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# (1, 2)*-D**SpOpen Sets in Bitopological Spaces

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**Abstract**

This article explains the concept of (1, 2)*D** semi- pre-open sets based on the concepts of semi- preopen sets and semi- pre- continuity in topological space. In addition to that the concept of (1,2)*D**Sp generalized continuous maps and generalized homeomorphisms are also discussed.

**Keywords**: (1, 2)*-Open map, (1, 2)*-D**SpOS, (1, 2)*-D**SpContinuous map.

## 1. Introduction

Bhattacharya and Lahiri [1] introduced a new class of semi generalized open sets by means of semi open sets introduced by Levine [5]. In view of that we introduce a new class of open sets namely (1, 2)*-D**Spopen sets and their properties are also studied.. Also (1, 2)*-D**SpContinuous maps, irresolute maps, (1, 2)*-D**SpConnected sets, homeomorphism are also studied with their characterizations.

## 2. Preliminaries

Entire area of this paper, (X, 1, 2) X will denote bitopological space (briefly, BTPS).

**Definition 2.1:** Let H be a subset of X. Then H is said to be $\tau_{1,2}$-open [7] if H = A ∪ B where A ∈ $\tau_1$ and B ∈ $\tau$

The complement of $\tau_{1,2}$-open set is called $\tau_{1,2}$-closed.

Notice that $\tau_{1,2}$-open sets need not necessarily form a topology

Note; 1,2-open sets need not necessarily form a topology.

**Definition 2.2 [7]:** Let H be a subset of a bitopological space X. Then

(i) the $\tau_{1,2}$-closure of H, denoted by $\tau_{1,2}$-cl(H), is defined as {F : H ⊆ F and F is $\tau_{1,2}$-closed}

(ii) the $\tau_{1,2}$-interior of H, denoted by $\tau_{1,2}$-int(H), is defined as {F : F ⊆ H and F is $\tau_{1,2}$-open}

**Definition 2.3:** A subset H of a BTPS X is called:

(i) (1, 2)*-semi-open set [8] if H $\subseteq$ $\tau$1,2-cl($\tau$1,2-int(H));

(ii) (1, 2)*-preopen set [6] if H $\subseteq$ $\tau$1,2-int($\tau$1,2-cl(H));

(iii) (1, 2)*-$\alpha$-open set [3] if H $\subseteq$ $\tau$1,2-int($\tau$1,2-cl($\tau$1,2-int(H)));

(iv) regular (1, 2)*-open set [6] if H = $\tau$1,2-int($\tau$1,2-cl(H)).

(v) (1, 2)*-gsp-closed [10, 11] if (1,2)*-cl(A) $\subseteq$ U whenever A $\subseteq$ U and U is (1, 2)*-open. Then complement of (1, 2)*-gsp-closed set is called (1, 2)*-gsp-open set.

The complements of the above-mentioned open sets are called their respective closed sets.

3. **Definition 2.4:** [2] A subset H of a space (X, $\tau$) is called $\omega$-cld if it contains all its condensation points. The complement of $\omega$-cld set is called $\omega$-open.

4. **Definition 2.5.** A bijection f : X → Y is called (1, 2)*-homeomorphism [4] if f is bijection, (1,2)*-continuous and (1,2)*-open.

5. **Definition 2.6:** A subset A of X is called (1, 2)*-D*-cld (briefly, (1,2)*-D*-cld) if (1, 2)*- scl*(A) $\subseteq$ (1, 2)*-int(U) whenever A $\subseteq$ U and U is (1, 2)*-$\omega$-open. The complement of (1, 2)*-D*-cld set is called (1, 2)*-D*-open.

6. **Definition 2.7:** (1, 2)*-D**-closed (briefly, (1, 2)*-D**-cld) if (1, 2)*-spcl(A) $\subseteq$ U whenever A $\subseteq$ U and U is (1,2)*-D*-open. The complement of (1, 2)*-D**-closed set is called (1, 2)*-D**-open. The class of all (1, 2)*-D**-cld in X is denoted by (1, 2)*-D**-C(X).

The complements of the above mentioned open sets are called their respective closed sets.

## 3 (1, 2)*-D**spOpen Sets

**Definition 3.1**

For S $\subseteq$ X , (1, 2)*-spcl**(S) = $\cap$\{K/S $\subseteq$ K , K is (1, 2)*gspClosed\}.

**Remark 3.2**

(1, 2)*-spcl**(S) = Kuratowski closure operator on X .

**Definition 3.3**

S $\subseteq$ X, (1, 2)*-D**spOpen iff there exists an $\tau$1,2OS
U Such that U$\subseteq$S $\subseteq$ (1, 2)*- spcl**(U). in X.

**Example 3.4**

Let G = {1, 2, 3}, $\tau$1 = { G, $\varphi$, {1} } and $\tau$2 = {G, $\varphi$, {1}, {1, 2}}. Then (1, 2)*-D**spOS of (X, $\tau$1, $\tau$2) are X, $\varphi$, {1}, {1,2} and {1,3}.

**Remark 3.5**

If C $\subseteq$ X, D $\subseteq$ X $\ni$ C $\subseteq$ D, then we have (1, 2)*-spcl**(C) $\subseteq$ (1, 2)*-spcl**( D ).

**Theorem 3.6**

For $S \subseteq X$. we have S is (1, 2)*- D**spOpen
iff $S \subseteq$ (1, 2)*-spcl**($\tau_{1,2}$Int(S)).

**Proof.**

Assume S is (1, 2)*- D**spOpen in X . $U \subseteq S$ implies $U \subseteq \tau_{1,2}$int(S). hence from Remark 3.5 and by defn 3.3, (1, 2)*-spcl**(U) $\subseteq$ (1, 2)*spcl**($\tau_{1,2}$-Int(S)). So $S \subseteq$ (1,2)*-spcl**($\tau_{1,2}$-Int(S)).

To prove the converse let $S \subseteq$ (1, 2)*-spcl**($\tau_{1,2}$Int(S)). substitute U = $\tau_{1,2}$-Int(S). finally by defn 3.3. S in X is (1, 2)*- D**spOS .

**Theorem 3.7 In BTS X**

$\tau_{1,2}$-OS(R) $\Rightarrow$ (1 ,2)*-D**spOS(R)

**Proof.**

Assume R be a $\tau_{1,2}$OS in X let

R = $\tau_{1,2}$Int(R) $\subseteq$ (1, 2)*-spcl**($\tau_{1,2}$Int(R)). We have S is (1 ,2)*-D**spOS in X .

**Example 3.8**

Reverse of theorem 3.7 is proved by this example

S = {1,3} is a (1 ,2)*-D**sp-OS in X but not an $\tau_{1,2}$-OS in X.

**Definition 3.9 In** BTS X

(1, 2)*-D**sp$T_{1/2}$ space for every (1 ,2)*-D**spOS is $\tau_{1,2}$OS

**Remark 3.10 In**

(1, 2)*$T_{1/2}$ space, Every (1, 2)*SpOS is (1 ,2)*-D**spOS.

**Remark 3.11**

(1 ,2)*-spcl**(A) $\subseteq \tau_{1,2}$spcl(A) for a subset A in X.

**Theorem 3.12** In BTS X.

S is (1, 2)*-D**spOS $\Rightarrow$ S is (1, 2)*-spOS .

**Proof** In X , Suppose S is (1, 2)*- D**spOS and By defn 3.3 and. By Remark 3.11, (1 ,2)*-spcl**(U) $\subseteq \tau_{1,2}$-spcl(U) . Hence $U \subseteq S \subseteq \tau_{1,2}$-spcl(U)

$\Rightarrow$ S is (1,2)*-spOS.

**Example 3.13**

To prove the reverse of thm 3.12 is not true assume G = {1, 2, 3}, $t_1$ = {G, φ, {2}} and $t_2$ = {G, φ }.

Then S = {2, 3} is ( 1, 2)*spOS but not a (1, 2)*-D**spOS.

**Remark 3.14**

**In BTS X**

**Consider**

C ⊆ X, D ⊆ X

we have (1, 2)*-spcl** (C∪D) = (1, 2)*-spcl**(C)∪ (1, 2)*-spcl**(D) .

**Theorem 3.15**

**In BTS X Consider**

C ⊆ X, D ⊆ X

We have

(1, 2)*-D**spOS

⇒ CunionD is also a (1, 2)*-D**spOS .

**Proof.**

**In BTS X**

Suppose C and D are (1, 2)*-D**spOS in X. By defn & Remark3.14, (1, 2)*-spcl**(S) ⊆ (1, 2)*-spcl** (T)

⇒ (1, 2)*-spcl** (S ∪ T).

⇒ S ∪ T is also (1, 2)*-D**spOS .

**Example 3.16 In BTS X**

Suppose C , D are (1 ,2)*-D**spOS ⇒

C ∩ D may not (1, 2)*-D**spOS .

Let X = {1, 2, 3, 4}, $t_1$ = { X, φ, {1, 2}, {1 ,2, 3}, {1, 2, 4}} , $t_2$ = { X, φ, { 1, 2 }, {3, 4} }.

Then the set A = {1,2,3} and B = {3,4} are (1,2)*- D**spOS in X and A ∩ B = {3} is not a (1,2)*-D**spOS.

**Theorem 3.17**

In BTS X

Assume B be a (1, 2)*-D**spOS , B ⊆ C and B ⊆ C ⊆ ( (1, 2)*- spcl**($\tau_{1,2}$Int(A)). we have C is a (1, 2)*-D**spOS

**Proof**

From statement B is (1, 2)*-D**spOS and By Thm 3.16 B ⊆ (1, 2)*-spcl**($\tau_{1,2}$Int(B)), Also B ⊆ C

⇒ $\tau_{1,2}$-Int(A) ⊆ $\tau_{1,2}$- Int(B). Hence, (1, 2)*-spcl**($\tau_{1,2}$Int(B)) ⊆ (1, 2)*-spcl**($\tau_{1,2}$Int(C)). We have C ⊆ (1, 2)*-spcl**($\tau_{1,2}$Int(B)) ⊆ (1, 2)*-spcl**($\tau_{1,2}$Int(C)) it proves C is (1, 2)*-D**spOS .

**Remark 3.18**

**A Map**

h : L → M is (1, 2)*gspContinuous

⇒ f((1, 2)*-spcl**(A)) ⊆ 1,2-spCl( f(A)).

**Theorem 3.19**

In BTS X

Suppose a map h : L → M be (1, 2)*gspContinuous and (1, 2)*Open ⇒ B is (1, 2)*-D**spOS

⇒ f(B) in Y is (1, 2)*-spOS .

**Proof**

From statement B is (1, 2)*-D**spOS in L. By defn 3.3 and. Remark 3.18,

h((1, 2)*-

spCl**(V)) ⊆ $\sigma_{1,2}$-spCl(h(B)). We have h(B) ⊆ h((1, 2)*- spCl**(V)) ⊆ $\sigma_{1,2}$-spCl(h(V)). Also given h is (1, 2)*Open Map h(V) in M is $\sigma_{1,2}$-Open . it follows that h(B) in M is (1, 2)*-spOS.

**Theorem 3.20** in BTS X consider

A Map h : L → M be a (1, 2)*homeomorphism. If B in L is (1, 2)*-D**spOS , then h(B) is (1, 2)*- D**spOS in M.

**Proof**

B is (1, 2)*-D**spOS in L.. By definition 3.3 h(V) ⊆ h(B) ⊆ h((1, 2)*-spCl**(V)). Also given h is (1, 2)*homeomorphism we have h((1, 2)*-spCl**(V)) ⊆ (1, 2)*- spCl**h(V)). it follows h(V) ⊆ h(B) ⊆(1, 2)*- spCl**( h(V)). so that h( B) in M is (1, 2) *-D**spOS

**Theorem 3.21**

in BTS X Consider A Map h : L → M if

h is (1, 2)*homeomorphism.and B in M is (1, 2)*-D**spOS

then ∃ $\tau_{1,2}$-OS such that $h^{-1}$(B) in M is (1, 2)*- D**spOS

**Proof**

From statement B in L is (1, 2)*-D**spOS . By defn 3.3 we have $h^{-1}$(V) ⊆ $h^{-1}$(B) ⊆ $h^{-1}$((1, 2)*-spCl**( V)). and Since h is

(1, 2)*homeomorphism ⇒ $h^{-1}$((1, 2)*-spCl**(V)) ⊆ (1, 2)*-spCl**($h^{-1}$(V)). hence we have $h^{-1}$(V) ⊆ $h^{-1}$(B) ⊆ (1, 2)*-spCl**($h^{-1}$(V)) thus $h^{-1}$(B) is (1, 2)*-D**spOS

## 4. (1, 2)*-D**spClosed and (1, 2)*-D**spOpen Mappings

**Definition 4. 1**

A Map h : L → M is (1, 2)*-D**spO- map if h(V) in M is (1, 2)*-D**spOS ∀ $\tau_{1,2}$OS V in M.

**Theorem 4.2 A map**

h : L →M is (1, 2)*-Open map ⇒ (1, 2)*D**spOpen -Map

**Proof.**

From statement h : L →M is (1, 2)*-Open map .and G is $\tau_{1,2}$-OS in L. we have h(G) in M is $\sigma_{1,2}$Open. From Theorem3.7, h(G) is

(1, 2)*-D**spOS in M.. Henceforth h is (1, 2)*-D**spOpen .

**Example 4.3**

Reverse ofTheorem 4.2 is not true. by this example

Let L= M= {a1, ,b1 ,c1} , $\tau_1$ = {L, φ, {a1}}, $\tau_2$ = { L, φ, {a1, c1}}. Let $\sigma_1$ = {L, φ, {a1}}, $\sigma_2$ = {L, φ, {a1}, {a1,b1}}.

Let h : L → M is an identity map. we have h is

(1, 2)*- D**spOpen but h is not (1, 2)*-Open. map

**Definition 4.4 The map**

h : L → M is (1, 2)*- D**spClosed Map if For every $\tau_{1,2}$-CS V in L, h(V) in M is (1, 2)*- D**spClosed

**Remark 4.5**

h : L → M is (1 ,2)*Closed ⇒ h is (1, 2)*- D**spClosed but conversely not true

**Proof.**

From Theorem 4.2. proof is clear

## 5. (1, 2)*-D**spContinuous Mappings

**Definition 5.1 A map**

h : K →L is called (1, 2)*-D**spContinuous ∀ $\sigma_{1,2}$-OS in L its inverse image of h is (1, 2)*-D**spOpen in K..

**Theorem 5.2**

**A map**

$$h : K \to L$$

h is (1, 2)*Continuous ⇒ h is (1, 2)*-D**spContinuous.

**Proof**

Assume R as a $\sigma_{1,2}$OS in L. Also h is (1, 2)*Continuous, $h^{-1}(R)$ is $\tau_{1,2}$Open in X. From Theorem 3.7, $h^{-1}(R)$ is (1, 2)*-D**spOpen in X . Thus h is (1, 2)*-D**spContinuous.

**Example 5.3 This example proves reverse of thm 5.2 Consider A map**

$h : K \to L$ let the two sets $L = K = \{a1, a2, a3\}$, $\tau_1 = \{L, \varphi, \{a1\}\}$, $\tau_2 = \{L, \varphi, \{a1\}, \{a1, a2\}\}$, $\sigma_1 = \{K, \varphi, \{a1\}\}$ and $\sigma_2 = \{K, \varphi, \{a1, a3\}\}$. Suppose $h : K \to L$ be the identity map

we have h is (1, 2)*- D**spContinuous but h is not (1, 2)*Continuous .

**Remark 5.4**

In (1, 2)*-D**sp-$T_{1/2}$ space, every (1, 2)*-D**spContinuous map is (1, 2)*Continuous.

**Theorem 5.5**

$h : K \to L$ is a map. we have the below implications are true.

- 1 h is (1, 2)*- D**spContinuous.
- 2. For each $\sigma_{1,2}$CS in L its inverse image is (1, 2)*-D**spClosed in K .

**Proof.**

(1) ⇒ (2) Let R is $\sigma_{1,2}$CS in L. Then L - R is $\sigma_{1,2}$Open in L. Also h is (1, 2)*-D**spContinuous, $f^{-1}$ (L - R) is (1, 2)*-D**spOpen in K. so that we have K / $f^{-1}$(R) is (1, 2)*-D**spOpen in K ⇒ $f^{-1}$(R) is (1, 2)*- D**spClosed in K.

(ii) ⇒ (i) Let S is a $\sigma_{1,2}$OS in L. Then L-S is $\sigma_{1,2}$Open in L. ⇒ $f^{-1}(L \setminus S)$ is (1, 2)*-D**spClosed in K, ⇒L \$f^{-1}$(S) is (1, 2)*-D**spClosed in L .So that $h^{-1}$(S) is (1, 2)*-D**spOpen in L. Hence h is (1, 2)*-D**spContinous.

**Theorem 5.6**

**Assume** $h : K \to L$ is a map

If h is (1, 2)*-D**spContinuous Map, Then h ($\tau_{1,2}$-D**spcl(B)) ⊆ $\sigma_{1,2}$-spcl(h(B)).

**Proof.**

Given h(B) ⊆ $\sigma_{1,2}$-spCl(h(B)), ⇒ B ⊆ $h^{-1}$($\sigma_{1,2}$-spCl((B)).

Then $\sigma_{1,2}$-spCl(h(B)) is a $\sigma_{1,2}$CS in L and

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h is (1, 2)*-D**spContinuous map ⇒ $h^{-1}$($\sigma_{1,2}$-spCl(h(B)) is (1, 2)*-D**spClosed in L. Hence $\tau_{1,2}$-D**spcl(B) ⊆ $h^{-1}$($\sigma_{1,2}$-scl(f(B).it proves h ($\tau_{1,2}$-D**spcl (B)) ⊆ $\sigma_{1,2}$-spcl(h(B)).

**(1, 2)*-D**spContinuous and (1, 2)*-D**spIrresolute Mappings Definition 6.1 Consider a map** h : K → L

H is (1, 2)*-D**spirresolute if for every (1, 2)*-D**spOS of L its inverse image of h is (1, 2)*-D**spOpen in K

**Remark 6.2**

**Consider a map** h : K → L

For every (1, 2)*-D**spCS of L by defn of 6.1 (1, 2)*-D**spClosed in K..

**Theorem 6.3**

**Consider a map**

**Proof.**

h : K → L is (1, 2)*-D**spirresolute implies h is (1, 2)*-D**spContinuous .

Suppose R is a $\tau_{1,2}$OS in K. Also h is (1, 2)*-D**spirresolute proves $h^{-1}$(R) is (1, 2)*-D**spOpen in K. Thus h is (1, 2)*-D**spContinuous.

**Example 6.4**

Reverse part of the Theorem 6.3 Can be proved by the following example to show it is not true

Let X = Y = {a1 ,a2 ,a3}, $\tau_1$ = {X, φ, {a1}, {a2}, { a1,a2}}, $\tau_2$ = {X, φ, {a1,a2}} , $\sigma_1$ = {X, φ, {a1}}, $\sigma_2$ = { X, φ, {a1}, {a1,a2}}. Let f : X → Y be the identity map. Hence f is (1, 2)*- D**sp-Continuous but f is not (1, 2)*-D**spirresolute.

**Theorem 6.5**

**Consider a map**

h : K → L

h is (1, 2)*Continuous and L is (1, 2)*-D**sp-$T_{1/2}$-space implies h is (1, 2)*- D**spirresolute.

**Proof**

Assume B be (1, 2)*-D**spOS in L. Also L is (1,2)*-D**sp-$T_{1/2}$-space, implies B is an $\sigma_{1,2}$OS in L and also h is (1, 2)*Continuous proves $h^{-1}$(B) is (1, 2)*-D**spOS in K. Thus h is (1, 2)*-D**spirresolute.

**Theorem 6.6**

**Consider a map**

h : K → L

h is (1, 2)*-D**spirresolute and k : L → M be an (1, 2)*-D**spirresolute maps. Then h o k : K → M is (1, 2)*- D**spirresolute.

**Proof.**

Suppose V be a (1, 2)*-D**spOS in M. so $h^{-1}$(V) is (1, 2)*-D**spOpen in L implies $h^{-1}(k^{-1}(V))$ is (1, 2)*-D**spOpen in K. Thus $(hok)^{-1}(V)$ is (1, 2)*-D**spOpen in K. Hence hok is (1, 2)*-D**spirresolute.

## 7. (1, 2)*-D**spConnected Sets

**Definition 7.1**

A space X is (1, 2)*-D**spdisConnected if it is the Union of two disjoint non empty (1, 2)*-D**spOS otherwise it is said to be (1, 2)*-D**spConnected

**Theorem 7.2**

IN BTS X, the following statements are true.

- X is (1, 2)*-D**spConnected.
- φ , X are the subsets which are both (1, 2)*-D**spOpen and (1, 2)*-D**spClosed .

**Proof.**

i ⇒ ii Let U ⊆ X which is (1, 2)*-D**spOpen & (1, 2)*-D**spClosed.

Then X/U is also (1, 2)*-D**spOpen & (1, 2)*-D**spClosed by defn of 7.1 .

U and X/U implies either

U = φ or X/U = φ.

ii ⇒ i Suppose A ,B in X such that AUB =X where A, B not equal to empty

(1, 2)*-D**spOS .

So A- X/B is (1, 2)*-D**spCS ⇒ A is(1, 2)*-D**spO⊆ X and (1, 2)*-D**spCS ⊆ X

as we assumed A = φ or X proves X is (1, 2)*- D**spConnected.

**Theorem 6.3 suppose a mapping** j : K → L is

i) (1, 2)*-D**spContinuous and onto ,K is (1, 2)*-D**spConnected

⇒ L is (1, 2)*Connected.

(ii) If j : K → L is (1, 2)*-D**spirresolute surjection map and K is (1 ,2)*-D**spConnected ⇒ L is (1, 2)*-D**spConnected.

**Proof.**

Assume L is not (1, 2)*Connected. We have L = C ∪ D is not empty where C and D are disjoint $\sigma_{1,2}$-OS in L.

Also j is (1, 2)*-D**spContinuous , onto K = $f^{-1}$(C) ∪ $f^{-1}$(D) where

$f^{-1}$(C) and $f^{-1}$(D) are disjoint but not empty (1, 2)*-D**spOSs contradicts X is (1, 2)*-D**spConnected. So that L is (1, 2)*Connected.

ii proof obvious from 7.1.

## 8. (1, 2)*-D**spHomeomorphisms

**Definition 8.1** f : X →Y is a bijection map called (1, 2)*-D**sphomeomorphism if the mapping is (1, 2)*-D**spContinuous ,(1, 2)*-D**spOpen.

**Remark 8.2**

Every (1, 2)*homeomorphism is (1, 2)*- D**sphomeomorphism but conversely not true

**Theorem 8.3** consider

The mapping h : X →Y, is 1-1 and onto we have the following statements are true.

- (i)$h^{-1}$: Y → X is (1, 2)*- D**spContinuous.
- (ii)The mapping is (1, 2)*-D**spOpen .
- (iii)the mapping is (1, 2)*- D**spClosed .

**Proof.**

- (i)⇒ (ii) Let K be any $\tau_{1,2}$-OS in X. Since $f^{-1}$ is (1 ,2)*-D**spContinuous,

f( K) in Y is (1, 2)*- D**spOpen . Thus the mapping is (1, 2)* D**spOpen.

- (ii)Implies iii In X

suppose F is $\tau_{12}$CS , Then X/F is $\tau_{12}$OS

and Also the mapping is (1, 2)*-D**spOpen ,

f (X/F) in Y is (1, 2)*-D**spOpen in Y.. But in Y, f(X/F) = Y /f(F)

where f (F) is (1, 2)*-D**spClosed . Thus the mapping is (1, 2)*-D**spClosed Map

(iii) implies (i)

Suppose R is $\tau_{1,2}$-CS in X , We have f (R) in Y is (1, 2)*-D**spClosed . Also the mapping f is (1, 2)*- D**spClosed its inverse mapping is (1, 2)*-D**spContinuous.

**Theorem 8.4**

Suppose the mapping f is 1-1 , onto and (1, 2)*-D**spContinuous Then the implications are true. To prove the mapping f is

- i)(1, 2)*-D**spOpen .
- ii)(1, 2)*-D**sphomeomorphism .
- iii)(1, 2)*-D**spClosed

**Proof**

Assume i) f is (1 ,2)*-D**spOpen also the mapping is 1-1 and onto , (1, 2)*-D**spContinuous From the definition8.1, the mapping is (1, 2)*-D**sphomeomorphism. (ii) is proved.

assume (ii) the mapping is (1, 2)*-D**spOpen , 1-1 and onto it is (1, 2)*-

D**spClosed from thm 7.8 . (iii) proved

assume iii f is (1, 2)*-D**spClosed and bijective. F is (1, 2)*-D**spOpen map. By Theorem 8.3 ( i), proved

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