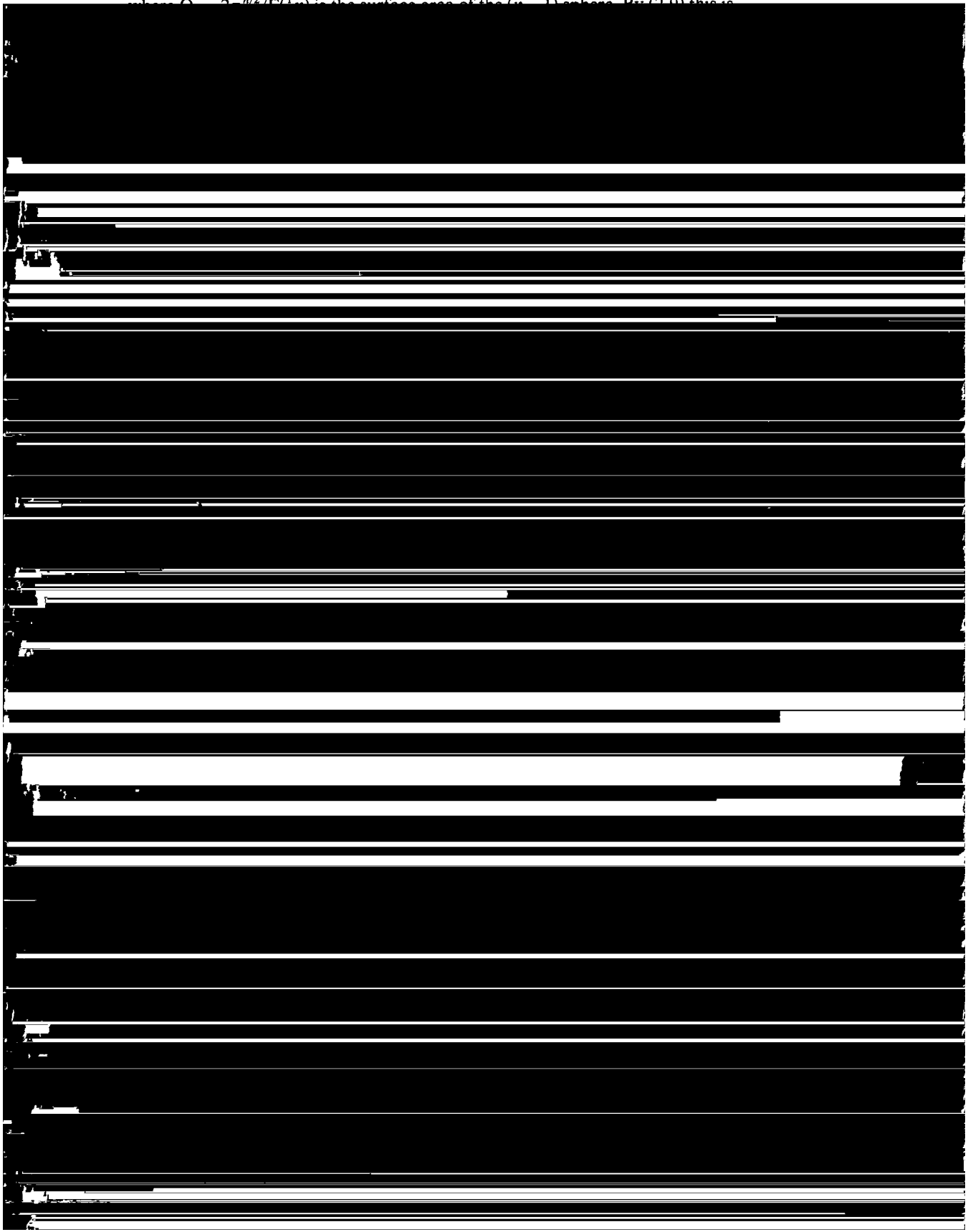


On double integrals over spheres

Radon transform. In § 4 using results of § 3 we derive some formulae in inverse scattering theory extending results of Devaney (1982a). We then discuss diffraction tomography where the inversion formula of § 3 yields a generalisation to what can be called multifrequency diffraction tomography. The same inversion formula is also used in the derivation of migration algorithms used in inverting seismic prospecting data (Beylkin and Burridge, 1987a, b), thus establishing a relationship between multifrequency diffraction

where $\Omega = 2\pi/\tau$, $F(\lambda)$ is the surface area of the $(n-1)$ -sphere. By (2.9) this is



where ξ and η are defined as in the lemma. Using (3.10) in (3.8) and setting $r = \rho(\lambda + \mu)$ we have

$$I = \frac{\lambda\mu}{\Omega_{n-1}(\lambda + \mu)} \frac{1}{C(1-\gamma)} \int_0^\infty |p|^{n-1} d|p| \times \int_{\mathbf{S}^{n-1} \times \mathbf{S}^{n-1}} f\left(|p| \frac{(\lambda\xi + \mu\eta)}{r}\right) \frac{W(r/(\lambda + \mu))}{r \sin^{n-3} \theta} d\xi d\eta \quad (3.11)$$

where

$$r = |\lambda\xi + \mu\eta|. \quad (3.12)$$

Next set

$$|p| = rk \quad d|p| = r dk \quad (3.13)$$

to get

$$I = \frac{\lambda\mu}{2\Omega_{n-1}(\lambda + \mu)} \frac{1}{C(1-\gamma)} \int_{-\infty}^\infty |k|^{n-1} dk \times \int_{\mathbf{S}^{n-1} \times \mathbf{S}^{n-1}} f(k(\lambda\xi + \mu\eta)) \frac{r^{n-1} W(r/(\lambda + \mu))}{\sin^{n-3} \theta} d\xi d\eta \quad (3.14)$$

where the integral over k has been extended to the whole real axis and

$$\sin^{n-3} \theta = [1 - (\xi \cdot \eta)^2]^{(n-3)/2}. \quad (3.15)$$

Inverse Fourier transform on the space $\mathbf{R} \times \mathbf{S}^{n-1} \times \mathbf{S}^{n-1}$

We can now formulate the following.

Theorem 1. Let g be a function on \mathbf{R}^n and \hat{g} its Fourier transform. Then

$$g(y) = \frac{1}{4(2\pi)^n \Omega_{n-1}} \int_{-\infty}^\infty |k|^{n-1} dk \int_{\mathbf{S}^{n-1} \times \mathbf{S}^{n-1}} d\xi d\eta \frac{|\xi + \eta|^{n-1}}{[1 - (\xi \cdot \eta)^2]^{(n-3)/2}} \times W\left(\frac{1}{2}|\xi + \eta|, y\right) \hat{g}(k\xi + k\eta) \exp[i(k\xi + k\eta) \cdot y] \quad (3.16)$$

where W is an arbitrary function such that

$$\int_0^1 W(\rho, y) d\rho = 1 \quad (3.17)$$

and where $\Omega_n = 2\pi^{n/2}/\Gamma(\frac{1}{2}n)$ is the surface area of the unit sphere in \mathbf{R}^n .

Theorem 1 can be generalised further and leads to

Theorem 2. Let g be a function on \mathbf{R}^n and \hat{g} its Fourier transform. Let $\lambda = \lambda(y)$ and $\mu = \mu(y)$ be two positive functions on \mathbf{R}^n . Then

$$g(y) = \frac{1}{4(2\pi)^n \Omega_{n-1}} \int_{-\infty}^\infty |k|^{n-1} dk \times \int_{\mathbf{S}^{n-1} \times \mathbf{S}^{n-1}} d\xi d\eta b(y, \xi, \eta) \hat{g}(k\lambda\xi + k\mu\eta) \exp[i(k\lambda\xi + k\mu\eta) \cdot y] \quad (3.18)$$

where

$$h(\nu, \xi, \eta) = \frac{|\lambda\xi + \mu\eta|^{n-1}}{2\lambda\mu} \frac{1}{W} \left(\frac{|\lambda\xi + \mu\eta|}{\nu} \right) \quad (3.19)$$

Using (2.11), (3.15), (3.19) and integrating over ψ , we have from (3.25)

$$g_B(y) = \frac{1}{(2\pi)^n} \int_{k_{\min}}^{k_{\max}} k^{n-1} dk \frac{1}{1-\gamma(y)} \int_{\gamma(y)}^1 d\rho \int_{S^{n-1}} d\nu \\ \times W(\rho, y) \rho^n (\lambda + \mu)^n \hat{g}(k\rho(\lambda + \mu)\nu) \exp[ik\rho(\lambda + \mu)\nu \cdot y]. \quad (3.26)$$

Changing the order of integration in (3.26) we arrive at

$$g_B(y) = \frac{1}{1-\gamma(y)} \int_{\gamma(y)}^1 d\rho W(\rho, y) g_\rho(y) \quad (3.27)$$

where

$$g_\rho(y) = \frac{1}{(2\pi)^n} \int_{\rho(\lambda + \mu)k_{\min} \leq |p| \leq \rho(\lambda + \mu)k_{\max}} dp \hat{g}(p) \exp(ip \cdot y). \quad (3.28)$$

Formula (3.27) can be interpreted as a superposition of band-limited reconstructions g_ρ .

Given the definitions of the operators R^* and K we substitute (3.30) into (3.18) to obtain

$$g(y) = (R^*Kv)(y) \tag{3.34}$$

The validity of the Born approximation in the context of the quantum-mechanical scattering can be justified under the assumption of smallness of the potential or for high energies (frequencies) for a given potential.

Our inversion formula provides a direct reconstruction of the potential and the inter-atomic distance function for the linearised inverse problem. Indeed, applying theorem 1 specialised to dimension $n = 3$ (see also § 3, remark 1) with $g \equiv V$ and using (4.4) we have

Both of these complications (as compared with the quantum-mechanical inverse scattering problem) have been resolved. The problem with point sources was reduced more or less routinely to the problem with incident plane waves. The solution in a variable background medium can be obtained in a systematic way if we restrict ourselves to