form

$$\mathcal{G} = \sum_{l,l'} \int [a_l^\dagger(w) \bar{g}_{ll'} a_{l'}(w) + A_l^\dagger(w) \hat{g}_{ll'} A_{l'}(w)]\, dw \qquad (15)$$

for suitable Hermitian coefficients.

We have seen that the power of ultralocality is far reaching. Nowhere did our arguments make use of the covariance of the base theory, nor of the dimensionality of space. Thus nearly every theory has similar properties. The original ultralocal theories are just single degree of freedom base theories, and are by now rather well under control[2,6]; for example, even for such models, interacting theories cannot have CCR. Hopefully, the study of such models will assist the study of genuine covariant diastrophic fields.

The solution of a covariant diastrophic field such as outlined in this Letter would be interesting on at least two counts. First, it would be a true covariant theory having infinite mass, field-strength, and coupling-constant renormalizations[6]; but, second, and more important, such theories may relate very closely to their base theories. For example, the *classical* solution to an equation like (2) is just $\varphi_{\rm cl}(x,w) = \varphi_{\rm cl}^{w}(x)$, namely a w-parametrized set of solutions of the base theory. In addition, one should not overlook the fact that every conventional covariant theory becomes a covariant diastrophic theory (in one less space dimension) if just *one* of the spacial gradient terms is dropped from the Lagrangrian. With this direct connection in mind it would seem not unreasonable if interacting, covariant field operators bore a closer resemblance to the bilinear diastrophic form rather than to the manifestly inequivalent linear form of a quasifree theory.

[1]Diastrophic quantum field theories were introduced in the author's 1971 Boulder lectures [J. R. Klauder, "Functional Techniques and Their Application in Quantum Field Theory," lectures given at the Fourteenth Annual Summer Institute for Theoretical Physics, University of Colorado, Boulder, Colorado, June 21-August 13, 1971 (unpublished)]. The terminology is meant to reflect the extension of a given (base) theory in a new direction (loosely, a diastrophism) parametrized by w.

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Interstellar CN Excitation at 2.64 mm

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A sensitive search was made for 2.64-mm line emission from a cloud of CN, whose excitation is known from optical measurements, with essentially a null result. This provides strong support for the proposition that the excitation temperature deduced from the optical CN lines is equal to the temperature of the microwave background.

The first confirmation of the discovery of microwave background radiation[1] was based upon the optically observed excitation of interstellar CN.[2,3] It had long[4] been known from optical-absorption line ratios that a considerable fraction of interstellar CN radicals is found in the first rotational level, at an energy above the ground state corresponding to a wavelength of 2.64 mm. Field and Hitchcock,[2] and Thaddeus and Clauser,[3] applied the existence of the CN excitation to the microwave background radiation. They argued that this excitation could not be maintained by collisions or by transitions from higher levels, and is thus excited directly by 2.64-mm photons. This problem of excitation aside, background-temperature measurements based upon such line observations are free of the sources of systematic error common to direct measurement techniques. Thus such CN observations can play a unique role in the precise determination of the background temperature.

Clauser and Thaddeus[5] have reported observations of the excitation in CN spectra from ten stars in various directions in the galaxy, all consistent with a single excitation temperature near 2.8 K. They argued that since one would expect different physical conditions in the various clouds studied, the role played by collisions in excitations would vary accordingly. Since no significant variation was observed, they concluded that the conditions within the clouds play no appreciable role in the excitation. In any case, the observed CN excitation provides an upper limit to the isotropic intensity of the background at 2.64 mm. The only case so far found in nature where "refrigeration" of a transition below the background temperature occurs is the 4830-MHz transition of interstellar formaldehyde in certain dark interstellar clouds.[6]

These problems can be unambiguously resolved by a direct measurement at 2.64 mm of the difference, if any, between the optically observed excitation temperature of the CN and the brightness temperature of the background behind it.[2] The result of such a measurement is reported herein.

The region selected for this work is in the direction of the star BD + 66°1675 because it has the highest concentration of CN of the stars studied. Munch[7] obtained CN spectra for this star as well as two other nearby stars. From Munch's spectra, Clauser and Thaddeus[5] deduced an excitation temperature of 2.39 ± 0.43 K in the direction of BD + 66°1675 and 2.45 ± 0.63 K in the direction of BD + 66°1674, about 1 arc min away. Within the error limit imposed by the spectral resolution, the velocities of all the features are the same, indicating that a single cloud covers the region. The question of the angular extent of the cloud is very important because the sensitivity of our experiment depends upon the antenna beam being filled by the CN cloud.

Our measurements were made using the 36-ft-diam parabolic antenna of the National Radio Astronomy Observatory[8] (NRAO) at Kitt Peak. Its beam diameter at 2.64 mm is approximately 1 min of arc. Our receiver is a single ended diode mixer with a single sideband noise temperature of approximately 2000 K. The i.f. passband is centered at 1390 MHz, and no effort has been made to suppress the response at the image frequency, 2780 MHz below the line frequency. The multichannel line receiver provided by NRAO for line studies with this antenna has two filter banks, both centered at the same frequency and operating simultaneously. The one used for this measurement has fifty channels, 250 kHz (0.66 km/sec) wide, spaced 250 kHz apart, while the other has forty channels approximately 1.6 MHz wide spaced 1 MHz apart.

Two preliminary experiments were performed in order to pinpoint the expected frequency spectrum of the CN emission as well as its angular extent. The first was a measurement of the CN lines in a dense, strongly excited[9] molecular cloud associated with the Orion Nebula. From our observations we determined the laboratory frequency of the strongest CN transition by applying a Doppler correction obtained from a precise measurement of the shift in the 110 201.4-GHz line of $^{13}C^{16}O$ in the same cloud. The frequencies of the weaker hyperfine components of the CN transition were also determined in this way. Although no measurements were planned at these other frequencies, one has to avoid them when selecting a comparison band for frequency switching.

The second set of observations was the 2.6-mm CO line in the direction of BD + 66°1675. Since the dipole moment of CO is 0.1 D compared with ~2 D for CN, the slower spontaneous emission time of the former makes it much easier to excite by collisions with neutral particles. Thus, CO in a cloud of $\sim 10^3$ hydrogen molecules per cubic centimeter is collisionally excited, while molecules with dipole moments near 1 D require a density in excess of 10^5 for strong excitation.[9] We have found CO emission in the direction of a number of dark clouds. Toward BD + 66°1675 we found CO lines corresponding to at least four different velocities, one of which, the most intense, has a velocity corresponding to that of the optical CN absorption in the direction of this star.[10] The CO line was found with approximately the same intensity 1 min of arc away from the star position in all directions, confirming the extended size of the cloud. The corresponding $^{13}C^{16}O$ line was also measured at the central point, with an intensity about one third that of the $^{12}C^{16}O$ line and a linewidth of approximately 400 kHz, i.e., almost two channels wide. Since we expect the CO and CN to be coextensive and the CN to be unsaturated, we expect the line shapes and velocities of the CN and $^{13}C^{16}O$ lines to be the same. Subject to this condition, we estimate the overall uncertainty in our determination of the expected line frequency to be 100 kHz.

The direction CN measurements themselves were straightforward. They were made by synchronously switching the local oscillator 5 MHz such that the line appeared alternately in two locations in the high-resolution filter bank, yielding two independent measurements for each integration. Seven integrations, each 1 h in duration, were carried out, four at one average setting of the local oscillator and three others at a frequency 1 MHz higher. Unfortunately, at this latter setting the expected line was near a defective channel during half of the switching cycle so only eleven of the fourteen independent measurements were taken for data.

For each measurement, the 1-h integrated outputs from the two channels in which the line was to appear was averaged and the average of adjacent channels was subtracted. These eleven differences were 0.07, 0.05, -0.08, -0.04, -0.045, 0.14, 0.025, -0.055, 0.04, 0.22, and 0.07 K. The average of these results is 0.036 K with an rms variation of 0.037 K. This fluctuation level may be compared with 0.032 K computed from the noise temperature of the receiver. We also tested for the possibility that we missed a portion of the line because our determination of the expected frequency was off by more than our estimated error limit of 100 kHz. This was done by obtaining averages, as before, for lines centered one 250-kHz channel above and below the derived frequency. In these two cases the final averages were 0.038 and 0.013 K, respectively, indicating that no stronger line exists within a frequency interval 3 times as great as our maximum expected error.

While our positive residual may reflect the presence of a small amount of excitation above the background, we regard our answer as essentially a null result supporting the conclusion that CN in dark clouds is in equilibrium with the background radiation. A quantitative evaluation follows.

If ΔT_A is the difference between the antenna temperature at the line frequency and an adjacent frequency, we then have

$$\Delta T_A = \eta(1-e^{-\tau})\left\{\frac{h\nu}{k[\exp(-h\nu/kT_{01})-1]} - \frac{h\nu}{k[\exp(-h\nu/kT_{\rm bg})-1]}\right\}, \quad (1)$$

where η is the beam efficiency of the antenna, 0.6 in our case; τ is the opacity of the line averaged over the signal channels; T_{01} the excitation temperature of the CN computed from the ratio of the population in the $J=0$ and $J=1$ states, i.e., 2.39 K; and $T_{\rm bg}$ is the equivalent black-body temperature at this wavelength.

Also, the opacity of CN at 2.64 mm may be computed from the relation

$$\tau = f\frac{c^2 g_1 A_{01} N_0}{8\pi g_0 \nu^2 \Delta\nu}\left[1-\exp\left(-\frac{h\nu}{kT_{01}}\right)\right]. \quad (2)$$

Now N_0, the column density of CN in the $J=0$ state, is computed from the 80 mÅ equivalent width of the $R(0)$ line to be 1.7×10^{13} cm^{-2}. A_{01} is 1.31×10^{-5} and f is the fraction of the intensity of the total $J=1$ to $J=0$ transition in the line under investigation. f has been experimentally determined to be approximately $\frac{1}{3}$ from our measurements of the relative intensities of the lines, in good agreement with theory. For $\Delta\nu$, we take 500 kHz, the spectral width of our measurement, rather than the narrower width of the line itself. From the above relation we then obtain 0.8 for τ.

Upon substitution in Eq. (1), we note immediately that in the absence of background radiation we would obtain a ΔT_A of 0.24 K, 6 times our probable error of 0.037 K. Our measured ΔT_A of 0.036 K corresponds to a difference of 0.14 K between T_{01} and $T_{\rm bg}$. Taking the value obtained for T_{01} by Clauser and Thaddeus we have

$$T_{\rm bg} = 2.25^{+0.6}_{-0.7}\ \text{K (95\% confidence)}.$$

The uncertainty in our measurement and the 0.4-K uncertainty in the optically determined T_{01} contribute approximately equally to the error. This result is in good agreement with the 3.3-mm result of Boynton, Stokes, and Wilkinson,[11] 2.46 K with a 0.4-K rms error, and with the result of Blair *et al.*[12] who found a flux corresponding to an equivalent black-body temperature of $3.1^{+0.5}_{-2.0}$ K in the spectral range between 6 and 0.08 mm.

We feel that the best value for the temperature at this wavelength comes from the determination of T_{01} determined from the weighted average of all the stellar CN lines, notably those in ζ Ophiuchus and ζ Perseus. This conclusion has been strengthened by our demonstration of the essential equivalence of T_{01} and T_{bg} in the cloud we have investigated. However, the possibility of a small amount of excitation, to a temperature of the order of 0.1 K above the background must be considered. Such an excitation could be accomplished by collisions with neutral hydrogen atoms if their density were of the order of 10^4 cm^{-3}.[3] Such a density is consistent with our CO data on a number of dark interstellar clouds.[13] It should be noted, though, that the cloud in front of BD +66°1675 has highest optically observed CN column density. If this reflects a higher volume density than the ζ Ophiuchus cloud, say, then the effect of collisional excitation would be proportionally less in the latter case. It is perhaps significant that we have not been able to observe $^{12}C^{16}O$ line emission in the direction of ζ Ophiuchus. From the ratios of equivalent widths in the optical CN lines, we would expect a $^{12}C^{16}O$ column density toward ζ Ophiuchus about one tenth that toward BD +66°1675. That such a column density is normally observable is demonstrated by our ability to detect the corresponding $^{13}C^{16}O$ line in the latter star. The absence of a CO detection toward ζ Ophiuchus could, of course, also be due to small angular size of the cloud, i.e., filling only a small part of our antenna beam, rather than a lack of sufficient collisional excitation.

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$A3$ Region of the Three-Pion Mass Spectrum in the Reaction $\pi^- p \to p\pi^+\pi^-\pi^-$ at 13 and 20 GeV/c*

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We report an investigation of the production channels of the $A3$ region of the $\pi^+\pi^-\pi^-$ mass spectrum from the reaction $\pi^- p \to p\pi^+\pi^-\pi^-$ at 13 and 20 GeV/c. Evidence that the $A3$ has a substantial branching ratio to 3π is obtained; its mass and width are measured as 1658 ± 8 MeV and 53^{+20}_{-16} MeV, respectively. To satisfactorily describe the data an additional peak is required with mass 1830 MeV and width 130 MeV.

A peak at about 1650 MeV in the $\pi^+\pi^\pm\pi^-$ mass from the reaction $\pi^\pm p \to p\pi^+\pi^\pm\pi^-$ has been reported in several experiments,[1] the majority of which interpret the peak as a resonance, the $A3$, with a width of more than 100 MeV. Crennell *et al.*,[2] in a study of this reaction in $\pi^- p$ scattering at 6 GeV/c, observed a broad (130 ± 30 MeV) enhancement in the $A3$ region which they find can be ex-