[1]B. Judek, Can. J. Phys. 50, 2082 (1972), and references therein.
[2]E. M. Friedlander, R. Gimpel, H. Heckman, Y. Karant, B. Judek, and E. Ganssauge, Phys. Rev. Lett. 45, 1084 (1980).
[3]P. L. Jain and G. Das, Phys. Rev. Lett. 48, 305 (1982).
[4]H. B. Barber, P. S. Freier, and C. J. Waddington, Phys. Rev. Lett. 48, 856 (1982).
[5]M. M. Aggarwal, K. B. Bhalla, G. Das, and P. L. Jain, Phys. Lett. 112B, 31 (1982).
[6]T. M. Liss, S. P. Ahlen, P. B. Price, and G. Tarlé, Phys. Rev. Lett. 49, 775 (1982).
[7]A. De Rujula, R. C. Giles, and R. L. Jaffe, Phys. Rev. D 17, 285 (1978).
[8]G. F. Chapline, Phys. Rev. D 25, 911 (1982).
[9]G. Baym, Prog. Part. Nucl. Phys. 8, 73 (1982).
[10]R. Saly, M. K. Sundaresan, and P. J. S. Watson, to be published.
[11]G. N. Fowler, S. Raha, and R. M. Weiner, to be published.
[12]H. Stöcker, G. Graebner, J. A. Maruhn, and W. Greiner, Phys. Lett. 95B, 192 (1980).
[13]G. Tarlé, S. P. Ahlen, and P. B. Price, Nature (London) 293, 556 (1981).
[14]R. L. Fleischer, P. B. Price, and R. M. Walker, *Nuclear Tracks in Solids: Principles and Applications* (Univ. of California Press, Berkeley, 1975).
[15]G. D. Westfall, L. W. Wilson, P. J. Lindstrom, H. J. Crawford, D. E. Greiner, and H. H. Heckman, Phys. Rev. C 19, 1309 (1979).
[16]Shi-lun Guo, unpublished results.
[17]D. E. Greiner, P. J. Lindstrom, H. H. Heckman, B. Cork, and F. S. Bieser, Phys. Rev. Lett. 35, 152 (1975).
[18]S. Nagamiya, in Proceedings of the Fifth High-Energy Heavy Ion Study, Lawrence Berkeley Laboratory Report No. LBL-12652, 1981 (unpublished), p. 141; P. B. Price and J. Stevenson, Phys. Rev. Lett. 34, 409 (1975).
[19]J. Stevenson, P. B. Price, and K. Frankel, Phys. Rev. Lett. 38, 1125 (1977).
[20]J. Gosset, H. H. Gutbrod, W. G. Meyer, A. M. Poskanzer, A. Sandoval, R. Stock, and G. D. Westfall, Phys. Rev. C 16, 629 (1977).
[21]A. Nir, Phys. Rev. Lett. 19, 336 (1967).
[22]B. Mason, *Principles of Geochemistry* (Wiley, New York, 1962), 2nd ed., Chap. 6.
[23]G. S. LaRue, J. D. Phillips, and W. M. Fairbank, Phys. Rev. Lett. 46, 967 (1981).

Vector Gluonium as a Possible Explanation for Anomalous ψ Decays

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Recent experiments at SLAC show unexpectedly large values for the ratios (1) $B(\psi\to\rho\pi)/B(\psi'\to\rho\pi)$ and (2) $B(\psi\to K^*\bar{K})/B(\psi'\to K^*\bar{K})$. It is proposed that these anomalies are caused by the mixing of the ground-state isoscalar vector mesons (ω, φ, ψ) with a $J^{PC}=1^{--}$ vector glueball (O) which was first postulated by Freund and Nambu in 1975. Its mass is estimated at $\simeq 2.4$ GeV and direct experimental searches for the O are suggested.

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Recent experiments at SLAC have revealed a very interesting set of anomalies in ψ, ψ' decays.[1] Measurements of the ψ, ψ' decay widths for the exclusive reactions $\psi\to X$, $\psi'\to X$ for $X=\bar{p}p$, $\bar{p}p\pi^0$, $K^+K^-\pi^+\pi^-$, $2\pi^+2\pi^-\pi^0$, $\omega\pi^+\pi^-$, $3\pi^+3\pi^-\pi^0$, $K^{*\pm}K^{\mp}$, $\rho\pi$, and e^+e^- are now available. From these data it is found that for each of these modes but two (namely $K^*\bar{K}$ and $\rho\pi$) the ratio

$$R_{\psi'\psi}\equiv B(\psi'\to X)/B(\psi\to X) \qquad (1)$$

is constant (within experimental errors), being given by

$$R_{\psi'\psi}=(12\pm 2)\%. \qquad (2)$$

Theoretically, if the three-glue continuum produces the final hadronic state, such a constant (i.e., independent of X) value for the ratio is easy to understand since one expects[2]

$$B(\psi'\to X)/B(\psi\to X) = [|\psi'(0)|^2/|\psi(0)|^2]\Gamma_{\text{tot}}^{\psi}/\Gamma_{\text{tot}}^{\psi'}. \qquad (3)$$

However, for the $\rho\pi$ and $K^*\bar{K}$ modes it is found that (to 90% confidence level)[1]

$$B(\psi'\to K^*\bar{K})/B(\psi\to K^*\bar{K})<1.96\% \qquad (4)$$

and

$$B(\psi'\to\rho\pi)/(B\psi\to\rho\pi)<1.25\%, \qquad (5)$$

each one of which is many times smaller than the theoretical expectations of $(12\pm 2)\%$. So far no theoretical solution to this puzzle has been advanced. We suggest a very simple, but, we believe, rather important and immediately testable explanation for this effect.

We propose that the enhancement of the $\psi\to K^*\bar{K}$ and $\psi\to\rho\pi$ decay modes is being caused by a quantum mechanical mixing of the ψ with a $J^{PC}=1^{--}$ vector gluonium, designated O. The decay width for $\psi\to\rho\pi(K^*\bar{K})$ via the sequence $\psi\to O\to\rho\pi(K^*\bar{K})$ must be much larger than the decay width for the (nonpole) continuum process $\psi\to$ three-glue $\to\rho\pi(K^*\bar{K})$. In the other channels (such as $\bar{p}p$, $\bar{p}p\pi^0$, etc.) the branching ratios of the O must be so small that the continuum contribution dominates over that of the O pole. For the case of the ψ' the contribution of the O pole must always be inappreciable in comparison to the continuum process.

The existence of such a gluonium was first postulated (with an estimated mass of 1.4 to 1.8 GeV) by Freund and Nambu[3] (FN hereafter) based on Okubo-Zweig-Iizuka (OZI) dynamics soon after the discovery of the ψ (ψ') mesons. Indeed FN predicted that the O would decay copiously into $\rho\pi$ and $K^*\bar{K}$ and they had in fact ignored its mixings with the ψ' and had assumed that it mixes only with the ground-state (ideally mixed) isosinglet vector mesons: ω, φ, and ψ. These properties are precisely what is required to account for the aforementioned anomaly embodied in Eqs. (4), (5), and (2).

Our own understanding of the O is based on a potential model,[4] for glueballs.[5] In this model the gluon is thought to have a dynamically generated effective mass estimated to lie in the range of 500 ± 200 MeV.[6,7] The short-distance part of the potential is extracted thus from massive QCD. In the long-distance part of the potential the color screening of gluons is brought about by a breakable string. In this potential model the mass for a low-lying three-glue state such as the O is estimated to be about 2.4 GeV.[8]

There are some other differences between our picture[8] for the O and that of FN.[3] In contrast to FN we take the mixing parameter (f_{OV}, $V=\omega,\varphi,\psi$) at the O-V junction to be a function of the invariant mass q^2. Thus we assume

$$f_{O\omega}(q^2):f_{O\varphi}(q^2):f_{O\psi}(q^2)=(\sqrt{2}:-1:1)f_O(q^2). \quad (6)$$

We expect a q^2 dependence in the mixing parameter of these ground-state mesons since the gauge coupling constant in QCD is momentum dependent and indeed the existing experimental data on φ,ψ decays cannot be understood in the pole model without a q^2 dependence. From a study of $\varphi\to\rho\pi$ which goes via $\varphi\to O\to\omega\to\rho\pi$ one finds $f_O(m_\varphi)=0.28\ \text{GeV}^2$. Similarly from $\psi\to\rho\pi$ (i.e., $\psi\to O\to\omega\to\rho\pi$) we find $f_O(m_\psi)\simeq0.065\ \text{GeV}^2$. Thus the mixing parameter is q^2 dependent and decreases rather sharply with increase in q^2.[8]

We can now calculate the rate for $O\to\rho\pi$ and $O\to K^*\bar{K}$. The decay $O\to\rho\pi$ proceeds via $O\to\omega\to\rho\pi$. We thus find

$$\Gamma_{O\to\rho\pi}=(3/96\pi)f_{\omega\rho\pi}^2f_{O\omega}^2(M_O)(M_O^2-m_\omega^2)(1-x_{\pi O\rho}^2)^{3/2}/M_O^3, \quad (7)$$

where $x_{\pi O\rho}\approx m_\pi/(M_O-m_\rho)$. Thus $\Gamma(O\to\rho\pi)$ is estimated to be in the range of 50 MeV for $M_O\simeq2.4$ GeV, where we have used $f_{O\omega}(M_O)\simeq0.13\ \text{GeV}^2$ as a reasonable extrapolation of the values for the mixing parameter deduced in the last paragraph.

Next the decay $O\to K^*\bar{K}$ is imagined to go via the sequence $O\to\varphi\to K^*\bar{K}$. The decay vertex for $\varphi\to K^*\bar{K}$ is similar to that of $\omega\to\rho\pi$. Thus $f_{\omega\rho\pi}^2=4f_{\rho\pi\pi}^2/m_\rho^2$ implies[9]

$$f_{\varphi K^*\bar{K}}^2=4f_{\varphi K\bar{K}}^2/m_\varphi^2=2f_{\rho\pi\pi}^2/m_\varphi^2. \quad (8a)$$

We do not expect these relations to hold as the ω and φ propagators go far off their mass shells as happens for ψ $(O)\to\rho\pi$ and ψ $(O)\to K^*\bar{K}$ for $M_O\geq2$ GeV. For such decays we expect the relevant q^2 to characterize these vertices rather than m_ρ or m_φ. So, for $M_O\geq2$ GeV we suggest

$$f_{K^*\bar{K}}^2\simeq0.5f_{\omega\rho\pi}^2. \quad (8b)$$

Using (8a) and (8b) we find (for $M_O\simeq2.4$ GeV)[10]

$$\Gamma_{O\to K^*\bar{K}}\simeq 8\text{ to }16\text{ MeV}. \quad (9)$$

We stress that the pole model is an oversimplification so that the exact numerical values of these decay widths should not be taken too seriously. However, these calculations indicate (as we have suggested earlier)[4,8] that the total widths of glueballs will be characteristic of ordinary hadrons and will not exhibit any "OZI forbiddenness."

These absolute decay widths of the O into $\rho\pi$ and $K^*\bar{K}$ must remain as tentative predictions whose tests will have to await the discovery of the O. However, the available measured rates for $\psi\to\rho^\pm\pi^\mp$, $\psi\to K^\pm K^{*\mp}$, and $\psi\to\bar{p}p$ do offer interesting tests for the pole model. Thus from (7) and (8a) or (8b) we find

$$R_{\rho/K^*}\equiv\Gamma(\psi\to\rho^\mp\pi^\pm)/\Gamma(\psi\to K^\mp K^{*\pm})\approx 4\text{ to }8\ \text{(pole model)}. \quad (10)$$

This ratio is actually independent of the mass of the O and the mixing parameter and within the expected uncertainties of the pole model may be compatible with the measured value

$$R_{\rho/K^*} = 3.4 \pm 0.8 \text{ (experiment)}. \tag{11}$$

In comparison we note that the nonpole continuum process suggests a value

$$R_{\rho/K^*} \leq 2 \text{ (nonpole; i.e., simple quark counting in QCD)}.$$

An important consistency check of our O hypothesis is also provided by the $\psi \to \bar{p}p$ mode. With use of the pole model (i.e., $\psi \to O \to \omega \to \bar{p}p$) we obtain

$$R_{\bar{p}p\rho\pi} = \Gamma(\psi \to \bar{p}p)/\Gamma(\psi \to \rho\pi) \approx 0.01 \text{ (pole model)}$$

which is very small compared to the measured value[1] $R_{\bar{p}p\rho\pi} \simeq 0.16$. For the $\bar{p}p$ mode the three-glue continuum contribution therefore dominates over the O-pole contribution. As a result the $\bar{p}p$ model is not anomalous and it obeys Eq. (2) as all normal modes do.

We now offer some experimental tests for our hypothesis. If our explanation for the $\rho\pi$ and $K^*\bar{K}$ modes of ψ is correct then *with no further assumptions it* immediately follows that the "safest" channels to search for the O are through the exclusive modes

$$\psi\ (\psi') \to K^*\bar{K}h,\ \psi\ (\psi') \to \rho\pi h;\ h = \pi\pi, \eta, \eta'. \tag{12}$$

Of course if the mass of the O is too close to the ψ then phase-space availability could seriously limit some of these possibilities.

Another way to search for the O in particular, and the three-gluon bound states in general, is via the inclusive reaction

$$\psi\ (\psi') \to (\pi\pi) + X, \tag{13}$$

where the $\pi\pi$ pair is an isosinglet. The three-glue bound states such as the O should show up as peaks in the missing mass (i.e., mass of X) distribution. A model-*dependent* rate for the specific reaction

$$\psi \to (\pi\pi) + O \tag{14}$$

can be arrived at as follows. Reactions such as (13) or (14) arise as five-gluon corrections to the lowest-order decay of ψ via three gluons. We assume that the scalar (0^{++}) ground-state glueball (called G) dominates the two-gluon channel leading to the formation of the isosinglet pion pair in the above reactions. This reaction (14) is seen to proceed via the sequence $\psi \to G + \psi$ followed by $G \to 2\pi$, and $\psi \to O$. The strength of the $G\psi\psi$ vertex is estimated by attributing the closely related decay $\psi' \to \psi\pi\pi$ to $\psi' \to G + \psi$, followed by $G \to \pi\pi$. We thus arrive at[8]

$$\Gamma(\psi \to (\pi\pi)_0 + O) \simeq 0.4 \text{ keV} \to B \simeq 0.6\% \tag{15}$$

as a crude estimate.

In our potential model, $M_O \simeq 2.4$ GeV (Ref. 8) and $M_G \simeq 1.2$ GeV.[4] Thus a two-body on-shell decay $\psi \to O + G$ is not kinematically allowed. However, $\psi' \to O + G$ can occur. Thus in a study of the inclusive reaction $\psi' \to \pi\pi X$ (with appropriate cuts on $M_{\pi\pi}$ to remove the ψ peak), a two-dimensional histogram of $M_{\pi\pi}$ versus the missing mass may reveal both the glueball states! Using G dominance in the two-gluon channel and $\psi \leftrightarrow O$ mixing one finds[8]

$$\Gamma(\psi' \to O + G) \simeq 3 \text{ to } 5 \text{ keV} \to B \simeq 1 \text{ to } 2\%. \tag{16}$$

These rates, while model dependent, are reasonable to encourage experimental searches.

There are a few remarks that we wish to make in brief..

(1) Since ψ' is a radial excitation of ψ, FN had ignored its mixing with the O. Actually in our model the mixing parameter f_{OV} is q^2 dependent and as discussed earlier it decreases rapidly with increase in q^2. So because of the q^2 dependence and because ψ' is a radial excitation, we expect $f_{O\psi'}{}^2 \ll f_{O\psi}{}^2$. Thus the branching ratios of ψ' relative to ψ for decays to $\rho\pi$ and $K^*\bar{K}$ channels which originate through the V-O mixing should be expected to be suppressed considerably more than what the propagator factor, i.e. $(m_{\psi'}{}^2 - m_O{}^2)^2/(m_\psi{}^2 - m_O{}^2)^2$ indicates. For $m_O \simeq 2.4$ GeV this propagator effect gives rise to a suppression factor of 4.

(2) Since the mixing must increase with the probability for annihilation of a vector meson into three gluons the simplest assumption that one can make is that [note $r_\alpha = \alpha_s{}^3(\psi')/\alpha_s{}^3(\psi)$]

$$f_{O\psi'}{}^2/f_{O\psi}{}^2 = |\psi'(0)|^2/|\psi(0)|^2 r_\alpha = [B(\psi' \to e^+e^-)/B(\psi \to e^+e^-)]\,\Gamma_{tot}{}^{\psi'}/\Gamma_{tot}{}^{\psi}. \tag{17}$$

Let us now consider the ratio

$$R_{\rho\pi ee} = \frac{\Gamma(\psi' \to \rho^\pm\pi^\mp)/\Gamma(\psi \to \rho^\pm\pi^\mp)}{\Gamma(\psi' \to e^+e^-)/\Gamma(\psi \to e^+e^-)}. \tag{18}$$

Using (17) and setting $\Lambda_{\rm QCD} = 0.3$ GeV, we obtain

$$R_{\rho\pi ee} \simeq 0.66[(M_O{}^2 - m_\psi{}^2)/(M_O{}^2 - m_{\psi'}{}^2)]^2. \qquad (19)$$

Figure 1 shows a graph of this ratio versus M_O. A very conservative upper bound for this ratio extracted from the experimental data,

$$R_{\rho\pi ee} \lesssim 0.15, \qquad (20)$$

is shown on the figure. With the particular assumption for the mixing given in (17) we find that the experimental data indicate

$$M_O \gtrsim 2.3 \text{ GeV}. \qquad (21)$$

Conversely, knowing the mass of the O one can, in this way, determined the nature of O-V mixing. If we use the data on the $K^{*\pm}K^{\mp}$ mode and similarly study the ratio $R_{K^*\bar{K}ee}$ very similar results on the mass of the O are obtained.

Since the candidate two-glue states[11] have mass $\simeq 1.5$ GeV, a three-glue state with a mass $\gtrsim 2.3$ GeV [which may well turn out to be compatible with our potential-model estimate $\simeq 2.4$ GeV (Ref. 8)] would lend support to the notion of a dynamical gluon mass as suggested by the works of Cornwall[6] and Bernard.[7]

(3) We wish to emphasize that a vector gluonium is considerably cleaner than gluonia with other quantum numbers, say $0^{\pm +}$ or 2^{++}. For one thing its mixing with quarkonia proceeds through $O(\alpha_s{}^3)$ rather than $O(\alpha_s{}^2)$ and so the mixing is much less. Also whereas a vector quarkonium can be produced rather abundantly in e^+e^- annihilation through one-photon exchange, the cross section for producing a vector gluonium is exceedingly small ($\lesssim 20$ pb).[12] Similarly the decay width for $O \to e^+e^-$ is estimated to be $\lesssim 1$ eV (Ref. 8) leading us to expect a branching ratio for $O \to e^+e^-$ of $\simeq 10^{-8}$ which is much, much smaller than what one expects from a vector quarkonium. Thus an interpretation of a vector gluonium candidate is likely to be far less difficult than that of the existing glueball candidates: the $\iota(1440)$ and the $\theta(1660)$.[12]

Since the existing data on ψ (ψ') is hinting at the existence of O, since the rates for the reactions in which it may be detectable appear promising, and since it can go a long way in illuminating the physics of gluonia we suggest that its direct searches be undertaken with renewed vigor.

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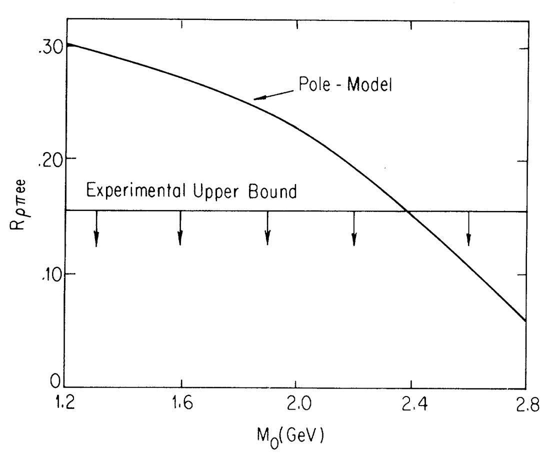

FIG. 1. A model-dependent extraction of the O mass from the experimental data on $\psi(\psi')$ decays into $\rho^\pm\pi^\mp$ and e^+e^- modes [see Eq. (18)]. Curve shows pole-model calculations with a simple, but *ad hoc*, assumption for the O-V mixing [see Eq. (17)]. The experimental upper bound is also shown. Very similar results are obtained if we consider the $K^\pm K^{*\mp}$ mode rather than $\rho\pi$.

[1] G. Trilling, in Proceedings of the Twenty-First International Conference on High Energy Physics, Paris, 26–31 July 1982 (to be published); E. Bloom, *ibid*; G. Feldman, private communication; M. Franklin, private communication, and Ph.D. thesis, Stanford University (unpublished).

[2] See, e.g., D. L. Scharre, in *High Energy Physics —1980*, edited by Loyal Durand and Lee G. Pondrom, AIP Conference Proceedings No. 68 (American Institute of Physics, New York, 1981), p. 673.

[3] P. G. O. Freund and Y. Nambu, Phys. Rev. Lett. 34, 1645 (1975). For later theoretical works on the O see D. Robson, Nucl. Phys. B130, 328 (1977); C. E. Carlson, J. J. Coyne, P. M. Fishbane, F. Gross, and S. Meshkov, Phys. Rev. D 23, 2765 (1981); see also S. Meshkov, invited talk at the Proceedings of the Sixth Workshop on Current Problems in Particle Theory, Italy, 1982, Report No. CALT-68-923 and UCI-82/35 (to be published); Wei-Shu Hou and A. Soni, University of California, Los Angeles Report No. UCLA/82/TEP/14 (to be published).

[4] J. M. Cornwall and A. Soni, Phys. Lett. 120B, 431 (1983).

[5]The last two papers in Ref. 3 have extensive references to the theoretical literature on glueballs.
[6]J. M. Cornwall, Phys. Rev. D 26, 1453 (1982), and references therein.
[7]C. Bernard, Phys. Lett. 108B, 431 (1982), and to be published.
[8]For details see the last paper of Ref. 3.
[9]Use of SU(6) relations [e.g., from B. Sakita and K. C. Wali, Phys. Rev. 139, B1355 (1965), Eq. A(6)] leads to a very similar result, namely, $f_{\varphi K^* \bar{K}}{}^2 \simeq \simeq 0.2 f_{\omega\rho\pi}{}^2$. We expect this also to fail as φ and ω go far off their mass shell.
[10]Note that the ratio $\Gamma(O \to \rho\pi)/\Gamma(\psi \to \rho\pi)$ tends to be independent of the $\omega\rho\pi$ vertex. So we use $\Gamma(O \to \rho\pi) \simeq 50$ MeV as a reference value in Eq. (9).
[11]Bloom, Ref. 1; D. L. Scharre, Stanford Linear Accelerator Report No. SLAC-PUB-2880 (unpublished); C. Edwards *et al.*, Phys. Rev. Lett. 48, 58 (1982). More recently a Brookhaven National Laboratory experiment has reported additional glueball candidates. See A. Etkin *et al.*, Phys. Rev. Lett. 49, 1620 (1982).
[12]Wei-Shu Hou, unpublished.

Search for Slowly Moving Massive Magnetic Monopoles

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An array of plastic scintillation counters was used to search for slowly moving, weakly ionizing particles between April and September 1982. The electronically defined velocity acceptance was $1\times10^{-4}c$ to $3\times10^{-2}c$. The sensitivity of the 2.7-m^2-sr detector was gradually increased until the threshold reached about $0.12I_{min}$. The decrease of scintillator excitation with velocity very likely introduced a lower velocity cutoff near $1.4\times10^{-4}c$. The flux limit for the high-sensitivity runs corresponds to an aperture—solid-angle—time product of $(5\times10^{-12}\ cm^{-2}\ sr^{-1}\ s^{-1})^{-1}$.

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Grand unified theories[1,2] suggest that magnetic monopoles may have been produced in the early universe.[3,4] The mass of this type of monopole is estimated to be $\sim M_x/\alpha_x$, where M_x is the leptoquark boson mass ($\sim10^{15}$ GeV) and α_x is the grand unified fine-structure constant ($\sim\frac{1}{50}$). Depending upon theoretical models, the predicted primordial monopole density can vary by many orders of magnitude.[5,6] Searches for magnetic monopoles have recently been summarized by Carrigan,[7] Carrigan, Craven, and Trower,[8] Longo,[9] and Loh.[10] These searches set limits of less than 10^{-27} light monopoles per baryon in matter, and a flux[11] of fast (highly ionizing) monopoles[12] of less than $7\times10^{-14}\ cm^{-2}\ sr^{-1}\ s^{-1}$. By measuring the magnetic flux change in a superconducting loop, Cabrera[13] sets a limit of $1.2\times10^{-10}\ cm^{-2}\ sr^{-1}\ s^{-1}$ and reports an interesting candidate event. The results of several searches for slow monopoles using plastic scintillation and proportional chamber detectors have been published.[14-18] The experiment of Bonarelli *et al.*[15] and the very sensitive experiment of Mashimo, Kawoge, and Koshiba[17] have lower velocity limits well above $10^{-3}c$. The proportional tube detector of Bartelt *et al.*[18] just reaches $10^{-3}c$. We report an intermediate flux limit in plastic scintillators with a velocity cutoff below $2\times10^{-4}c$.

Astrophysical arguments based upon average density limits and galactic magnetic field survival have also been used to set limits on monopole flux. The older arguments of Parker[19] have recently been revised by Turner, Parker, and Bogdan,[20] and similar arguments have been presented by Shapiro and Wasserman.[21] For experimental purposes, three possibilities must be considered: (1) Monopoles are distributed uniformly throughout the universe. Fluxes of massive monopoles at Cabrera's level are easily excluded under this assumption. (2) Monopoles are gravitationally bound to the galaxy, and account for most of the halo mass. This assumption unambiguously implies velocities near $10^{-3}c$ and can be stretched (with difficulty, especially for magnetic field survival) to Cabrera's flux limit. (3) Monopoles are gravitationally bound to stellar systems. While it is hard to envisage any mechanism which would lead to this situation, it cannot be ruled

