

$S_{\tau_{ij}}$ - sag^* -Closed Sets in Supra Bitopological Spaces

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ABSTRACT: In this paper, we introduce supra strongly ag^* -closed sets (briefly, $S_{\tau_{ij}}$ - sag^* -closed sets) and $S_{\tau_{ij}}$ - sag^* -open sets in supra bitopological spaces and their properties are analyzed. Further, we define and study three supra bitopological spaces $S_{\tau_{ij}-s}T_c$, $S_{\tau_{ij}-s}T_g$ and $S_{\tau_{ij}-s}T_g^*$ -spaces. Also, some of their properties have been investigated.

MATHEMATICS SUBJECT CLASSIFICATION: 54D05, 54D10, 54D08, 54D20

KEYWORDS: Supra bitopology, $S_{\tau_{ij}}$ - sag^* -closed sets, $S_{\tau_{ij}}$ - sag^* -open sets, $S_{\tau_{ij}-s}T_c$ -space, $S_{\tau_{ij}-s}T_g$ -space and $S_{\tau_{ij}-s}T_g^*$ -space .

I. INTRODUCTION

In 1963, Kelly [6] initiated the study of bitopological spaces. Sheik John and Sundaram [15] introduced the concept of strongly alpha generalized star closed sets in bitopological spaces. The concept of supra topological spaces have been introduced by Mashhour [10] in 1983. In topological space the arbitrary union condition is enough to have a supra topological space. Gowri and Rajayal [2] are initiated the concept of supra bitopological spaces. The aim of this communication is to introduce the concepts of $S_{\tau_{ij}}$ - sag^* -closed sets as well as $S_{\tau_{ij}}$ - sag^* -open sets and discussed some of their properties in supra bitopological spaces. Also, three new supra bitopological spaces are introduced namely, $S_{\tau_{ij}-s}T_c$, $S_{\tau_{ij}-s}T_g$ and $S_{\tau_{ij}-s}T_g^*$ -spaces. Finally, we examine the characterizations of these types of spaces.

II. PRELIMINARIES

Definition 2.1 [10] (X, S_{τ}) is said to be a supra topological space if it is satisfying these conditions:

- (1) $X, \emptyset \in S_{\tau}$
- (2) The union of any number of sets in S_{τ} belongs to S_{τ} .

Definition 2.2 [10] Each element $A \in S_{\tau}$ is called a supra open set in (X, S_{τ}) , and its compliment is called a supra closed set in (X, S_{τ}) .

Definition 2.3 [10] If (X, S_{τ}) is a supra topological spaces, $A \subseteq X$, $A \neq \emptyset$, S_{τ_A} is the class of all intersection of A with each element in S_{τ} , then (A, S_{τ_A}) is called a supra subspace of (X, S_{τ}) .

Definition 2.4 [10] The supra closure of the set A is denoted by $S_{\tau-cl}(A)$ and is defined as $S_{\tau-cl}(A) = \bigcap \{B : B \text{ is a supra closed and } A \subseteq B\}$.

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Definition 2.5 [10] The supra interior of the set A is denoted by $S_{\tau}\text{-int}(A)$ and is defined as $S_{\tau}\text{-int}(A) = \cup\{B : B \text{ is a supra open and } B \subseteq A\}$.

Definition 2.6 [2] If S_{τ_1} and S_{τ_2} are two supra topologies on a non-empty set X , then the triplet $(X, S_{\tau_1}, S_{\tau_2})$ is said to be a supra bitopological space.

Definition 2.7 [2] Each element of S_{τ_i} is called a supra τ_i -open sets (briefly, S_{τ_i} -open sets) in $(X, S_{\tau_1}, S_{\tau_2})$. Then the complement of S_{τ_i} -open sets are called a supra τ_i -closed sets (briefly, S_{τ_i} -closed sets), for $i = 1, 2$.

Definition 2.8 [2] If $(X, S_{\tau_1}, S_{\tau_2})$ is a supra bitopological space, $Y \subseteq X$, $Y \neq \emptyset$, then $(Y, S_{\tau_1}^*, S_{\tau_2}^*)$ is a supra bitopological subspace of $(X, S_{\tau_1}, S_{\tau_2})$ if $S_{\tau_1}^* = \{U \cap Y; U \text{ is a } S_{\tau_1}\text{-open in } X\}$ and $S_{\tau_2}^* = \{V \cap Y; V \text{ is a } S_{\tau_2}\text{-open in } X\}$.

Definition 2.9 [2] The S_{τ_i} -closure of the set A is denoted by $S_{\tau_i}\text{-cl}(A)$ and is defined as $S_{\tau_i}\text{-cl}(A) = \cap\{B : B \text{ is a } S_{\tau_i}\text{-closed and } A \subseteq B, \text{ for } i = 1, 2\}$.

Definition 2.10 [2] The S_{τ_i} -interior of the set A is denoted by $S_{\tau_i}\text{-int}(A)$ and is defined as $S_{\tau_i}\text{-int}(A) = \cup\{B : B \text{ is a } S_{\tau_i}\text{-open and } B \subseteq A, \text{ for } i = 1, 2\}$.

Definition 2.11 [3] A subset A of a supra bitopological space $(X, S_{\tau_1}, S_{\tau_2})$ is called an $S_{\tau_{ij}}$ - α -open if $A \subseteq S_{\tau_i}\text{-int}(S_{\tau_j}\text{-cl}(S_{\tau_i}\text{-int}(A)))$, where $i \neq j$, $i, j = 1, 2$.

The complement of $S_{\tau_{ij}}$ - α -open set is said to be $S_{\tau_{ij}}$ - α -closed set.

The family of $S_{\tau_{ij}}$ - α -open (resp. $S_{\tau_{ij}}$ - α -closed) sets of X is denoted by $S_{\tau_{ij}}\text{-}\alpha O(X)$ (resp. $S_{\tau_{ij}}\text{-}\alpha C(X)$), where $i \neq j$, $i, j = 1, 2$.

Through out this paper, For a subset A of $(X, S_{\tau_1}, S_{\tau_2})$, $S_{\tau_j}\text{-acl}(A)$ denote the aclosure of A with respect to the topology S_{τ_j} .

Definition 2.12 [4] A subset A of a supra bitopological space $(X, S_{\tau_1}, S_{\tau_2})$ is said to be supra τ_{ij} -generalized closed (briefly $S_{\tau_{ij}}$ -g-closed) if $S_{\tau_j}\text{-cl}(A) \subseteq U$ whenever $A \subseteq U$ and $U \in S_{\tau_i}$ -open, where $i, j = 1, 2$ and $i \neq j$.

The complement of $S_{\tau_{ij}}$ -g-closed set is said to be $S_{\tau_{ij}}$ -g-open.

The family of all $S_{\tau_{ij}}$ -g-closed (resp. $S_{\tau_{ij}}$ -g-open) sets of $(X, S_{\tau_1}, S_{\tau_2})$ is denoted by $S_{\tau_{ij}}\text{-g}C(X)$ (resp. $S_{\tau_{ij}}\text{-g}O(X)$), where $i, j = 1, 2$ and $i \neq j$.

Definition 2.13 [5] A subset A of a supra bitopological space $(X, S_{\tau_1}, S_{\tau_2})$ is said to be supra τ_{ij} -generalized star-closed (briefly, $S_{\tau_{ij}}$ -g*-closed) if $S_{\tau_j}\text{-cl}(A) \subseteq U$ whenever $A \subseteq U$ and $U \in S_{\tau_i}$ -g-open, where $i, j = 1, 2$ and $i \neq j$.

The complement of $S_{\tau_{ij}}$ -g*-closed set is said to be $S_{\tau_{ij}}$ -g*-open.

The family of all $S_{\tau_{ij}}$ -g*-closed (resp. $S_{\tau_{ij}}$ -g*-open) sets of $(X, S_{\tau_1}, S_{\tau_2})$ is denoted by $S_{\tau_{ij}}\text{-g}^*C(X)$ (resp. $S_{\tau_{ij}}\text{-g}^*O(X)$), where $i, j = 1, 2$ and $i \neq j$.

Definition 2.14 [4&5] supra biopological space $(X, S_{\tau_1}, S_{\tau_2})$ is said to be

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- (1) $S_{\tau_{ij}}-T_{1/2}$ -space[4] if every $S_{\tau_{ij}}$ -g-closed set is S_{τ_j} -closed.
- (2) Pairwise $S_{\tau}-T_{1/2}$ -space[4] if it is $S_{\tau_{ij}}-T_{1/2}$ -space and $S_{\tau_{ij}}-T_{1/2}$ -space.
- (3) $S_{\tau_{ij}}-T_{1/2}^*$ -space[5] if every $S_{\tau_{ij}}$ -g*-closed set is S_{τ_j} -closed.
- (4) Pairwise $S_{\tau}-T_{1/2}^*$ -space[5] if it is $S_{\tau_{ij}}-T_{1/2}^*$ -space and $S_{\tau_{ij}}-T_{1/2}^*$ -space.
- (5) $S_{\tau_{ij}}-T_{1/2}^{**}$ -space[5] if every $S_{\tau_{ij}}$ -g-closed set is $S_{\tau_{ij}}-g^*$ -closed.

III. $S_{\tau_{ij}}$ -STRONGLY ag^* -CLOSED SETS

In this section we introduce the concept of $S_{\tau_{ij}}$ -strongly ag^* -closed sets in supra bitopological spaces.

Definition 3.1 A subset A of a supra bitopological space $(X, S_{\tau_1}, S_{\tau_2})$ is said to be supra τ_{ij} -strongly ag^* -closed (briefly, $S_{\tau_{ij}}-sag^*$ -closed) if $S_{\tau_j}\text{-acl}(A) \subseteq U$ whenever $A \subseteq U$ and $U \in S_{\tau_i}\text{-}g^*\text{-open}$, where $i, j = 1, 2$ and $i \neq j$.

The complement of $S_{\tau_{ij}}-sag^*$ -closed set is said to be $S_{\tau_{ij}}-sag^*$ -open.

The family of all $S_{\tau_{ij}}-sag^*$ -closed (resp. $S_{\tau_{ij}}-sag^*$ -open) sets of $(X, S_{\tau_1}, S_{\tau_2})$ is denoted by $S_{\tau_{ij}}-s^*C(X)$ (resp. $S_{\tau_{ij}}-s^*O(X)$), where $i, j = 1, 2$ and $i \neq j$.

Example 3.2 Let $X = \{a, b, c\}$,

$$S_{\tau_1} = \{\emptyset, X, \{a, b\}, \{b, c\}\},$$

$$S_{\tau_2} = \{\emptyset, X, \{a, c\}, \{b, c\}\},$$

$$S_{\tau_{12}}-s^*C(X) = \{\emptyset, X, \{a\}, \{b\}, \{a, c\}\}.$$

Therefore $(X, S_{\tau_1}, S_{\tau_2})$ is $S_{\tau_{ij}}-sag^*$ -closed set.

Definition 3.3 A subset A of supra bitopological space $(X, S_{\tau_1}, S_{\tau_2})$ is said to be pairwise $S_{\tau}-sag^*$ -closed (briefly, $p-S_{\tau}-sag^*$ -closed) if A is $S_{\tau_{12}}-sag^*$ -closed and $S_{\tau_{21}}-sag^*$ -closed. The complement of a pairwise $S_{\tau}-sag^*$ -closed set is said to be pairwise $S_{\tau}-sag^*$ -open (briefly, $p-S_{\tau}-sag^*$ -open.)

Remark 3.4 By setting $S_{\tau_1} = S_{\tau_2}$ in Definition 3.1, a $S_{\tau_{ij}}-sag^*$ -closed becomes

$S_{\tau}-sag^*$ -closed.

Proposition 3.5 If A is S_{τ_j} -closed subset of $(X, S_{\tau_1}, S_{\tau_2})$ then A is $S_{\tau_{ij}}-sag^*$ -closed.

Proof: It is obvious that every S_{τ_j} -closed set is $S_{\tau_{ij}}-sag^*$ -closed.

The converse of the above Proposition 3.5, is not true as seen from the following example.

Example 3.6 Let $X = \{a, b, c\}$,

$$S_{\tau_1} = \{\emptyset, X, \{a, b\}, \{b, c\}\},$$

$$S_{\tau_2} = \{\emptyset, X, \{a, c\}, \{b, c\}\},$$

$$S_{\tau_{12}}-s^*C(X) = \{\emptyset, X, \{a\}, \{b\}, \{a, c\}\}.$$

Then the subset $\{b\}$ is $S_{\tau_{12}}-sag^*$ -closed but it is not S_{τ_2} -closed in $(X, S_{\tau_1}, S_{\tau_2})$.

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Proposition 3.7 If A is S_{τ_j} - g^* -closed subset of $(X, S_{\tau_1}, S_{\tau_2})$ then A is $S_{\tau_{ij}}$ - sag^* -closed set.

The converse of the above Proposition 3.7, is not true from the following example.

Example 3.8 Let $X = \{a, b, c\}$,

$$S_{\tau_1} = \{\emptyset, X, \{a, b\}, \{b, c\}\},$$

$$S_{\tau_2} = \{\emptyset, X, \{c\}, \{a, b\}\},$$

$$S_{\tau_2} - g^*C(X) = \{\emptyset, X, \{c\}, \{a, b\}\},$$

$$S_{\tau_{12}} - s^*C(X) = \{\emptyset, X, \{a\}, \{c\}, \{a, b\}, \{a, c\}\}.$$

Here the subset $\{a, c\}$ is $S_{\tau_{12}}$ - sag^* -closed but it is not S_{τ_2} - g^* -closed set in $(X, S_{\tau_1}, S_{\tau_2})$.

Proposition 3.9 If A is both S_{τ_i} - g^* -open and $S_{\tau_{ij}}$ - sag^* -closed, then A is S_{τ_j} - α -closed.

Proof: Suppose that A is S_{τ_i} - g^* -open and $S_{\tau_{ij}}$ - sag^* -closed. Then $A \subseteq A$ implies that S_{τ_j} - $\text{acl}(A) \subseteq A$. Obviously, $A \subseteq S_{\tau_j}$ - $\text{acl}(A)$. Therefore A is S_{τ_j} - α -closed.

Proposition 3.10 If A is $S_{\tau_{ij}}$ - g^* -closed subset of $(X, S_{\tau_1}, S_{\tau_2})$ then A is $S_{\tau_{ij}}$ - sag^* -closed set.

The reverse of the Proposition 3.10, is not true from the following example.

Example 3.11 Let $X = \{a, b, c, d\}$,

$$S_{\tau_1} = \{\emptyset, X, \{a\}, \{a, d\}, \{b, c, d\}\},$$

$$S_{\tau_2} = \{\emptyset, X, \{b\}, \{b, c\}, \{a, c, d\}\},$$

$$S_{\tau_{12}} - g^*C(X) = \{\emptyset, X, \{b\}, \{a, d\}, \{a, c, d\}, \{a, b, c\}\},$$

$$S_{\tau_{12}} - s^*C(X) = \{\emptyset, X, \{b\}, \{a, b\}, \{a, c\}, \{a, d\}, \{a, b, c\}, \{a, c, d\}, \{a, b, d\}\}.$$

Then the subset $\{a, b, d\}$ is $S_{\tau_{12}}$ - sag^* -closed set but it is not $S_{\tau_{12}}$ - g^* -closed set in $(X, S_{\tau_1}, S_{\tau_2})$

Remark 3.12 If $A, B \in S_{\tau_{12}} - s^*C(X)$ then $A \cup B \notin S_{\tau_{12}} - s^*C(X)$. The following example supports our claim.

Example 3.13 Let $X = \{a, b, c, d\}$,

$$S_{\tau_1} = \{\emptyset, X, \{b\}, \{b, c\}, \{a, c, d\}\},$$

$$S_{\tau_2} = \{\emptyset, X, \{a\}, \{a, d\}, \{b, c, d\}\},$$

$$S_{\tau_{12}} - s^*C(X) = \{\emptyset, X, \{a\}, \{b\}, \{c\}, \{a, b\}, \{a, b, c\}, \{a, b, d\}, \{b, c, d\}\}.$$

Here $A = \{a\}$ and $B = \{c\}$ then $A \cup B = \{a\} \cup \{c\} = \{a, c\}$ not in $S_{\tau_{12}} - s^*C(X)$.

Remark 3.14 If $A, B \in S_{\tau_{12}} - s^*C(X)$ then $A \cap B \notin S_{\tau_{12}} - s^*C(X)$, as seen from the following example.

Example 3.15 In Example 3.13 ,

$$S_{\tau_{12}} - s^*C(X) = \{\emptyset, X, \{a\}, \{b\}, \{c\}, \{a, b\}, \{a, b, c\}, \{a, b, d\}, \{b, c, d\}\}.$$

Here $A = \{a, b, d\}$ and $B = \{b, c, d\}$ then $A \cap B = \{a, b, d\} \cap \{b, c, d\} = \{b, d\}$ not in $S_{\tau_{12}} - s^*C(X)$.

Remark 3.16 $S_{\tau_{12}} - s^*C(X)$ is generally not equal to $S_{\tau_{21}} - s^*C(X)$. Then the following example supports our claim.

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Example 3.17 Let $X = \{a, b, c\}$,

$$S_{\tau_1} = \{\emptyset, X, \{c\}, \{a, b\}, \{b, c\}\},$$

$$S_{\tau_2} = \{\emptyset, X, \{b\}, \{a, b\}, \{a, c\}, \{b, c\}\},$$

$$S_{\tau_{12}}\text{-}s^*C(X) = \{\emptyset, X, \{a\}, \{b\}, \{c\}, \{a, c\}\} \text{ and}$$

$$S_{\tau_{21}}\text{-}s^*C(X) = \{\emptyset, X, \{a\}, \{c\}, \{a, b\}\}.$$

Therefore, $S_{\tau_{12}}\text{-}s^*C(X) \neq S_{\tau_{21}}\text{-}s^*C(X)$.

Proposition 3.18 If $S_{\tau_1} \subseteq S_{\tau_2}$ in $(X, S_{\tau_1}, S_{\tau_2})$ then $S_{\tau_{21}}\text{-}s^*C(X) \subseteq S_{\tau_{12}}\text{-}s^*C(X)$.

Proof: Let A be $S_{\tau_{21}}\text{-}s^*C(X)$. Then $S_{\tau_1}\text{-}acl(A) \subseteq U$, whenever $A \subseteq U$ and U is S_{τ_2} - g^* -open. Since $S_{\tau_1} \subseteq S_{\tau_2}$, $S_{\tau_2}\text{-}acl(A) \subseteq U$, whenever $A \subseteq U$ and U is S_{τ_1} - g^* -open. Hence A is $S_{\tau_{12}}\text{-}s^*C(X)$.

Remark 3.19 The converse of the above Proposition 3.18, is not true from the following example.

Example 3.20 Let $X = \{a, b, c, d\}$,

$$S_{\tau_1} = \{\emptyset, X, \{a, b\}\},$$

$$S_{\tau_2} = \{\emptyset, X, \{a, b, d\}\},$$

$$S_{\tau_{12}}\text{-}s^*C(X) = \{\emptyset, X, \{c\}, \{d\}, \{a, c\}, \{a, d\}, \{b, c\}, \{b, d\}, \{c, d\}, \{a, b, c\}, \{a, b, d\}, \{a, c, d\}, \{b, c, d\}\}$$

$$S_{\tau_{21}}\text{-}s^*C(X) = \{\emptyset, X, \{c\}, \{a, c\}, \{b, c\}, \{c, d\}, \{a, b, c\}, \{a, c, d\}, \{b, c, d\}\}.$$

Then $S_{\tau_{21}}\text{-}s^*C(X) \subseteq S_{\tau_{12}}\text{-}s^*C(X)$ but S_{τ_1} is not contained in S_{τ_2} .

Proposition 3.21 If A is $S_{\tau_{ij}}\text{-}sag^*$ -closed, then $S_{\tau_j}\text{-}acl(A) - A$ contains no non empty $S_{\tau_i}\text{-}g^*$ -closed set.

Proof: Let A be $S_{\tau_{ij}}\text{-}sag^*$ -closed set and F be a non empty $S_{\tau_i}\text{-}g^*$ -closed subset such that $F \subseteq S_{\tau_j}\text{-}acl(A) - A = S_{\tau_j}\text{-}acl(A) \subseteq A^c$. Therefore, $F \subseteq S_{\tau_j}\text{-}acl(A)$ and $F \subseteq A^c$.

Since F^c is a $S_{\tau_i}\text{-}g^*$ -open and A is $S_{\tau_{ij}}\text{-}sag^*$ -closed set in $(X, S_{\tau_1}, S_{\tau_2})$, We have $S_{\tau_j}\text{-}acl(A) \subseteq F^c$. That is $F \subseteq [S_{\tau_i}\text{-}cl(A)]^c$. Hence $F \subseteq [S_{\tau_i}\text{-}cl(A)] \cap [S_{\tau_i}\text{-}cl(A)]^c = \emptyset$. Therefore, $F = \emptyset$. Hence, $S_{\tau_j}\text{-}acl(A) - A$ contains no non empty $S_{\tau_i}\text{-}g^*$ -closed set.

Remark 3.22 The converse of the above Proposition 3.21, is not true as seen from the following example.

Example 3.23 In Example 3.11,

$$S_{\tau_{12}}\text{-}s^*C(X) = \{\emptyset, X, \{b\}, \{a, b\}, \{a, c\}, \{a, d\}, \{a, b, c\}, \{a, c, d\}, \{a, b, d\}\}.$$

If $A = \{b, c, d\}$ then $S_{\tau_2}\text{-}acl(A) - A = \{a\}$ does not contain any non empty $S_{\tau_2}\text{-}g^*$ -closed set. But A is not a $S_{\tau_{ij}}\text{-}sag^*$ -closed set.

Corollary 3.24 If A is $S_{\tau_{ij}}\text{-}sag^*$ -closed set in $(X, S_{\tau_1}, S_{\tau_2})$, then A is $S_{\tau_j}\text{-}a$ -closed if and only if $S_{\tau_j}\text{-}acl(A) - A$ is $S_{\tau_i}\text{-}g^*$ -closed.

Proof:

Necessity:

If A is $S_{\tau_j}\text{-}a$ -closed, then $S_{\tau_j}\text{-}acl(A) = A$. That is $S_{\tau_j}\text{-}cl(A) - A = \emptyset$ and hence $S_{\tau_j}\text{-}acl(A) - A$ is $S_{\tau_i}\text{-}g^*$ -closed.

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Sufficiency:

If $S_{\tau_j}\text{-acl}(A) - A$ is $S_{\tau_i}\text{-}g^*$ -closed, then by Proposition 3.21, $S_{\tau_j}\text{-acl}(A) - A = \emptyset$, since A is $S_{\tau_{ij}}\text{-}sag^*$ -closed. Therefore A is $S_{\tau_j}\text{-}\alpha$ -closed.

Proposition 3.25 *If A is an $S_{\tau_j}\text{-}sag^*$ -closed set of $(X, S_{\tau_1}, S_{\tau_2})$ such that $A \subseteq B \subseteq S_{\tau_j}\text{-acl}(A)$, then B is also an $S_{\tau_{ij}}\text{-}sag^*$ -closed set of $(X, S_{\tau_1}, S_{\tau_2})$, where $i, j = 1, 2$ and $i \neq j$.*

Proof: Let U be a $S_{\tau_i}\text{-}g^*$ -open set of $(X, S_{\tau_1}, S_{\tau_2})$, such that $B \subseteq U$. Then, $A \subseteq U$. Since A is a $S_{\tau_{ij}}\text{-}sag^*$ -closed set, then $S_{\tau_j}\text{-acl}(A) \subseteq U$. Also, $S_{\tau_j}\text{-acl}(B) \subseteq S_{\tau_j}\text{-acl}(S_{\tau_j}\text{-acl}(A)) = S_{\tau_j}\text{-acl}(A) \subseteq U$ which implies, $S_{\tau_j}\text{-acl}(B) \subseteq U$. Hence, B is also an $S_{\tau_{ij}}\text{-}sag^*$ -closed set of $(X, S_{\tau_1}, S_{\tau_2})$.

Remark 3.26 *Intersection of $S_{\tau_{ij}}\text{-}sag^*$ -closed sets and $S_{\tau_i}\text{-}g^*$ -open sets is neither $S_{\tau_{ij}}\text{-}sag^*$ -closed nor $S_{\tau_i}\text{-}g^*$ -open as can be seen from the following example.*

Example 3.27 *Let S_{τ_1} and S_{τ_2} in Example 3.11 ,*

$$S_{\tau_1}\text{-}g^*O(X) = \{\emptyset, X, \{a\}, \{d\}, \{a, d\}, \{b, c, d\}\},$$

$$S_{\tau_1}\text{-}s^*C(X) = \{\emptyset, X, \{b\}, \{a, b\}, \{a, c\}, \{a, d\}, \{a, b, c\}, \{a, c, d\}, \{a, b, d\}\}.$$

We have $A = \{b, c, d\}$ is $S_{\tau_1}\text{-}g^$ -open and $B = \{a, b, c\}$ is $S_{\tau_{12}}\text{-}sag^*$ -closed set, their intersection $\{b, c\}$ is neither $S_{\tau_{12}}\text{-}sag^*$ -closed set nor $S_{\tau_1}\text{-}g^*$ -open set.*

Proposition 3.28 *For each element $x \in X$, the singleton $\{x\}$ is $S_{\tau_i}\text{-}g^*$ -closed or $\{x\}^c$ is $S_{\tau_{ij}}\text{-}sag^*$ -closed.*

Proof: Suppose that $\{x\}$ is not $S_{\tau_i}\text{-}g^*$ -closed. Then $\{x\}^c$ is not $S_{\tau_i}\text{-}g^*$ -open and X is the only $S_{\tau_i}\text{-}g^*$ -open set which contains $\{x\}^c$ and $\{x\}^c$ is $S_{\tau_{ij}}\text{-}sag^*$ -closed.

Proposition 3.29 *In a supra bitopological space $(X, S_{\tau_1}, S_{\tau_2})$ if $S_{\tau_i}\text{-}g^*$ -open $\subseteq S_{\tau_j}\text{-}closed$ then every subset of X is an $S_{\tau_{ij}}\text{-}sag^*$ -closed set of $(X, S_{\tau_1}, S_{\tau_2})$.*

Proof: Let $S_{\tau_i}\text{-}g^*$ -open $\subseteq S_{\tau_j}\text{-}closed$. Let A be a subset of X such that $A \subseteq U$, Where U is $S_{\tau_i}\text{-}g^*$ -open set. Then $S_{\tau_j}\text{-acl}(A) \subseteq S_{\tau_j}\text{-cl}(A) \subseteq S_{\tau_j}\text{-cl}(U)$ and hence A is an $S_{\tau_{ij}}\text{-}sag^*$ -closed set of $(X, S_{\tau_1}, S_{\tau_2})$.

IV. $S_{\tau_{ij}}\text{-STRONGLY } ag^*\text{-OPEN SETS}$

In this section we introduce the concept of $S_{\tau_{ij}}\text{-strongly } ag^*$ -open sets in supra bitopological spaces.

Definition 4.1 *A subset A of a supra bitopological space $(X, S_{\tau_1}, S_{\tau_2})$ is said to be supra $\tau_{ij}\text{-strongly } ag^*$ -open (briefly, $S_{\tau_{ij}}\text{-}sag^*$ -open) set if A^c is $S_{\tau_{ij}}\text{-}sag^*$ -closed set in $(X, S_{\tau_1}, S_{\tau_2})$.*

The family of all $S_{\tau_{ij}}\text{-}sag^$ -open sets of $(X, S_{\tau_1}, S_{\tau_2})$ is denoted by $S_{\tau_{ij}}\text{-}s^*O(X)$.*

Remark 4.2 *The union of any two $S_{\tau_{ij}}\text{-}sag^*$ -open set is not necessary $S_{\tau_{ij}}\text{-}sag^*$ -open set as seen in the following example.*

Example 4.3 *Let $X = \{a, b, c, d\}$,*

$$S_{\tau_1} = \{\emptyset, X, \{b\}, \{b, c\}, \{a, c, d\}\},$$

$$S_{\tau_2} = \{\emptyset, X, \{a\}, \{a, d\}, \{b, c, d\}\},$$

$S_{\tau_{12}}\text{-}s^*O(X) = \{\emptyset, X, \{a\}, \{c\}, \{d\}, \{c, d\}, \{a, b, d\}, \{a, c, d\}, \{b, c, d\}\}$. Here $\{a\}$ and $\{d\}$ are $S_{\tau_{12}}\text{-}sag^*$ -open sets but their union $\{a\} \cup \{c\} = \{a, c\}$ is not $S_{\tau_{12}}\text{-}sag^*$ -open.

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Remark 4.4 The intersection of any two $S_{\tau_{ij}}$ -sag*-open set is not necessary $S_{\tau_{ij}}$ -ag*-open set as in the following example.

Example 4.5 In Example 4.3 ,

$S_{\tau_{12}}\text{-}s^*O(X) = \{\emptyset, X, \{a\}, \{c\}, \{d\}, \{c, d\}, \{a, b, d\}, \{a, c, d\}, \{b, c, d\}\}$. Here $\{b, c, d\}$ and $\{a, b, d\}$ are $S_{\tau_{12}}$ -sag*-open sets but $\{b, c, d\} \cap \{a, b, d\} = \{b, d\}$ is not $S_{\tau_{12}}$ -sag*-open.

Remark 4.6 Every S_{τ_1} -open set is $S_{\tau_{ij}}$ -sag*-open but the converse is not true in general as can be seen from the following example.

Example 4.7 Let $X = \{a, b, c\}$,

$S_{\tau_1} = \{\emptyset, X, \{a, b\}, \{b, c\}\}$,

$S_{\tau_2} = \{\emptyset, X, \{c\}, \{a, b\}\}$,

$S_{\tau_{12}}\text{-}s^*O(X) = \{\emptyset, X, \{b\}, \{c\}, \{a, b\}, \{b, c\}\}$.

Here $\{b\}$ is $S_{\tau_{12}}$ -sag*-open but it is not S_{τ_1} -open.

Remark 4.8 The intersection of $S_{\tau_{ij}}$ -sag*-open set and S_{τ_j} -open set is not $S_{\tau_{ij}}$ -sag*-open as seen from the following example.

Example 4.9 In Example 4.3 ,

$S_{\tau_{12}}\text{-}s^*O(X) = \{\emptyset, X, \{a\}, \{c\}, \{d\}, \{a, b, d\}, \{a, c, d\}, \{b, c, d\}\}$.

Here $A = \{a, d\}$ is S_{τ_2} -open and $B = \{a, b, d\}$ is $S_{\tau_{12}}$ -sag*-open but their intersection $\{a, d\}$ is not $S_{\tau_{12}}$ -sag*-open.

Theorem 4.10 A subset of supra bitopological space in $(X, S_{\tau_1}, S_{\tau_2})$ is $S_{\tau_{ij}}$ -sag*open set if and only if $B \subseteq S_{\tau_j}\text{-aint}(A)$ whenever B is S_{τ_i} -g*-closed and $B \subseteq A$, where $i, j = 1, 2$ and $i \neq j$.

Proof: Let A be τ_{ij} -sag*-open set. Let B be a S_{τ_i} -g*-closed set such that $B \subseteq A$. Let $A \subseteq B$ and B is S_{τ_i} -g*-closed. Then $A^c \subseteq B^c$ and B^c is S_{τ_i} -g*-open. We have A^c is $S_{\tau_{ij}}$ -sag*-closed. Hence, $[S_{\tau_j}\text{-acl}(A)]^c \subseteq B^c$. Therefore, $B \subseteq S_{\tau_j}\text{-aint}(A)$. Conversely, suppose $B \subseteq S_{\tau_j}\text{-aint}(A)$ whenever $B \subseteq A$ and B is S_{τ_i} -g*-closed. Let $A^c \subseteq U$ and U is S_{τ_i} -g*-open. Then $U^c \subseteq A$ and U^c is S_{τ_i} -g*-closed. By hypothesis $U^c \subseteq S_{\tau_j}\text{-aint}(A)$. Hence, $[S_{\tau_j}\text{-aint}(A)]^c \subseteq U$. That is $[S_{\tau_j}\text{-acl}(A)]^c \subseteq U$. Consequently, A^c is $S_{\tau_{ij}}$ -sag*-closed set. Hence, A is $S_{\tau_{ij}}$ -sag*-open. \square

Theorem 4.11 Let A and B be subsets of supra bitopological space $(X, S_{\tau_1}, S_{\tau_2})$ such that $S_{\tau_j}\text{-aint}(A) \subseteq B \subseteq A$. If A is $S_{\tau_{ij}}$ -sag*-open, then B is $S_{\tau_{ij}}$ -sag*-open, where $i, j = 1, 2$ and $i \neq j$.

Proof: Let A be $S_{\tau_{ij}}$ -sag*-open. Let U be a S_{τ_i} -g*-closed such that $U \subseteq B$. Since $U \subseteq B$ and $B \subseteq A$, we have $U \subseteq A$. Therefore, $U \subseteq S_{\tau_j}\text{-aint}(A)$. Since $S_{\tau_j}\text{-aint}(A) \subseteq B$, we have $S_{\tau_j}\text{-aint}(S_{\tau_j}\text{-aint}(A)) \subseteq S_{\tau_j}\text{-aint}(B)$. Therefore, $S_{\tau_j}\text{-aint}(A) \subseteq S_{\tau_j}\text{-aint}(B)$.

Consequently, $U \subseteq S_{\tau_j}\text{-aint}(B)$. Hence, B is $S_{\tau_{ij}}$ -sag*-open

Theorem 4.12 A subset A is $S_{\tau_{ij}}$ -sag*-closed set then $S_{\tau_j}\text{-acl}(A) - A$ is $S_{\tau_{ij}}$ -sag*-open.

Proof: Let A be $S_{\tau_{ij}}$ -sag*-closed set. Let $F \subseteq S_{\tau_j}\text{-acl}(A) - A$, where F is S_{τ_i} -g*-closed set. Since A is $S_{\tau_{ij}}$ -sag*-closed, we have $S_{\tau_j}\text{-acl}(A) - A$ does not contain non empty S_{τ_i} -g*-closed by Proposition 3.21, Consequently, $F = \emptyset$. Therefore, $\emptyset \subseteq S_{\tau_j}\text{-acl}(A) - A$, $\emptyset \subseteq S_{\tau_j}\text{-aint}(S_{\tau_j}\text{-acl}(A) - A)$, we obtain $F \subseteq S_{\tau_j}\text{-aint}(S_{\tau_j}\text{-acl}(A) - A)$.

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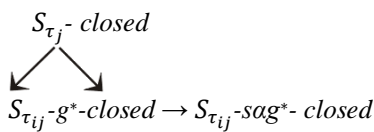
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Hence, S_{τ_j} -acl(A) – A is $S_{\tau_{ij}}$ -sag*-open.

Remark 4.13 From the above results, we get the following relations.



The converse of the above relations is not true.

V. $S_{\tau_{ij}}$ - s^*T_c , $S_{\tau_{ij}}$ - s^*T_g AND $S_{\tau_{ij}}$ - $s^*T_g^*$ -SPACES IN SUPRA BITOPOLOGICAL SPACES

In this section, We introduce $S_{\tau_{ij}}$ - s^*T_c -space, $S_{\tau_{ij}}$ - s^*T_g -space and $S_{\tau_{ij}}$ - $s^*T_g^*$ - space in supra bitopological spaces with the help of $S_{\tau_{ij}}$ -sag*-closed set.

Definition 5.1 A supra bitopological space $(X, S_{\tau_1}, S_{\tau_2})$ is said to be $S_{\tau_{ij}}$ - s^*T_c - space if every $S_{\tau_{ij}}$ -sag*-closed set is S_{τ_i} -closed.

Proposition 5.2 If $(X, S_{\tau_1}, S_{\tau_2})$ is $S_{\tau_{ij}}$ - s^*T_c -space, then it is an $S_{\tau_{ij}}$ - $T_{1/2}^*$ - space but not conversely.

Example 5.3 Let $X = \{a, b, c\}$,

$$S_{\tau_1} = \{\emptyset, X, \{c\}\},$$

$$S_{\tau_2} = \{\emptyset, X, \{c\}, \{a, b\}\}.$$

Then $(X, S_{\tau_1}, S_{\tau_2})$ is $S_{\tau_{ij}}$ - $T_{1/2}^*$ -space but not a $S_{\tau_{ij}}$ - s^*T_c - space.

Theorem 5.4A supra bitopological space $(X, S_{\tau_1}, S_{\tau_2})$ is $S_{\tau_{ij}}$ - s^*T_c -space if and only if $\{x\}$ is S_{τ_j} -open or S_{τ_i} - g^* -closed for each $x \in X$.

Proof: Suppose that $\{x\}$ is not S_{τ_i} - g^* -closed. Then by Proposition 3.28, $\{x\}^c$ is $S_{\tau_{ij}}$ -sag*-closed set. Since $(X, S_{\tau_1}, S_{\tau_2})$ is $S_{\tau_{ij}}$ - s^*T_c -space, $\{x\}^c$ is S_{τ_j} - closed. Therefore $\{x\}$ is S_{τ_j} - open.

Conversely, let A be an $S_{\tau_{ij}}$ -sag*-closed set. By assumption, $\{x\}$ is S_{τ_j} -open or S_{τ_i} - g^* -closed. for any $x \in S_{\tau_j}$ -acl(A) $\subseteq S_{\tau_j}$ - cl(A).

Case (i): Suppose that $\{x\}$ is S_{τ_j} -open. Since $\{x\} \cap A \neq \emptyset$, We have $x \in A$.

Case (ii): Suppose that $\{x\}$ is S_{τ_j} - g^* -closed. If x not in A, then $\{x\} \subseteq S_{\tau_j}$ -acl(A) – A, Which is a contradiction to Proposition 3.21. Therefore $x \in A$.

Thus in both cases, We conclude that A is S_{τ_j} -closed. Hence $(X, S_{\tau_1}, S_{\tau_2})$ is $S_{\tau_{ij}}$ - s^*T_c -space.

Remark 5.5 (X, S_{τ_1}) -space is not generally a S_{τ_j} - s^*T_c -space even if $(X, S_{\tau_1}, S_{\tau_2})$ is $S_{\tau_{ij}}$ - s^*T_c -space as shown in the following example.

Example 5.6 Let $X = \{a, b, c\}$,

$$S_{\tau_1} = \{\emptyset, X, \{c\}, \{a, b\}, \{b, c\}\},$$

$$S_{\tau_2} = \{\emptyset, X, \{b\}, \{a, b\}, \{a, c\}, \{b, c\}\}.$$

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Then (X, S_{τ_1}) is not a $S_{\tau-s}T_c$ -space but $(X, S_{\tau_1}, S_{\tau_2})$ is $S_{\tau_{12}-s}T_c$ -space.

Definition 5.7A supra bitopological space $(X, S_{\tau_1}, S_{\tau_2})$ is said to be pairwise $S_{\tau-s}T_c$ -space if it is both $S_{\tau_{12}-s}T_c$ and $S_{\tau_{21}-s}T_c$ -space.

Proposition 5.8 If $(X, S_{\tau_1}, S_{\tau_2})$ is pairwise $S_{\tau-s}T_c$ -space then it is pairwise $S_{\tau-T_{1/2}^*}$ -space but not conversely.

Example 5.9 In Example 5.3, Then $(X, S_{\tau_1}, S_{\tau_2})$ is pairwise $S_{\tau-T_{1/2}^*}$ -space. But

$(X, S_{\tau_1}, S_{\tau_2})$ is not a pairwise $S_{\tau-s}T_c$ -space, since it is not a $S_{\tau_{21}-s}T_c$ -space.

Definition 5.10A supra bitopological space $(X, S_{\tau_1}, S_{\tau_2})$ is said to be $S_{\tau_{ij}-s}T_g$ -space if every $S_{\tau_{ij}-s}T_g$ -closed set is $S_{\tau_{ij}-g}$ -closed.

Proposition 5.11 If $(X, S_{\tau_1}, S_{\tau_2})$ is $S_{\tau_{ij}-s}T_c$ -space is an $S_{\tau_{ij}-s}T_g$ -space but not conversely.

Example 5.12 Let $X = \{a, b, c\}$,

$$S_{\tau_1} = \{\emptyset, X, \{c\}, \{a, b\}, \{b, c\}\},$$

$$S_{\tau_2} = \{\emptyset, X, \{a, c\}, \{b, c\}\}.$$

Then $(X, S_{\tau_1}, S_{\tau_2})$ is $S_{\tau_{12}-s}T_g$ -space but not a $S_{\tau_{12}-s}T_c$ -space.

Theorem 5.13A supra bitopological space $(X, S_{\tau_1}, S_{\tau_2})$ is $S_{\tau_{ij}-s}T_c$ -space if and only if it is both $S_{\tau_{ij}-s}T_g$ and $S_{\tau_{ij}-T_{1/2}^*}$ -space.

Proof: Suppose that $(X, S_{\tau_1}, S_{\tau_2})$ is $S_{\tau_{ij}-s}T_c$ -space. Then by Proposition 5.2 and

Proposition 5.11 $(X, S_{\tau_1}, S_{\tau_2})$ is $S_{\tau_{ij}-T_{1/2}^*}$ -space and $S_{\tau_{ij}-s}T_g$ -space.

Conversely, suppose that $(X, S_{\tau_1}, S_{\tau_2})$ is both $S_{\tau_{ij}-s}T_g$ -space and $S_{\tau_{ij}-T_{1/2}^*}$ -space.

Let A be a $S_{\tau_{ij}-s}T_g$ -closed set of $(X, S_{\tau_1}, S_{\tau_2})$. since $(X, S_{\tau_1}, S_{\tau_2})$ is an $S_{\tau_{ij}-s}T_g$ -space, A is an $S_{\tau_{ij}-g}$ -closed set. Since $(X, S_{\tau_1}, S_{\tau_2})$ is an $S_{\tau_{ij}-T_{1/2}^*}$ -space, A is $S_{\tau_{ij}-g}$ -closed set of $(X, S_{\tau_1}, S_{\tau_2})$. Therefore, $(X, S_{\tau_1}, S_{\tau_2})$ is an $S_{\tau_{ij}-s}T_c$ -space.

Definition 5.14A supra bitopological space $(X, S_{\tau_1}, S_{\tau_2})$ is said to be $S_{\tau_{ij}-s}T_g^*$ -space if every $S_{\tau_{ij}-s}T_g^*$ -closed set is $S_{\tau_{ij}-g^*}$ -closed set.

Proposition 5.15 Every $S_{\tau_{ij}-s}T_g^*$ -space is a $S_{\tau_{ij}-s}T_g$ -space but not conversely.

Example 5.16 Let $X = \{a, b, c\}$,

$$S_{\tau_1} = \{\emptyset, X, \{b\}\},$$

$$S_{\tau_2} = \{\emptyset, X, \{b, c\}\}.$$

Then $(X, S_{\tau_1}, S_{\tau_2})$ is $S_{\tau_{12}-s}T_g$ -space but not a $S_{\tau_{12}-s}T_g^*$ -space.

Proposition 5.17 Every $S_{\tau_{ij}-s}T_c$ -space is an $S_{\tau_{ij}-s}T_g^*$ -space but not conversely from the following example.

Example 5.18 Let $(X, S_{\tau_1}, S_{\tau_2})$ be as in Example 5.3. Then $(X, S_{\tau_1}, S_{\tau_2})$ is $S_{\tau_{12}-s}T_g^*$ -space but not a $S_{\tau_{12}-s}T_c$ -space.

Theorem 5.19A supra bitopological space $(X, S_{\tau_1}, S_{\tau_2})$ is $S_{\tau_{ij}-s}T_c$ -space if and only if it is both $S_{\tau_{ij}-s}T_g^*$ and $S_{\tau_{ij}-T_{1/2}^*}$ -space. $(X, S_{\tau_1}, S_{\tau_2})$ is $S_{\tau_{ij}-T_{1/2}^*}$ -space.

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Proof: Suppose that $(X, S_{\tau_1}, S_{\tau_2})$ is $S_{\tau_{ij}\text{-}s}T_c$ -space. Then by Proposition 5.2 and

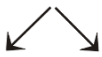
Proposition 5.17, $(X, S_{\tau_1}, S_{\tau_2})$ is $S_{\tau_{ij}\text{-}T_{1/2}^*}$ -space and $S_{\tau_{ij}\text{-}s}T_g^*$ -space.

Conversely, suppose that $(X, S_{\tau_1}, S_{\tau_2})$ is both $S_{\tau_{ij}\text{-}s}T_g^*$ -space and $S_{\tau_{ij}\text{-}T_{1/2}^*}$ -space.

Let A be a $S_{\tau_{ij}\text{-}s}ag^*$ -closed set of $(X, S_{\tau_1}, S_{\tau_2})$. Since $(X, S_{\tau_1}, S_{\tau_2})$ is an $S_{\tau_{ij}\text{-}s}T_g^*$ -space, A is an $S_{\tau_{ij}\text{-}g^*}$ -closed set. Since $(X, S_{\tau_1}, S_{\tau_2})$ is an $S_{\tau_{ij}\text{-}T_{1/2}^*}$ -space, A is S_{τ_j} -closed set of $(X, S_{\tau_1}, S_{\tau_2})$. Therefore, $(X, S_{\tau_1}, S_{\tau_2})$ is an $S_{\tau_{ij}\text{-}s}T_c$ -space.

Remark 5.20 From the above results we have the following implications.

$$S_{\tau_{ij}\text{-}s}T_c\text{-space} \rightarrow S_{\tau_{ij}\text{-}T_{1/2}^*}\text{-space}$$



$$S_{\tau_{ij}\text{-}s}T_g^*\text{-space} \rightarrow S_{\tau_{ij}\text{-}s}T_g\text{-space}$$

The converse of the above implications is not true.

VI. CONCLUSION

In this paper, we have introduced the new class of sets called $S_{\tau_{ij}\text{-}s}ag^*$ -closed sets, $S_{\tau_{ij}\text{-}s}ag^*$ -open sets and compared their results of $S_{\tau_{ij}\text{-}g^*}$ -closed sets. Also, we construct three new types of supra bitopological spaces. Further, we are interested to find some interesting results in supra bitopological spaces.

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