Solar V appendix

Sun · V · downloadable appendix

Document	Solar V appendix
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Solar vanadium: 3.934 ± 0.079

Asplund, Amarsi & Grevesse 2021: 3.90 ± 0.08 · this measurement +0.034 dex

Asplund, Amarsi & Grevesse (2021) give no line recipe we can repeat for this element, so this is our best HARPS product: the Reference Grade analysis with the most complete treatment, then the most lines.

VIS: 3.934 ± 0.079 · HARPS · VIS · V I · reference lines · 1D LTE

Highlighted Products

VIS

3.916 ± 0.077

V I · reference lines · 1D LTE · Kitt Peak (Kurucz 2005) · Reference Grade

red-optical

3.920 ± 0.148

V I · reference lines · 1D LTE · Kitt Peak (Kurucz 2005) · Reference Grade

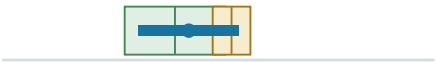
Line grades

Every product is measured on one of three grades of spectral lines and the grades are never mixed in one number.

Grade	What it means	This element
Reference Grade	lines from a published solar line set (Asplund et al. 2021 and similar), measured with the oscillator strengths the authors used	12 products -- SET-V_AGSS21; V I · reference lines; V II · reference lines
Codex Grade	lines chosen by the Codex whose oscillator strength carries a published uncertainty (laboratory measurement, NIST accuracy class A-C, or the paper's own stated error), between 5% and 60% deep	9 products -- V I · Codex-graded lines; V II · Codex-graded lines
Deep Grade	the same oscillator-strength rule on lines deeper than 60% -- stronger lines, more sensitive to damping and the model atmosphere	none for the Sun: every line in this grade is excluded as saturated or an outlier (see Excluded lines)

Error-bar Forest Plot

VIS — HARPS
A(V) dex; axis 3.63–4.31

V II · Codex-graded lines · 1D LTE Codex Grade · 15 lines		4.052 ±0.113
V II · reference lines · 1D LTE Reference Grade · 4 lines		4.072 ±0.090
SET-V_AGSS21 · 1D LTE Reference Grade · 27 lines		3.855 ±0.084
V I · Codex-graded lines · 1D LTE Codex Grade · 174 lines		3.922 ±0.080
V I · reference lines · 1D LTE Reference Grade · 181 lines		3.934 ±0.079

VIS — Kitt Peak (Kurucz 2005)
A(V) dex; axis 3.63–4.31

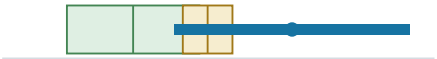
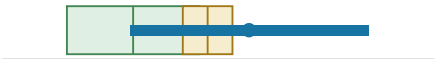
V II · Codex-graded lines · 1D LTE Codex Grade · 14 lines		4.012 ±0.155
V II · reference lines · 1D LTE Reference Grade · 5 lines		3.969 ±0.314
SET-V_AGSS21 · 1D LTE Reference Grade · 27 lines		3.875 ±0.073
V I · Codex-graded lines · 1D LTE Codex Grade · 182 lines		3.895 ±0.077
V I · reference lines · 1D LTE Reference Grade · 191 lines		3.916 ±0.077

VIS — Kitt Peak (1984, molecfit)
A(V) dex; axis 3.63–4.31

V II · Codex-graded lines · 1D LTE Codex Grade · 14 lines		4.016 ±0.127
V II · reference lines · 1D LTE Reference Grade · 5 lines		3.975 ±0.201
SET-V_AGSS21 · 1D LTE Reference Grade · 27 lines		3.880 ±0.073
V I · Codex-graded lines · 1D LTE Codex Grade · 178 lines		3.891 ±0.077
V I · reference lines · 1D LTE Reference Grade · 186 lines		3.915 ±0.077

VIS axis: 3.63 · 3.80 · 3.97 · 4.14 · 4.31 A(V) dex

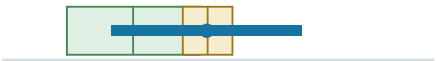
red-optical — IAG FTS
A(V) dex; axis 3.74–4.26

V I · Codex-graded lines · 1D LTE Codex Grade · 13 lines		4.092 ±0.142
V I · reference lines · 1D LTE Reference Grade · 14 lines		4.040 ±0.144

red-optical — Kitt Peak (Kurucz 2005)
A(V) dex; axis 3.74–4.26

V I · Codex-graded lines · 1D LTE Codex Grade · 19 lines		3.920 ±0.148
V I · reference lines · 1D LTE Reference Grade · 19 lines		3.920 ±0.148

red-optical — Kitt Peak (1984, molecfit)
A(V) dex; axis 3.74–4.26

V I · Codex-graded lines · 1D LTE Codex Grade · 12 lines		3.989 ±0.115
V I · reference lines · 1D LTE Reference Grade · 12 lines		3.955 ±0.140

red-optical axis: 3.74 · 3.87 · 4.00 · 4.13 · 4.26 A(V) dex

How to read this forest. Each row is one independent product, preserving its band, holding, engine, indicator and line set. Engines and indicator families are never averaged. Each bar is the uncertainty as Asplund et al. 2021 quote it: line-to-line scatter, the 3D-model term and the NLTE term (at least 0.03 dex). For a molecule the NLTE term is replaced by its dependence on the other element, and the 3D term comes from the 3D-to-1D difference Amarsi et al. 2021 publish for the same band. Atomic-data and observational terms are not in the bar, as in Asplund; they stay in the full error budget attached to the row. Grades describe the supplied line-pool provenance, not engine quality; evaluated theoretical CNO oscillator strengths are not relabelled as laboratory evidence. Quarantined, failed and unconstrained fits have no abundance mark. Experimental products remain explicitly not adopted. Literature references provide context, never tuning targets.

How this was measured

Every vanadium value on this page comes from fitting synthetic spectra to the observed solar spectrum, line by line or band by band, with the vanadium abundance as the free parameter. The synthesis includes the atomic lines and the molecular opacity in every window, so blended absorption is modelled rather than attributed to the line being measured. The continuum is placed locally around every line by comparing the observation with the synthesis on its own highest pixels, and ground-based spectra are telluric-corrected across their full range.

Each indicator is measured independently on each solar spectrum and reported separately; nothing is averaged across indicators or instruments. Where a 3D or NLTE correction is published for the lines, it is applied as its own product (1D-LTE, 1D-NLTE and 3D-NLTE are separate rows). Every value carries a full uncertainty budget: fit, line strengths, microturbulence, continuum, fit window, model atmosphere, telluric residual, and the spread between spectra, each measured by refitting with that one input changed. The headline at the top is the Asplund-grade product: a published line set, the most complete treatment, then the most lines.

Band	VIS
What was measured	V I · Codex-graded lines; V II · Codex-graded lines
Solar spectra	HARPS, Kitt Peak (1984, molecfit), Kitt Peak (Kurucz 2005)
Treatments	1D-LTE
Lines	14–182
Result A(V)	3.891–4.052 (1D-LTE)
Largest uncertainty terms (dex)	model atmosphere 0.06, fit / line-to-line scatter 0.03

Band	VIS
What was measured	V I · reference lines; V II · reference lines
Solar spectra	HARPS, Kitt Peak (1984, molecfit), Kitt Peak (Kurucz 2005)
Treatments	1D-LTE
Lines	4–191
Result A(V)	3.915–4.072 (1D-LTE)
Largest uncertainty terms (dex)	model atmosphere 0.06, fit / line-to-line scatter 0.03

Band	VIS
What was measured	SET-V_AGSS21
Solar spectra	HARPS, Kitt Peak (1984, molecfit), Kitt Peak (Kurucz 2005)
Treatments	1D-LTE
Lines	27
Result A(V)	3.855–3.880 (1D-LTE)
Largest uncertainty terms (dex)	model atmosphere 0.06, fit / line-to-line scatter 0.02

Band	red-optical
What was measured	V I · Codex-graded lines
Solar spectra	IAG FTS, Kitt Peak (1984, molecfit), Kitt Peak (Kurucz 2005)
Treatments	1D-LTE
Lines	12–19
Result A(V)	3.920–4.092 (1D-LTE)
Largest uncertainty terms (dex)	fit / line-to-line scatter 0.13, model atmosphere 0.06

Band	red-optical
What was measured	V I · reference lines
Solar spectra	IAG FTS, Kitt Peak (1984, molecfit), Kitt Peak (Kurucz 2005)
Treatments	1D-LTE
Lines	12–19
Result A(V)	3.920–4.040 (1D-LTE)
Largest uncertainty terms (dex)	fit / line-to-line scatter 0.13, model atmosphere 0.06

Solar vanadium context

Vanadium is measured from neutral V I and ionized V II lines in the visible and red. Most vanadium lines are split into many closely spaced parts by the nucleus (hyperfine structure), and the line lists carry every part, so each line is fitted as the whole group. The reference lines are the V I lines Asplund et al. 2021 used; a wider set of lines with laboratory oscillator strengths and the Codex's own line selection are shown as separate products. The visible V I lines agree with Asplund. V II has only a handful of usable lines, so it is a cross-check rather than the headline. The red lines measured on the IAG atlas read about 0.1 dex higher than the same lines on Kitt Peak. In the infrared (CRIRES+) the vanadium lines are only 1-3 percent deep and we could not measure them: the standard fit finds no line, and a fit that also adjusts the continuum returns similar numbers where there is no vanadium line at all, so no infrared product is published. The near-ultraviolet is held.

Published line sets · gf uncertainty model · Methodology

Download the evidence

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Source feed — includes quarantined fit outputs, not adopted abundances

Complete product visibility audit

Shared website/PDF report

Reproducibility manifest

Complete references and product-to-source bindings

Reproducibility

Generated from the pinned science snapshot. Source commit c48c43b8a2dc2d6b5f6e30f6f9f331bbd3736349
Feed V.json v1.23 · updated 2026-11-19T15:06:35Z
Generated 2026-11-19T08:06:43-07:00 (source commit timestamp)
Feed SHA-256 b3c514388a4f9e04303ffdc9761293f83e6f4b672ea15a5fc077fe6f9c6c2d49
Generator scripts/generate_cno_publication.py v1.0.0

Pinned scientific source

References / Data & Model Sources

Sources are separated by their role. Registered grid lineage and quarantined diagnostics do not imply an adopted abundance or an applied correction.

See the source notes for the distinction between reference lineage and the treatment actually recorded in each feed entry.

Science and provenance source notes

Solar abundance and indicator analyses. Solar V comparison literature; not an adopted Codex abundance. Sources: [1], [2].

Atomic data and gf authorities. V II oscillator strengths of this pool, as the product's own uncertainty budget records them (with their lineage). Sources: [3], [4].

Model and grid sources. Feed treatment: 1D-LTE synthesis (Turbospectrum); no NLTE/3D correction claimed. Sources: [5].

Solar abundance and indicator analyses. Published line set V_AGSS21 (the line selection). Sources: [6].

Atomic data and gf authorities. V I oscillator strengths of this pool, as the product's own uncertainty budget records them (with their lineage). Sources: [7].

Product-to-source index

VIS · HARPS · V II · Codex-graded lines · 1D LTE · [1], [2], [3], [4], [5] V-products-4438624036cc

VIS · HARPS · V II · reference lines · 1D LTE · [1], [2], [3], [5] V-products-7e5d84c371bb

VIS · Kitt Peak (Kurucz 2005) · V II · Codex-graded lines · 1D LTE · [1], [2], [3], [4], [5] V-products-4652c319d8bc

VIS · Kitt Peak (Kurucz 2005) · V II · reference lines · 1D LTE · [1], [2], [3], [5] V-products-605419449d11

VIS · Kitt Peak (1984, molecfit) · V II · Codex-graded lines · 1D LTE · [1], [2], [3], [4], [5] V-products-31b072fcec59

VIS · Kitt Peak (1984, molecfit) · V II · reference lines · 1D LTE · [1], [2], [3], [5] V-products-127e989eecca

VIS · HARPS · SET-V_AGSS21 · 1D LTE · [1], [2], [6], [7], [5] V-products-a3daa3263a48

VIS · HARPS · V I · Codex-graded lines · 1D LTE · [1], [2], [7], [4], [5] V-products-17ccded86b4a

VIS · HARPS · V I · reference lines · 1D LTE · [1], [2], [7], [5] V-products-1208d807c210

VIS · Kitt Peak (Kurucz 2005) · SET-V_AGSS21 · 1D LTE · [1], [2], [6], [7], [5] V-products-5ad91009195c

VIS · Kitt Peak (Kurucz 2005) · V I · Codex-graded lines · 1D LTE · [1], [2], [7], [4], [5] V-products-5a2eca56e670

VIS · Kitt Peak (Kurucz 2005) · V I · reference lines · 1D LTE · [1], [2], [7], [5] V-products-77f0ce702c76

VIS · Kitt Peak (1984, molecfit) · SET-V_AGSS21 · 1D LTE · [1], [2], [6], [7], [5] V-products-ee419979428e

VIS · Kitt Peak (1984, molecfit) · V I · Codex-graded lines · 1D LTE · [1], [2], [7], [4], [5] V-products-8d0a1d7b00b7

VIS · Kitt Peak (1984, molecfit) · V I · reference lines · 1D LTE · [1], [2], [7], [5] V-products-9787e0500a04

red-optical · IAG FTS · V I · Codex-graded lines · 1D LTE · [1], [2], [7], [4], [5] V-products-9aac59334533

red-optical · IAG FTS · V I · reference lines · 1D LTE · [1], [2], [7], [5] V-products-410a1660b4c3

red-optical · Kitt Peak (Kurucz 2005) · V I · Codex-graded lines · 1D LTE · [1], [2], [7], [4], [8], [5] V-products-f94ce11e5f83

red-optical · Kitt Peak (Kurucz 2005) · V I · reference lines · 1D LTE · [1], [2], [7], [8], [5] V-products-51811ac7eee9

red-optical · Kitt Peak (1984, molecfit) · V I · Codex-graded lines · 1D LTE · [1], [2], [7], [4], [5] V-products-f4b4bcc9644a

red-optical · Kitt Peak (1984, molecfit) · V I · reference lines · 1D LTE · [1], [2], [7], [5] V-products-10cdac091bb4

Complete applicable bibliography

Solar abundance and indicator analyses

[1] — Asplund, M.; Amarsi, A. M.; Grevesse, N. (2021). The chemical make-up of the Sun: A 2020 vision. A&A 653, A141 DOI: 10.1051/0004-6361/202140445. source record

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[6] — Scott, P.; Asplund, M.; Grevesse, N.; Bergemann, M.; Sauval, A. J. (2015). The elemental composition of the Sun. II. The iron group elements Sc to Ni. A&A 573, A26 DOI: 10.1051/0004-6361/201424110. source record

Atomic data and gf authorities

[3] — Wood, M. P.; Lawler, J. E.; Den Hartog, E. A.; Sneden, C.; Cowan, J. J. (2014). Improved V II log(gf) Values, Hyperfine Structure Constants, and Abundance Determinations in the Photospheres of the Sun and Metal-poor Star HD 84937. ApJS 214, 18 DOI: 10.1088/0067-0049/214/2/18. source record

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[7] — Lawler, J. E.; Wood, M. P.; Den Hartog, E. A.; Feigenson, T.; Sneden, C.; Cowan, J. J. (2014). Improved V I log(gf) Values and Abundance Determinations in the Photospheres of the Sun and Metal-poor Star HD 84937. ApJS 215, 20 DOI: 10.1088/0067-0049/215/2/20. source record

[8] — Holmes, C. E.; Pickering, J. C.; Ruffoni, M. P.; Blackwell-Whitehead, R.; Nilsson, H.; Engström, L.; Hartman, H.; Lundberg, H.; Belmonte, M. T. (2016). Experimentally Measured Radiative Lifetimes and Oscillator Strengths in Neutral Vanadium. ApJS 224, 35 DOI: 10.3847/0067-0049/224/2/35. source record

Model and grid sources

[5] — Gerber, J. M.; Magg, E.; Plez, B.; Bergemann, M.; Heiter, U.; Olander, T.; Hoppe, R. (2023). Non-LTE radiative transfer with Turbospectrum. A&A 669, A43 DOI: 10.1051/0004-6361/202243673. source record