Evidence suggesting the presence of extinct Mn-53 (mean life $\tau = 5 \text{ Ma}$) has recently been reported by Birck and Allegre (1). My purpose here is to point out that their data are inconsistent with the prediction of a single stage model in which both the $^{53}\text{Mn}/^{55}\text{Mn}$ and $^{53}\text{Cr}/^{52}\text{Cr}$ were initially homogeneous, and to explore the virtues and the consequences of the three alternative interpretations of this inconsistency: (a) the host material has experienced multiple staged evolution, or (b) $^{53}\text{Mn}$ was heterogeneously distributed, or (c) $^{53}\text{Cr}$ has intrinsic anomalies.

The systematics of $^{53}\text{Mn}-^{53}\text{Cr}$ evolution is depicted in Fig.1 where $^{55}\text{Mn}/^{52}\text{Cr}$ is plotted against $\varepsilon(53\text{Cr}/52\text{Cr})$, the fractional deviation of $^{53}\text{Cr}/^{52}\text{Cr}$ from the normal in units of 0.01%. The increase of the Cr ratio owing to $^{53}\text{Mn}$ decay for objects (P,Q, etc.) formed through chemical fractionation from source S at time $t_1$ is described by:

$$^{53}\text{Cr}/^{52}\text{Cr}(t) = I_1 + (53\text{Mn}/55\text{Mn})(t_1 - t_1)/\tau \times (55\text{Mn}/52\text{Cr}) - (1)$$

if the initial $^{53}\text{Cr}/^{52}\text{Cr} = I_1$ and $^{53}\text{Mn}/^{55}\text{Mn}$ were homogeneous.

Eq.1 is valid as long as these objects remain a close system (i.e. experienced only "single stage evolution"). Therefore, at subsequent times, they plot on a linear array ("isochron") whose slope increases with time but whose intercept is fixed at $I_1$. Since the source S can be considered simply as an unfractionated object it also satisfies eq.1. So, at time $t_2$, isochron $P_2Q_2$ passes thru $S_2$ and, at present, isochron $P_3Q_3$ passes thru $S_3$. We have thus demonstrated that, in a single-stage homogeneous model, the isochrons for a group of cogenetic objects such as Allende inclusions or the minerals in a single inclusion should always pass thru their putative source, the solar system (0). In contrast, isochrons for objects suffered multiple stage evolution may show offsets from the solar system point. For example, object $P'$ formed from P thru chemical fractionation at $t_2$ with an initial $I_2'$ would plot today on an isochron connecting that initial and its source $P_3$ which does not pass thru $S_3$. Note that, for the two-staged model considered here, the isochron is shifted to the left(right) of the solar system point if the intermediate source P has a Mn/Cr ratio higher(lower) than the solar value.

The key data reported in (1) and my interpretations are summarized using the same diagram (Fig.2). Although representing the best can be obtained so far, these data do not yet provide an unequivocal proof of the presence of $^{53}\text{Mn}$ hence require further substantiation. From these data it is evident that neither the whole rock (open dots) isochron nor the mineral isochron for inclusion BR-1 (solid dots) passes thru the solar system point. This is probably not a problem of erroneous solar Mn/Cr being adopted since the solar photospheric value agree with the CI meteoritic value and the error estimates seem to be much less than the offset of the solar system point from the isochrons. Therefore, either multiple-stage evolution or isotopic heterogeneity is implicated. If the former is correct and only two stage models are considered then the intermediate stage source should have a higher Mn/Cr than the Allende inclusions since the isochrons are observed to be shifted to the left of the solar system point. This is a bit surprising because it implies the existence of a less refractory reservoir prior to the formation of Allende inclusions. If the latter alternative is correct then we can infer the size of the required heterogeneity. If this is owing to a nonuniform distribution of $^{53}\text{Mn}$ then the initial $^{53}\text{Mn}/^{55}\text{Mn}$ for the solar system should
be about $2.4 \times 10^{-5}$ if it shared the same initial $^{53}\text{Cr}/^{52}\text{Cr}$ with the Allende inclusions. This $^{53}\text{Mn}$ abundance is about a factor of two lower than that for the Allende inclusions. Alternatively, since an isochron passing thru the solar system point with a slope corresponding to an initial $^{53}\text{Mn}/^{55}\text{Mn}$ equals to the averaged Allende values has an intercept $-0.02\%$ below the initial Cr ratios for the Allende inclusions, the offset can be attributed to an intrinsic excess of $0.02\%$ in $^{53}\text{Cr}$ for the Allende inclusions. Birck and Allegre(1) have shown that these inclusions have $^{54}\text{Cr}$ excesses of about $0.06\%$. Therefore, the ratio between $\varepsilon(^{53}\text{Cr}/^{52}\text{Cr})$ and $\varepsilon(^{54}\text{Cr}/^{52}\text{Cr})$ is $0.3$.

Interestingly, this is identical to that observed in the Cr anomalies for the FUN inclusion EK1-4-1 according to Papanastassiou(2) suggesting that a single component may be responsible for the intrinsic Cr anomalies in both FUN and ordinary inclusions.

It is important to consider whether the $^{53}\text{Mn}$, $^{54}\text{Cr}$, and the inferred $^{53}\text{Cr}$ could have been co-produced as a single component. Using the data on inclusion BR-1 from (1) and the $^{53}\text{Cr}$ excess of $0.016\%$ inferred above and assuming that the inclusion Cr is a mixture between such a component and the normal, I estimate that its composition is $^{53}\text{Cr}:^{54}\text{Cr}:^{53}\text{Mn} = 1.3:1:0.7$ (by number), provided that it contains little $^{56}\text{Cr}$ and $^{52}\text{Cr}$. Neutron rich e process nucleosynthesis has been proposed to explain the correlated $^{48}\text{Ca}$, $^{50}\text{Ti}$, and $^{54}\text{Cr}$ effects in these inclusions(3,4). The relatively high abundance of $^{53}\text{Mn}$ and $^{53}\text{Cr}$ estimated above appears difficult to be reconciled with the high neutron excess required for the production of low $^{46}\text{Ca}/^{48}\text{Ca}$ material. Perhaps it is more reasonable to consider the coproduction of these two nuclides in processes that are necessary to explain the effects among the low mass isotopes of Ca and Ti.


Fig.1 $^{53}\text{Mn} - ^{53}\text{Cr}$ evolution models Fig.2 Interpreting data from (1)