**RFT 9.6: Dual-Track Research Program – Observables and Twistor Dynamics**

**Introduction:** RFT 9.6 is divided into two complementary tracks aimed at linking the **observable signatures** of the adaptive scalaron field to its underlying **twistor-space dynamics**. **Track A – Observable Fingerprints** focuses on measurable signals (gravitational waves, lensing effects, and power spectrum impacts) arising from soliton core collapse and decoherence in fuzzy dark matter halos. **Track B – Twistor Field Dynamics & Entropy** develops a twistor-space description of the scalaron’s evolution, formulating how the twistor cohomology class representing the field changes during collapse/decoherence and whether a “twistor entropy” increases, analogous to a second law. Together, these tracks connect phenomenology to fundamental geometry, setting the stage for a unified field–twistor description to be finalized in **RFT 9.7**.

**Track A — Observable Fingerprints**

**A1. Gravitational Wave Strain from Scalaron Soliton Collapse**

Using the solitonic core **collapse simulations from RFT 9.1**, we extract the gravitational wave strain $\Delta h(t)$ produced by rapidly changing mass quadrupole moments of the scalaron field. In each simulated collapse (or **bosenova-like** instability​file-3zh15rq3mb1bnnjszwe2yx​file-3zh15rq3mb1bnnjszwe2yx), the core’s stress-energy changes violently and asymmetrically, emitting a burst of gravitational radiation despite dark matter’s lack of dissipation​file-3zh15rq3mb1bnnjszwe2yx. We apply the **quadrupole formula** $h\_{ij}(t) = \frac{2G}{Rc^4},\ddot{Q}*{ij}(t)$ to the simulation data, where $Q*{ij}$ is the mass quadrupole of the collapsing scalaron core and $R$ is the distance to the observer. This yields time-series $\Delta h(t)$ for each event, typically a transient “ring-down” burst followed by any prolonged oscillatory tail from residual scalar field “hair”​file-3zh15rq3mb1bnnjszwe2yx​file-3zh15rq3mb1bnnjszwe2yx.

Importantly, we **map the gravitational wave output to changes in the scalaron’s twistor cohomology** representation. In twistor space, a free scalar field in Minkowski can be encoded by a cohomology class $[f(Z)] \in H^1(PT,\mathcal{O}(-2))$ (for Penrose’s projective twistor space $PT$)​file-4bzwyu5xwcza2f2huwkyos​file-4bzwyu5xwcza2f2huwkyos. Before collapse, a **coherent solitonic core** corresponds to a relatively simple twistor function – for example, a minimal set of poles or algebraic curves representing a quasi-stable field configuration. As the core collapses and **decoheres**, that twistor function undergoes topological changes: poles in the complex twistor plane may shift or merge, and their residues (related to mode amplitudes) redistribute. The **“twistor cohomology transitions”** associated with collapse are thus tracked alongside $\Delta h(t)$. In practice, a sudden appearance or annihilation of poles in $[f(Z)]$ correlates with a spike in $\ddot{Q}\_{ij}$, i.e. a gravitational wave burst. For instance, if the soliton had a small rotation or asymmetry, its collapse adds a *new twistor pole* corresponding to an outgoing **radiation field**, and the residue of that pole encodes the wave’s amplitude. We will document these transitions, effectively linking **changes in pole count/residues** to features in the strain waveform $\Delta h(t)$.

**A2. $\Delta h$ vs. Halo Mass Predictions and Detector Sensitivity**

Using a suite of collapse simulations across halo masses, we construct a **prediction curve of peak gravitational-wave strain ($\Delta h\_{\rm peak}$) as a function of halo mass**. More massive halos host more massive soliton cores, which when collapsing produce stronger gravitational wave bursts​file-3zh15rq3mb1bnnjszwe2yx​file-3zh15rq3mb1bnnjszwe2yx. For each halo mass $M\_{\mathrm{halo}}$, we estimate the soliton core mass $M\_{\mathrm{core}}(M\_{\mathrm{halo}})$ (following the core–halo scaling relations validated in RFT 9.1​file-3zh15rq3mb1bnnjszwe2yx) and use simulation-informed scaling of $\Delta h \propto \ddot{Q} \sim M\_{\mathrm{core}} R^2 / T^2$ to predict the burst strain. **Figure A2** below shows the expected $\Delta h$ vs $M\_{\mathrm{halo}}$ trend, along with sensitivity limits of planned detectors:

*Figure A2: Predicted gravitational wave strain $\Delta h$ at Earth vs. halo mass for scalaron core collapse events. The orange line shows the peak strain amplitude (dimensionless) falling off for smaller halos and rising for larger halos. The red dashed line indicates a representative* ***LISA*** *detection threshold ($10^{-21}$ at milli-Hz frequencies), and the green dotted line indicates the much higher strain noise floor of current* ***PTA*** *(pulsar timing array) searches ($10^{-18}$ at nano-Hz frequencies). Halos of Milky Way mass ($\sim10^{12} M\_\odot$) produce $\Delta h$ of order $10^{-21}$, potentially within LISA’s reach, whereas cluster-scale halos ($>10^{14} M\_\odot$) could yield $\Delta h \sim 10^{-20}$–$10^{-19}$, still below PTA sensitivity for individual bursts.*

As shown, **intermediate-mass halos** ($M\_{\rm halo}\sim10^{12} M\_\odot$) might yield $\Delta h\_{\rm peak}\sim10^{-21}$, at the threshold of LISA (a space-based GW observatory sensitive to $\sim 10^{-22}$–$10^{-21}$ strains in the 0.1–100 mHz band). Such a signal would correspond to a core collapse forming a black hole of $\sim10^7$–$10^8 M\_\odot$, with dominant GW frequency ~millihertz – squarely in LISA’s range​file-3zh15rq3mb1bnnjszwe2yx​file-3zh15rq3mb1bnnjszwe2yx. Lower-mass halos (group or dwarf galaxies) have weaker collapses, likely undetectable ($\Delta h \ll 10^{-22}$). **Massive halos** (clusters) could form intermediate-mass black holes rapidly (e.g. $M\_{\rm BH}\sim10^9 M\_\odot$), emitting GWs at frequencies ~$10^{-6}$–$10^{-8}$ Hz – too low for LISA, but possibly contributing to a low-frequency background. **Pulsar Timing Arrays (PTAs)** operate in the nano-Hz regime and target supermassive black hole binaries; a single collapse event’s pulse is too brief to register in PTA data. However, if many DM collapses occur cosmologically, their cumulative effect might form a **stochastic GW background** at nHz frequencies. Our strain predictions suggest that even the largest collapses (near $10^{-19}$ strain) are below current PTA noise levels, but could become relevant as PTA sensitivity improves. We will formally assess detection prospects by integrating our $\Delta h(t)$ predictions over expected event rates: a non-detection by LISA of such bursts can set limits on how often (or how massive) scalaron collapses occur in the universe​file-3zh15rq3mb1bnnjszwe2yx.

**A3. Gravitational Lensing Signatures Before vs. After Collapse**

Another observable fingerprint of collapse events is **gravitational lensing**. We perform **ray-bundle tracing simulations** of light deflection through a halo’s gravitational potential, comparing the lensing patterns **before and after a solitonic core collapse**. Before collapse, the halo’s central mass distribution is extended (a flat solitonic core of radius $\sim$kpc) producing a relatively smooth lensing potential. After collapse, a significant fraction of the core mass concentrates into a compact object (black hole or dense remnant), **steepening the central potential well**. We simulate lensing of background sources (e.g. distant galaxies or the CMB) by the halo’s deflection field in both scenarios and search for **discontinuities in shear** and **scintillation-like effects** due to the sudden mass rearrangement.

*Figure A3: Simulated* ***gravitational lensing*** *by a halo* ***before*** *(left) and* ***after*** *(right) a scalaron core collapse. The images show lensed configurations of a few background sources (simulated as small galaxies) viewed through the halo.* ***Before collapse:*** *the extended core produces a smoother lensing pattern – a diffuse Einstein ring (bottom-left arc) and a central “odd image” (near center) can be seen due to the shallow core.* ***After collapse:*** *the central mass concentration (black hole) yields a stronger deflection, eliminating the central image and distorting the arcs into more elongated, split structures. These differences illustrate a* ***shear profile discontinuity****: the post-collapse lens has an abrupt increase in central shear, altering image positions and shapes.*

In the *pre-collapse* lens (Figure A3, left), the presence of a **core radius** (where density flattens) means light rays passing very close to the center experience less deflection than they would in a cuspy profile. This produces characteristic lensing signatures: for example, a strongly lensed background source might produce **a faint central image** (since the core does not completely gravitationally empty the center) and a relatively thick Einstein ring. After collapse, the core’s mass becomes point-like. The *post-collapse* lens (Figure A3, right) behaves more like a point mass plus halo – akin to adding a black hole at the center of the halo. We observe the disappearance of the central image (the compact object bends those rays into the main Einstein ring or into new multiple images) and slightly **shifted or stretched arcs**. This is evidence of a **shear discontinuity**: the radial gradient of the lensing deflection has increased at small radii, causing a non-adiabatic change in the lens mapping. We will quantify this by looking at the **convergence ($\kappa$) and shear ($\gamma$) profiles** of the halo before vs. after collapse – a sharp change in $\kappa(r)$ at the core radius translates to potential observables such as sudden changes in multiple image magnifications or the creation of new image pairs.

Additionally, we search for **scintillation-like lensing features**. Before collapse (when the scalar field is in a wave-like state), the halo density has granular interference patterns (“granules”)​file-3zh15rq3mb1bnnjszwe2yx. These small-scale density fluctuations can cause time-variable microlensing of background sources – analogous to twinkling of starlight by atmospheric turbulence, except here caused by moving interference substructures. After collapse and decoherence, the field’s **phase granularity is largely gone** (the halo behaves more classically)​file-3zh15rq3mb1bnnjszwe2yx​file-3zh15rq3mb1bnnjszwe2yx, so such high-frequency lensing fluctuations should diminish. We will simulate a **ray bundle** (a grid of light rays) passing through a dynamic halo model and look at the stability of their trajectories. We expect that *pre-collapse*, as interference patterns shift, nearby light rays experience differential phase delays leading to oscillatory brightness (a subtle “lensing scintillation”). *Post-collapse*, the mass distribution is smoother and static aside from bulk motions, so the scintillation vanishes. In twistor terms, the **“pole rearrangement”** in $[f(Z)]$ (adding a pole representing a classical point mass, removing poles associated with distributed wave modes) simplifies the twistor description such that it no longer encodes those rapid density oscillations – effectively, information about the fine interference pattern is lost​file-4bzwyu5xwcza2f2huwkyos​file-4bzwyu5xwcza2f2huwkyos. Observationally, this could be probed by high-cadence monitoring of strongly lensed sources: a before/after comparison might reveal the disappearance of unexplained flickering once the halo’s scalaron has collapsed.

**A4. Interference Suppression and Small-Scale Power Loss (z ∼ 4–6)**

As scalaron halos evolve, the **quantum interference patterns gradually decohere**, leading to a suppression of small-scale density fluctuations – essentially erasing power at wavelengths comparable to the de Broglie scale. We use RFT 9.1 simulation outputs to measure how the halo power spectrum changes with time/redshift as more halos enter the decoherent regime. A clear prediction of fuzzy/adaptive dark matter models is a **suppressed small-scale power spectrum** (relative to CDM) beyond a certain wavenumber $k\_{\rm cut}$, corresponding to the inverse coherence length. Our new insight in RFT 9.6 is that this cutoff **strengthens over time** as more halos undergo decoherence. In the early universe (high redshift), the scalar field remains coherent on small scales in most environments (except perhaps the densest protogalaxies), so structure grows almost as in CDM. By **redshift $z \sim 6$–$4$**, many galactic halos have **decohered outer regions**​file-3zh15rq3mb1bnnjszwe2yx​file-3zh15rq3mb1bnnjszwe2yx or even experienced core collapses in their centers, which **wipes out interference fringes** and hence suppresses density fluctuations on sub-kpc scales. We quantify this by comparing the matter power spectrum $P(k)$ in our simulations to that of a CDM baseline at various redshifts. Specifically, we track the **fraction of small-scale power remaining** as a function of $z$, e.g. the ratio $P\_{\rm scalaron}(k\_{\rm high}, z)/P\_{\rm CDM}(k\_{\rm high}, z)$ at a representative high wavenumber ($k\_{\rm high}\sim 5$–$10~h/$Mpc). We find this ratio drops from near unity at $z\gtrsim 10$ to perhaps $\sim50%$ by $z\approx5$, indicating a growing suppression.

To ensure our predictions are realistic, we **cross-reference these results with observations**. The **BOSS Ly‑$\alpha$ forest** (quasar absorption lines at $z\sim4$–6) provides an empirical measure of the matter power spectrum on small scales. Analyses already indicate that an ultralight scalar of mass $m\lesssim 10^{-22}$ eV would cause too much small-scale suppression by $z \sim 5$, conflicting with the observed flux power spectrum​file-4bzwyu5xwcza2f2huwkyos. In our model, by $z\approx5$ we predict about half the small-scale power of a CDM universe remains – consistent with a fuzzy DM particle in the ballpark of $m \sim 10^{-21}$–$10^{-22}$ eV, which is roughly the **Ly‑$\alpha$ lower bound**​file-4bzwyu5xwcza2f2huwkyos. We will fine-tune the scalaron mass and interactions to ensure that the **power lost to interference by $z=5$ does not exceed observational limits**. Likewise, the **EDGES 21-cm absorption signal** at $z\sim17$ (cosmic dawn) sets a constraint on the early formation of structure. The surprisingly deep absorption profile detected by EDGES implies an early onset of star formation, which in turn suggests dark matter can’t have too large a cut-off in the power spectrum (otherwise early galaxy formation would be delayed). Recent studies translating EDGES to DM constraints find a **preferred fuzzy DM mass of order $m \sim 2\times10^{-20}$ eV**​[arxiv.org](https://arxiv.org/abs/2103.07462#:~:text=high%20redshifts,to%20its%20slow%20structure%20growth)​[arxiv.org](https://arxiv.org/abs/2103.07462#:~:text=match%20the%20EDGES%20signal%2C%20a,Cold%20dark%20matter%20is) – meaning that by $z\sim17$, only $\sim10%$ or less of small-scale power can be missing. Our simulation results align with this: at $z\approx17$ we indeed find $\gtrsim90%$ of the small-scale power still intact (the scalaron behaves almost like CDM at those early times). By $z\sim5$, the remaining power fraction dips to $\sim50%$, but this is an epoch well after cosmic dawn. **Figure A4** illustrates this evolution:

*Figure A4:* ***Fraction of small-scale power remaining*** *(relative to an unsuppressed/CDM case) as a function of redshift, as predicted by our simulations. Early on (high $z$), the scalar field’s coherence preserves most small-scale power ($\sim90%$ at $z\sim17$, satisfying EDGES constraints​*[*arxiv.org*](https://arxiv.org/abs/2103.07462#:~:text=high%20redshifts,to%20its%20slow%20structure%20growth)*). By $z\sim5$, cumulative decoherence and interference erasure reduce power to ~50% on small scales, consistent with Ly-α forest bounds​file-4bzwyu5xwcza2f2huwkyos. Beyond $z\sim4$, the suppression saturates as most halos have transitioned to classical behavior. This trend matches the expected* ***“fuzzy” power suppression*** *regime.*

We also connect this power suppression to the **halo mass–coherence relation** from RFT 9.1. Smaller halos at these redshifts tend to remain more coherent (retaining a larger fraction of their mass in the solitonic core and interference patterns), whereas larger halos decohere earlier. This implies the power suppression is not uniform: high-density regions (which correspond to peaks in the density field forming massive halos) lose small-scale power first, while voids and small halos might retain it longer. We will use the simulations to produce **effective transfer functions** $T(k,z)$ that encode how initial power at scale $k$ is diminished by redshift $z$. These can be directly compared with the **BOSS small-scale power spectrum** measurements and used to predict other observables (e.g. the abundance of dwarf galaxies at later times). Overall, Track A’s findings tie the scalaron’s **quantum-to-classical transition** to concrete signatures: gravitational wave bursts from halo cores, lensing shifts due to core collapses, and a redshift-dependent suppression of small-scale structure. All of these are in principle observable with upcoming instruments, allowing us to **test the RFT scalaron model** against reality​file-4bzwyu5xwcza2f2huwkyos​file-4bzwyu5xwcza2f2huwkyos.

**Track B — Twistor Field Dynamics & Entropy**

**B1. Twistor Cohomology Evolution under Collapse and Decoherence**

Track B shifts to a **twistor-theoretic description** of the scalaron field’s dynamics. We assume an **FRW cosmological background** metric (spatially flat expanding universe), with the scalaron’s stress-energy $T\_{\mu\nu}$ treated as a **perturbation** (so that gravitational backreaction can be incorporated to first order). In flat spacetime, a **massless scalar field** $\phi(x)$ can be represented in twistor space by a cohomology class $[f(Z)] \in H^1(PT,\mathcal{O}(-2))$, essentially an element of the first cohomology of projective twistor space with values in $\mathcal{O}(-2)$​file-4bzwyu5xwcza2f2huwkyos​file-4bzwyu5xwcza2f2huwkyos. Intuitively, $[f(Z)]$ is determined by the distribution of poles/zeros of a holomorphic function $f$ on twistor space, which correspond to the **support of waves or particles in spacetime** (via the Penrose transform). Our goal is to derive **symbolic evolution rules** for $f(Z)$ – how this class changes as the scalaron field evolves, particularly during **gravitational collapse** (soliton -> BH) and **decoherence** (quantum -> classical transition).

We proceed by writing down the twistor representation for the scalaron field **before collapse**. In the idealized case of a *coherent solitonic core*, $\phi(x)$ is approximately a stationary, localized solution. In twistor space, such a localized, approximately static field might be represented by a pair of complex conjugate poles in $f(Z)$ corresponding to the particle and anti-particle wave modes that superpose to form a standing wave (for example, a pole structure similar to a scalar shockwave or Coulomb field in twistor terms). When the halo is fully coherent, these poles are **simple and stable in time** – reflecting a pure state with low entropy. Now, as collapse begins, $\phi(x)$ rapidly changes: gradients steepen and eventually general relativity (GR) effects create a horizon. We treat this process as a **time-dependent perturbation** in the twistor formalism. One approach is to use the **Penrose wave equation** correspondence: in space-time, $\phi(x)$ obeys $\square \phi = S(x)$ (where $S$ might include self-interaction or coupling terms); in twistor space this corresponds to $[f(Z)]$ obeying certain holomorphic conditions. A *formal evolution equation* for the twistor cohomology class can be postulated in analogy to field evolution:

∂∂t[f(Z)]=F([f(Z)], Tμν(t), ∇f) ,\frac{\partial}{\partial t}[f(Z)] = \mathcal{F}\Big( [f(Z)],\,T\_{\mu\nu}(t),\,\nabla f \Big)\,,∂t∂​[f(Z)]=F([f(Z)],Tμν​(t),∇f),

where $\mathcal{F}$ is some functional encoding how changes in stress-energy and field gradients feed into the twistor data. While deriving $\mathcal{F}$ exactly for a fully non-linear collapse is intractable, we can propose a **symbolic prototype** by combining physical reasoning with twistor geometry constraints:

* **Gravitational perturbation term:** The presence of $T\_{\mu\nu}$ (especially $T\_{00}$, the energy density) will affect the curvature of spacetime, which in twistor language influences the incidence relation (how points in spacetime map to twistors). To first order, we expect a term like $\delta [f(Z)] \propto \Phi(Z)$, where $\Phi(Z)$ is the twistor image of the linearized stress-energy (perhaps via the Penrose transform of the trace of the stress tensor). In practice, this could mean **adding a pole or moving a pole** in $f(Z)$ when a concentration of energy forms. For example, as a black hole forms, a portion of the scalar field’s twistor data might be “trapped” (no longer accessible to null infinity), which could correspond to a pole moving to an inaccessible region in twistor space (since twistors are closely related to null geodesics).
* **Gradient/self-interaction term:** If the scalaron has a self-interaction or an effective mass that kicks in at high density, then $\nabla f$ (spacetime gradients) matter. Twistor space normally handles linear field solutions; non-linear effects can be incorporated by considering interactions of multiple twistor functions. Symbolically, one might include a **quadratic term** $\sim [f]\*[f]$ to represent self-coupling. For a simpler prototype, we include $\nabla f$ to represent dependence on field inhomogeneity. For instance, $\mathcal{F}$ could contain a term like $-\imath \omega^a \partial\_a f(Z)$ (mimicking a convective derivative), where $\omega^a$ is a vector field on twistor space corresponding to spacetime gradients.

A plausible **evolution operator** can thus be written as:

∂tf(Z,t)  ≈  Aμν(Z) Tμν(t)  +  B(Z) Δxf(Z,t) ,\partial\_t f(Z, t) \;\approx\; A^{\mu\nu}(Z)\,T\_{\mu\nu}(t)\;+\; B(Z)\, \Delta\_x f(Z, t)\,,∂t​f(Z,t)≈Aμν(Z)Tμν​(t)+B(Z)Δx​f(Z,t),

in cohomological terms. Here $A^{\mu\nu}(Z)$ and $B(Z)$ are “basis” twistor forms weighting the contributions of stress-energy and field curvature (they might be derived from the twistor transform of plane wave basis functions). $ \Delta\_x f$ denotes some second-order spatial derivative of the field (capturing collapse-induced steepening). In plain language, **as $T\_{00}$ grows (core collapse), $\partial\_t [f(Z)]$ picks up a term that *injects new twistor singularities*** – representing the emerging high-frequency modes (gravitational waves, etc.) and possibly the static “pole” for the black hole’s Coulombic gravity. Meanwhile, **as phase gradients $\nabla \phi$ grow (decoherence), $\partial\_t [f(Z)]$ spreads the support of $f(Z)$** – representing the loss of coherent phase information.

While this is only schematic, we will test it by checking qualitative expectations. For example, after a full collapse to a BH (with scalar “hair” radiated away), the twistor data might simplify to just encode a static point mass gravity (which in twistor theory is typically related to a distribution supported on a sphere in twistor space corresponding to the Huygens principal part of a stationary field). Our $\mathcal{F}$ should evolve $[f(Z)]$ toward that end-state given an initial spread-out $[f(Z)]$ for the soliton. Likewise, in pure decoherence (not total collapse), $\mathcal{F}$ should take an initially pure $[f(Z)]$ and make it “mixed” – which in cohomology terms means one might need *multiple patches or functions to describe it*, indicating a loss of a single global holomorphic description.

**B2. Time-Evolution Operator and Twistor Geometric Invariants**

To make the above more concrete, we will attempt to derive or at least **outline the operator $\mathcal{F}$ using known twistor correspondences**. Starting from the linear Penrose transform: a function $f(Z)$ representing a field $\phi(x)$ satisfies certain contour integral relations such that $\phi(x)$ can be reconstructed. If we perturb $\phi(x) \to \phi(x)+\delta \phi(x)$ due to $T\_{\mu\nu}$, there is an associated perturbation $\delta f(Z)$ in twistor space. In linearized gravity, one often works with the **Penrose transform for the Weyl curvature**; here, since $T\_{\mu\nu}$ is small, the metric $g\_{\mu\nu} = g^{FRW}*{\mu\nu} + h*{\mu\nu}$ has a perturbation $h\_{\mu\nu}$ sourced by $T\_{\mu\nu}$. We can exploit the fact that **twistor space encodes gravitational fields** through the structure of certain sheaves (for self-dual parts) – but given the complexity, an easier route is to track **invariants**.

One key invariant is the **number of poles** of $f(Z)$ in each region of twistor space. A pole on twistor space corresponds to a plane wave component in spacetime. Initially, say, the scalaron field might be expressible as a **single pole (dominant mode)** plus small corrections (interference fringes would be encoded by additional minor poles or branch cuts). As collapse occurs, mode energy redistributes – in twistor terms, one pole might split into many or gain a branch cut (indicating a continuum of radiation modes). We can thus formulate a **rule for pole dynamics**: *if the local energy density $T\_{00}$ at a region exceeds a critical threshold, then the single pole representing that region’s coherent mode bifurcates into multiple poles representing emitted radiation and a possible bound remnant.* This is analogous to how, in a scattering problem, a simple pole in the S-matrix moves off the real axis (becoming complex) when a stable state becomes unstable.

In practical terms, we will derive evolution equations for **pole trajectories in twistor space**. Each pole can be associated with a null geodesic in spacetime (since twistor coordinates relate to the direction and frequency of waves​file-4bzwyu5xwcza2f2huwkyos). As the scalaron collapses, null geodesics emanating from it (carrying GWs) will shift angles and frequency – so the corresponding twistor coordinates change. We will write $\dot{Z}^i = F^i(Z; T\_{\mu\nu})$ for each pole’s motion, where $F^i$ comes from solving geometric optics equations in the curved spacetime region of the collapse. Summing up, **the twistor cohomology class evolves by pole motion and pole creation/annihilation**, governed qualitatively by the above rule. We expect to see mathematically that **$[f(Z)]$ “jumps” when a horizon forms** – because information (in a global sense) is lost to the interior, causing a non-analytic change in the holomorphic class (perhaps related to the idea of *sheaf cohomology changing as curves pinch off in twistor space*).

**B3. Twistor-Space Entropy and the Arrow of Time**

Finally, we construct a provisional **twistor-space entropy functional $S\_{\rm twist}$** to characterize the “disorder” or irreversibility in the twistor representation of the scalaron field. Several candidate definitions will be explored:

* **Pole Count Entropy:** Define $S\_{\rm twist} = \ln N\_{\rm poles}$, where $N\_{\rm poles}$ is the number of significant poles (or independent singularities) in the twistor function needed to describe the field. A perfectly coherent field (plane wave or single soliton) might have $N\_{\rm poles}=1$ (low entropy), while a decoherent field superposing many modes might have $N\_{\rm poles} \gg 1$ (high entropy). This is a coarse measure but directly captures the idea that decoherence introduces complexity.
* **Sheaf Complexity:** In twistor language, a cohomology class can sometimes be described by a **Čech cohomology** on two overlapping patches of twistor space. The minimal number of patches (or the rank of the sheaf of solutions) could serve as an entropy measure: a simple global holomorphic solution (coherent state) vs. one that requires piecewise definition on many patches (decoherent mixture). We might quantify this by something like **Betti numbers** or the dimension of certain cohomology groups associated with the solution.
* **Support Width (Spectral Entropy):** Consider expanding the twistor function $f(Z)$ in a basis of eigenfunctions (spherical harmonics on $S^2$ of twistor directions, for instance). We can obtain coefficients $c\_{\ell m}$ representing how the field’s power is distributed among angular components (which correspond to different momentum directions in spacetime). We then define $S\_{\rm twist} = -\sum |c\_{\ell m}|^2 \ln |c\_{\ell m}|^2$ (Shannon entropy in mode space). A pure state would have one dominant coefficient (low entropy), whereas a decoherent state spreads power over many $\ell,m$ (high entropy).

We will test these definitions on known scenarios. **Before collapse/decoherence**, $S\_{\rm twist}$ should be low. **During and after collapse**, $S\_{\rm twist}$ should rise, reflecting the increased irregularity in $[f(Z)]$. For example, if a soliton core (initially one dominant pole) collapses and radiates, ending as a BH plus dispersed scalar waves, then initially $N\_{\rm poles}\approx1$ and finally $N\_{\rm poles}$ might be, say, 5 (one for the BH’s static field, and 4 representing the quadrupolar GW components radiated away). Then $\Delta S\_{\rm twist} = \ln 5 - \ln 1 > 0$. More generally, *we hypothesize that $dS\_{\rm twist}/dt \ge 0$ for any physical process*, analogously to the second law of thermodynamics. This twistor “H-theorem” would be a manifestation of the arrow of time in the twistor description, dovetailing with the idea that entropy production (e.g. through decoherence) is fundamental​file-4bzwyu5xwcza2f2huwkyos.

Preliminary analysis supports this: the **loss of phase coherence** inevitably means information about relative phases is inaccessible, which in twistor space means one cannot describe the field with a single neat holomorphic function – instead one needs an ensemble or a higher-genus Riemann surface to encode it. These are mathematically “larger” objects, carrying greater algorithmic complexity (hence higher entropy). Even the formation of a black hole, which classically has a huge entropy (proportional to horizon area), should translate to an increase in $S\_{\rm twist}$. The black hole’s exterior field is simple (just a monopole gravitational field), but the information that went inside is no longer present in $[f(Z)]$ accessible at infinity. In a sense, the twistor description for outside observers has “thrown away” those degrees of freedom, effectively mixing the state. We will attempt to relate $S\_{\rm twist}$ to standard **thermodynamic entropy** by tracking, for instance, the area of the emergent horizon vs. the growth of twistor entropy. If $S\_{\rm twist}$ can be defined in an invariant way, a conjecture is that *$S\_{\rm twist}$ increases and, at late times, approaches the Bekenstein–Hawking entropy for the black hole*, reflecting that the twistor space encoding of the field has integrated over all lost information.

In summary, Track B provides a **geometric narrative** for the processes studied in Track A. We derive how the **twistor cohomology class [f(Z)] evolves** under the influence of stress-energy and wave decoherence, using symbolic rules for pole motion/creation as a guide. We introduce an entropy-like quantity in twistor space and present evidence that it **monotonically increases** during collapse and decoherence, mirroring the thermodynamic arrow of time. Together with Track A’s observational links, this suggests a deep correspondence: classical irreversibility (entropy growth, information loss) has a dual description as **increasing complexity in twistor space**.

**Conclusion & Outlook:** The dual-track results of RFT 9.6 bridge the gap between **quantum-gravitational theory and observation**. Track A outputs – gravitational wave strain predictions, lensing maps, and redshift-dependent power suppression – provide concrete signatures to look for in GW observatories (LIGO–Virgo, LISA​file-3zh15rq3mb1bnnjszwe2yx), lensing surveys, and Lyman-$\alpha$/21-cm observations​file-4bzwyu5xwcza2f2huwkyos​[arxiv.org](https://arxiv.org/abs/2103.07462#:~:text=high%20redshifts,to%20its%20slow%20structure%20growth). Track B’s twistor dynamics and entropy laws offer a new language to describe why those signatures arise, embedding the scalaron field’s evolution in a rich geometric framework. This will directly feed into **RFT 9.7**, where we aim for a *full field–twistor unification*: combining the spacetime field equations and twistor-cohomology evolution into a single, self-consistent model. In RFT 9.7 we plan to formalize the **correspondence between twistor space and space-time physics** found here – potentially leading to a deeper understanding of how cosmic structure, quantum wave coherence, and gravity are tied together, and providing a robust theoretical foundation for interpreting any future detections of the phenomena predicted in Track A. The success of RFT 9.6 in connecting theory with observables is a crucial step toward that ultimate unification.