENGLISH A higher $\log g$ means stronger gravity at the surface $\rightarrow$ denser, higher-pressure atmosphere $\rightarrow$ more collision broadening $\rightarrow$ stronger damping wings. For dwarfs ($\log g \approx 4.4$) vs giants ($\log g \approx 2.0$), the same spectral line can look completely different. We use Fe I vs Fe II balance to determine $\log g$ (see §4.2 of methodology).

UNITS $\log_{10}(\text{cm/s}^2)$ — "dex" (dimensionless logarithm)

EXAMPLE	55 Cnc: $\log g = 4.41$. Sun: $\log g = 4.44$. A red giant: $\log g \approx 2.0$ (much lower pressure).
SEE ALSO	T_{eff} , Ionization equilibrium, Fe I, Fe II

Microturbulence (ξ) <i>xi — "zy"</i>	
DEFINITION	A velocity parameter representing small-scale, non-thermal motions in the stellar photosphere (convective turbulence). Typically 0.8–1.5 km/s for FGK dwarfs. Suppresses saturation of strong lines.
PLAIN ENGLISH	Even after accounting for thermal and rotation broadening, strong lines still appear broader than a pure thermal model predicts. This excess broadening is modelled as microturbulence — tiny swirling motions in the photosphere smaller than a mean free path. If ξ is wrong, strong lines and weak lines give different abundances. We derive ξ by requiring all Fe I lines, regardless of strength, to give the same iron abundance.
UNITS	km/s (velocity)
EXAMPLE	55 Cnc: $\xi \approx 0.9$ km/s (typical for K dwarfs). Sun: $\xi \approx 1.0$ km/s.
SEE ALSO	Microturbulence check (§4.2), Curve of growth, EW

[Fe/H] – Iron Abundance / Metallicity	
DEFINITION	The logarithmic ratio of iron abundance in a star relative to the Sun. Used as a proxy for overall "metallicity" (abundance of all heavy elements). $[\text{Fe}/\text{H}] = 0.00$ by definition for the Sun.

PLAIN ENGLISH	$[\text{Fe}/\text{H}] = \log(N_{\text{Fe}}/N_{\text{H}})_{\text{star}} - \log(N_{\text{Fe}}/N_{\text{H}})_{\text{Sun}}$. Each +0.10 dex represents ~26% more iron than the previous level. +0.32 dex (55 Cnc) means roughly twice the solar iron abundance. Stars with more metals are more likely to host planets.
UNITS	dex (dimensionless logarithmic ratio)
EXAMPLE	55 Cancri A: $[\text{Fe}/\text{H}] = +0.32$ (metal-rich — twice solar). Sun: $[\text{Fe}/\text{H}] = 0.00$. HD 89307: $[\text{Fe}/\text{H}] = -0.14$ (slightly metal-poor). Gliese 581: $[\text{Fe}/\text{H}] = -0.33$.
SEE ALSO	Metallicity, $[\text{X}/\text{H}]$, $[\text{X}/\text{Fe}]$, dex

Spectral Type (OBAFGKM)	
DEFINITION	A classification system for stars based on their surface temperature and the pattern of absorption lines in their spectra. From hottest (O) to coolest (M).
PLAIN ENGLISH	The mnemonic "Oh Be A Fine Girl/Guy, Kiss Me" helps remember the sequence. Each type is subdivided 0–9 (e.g., G2 = slightly hotter than G5). The Sun is G2V — G-type, subtype 2, V = main sequence ("V" is Roman numeral 5, for luminosity class V).
UNITS	Unitless classification
EXAMPLE	Sun: G2V. 55 Cancri A: K0IV-V. HD 89307: G0V. Gliese 581: M3V.
SEE ALSO	T_{eff} , Main sequence

SECTION 5

Abundance Notation and Units

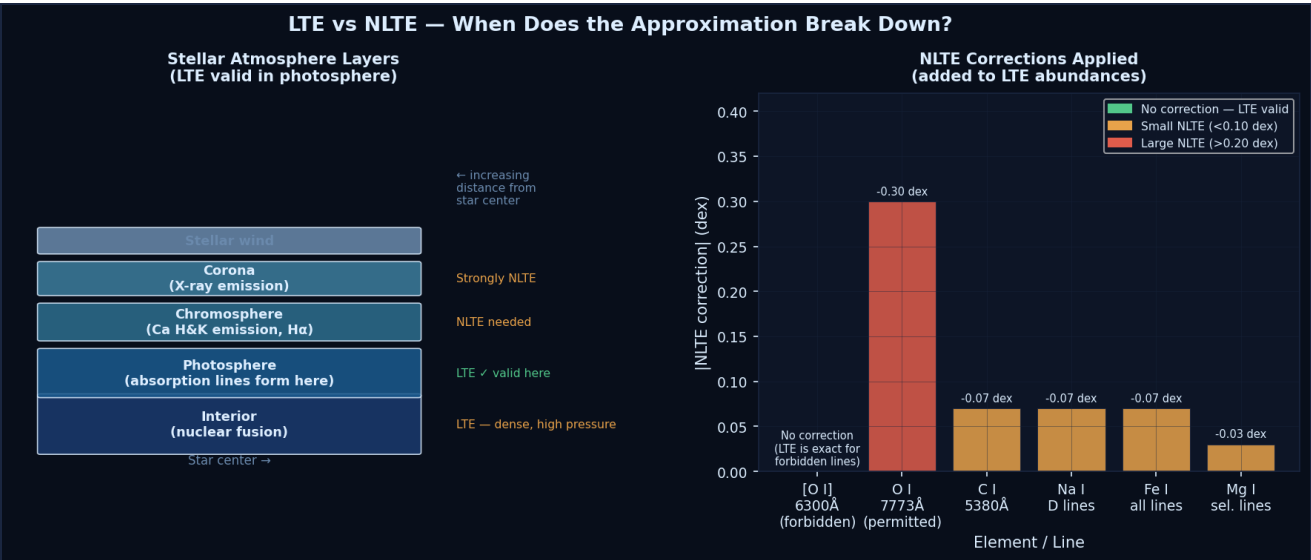


Fig 5. Left: solar elemental abundances on the logarithmic $A(X)$ scale — hydrogen = 12.00 by definition. Life-essential CHNOPS elements (green), alpha elements (blue), and iron-peak elements (orange) are highlighted. Right: $[Fe/H]$ notation explained, showing how metallicity correlates with the probability of hosting planets. 55 Cancri A at $[Fe/H] = +0.32$ is at the high-metallicity end.

dex	
DEFINITION	Short for "decimal exponent." A logarithmic unit used throughout astronomy. A difference of 1.0 dex represents a factor of 10 in the actual quantity.
PLAIN ENGLISH	1.0 dex = factor of 10. 0.3 dex $\approx$ factor of 2. 0.1 dex $\approx$ factor of 1.26 (26% difference). So when we say $[Fe/H] = +0.32$, it means 55 Cnc has $10^{0.32} \approx 2.1$ times more iron than the Sun.
UNITS	Dimensionless (logarithmic)
EXAMPLE	$[Fe/H] = +0.32 \rightarrow$ factor of ~ 2.1 more iron than Sun. $\sigma = 0.05$ dex $\rightarrow$ $\sim 12\%$ uncertainty in actual abundance.
SEE ALSO	$[Fe/H]$, $[X/H]$, $A(X)$

A(X) – Astronomical Abundance Scale

DEFINITION The logarithmic abundance of element X on a scale where hydrogen = 12.00. Defined as $A(X) = \log(N_X/N_H) + 12$, where N_X and N_H are the number of atoms per unit volume.

PLAIN ENGLISH Why +12? Because hydrogen is the most abundant element in stars — about 10^{12} times more abundant than the least abundant elements. Adding 12 makes all abundances positive and manageable. $A(H) = 12.00$ always. $A(Fe) = 7.46$ for the Sun means roughly 1 iron atom per 35,000 hydrogens.

UNITS Dimensionless (logarithmic)

EXAMPLE $A(Fe)_{\text{Sun}} = 7.46$ (Asplund 2021). $A(Na)_{\text{Sun}} = 6.24$. $A(Fe)_{55\text{Cnc}} \approx 7.78$ ($[Fe/H] = +0.32$ above solar).

SEE ALSO $[X/H]$, dex

$[X/H]$ – Elemental Abundance Ratio

DEFINITION The abundance of element X in a star relative to the Sun, on the logarithmic dex scale. $[X/H] = A(X)_{\text{star}} - A(X)_{\text{Sun}}$.

PLAIN ENGLISH The brackets [] are standard notation for "abundance relative to the Sun." $[Fe/H] = 0.00$ means the same iron as the Sun. $[C/H] = +0.20$ means 60% more carbon than the Sun. This notation removes the very large $A(X)$ numbers and focuses on differences from solar.

UNITS dex

EXAMPLE $[Fe/H] = +0.32$ (55 Cnc iron). $[Na/H] = +0.37$ (estimated sodium). $[O/H] = +0.12$ (estimated oxygen — less enhanced than Fe).

SEE ALSO

$[X/Fe]$, $A(X)$, dex

$[X/Fe]$ – Abundance Ratio Relative to Iron

DEFINITION

The abundance of element X relative to iron (rather than hydrogen).
 $[X/Fe] = [X/H] - [Fe/H]$. Reveals nucleosynthetic patterns independent of overall metallicity.

PLAIN ENGLISH

If a star is metal-rich ($[Fe/H] = +0.32$), ALL elements tend to be more abundant — that's just what metal-rich means. $[X/Fe]$ asks: "is element X enhanced or depleted RELATIVE to iron?" Alpha elements (Mg, Si, Ca) enhanced relative to iron ($[\alpha/Fe] > 0$) means the star formed early in galactic history, before Type Ia supernovae had time to add iron.

UNITS

dex

EXAMPLE

$[Mg/Fe] = +0.05$ for 55 Cnc: slightly enhanced Mg relative to Fe — typical for a mildly metal-rich K dwarf.

SEE ALSO

$[X/H]$, Alpha-element enhancement, Galactic chemical evolution

C/O Ratio

DEFINITION

The ratio of carbon to oxygen atoms in a stellar photosphere (or planetary composition). Solar C/O = 0.55. Below ~0.8: oxygen-rich chemistry (silicates). Above ~0.8: carbon-rich chemistry (SiC, graphite).

PLAIN ENGLISH	This is the most important single number for predicting rocky planet composition. On Earth, minerals like quartz (SiO_2), olivine (Mg_2SiO_4), and feldspar dominate because oxygen is more abundant than carbon. If a star has $\text{C/O} > 0.8$, its planets might instead have silicon carbide (SiC) or graphite — possibly even diamond — instead of silicates. The contested C/O measurement for 55 Cancri (0.78 or >1 ?) is a primary science goal of this project.
UNITS	Dimensionless ratio
EXAMPLE	Sun: $\text{C/O} = 0.55$. Earth crust: $\text{C/O} \ll 1$ (oxygen dominant). Carbon planets (hypothetical): $\text{C/O} > 0.8$.
SEE ALSO	$[\text{C/H}]$, $[\text{O/H}]$, Planetary composition

SECTION 6

Model Atmospheres and LTE



Fig 6. Left: stellar atmosphere layers from the dense interior (LTE valid) through the photosphere (where absorption lines form) to the chromosphere and corona (NLTE effects become important). Right: NLTE correction magnitudes for key lines. The forbidden $[\text{O I}]$ line at $6300 \text{ \AA}$ requires NO correction – a key reason it is our preferred oxygen indicator.

Model Atmosphere	
DEFINITION	A mathematical model of the physical conditions (temperature, pressure, density, opacity) in a stellar atmosphere as a function of depth, computed from equations of radiative transfer and hydrostatic equilibrium.
PLAIN ENGLISH	Without a model atmosphere, we can't convert an absorption line depth into an abundance — we wouldn't know the temperature and pressure conditions where the line was formed. ATLAS9 (Kurucz) provides pre-computed grids of model atmospheres parameterized by T_{eff} , $\log g$, $[M/H]$, and ξ .
UNITS	N/A — abstract mathematical model
EXAMPLE	ATLAS9 model for 55 Cnc: $T_{\text{eff}}=5196$ K, $\log g=4.41$, $[M/H]=+0.32$. Each model has 64 atmospheric layers with T, P, density at each depth.
SEE ALSO	ATLAS9, LTE, T_{eff} , $\log g$

ATLAS9 / Castelli-Kurucz	
DEFINITION	The industry-standard grid of 1D, plane-parallel, LTE model atmospheres for FGK stars, developed by Dr. Robert Kurucz (Harvard) and updated by Castelli & Kurucz (2003). Used in the Exoplanet Codex pipeline.
PLAIN ENGLISH	ATLAS9 has been the backbone of stellar abundance analysis since the 1970s. The fact that it's still the standard in 2026 reflects how well the fundamental physics was captured. It's fast, well-tested, and matches observations of FGK dwarfs extremely well. MARCS (Sweden) is an alternative grid used for cross-validation.

UNITS	N/A — software package and data grid
EXAMPLE	For 55 Cnc, we interpolate the ATLAS9 grid to exactly $T_{\text{eff}}=5196$ K, $\log g=4.41$. The model predicts how deep each absorption line should be for a given elemental abundance.
SEE ALSO	LTE, Model atmosphere, MARCS

LTE – Local Thermodynamic Equilibrium

DEFINITION	The assumption that each small volume of the photosphere is in thermal equilibrium at the local temperature T , so that the Boltzmann and Saha equations correctly describe the distribution of atoms across energy levels and ionization states.
PLAIN ENGLISH	LTE is like assuming that every tiny parcel of stellar gas behaves as a perfect "black box" responding only to its local temperature — not to radiation from other layers or from outside the star. This is an excellent approximation in the dense photospheres of FGK dwarfs, where collisions are so frequent that local thermal equilibrium is maintained. It breaks down in low-density regions (chromosphere, corona).
UNITS	N/A — physical approximation
EXAMPLE	LTE valid for: photosphere of FGK dwarfs, most absorption lines. LTE breaks down for: O I 7771–7775 Å triplet (requires NLTE correction of -0.20 to -0.40 dex); resonance lines of Na I, Li I.
SEE ALSO	NLTE, Model atmosphere, Saha equation

NLTE – Non-Local Thermodynamic Equilibrium	
DEFINITION	The condition where the radiation field or collisional rates are insufficient to maintain LTE, so the actual level populations differ from Boltzmann/Saha predictions. NLTE corrections are additive offsets applied to LTE abundances.
PLAIN ENGLISH	Some spectral lines form partly in the low-density outer photosphere where the radiation field (photons from deep inside the star) "pumps" atoms into higher energy states than thermal collisions alone would produce. This changes the line depth in ways the LTE model can't capture. We apply published NLTE correction grids (Amarsi et al. 2021) to fix this.
UNITS	Correction in dex, typically -0.03 to -0.40 dex
EXAMPLE	O I 7773 Å: NLTE correction ≈ -0.30 dex. Na I D: -0.07 dex. [O I] 6300 Å: 0.00 dex (no correction needed — forbidden lines form under LTE).
SEE ALSO	LTE, Forbidden line, Amarsi et al.

Forbidden Line	
DEFINITION	A spectral transition prohibited under electric-dipole selection rules but occurring via magnetic-dipole or electric-quadrupole transitions. Denoted with brackets: [O I] for the forbidden oxygen line.

PLAIN ENGLISH	In high-density environments, atoms are constantly colliding and de-exciting before they can absorb via forbidden transitions. But the forbidden [O I] 6300.304 Å line can still form as an absorption line against the bright continuum. The key advantage: forbidden lines form strictly under LTE — no NLTE correction needed, making them cleaner oxygen abundance indicators.
UNITS	N/A — type of atomic transition
EXAMPLE	[O I] 6300.304 Å: the most important forbidden line for stellar oxygen abundance work. Note: the Ni I blend at 6300.336 Å is only 0.032 Å away — a key systematic for C/O measurements.
SEE ALSO	LTE, NLTE, [O I], Ni I blend

SECTION 7

Nucleosynthesis and Element Groups

The elements in a star did not form in that star — they were forged in supernovae and other stars over billions of years of galactic chemical evolution. Understanding which process made each element explains the patterns we see in stellar abundances.

Alpha Elements (α)	
DEFINITION	Elements with atomic masses that are integer multiples of the helium nucleus (alpha particle, mass 4): O, Ne, Mg, Si, S, Ar, Ca, Ti. Produced primarily by massive stars and Type II supernovae.

PLAIN ENGLISH	These elements are produced by alpha capture — successive fusion of helium nuclei onto heavier elements. They're called "alpha elements" because each step adds one alpha particle (helium nucleus). Since they come from short-lived massive stars, they were abundant early in galactic history. The ratio $[\alpha/\text{Fe}]$ tells us WHEN a star's birth cloud was enriched.
UNITS	N/A — element classification
EXAMPLE	High $[\alpha/\text{Fe}]$ (e.g., +0.3) = old star formed before Type Ia SNe contributed iron. Low $[\alpha/\text{Fe}]$ (~0) = star formed after the galaxy was enriched with iron from Type Ia SNe. 55 Cnc has solar $[\alpha/\text{Fe}]$ — consistent with its ~10 Gyr age.
SEE ALSO	Iron-peak elements, Type II supernova, $[\alpha/\text{Fe}]$, Galactic chemical evolution

Iron-Peak Elements	
DEFINITION	Elements near iron in the periodic table (V, Cr, Mn, Fe, Co, Ni, Cu) that have the highest nuclear binding energy per nucleon. Produced primarily by Type Ia supernovae. Also includes Al as a refractory rocky-planet tracer.
PLAIN ENGLISH	Iron is the "most stable" nucleus — you can't release energy by fusing iron into heavier elements or splitting it into lighter ones. Elements near iron share this high stability. Type Ia supernovae (white dwarf explosions in binary systems) are the primary source, enriching the galaxy with iron-peak elements over billion-year timescales.
UNITS	N/A — element classification

EXAMPLE	Ni/Fe ratio in rocky planets predicts core composition. Co and Cr trace the relative contributions of Type Ia vs Type II supernovae. Cu (odd-Z, bio-essential trace metal) is measured from Cu I 5105/5218 Å. Al (refractory, crustal composition) uses two weak lines at 6696/6698 Å — best-effort measurement.
SEE ALSO	Alpha elements, Type Ia supernova, [Fe/H]

CHNOPS <i>SAY-nops</i>	
DEFINITION	The six elements essential for all known life: Carbon (C), Hydrogen (H), Nitrogen (N), Oxygen (O), Phosphorus (P), Sulfur (S). Their relative abundances in a star predict whether its planets could host life.
PLAIN ENGLISH	These six elements make up ~98% of all living matter on Earth. Carbon forms the backbone of organic molecules. Hydrogen and oxygen combine to make water. Nitrogen is in DNA and proteins. Phosphorus is in ATP (the cell's energy currency) and DNA. Sulfur is in amino acids. Phosphorus is now recognised as the LIMITING nutrient — it's the scarcest of the six in most stellar environments and varies by 10× across FGK stars.
UNITS	N/A — element group acronym
EXAMPLE	The CHNOPS habitability index compares a star's C:N:O:P:S ratios to the "Redfield ratio" — the composition of marine organisms on Earth.
SEE ALSO	Habitability, Redfield ratio, P I lines

s-process Elements (Ba, Y, Eu)	
DEFINITION	Elements heavier than iron formed by the slow neutron capture process (s-process) in AGB (Asymptotic Giant Branch) stars. Include Ba, Y, Zr, La, Ce, Nd.
PLAIN ENGLISH	When iron nuclei slowly capture neutrons (one at a time), with time between each capture for the nucleus to beta-decay, you build up s-process elements. This happens inside evolved giant stars. The ratio Y/Mg is a stellar "chemical clock" — young stars have more Y relative to Mg because more AGB stars have had time to enrich the galaxy.
UNITS	N/A — nucleosynthesis process
EXAMPLE	Ba II 5853.67 Å is a strong, easily measurable s-process line. Y II 4883 Å traces galactic age.
SEE ALSO	r-process, Alpha elements, Galactic chemical evolution

SECTION 8

Pipeline and Analysis Terms

HARPS	
DEFINITION	High Accuracy Radial velocity Planet Searcher. A spectrograph at the ESO 3.6m telescope, La Silla, Chile. Spectral resolution $R \sim 115,000$, wavelength coverage 3780–6910 Å. The primary instrument for Exoplanet Codex spectroscopy.

PLAIN ENGLISH	HARPS was built to measure stellar radial velocities to 1 m/s precision — accurate enough to detect the wobble caused by an Earth-sized planet. This extreme precision requires high spectral resolution, which is exactly what we need for abundance work. It is also why we have 88 archival HARPS spectra of 55 Cancrī — it was a prime target for planet searches.
UNITS	$R = \lambda/\Delta\lambda = 115,000$ (dimensionless)
EXAMPLE	HARPS can resolve features separated by 0.05 Å at 5800 Å. ELODIE (used in 2010 thesis): $R \sim 42,000$.
SEE ALSO	ELODIE, Spectral resolution, ESO archive

HST/STIS	
DEFINITION	Space Telescope Imaging Spectrograph — a UV and optical spectrograph aboard the Hubble Space Telescope. Wavelength coverage ~1150–10,000 Å. Used in the Codex for UV spectral lines inaccessible from Earth's surface.
PLAIN ENGLISH	Earth's atmosphere absorbs ultraviolet light below ~3000 Å, blocking access to many important spectral lines of carbon, nitrogen, oxygen, and other elements. STIS on HST orbits above the atmosphere, providing access to these UV features. For 55 Cnc A, gratings G140M, G750L, G430L were used; for Alpha Cen A, the high-resolution echelle gratings E140H, E140M, E230H, E230M were used.
UNITS	N/A — instrument
EXAMPLE	O I UV lines at ~1302 Å and C II at ~1335 Å are only accessible via HST/STIS — both blocked by the atmosphere at ground-based observatories.

SEE ALSO

HST/COS, MAST, Multi-wavelength analysis, HARPS

HST/COS

DEFINITION

Cosmic Origins Spectrograph — a far-ultraviolet spectrograph aboard the Hubble Space Telescope. Wavelength coverage ~1150–3200 Å. Optimized for high sensitivity in the far-UV where STIS has lower throughput.

PLAIN ENGLISH

COS was installed on HST during Servicing Mission 4 (2009) specifically to boost sensitivity in the far-UV. It detects extremely faint UV features that would otherwise require impractically long exposure times. Used in the Codex where far-UV spectra are available and needed for element coverage.

UNITS

N/A — instrument

EXAMPLE

Far-UV coverage ~1150–3200 Å includes Ly- α at 1216 Å and UV transitions of N, C, Si, and O not accessible from the ground.

SEE ALSO

HST/STIS, MAST, Multi-wavelength analysis

MAST

DEFINITION

Mikulski Archive for Space Telescopes — NASA's archive for data from the Hubble Space Telescope and other space observatories. All HST spectra used in the Codex are retrieved from MAST.

PLAIN ENGLISH	MAST is to space telescope data what the ESO Science Archive is to ground-based data. It hosts the full HST archive — including all STIS and COS spectra — and provides free public access after a 12-month proprietary period. The Codex retrieves all HST data from mast.stsci.edu.
UNITS	N/A — data archive
EXAMPLE	Alpha Cen A: ~111 HST observations retrieved from MAST spanning multiple programs and gratings (downloading as of May 2026).
SEE ALSO	HST/STIS, HST/COS, ESO archive

Multi-wavelength analysis	
DEFINITION	Combining spectra from multiple wavelength regimes — typically optical (HARPS, 3780–6910 Å) and ultraviolet (HST, ~1150–3200 Å) — to access elemental spectral lines unavailable in any single wavelength window.
PLAIN ENGLISH	No single spectrograph covers everything. HARPS gives excellent optical coverage but cannot see UV lines. HST/STIS and COS cover the UV but don't observe from the ground. By combining both data sets, we access a much wider set of element lines — including UV transitions of N, O, C, and S that are essential for the CHNOPS habitability assessment.
UNITS	N/A — analysis strategy
EXAMPLE	For Alpha Cen A: HARPS provides 75 high-SNR optical spectra; HST STIS/COS provides UV coverage down to 1150 Å. Together they enable measurement of all 27 target elements including those with only UV spectral lines.

SEE ALSO

HST/STIS, HST/COS, HARPS, MAST, CHNOPS

S/N – Signal-to-Noise Ratio

DEFINITION

The ratio of the signal (flux) to the noise (random fluctuations) in a spectrum. Higher S/N = cleaner, more precise measurements.

PLAIN ENGLISH

Every spectrum has noise — random fluctuations from photon counting statistics. $S/N = 200$ means the signal is 200 times the noise. For abundance work, $S/N > 200$ is the minimum; $S/N > 400$ is preferred. Weak lines like P I ($EW \approx 12 \text{ m\AA}$) require $S/N > 300$ for a reliable measurement.

UNITS

Dimensionless ratio

EXAMPLE

55 Cnc single HARPS exposure: $S/N \approx 100$. Co-added 88 spectra: $S/N \approx \sqrt{88} \times 100 \approx 940$.

SEE ALSO

Co-adding, Photon noise, EW uncertainty

Radial Velocity (RV)

DEFINITION

The component of a star's velocity along our line of sight (toward or away from us). Measured from the Doppler shift of spectral lines. Must be corrected before co-adding spectra.

PLAIN ENGLISH

If a star moves toward us, all its spectral lines shift to shorter (bluer) wavelengths. If it moves away, they shift to longer (redder) wavelengths. The formula: $\Delta\lambda/\lambda = v/c$. 55 Cnc has a systemic RV of +27.58 km/s (receding at 27.58 km/s). Its 5-planet system causes additional RV variation of $\pm 100 \text{ m/s}$ — small but significant when co-adding spectra.

UNITS	km/s
EXAMPLE	55 Cnc systemic RV = +27.58 km/s. At 5895 Å, this shifts all lines by: $5895 \times 27.58 / 299792 \approx 0.54$ Å.
SEE ALSO	Doppler shift, Barycentric correction, Co-adding

Barycentric Correction	
DEFINITION	A correction applied to observed wavelengths to remove the component of Earth's orbital motion along the line of sight to the star. Applied automatically by the ESO HARPS pipeline.
PLAIN ENGLISH	Earth orbits the Sun at ~30 km/s. Depending on the time of year and direction of observation, Earth is moving toward or away from the target star at up to ± 30 km/s. This shifts all spectral lines by up to ± 0.6 Å at 5800 Å. The barycentric correction transforms wavelengths to what would be measured from the solar system barycentre (centre of mass).
UNITS	km/s velocity correction; Angstroms wavelength shift
EXAMPLE	The ESO HARPS pipeline applies the barycentric correction to all S1D spectra automatically — we only need to apply the stellar systemic RV correction separately.
SEE ALSO	Radial velocity, Doppler shift

Curve of Growth

DEFINITION

The relationship between the equivalent width of a spectral line and the abundance of the absorbing element. Has three regimes: linear, flat (saturated), and damping.

PLAIN ENGLISH

If you add more iron atoms to a stellar atmosphere, iron lines get deeper. But the relationship is not simple. Weak lines grow linearly with abundance (more atoms = proportionally deeper). Strong lines saturate (the core is already black — adding more atoms doesn't help). Very strong lines eventually grow again via pressure-broadened wings. The curve of growth tells us which regime each line is in.

UNITS

Axes: $\log(\text{abundance})$ vs $\log(EW/\lambda)$ (both dimensionless)

EXAMPLE

Fe I at 5328 Å ($EW=75 \text{ mÅ}$): linear regime. Na D ($EW=480 \text{ mÅ}$): damping regime. A flat-part line: sensitive to microturbulence ξ .

SEE ALSO

Equivalent width, Microturbulence, Voigt profile

VALD3 – Vienna Atomic Line Database

DEFINITION

The primary online database for atomic and molecular spectral line data, providing wavelengths, excitation potentials, oscillator strengths ($\log gf$), and damping constants for hundreds of millions of spectral transitions.

PLAIN ENGLISH	VALD3 is to stellar spectroscopists what NIST Standard Reference Materials are to chemists — the authoritative source for atomic data. Before we can calculate abundances from an EW measurement, we need to know the transition probability (log gf) of that line. VALD3 provides this for every line we use.
UNITS	N/A — online database
EXAMPLE	For 55 Cnc, we submitted an "Extract Stellar" request to VALD3 with $T_{\text{eff}}=5196$ K, $\log g=4.41$, threshold 0.001, HFS enabled, returning ~125,000 transitions across 3780–6910 Å for 27 target elements (includes hyperfine structure components for Ba, Eu, Li, Mn).
SEE ALSO	log gf, NIST, Excitation potential

log gf – Oscillator Strength

DEFINITION	The logarithm of the product of the statistical weight (g) and the oscillator strength (f) for an atomic transition. Determines the transition probability — how likely an atom is to absorb a photon of that wavelength.
PLAIN ENGLISH	log gf is the "volume knob" for how strong a spectral line is. A high log gf (e.g., 0.0) means a highly probable transition — a strong line. A low log gf (e.g., -5.0) means a very improbable transition — a weak line. Poorly known log gf values are a major source of systematic uncertainty in abundance work — we only use NIST grades A and B.
UNITS	Dimensionless (logarithmic)
EXAMPLE	Na I D1: $\log gf = -0.184$ (NIST grade A+). Fe I at 5328 Å: $\log gf = -1.466$ (NIST grade A). [O I] 6300 Å: $\log gf = -9.717$ (forbidden line — very weak transition probability).

SEE ALSO

NIST quality grades, Oscillator strength, EW

NIST Quality Grades (A+, A, B, C, D)

DEFINITION Quality grades assigned by the National Institute of Standards and Technology to oscillator strength (log gf) measurements, based on their estimated uncertainty.

PLAIN ENGLISH Not all log gf values are equally reliable. NIST grades each value: A+ (<1% uncertainty), A (<3%), B (<10%), C (<25%), D (>25%). We only use grades A+, A, and B in the Codex pipeline. Using a grade C or D log gf value could introduce a 0.1–0.3 dex systematic error — swamping our actual measurement precision.

UNITS Letter grade (A+, A, B, C, D)

EXAMPLE We measure ~200 lines total but include only ~140 in our primary analysis after filtering for NIST grade $\geq$ B.

SEE ALSO log gf, Systematic uncertainty, NIST

SECTION 9

Key Science Outputs

Mg/Si Ratio

DEFINITION The ratio of magnesium to silicon abundance in a stellar photosphere, used to predict the dominant silicate minerals in rocky planets.

PLAIN ENGLISH	Magnesium and silicon are the two main ingredients of rock-forming silicates. Their ratio determines the mineral balance: $\text{Mg/Si} > 1 \rightarrow$ olivine-dominated mantle (Mg_2SiO_4 , like Earth's upper mantle). $\text{Mg/Si} < 1 \rightarrow$ pyroxene-dominated (MgSiO_3). This directly predicts whether an exoplanet would have an olivine or pyroxene-rich interior — which affects volcanism, plate tectonics, and habitability.
UNITS	Dimensionless atomic ratio
EXAMPLE	Sun: $\text{Mg/Si} = 1.05$. Earth: $\text{Mg/Si} \approx 1.02$. Mars: $\text{Mg/Si} \approx 0.95$. 55 Cnc A: $\text{Mg/Si} \approx 0.93$ (literature) — slight pyroxene tendency.
SEE ALSO	C/O ratio, Fe/Si, Rocky planet composition

Fe/Si Ratio	
DEFINITION	The ratio of iron to silicon abundance, used to predict the core mass fraction of rocky planets.
PLAIN ENGLISH	Iron sinks to the core during planetary formation (iron is denser than silicates). Higher Fe/Si in the host star means more iron in the planet, and therefore a larger iron core relative to the mantle. Earth's Fe/Si is higher than solar because of core formation — a large iron core (32% of Earth's mass) concentrated the iron.
UNITS	Dimensionless atomic ratio
EXAMPLE	Sun: $\text{Fe/Si} = 0.86$ (by mass). Earth: $\text{Fe/Si} = 1.69$ (enriched due to large core).
SEE ALSO	Mg/Si, C/O ratio, Core mass fraction

[α /Fe] – Alpha Enhancement

DEFINITION	The mean enhancement of alpha elements relative to iron: [α /Fe] = mean([Mg/Fe], [Si/Fe], [Ca/Fe], [Ti/Fe]). A tracer of galactic chemical evolution and stellar age.
PLAIN ENGLISH	Early in the Milky Way's history, only massive short-lived stars had died, producing alpha elements but little iron. Over time, Type Ia supernovae (which take ~1 billion years to explode) added large amounts of iron, gradually lowering [α /Fe]. Old stars (formed early) have high [α /Fe]; young stars (like the Sun) have near-solar [α /Fe].
UNITS	dex
EXAMPLE	55 Cnc ([α /Fe] $\approx$ 0): solar-ratio alpha elements — typical for a 10 Gyr old thin-disk star. Metal-poor halo stars ([α /Fe] $\approx$ +0.4): very old, formed before Type Ia SNe.
SEE ALSO	Alpha elements, Type Ia supernova, Galactic chemical evolution

CHNOPS Habitability Index

DEFINITION	A quantitative score comparing a star's measured C:N:O:P:S abundance ratios to the "Redfield ratio" — the elemental composition of marine organisms on Earth. Provides a normalised measure of bio-essential element availability.

PLAIN ENGLISH	Life on Earth needs certain elements in approximately certain ratios. The Redfield ratio (C:N:P = 106:16:1 in marine organisms) is the starting point. By comparing a star's CHNOPS ratios to this biological benchmark, we get a number that captures "how well does this system's chemistry match the chemistry of life?" A score of 1.0 = identical to Redfield. Scores < 1.0 indicate depletion in one or more bio-essential elements.
UNITS	Dimensionless index (Redfield-normalised)
EXAMPLE	A star depleted in phosphorus by 10× relative to carbon would score poorly on the CHNOPS index even if C, N, O, and S look fine — because P is the limiting nutrient.
SEE ALSO	CHNOPS, Redfield ratio, P I lines, Astrobiology