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connection is the trivial connection on this module. Moreover, it is easy to show that the sequence (2.1) is horizontal with respect to the respective Gauss-Manin connections.

Suppose now that S is an affine curve over K and $Z = \emptyset$. Then the short exact sequence (2.2) becomes

$$0 \rightarrow f^* \Omega_S^1 \otimes \Omega_{X/S}^1(-1) \rightarrow \Omega_{X/S}^1 \rightarrow \Omega_{X/S}^1 \rightarrow 0 .$$

Taking cohomology of this sequence yields the Leray long exact sequence

$$(2.3) \quad \dots \rightarrow H_{DR}^i(X/S) \xrightarrow{\nabla} \Omega_S^1 \otimes H_{DR}^i(X/S) \rightarrow H_{DR}^{i+1}(X) \rightarrow H_{DR}^{i+1}(X/S) \xrightarrow{\nabla} \dots$$

3. SECTIONS OF A FAMILY AND EXTENSIONS OF CONNECTIONS

Suppose now S is a smooth connected affine curve over a field K of characteristic zero and $f: X \rightarrow S$ is a smooth proper morphism of schemes over K , with geometrically connected fibers. These assumptions will be in force throughout the remainder of this paper. Suppose Z is a closed subscheme of X finite over S . Suppose the normalization $n: \tilde{Z} \rightarrow Z$ of Z is smooth over S . After repeated blowing ups at closed points we find a scheme $m: \tilde{X}' \rightarrow X$, which contains \tilde{Z} and is such that the restriction of m to \tilde{Z} is n . Let \tilde{X} equal the complement in \tilde{X}' of the singular locus of \tilde{X}'/S . This locus is a closed subscheme of \tilde{X}' disjoint from \tilde{Z} . The long exact sequence 2.1 becomes

$$(3.1) \quad 0 \rightarrow K[S] \rightarrow K[\tilde{Z}] \rightarrow H_{DR}^1(\tilde{Z}/S, \tilde{Z}) \rightarrow H_{DR}^1(\tilde{X}/S) \rightarrow 0$$

Let H denote the pullback of $H_{DR}^1(\tilde{X}/S, \tilde{Z})$ by means of the horizontal monomorphism from $H_{DR}^1(X/S)$ into $H_{DR}^1(\tilde{X}/S)$. We claim that H is independent of the choice of \tilde{X} . Indeed, there exists a non-empty affine open subscheme S' of S such that the map from $\tilde{X} \times_S S'$ to $X' = : X \times_S S'$ is an isomorphism. If $Z' = Z \times_S S'$, then Z' is smooth over S' and it is easy to see that $H \otimes K[S'] \cong H_{DR}^1(X'/S', Z')$. Hence H is an extension of the connection $H_{DR}^1(X'/S', Z')$ on S' to a connection on S . Since such an extension is unique if it exists, it follows that H is independent of the choice of \tilde{X} and so we set $H_{DR}^1(X/S, Z) = H$. We obtain from the previous exact sequence, a natural exact sequence

$$0 \rightarrow K[S] \rightarrow K[\tilde{Z}] \rightarrow H_{DR}^1(X/S, Z) \rightarrow H_{DR}^1(X/S) \rightarrow 0 .$$

For a section s of X/S , we will also use s to denote the induced reduced closed subscheme $s(S)$ of X when convenient. Now suppose s and t are two distinct sections of X/S . Let $Z = s \cup t$. Then \tilde{Z} , the normalization of Z , is just two disjoint copies of S and so is étale over S . (The sections s and t

induce maps from S to \tilde{Z} which we denote by the same names.) The map $t^* - s^*: K[\tilde{Z}] \rightarrow K[S]$ is horizontal, surjective and its kernel is the image of $K[S]$ under the map in (3.1). Hence we obtain a horizontal exact sequence

$$0 \rightarrow K[S] \rightarrow H_{DR}^1(X/S, Z) \rightarrow H_{DR}^1(X/S) \rightarrow 0$$

and so an extension of $H_{DR}^1(X/S)$ by the trivial connection. We let $E(s, t)$ denote this extension if $s \neq t$ and $E(s, s)$ denote the trivial extension of $H_{DR}^1(X/S)$ by $K[S]$. We call the class of $E(s, t)$ in $\text{Ext}(H_{DR}^1(X/S), K[S])$ $M(s, t)$.

PROPOSITION 1.3.1. *Suppose r, s, t are sections of X/S . Then*

$$M(r, t) = M(r, s) + M(s, t).$$

In particular, $M(r, s) = -M(s, r)$.

Proof. If r, s and t are not distinct the proposition is obvious from the definitions. Therefore suppose that r, s and t are distinct. If T is a subset of $\{r, s, t\}$ let $Z_T = \bigcup_{u \in T} u$. Either by replacing X by \tilde{X} or by shrinking S and using Corollary 1.1.3 we may assume that $Z_{\{r, s, t\}}$ is étale over S . Let \mathcal{F}_T denote the complex $\Omega_{X/S, Z_T}^\bullet$. We set $H(T) = H_{DR}^1(X/S, Z_T)$. Then from the exact sequence of complexes

$$0 \rightarrow \mathcal{F}_{\{r, s, t\}} \rightarrow \mathcal{F}_{\{r, s\}} \otimes \mathcal{F}_{\{s, t\}} \rightarrow \mathcal{F}_{\{s\}} \rightarrow 0$$

(where the first map is the diagonal and the last is the difference) we obtain an exact sequence

$$0 \rightarrow H(r, s, t) \rightarrow H(r, s) \oplus H(s, t) \rightarrow H(s)$$

moreover, $H(s) \cong H_{DR}^1(X/S)$ and the last map is the difference of the maps from $H(r, s)$ and from $H(s, t)$ to $H_{DR}^1(X/S)$ (and is, in particular, a surjection).

Next from the exact sequence of complexes

$$0 \rightarrow \mathcal{F}_{\{r, s, t\}} \rightarrow \mathcal{F}_{\{r, t\}} \rightarrow \mathcal{S} \rightarrow 0$$

where \mathcal{S} is the complex $(\mathcal{I}_{\{r, t\}} / \mathcal{I}_{\{r, s, t\}} \rightarrow 0 \rightarrow \dots) \cong (K[S] \rightarrow 0 \rightarrow \dots)$ we obtain an exact sequence

$$0 \rightarrow K[S] \rightarrow H(r, s, t) \rightarrow H(r, t) \rightarrow 0$$

Moreover the first map is the composition of the map from $K[Z_{\{r, s, t\}}]$ into $H(r, s, t)$ and the map h from $K[S]$ into $K[Z_{\{r, s, t\}}]$ characterized by $r^*h(f) = t^*h(f) = 0$ and $t^*h(f) = f$. It follows from this that $H(r, t)$ is the

Baer sum of $H(r, s)$ and $H(s, t)$. Since all the maps discussed above are horizontal this statement is true on the level of connections as well. This proves the proposition. \square

Suppose X' is a smooth scheme over S and $g: X' \rightarrow X$ is an S -morphism. Then the natural map $g^*: H_{DR}^1(X/S) \rightarrow H_{DR}^1(X'/S)$ induces a natural map $g^*: \text{Ext}(H_{DR}^1(X'/S), K[S]) \rightarrow \text{Ext}(H_{DR}^1(X/S), K[S])$. By the naturality of all our constructions we have:

PROPOSITION 1.3.2. *Suppose X'/S has geometrically connected fibers and s and t are two sections of X'/S . Then*

$$M(g \circ s, g \circ t) = g^*M(s, t) .$$

Suppose X_0 is a smooth connected scheme over K and $X = S \times_K X_0$. Then

$$(\Omega_{X/S}^\bullet, d_{X/S}) \cong K[S] \otimes (\Omega_{X_0/K}^\bullet, d_{X_0/K})$$

and so in particular,

$$H_{DR}^1(X/S) \cong K[S] \otimes H_{DR}^1(X_0/K)$$

and the Gauss-Manin connection

$$\nabla: H_{DR}^1(X/S) \rightarrow \Omega_S^1 \otimes_{K[S]} H_{DR}^1(X/S)$$

is (d, id) . If $H = H_{DR}^1(X/S)$, it follows from this that

$$\text{Ext}(H, K[S]) \cong H^1(\check{H}, \check{\nabla}) \cong \text{Hom}_K(H_{DR}^1(X_0/K), H_{DR}^1(S/K)) .$$

Explicitly, this last isomorphism can be described as follows:

$$\text{if } h \in \text{Hom}(H, \Omega_S^1) \cong \Omega_S^1 \otimes \check{H} ,$$

then $h \text{ mod } \check{\nabla}\check{H}$ goes to the map $(\omega \in H_{DR}^1(X_0/K) \rightarrow h(1 \otimes \omega) \text{ mod } dK[S])$.

PROPOSITION 1.3.3. *Suppose X_0 is a smooth connected scheme over K and $X = S \times_K X_0$. Suppose u and v are two morphisms from S to X_0 and $s = (id, u)$ and $t = (id, v)$. Then $M(s, t)$ is $v^* - u^*$ as an element of $\text{Hom}_K(H_{DR}^1(X_0/K), H_{DR}^1(S/K))$.*

Proof. We may suppose that $s \cap t = \emptyset$. Let $Z = s \cup t$. Suppose $h: H_{DR}^1(X/S) \rightarrow H_{DR}^1(X/S, Z)$ is a section. Let $(\{\omega_U\}, \{f_{U,V}\})$ be a one-hypercycle for $(\Omega_{X_0/K}^\bullet, d_{X_0/K})$ and $[\omega]$ the image the class of $1 \otimes (\{\omega_U\}, \{f_{U,V}\})$ in $H_{DR}^1(X/S)$. Then $\nabla[\omega] = 0$. We wish to compute $\nabla h([\omega]) - h(\nabla[\omega]) = \nabla h([\omega])$. We will abuse notation and identify ω_U with $1 \otimes \omega_U$ in $\Omega_X^1(U)$ and $f_{U,V}$ with $1 \otimes f_{U,V}$ in $\mathcal{O}_X(U \cap V)$. Let $\bar{\omega}_U$ denote the image of ω_U in $\Omega_{X/S}^1(U)$. Then $h([\omega])$ is the class of

$$(\{\bar{\omega}_U - d_{X/S}g_U\}, \{f_{U,V} - (g_U - g_V)\})$$

for some one-chain $\{g_U\}$ with coefficients in \mathcal{O}_X such that

$$s^*f_{U,V} = u^*f_{U,V} = s^*(g_U - g_V) \quad \text{and} \quad t^*f_{U,V} = v^*f_{U,V} = t^*(g_U - g_V).$$

Let $\eta_U = \omega_U - dg_U$. Now

$$s^*\eta_U - s^*\eta_V = s^*df_{U,V} - s^*d(g_U - g_V) = 0$$

by the conditions that $\{g_U\}$ must satisfy and the fact that $(\{\omega_U\}, \{f_{U,V}\})$ is a hypercycle. Similarly, $t^*\eta_U - t^*\eta_V = 0$. Let η_s and η_t be the elements of Ω_S^1 determined by the cocycles $\{s^*\eta_U\}$ and $\{t^*\eta_U\}$ respectively.

Now to compute $\nabla h([\omega])$ we must lift $\bar{\omega}_U - d_{X/S}g_U$ to a section of $\Omega_{X,Z}^1$. Let $e_{s,U}$ and $e_{t,U}$ be elements of $\mathcal{O}_X(U)$ such that $s^*e_{s,U} = 1$, $t^*e_{t,U} = 0$, $t^*e_{s,U} = 0$ and $s^*e_{t,U} = 1$. These elements exist since Z is étale over S . Then $\eta_U - (e_{s,U}\eta_s + e_{t,U}\eta_t)$ is such a lifting. To compute $\nabla h([\omega])$ we must take the hyper-coboundary of $(\{\eta_U - (e_{s,U}\eta_s + e_{t,U}\eta_t)\}, \{f_{U,V} - (g_U - g_V)\})$. It is

$$(\{\eta_s \otimes d_{X/S}e_{s,U} + \eta_t \otimes d_{X/S}e_{t,U}\}, \{\eta_s \otimes (e_{s,U} - e_{s,V}) + \eta_t \otimes (e_{t,U} - e_{t,V})\}, 0).$$

The class of this hypercycle is the image of

$$\eta_t - \eta_s \in \Omega_S^1 \quad \text{in} \quad \Omega_S^1 \otimes H_{DR}^1(X/S, Z)$$

(recall that we've determined a map of $K[S]$ into $H_{DR}^1(X/S, Z)$). Hence $\nabla h([\omega]) = \eta_t - \eta_s$.

The proposition now follows from the fact that

$$(\{\eta_s + ds^*g_U\}, \{s^*g_U - s^*g_V\}) = u^*(\{\omega_U\}, \{f_{U,V}\})$$

and

$$(\{\eta_t + dt^*g_U\}, \{t^*g_U - t^*g_V\}) = v^*(\{\omega_U\}, \{f_{U,V}\}). \quad \square$$

COROLLARY 1.3.4. *If, in the above, u and v are constant, then $M(s, t) = 0$.*

4. ABELIAN SCHEMES

Suppose now that A is an Abelian scheme over S . Let $m: A \times_S A \rightarrow A$ be the addition law and e the zero section. For $s, t \in A(S)$, let $M(s) = M(e, s)$ and $s + t = m(s, t)$.

THEOREM 1.4.1. *The map M from $A(S)$ to $\text{Ext}(H_{DR}^1(A/S), K[S])$ is a homomorphism.*