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ON THE HYPERCENTER OF A NEAR-FIELD SPACE OVER A NEAR-FIELD

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ABSTRACT

The problems we are going to consider here arose in another context, that of near-field spaces with sub near-field spaces and where existing rings with polynomial identities similar to that of. However, author feel the subject matter has an independent interest, and Dr N V Nagendram develop the material here. In what follows N will always be an associative near-field space over a near-field, Z(N) the center of N, and J(N) the Jacobson radical sub near-field space of a near-field space over a near-field N. When there will be no danger of ambiguity, we shall write Z(N) and J(N) as Z and J, respectively throughout this paper. We now define a certain sub near-field space of a near-field R which is closely related to the center.

Keywords: *sub near-field space, near-field space, hypercenter, division sub near-field space, semi simple near-field space.*

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Definition: The hyper center S(N) of N is S(N) = ($a \in N$ / $a x^n = x^n a$, $n = n(x, a) \geq 1$, all $x \in N$). Here, too, we shall often write S(N) as S whenever there is no confusion as to the near-field space over a near-field in question The following (a), (b) and (c) three basic properties of S are trivial to verify. They will be used almost everywhere in the paper.
(a). $S \supset Z$.
(b). S is a sub near-field space over a near-field N.
(c). If ϕ is an automorphism of N then $\phi(S) \subset S$.

Thus S need not be equal to Z is clear. If N is a non commutative nil near-field space over a near-field then S = N but $Z \neq N$. Our claim is to see that how close S and Z are to each other. In view of the remark just made, the presence of nil sub near-field spaces under a near-field space over a near-field in N should interface with the equality of S and Z. In the absence of nil sub near-field spaces in N we will show that, indeed, S = Z.

Lemma 1: If D is division near-field space over a near-field S(D) = Z(D).

Proof: When D is a division near-field space then it is trivial that only is S a sub near-field space of D, in fact, S is a sub division near-field space of D over a near-field. Since $\varphi(S) \subset S$ for every automorphism of D, we have S = D or $S \subset Z$. This second possibility, together with $Z \subset S \Rightarrow S = Z$ is the desired conclusion.

Suppose then that S = D, this means that, given $a, b \in D$ then $ab^n = b^n a$ for some $n = n(a, b) \geq 1$. By a theorem of Kaplansky as extended by Dr N V Nagendram we get D is commutative. In this case, of course, D = Z, hence certainly S = Z. This completes the proof of the lemma.

Having the result for division near-field spaces in hand, we follow the usual pattern of pushing the result through for semi-simple near-field spaces over a near-field N.

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Lemma 2: If N is a semi-simple near-field space over a near-field, then S(N) = Z(N).

Proof: Given N is semi-simple near-field space over a near-field, it is a sub-direct product of primitive sub near-field spaces N_λ. Moreover, as is trivial, S(N) maps into $S(N_\lambda)$ for each λ. Thus if we knew that $S(N_\lambda) = Z(N_\lambda)$ for each λ, we would get the required equality S(N) = Z(N).

Hence, without loss of generality, we may assume that N is primitive sub near-field space over a near-field, therefore N is dense near-field space of linear transformations on a vector space V over a division near-field space D. If $\dim_D(V) = 1$ then N = D, and since N is a division near-field space over a near-field we would have S(N) = Z(N) by lemma 1. Hence we may suppose $\dim_D(V) > 1$.

Let s ≠ 0 be in S and suppose that for some v ∈ V, v and vs are linearly independent over D. By density of the action of N on V, there exists an x ∈ N with vx = 0 and vsx = vs. Thus $vsx^m = vs$ for all m ≥ 1. Since, s ∈ S, $sx^n = x^ns$ for some n ≥ 1. Hence $vs = vx^ns = 0$, a contradiction.

Thus, given v ∈ V, vs = λ(v)v where λ(v) ∈ D. If v, w ∈ V are linearly independent over D then, we claim, λ(v) = λ(w). For, vs = λ(v)v, wt = λ(w)w, and (v + w) s = λ(v + w) (v + w).

These yield [λ(v) - λ (v + w) + (λ(w) - λ(v + w)] w = 0 by the independence of v and w over D we conclude that λ(v) = λ(v + w) = λ(w). Since λ is constant on independent elements, and since $\dim_D(V) > 1$, we get that λ(v) = λ, λ independent of v, for all v ∈ V.

If x ∈ N then, since vx ∈ V, (vx)s = λ(vx), hence v(xs) = λ(vx). On the other hand, vs = λv whence (vs)x = (λv)x = λ(vx) and so v(sx) = λ(vx). The net result of this is that v(xs) = v(sx), hence v(xs – sx) = 0 for all v ∈ V. Since N acts faithfully on V, we have xs – sx = 0 for all x ∈ N. this puts s ∈ Z. Thus we have that S ⊂ Z, and so, S = Z.

Lemma 3: Let N be any near-field space. If a ∈ S(N) is nilpotent near-field space then aNa is a nil right sub near-field space of N. Hence a and aN lie in J(N).

Proof: Let a ≠ 0 in S be nilpotent sub near-field space. Then $a^n = 0$, $a^{n-1} \neq 0$ for some n > 1. Given x ∈ N, then since $a^{n-1} \in S$, $(ax)^m a^{n-1} = a^{m-1}(ax)^m = 0$, for a suitable m ≥ 1. Pick j minimal such that $(ax)^u a^j = 0$ for some integer u ≥ 1. If j = 1, this would yield $(ax)^{u+1} = 0$ and so ax is nilpotent, if j > 1, then since $x(ax)^u a.\ a^{j-1} = 0$, $(xa)^{u+1} a^{j-1} = 0$. Since $a^{j-1} \in S$, $a^{j-1}((xa)^{u+1})^s = ((xa)^{u+1})^s a^{j-1} = 0$ for some s ≥ 1. Thus $a^{j-1}(xa)^r = 0$, where r = (u + 1)s. Hence $a^{j-1}(ax)^{r+1} = 0$. Since $a^{j-2} \in S$, $((ax)^{r+1})^v\ a^{j-2} = a^{j-2}\ ((ax)^{r+1})^v = 0$. But this contradicts the minimal nature of j, in short, j = 1 and ax is nilpotent for every x. therefore, aN is nil near-field space over a near-field. This completes the proof of the lemma.

Theorem 1: Let N be a prime near-field space with no non-zero nil sub near-field spaces. Then S(N) has no nil potent sub near-field spaces.

Proof: Let M be the set of all nilpotent sub near-field spaces in S. Given a, b∈S then $ab^n = b^na$ for some n = n(a, b)≥1. Clearly N is a sub near-field space of S. In fact it is the maximal nil sub near-field space of S.

Suppose that M ≠ 0. Since φ(S) ⊂ S for all automorphisms φ of N, we have that φ(M) ⊂ M. By lemma 3, M ⊂(N).

If x ∈ (N) then the mapping φ: N → N defined by $\varphi(y) = (1 + x)\, y(1 + x)^{-1}$ for y ∈ N is an automorphism of N. Hence $(1 + x)\, N\, (1 + x)^{-1} \subset N$.

Suppose that a ≠ 0 is in N where $a^2 = 0$. If x ∈ N then ax is nilpotent sub near-field space by lemma 3, hence $(1 + ax)^{-1} = 1 - ax + (ax)^2 - ....$ Since $(1 + ax)\, a\, (1 + ax)^{-1} \in N$, we have that $(1 + ax)\, a\, [1 - ax + (ax)^2 - ....] \in N$. Because $a^2 = 0$, this last relation reduces to (1 + ax) a ∈ N, and so axa ∈ N ∀ x ∈ N. In short, aNa ⊂ N.

If y ∈ J(N) and b ∈ N then $(by - yb)\,(1+y)^{-1} = b - (1+y)b(1+y)^{-1}$ is in N. let y = ax where $a^2 = 0$, a ∈ N. Hence $(axb - bax)(1 - ax)^{-1} \in N$. Multiply this from the left by a, using $a^2 = 0$ we arrive at $abax(1 - ax)^{-1} \in N$ ∀ x ∈ N. Given any w∈ J(N) true that any w ∈ N then $w = x\,(1 - ax)^{-1}$ where $x = (wa + 1)^{-1}w$ is in J(N). Thus we get (aba) J(N) ⊂ N.

If y ∈ J(N) and b ∈ N then $(by - yb)(1 + y)^{-1} = b - (1 + y)\, b\, (1 + y)^{-1}$ is in N. Let y = ax where $a^2 = 0$, a ∈ N.

Hence $(axb - bax)(1 - ax)^{-1} \in N$. on left multiplication by a using $a^2 = 0$ we arrive at $abax\,(1 - ax)^{-1} \in N$ ∀ x ∈ N. Given any w∈J(N) in fact any w∈N then $w = x(1 - ax)^{-1}$, where $x = (wa + 1)^{-1}\, w$ is in J(N). Thus we get (aba) J(N) ⊂ N.

If y ∈ (N) then (1 + y) (aba J(N)) $(1 + y)^{-1} \subset (1 + y)$ N $(1 + y)^{-1} \subset$ N. Since J(N)) $(1 + y)^{-1} \subset$ J(N) and aba J(N) ⊂ N ⇒ yaba (N) ⊂ N ∀ y ∈ J(N). In other words, J(N) aba J(N) ⊂ N. But J(N) aba J(N) is a sub near-field space of N, and since it lies in N, it must be nil sub near-field space of a near-field space over a near-field. We conclude that J(N) aba J(N) = 0. Since aba ∈ (N) and J(N) has no nilpotent sub near-field spaces, we get that aba = 0 for b ∈ N, i.e., aNa = 0. Summarizing, if $a^2 =0$ where a ∈ N, then aNa = 0.

If b∈ N and $b^2 = 0$ then we have seen that bNb ⊂ N. So, if $a^2 = 0$ where a ∈ N, then abNba ⊂ aNa = 0. Since N is prime near-field space over a near-field, this yields that ab = 0 or ba = 0. In particular, if x ∈ J(N) then b = (1 + x) a $(1 + x)^{-1}$ is in N and $b^2 = 0$. Hence ab = 0 or ba = 0. Now, ab = 0 yields axa = 0 and ba = 0 yields a $(1 + x)^{-1}$ a = 0.

We claim that if x ∈ J(N) is nilpotent near-field space over a near-field then axa = 0, we go by induction on the index of nil potency of x.

If $x^2 = 0$ then $(1 + x)^{-1} = 1 – x$, hence, by the above, either axa = 0 or a $(1 + x)^{-1}$ a = 0 ; because $(1 + x)^{-1} = 1 – x$, this reads as axa =0 or a (1 – x)a = 0. Since $a^2 = 0$, a(1 – x) a = 0 ⇒ axa = 0. Then either possibility leads to fact that axa = 0.

Suppose that x ∈ J(N), $x^n = 0$. Since x^j for j > 1, has index nil potency less than n, by induction, $ax^ja = 0$ for j > 1. Now, we know that axa = 0 or a $(1 + x)^{-1}$ a = 0. Since $(1 + x)^{-1} = 1 – x + x^2 - ..... \pm x^{n-1}$ and since $ax^ja = 0$ for j > 1, a $(1 + x)^{-1}$ a = 0 yields $0 = a (1 – x + x^2 - ... \pm x^{n-1})a = -$ axa.

Thus, indeed axa = 0 follows, for all nilpotent x ∈ J(N).

Let a, b ∈ N with $a^2 = 0$ and $b^2 = 0$. If r ∈ N then, by lemma 3, br ∈ (N) and is nilpotent sub near-field space ove a near-field. Thus, by the result derived above, a(br)a = 0 which is to say, abNa = 0. Since N is prime near-field space over a near-field, we get ab = 0. If x ∈ J(N) let b = a(1 + x) a$(1 + x)^{-1}$ = axa $(1 + x)^{-1}$ yields that axa = 0 and so aJ(N)a = 0. Because N is prime near-field space over a near-field and J(N) ≠ 0 is a sub near-field space of N, we conclude that a = 0. Thus N is 0 and S(N) has no nilpotent sub near-field spaces. This completes the proof of the theorem.

Lemma 4: Let N be a prime near-field space over a near-field with no nil sub near-field spaces. Then S(N) is commutative and non zero sub near-field space of S(N) is not a zero divisor sub near-field space in N.

Proof: Given a, b ∈ S then $ab^n = b^na$ for some n ≥ 1. The Commutator sub near-field space of a near-field space over a near-field S of N is nil potent sub near-field space, according to theorem 1, S has no nilpotent sub near-field spaces. Thus the Commutator sub near-field space of S is 0, hence S must be commutative.

Suppose, that a ≠ 0 is in S and au = 0 for some u ∈ N. If x ∈ N then y = uxa satisfies $y^2 = 0$ and ay = 0. But (1 + y) a $(1 + y)^{-1}$ = (1 + y) a (1 – y) is in S, i.e., a + ya ∈ S, whence ya ∈ S. However, $(ya)^2$ = = yaya = 0. Since S has no nilpotent sub near-field spaces, we must have ya = 0. Recalling that y = uxa, we have $uxa^2 = 0$ ∀ x ∈ N. Since $a^2 \neq 0$ and N is prime near-field space over a near-field, we get u = 0. Hence au = 0 ⇒ u = 0 and so a is not a zero divisor sub near-field space in N.

MAIN RESULT ON THE HYPERCENTER OF A NEAR-FIELD SPACE OVER A NEAR-FIELD

Theorem 2: Let N be a near-field space over a near-field with no nilpotent sub near-field spaces. Then S(N) = Z(N).

Proof: Since N is sub direct product of prime near-field spaces N_β with no nil sub near-field spaces, Since S(N) maps into $S(N_\beta)$, if we could prove that $S(N_\beta) = Z(N_\beta)$ for each β, we would get that S(N) = Z(N). With loss of generality (w. g. l.), N is a prime near-field space with no nil sub near-field spaces. Also, if J(N) = 0 then by lemma 2, S(N) = Z(N), therefore we may assume that J(N) ≠ 0.

Since N prime near-field space and J ≠ 0, the centralizer near-field space of J in N must be precisely Z(N). In particular, Z(J) ⊂ Z(N). Thus to prove that S = Z, it is enough to show that S centralizes J.

Suppose then that a ∈ S and x ∈ J and ax – xa ≠ 0.

Now 0 ≠ (ax – xa) $(1 + x)^{-1}$ = a – (1 + x) a $(1 + x)^{-1}$ ∈ S.

Clearly, since x ∈ J, (ax – xa) $(1 + x)^{-1}$ ∈ Z. Therefore, 0 ≠ (ax – xa) $(1 + x)^{-1}$ is in S ∩ J, and so S ∩ J ≠ 0. If we could show that S ∩ J ⊂ Z. Then we would have (ax – xa) $(1 + x)^{-1}$ ∈ Z Also if b ∈ S, then b(ax – xa) $(1 + x)^{-1}$ ∈ S ∩ J ⊂ Z and since both 0 ≠ (ax – xa) $(1 + x)^{-1}$ ∈ Z and b(ax – xa) $(1 + x)^{-1}$ ∈ Z and since sub near-field spaces of Z are not zero divisor sub near-field spaces of a near-field space N, these relations would imply that $b \in Z$ and we would get the desired conclusion S(N) = Z(N).

It is obvious that if N is a prime near-field space with no nilpotent sub near-field spaces of near-field space over a near-field and J(N) = N then S(N) = Z(N).

So we suppose that N is prime near-field space, no nil potent sub near-field spaces and J(N) = N.

Suppose that $0 \neq a \in S$, $x \in N$ and $x \in N$ is such that xa = ax and zx = xz. Then since $(1 + x)\, a(1 + x)^{-1}$ and $(1 + zx)\, a\, (1 + zx)^{-1}$ are in N, we have (i) $(1 + x)\, a = a_1 (1 + x)$ (ii) $(1 + zx)\, a = a_2 (1 + zx)$ where $a_1, a_2 \in S$. Multiply (i) by z and subtract (ii); since z commutes with x and with a we get, (iii) $za - a = xa_1 - a_2 + (a_1 + a_2)zx$.

Now xa – a commutes with a, since z does. Also since $a_1, a_2 \in S$ and S is commutative, $za_1 - a_2$ commutes with a. Thus from (iii) we deduce that $(a_1 - a_2)$ zx commutes with a. This gives $(a_1 - a_2)\, z(xa - ax) = 0$.

If $a_1 - a_2 \neq 0$, since $a_1 - a_2 \in S$ it is not a zero divisor sub near-field space in N. So we conclude that z(ax – xa) = 0. On the other hand, if $a_1 = a_2$, remaining to (iii) we see that $za - a = za_1 - a_1$ and so $(1 - z)\, (a - a_1) = 0$. Since $z \in N = J$, $(1 - z)\, (a - a_1) = 0$ forces $a = a_1$, But then (i) tells us that xa = ax in which case certainly z(xa – ax) = 0. Hence if $z \in N$ commutes with both $a \in S$ and $x \in N$ then z(xa – ax) = 0.

Now if $a \neq 0$ is in S, and $x \in N$ then $ax^n = x^n a$ for some $n \geq 1$. If $z = x^n$ then za = az and zx = xz whence z (xa – ax) = 0 i.e., $x^n(xa - ax) = 0$. But then $x^n\, (ax - xa)\, (1 + x)^{-1} = 0$. Since $(ax - xa)\, (1 + x)^{-1} \in S$, if it is not 0, it is not zero divisor sub near-field space. So if $xa - ax \neq 0$ then $x^n = 0$. Therefore a commutes with all nilpotent sub near-field spaces in N over a near-field.

Consequently, if $ay - ya \neq 0$, ay – ya is not a zero divisor near-field space, so certainly cannot be nilpotent sub near-field space. Thus a must commute with ay – ya. If ay – ya = 0 then a certainly commutes with ay – ya. Therefore a commutes with all ax – xa, $x \in N$. if char $N \neq 2$ it is well known result that this forces a to be in Z. So if char $N \neq 2$, then $S \subset Z$, whence S(N) = Z(N). on the other hand, if cahr N = 2 , since a (ax + xa) = (ax + xa)a for all $x \in N$, we get $a^2 \in Z$. Thus $z = a^2$ commutes with a and any x. In consequence, $0 = z(ax + xa) = a^2\, (ax + xa)$. But a is not a zero divisor near-field space of N, we consequently get that ax = xa and so $a \in Z$. Thus here too we end up with $S \subset Z$ and so S(N) = Z(N). we have now succeeded in proving that S(N) = Z(N) thereby establishing the theorem. This completes the proof of the theorem.

MAIN RESULT ON PROPERTY OF S(N) IN GENERAL CASE OF THE HYPERCENTER OF A NEAR-FIELD SPACE OVER A NEAR-FIELD.

Theorem 3: Let N be a near-field space and S(N) its hypercenter. If $a \in S(N)$ and $x \in N$ then ax – xa generates a nil potent sub near-field space of N. In particular, ax – xa is nilpotent sub near-field space over a near-field for every $x \in N$.

Proof: Unfortunately the property that ax – xa generate a li potent sub near-field space for all $x \in N$ is not sufficient to force a to lie in S(N). If N = { $\begin{bmatrix} \alpha & \beta \\ 0 & \gamma \end{bmatrix}$ / α, β, γ integers} then a = $\begin{pmatrix} 1 & 1 \\ 0 & 1 \end{pmatrix}$ has the property that ax – xa generate a nil sub near-field space of N over a near-field. Yet a fails to commute with any power of x = $\begin{pmatrix} 1 & 0 \\ 0 & 0 \end{pmatrix}$ hence $a \notin S(N)$. This indicates that the theorem is about as much as we can say in the general case.

Let B be a commutative sub near-field space such that given $x \in N$, then $x^{n(x)} \in B$. Then the nilpotent sub near-field spaces of N form a sub near-field space N and N/N is commutative. We had done this for the case B = Z. This result by author of Dr N V Nagendram is a very special case of this research article of advance in near-field spaces over a near-field under algebra of mathematics. To prove this result it is trivial to reduce to the case when N has no nil potent sub near-field spaces. Since $B \subset S$, and since S = Z, when N has no nilpotent sub near-field spaces, we have $B \subset Z$. Thus given $x \in N$, $x^{n(x)} \in B \subset Z$. N must be commutative. This completes the proof of the theorem.

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