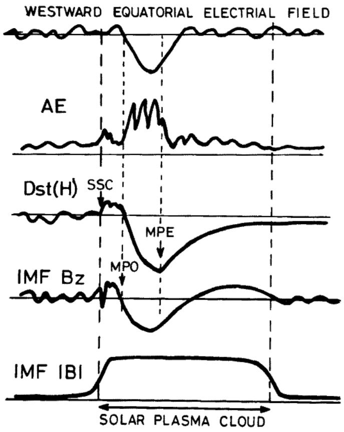

Figure 4. Suggested morphologies of interplanetary magnetic field *B*, *Bz*, *Dst* index, *AE* index and residual westward electric field during magnetic storms.

turning of IMF some hours later, the auroral electrojet (*AE*) decreases and ring current decreases, associated with the recovery phase of the storm. During the main phase of the storm, when IMF (*B*) is large and is southward, the magnetospheric electric field at high latitude extends to the equatorial ionosphere causing an additional decrease of *H* at the equatorial stations beside the one expected by the ring current alone.

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Glass based on a single proto-tile and inflation species without discrete diffractogram

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The discovery of quasicrystals in the 80s has led to a qualitative change in our understanding about atomic arrangements, including definition of solids having discrete diffractograms. Owing to this, the emphasis has now been shifted to reciprocal space from direct space that was in vogue prior to the seminal finding of quasi-periodic atomic arrangements having non-crystallographic point group symmetry. The purpose of this communication is to cite two specific examples of two-dimensional tiling from literature that do not possess discrete diffractograms, but have subtle distinctions in direct space. It will be shown that one of the above constructs offers the first ever example of an isotropic glass based on a single proto-tile. The second example, on the other hand, displays characteristics which are akin to those of glasses in reciprocal space, but possesses finite rank in direct space. The consequence of these will be discussed in relation to Pisot–Vijayaraghavan (PV) number. It will be concluded that foundation of Copernican crystallography incorporating these is still missing and needs further substantiation.

THE geometry of packings and coverings has always been at the centre of formulation of models of atomic arrangements in the solid state. A vast majority of these has been shown to possess a three-dimensional (*d*) unit

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cell or building block whose repetition guarantees long-range translational order. Consequently, such structures give rise to discrete diffractograms. The advent of quasi-crystals has led to many important changes in our conceptions regarding the structure of solids. These pertain to the introduction of a proto-set of finite number of tiles instead of a single unit cell for tiling or packing, and higher dimensional structural description. Another remarkable departure in the paradigm of crystallography relates to the replacement of the notion of tiling with that of covering by a quasi-unit cell in case of two-dimensionally quasi-periodic decagonal phase[1]. However, none of the above approaches (coverings or tilings) has currently been applied to model the structures of glasses that are believed to lack both long-range translational order and notion of a unit-cell or a single building block. The discoveries of incommensurate structures[2] in the 70s and those of icosahedrally-related structures[3] in the 80s have broadened the scope of studies of solid state. All these solids possess discrete diffractograms like those of crystals and as such, the generalization of the concepts of basis vectors by Mermin[4] definitely represents Copernican crystallography. However, if one can construct an example of a point set having basis vectors in direct space with no discrete diffractogram, then we believe that such a class of point sets is a novel one and cannot be taken care of by the generalized scheme of Mermin[5]. It will therefore be imperative on our part to change our viewpoints pertaining to solids without Bragg peaks to necessarily conform to glassy atomic arrangements.

It will be shown in this communication that we can consider Radin[6] construct for a truly isotropic ideal glass based on a single proto-tile. Further, we will also discuss the first ever model from literature[7] to assert that non-existence of a discrete diffractogram does not imply only conventionally known glasses. As a consequence of this, it will be concluded that some of the beliefs of solid-state science need suitable modifications. These refer to (a) identification of a single proto-tile in the tiling necessarily means a crystal, and (b) orientational order indicates existence of a basis set implying a discrete diffractogram. Our discussions in this communication offer the counter examples of both of these concepts.

The conventionally known non-crystalline glassy phases (for metallic, ceramic and polymeric materials) having different bonding characteristics for various materials, display common features like possessing only short-range order and hence ruling out the possibility of a single building block or even a finite set of building blocks or proto-tiles. As a consequence of this, the basis set of atomic position vectors in this class of materials has infinite rank. This, in turn, leads to the absence of a discrete diffractogram. This characteristic, therefore, has served as an experimental evidence for differentiating between a crystalline/quasicrystalline and a non-crystalline material. It is against this background that we recall the construct of Radin[6] tiling based on a right angled triangle (akin to a proto-tile) having sides of 1, 2, √5. In his construct, each basic triangle can be subdivided into five equal triangles congruent to the former, after every step of inflation or deflation by a factor of √5 (see Figure 1 *a*). A further inflation of Figure 1 *a* leads to twenty-five triangles congruent to the basic tile or proto-tile mentioned earlier (see Figure 1 *b*). Four such inflated right angled triangles (cf. Figure 1 *b*) have been shown inside a rhomb in Figure 1 *c*, where one easily identifies a single proto-tile as the smallest basic triangle. Hence we achieve the tiling in two-dimensional space based on a single proto-tile, indicating that unit cell-like objects exist. But if we look at the number of orientations in which they occur in the tiling, we note that they keep changing and increase with the number of inflation steps. Thus we may infer that in the limit, they will occur in infinite orientations. This will rule out the possibility of a basis set for knowing the position of a given vertex, a priori and consequently the diffraction space will be akin to those of the conven-

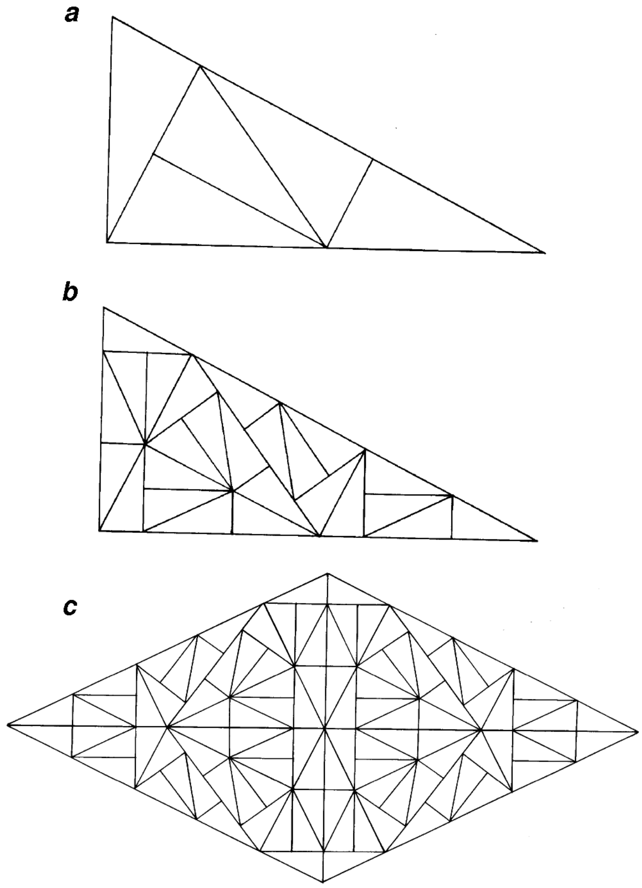

Figure 1. ***a***, Subdivision of a right angled triangle into five equal parts congruent to the basic right angled triangle (the proto-tile) with sides 1,2,√5; ***b***, Further partitioning of (***a***) into twenty-five congruent triangles. The number of orientations of the proto-tile has increased with respect to (***a***); ***c***, Four copies of (***b***) inside a rhomb, arranged to retain mirror symmetry along the diagonals.

tional glassy materials. We are unaware of such a discussion on a model glass akin to the above in literature. Thus, the example of Radin[6] for the five equal subdivisions of a right angled triangle and that of Penrose[8] for an isosceles triangle (and similar others) may be considered as model examples of a single proto-tile or a single building block-based glass. We have shown in Figure 1 *c*, the presence of two mirrors along the diagonals of the rhomb, which will of course lead to symmetry-breaking in the isotropic glass. Such an interesting case of phase transformation in this class of materials has become a possibility owing to the presence of a single building block that is the right angled triangle in the Radin[6] construct.

Danzer[7,9] has recently constructed the first ever inflation species based on four proto-tiles and an inflation rule that is non-repetitive. Let us consider the fundamentals of such an inflation species. This is based on a right angled triangle with sides 1, η, η^4. Here η satisfies the equation $1 - x - x^4 = 0$, with $x = \eta^2$. In his inflation species, the proto-set consists of four proto-tiles A, B, C and D, with B = η A, C = η B and D = η C and there exists a method of decomposing any inflated triangles in terms of the above proto-tiles. Figure 2 *a* displays the proto-tile A and Figure 2 *b*, *c* depicts the method of decomposition of η^4 A and η^8 A, respectively into triangles congruent to the above-mentioned proto-tiles. By adopting a similar procedure, proto-tiles inflated to any level can be decomposed into triangles congruent to the members of the proto-set. Figure 3 shows the nature of tiling in two-dimension, that is expected for η^{24} A. We note that the proto-tiles occur only in a finite number of orientations in Figure 3 and as such a basis set of vectors exists with respect to which the position of any vertex of the tile can be given. We are dealing with a two-dimensional case and hence the aforesaid basis set of rank m (≥ 2) will be expressible in terms of two orthonormal Cartesian vectors with the help of a rectangular matrix of order $m \times 2$ ($m > 2$) and will therefore possess only a generalized inverse of order $2 \times m$. It has been shown by Mandal[10] that the transpose of the latter will serve as a basis in the reciprocal space. Under this assumption, the species is expected to display a discrete reciprocal space and hence a discrete diffractogram. However, this prediction based on the existence of a basis set in direct space does not seem to conform to the findings of number theory. It has been claimed in literature[11] that the underlying point lattice of an inflation species displays a discrete diffractogram only if the leading eigenvalue of the characteristic equation for the construction is a Pisot–Vijayaraghavan

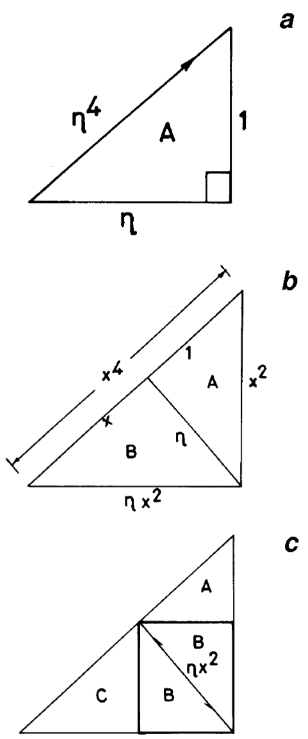

Figure 2. ***a***, Danzer proto-tile A; ***b***, Decomposition of η^4 A ≡ η D into two proto-tiles, A and B; ***c***, η^8 A triangle giving rise to proto-tiles A, B and C.

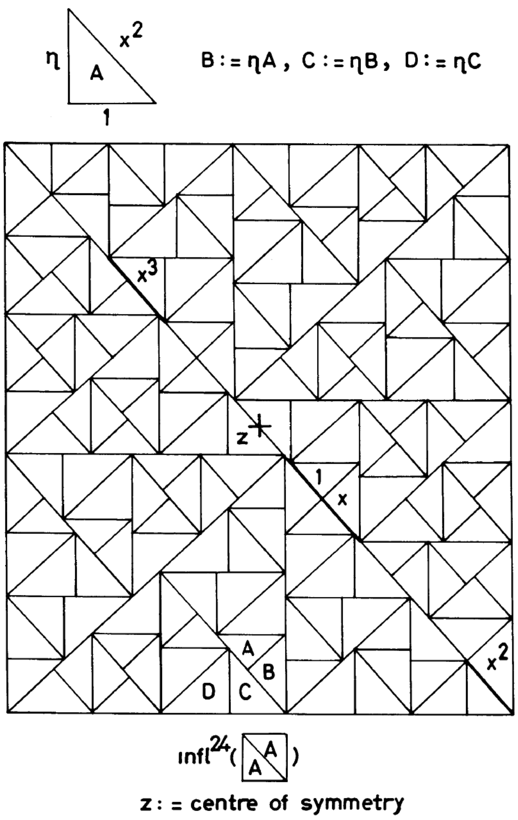

Figure 3. Nature of tiling after η^{24} A along with the four proto-tiles and inversion centre marked Z (courtesy Danzer). The proto-tiles occur only in finite orientations in contrast to Figure 1. Existence of the proto-tiles A, B, C and D in the tiling is also marked.

(PV) number. However this is not the case for the inflation species proposed by Danzer[7]. For the sake of continuity, we shall define a PV number. A real number is said to be an algebraic integer, if it is the root of a monic polynomial with integral coefficients. For example, the golden number $\tau = (1/2)\ (1 + \sqrt{5})$ is an algebraic integer, since it is the leading root of a polynomial $x^2 - x - 1 = 0$. Further, it has another root equal to $-(1/\tau)$. An algebraic integer is a PV number, if it is greater than 1 and all its conjugates are strictly less than 1 in absolute value. This clearly indicates that inflation factor τ utilized in Penrose tiling is a PV number and existence of a discrete diffractogram for such a point set is consistent with the assertion based on number theory. However the characteristic polynomial ($x^4 - x - 1 = 0$) for Danzer[9] inflation species has the following solutions:

$$x_1 = 1.220744085;\ x_2 = -0.248 + 1.034i;\ x_3 = -0.248 - 1.034i;\ x_4 = -0.724.$$

We note that $|x_2| = |x_3| = 1.063$ and they are complex conjugates of each other. Further, the inflation factor $\eta = (x_1)^{1/2}$ based on the leading root x_1 obviously does not qualify to be a PV number. The concept of a PV number seems to play a crucial role in the area of aperiodic tiling. Any aperiodic tiling with finite numbers (≥ 2) of proto-tiles necessarily requires consideration of irrational number. The quasiperiodic materials are a special class of aperiodic systems for which the underlying point set has an additional requirement, that the characteristic irrational is a PV number.

We have mentioned above that 2d quasiperiodic systems discussed so far in the literature are based on a PV number and the tilings associated with these admit only two relatively incommensurate lengths along each of the directions. Thus they can be generated with the help of 4d-description with only one 2d acceptance domain in pseudo space. The structure factor in this case can easily be given with the help of the convolution of two functions related to the 4d lattice and the 2d acceptance domain. Owing to this, the 4d reciprocal space is discrete and the resulting physical reciprocal space component possesses a discrete diffractogram. However, we do not have such a higher dimensional construct for the Danzer-type of tiling akin to the above and hence we do not expect a discrete diffractogram. Therefore we conclude that when we know the diffraction patterns, then associating a basis set for indexing peak positions as well as for specifying atomic positions seems to be justified, but it is definitely not true the other way. We believe that emphasis of classification of solids needs careful considerations before we claim consistency in our approach[4,5]. A natural corollary that follows as a consequence can therefore be stated that all tilings, which admit inflation factor based on a non-PV number, can never be generated by conventional higher dimensional formalism. We shall conclude this discussion by referring to the generalized scheme of reciprocal space description for all those materials for which a discrete diffractogram exists. Mermin[4,5], while advocating the Bienenstock and Ewald[12] approach in the teaching of crystallography, replaced the identical density criterion by the indistinguishable density scheme in reciprocal space for solids having long-range order. He could show that such a technique would not require unnecessary and unphysical demand of higher dimensional description. Let us investigate the above assertion with reference to Danzer[9] construct. The indistinguishable density criterion cannot be applied as Bragg peaks do not exist based on the consideration of PV number, as mentioned earlier. Yet such a construct does not fall in the category of glass, as explained earlier.

Thus we have put forward the concept of a model glass in terms of a single building block or a proto-tile. The proto-tile occurs in infinite orientations, ruling out the possibility of a basis set of finite rank as well as discrete diffractogram. In sharp contrast to the above, we have also presented the example of a 2d tiling based on a proto-set with four proto-tiles with finite rank in the direct space, without any discrete diffractogram. Hence we conclude that categorizing all solids without a discrete diffractogram to conform to glass or non-crystalline materials is far from being objectively true, in view of the qualitatively distinct features in direct space. We believe that the model of glass based on a single proto-tile may be considered as an ideal glass having total isotropic behaviour, without any signature of short-range order existing beyond the proto-tile. Like 2d quasiperiodic and 1d periodic solids one may think of 2d single proto-tile-based glass stacked periodically along the third direction to preserve long-range translational order along this. Both the examples discussed in the present communication are novel, calling for attention of theoreticians and experimentalists involved in the fascinating area of structural characterization.

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Effect of metal ions and other antileishmanial drugs on Stibanate-resistant *Leishmania donovani* promastigotes of Indian origin

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Pentavalent antimonial Sb(V)-resistant *Leishmania* promastigotes isolated from Indian kala-azar patients were found to be cross-resistant to other heavy metal ions and two antileishmanial drugs, pentamidine isethionate and amphotericin B, used for treatment of Sb(V)-unresponsive patients. Results strongly suggest the presence of transport activities in resistant cells which are actively responsible for efflux of these drugs.

IN general, parasites belonging to *Leishmania donovani* complex, namely *L. donovani*, *L. infantum* and *L. chagasi* are the causative agents of visceral leishmaniasis (VL) or kala-azar (KA), a fatal disease if it remains untreated. The digenic lifecycle of *Leishmania* consists of an extra-cellular promastigote form, present in the midgut of vector sandfly and an intracellular amastigote form, present within host macrophages. Promastigotes are transmitted from one host to another by the bite of sandfly vectors. KA poses a major health problem in most tropical countries, including the Indian subcontinent. Organic pentavalent antimonials Sb(V) (Stibanate, Pentostam, Glucantime) are the drug of first choice for treatment of KA. When these drugs fail, pentamidine isethionate or amphotericin B are used as drugs of second choice[1]. It was reported that in Bihar, unresponsiveness to Sb(V) has increased from 34 to 64% between 1994 and 1997 (ref. 2).

Wild-type promastigotes of six different *Leishmania* isolates were cloned by limited dilution [3]. Among these, RS was isolated from a post kala-azar dermal leishmaniasis (PKDL) patient, CK and MF from Stibanate-unresponsive kala-azar patients and AG83, GE1 and GE2 from kala-azar patients who were successfully treated with Stibanate. It was observed that nearly 33% of the clones of AG83 and GE1 and 80% of the clones of GE2 were resistant to 3.0 mg/ml Stibanate in culture (Table 1), indicating that wild-type parasites isolated from Indian KA patients responsive to Sb(V) therapy are a mixture of drug-sensitive and resistant cells. These results are similar to the one reported by Grogl *et al.*[4], that wild type promastigotes of *Leishmania* species isolated from patients with American cutaneous leishmaniasis represented a mixed population, with different degrees of sensitivity to Sb(V). However, it is not apparent why per cent of resistant cells in GE2 is significantly higher than that in either AG83 or GE1 (Table 1). Unlike AG83, GE1 and GE2, all clones derived from CK and MF isolated from KA patients unresponsive to Sb(V) treatment and RS isolated from a PKDL patient were resistant to 3 mg/ml Stibanate (Table 1). It is generally believed that PKDL is caused by residual parasites surviving upon successful chemotherapy, which escape to the skin after the KA patient is clinically cured. This may be one of the reasons supporting the fact that all the clones derived from RS were resistant to Stibanate.

For further studies, three resistant clones (GE1F8R, CK1R, RS1R) derived from GE1, CK and RS and one sensitive clone (GE1C6S) derived from GE1 were selected. It was observed that in addition to Sb(V) resistance, the parasites were also cross-resistant to heavy metal ions such as Sb^{3+}, As^{3+} and Zn^{2+} (Figure 1), and three other mechanistically unrelated drugs, namely amphotericin B, pentamidine isethionate and colchicine (Figure 2). It was observed that the resistant cells can grow in presence of 1.5, 6.0 and 5.0 μM amphotericin B, pentamidine isethionate and colchicine. However, the same concentrations of these drugs are lethal to *in vitro* growth of the

Table 1. *In vitro* Stibanate sensitivity of clones derived from different isolates of *L. donovani* promastigotes

Isolate	Total	Number of clones: Sensitive (%)	Number of clones: Resistant (%)
AG83	13	9 (69)	4 (31)
GE1	3	2 (67)	1 (33)
GE2	10	2 (20)	8 (80)
CK	3	0 (Nil)	3 (100)
MF	4	0 (Nil)	4 (100)
RS	4	0 (Nil)	4 (100)

Promastigotes (5×10^5 cells/ml) were incubated at 22–25°C in medium M-199 supplemented with 20.0 mM HEPES, pH, 7.5 and 10.0% foetal calf serum in presence of 3.0 mg/ml Stibanate and viable cells were counted on day 7. Final cell counts were in the order of 10^7 and $< 10^4$ for resistant and sensitive parasites, respectively.

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