describe the space-time evolution of the Wigner transforms, whereas the constraint equations describe the "orthogonal" evolution in momentum space, and express a normalization condition imposed by unitarity and the renormalization group. In order to relate these operator equations to physically-relevant (observable) quantities, we define the *Wigner operators* $\hat{F}_\alpha(r,p)$ $(\alpha \equiv q, g, \chi, U)$ in terms of the operators $\mathcal{S}$, $\mathcal{D}$, Δ, $\tilde{\Delta}$ and the self energies Σ, Π, Δ, $\tilde{\Delta}$ as follows:

$$
\begin{aligned}
i\mathcal{S}_{ij}(r,p) &= \delta_{ij}\ (\gamma \cdot p + \Sigma)\ (2\pi i)\,\delta\left(p^2 - \Sigma^2\right)\ \hat{F}_q(r,p) \\
i\mathcal{D}^{\mu\nu}_{ab}(r,p) &= \delta_{ab}\ \varepsilon^{\mu\sigma}(p,s)\varepsilon^{\nu\,*}_{\sigma}(p,s)\ (2\pi i)\,\delta\left(p^2 - \Pi\right)\ \hat{F}_g(r,p) \\
i\Delta(r,p) &= (2\pi i)\,\delta\left(p^2 - \Xi\right)\ \hat{F}_\chi(r,p) \\
i\tilde{\Delta}(r,p) &= (2\pi i)\,\delta\left(p^2 - \tilde{\Xi}\right)\ \hat{F}_U(r,p)\ .
\end{aligned}
\tag{37}
$$

Then, by tracing over color and spin polarizations, and taking the expectation values (or, in a medium, the ensemble average) of these Wigner operators, one obtains the scalar functions

$$
F_\alpha(r,p) \ \equiv\ F_\alpha(t,\vec{r};\vec{p},p^2 = M_\alpha^2) \qquad\qquad (\,\alpha\ =\ q,\ g,\ \chi,\ U\,)
\tag{38}
$$

with

$$
\begin{aligned}
F_q(r,p) &= \langle\, Tr[\mathcal{S}(r,p)]\,\rangle \quad , & M_q^2 &= \Sigma^2(r,p) \\
F_g(r,p) &= \langle\, Tr[\mathcal{D}(r,p)]\,\rangle \quad , & M_g^2 &= \Pi(r,p) \\
F_\chi(r,p) &= \langle\, \Delta(r,p)\,\rangle \quad , & M_\chi^2 &= \Xi(r,p) \\
F_U(r,p) &= \langle\, Tr[\tilde{\Delta}(r,p)]\,\rangle \quad , & M_U^2 &= \tilde{\Xi}(r,p)\ .
\end{aligned}
\tag{39}
$$

The c-number functions $F_\alpha(r,p)$ are the quantum-mechanical analogues of the classical phase-space distributions that measure the number of particles at time t in a 7-dimensional phase-space element $d^3r d^4p$. Due to the effects of the self energies, three-momentum and energy are generally independent variables, because the quanta can be off mass shell, i.e., for zero rest masses, $E^2 = \vec{p}^{\,2} + M_\alpha^2 \neq \vec{p}^{\,2}$, where M_α^2, eq. (39), represents the off-shellness due to the self and mutual interactions of the quanta ($M^2 = 0$ for on-shell particles). In contrast to the classical propagation of on-shell particles, the Wigner functions (37) incorporate the quantum "Zitterbewegung" even in the absence of interactions with other particles. These spatial fluctuations arise from the combination $p^2 - \partial_r^2/4$ acting on the Wigner operators in