# 📐 NEXAH — EQUATIONS & VALIDATIONS

Concrete formulas, datasets, and pass/fail metrics for scientific checking of the Stellar & Lunar modules.
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## 0) Units & Constants (Reference)

- **1 AU** = 149 597 870 700 m (IAU 2012, exact)
- **1 ly** ≈ 9 460 730 472 580 800 m (IAU)
- **1 mile** = 1.609344 km (international mile)
- **Royal cubit** (canonical) ≈ 0.5235 m (historic range ~0.523–0.525 m)

📄**CSV:** `units_reference_table.csv`

**Use:** All reported distances/angles must quote both the **native unit** and a **converted AU/ly** value.

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## 1) Gravity Shell Model — Planetary g

**Codex model (testable):**

$$g(n;\theta,\varphi,\phi) = g_c\, n^{-\phi} \cdot \cos\big(n\,\theta + \varphi\big), \qquad g_c = 9.81\,\mathrm{m/s^2}$$

**Current priors (from Titan "Grey Elevator" scans):**
- Local extremum near **n ≈ 1.099–1.100** at **θ ≈ 106°**, **phase ≈ 25°**.
- Assets: `theta_phase_grid_scan_extremum.csv`, `theta_phase_grid_distance_heatmap.png`, `gn_curve_best_extremum_near_1p1.png`.

**Dataset:** `planetary_gravity_codex_mapping.csv` (g_obs for Mercury...Neptune).

**Fit plan:** 1. Assign shell indices **n_p ∈ {1.0, 1.1, 1.2, ...}** (or narrow band around priors) per planet $p$.
2. Optimize **(θ, φ, ϕ)** by RMSE minimization between $g(n_p)$ and observed **g_obs,p**.
3. Report: **RMSE, MAE, $R^2$**, residual plots, and **leave-one-out** validation.
4. Baselines to beat:
- Constant reference, $g \equiv \bar{g}$.
- Simple radius power-law, $g \propto r^{-2}$ with fitted constant.

**Pass / Fail:**
🔗Pass if RMSE(model) < RMSE(baselines) **and** residuals show no systematic trend across planets.

**Outputs:** `gravity_fit_report.md`, `gravity_residuals.csv`, `gravity_residual_plot.png`.

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## 2) Lunar Elemental Axis ↔ Albedo

**Variables:**
- **x:** elemental axis ∈ [0,1] (Ice/Wurzel → $N_2$/Stängel → Fire/Blüte)
- **y:** geometric albedo ∈ [0,1]

**Data:** `lunar_elemental_panel.csv`, `lunar_elemental_panel_csv__extended_.csv`

**Models:**
- Null: $y = a + bx$ (OLS)
- Alt-1: Logistic $y = \sigma(a + bx + cx^2)$
- Alt-2: Monotone spline (shape-constrained)

**Diagnostics:** $R^2$, **AIC/BIC**, **Spearman ρ**, Cook's distance (outlier influence).
**Robustness:** 1-out Cross-Validation; bootstrapped CIs.

**Pass / Fail:**
🔗Pass if an Alt-model improves AIC/BIC vs. linear **and** keeps monotonicity with stable coefficients under CV.

**Charts:** `lunar_elemental_panel_scatter.png` (updated), `lunar_fit_bands.png`, `lunar_residuals.png`.

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## 3) Phase-Scan Reproducibility (n≈1.1 extremum)

**Input:** `theta_phase_grid_scan_extremum.csv`, `theta_phase_grid_distance_heatmap.png`
**Method:** Re-run grid (θ=92…108°, phase=−30…+30°; step ≤1°) with cubic interpolation; perturb grid seed.
**Target:** nearest extremum at **n* ≈ 1.1**.

**Pass / Fail:**
🔗Pass if the optimum remains within **±1° in θ** and **±2° in phase** across perturbations.
**Outputs:** `phase_scan_table.csv` (already present), `phase_scan_windows.svg/png`.

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## 4) Stellar Cross Geometry (Sirius–Vega–Orion)

**Goal:** Validate that constructed axes intersect at the declared flux point on the celestial sphere.

**Data placeholders:** RA/Dec (J2000) for **Sirius A**, **Vega**, **Orion (Trapez/region center)**, optional **South Cross**.

**Procedure:**
- Convert RA/Dec to unit vectors; compute great-circle bearings and intersection point.
- Compare with designed cross angles from `stellar_cross_mapping.png`.

**Pass / Fail:**
🔗Pass if bearings reproduce the designed cross within **±0.5°**.

**Outputs:** `stellar_cross_check.md`, `star_anchor_table.csv` (RA/Dec), `resonant_stellar_cross_diagram.png`.

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## 5) Provenance · Reproducibility

- Sources: **JPL Horizons / SBDB**, **NASA PDS**, **USGS Astrogeology**, **SIMBAD/VizieR**.
- Freeze scripts + random seeds; export all intermediate CSVs to `/data/` with a `DATA_GALLERY_README.md` (schema + links).
- Name every derived figure with the **exact parameter set** in the filename (e.g. `theta106_phase25_phi1618_fitA.png`).

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## 6) Deliverables Checklist (v1 cycle)

- [x] `units_reference_table.csv`
- [x] `EQUATIONS_SHEET_v1.md` (autogenerated in /mnt/data)
- [ ] `planetary_gravity_codex_mapping.csv` → residuals + report
- [ ] `lunar_elemental_panel` fits → AIC/BIC table
- [ ] `theta_phase_grid` reproducibility note
- [ ] `star_anchor_table.csv` + geometry check
- [ ] Zip: `NEXAH_DATA_BUNDLE` (CSVs + thumbnails)

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### Notes

- Keep narrative visuals (Stellar Series) getrennt von **Validation Artifacts**.
- Jede Aussage im AWE-Field erhält hier einen **Test-Haken** (Pass/Fail + Begründung).
- Wenn ein Test *nicht* besteht: klar markieren, Hypothese justieren (Parameter/Modell ändern), erneut testen.