Svensson, Montfrooij, and de Schepper Reply: We have analyzed the roton mode \cite{1} in $^4$He at $p = 20$ bars close to $T_\lambda$ in terms of only one damping rate $z_\lambda$ and one corresponding coupling parameter $f_{\text{un}}$. We found that the transition from the superfluid to the normal-fluid phase is marked by a dramatic increase in $z_\lambda$ and by a small increase in $f_{\text{un}}$ (reflecting the disappearance of the multiphonon component). These continuous changes take place predominantly just below $T_\lambda$ and result in nonpropagating modes at $T_\lambda$. Glyde et al. \cite{2} argue that the above mentioned observations do not signify a departure from the Glyde-Griffin (GG) interpretation (Ref. \cite{3} in \cite{1}) and that the softening of the roton mode caused by the increased damping is physically meaningless.

First, we stress that there was nothing in our analysis which could have forced any particular behavior to occur precisely at $T_\lambda$, as is clearly observed (see also Fig. 4 in \cite{1}). Our analysis did not rely upon any presumed shape of the multiphonon component. Of course, all methods of analysis should give the same result above $T_\lambda$ in the absence of the multiphonon component. We show the results for the roton mode at saturated vapor pressure (SVP) \cite{3} in Fig. 1 where the results extend to within 0.0007 K of $T_\lambda$. Clearly, the behavior at SVP is similar to that at 20 bars, albeit that the roton mode does not soften completely ($z_\lambda/2 < f_{\text{un}}$). This directly shows the physical significance of propagating vs nonpropagating modes: at SVP, the roton mode in the normal-fluid phase is propagating but strongly damped, while at 20 bars the damping has increased (due to the increased density) resulting in overdamped modes. In the GG model, regular density fluctuations (zero-sound and/or particle-hole modes) combine with a contribution arising from exciting single particles out of the condensate: above $T_\lambda$ only regular density fluctuations are visible, whereas below $T_\lambda$ the sharp single-particle contribution begins to grow as the condensate fraction $n_0(T)$ grows (Ref. \cite{3} in \cite{1}). This would result in the coexistence of a sharp and a broad component below $T_\lambda$, with the sharp component gradually replacing the broad component as the temperature is lowered, as illustrated in model calculations (Figs. 5 and 6 in Ref. \cite{4}). Thus, the main issue is whether, below $T_\lambda$, the roton mode consists of one or two components (apart, of course, from the multiphonon component at high frequencies). We have shown that only one component is required to describe the roton mode below $T_\lambda$, both at SVP \cite{3} and at 20 bars \cite{1}. Therefore, our results cannot be explained using the GG model, unless of course the two components in the GG model hybridize into one (having one lifetime and excitation energy) at all temperatures and pressures, independent of the value of $n_0(T)$. We also show the results for the phonon and maxon excitations, obtained using identical analysis, in Fig. 1. Although these data only approach $T_\lambda$ to within 0.02 K, it is clear that the rapid increase in $z_\lambda$ as $T_\lambda$ is approached, combined with the disappearance of the multiphonon component, occurs over the entire region $q < 2 \text{ Å}^{-1}$. We believe that, to be deemed successful, any interpretation of the excitations in $^4$He must account for this similarity for all $q$ values.

E. C. Svensson
National Research Council Chalk River Laboratories Chalk River, Ontario, Canada K0J 1J0

W. Montfrooij
ISIS Pulsed Source Rutherford Appleton Laboratory Didcot, OX11 0QX, United Kingdom

I. M. de Schepper
Interfaculty Reactor Institute Delft University of Technology Mekelweg 15, 2629JB Delft, The Netherlands

Received 12 September 1997 [S0031-9007(98)05592-6] PACS numbers: 67.40. – w, 05.30. – d, 67.20. + k